Greenland Ice Sheet Surface Mass Balance Sensitivity to Supraglacial Lakes Parametrization in the Regional Climate Model MAR

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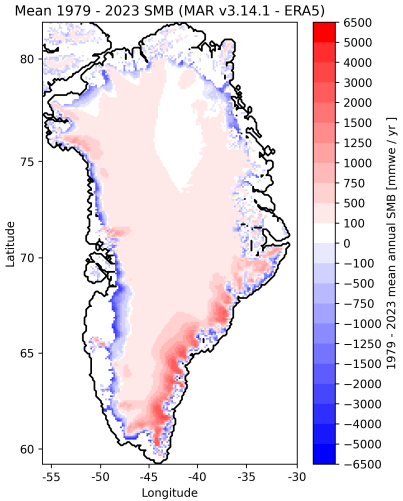
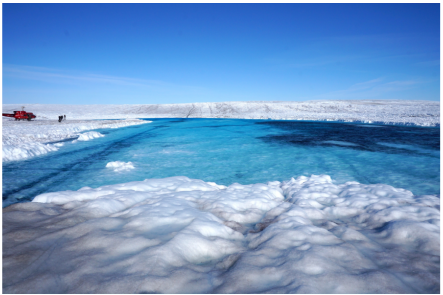
The Greenland Ice Sheet Surface Mass Balance (SMB)



$$SMB = SF + RF - RU - SU$$

Source: M. Tedesco

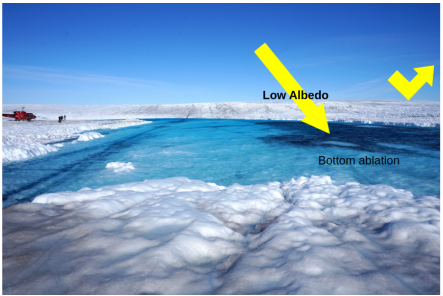
Impact of supraglacial lakes on the GrIS SMB



Source: B. Noël

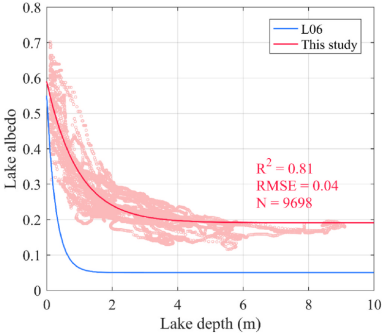
Supraglacial lake = (melt)water accumulation in a topographic depression over the ice sheet

SGLs & SMB: albedo



Source: B. Noël

SEB = **(1-α)** $\times$ **SWD** + LWD - LWU + SHF + LHF

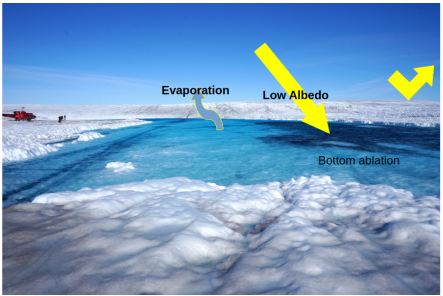


Wu *et al.* (2025)

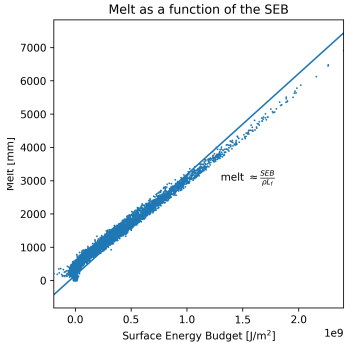
Albedo as a function of SGL depth.

SGLs & SMB: evaporation

↗ Evap. ⇒ ↘ LHF ⇒ ↘ SEB⇒ ↘ melt

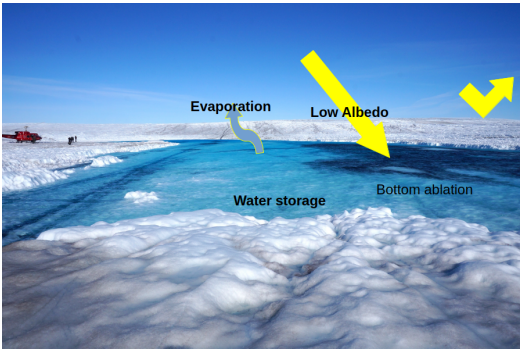


Source: B. Noël $\text{SEB} = (1\text{-}\alpha) \times \text{SWD} + \text{LWD} - \text{LWU} + \text{SHF} + \textbf{LHF}$

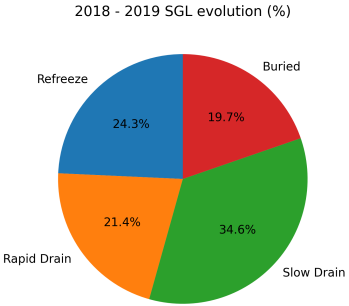


Energy used to evaporate water is not available to melt ice

SGLs & SMB: refreezing



Source: B. Noël

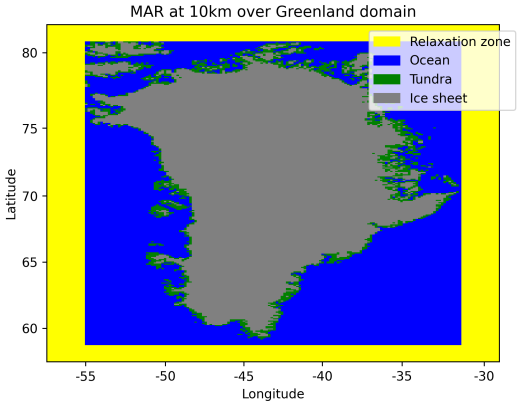


Adapted from Dunmire *et al.* (2025)

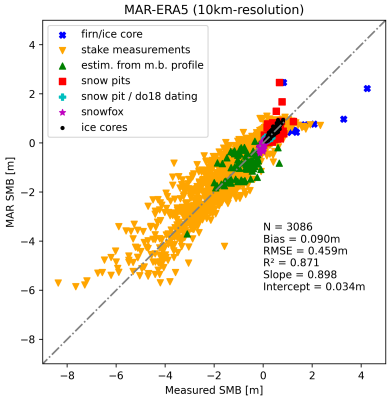
The MAR regional atmospheric climate model

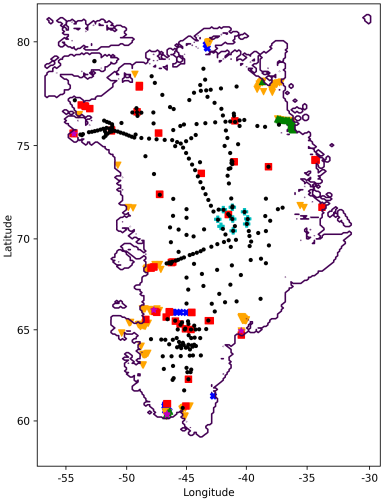
- Simulates the climate and SMB of the GrIS
- Forced by ERA5 reanalysis on a 6-hourly basis
- Good agreement with SMB measurements
- Does not capture supraglacial lakes processes

$\Rightarrow$ parameterization through sensitivity experiments



The MAR regional atmospheric climate model

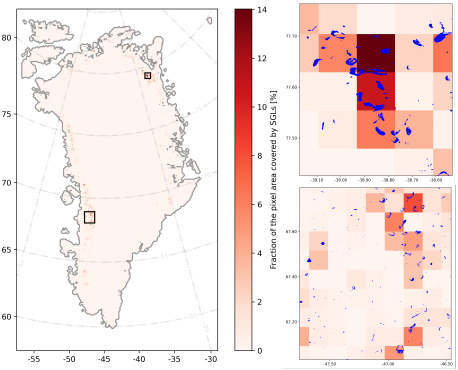




Sensitivity experiments

Goal: Parameterize key lake processes that affect the GrIS SMB.
Lake fraction: prescribed from satellite data

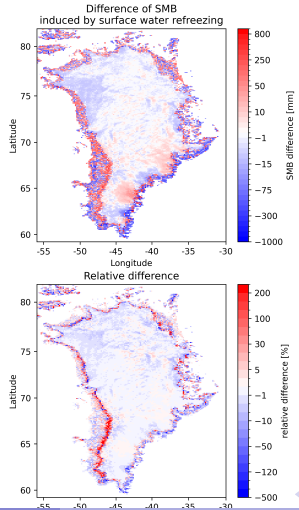
- Change the albedo depending on the fraction of lakes
- Enable evaporation over SGL-covered pixels
  - Function of the lake temperature
- Authorize or not surface water refreezing



SGLs extent (based on Zhang *et al.* data)

Enabling refreezing ...

- Adding refreezing increases the SMB. The effects strongly depends on the "runoff speed"
- Others tests over the impact of albedo and evaporation are running



Conclusions and Perspectives

The effect of SGLs on GrIS SMB is limited but will increase under projected climate warming

Explicitely representing lake processes in MAR will enable exploring SGLs effect on SMB in future projections

Capturing lake processes is challenging as SGLs extent is smaller than the MAR grid resolution.

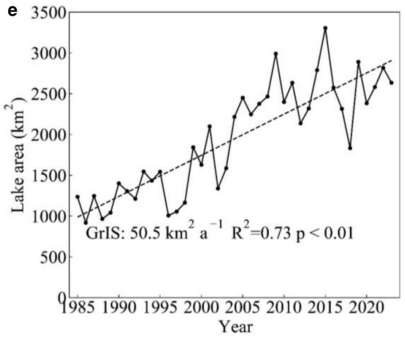
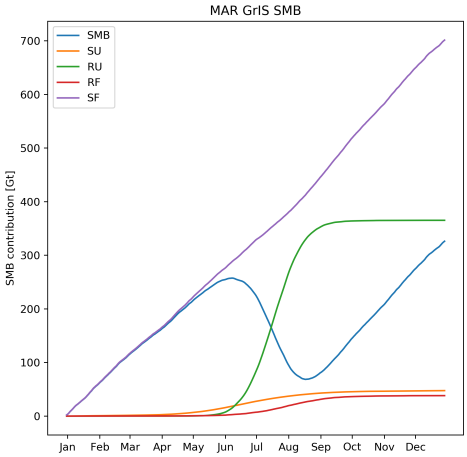


Figure: Maximum lake extent time series

Source: Fan *et al.* (2025)

Supplementary Material



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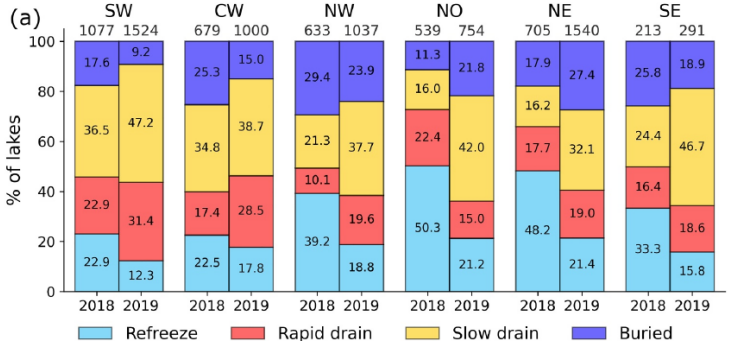

Dunmire *et al.* (2025)

Future Prospects: Represent supraglacial hydrology

- Lüthje *et al.* (2006) : explicit physical modelling of SGLs
- Law *et al.* (2020) new SGL model

Modelling the evolution of supraglacial lakes on the West Greenland ice-sheet margin

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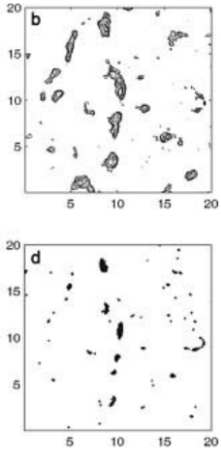

Figure: **b**:modelled lake-covered zones ; **d**:observed lake coverage

Runoff in MAR

Adding refreezing increases the SMB. The effects strongly depends on the runoff characteristic time (t^*).

$$\frac{dW}{dt} = -W/t^*$$

$$\Rightarrow W(t) = W(t_0) \times \exp -t/t^*$$