ESA CCI SnowC2 Kick-off meeting

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

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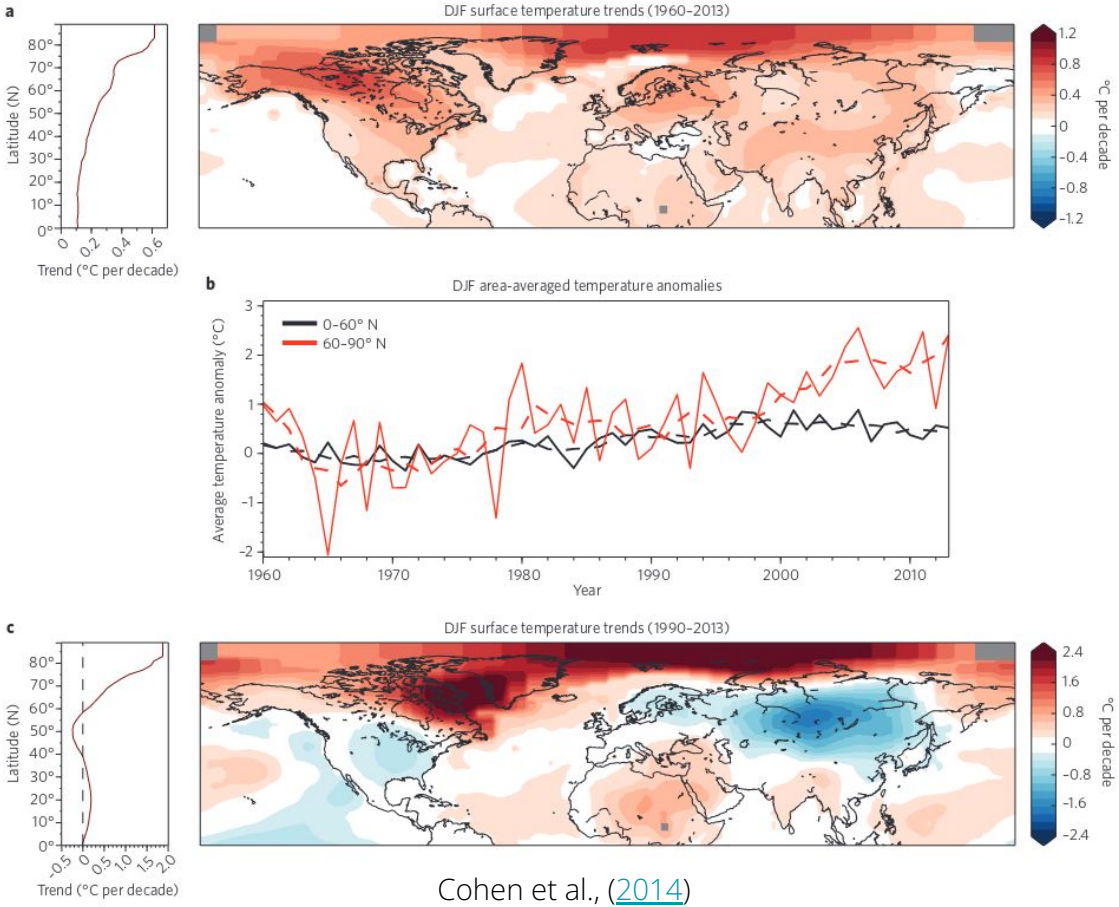
ESA CCI Fellowship — 01/10/2023 to 30/09/2025 (2 years)

supervised by Christophe Kinnard and Alexandre Roy

Context: Arctic Amplification



Cohen et al., (2014)

- 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)
- ⇒ melting of Arctic sea ice and spring snow cover
- Impacts on ecosystems and human activities such as transportation, resource extraction, water supply, use of land and infrastructure among others.
- 1.035 Pg-C (>66° N, 3m soil) - By 2100, 55 to 232 Pg C-CO2-e could be emitted via permafrost degradation (Schuur et al., 2022)

Snow: essential component of the climate system

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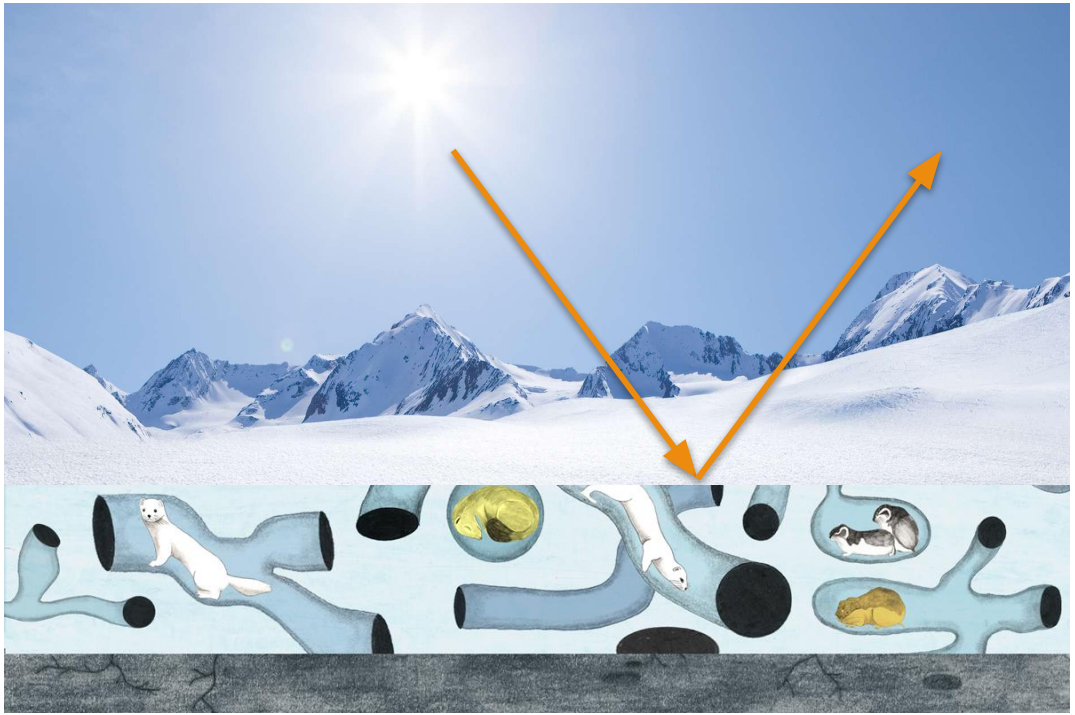
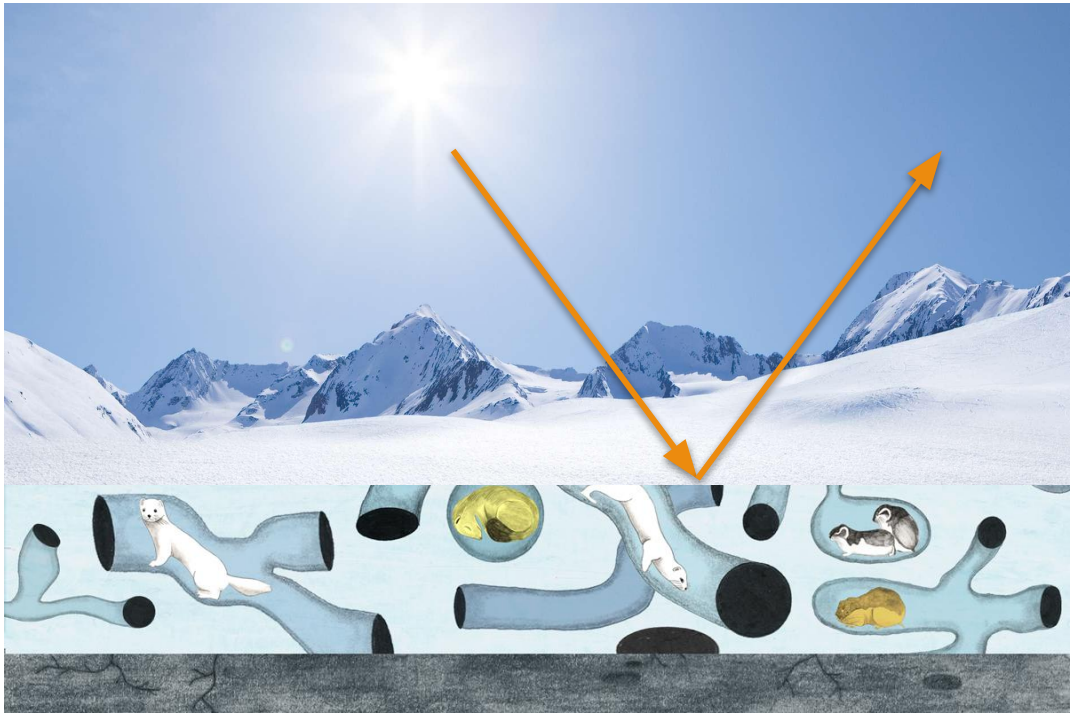


Snow: essential component of the climate system



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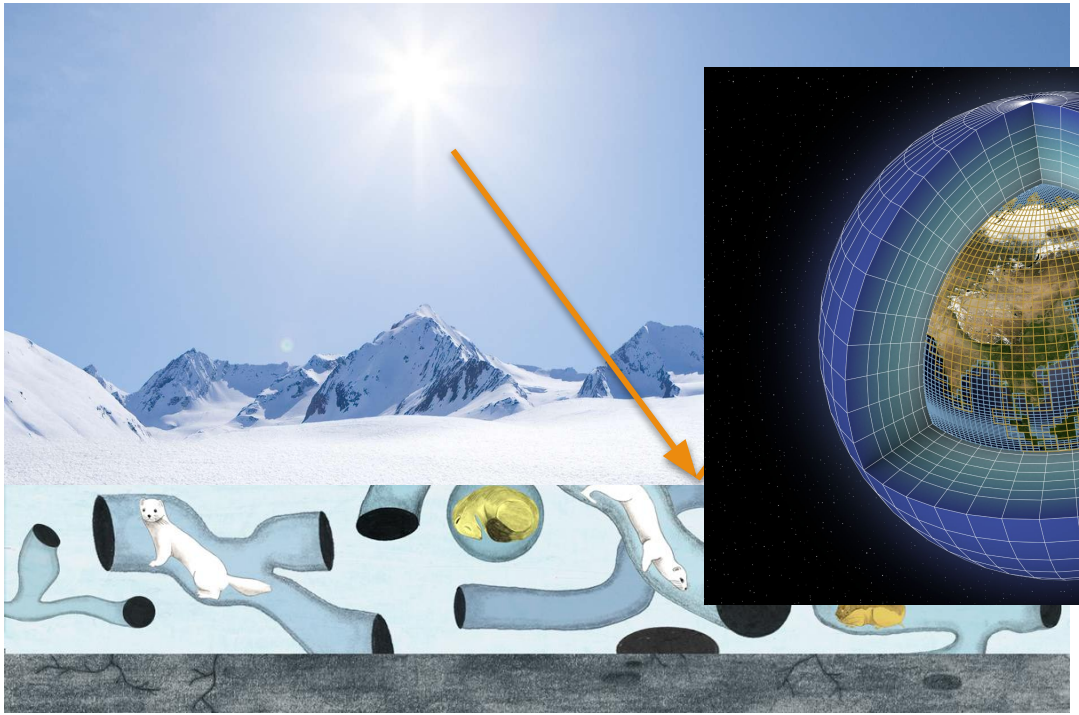
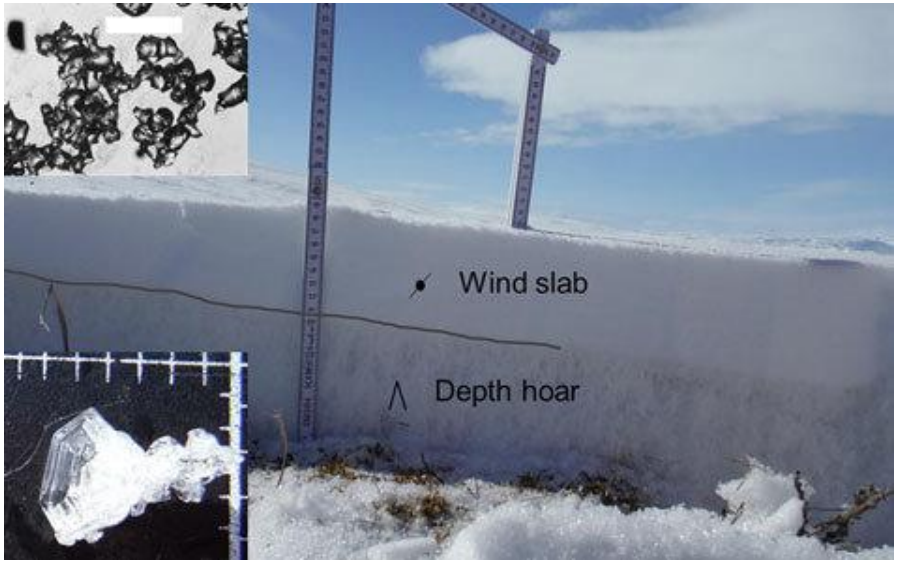
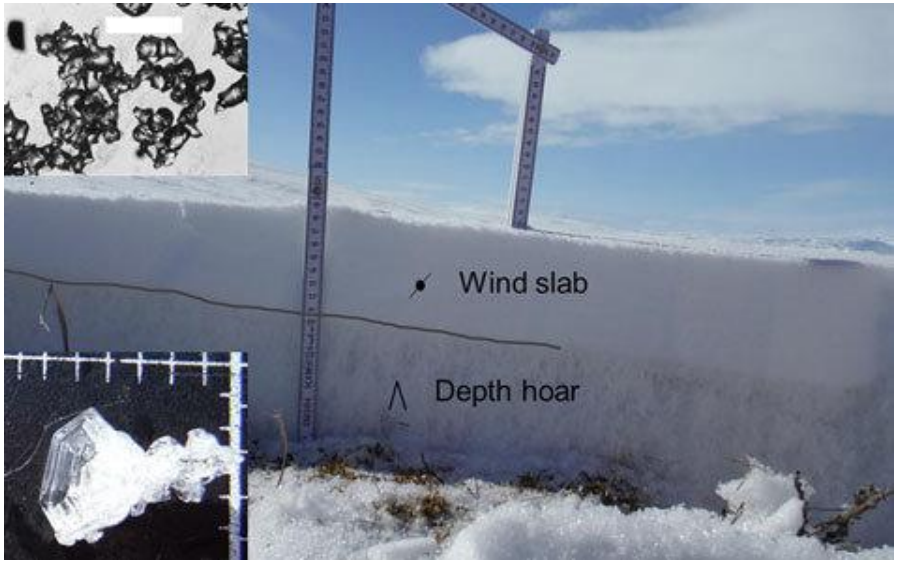


Arctic snowpack



Domine et al., (2019)

Arctic snowpack



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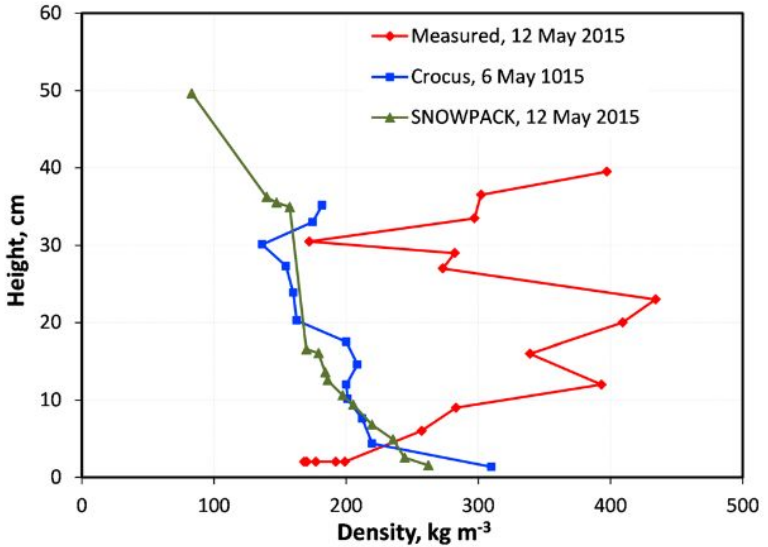

Figure 3. Comparison of measured snow density profiles at Bylot Island in May 2015 with those simulated using the detailed snow models Crocus and SNOWPACK. Crocus runs of 6 May are shown because Crocus simulates melting on 7 May, and this extra process makes comparisons irrelevant on 12 May.

Domine et al., (2018)

Arctic snowpack: solution?

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Physical solution

Implement the water vapor fluxes explicitly in the snowpack (→ snow mass redistribution):

- IVORI project (Marie Dumont, ERC ~2M €)
- Jafari et al., (2020): The Impact of Diffusive Water Vapor Transport on Snow Profiles in Deep and Shallow Snow Covers and on Sea Ice
- Simson et al. (2021): Elements of future snowpack modeling – Part 2: A modular and extendable Eulerian–Lagrangian numerical scheme for coupled transport, phase changes and settling processes

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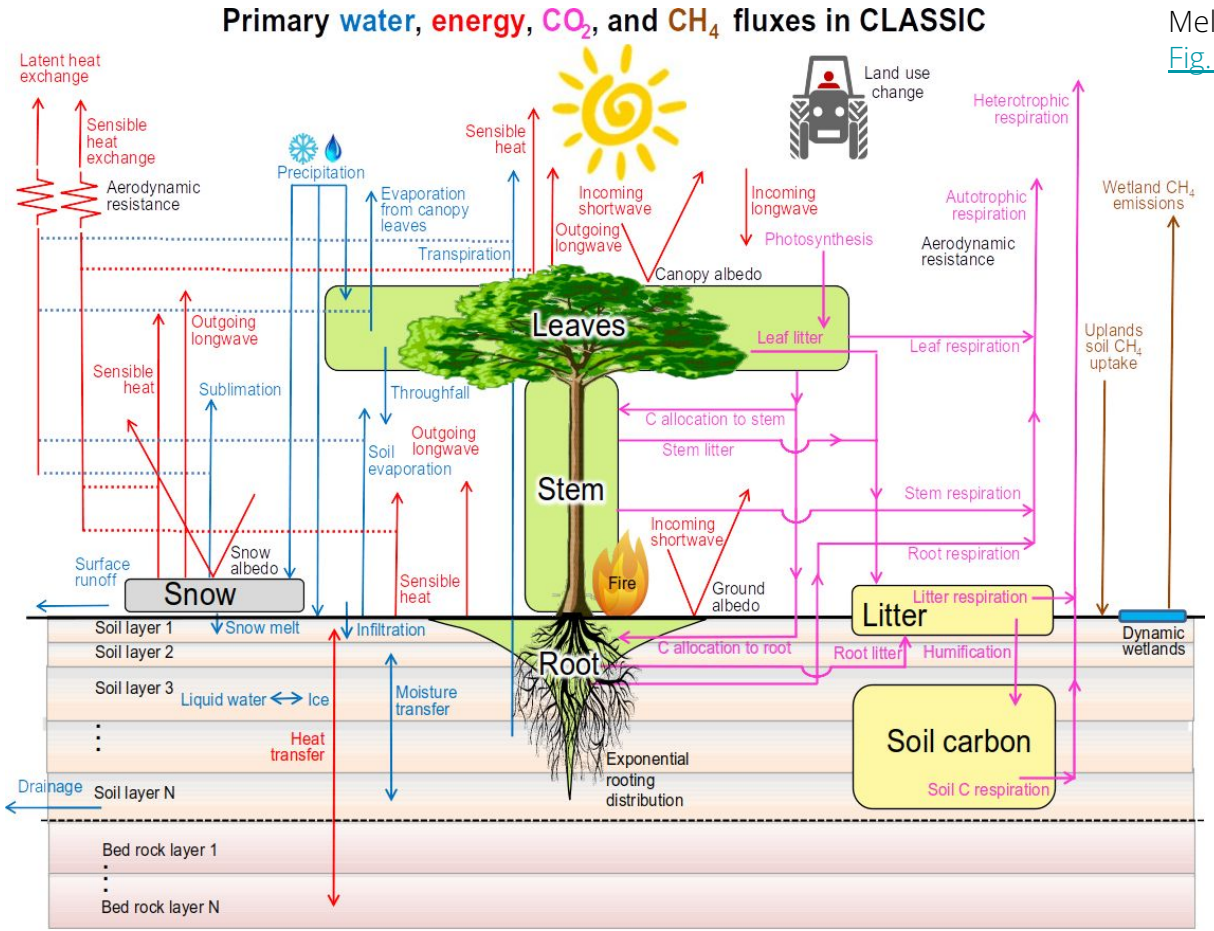
Practical solution

Increase the compaction due to the wind + reduce the density of the lower layers, e.g.:

- Royer et al. (2021): Improved Simulation of Arctic Circumpolar Land Area Snow Properties and Soil Temperatures
- Lackner et al., (2022): Snow properties at the forest–tundra ecotone: predominance of water vapor fluxes even in deep, moderately cold snowpacks

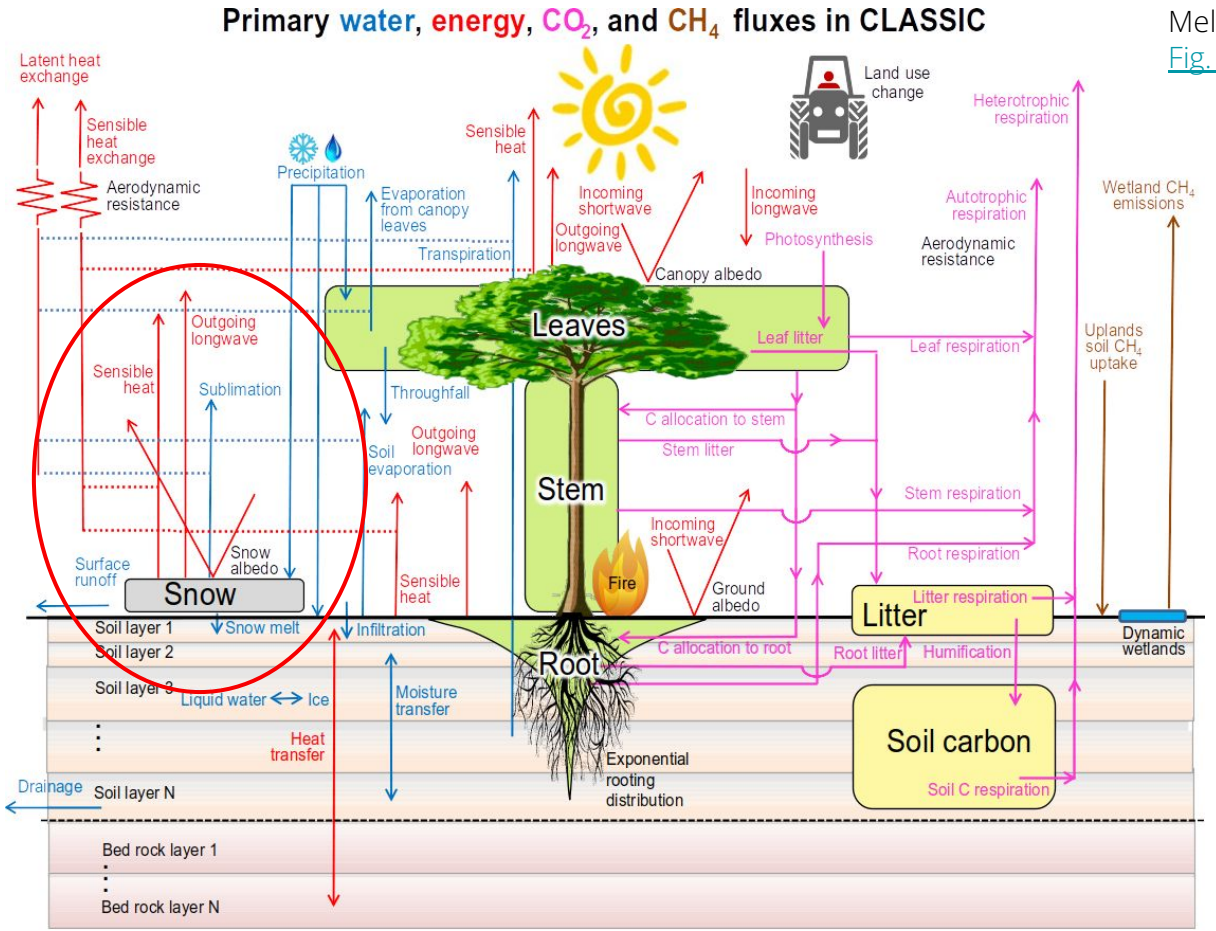
Challenge: never applied worldwide and often site specific…

Snow model in CLASSIC: description



Melton et al. (2020), Fig. 1

Snow model in CLASSIC: description



Melton et al. (2020), Fig. 1

Objectives of the project

1. Implement a multilayer snowpack in CLASSIC (1D simulations)
   - technical challenges: model not so modular and snow is included in many files/routines
   - physical challenges: include Arctic snowpack characteristics (if possible) + blowing snow, etc.
   - → assess these changes at site level simulations (SnowMIP + 3 Arctic sites)

Model development and assessments

New Arctic simulations

#1 Implement multilayer snow model in CLASSIC (site simulations)

Credit: Sawtooth Avalanche Center

Objectives of the project

1. Implement a multilayer snowpack in CLASSIC (1D simulations)
2. Test new snow cover fraction parameterizations + multilayer snowpack in spatial simulations (Arctic) → use of ESA CCI data (snow, land type, etc.) to calibrate and asses these new developments

Model development and assessments

New Arctic simulations

#1 Implement multilayer snow model in CLASSIC (site simulations)

Credit: Sawtooth Avalanche Center

#2 Snow cover param + multilayer snowpack (spatial simulations)

Objectives of the project

1. Implement a multilayer snowpack in CLASSIC (1D simulations)
2. Test new snow cover fraction parameterizations + multilayer snowpack in spatial simulations (Arctic) → use of ESA CCI data (snow, land type, etc.) to calibrate and asses these new developments
3. New simulations over the whole Arctic with new snowpack (assessment on the surfaces fluxes)

Model development and assessments

New Arctic simulations

#1 Implement multilayer snow model in CLASSIC (site simulations)

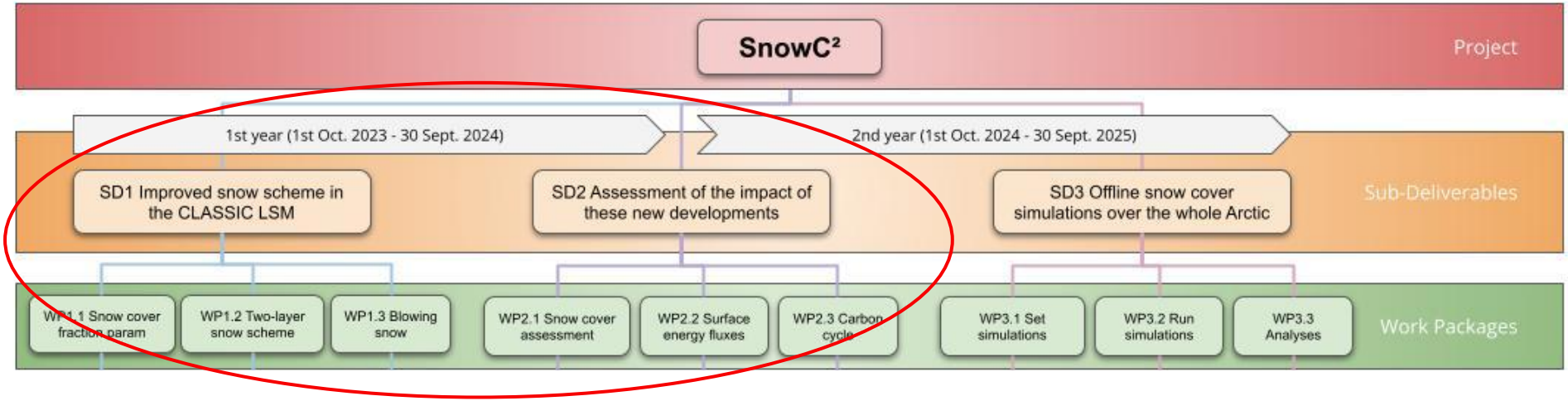
Credit: Sawtooth Avalanche Center

#2 Snow cover param + multilayer snowpack (spatial simulations)

#3 Improved Arctic simus (snow, energy/carbon fluxes, etc.)

Work Package breakdown: Snow cover heterogeneity and its impact on the Climate and Carbon cycle of Arctic regions

ESA CCI Fellowship - Mickaël Lalande - supervised by Christophe Kinnard at UQTR / RIVES (Canada)



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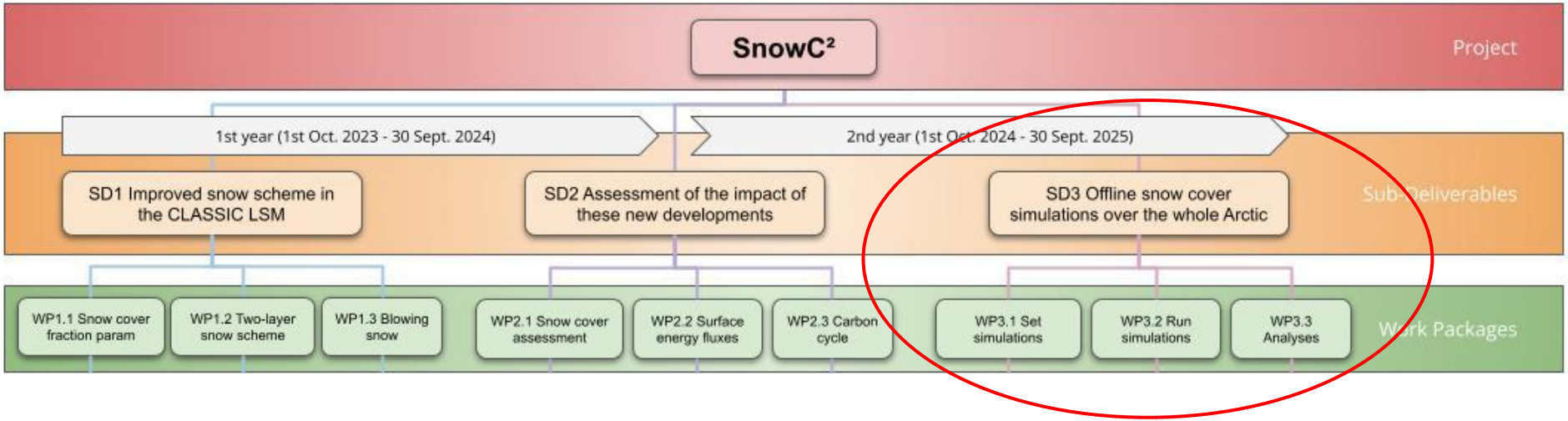

Project (2 years): **Snow cover heterogeneity and its impact on the Climate and Carbon cycle of Arctic regions (SnowC^2)**

01/10/2023 – 30/09/2025

Objectives : **Improving snow model in CLASSIC** (SCF, multi-layer snow scheme, blowing snow sublimation) and **assessing these improvements over the Arctic**

Location : **Trois-Rivières, QC, UQTR / GLACIOLAB / RIVE (Canada)**

Supervision : **Christophe Kinnard** (+ Alexandre Roy / ECCC)

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Bibliography

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

Jafari, M., Gouttevin, I., Couttet, M., Wever, N., Michel, A., Sharma, V., Rossmann, L., Maass, N., Nicolaus, M., & Lehning, M. (2020). The Impact of Diffusive Water Vapor Transport on Snow Profiles in Deep and Shallow Snow Covers and on Sea Ice. Frontiers in Earth Science, 8. https://www.frontiersin.org/articles/10.3389/feart.2020.00249

Lackner, G., Domine, F., Nadeau, D. F., Lafaysse, M., & Dumont, M. (2022). Snow properties at the forest–tundra ecotone : Predominance of water vapor fluxes even in deep, moderately cold snowpacks. The Cryosphere, 16(8), 3357-3373. https://doi.org/10.5194/tc-16-3357-2022

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

References

Schuur, E. A. G., Abbott, B. W., Commane, R., Ernakovich, J., Euskirchen, E., Hugelius, G., Grosse, G., Jones, M., Koven, C., Leshyk, V., Lawrence, D., Loranty, M. M., Mauritz, M., Olefeldt, D., Natali, S., Rodenhizer, H., Salmon, V., Schädel, C., Strauss, J., … Turetsky, M. (2022). Permafrost and Climate Change : Carbon Cycle Feedbacks From the Warming Arctic. Annual Review of Environment and Resources, 47(1), 343-371. https://doi.org/10.1146/annurev-environ-012220-011847

Simson, A., Löwe, H., & Kowalski, J. (2021). Elements of future snowpack modeling – Part 2 : A modular and extendable Eulerian–Lagrangian numerical scheme for coupled transport, phase changes and settling processes. The Cryosphere, 15(12), 5423-5445. https://doi.org/10.5194/tc-15-5423-2021