

Evaluation of a coupled climate ice sheet model over the Greenland ice sheet and sensitivity to atmospheric, snow and ice sheet parameters

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Ensemble design

- **FAMOUS-BISICLES** with slab ocean
- Fixed [CO₂] – **historical** run
- 100 climate years
- 10 times acceleration: 10 ice sheet years per climate year
- **13 perturbed parameters** – 169 simulations

Category	Number	Model
Snow and ice albedo	3	FAMOUS
Sea ice albedo	1	FAMOUS
Clouds/precipitation	5	FAMOUS
Lapse rate downscaling	1	
Ice sheet dynamics	3	BISICLES

Ensemble design

FAMOUS-BISICLES

- Variant of FAMOUS-ice (Smith et al., 2021a). Low resolution ($7.5^\circ \times 5^\circ$) global climate model two-way coupled to a higher resolution adaptive mesh ice sheet model, BISICLES (Cornford et al., 2013)
- Uses a system of elevation classes to downscale the lower resolution atmospheric variables onto the ice sheet grid and calculates surface mass balance using a multilayer snow model
- Computationally affordable enough to simulate the millennial evolution of the coupled climate-ice sheet system
- Has been shown to simulate Greenland well in previous work using the Glimmer shallow ice model (Gregory et al., 2020)

Ensemble design

Parameter	Description	Min	Max	Category	Model
daice	Effect of melt ponds on ice albedo	-0.4	0	Snow and ice albedo	FAMOUS
ρ_{thres}	Heterogeneity of "denser" firn and presence of lower albedo areas	250	800	Snow and ice albedo	FAMOUS
AV_GR	Effect of snow grain size on albedo	0.001	0.01	Snow and ice albedo	FAMOUS
RHcrit	threshold of relative humidity for cloud formation	0.6	0.9	Clouds/precipitation	FAMOUS
VF1	precipitating ice fall-out speed	0.5	2.0	Clouds/precipitation	FAMOUS
CT	conversion rate of of cloud liquid water droplets to precipitation	0.5×10^{-4}	4×10^{-4}	Clouds/precipitation	FAMOUS
CW	Threshold value of cloud liquid water for formation of precipitation	1×10^{-4}	2×10^{-3}	Clouds/precipitation	FAMOUS
ENTCOEF	involved in entrainment rate calculation	0.6	9.0	Clouds/precipitation	FAMOUS
α_M	sea ice low albedo	0.2	0.65	Sea ice albedo	FAMOUS
tgrad	Lapse rate for temperature downscaling on ice sheet grid	-10°/km	-2°/km		
n	Exponent in Glen's flow law	1.9	4.5	Ice sheet dynamics	BISICLES
β	Basal drag coefficient (inversion)	/2	$\times 2$	Ice sheet dynamics	BISICLES
muCoef	Locally alters ice effective viscosity (inversion)	/2	$\times 2$	Ice sheet dynamics	BISICLES

Ensemble design

* Snow density threshold (ρ_{thres})

$$\begin{cases} f_{\text{snow}} = 1 \\ f_{\text{snow}} = 1 - \frac{\rho_{\text{snow}} - \rho_{\text{thres}}}{800 - \rho_{\text{thres}}} \end{cases}$$

$$\rho_{\text{snow}} < \rho_{\text{thres}}$$

$$\rho_{\text{snow}} > \rho_{\text{thres}}$$

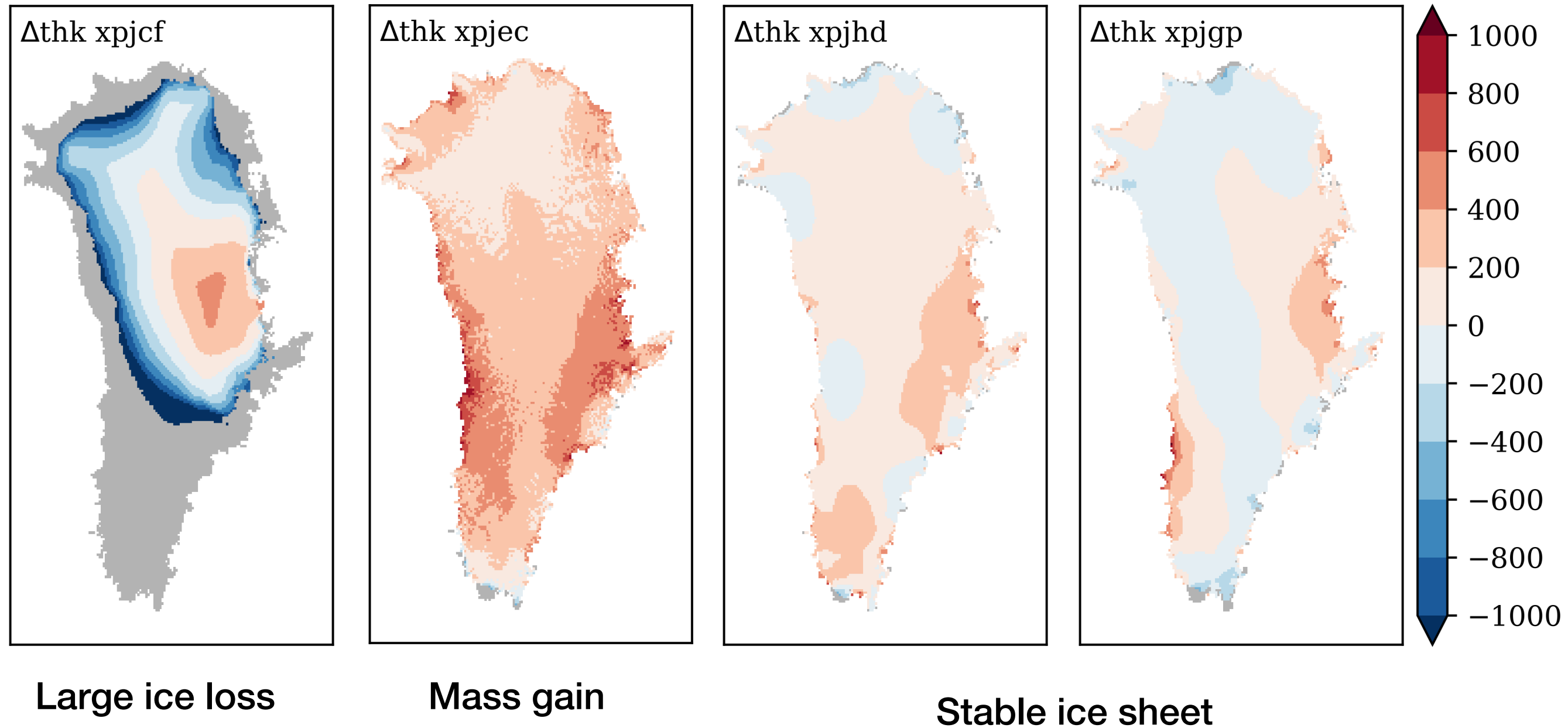
$$a = a_{\text{snow}} \times f_{\text{snow}} - a \times (1 - f_{\text{snow}})$$

* Basal drag coefficient (β)

$$\tau_b = -\beta u^{1/m}$$

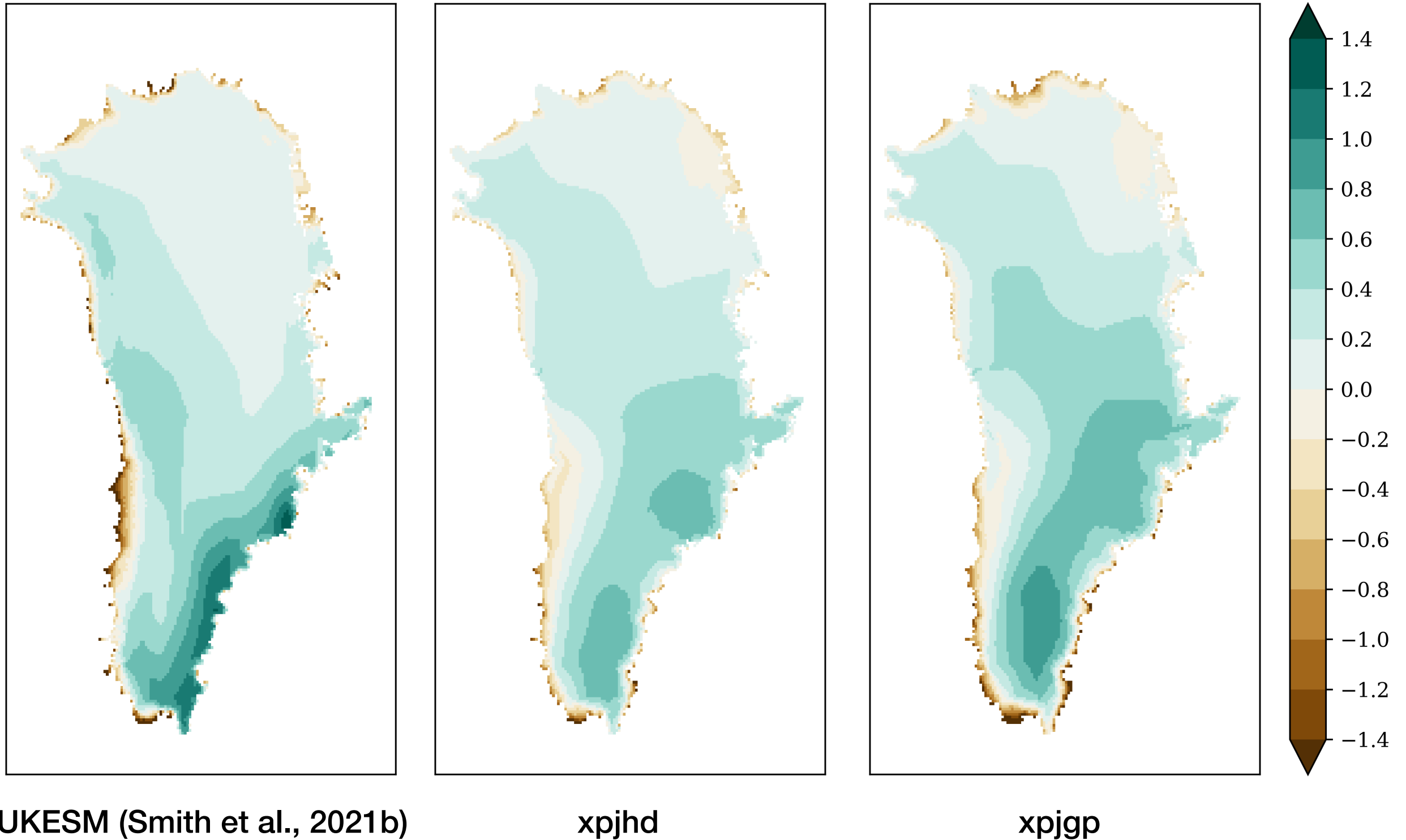
Evaluation

Ice thickness difference (m) over 1000 ice sheet years



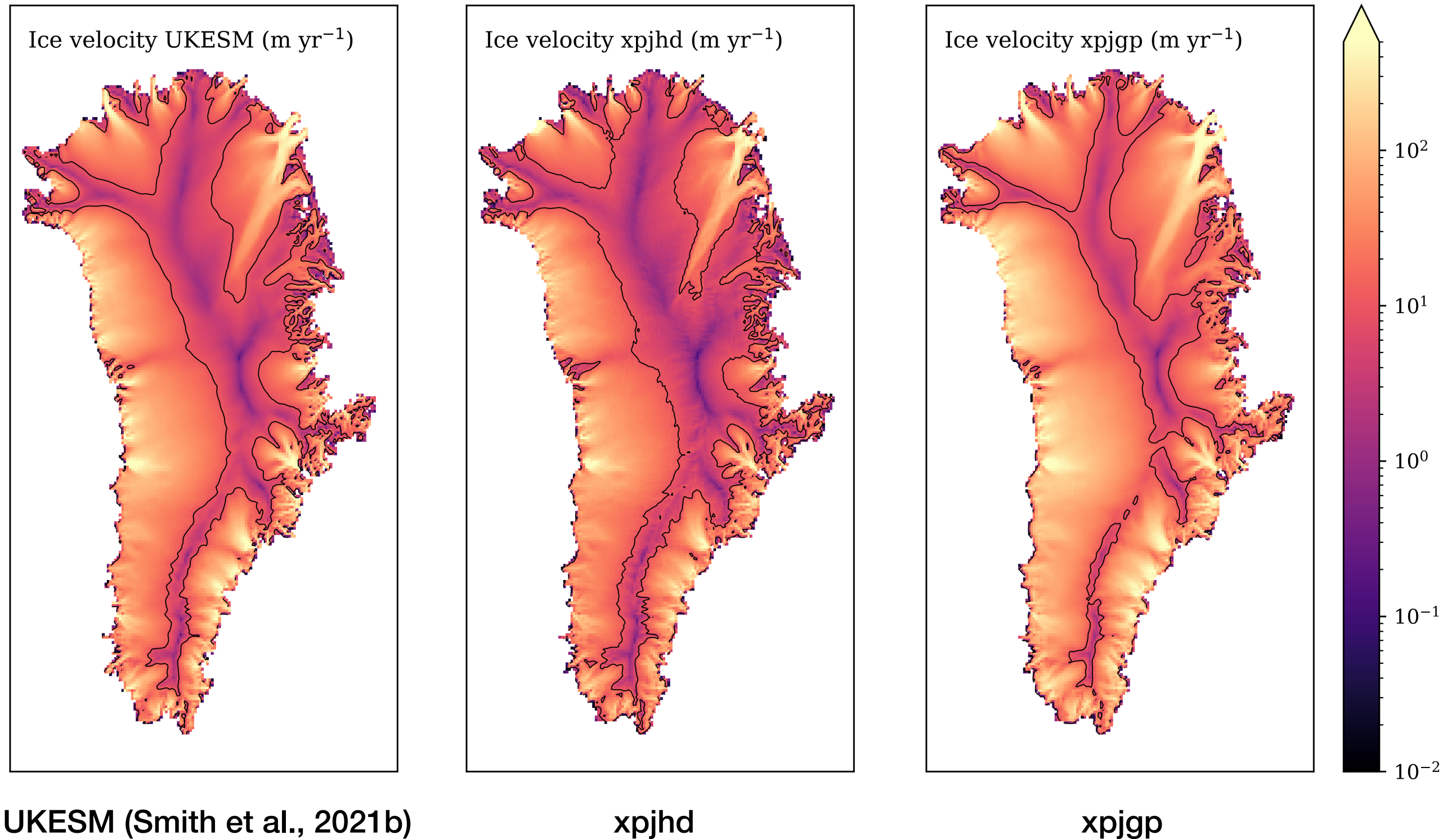
Evaluation

Surface mass balance (m yr^{-1}) of stable simulations compared to UKESM

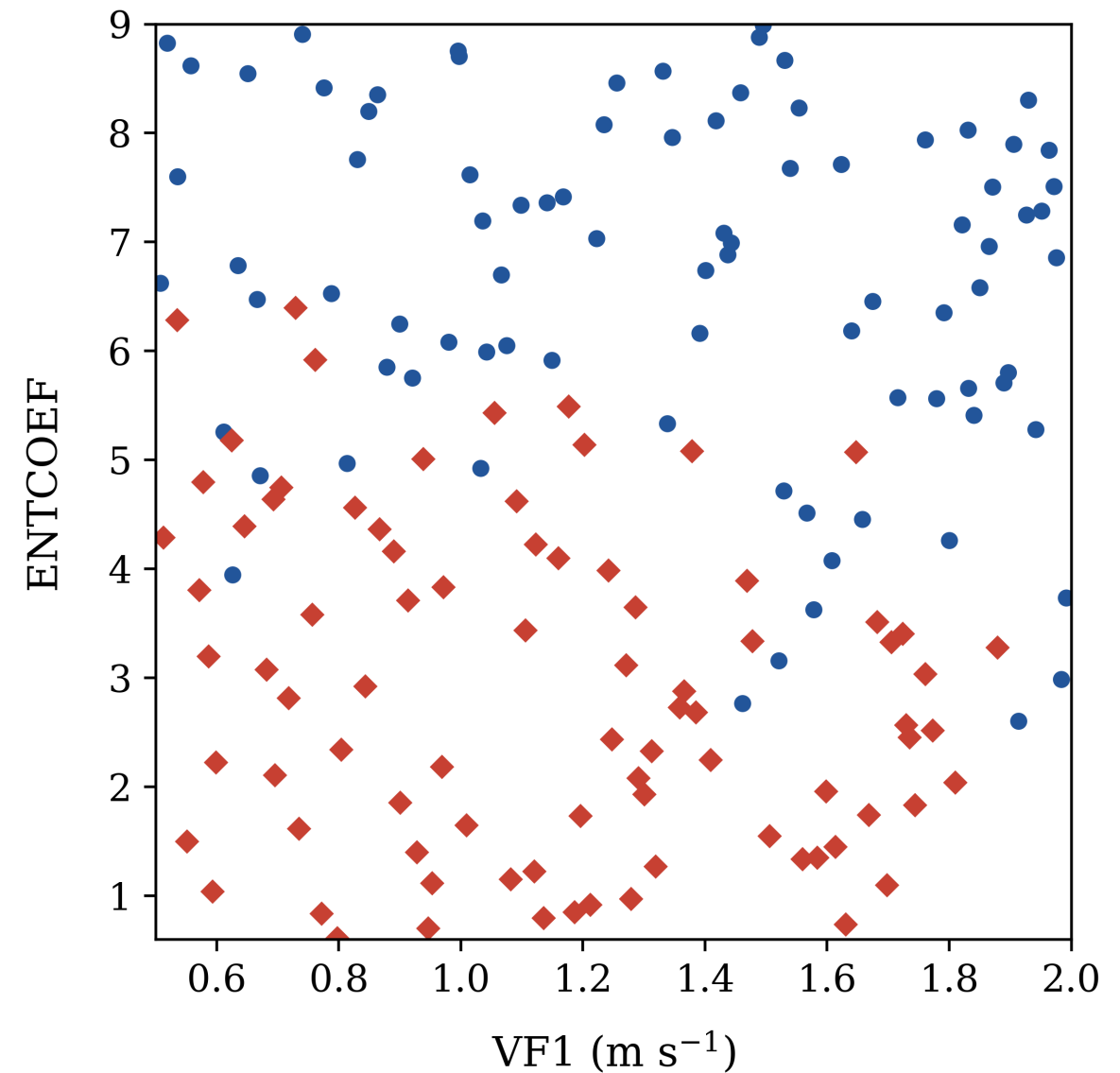
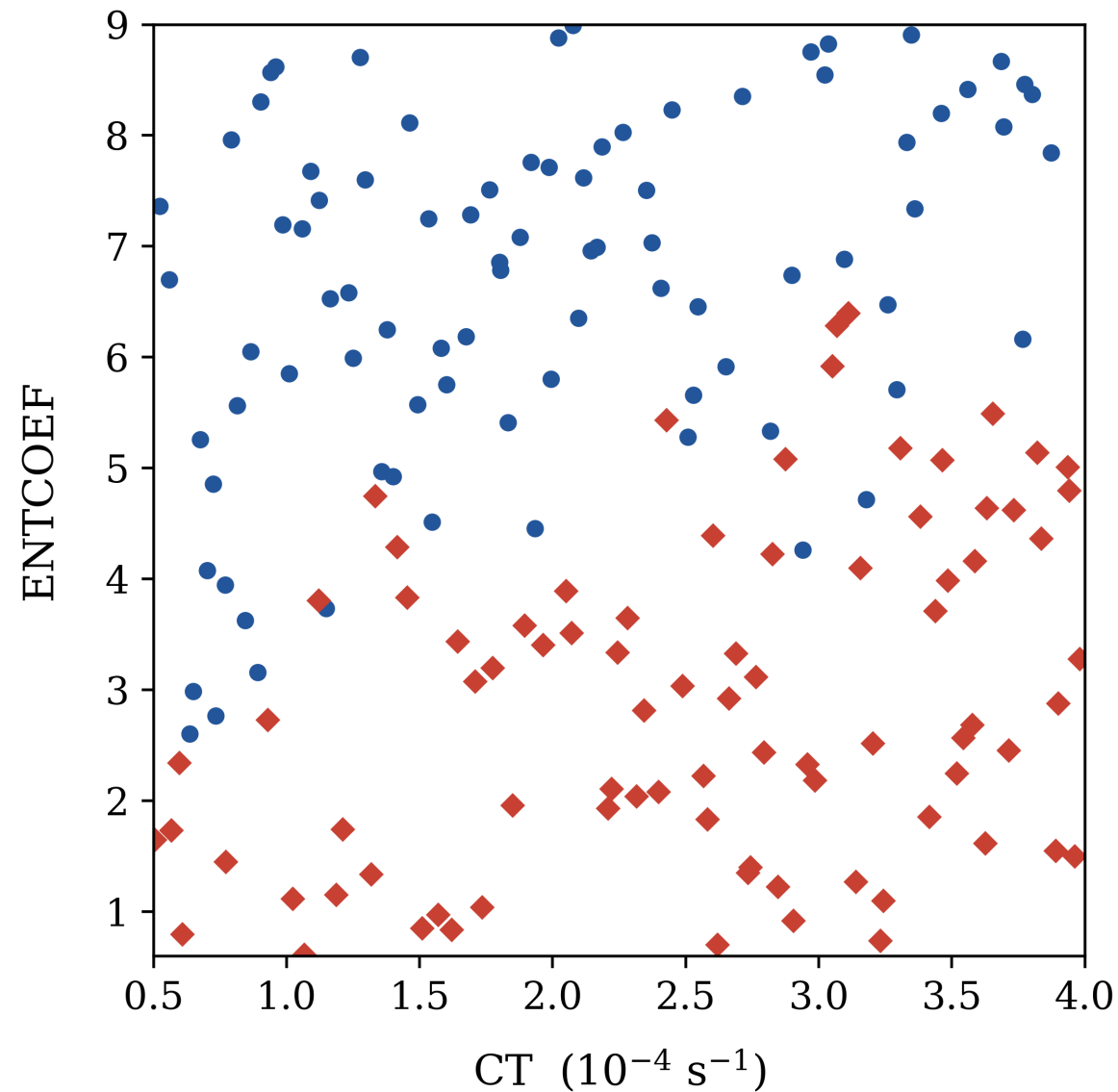


Evaluation

Ice velocities (m yr⁻¹) of stable simulations compared to UKESM-BISICLES



Failed runs



ENTCOEF

Involved in entrainment rate calculation

CT

Conversion rate of of cloud liquid water droplets to precipitation

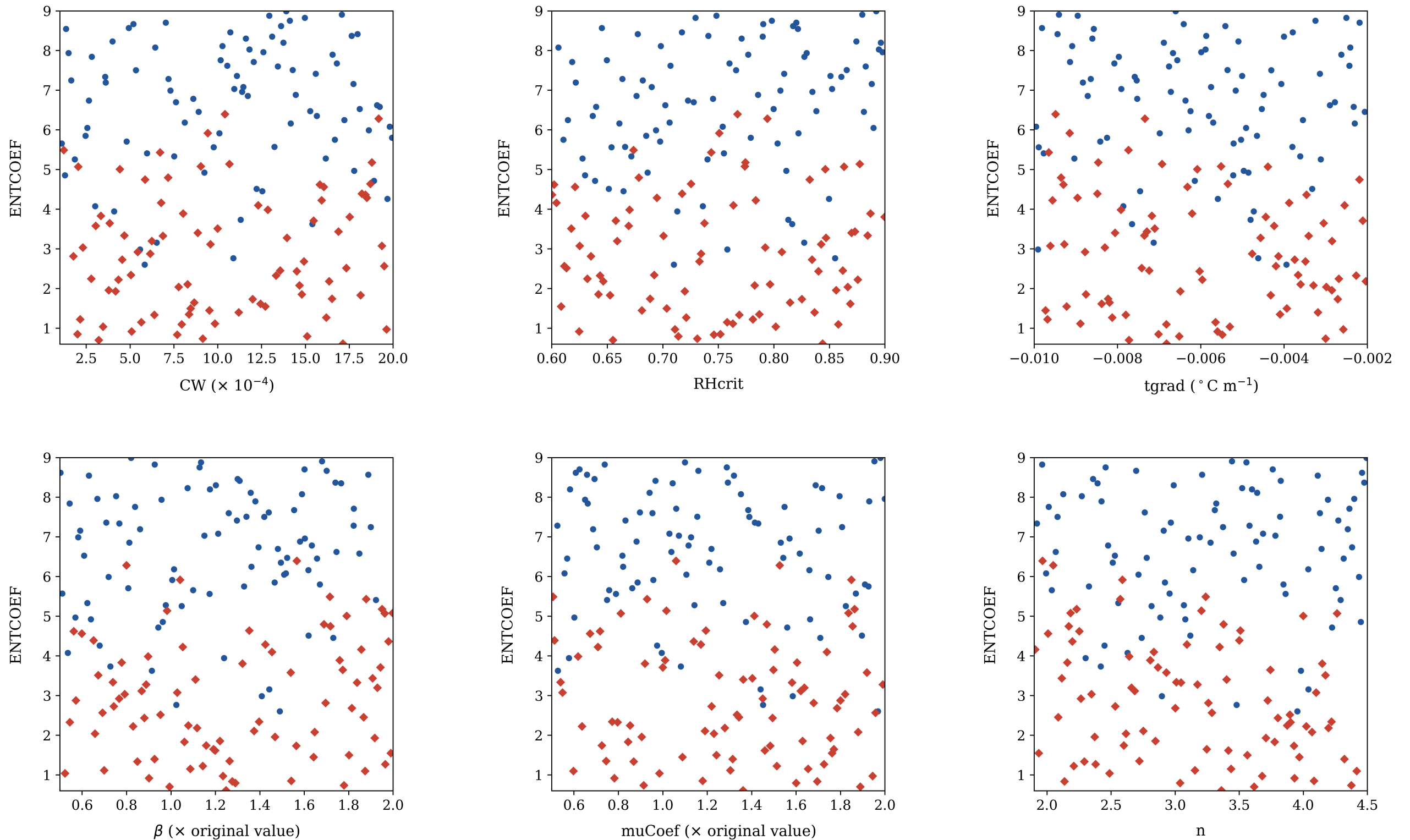
VF1

Precipitating ice fall-out speed

● Successful runs ◆ Failed runs

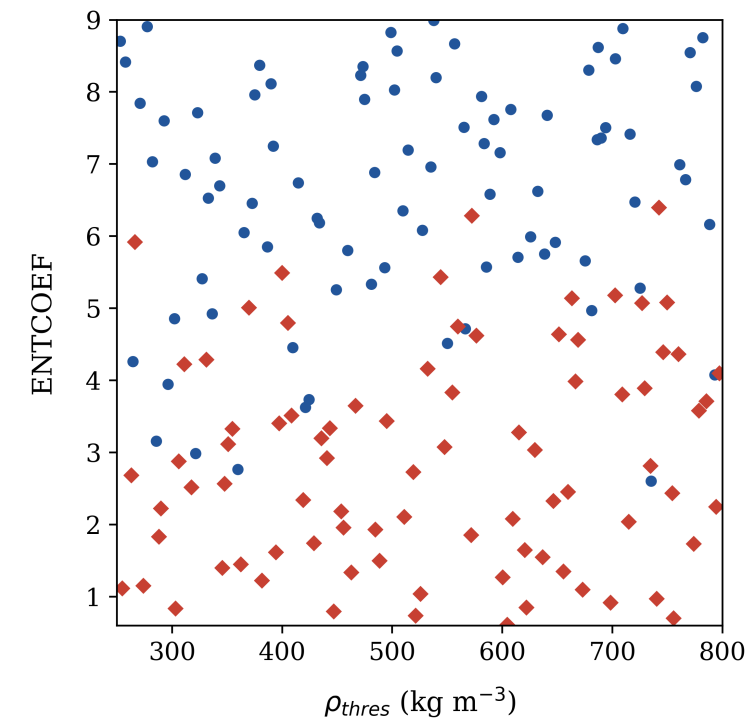
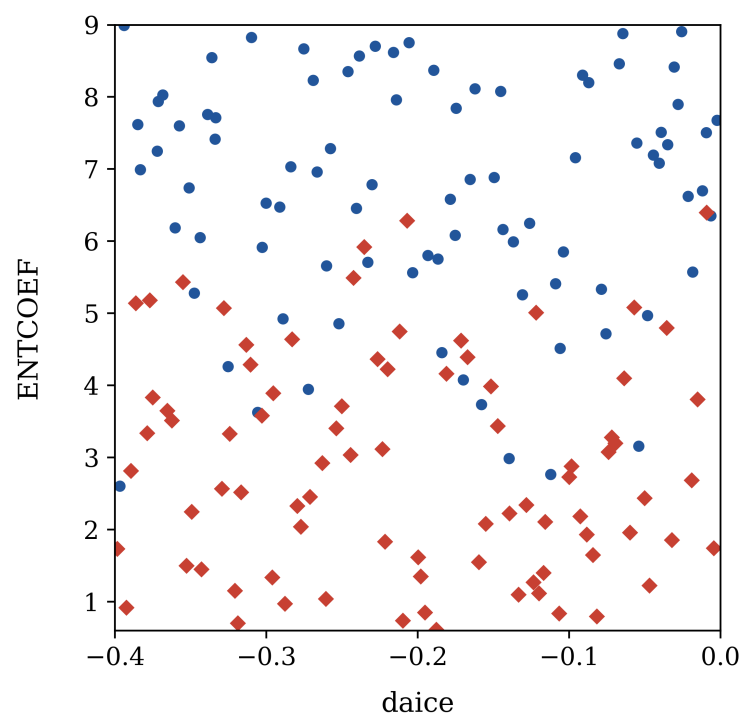
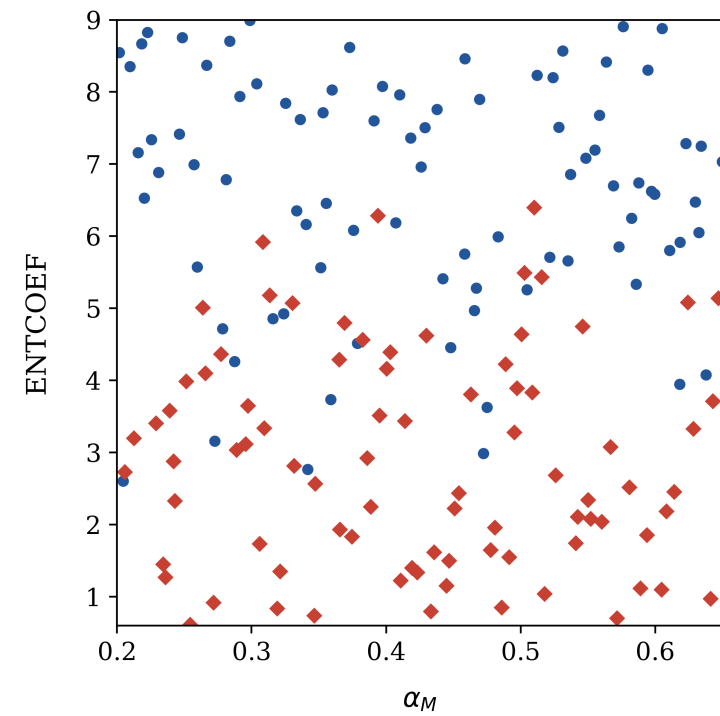
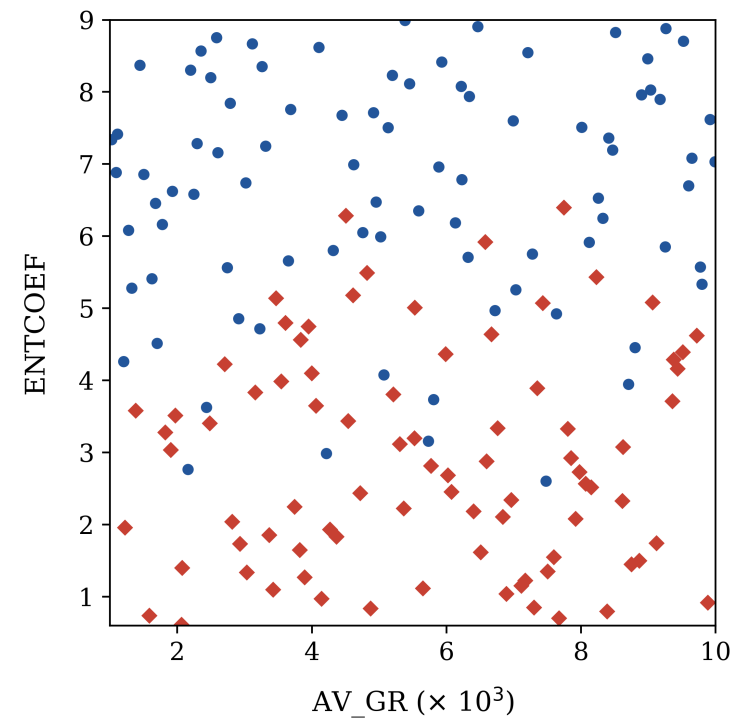
Failed runs

Other parameter combinations: ENTCOEF

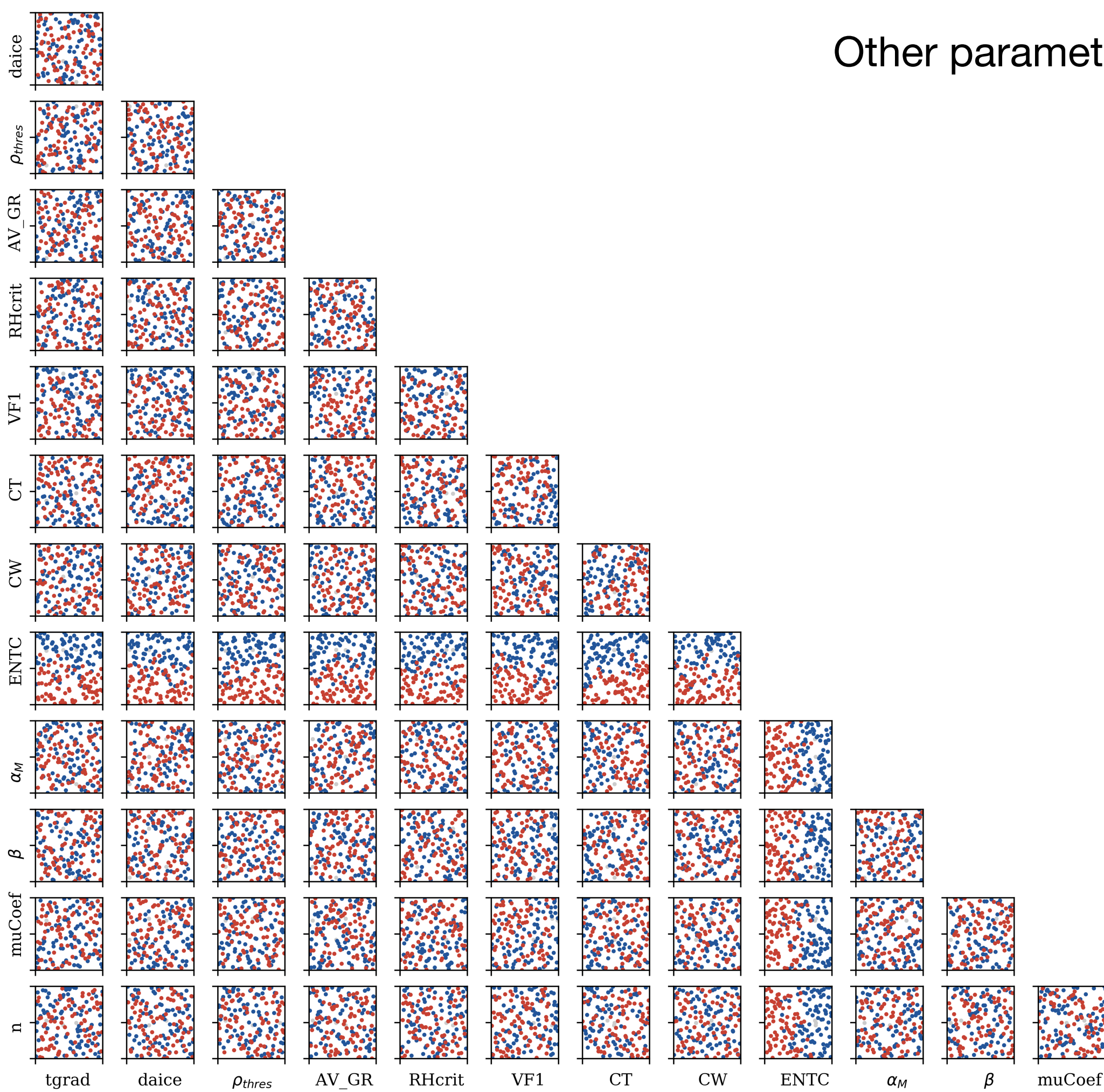


Failed runs

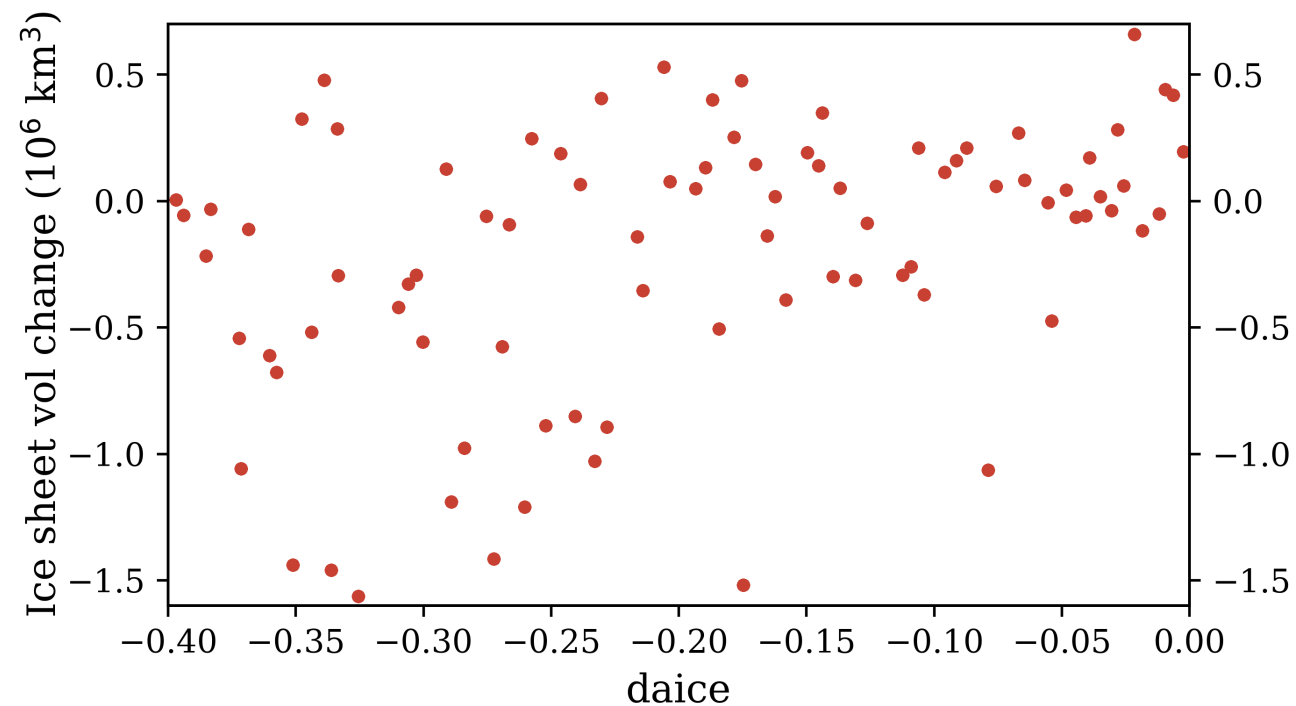
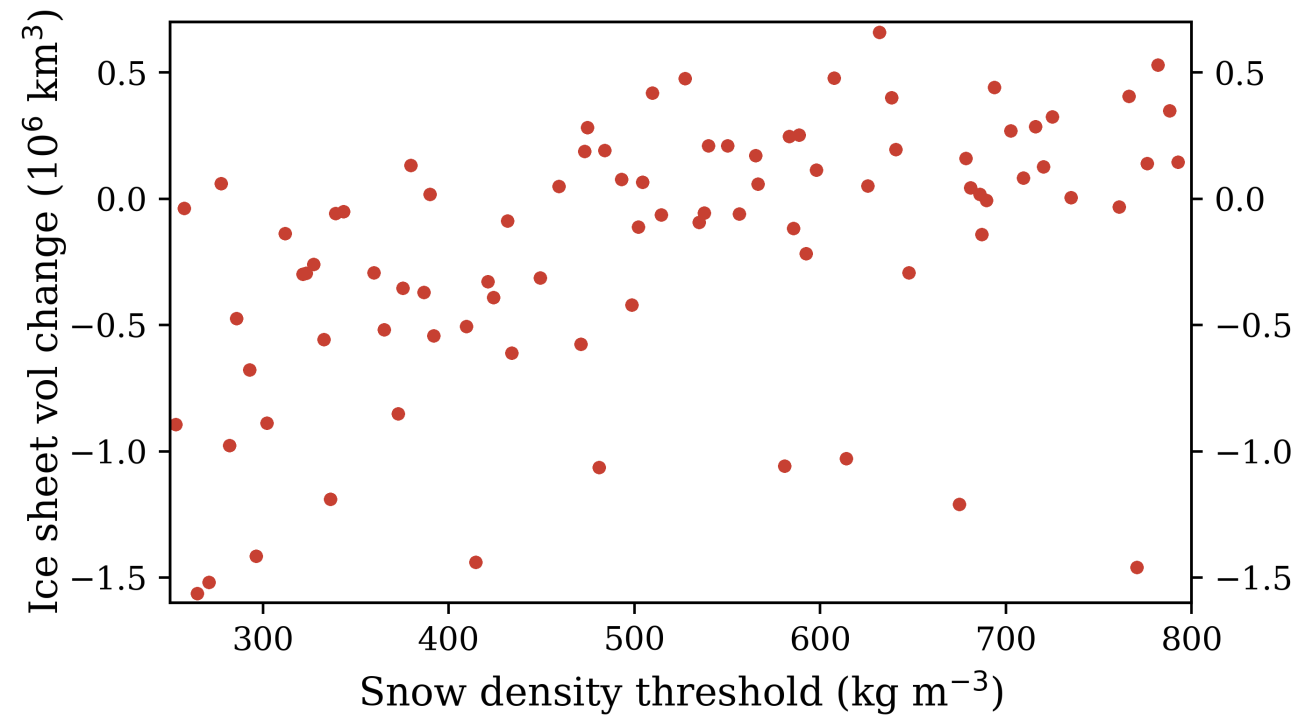
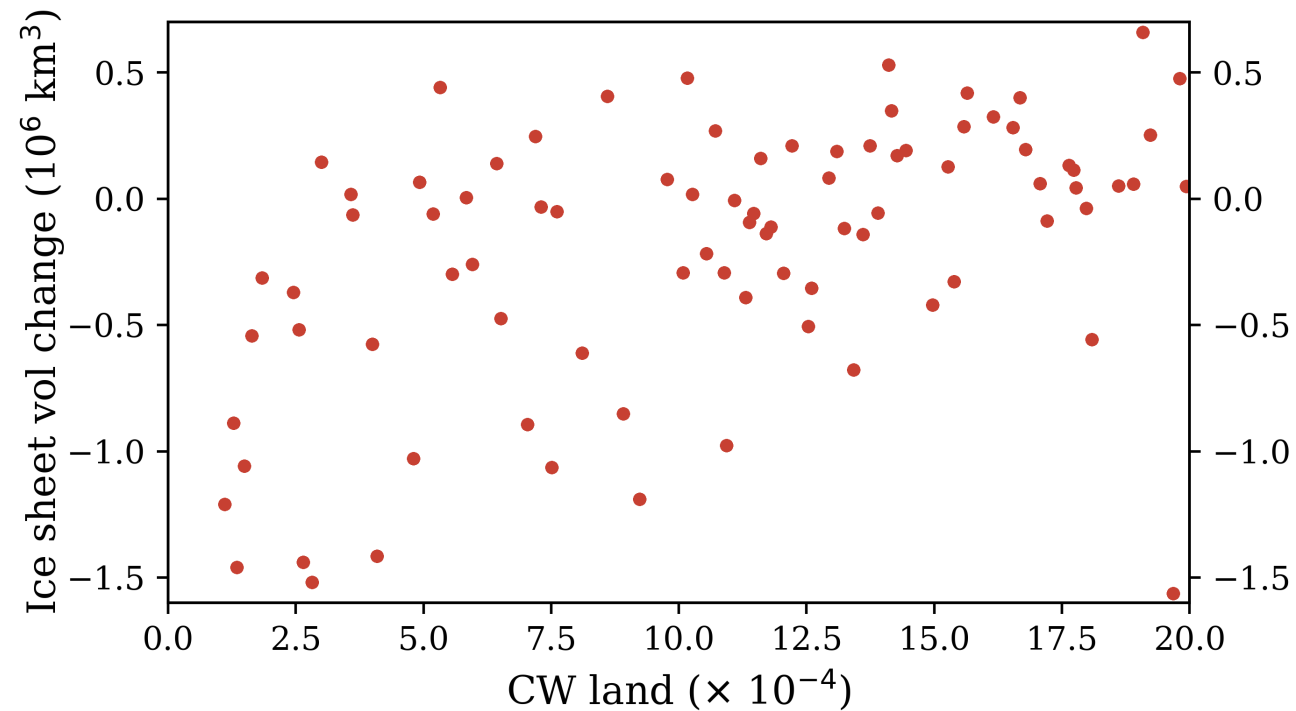
Other parameter combinations: ENTCOEFF



Other parameter combinations



Ice volume change vs parameters



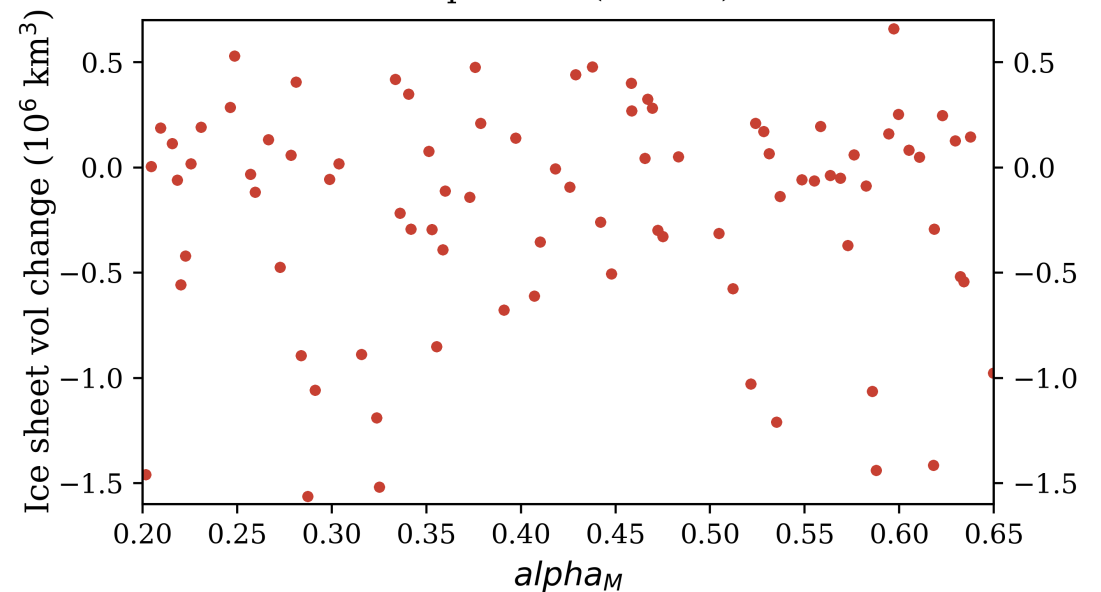
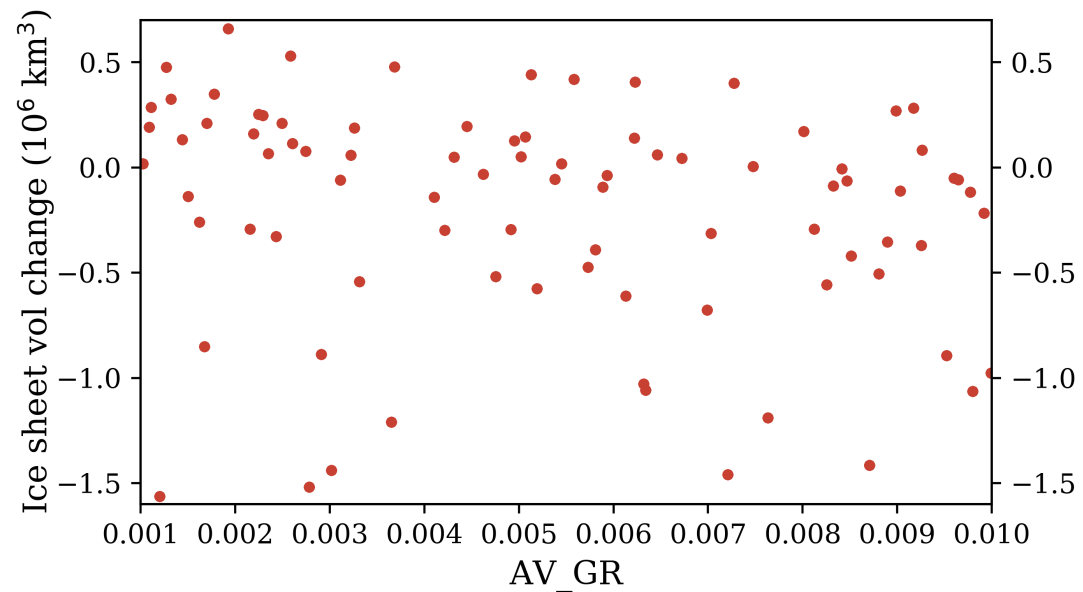
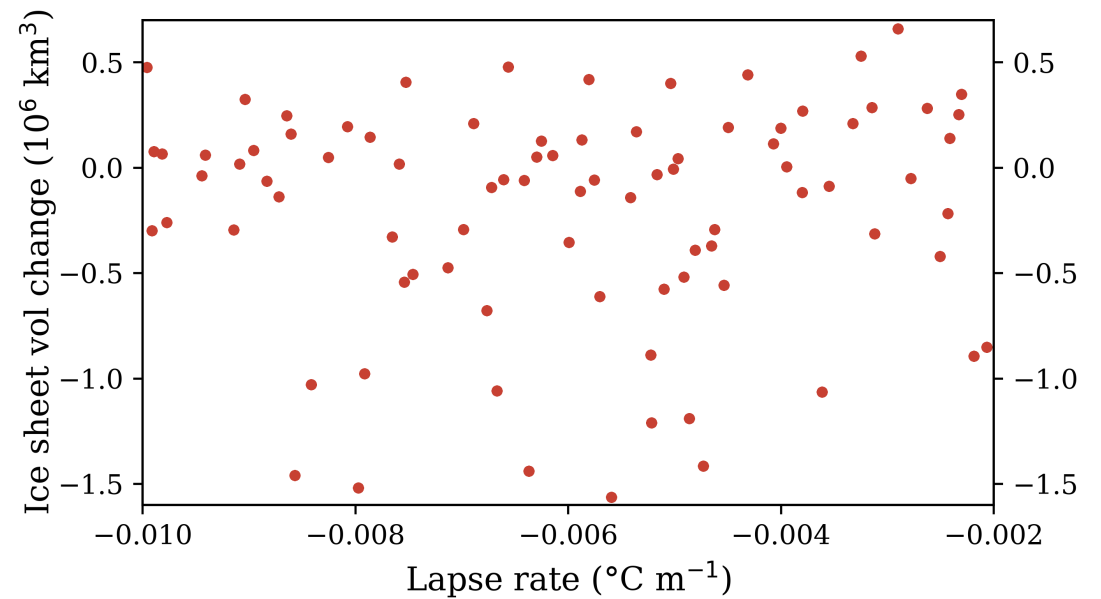
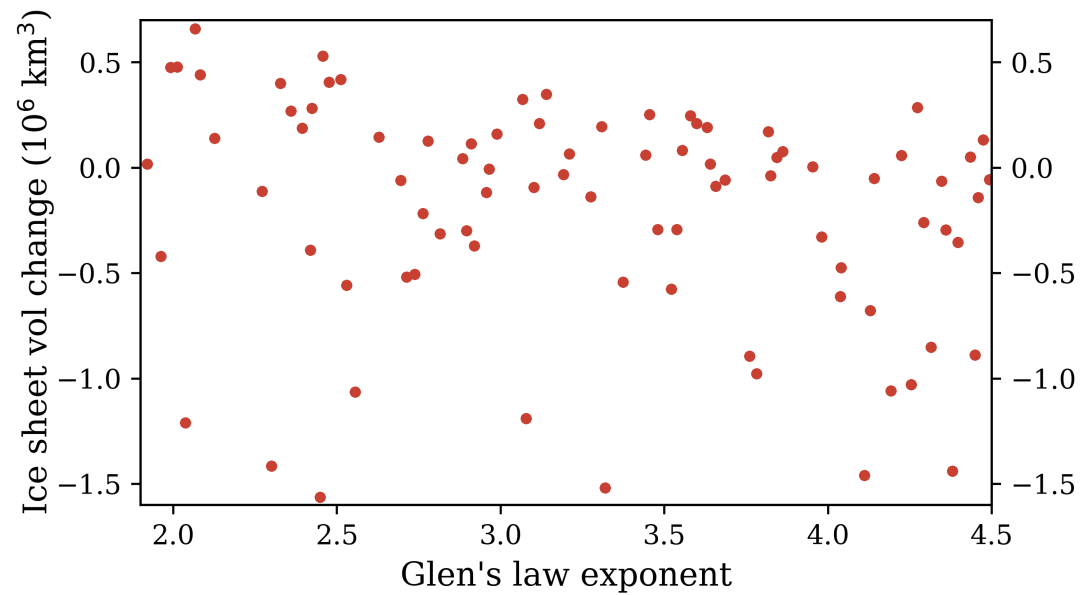
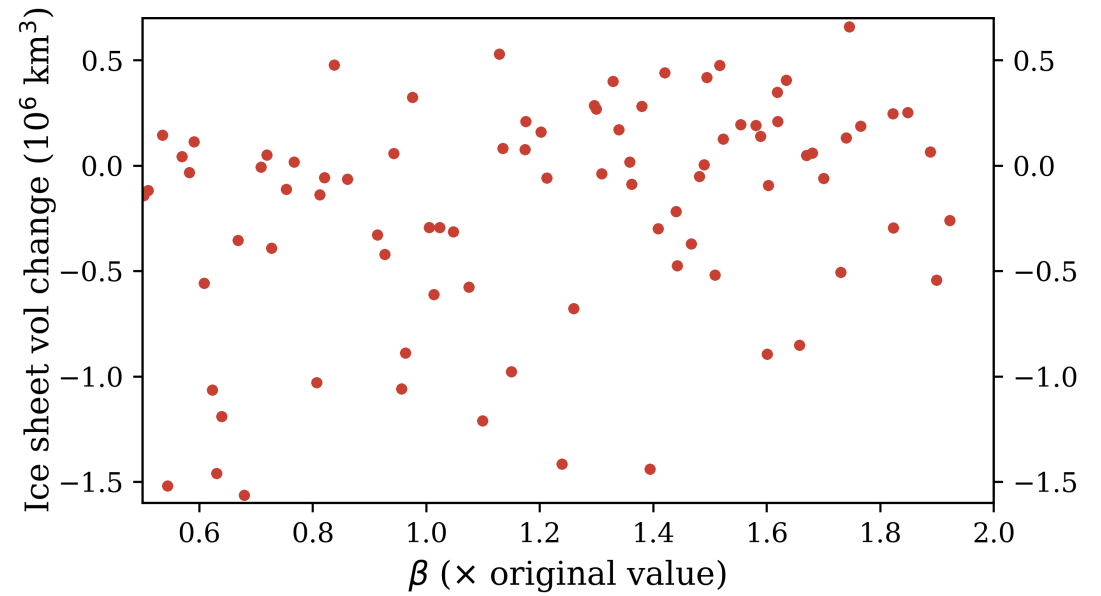
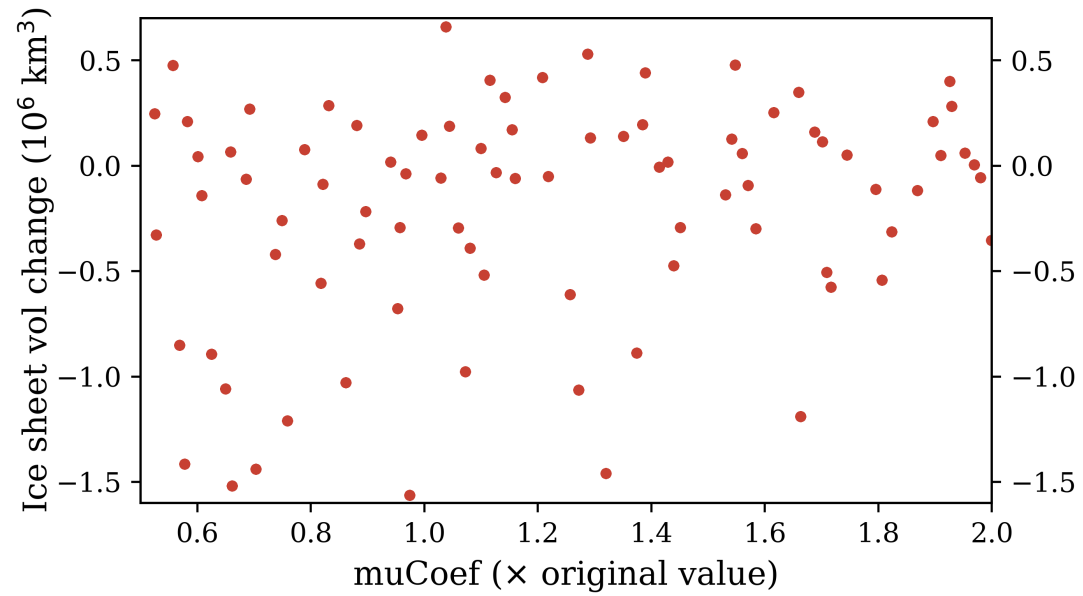
Cw

ρ_{thres}

daice

Threshold value of cloud liquid water for formation of precipitation
Heterogeneity of "denser" firn and presence of lower albedo areas
Effect of melt ponds on ice albedo

Ice volume change vs parameters



Ice volume change vs parameters

