Modelling the Impacts of Summer Extreme Precipitation Events on Surface Mass Balance in Southern Greenland

Supplementary Material

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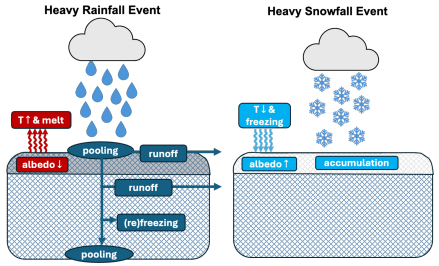
Abstract & Supplementary Information

1. Background & Motivation

The warming Arctic is expected to become wetter (McCrystall et al., 2021), and slight changes in mean precipitation conditions can cause much **larger shifts in extremes** (Pendergrass, 2018). Extreme precipitation can have **complex impacts on the surface mass balance** (SMB) of land ice, particularly in the summer.

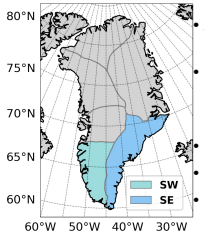


Example case studies: Doyle et al. (2015), Harper et al. (2023); Oerlemans & Klok (2004)

Southern Greenland experiences many extreme precipitation events and is vulnerable to climatic changes (e.g., Bevis et al., 2019), but we **do not know the longer-term SMB impacts** of these events.

Objective: Assess and compare impacts of historical and future warm-season extreme precipitation on SMB in Southern Greenland.

2. Data & Methods

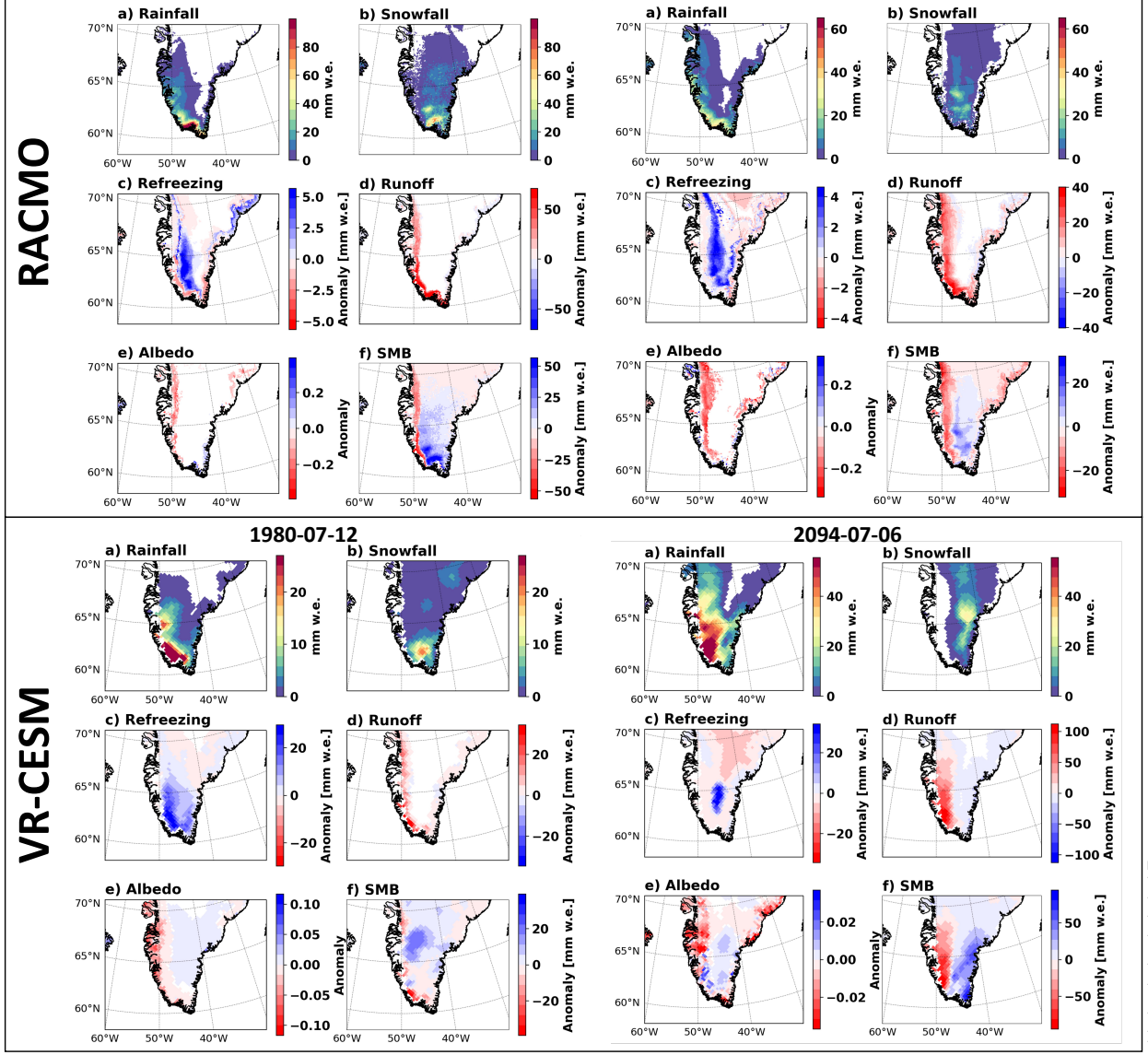


- *Subregions:* SW and SE basins (Rignot & Mouginot, 2012)
- *Extreme precipitation day:* top 5% of precipitation days based on volume within the subregion
- *Warm season:* July-September (JJAS)
- *Historical period (HIST):* 1980 – 1998
- *Future period (FUT):* 2080 – 2098 (SSP5-8.5)

Model	Spatial Resolution	Source
Regional Atmospheric Climate Model v2.3 (**RACMO**)	~ 12 km	Noël et al. (2018)
Variable-resolution Community Earth System Model (**VR-CESM**)	~ 25 km	*Historical*: Herrington et al. (2022) *Future*: Loeb et al. (submitted to JGR Atmospheres)

3. Extreme Precipitation Day Case Studies

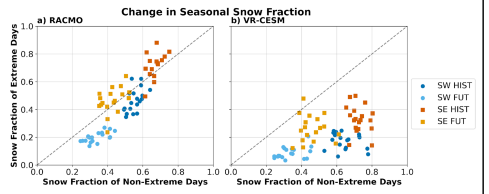
Anomalies: relative to 30 day running mean

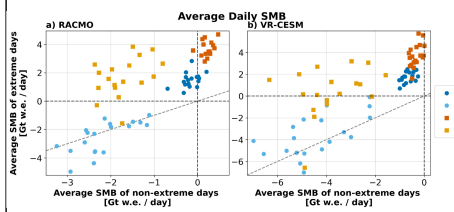


4. Seasonal Context

Changing snow fraction:

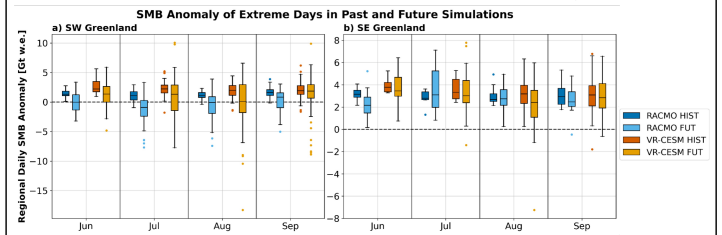
- RACMO shows similar snow fraction between extreme and non-extreme precipitation days
- VR-CESM shows lower snow fraction on extreme days





SMB Contributions:

- Historically, accumulation on extreme days outweighs ablation ($SMB_{ex} > SMB_{non\text{-}ex}$)
- In SW Greenland, SMB_{ex} becomes more negative than $SMB_{non\text{-}ex}$ in the future (particularly in RACMO)



- Large increase in variability of SMB of extreme days in both subregions
- Future events commonly produce a negative SMB anomaly in SW Greenland

5. Key Takeaways

- Extreme summer **rainfall** drives increased runoff, decreased albedo, and accelerated ice loss, whereas **snowfall** can lead to the opposite.
- **Snow fraction decreases** in the future, increasing the potential for mass loss (particularly in SW Greenland).
- Warmer future brings **more variable responses** to extreme precipitation.
- Vast majority of historical events have positive seasonal SMB impact but some events have negative SMB impact in future.

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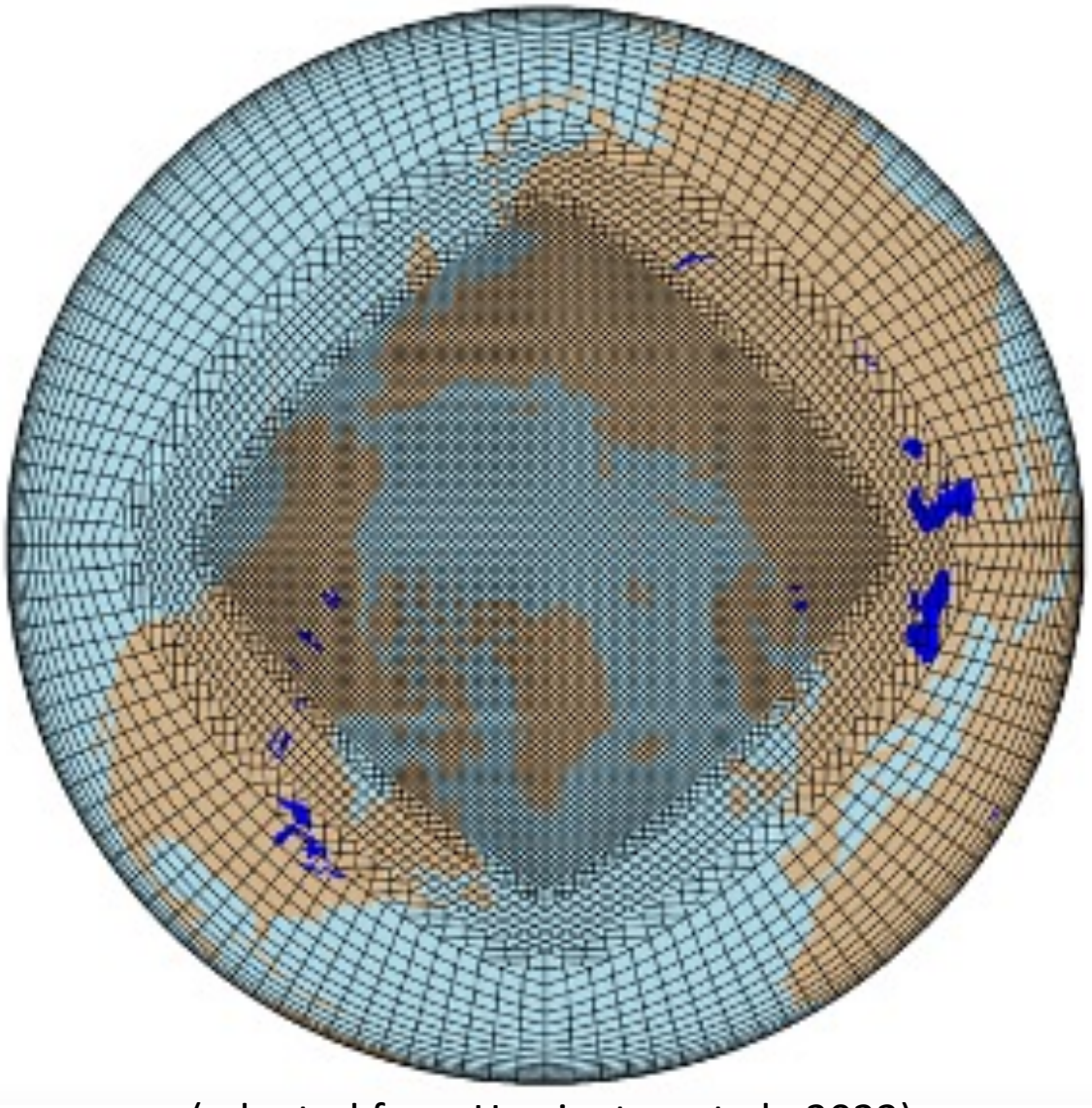
We acknowledge the support of the Natural Sciences and Engineering Research Council of Canada (NSERC) and additional funding from the Canada 150 Research Chairs Program. The authors would also like to thank Dr. Brice Noël for sharing the RACMO2.3 data, and Dr. Jan Lenaerts and the NCAR Land Ice Working Group for VR-CESM run computing time.

VR-CESM ARCTIC Grid

- 1 degree lat x lon global simulation
- 0.25 degree lat x lon over the Arctic

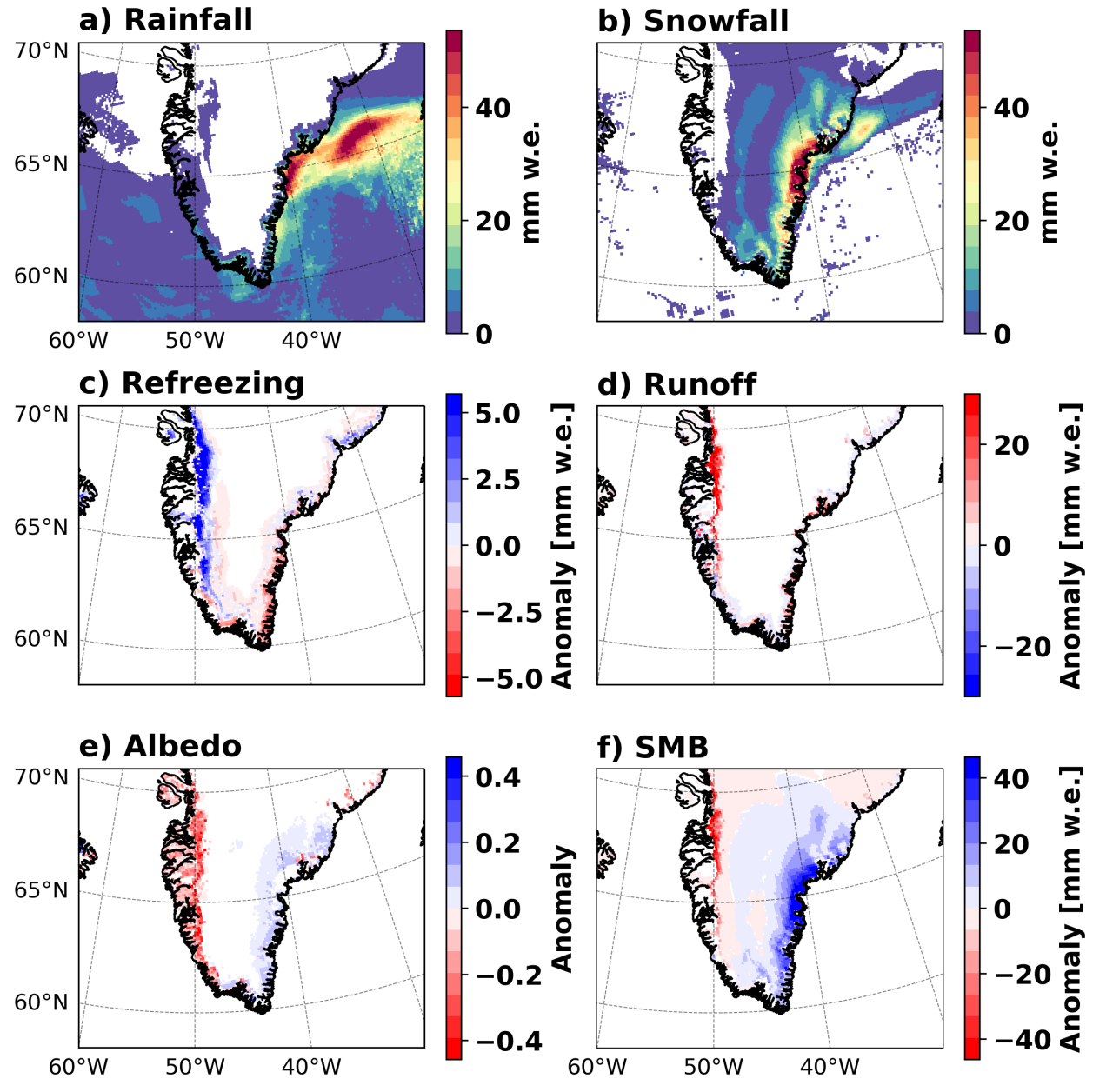


(adapted from Herrington et al., 2022)

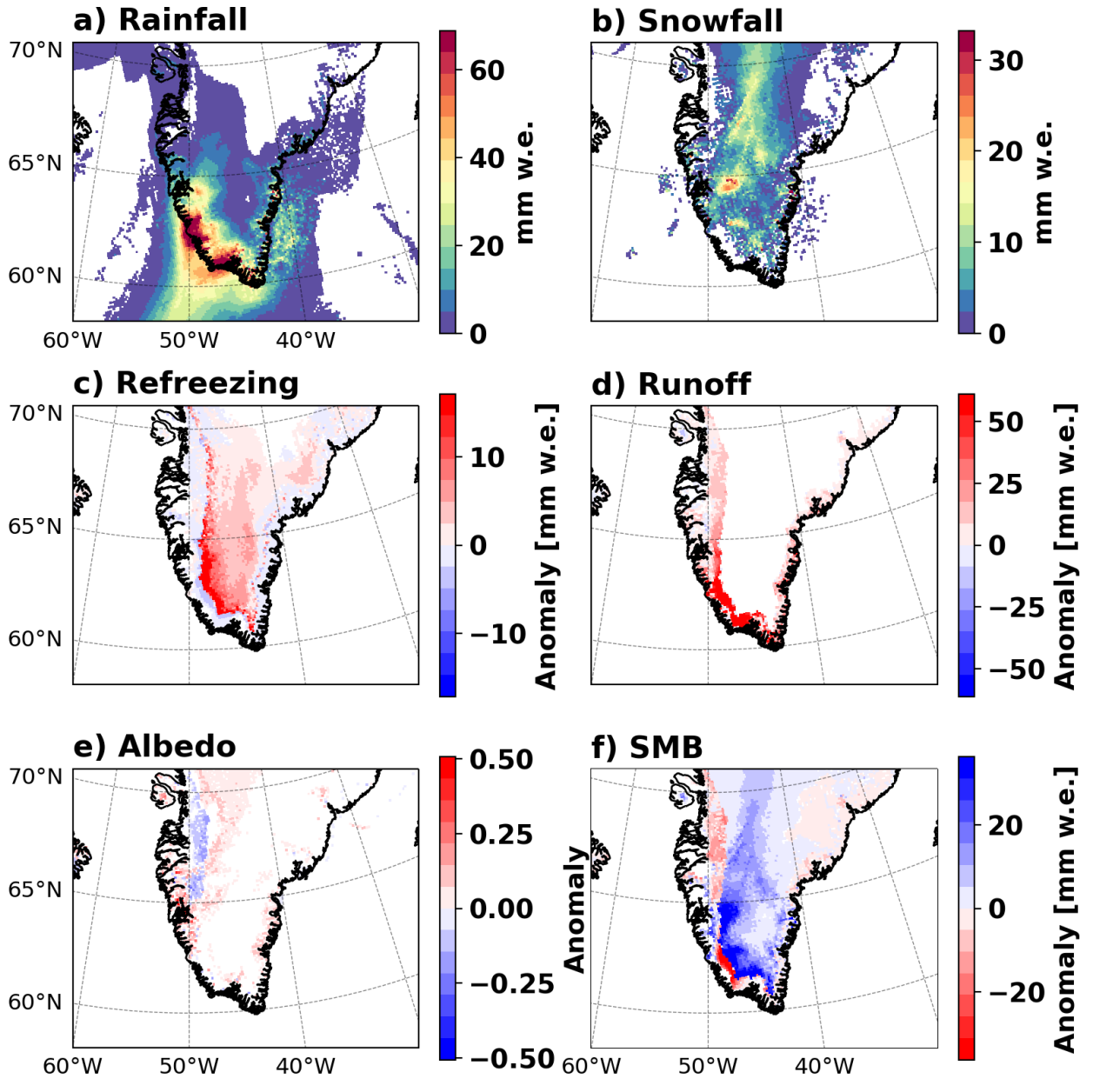
Additional Case Studies

RACMO - HIST

1982-08-31

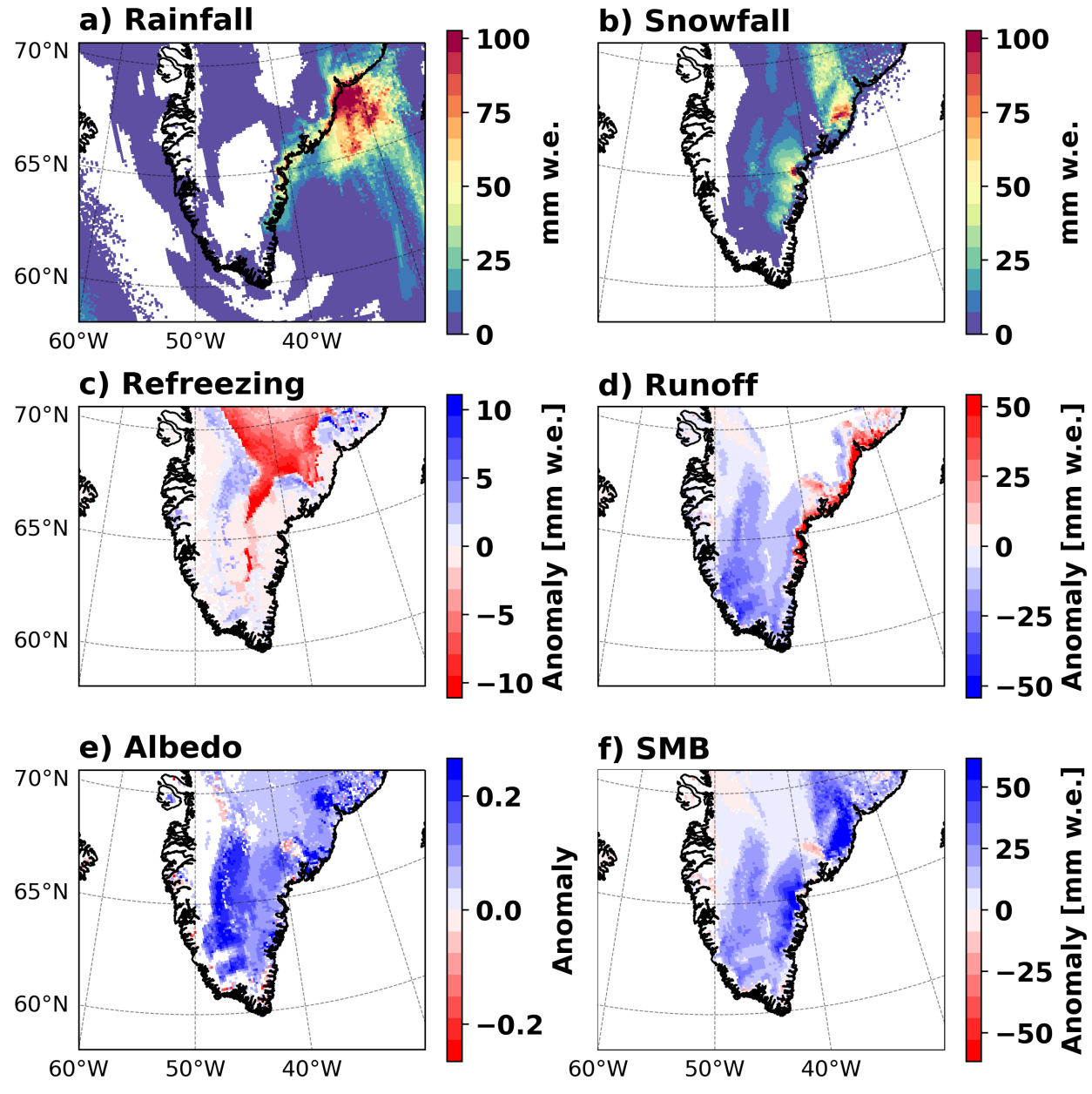


1993-08-06

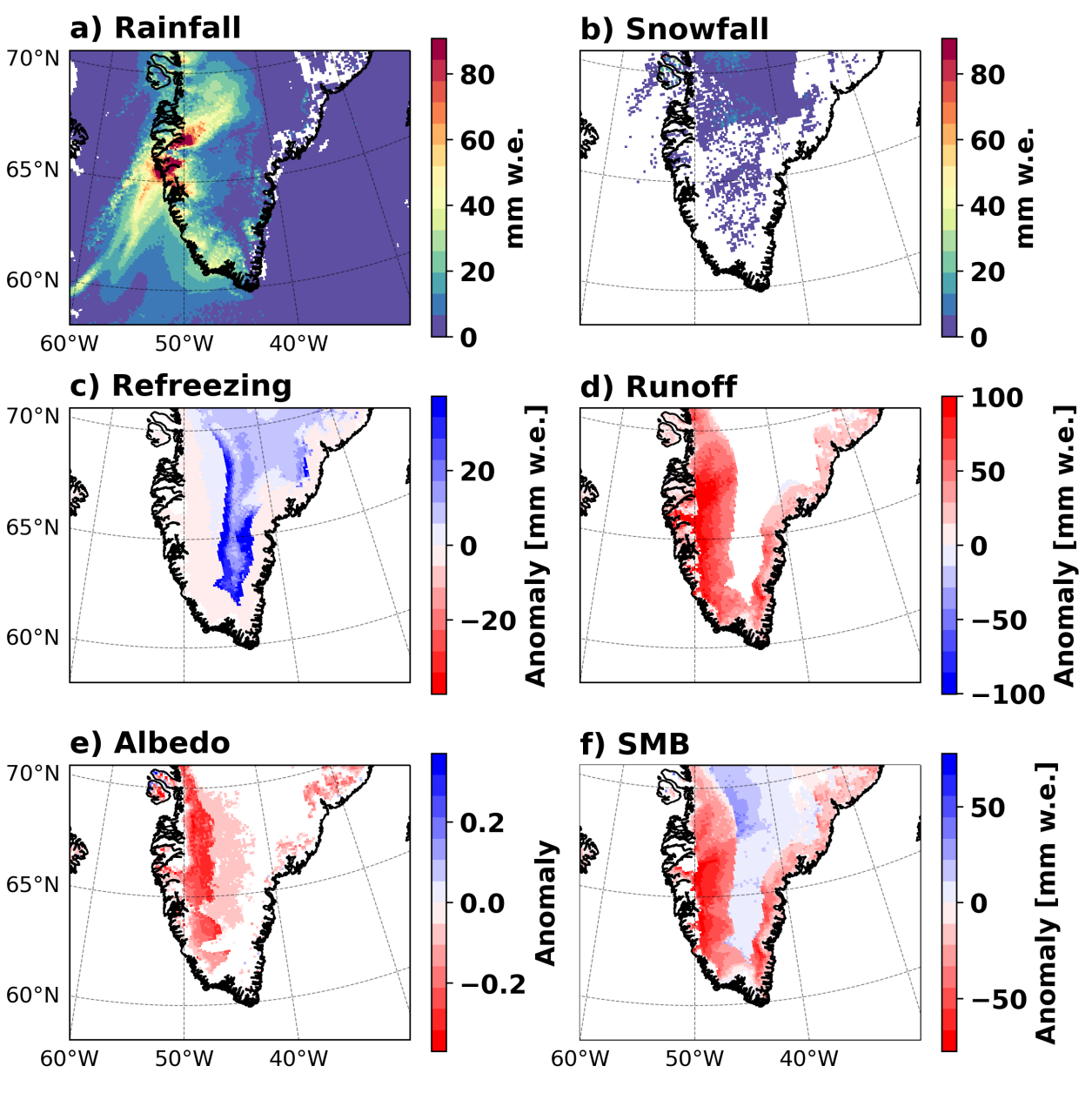


RACMO - FUT

2097-07-13

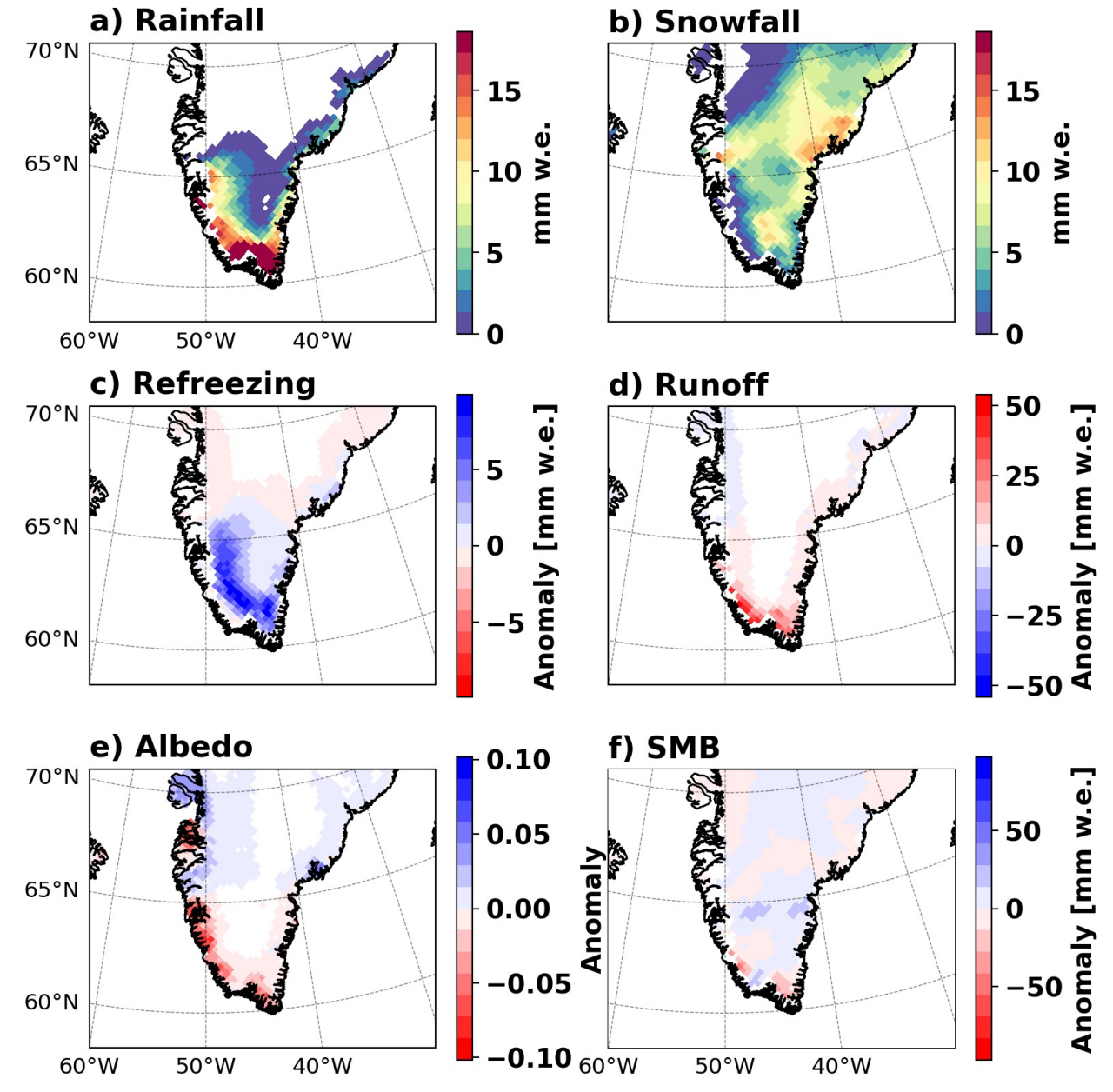


2082-08-08

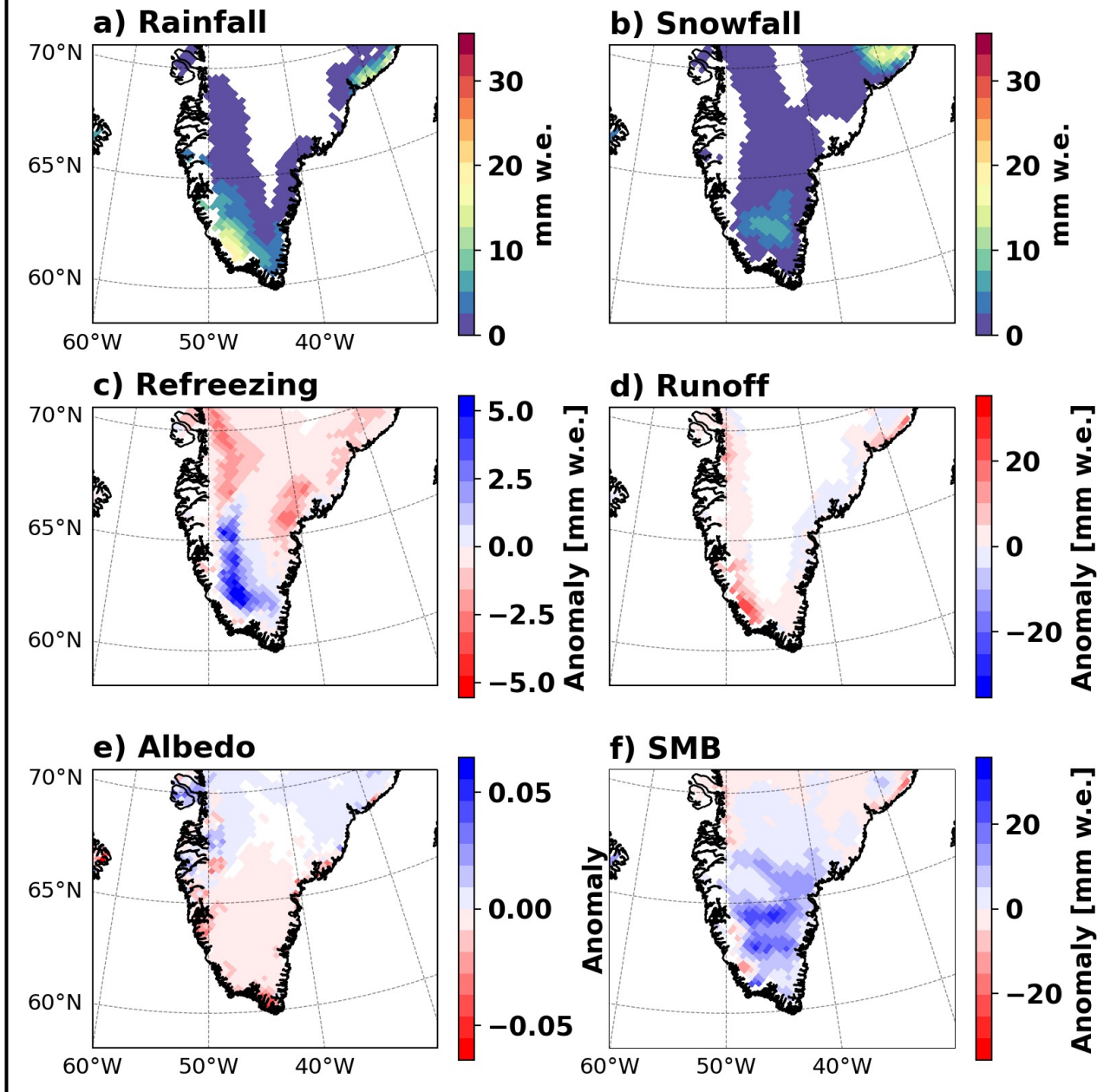


VR-CESM - HIST

1996-09-28

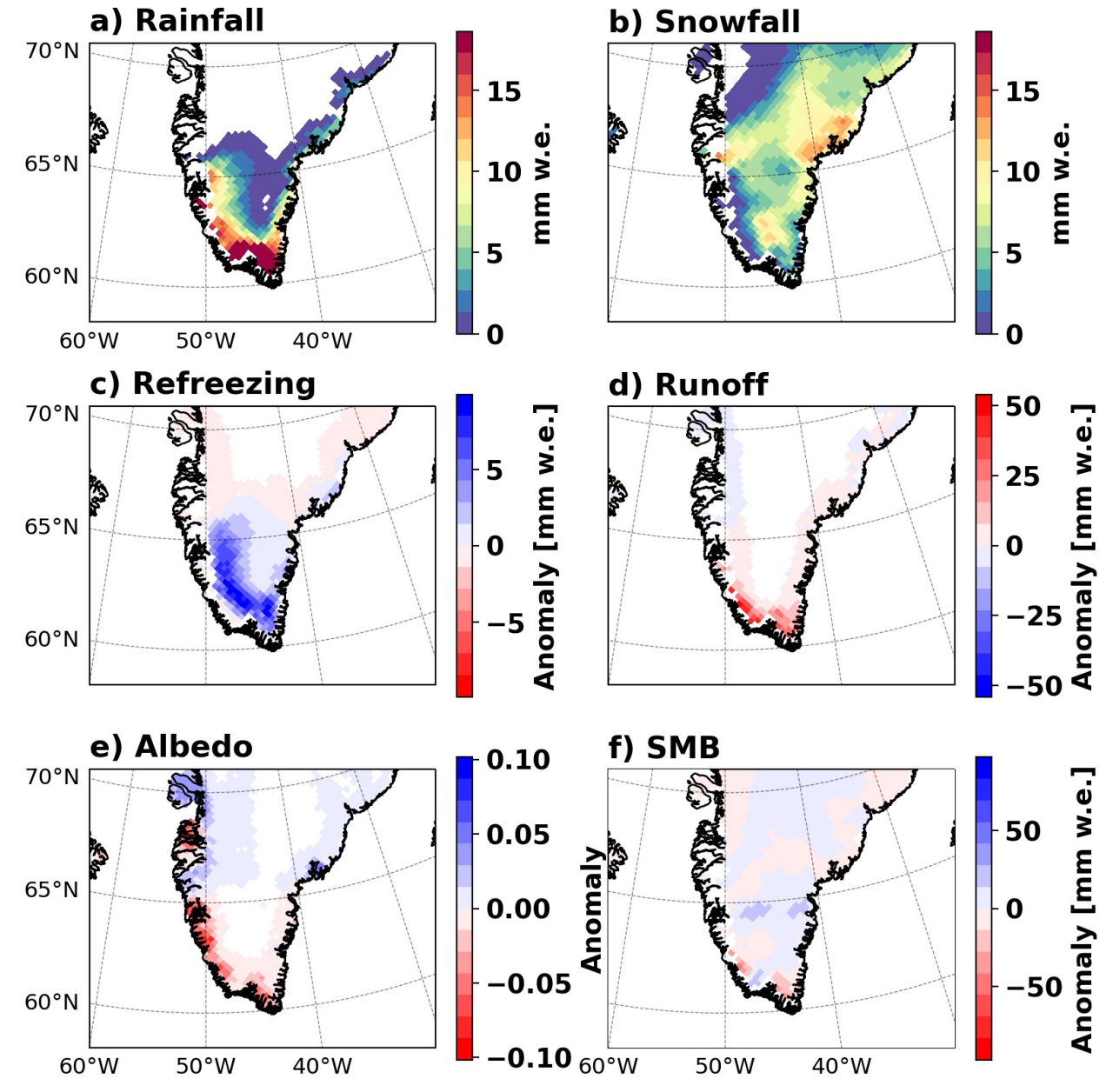


1997-08-02

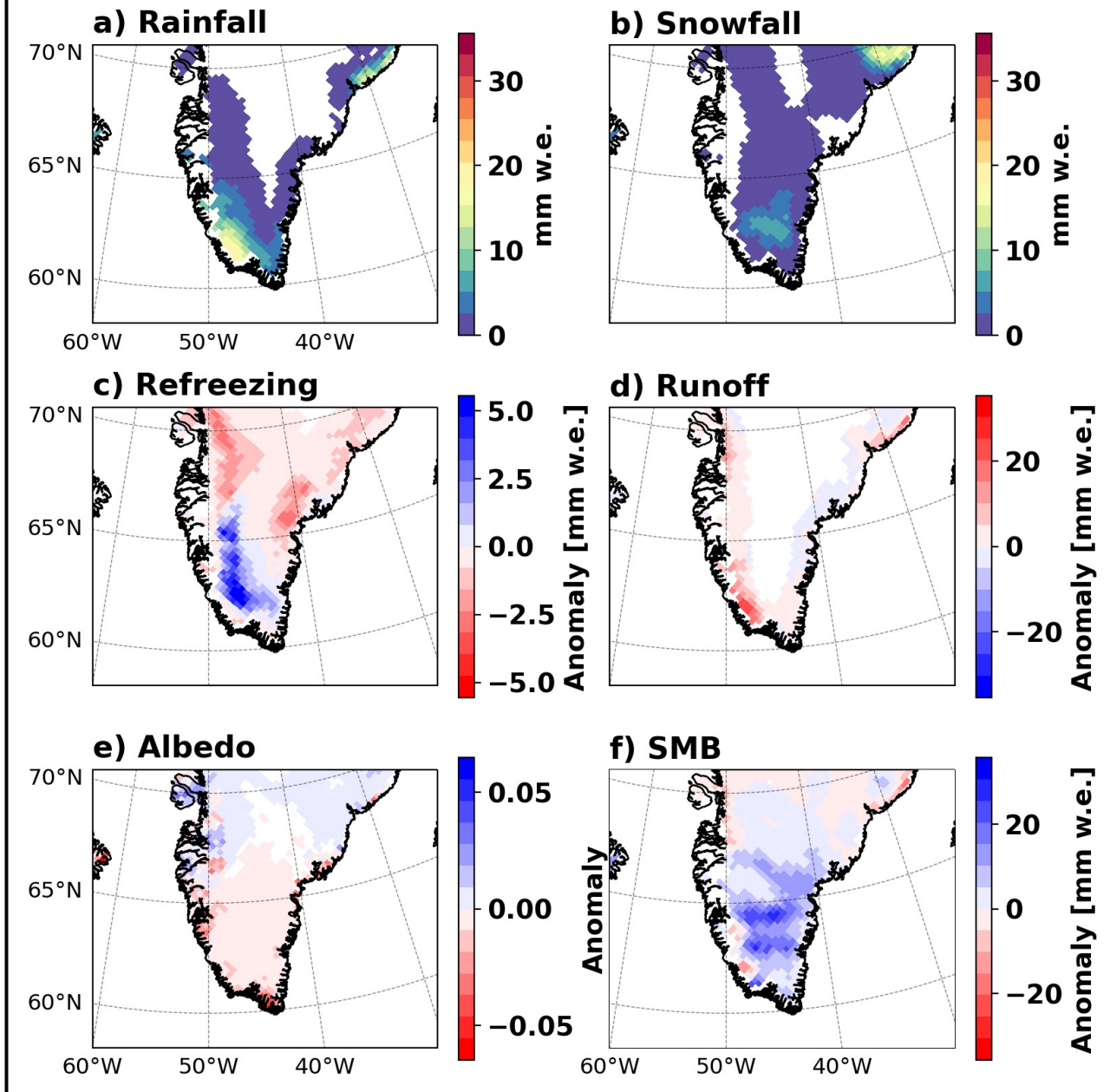


VR-CESM - HIST

1996-09-28



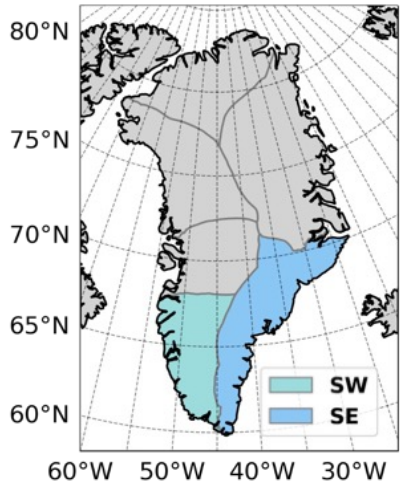
1997-08-02



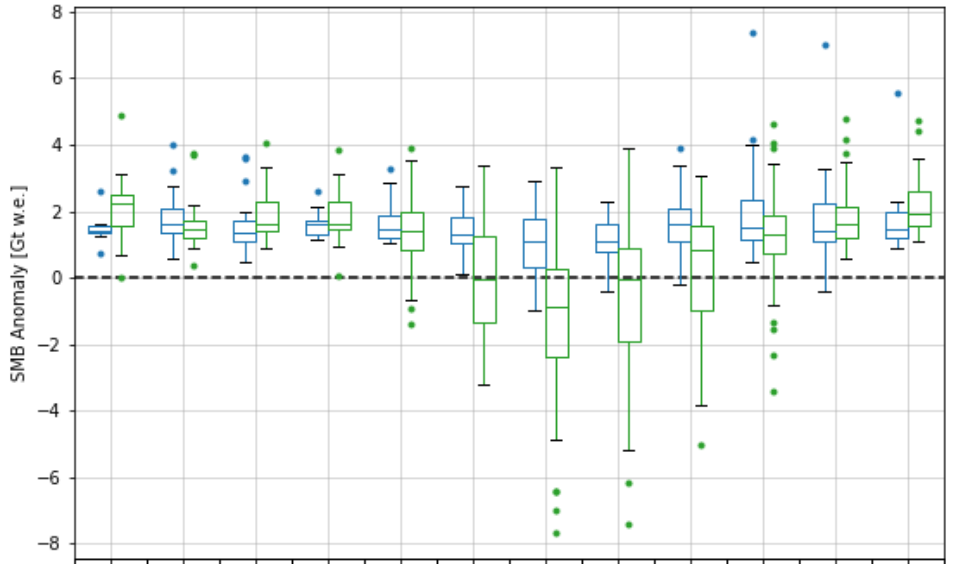
Seasonal Statistics

Monthly Extreme day SMB Anomalies

- **Blue**: HIST (1980-1999)
- **Green**: FUT (2080-2099)
- Anomaly relative to 30-day running mean
- Table: number of extreme days in each month

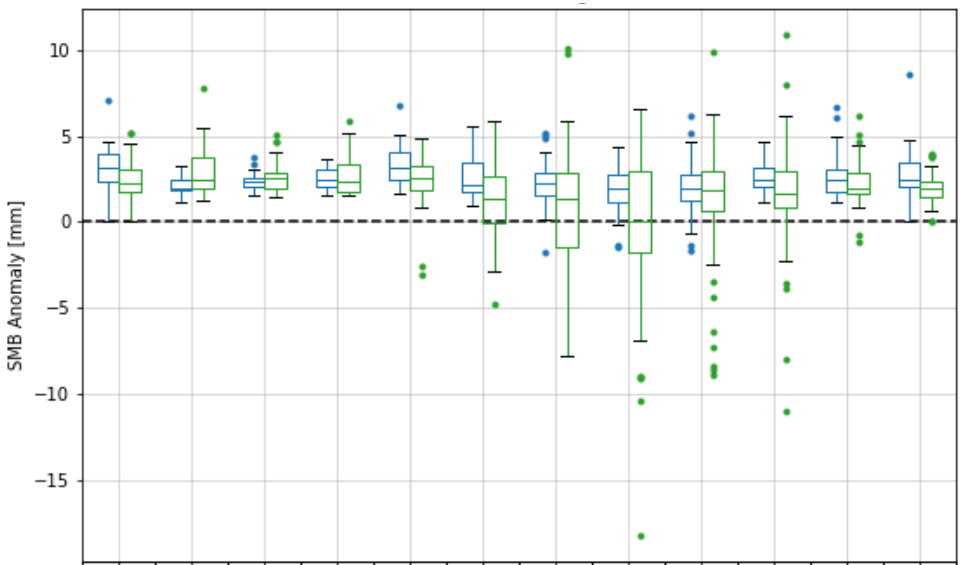


a) RACMO SW Greenland



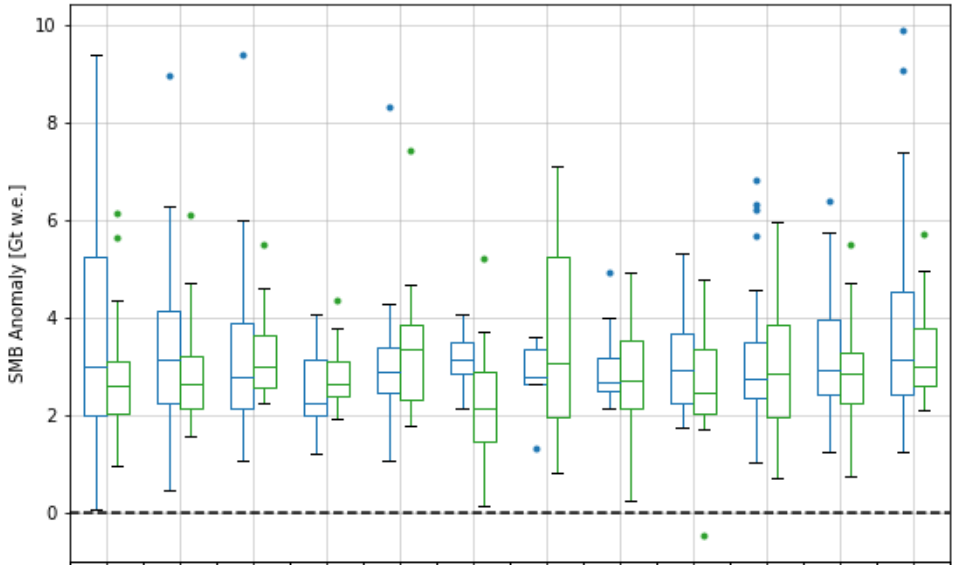
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
HIST	9	23	22	12	18	18	43	47	52	48	44	11
FUT	11	16	24	25	50	36	94	127	96	94	40	16

b) VR-CESM SW Greenland



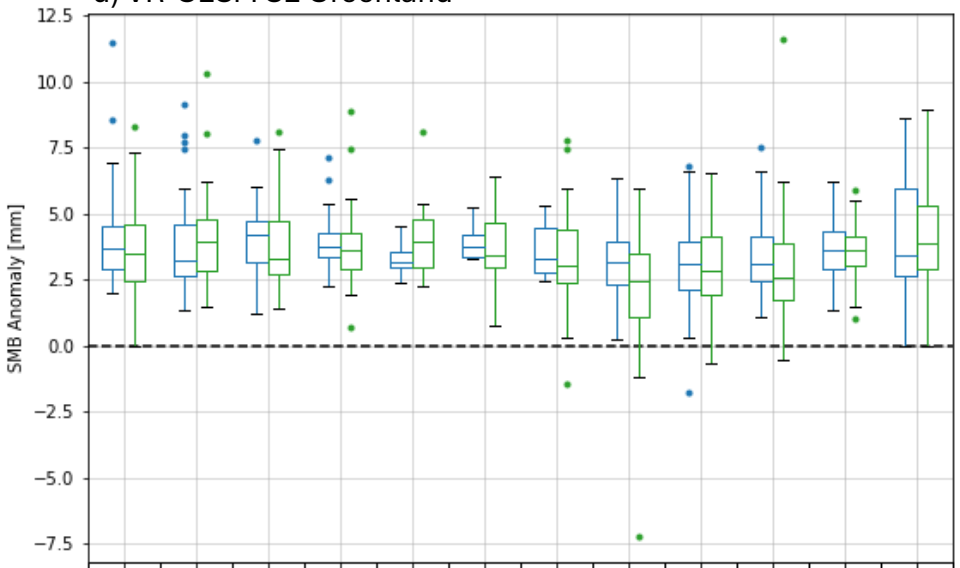
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
HIST	29	19	16	20	16	23	40	51	50	34	28	21
FUT	34	24	36	16	31	49	69	85	78	71	46	43

c) RACMO SE Greenland



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
HIST	44	44	51	34	18	11	6	14	21	23	32	49
FUT	51	28	15	15	15	14	7	19	27	31	28	20

d) VR-CESM SE Greenland



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
HIST	43	44	27	26	15	6	12	27	31	49	32	35
FUT	40	27	35	24	21	16	24	18	33	46	21	43

Future Work

- Statistical testing of increased variability of SMB response to extreme precipitation
- Focus on the ablation zone specifically to better understand potential for mass loss/gain in the future
- Compare to other regions of Greenland and the glaciers and ice caps of the eastern Canadian Arctic

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