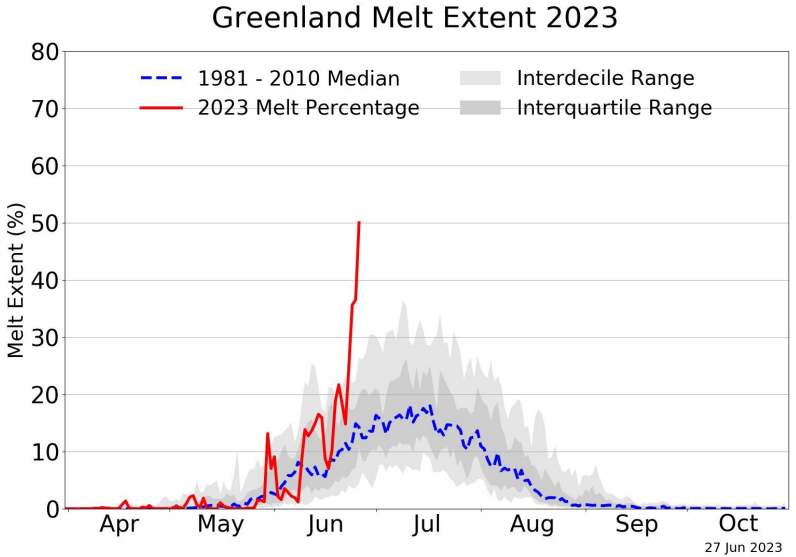
Calibration of snow albedo over Greenland with MODIS data

Nina Raoult, V. Bastrikov, S. Charbit, C. Dumas, F. Maignan, C. Ottlé

ORCHIDEE-dev snow meeting - 26 October 2023

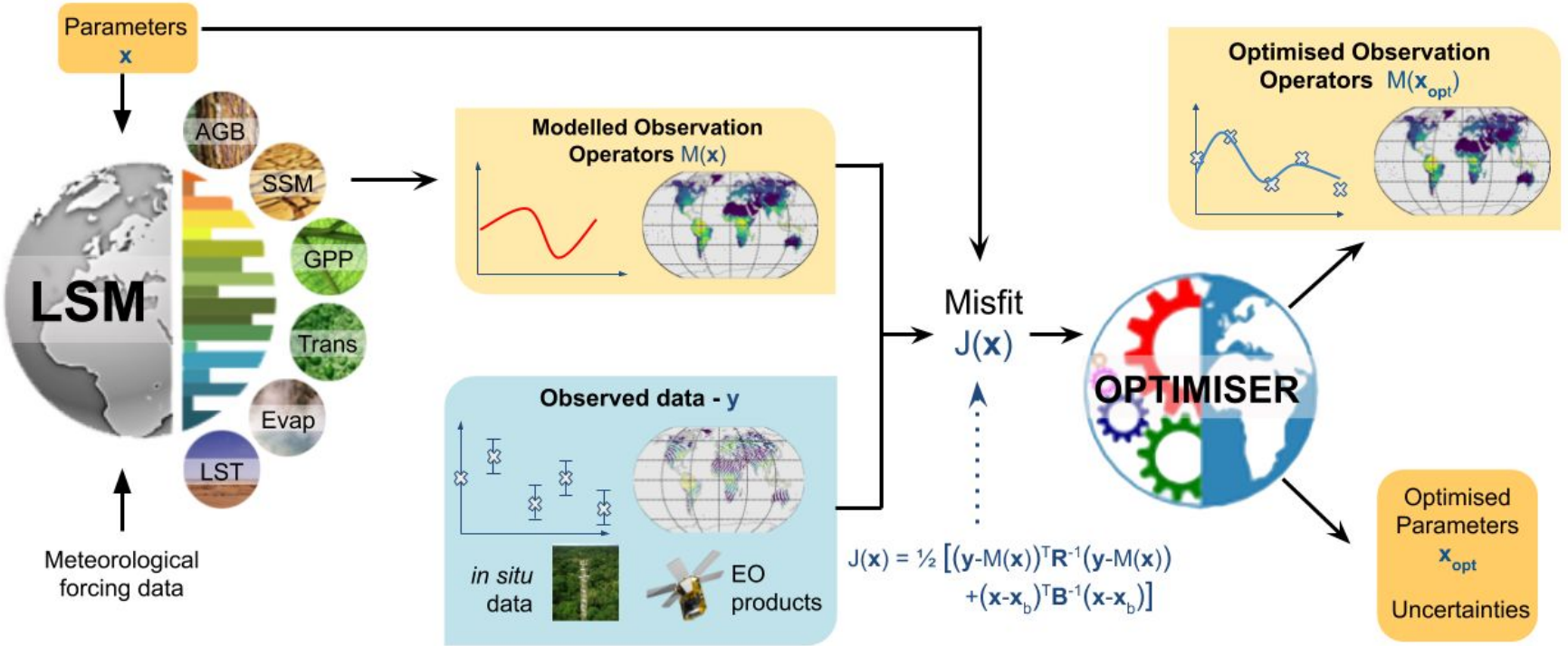


Overview

- **Goal**: finding one set of parameters for the whole of Greenland
  - Challenges:
    - Large area with different behaviours at the edges and the middle
    - Gradual warming over the last decade

- **Approach**: Perform a calibration/validation study using ORCHIDAS - the ORCHIDEE data assimilation system

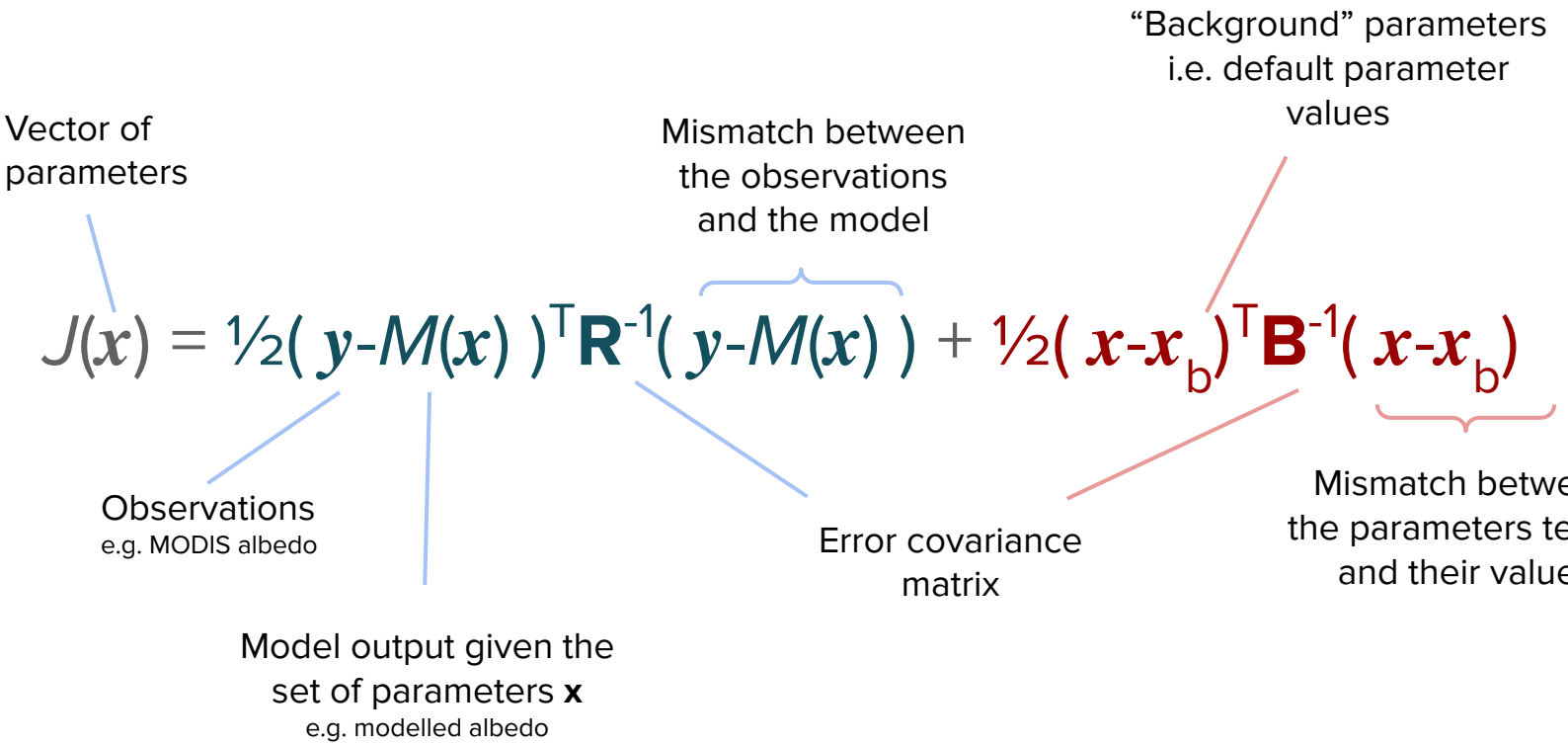
ORCHIDAS
DATA ASSIMILATION SYSTEMS



DATA ASSIMILATION SYSTEM: parameter optimisation

https://orchidas.lsce.ipsl.fr/

Principles of Data Assimilation



The parameters (x)

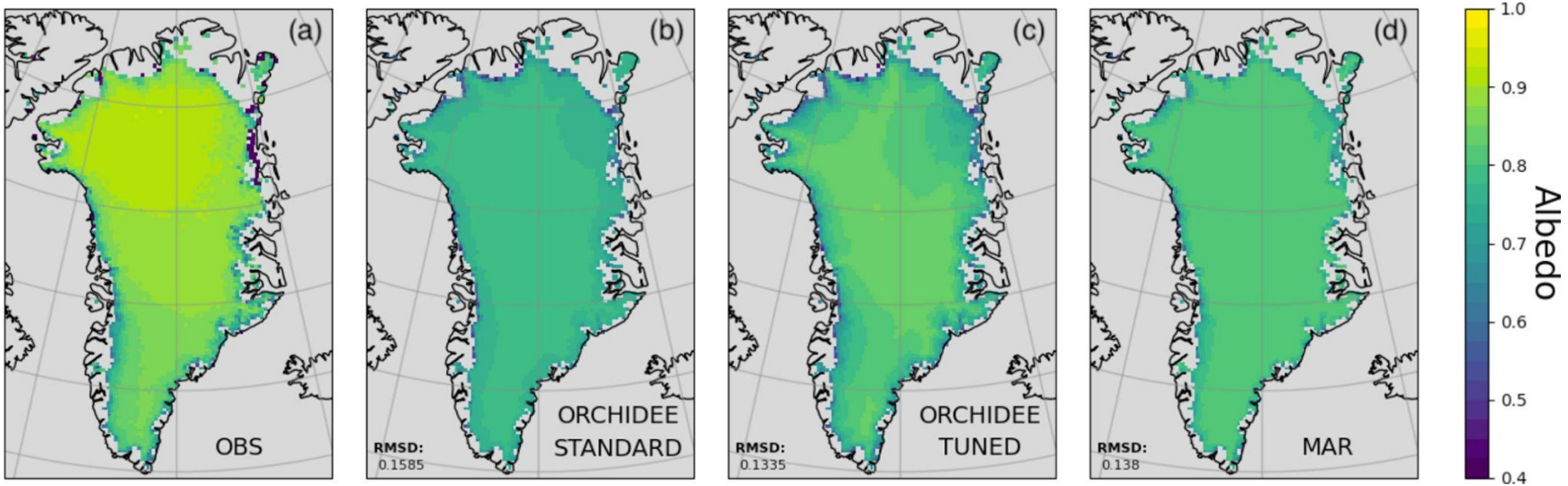
Parameters already extensively tuned

			Prior (x_b)	Min	Max
Sum to be the albedo of fresh snow	A_{aged}	SNOWA_AGED*	0.525	0.50	0.70
	B_{dec}	SNOWA_DEC*	0.349	0.10	0.40
Transformation time constant for snow on nobio/snowfall depth required to reset the snow age?	δ_c	SNOW_TRANS_NOBIO	1	0.2	2
Time constant of the albedo decay of snow on nobio (days) - snow age decay rate	τ_{dec}	TCST_SNOWA_NOBIO	2	1	10
Tuning constants for nobio areas	ω	OMG1	2.5	1	7
	β	OMG2	4	0.5	4
Maximum snow age	τ_{max}	MAX_SNOW_AGE	50	40	60
Ice albedo	α_{ICE}	ALB_ICE†	0.4	0.3	0.5

*parameters are PFT specific therefore optimising the PFT1 (bare soil) parameter. Also there sum must be less than or equal to 1

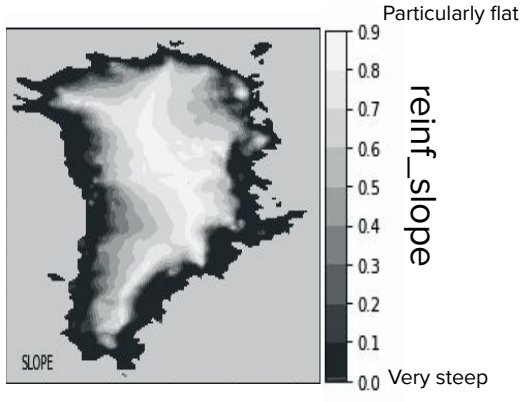
†this parameter takes two values which are both equal.

Observed and modelled albedo give different spatial patterns

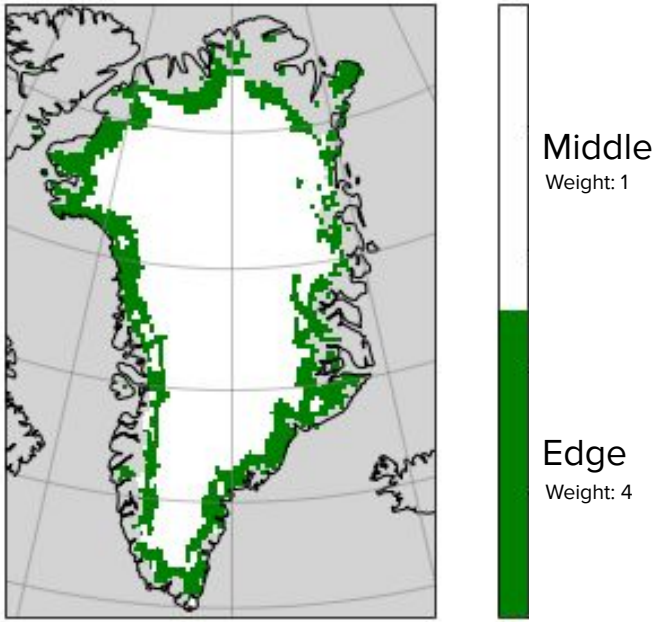


Summer Albedo (averaged over time 2000-2017)

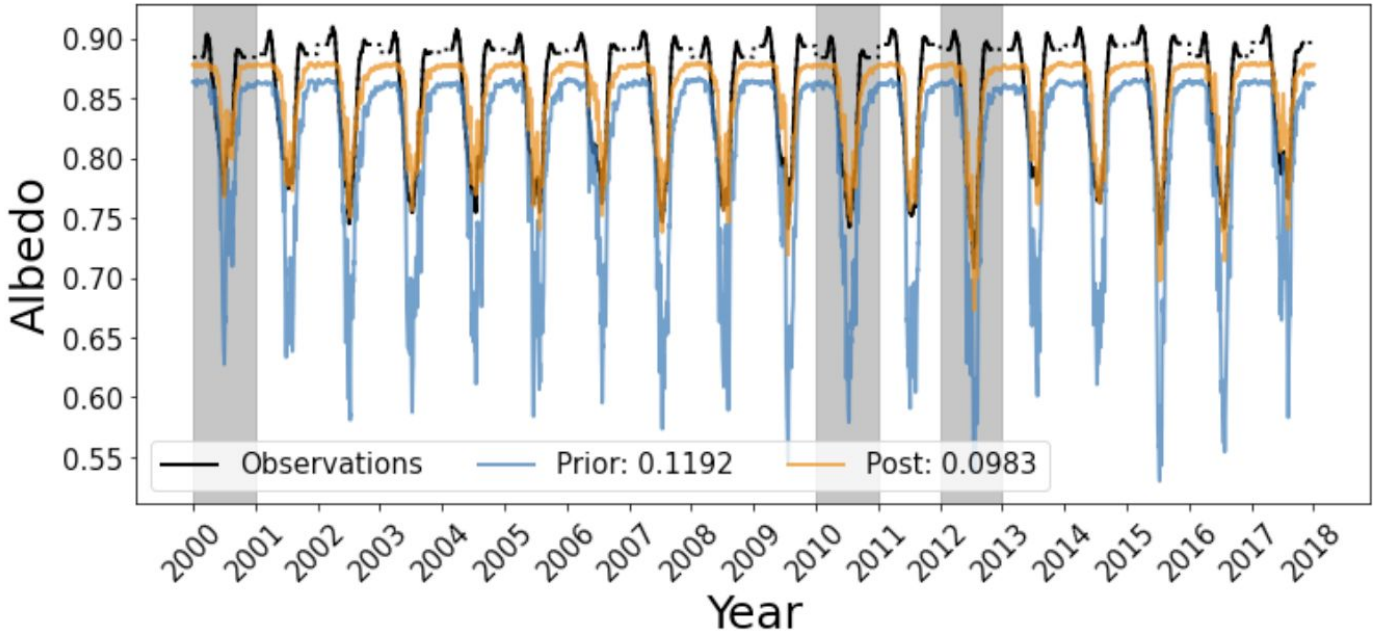
Using “reinf_slope” feature in ORCHIDEE, we can easily select the edges



reinf_slope = “fraction of rainfall re-infiltrated given the slope”

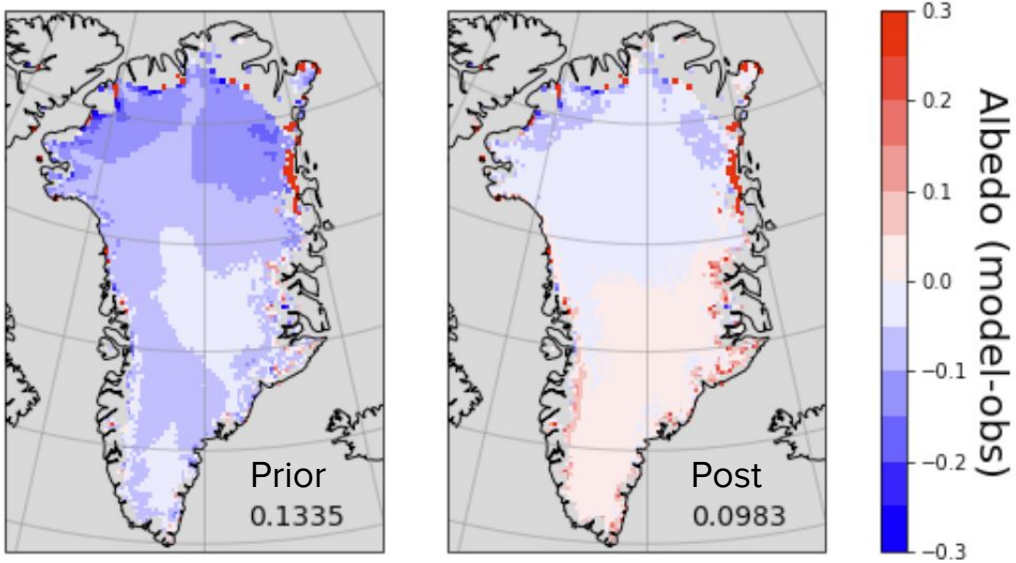


By optimising using three random years, we improve modelled ableddo

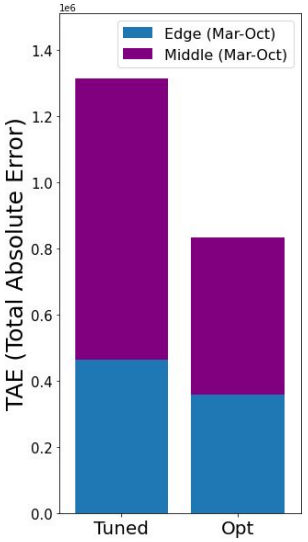


Averaged over space

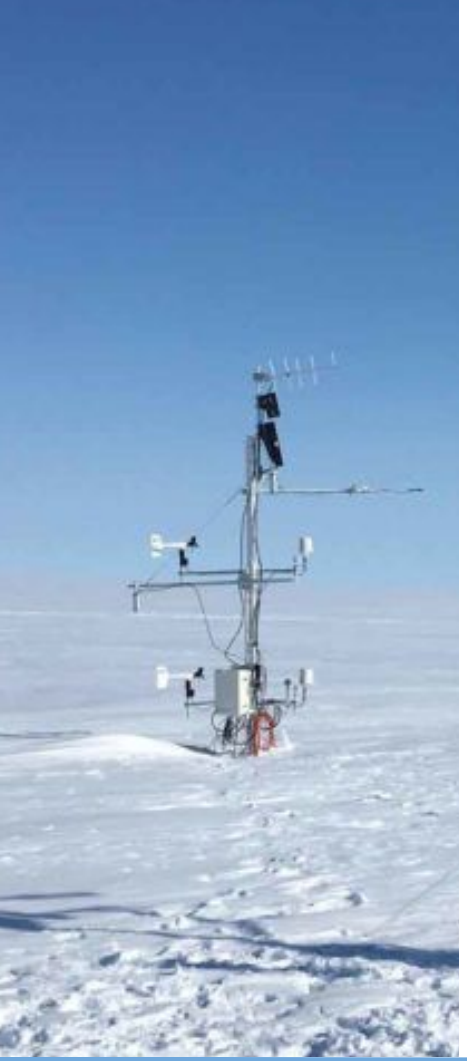
By optimising using three random years, we improve modelled abledo



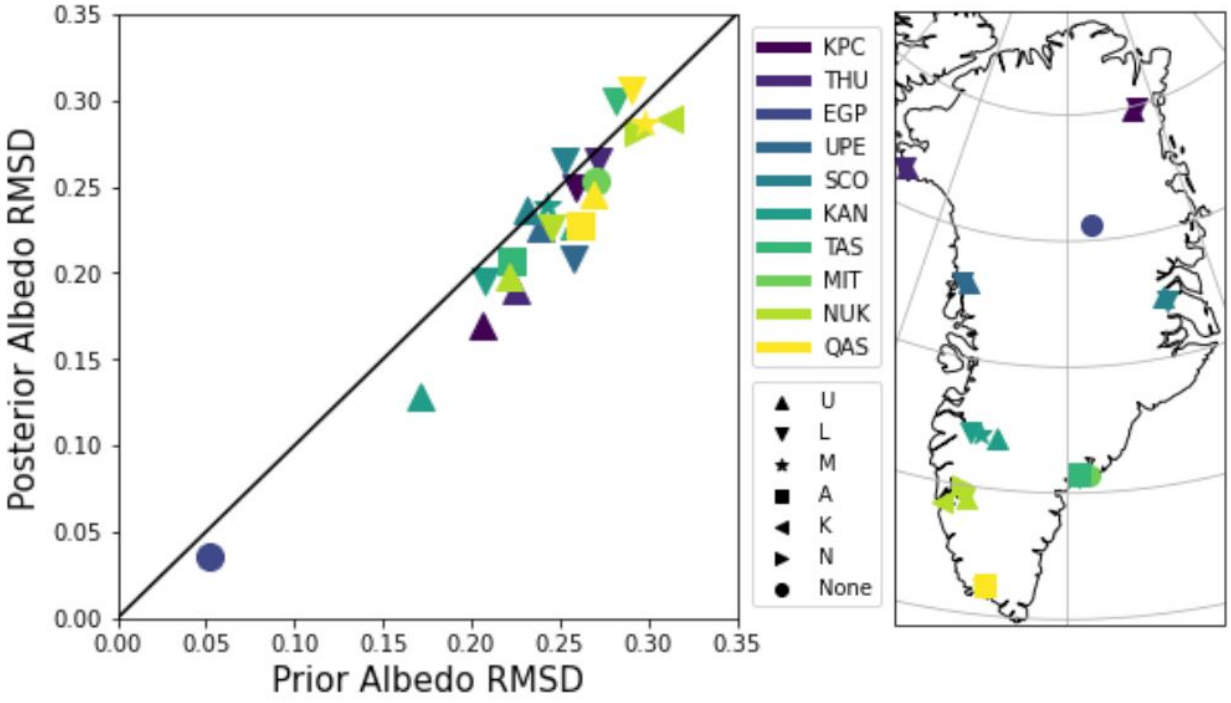
Averaged over time



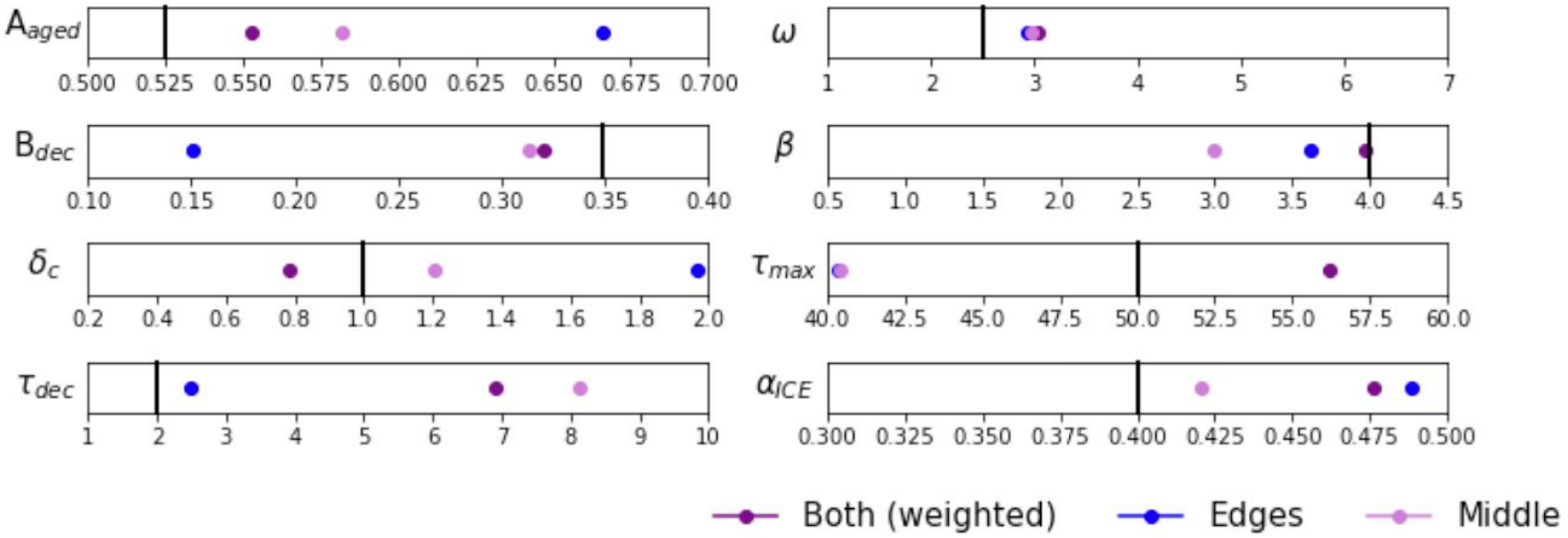
All points



Using PROMICE *in situ* data to validate



Different optimised parameters are found when focusing solely on the middle or edges

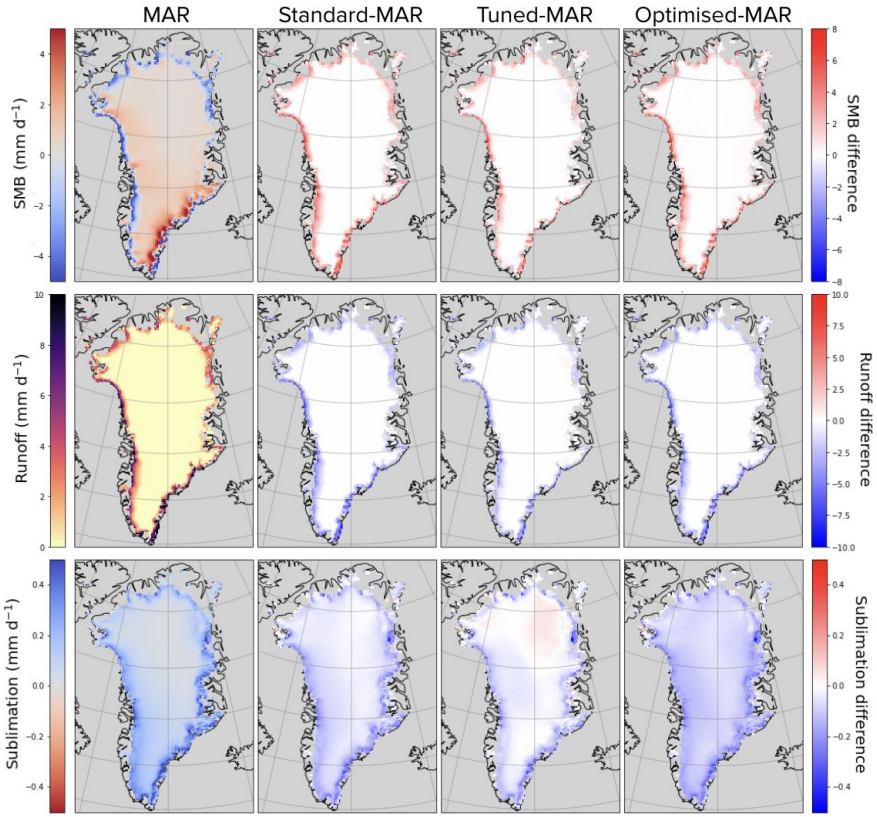


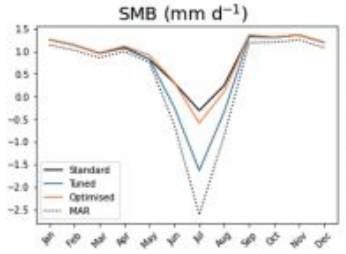
The impact of the new parameters on the surface mass balance

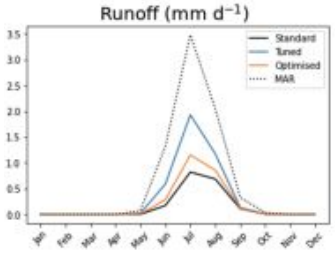
Surface Mass Balance

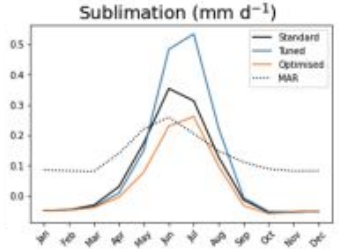
Runoff

Sublimation

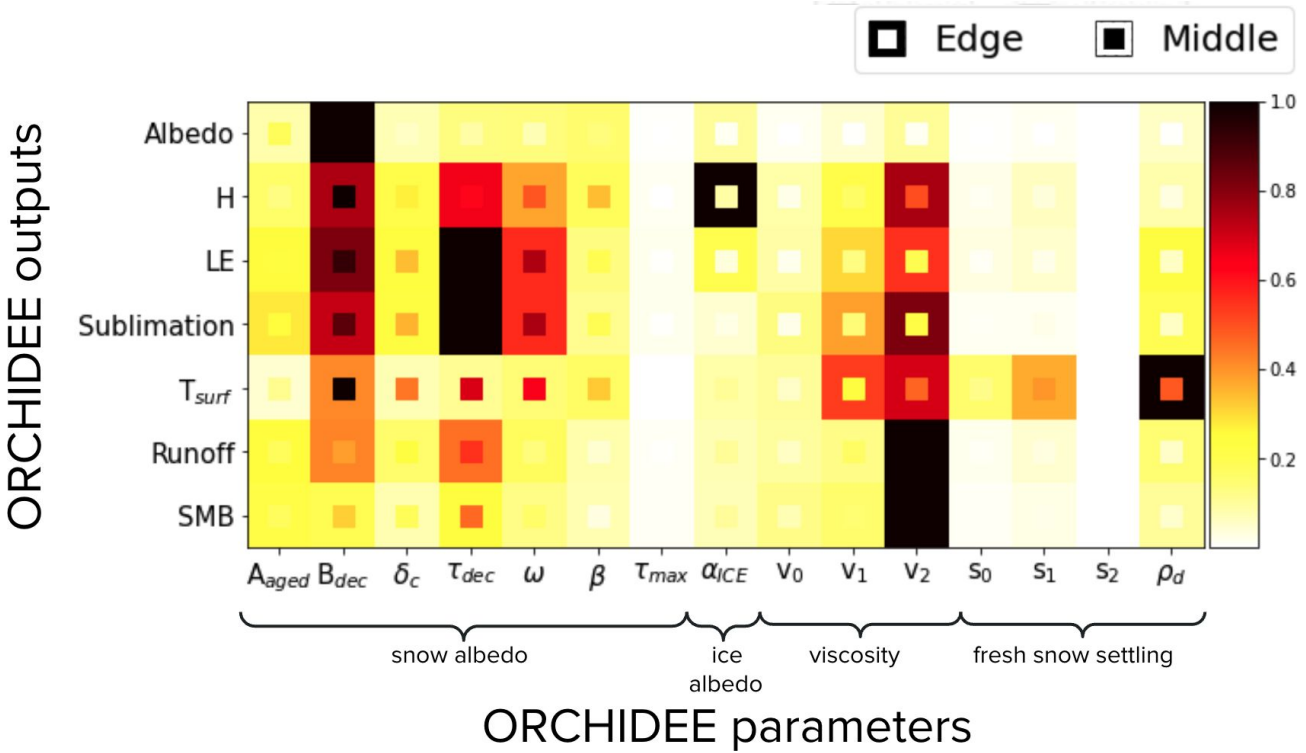








We can use parameter sensitivity experiment to help set up future optimisations



Take home messages:

- By **weighting the edges**, we were able to **improve modelled albedo** over the whole GrIS
- Improvement also found when **validated** against **independent data**
- Albedo has a **strong impact on other** ice sheet model **processes**
- This work **influenced** important model **developments**
- Future steps include **multi-data stream calibrations**

Raoult, N., Charbit, S., Dumas, C., Maignan, F., Ottlé, C., and Bastrikov, V.: Improving modelled albedo over the Greenland ice sheet through parameter optimisation and MODIS snow albedo retrievals, The Cryosphere, 17, 2705–2724, https://doi.org/10.5194/tc-17-2705-2023, 2023.

n.m.raoult2@exeter.ac.uk
@NinaRaoult

The parameters in the context of albedo parameterisation

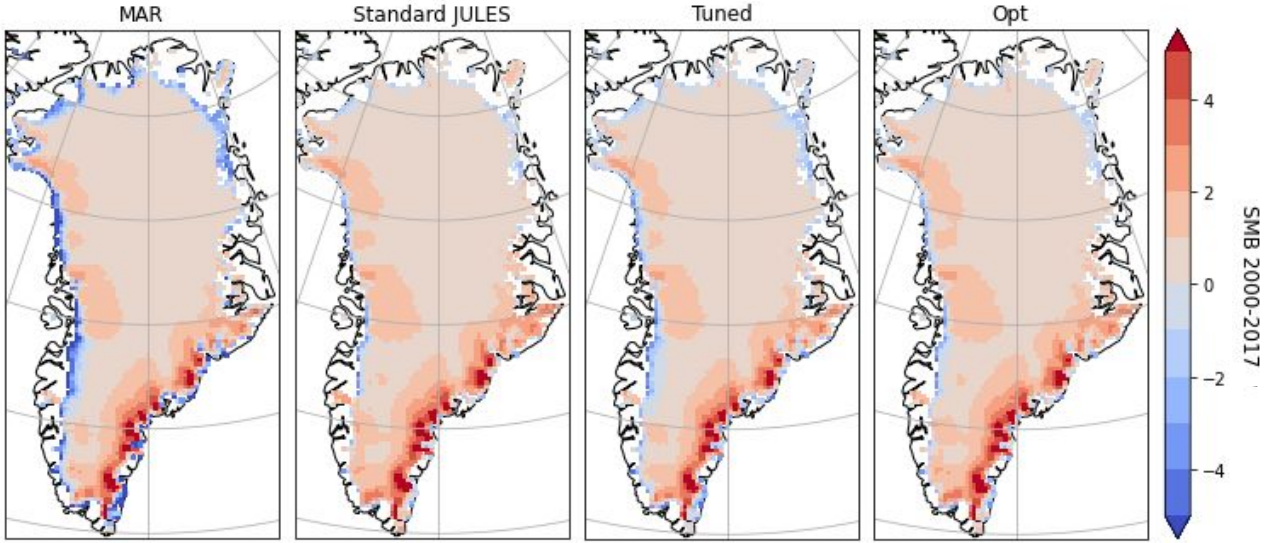
P_{snow} = snowfall
T_0 = melting temperature
τ_{snow} = snow age

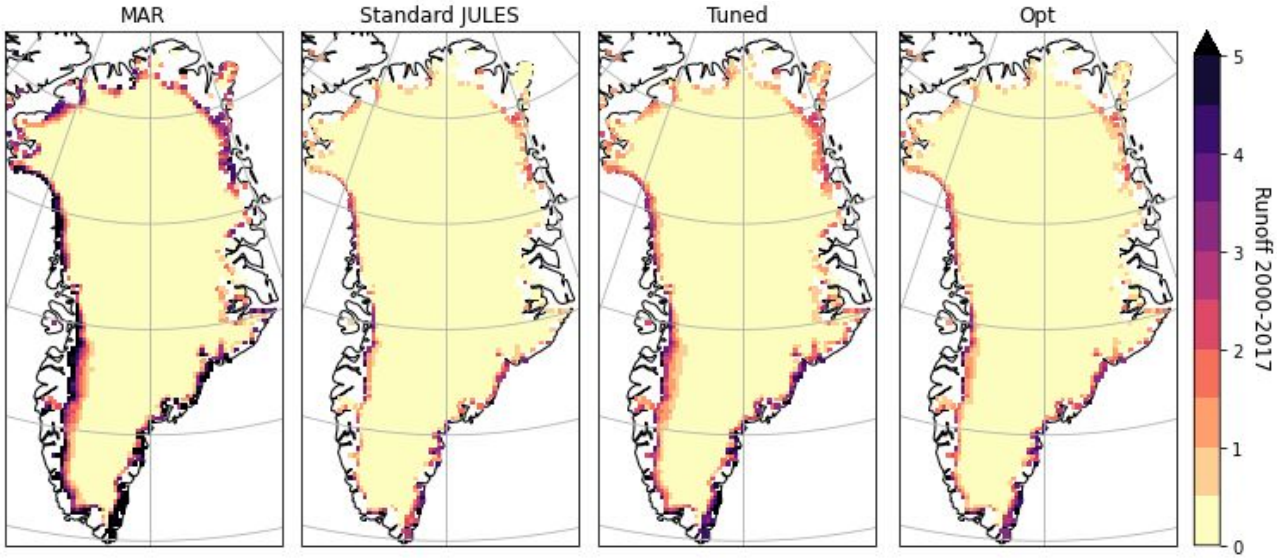
$$\alpha_{snow} = A_{aged} + B_{dec} \exp\left(-\frac{\tau_{snow}}{\tau_{dec}}\right)$$

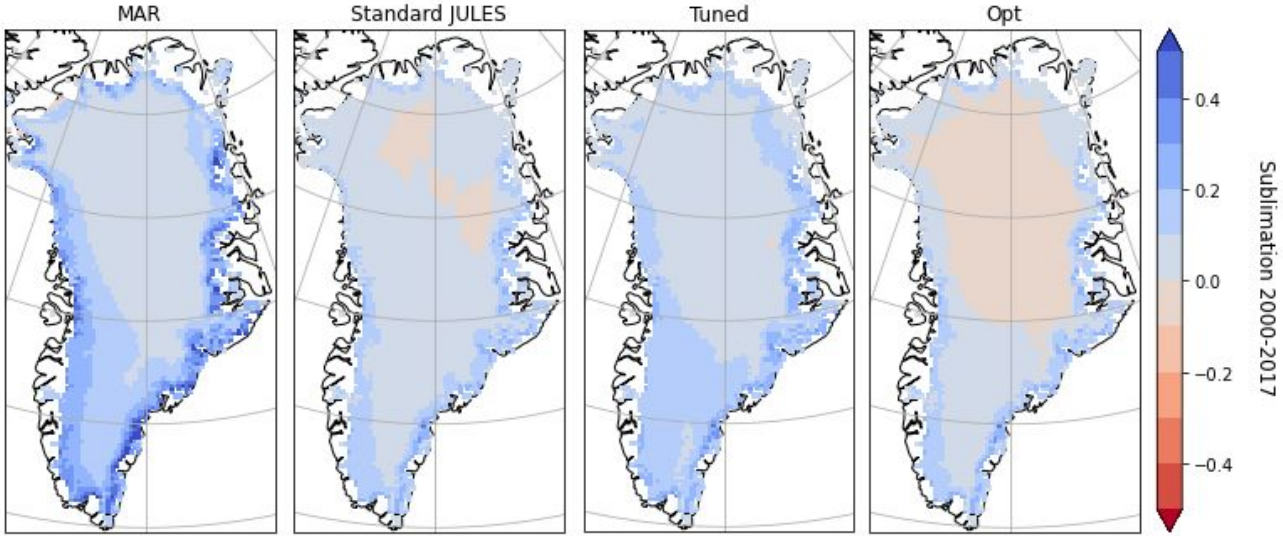
$$\tau_{snow}(t+dt) = \exp\left(-\frac{P_{snow}}{\delta_c}\right).\left[\tau_{snow}(t) + dt\,.\left(1 - \frac{\tau_{snow}}{\tau_{max}}\right)\right] + \left[\frac{\exp\left(-\frac{P_{snow}}{\delta_c}\right).\left[\tau_{snow}(t) + dt\,.\left(1 - \frac{\tau_{snow}}{\tau_{max}}\right)\right].-\tau_{snow}(t)}{1 + \left(\frac{\text{Max}\,(T_0 - Tair,\ 0)}{\omega}\right)^{\beta}}\right]$$

The effect of low temperatures on metamorphism

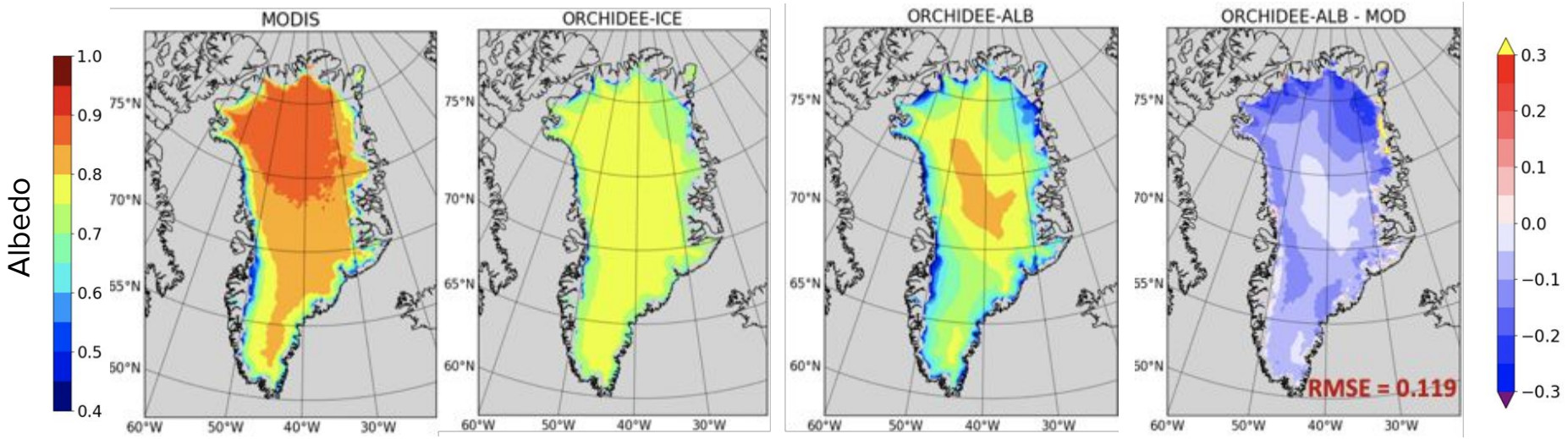
In red the seven albedo parameters to be calibrated against MODIS data (for non-ice surfaces only)


MAR
Standard JULES
Tuned
Opt
4
2
0
−2
−4
SMB 2000-2017


MAR
Standard JULES
Tuned
Opt
Runoff 2000-2017
0
1
2
3
4
5


MAR
Standard JULES
Tuned
Opt
0.4
0.2
0.0
−0.2
−0.4
Sublimation 2000-2017

The observations, model and difference: y, $M(x)$, $(y - M(x))$



Summer Albedo (averaged over time 2000-2017)