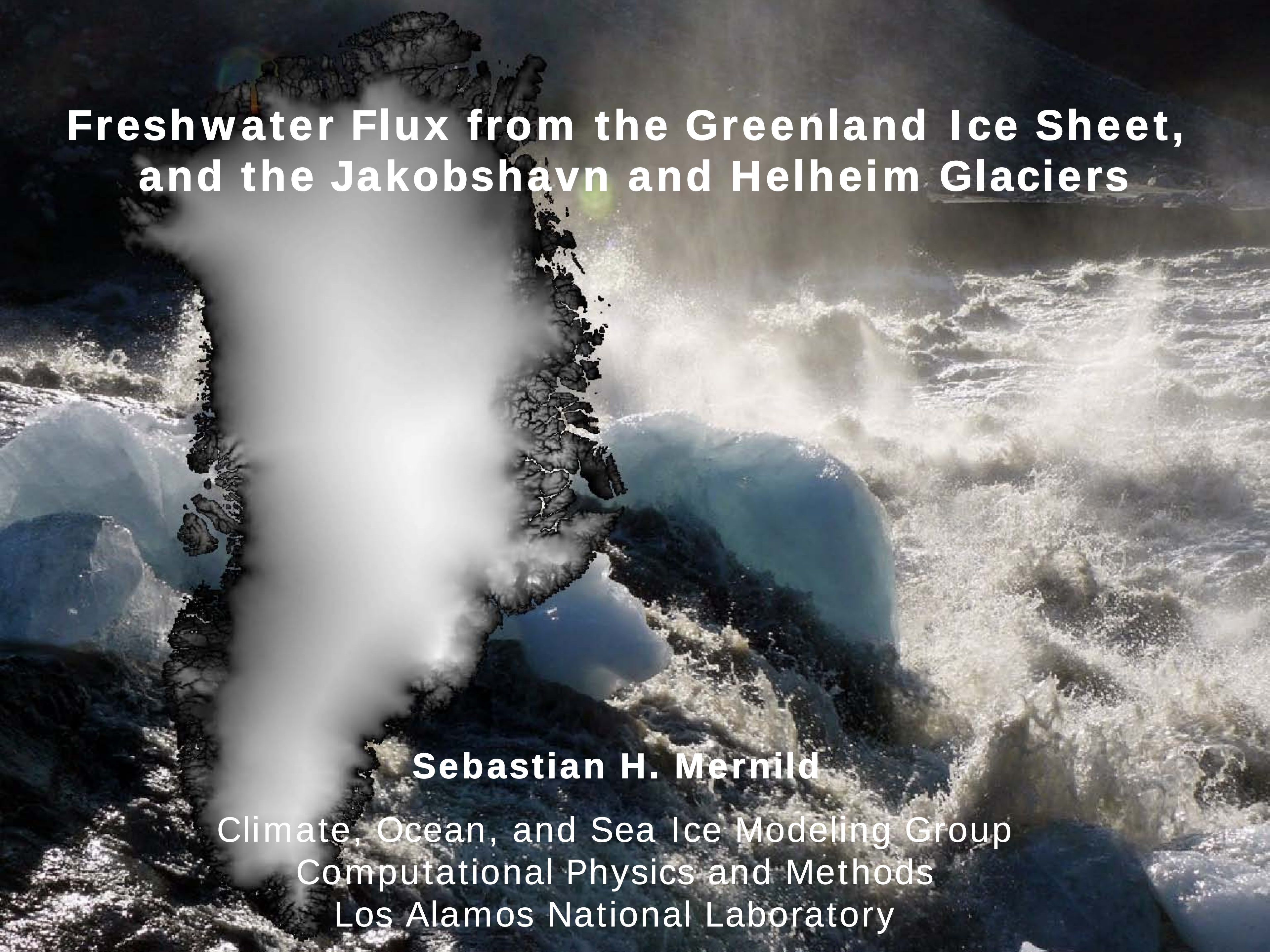


Freshwater Flux from the Greenland Ice Sheet, and the Jakobshavn and Helheim Glaciers

Sebastian H. Mernild

Climate, Ocean, and Sea Ice Modeling Group
Computational Physics and Methods
Los Alamos National Laboratory

Resent research:

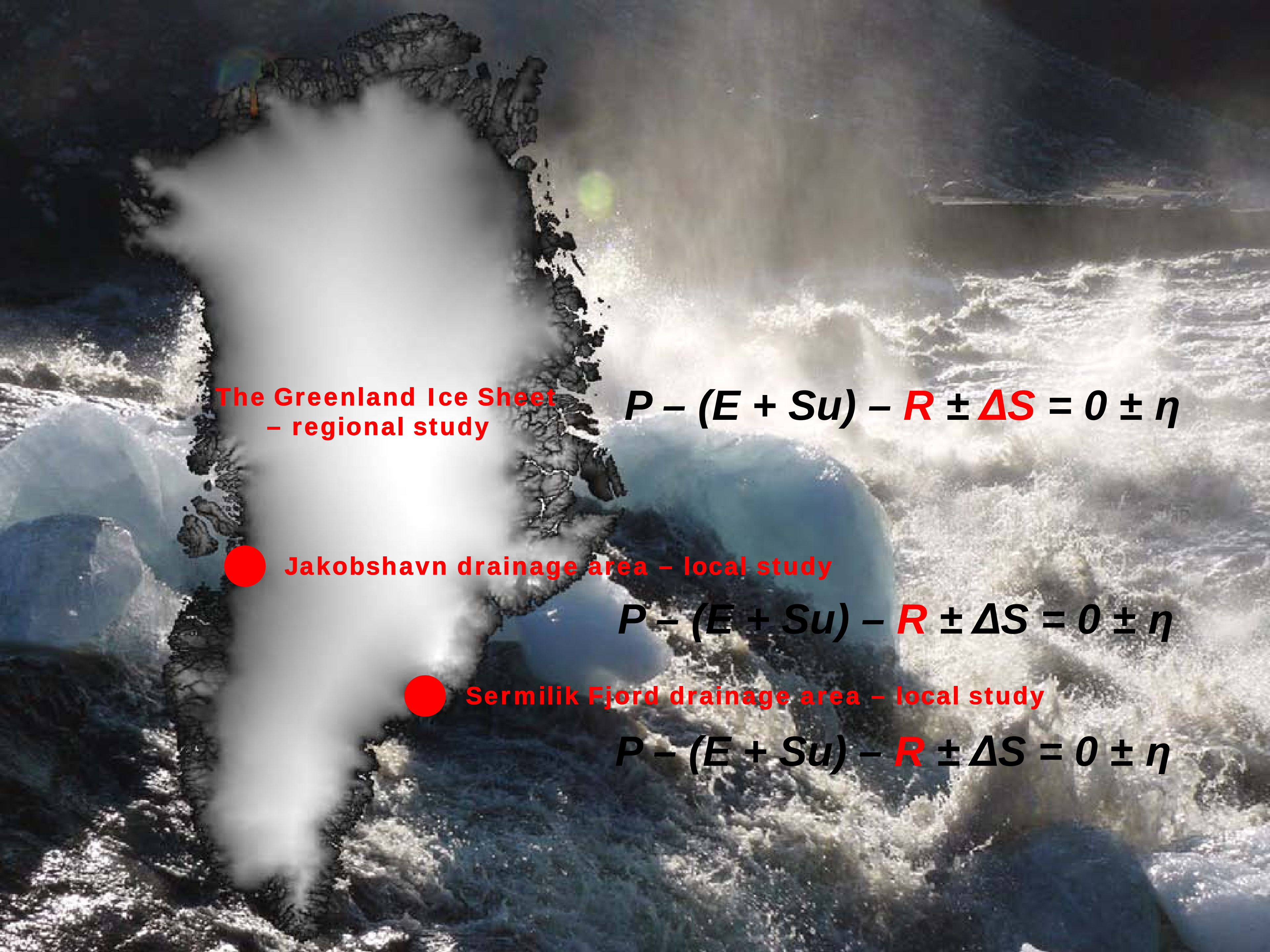
the purpose is to investigate…

… cold hydrology (the water balance) and cryospheric processes in relation to past and present climate conditions on regional/local scale for the surface of the Greenland Ice Sheet (GrIS).

The water balance:

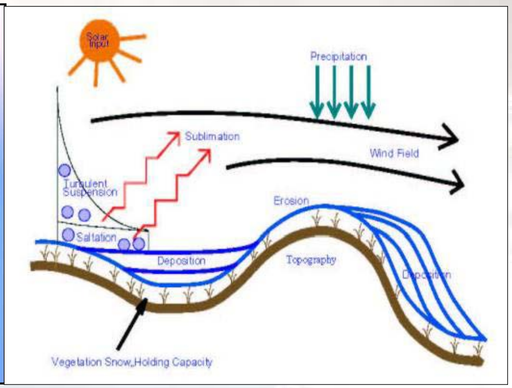
$$P - (E + Su) - R \pm \Delta S = 0 \pm \eta$$

where,
P is precipitation,
E is evaporation,
Su is sublimation,
R is runoff,
ΔS is change in storage (change in surface mass balance), and
η is the is the water balance discrepancy (error).



The Greenland Ice Sheet
– regional study
P – (E + Su) – R ± ΔS = 0 ± η
Jakobshavn drainage area – local study
P – (E + Su) – R ± ΔS = 0 ± η
Sermilik Fjord drainage area – local study
P – (E + Su) – R ± ΔS = 0 ± η

SnowModel: *SnowModel is a spatially-distributed surface snowpack evolution and surface melt modeling system*



MicroMET: Micro-Meteorological Distribution Model (*Liston & Elder 2006*); distributing MET data from point values to spatial grid values.

EnBal: Surface Energy Balance/Melt Model (*Liston et al. 1999*); EnBal performs surface energy balance calculations: $(1-a)Qsi + Qli + Qle + Qh + Qe + Qc = Qm$

SnowPack: 1-D, Single-Layer Snowpack Model (*Liston & Hall 1995*); snowpack-evolution model that defines snowpack changes in response to precipitation, melt fluxes, and snow distribution defined by MicroMET, EnBal, and SnowTran-3D.

SnowTran-3D: Blowing and Drifting Snow Model (*Liston & Sturm 1998; Liston et al. 2006*); SnowTran-3D is a three-dimensional model that simulates snow depth evolution (deposition and erosion) resulting from windblown snow.

SnowModel (modifications and tests):

SnowModel usefull on glaciers: Energy balance calculations were implemented to simulate glacier-ice melt after winter snow cover had melted away (*Mernild et al. 2006a, JHM*)

Precipitation adjustment routines was implemented (*Mernild et al. 2006a, JHM*)

Air temperature inversion routines in coastal areas (*Mernild & Liston 2010, JAMC*)

Variable albedo (*Mernild et al. 2010, JGLAC*)

Routing of runoff through the GrIS to the coast line (*Liston & Mernild in prep.*): IceHydro.

***SnowModel** was tested/vaildated at the:*

- Mittivakkat Catchment, SE Greenland,

- Zackenberg Catchment, NE Greenland,

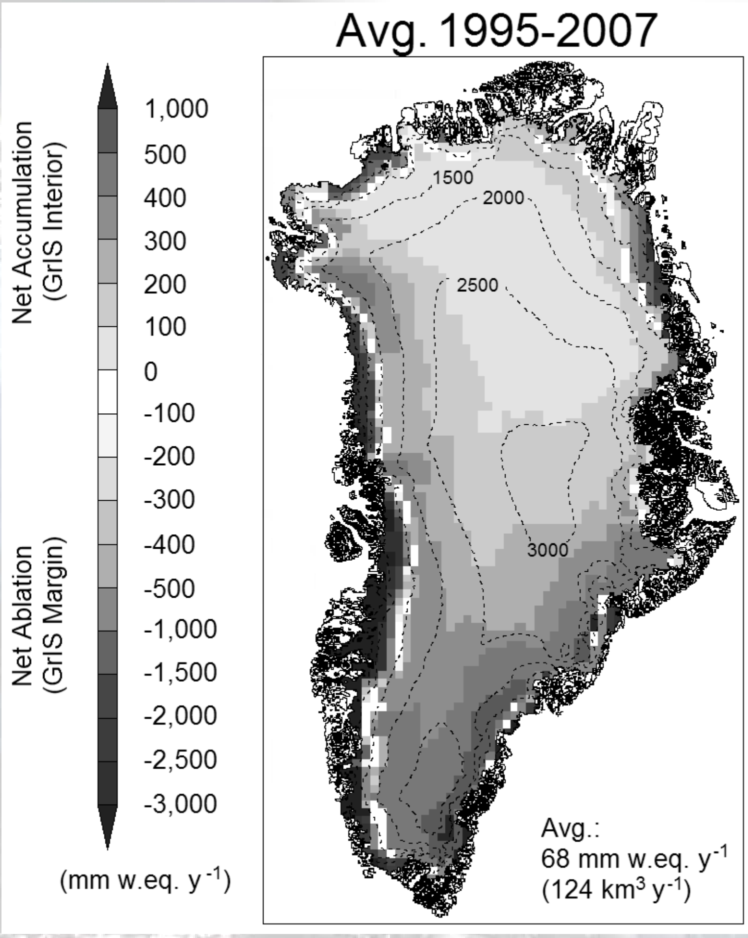
- Greenland Ice Sheet (regional/local scale),

- Jakobshavn Catchment, W Greenland,

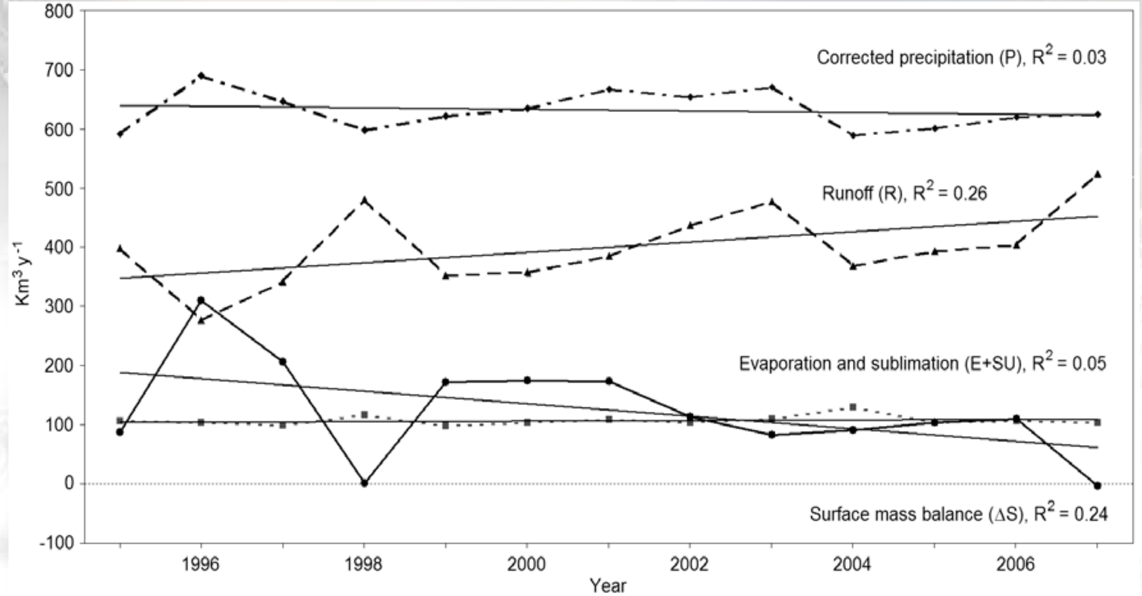
- Kangerlussuaq Catchment, W Greenland,

- Sermilik Fjord Catchment, SE Greenland.

The GrIS for present time…



Mernild et al. 2009b, HYP

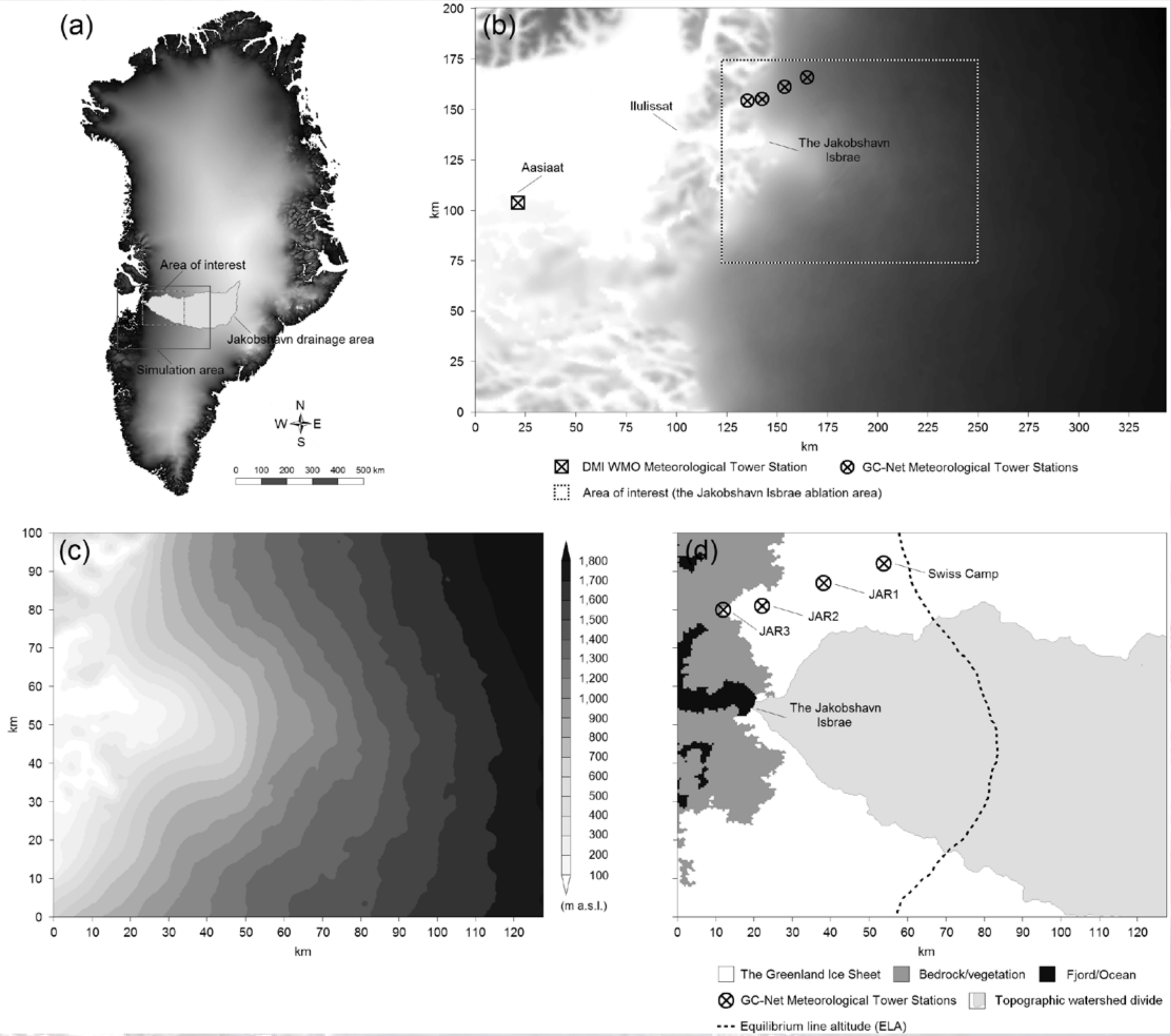


Rank-ordered GrIS precipitation (P), runoff (R), surface mass-balance (ΔS), and air temperature anomaly for 1995 through 2007

Rank	Corrected precipitation (P), km^3 y^{-1}	Runoff (R), km^3 y^{-1}	Surface mass-balance (ΔS), km^3 y^{-1}	Air temperature anomaly, °C
1	690 (1996)	523 (2007)	310 (1996)	1.05 (2005)
2	669 (2003)	481 (1998)	205 (1997)	0.86 (2003)
3	666 (2001)	477 (2003)	174 (2000)	0.38 (2007)
4	653 (2002)	436 (2002)	173 (2001)	0.38 (2002)
5	646 (1997)	404 (2006)	172 (1999)	0.37 (2006)
6	635 (2000)	398 (1995)	113 (2002)	0.36 (2000)
7	624 (2007)	392 (2005)	109 (2006)	0.21 (2004)
8	622 (1999)	385 (2001)	103 (2005)	−0.12 (2001)
9	619 (2006)	369 (2004)	91 (2004)	−0.25 (1998)
10	600 (2005)	358 (2000)	87 (1995)	−0.40 (1996)
11	598 (1998)	352 (1999)	83 (2003)	−0.82 (1999)
12	591 (1995)	341 (1997)	2 (1998)	−0.84 (1997)
13	589 (2004)	277 (1996)	−3 (2007)	−1.21 (1995)
Average and standard deviation	631 ± 32	397 ± 62	124 ± 83	0 ± 0.68

Mernild et al. 2009b, HYP

Jakobshavn drainage area - runoff (2000-2007)



Mernild et al. 2010, JGLAC

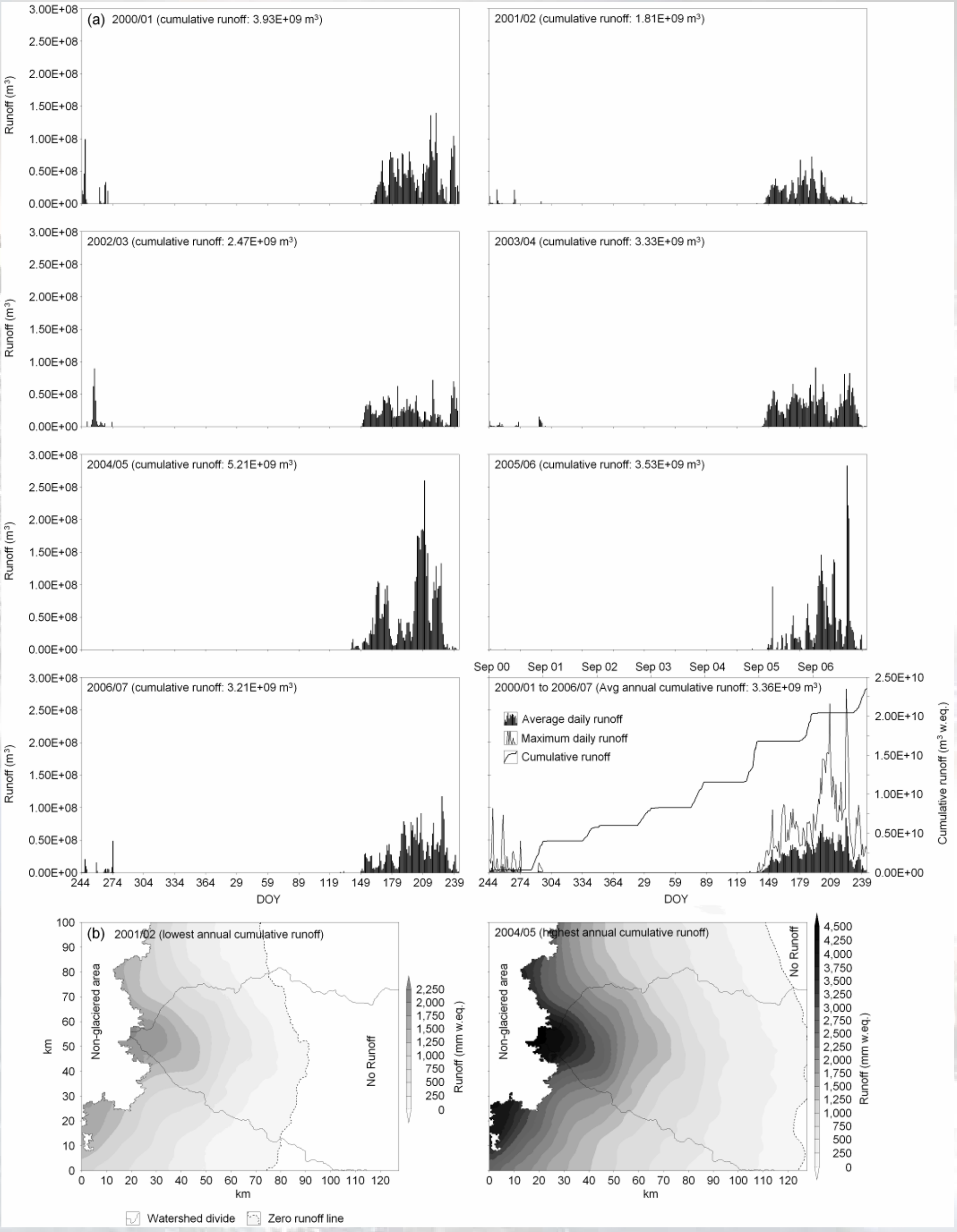
Jakobshavn drainage area - runoff (2000-2007)

Simulated annual surface melt varied from as low as 3.83×109 m3 (2001/02) to as high as 8.64×109 m3 (2004/05).

Modeled surface melt occurred at elevations reaching 1,870 m a.s.l. for 2004/05.

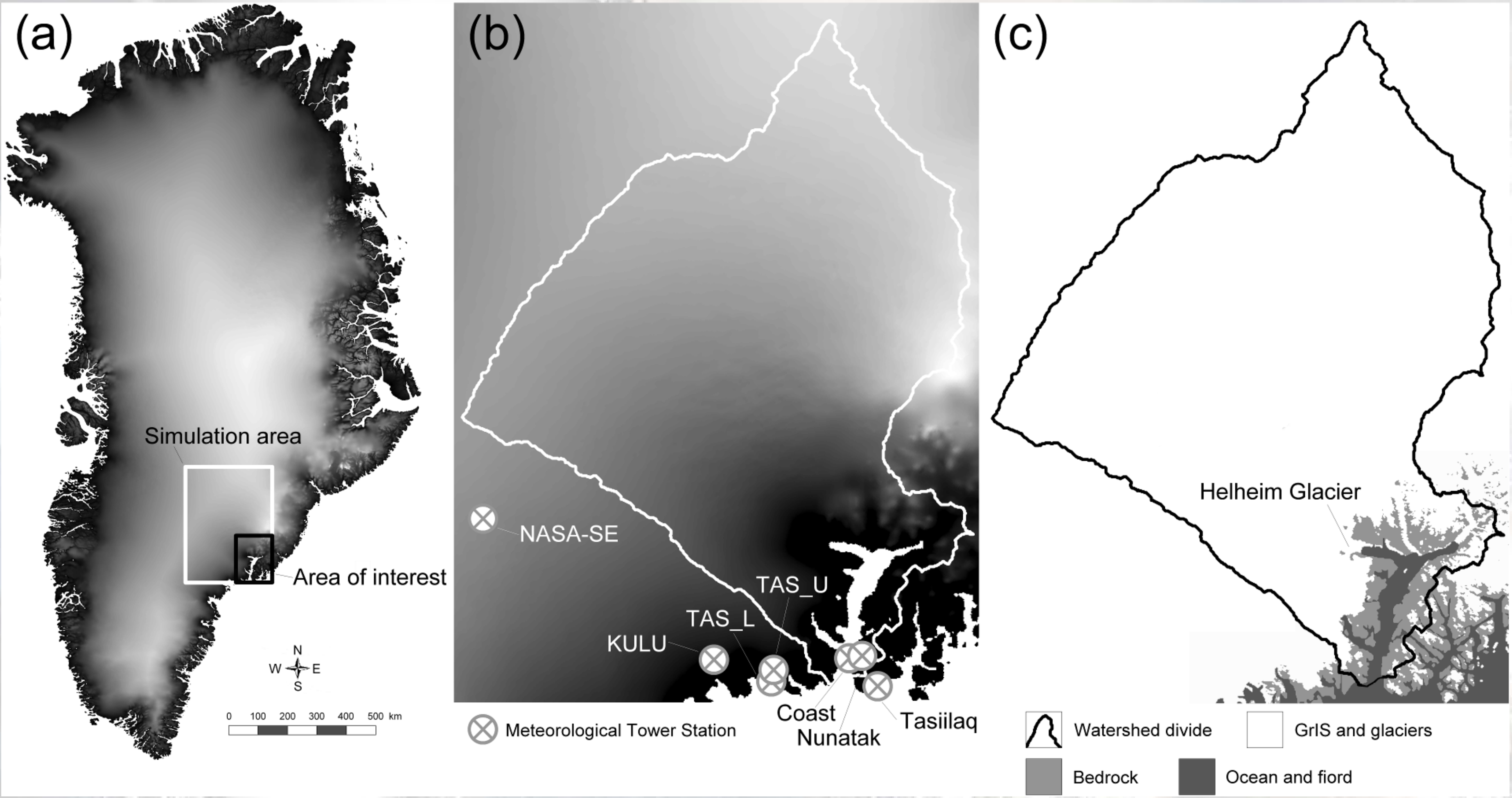
Cumulative runoff at the Jakobshavn glacier terminus of ~2.25 m w.eq. to ~4.5 m w.eq., respectively.

The average modeled Jakobshavn runoff of **3.4km3 a–1** was merged with previous estimates of Jakobshavn ice discharge to quantify the freshwater flux to Illulissat Icefjord. For both runoff and ice discharge the average trends are similar, indicating increasing (insignificant) influx of fresh water to Ilulissat Icefjord for the period 2000/01–2006/07. This study suggests that surface runoff forms a minor part of the overall Jakobshavn freshwater flux to the fjord: **about 7%** (3.4 km3 a–1) of the average annual **freshwater flux of 51.0km3** a–1 originates from the surface runoff.



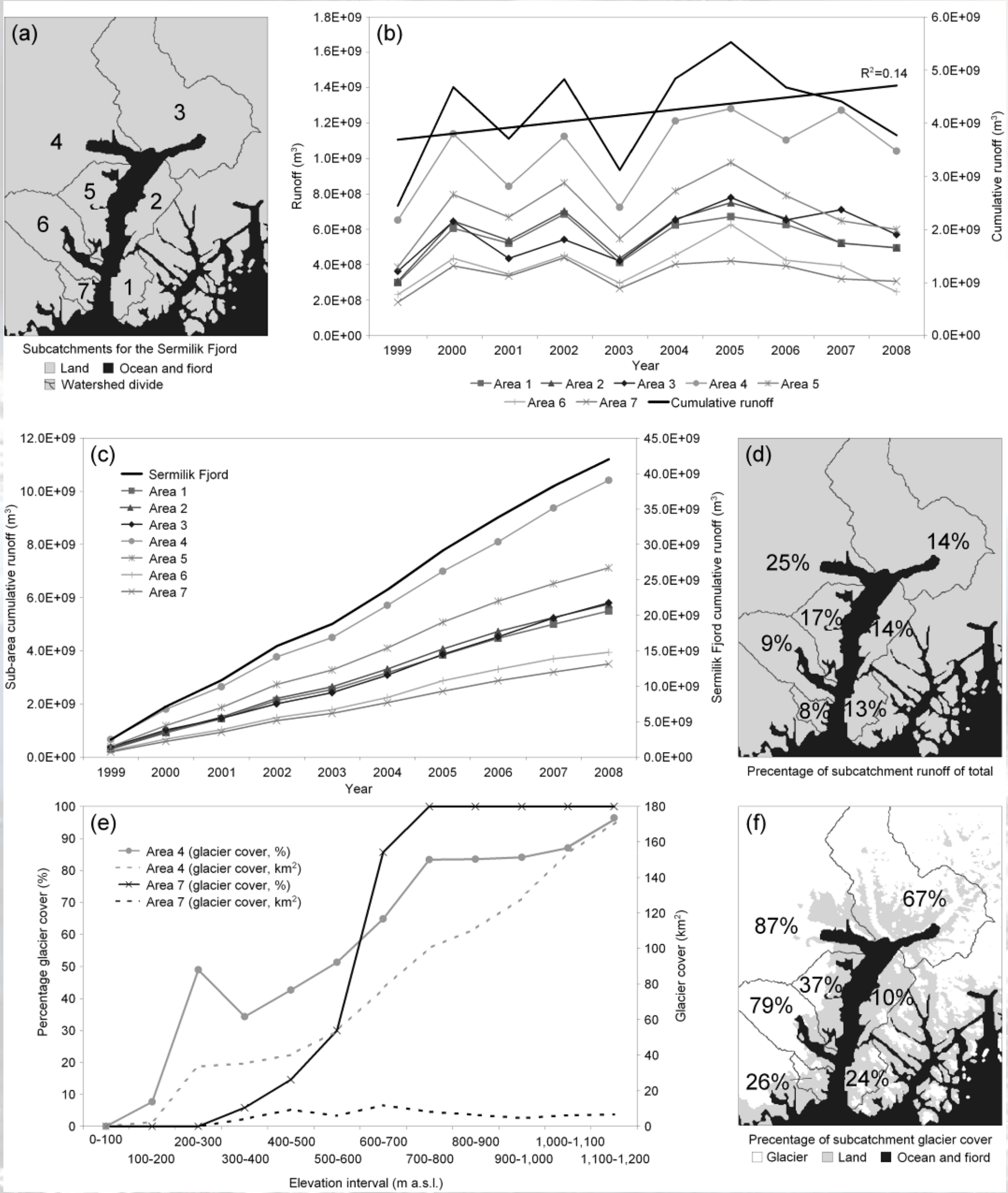
Mernild et al. 2010, JGLAC

Sermilik Fjord drainage area - runoff (1999-2008)



Mernild et al. submitted

Sermilik Fjord drainage area - runoff (1999-2008)



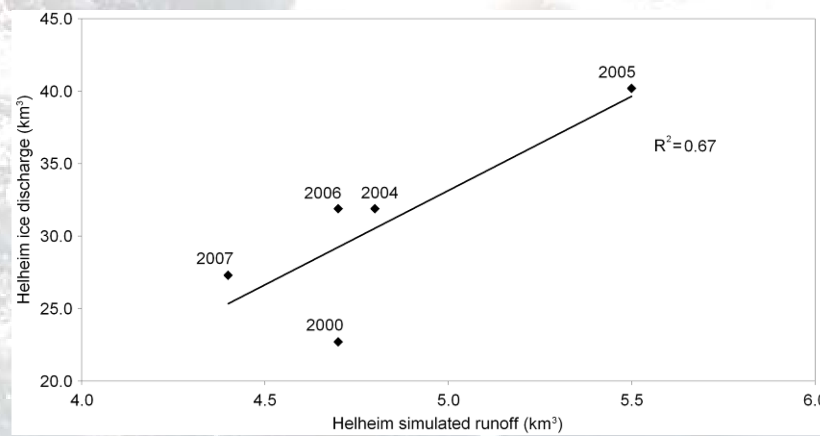
Mernild et al. submitted

Simulated runoff to Sermilik Fjord was highly variable, and showed annual values from 2.45×109 m3 in 1999 to 5.53×109 m3 in 2005. From 1999–2008, an average increase of 1.02×109 m3 in annual runoff was simulated (R2=0.14): a statistically insignificant increase.

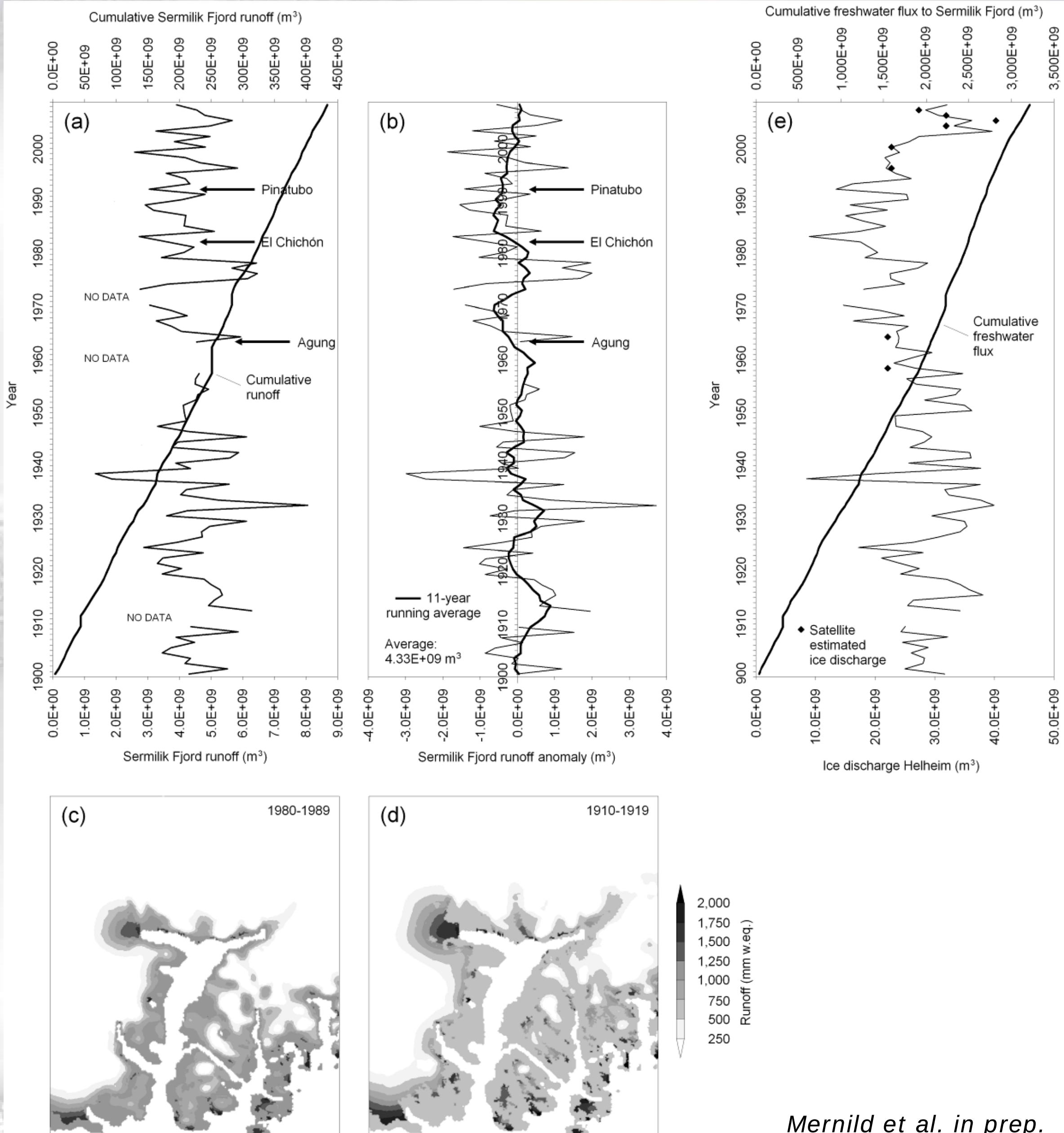
The **Helheim sub-catchment** runoff accounted for **~25%** (10.4×109 m3) of the overall runoff to Sermilik Fjord.

Modeled runoff was merged with available estimates of ice discharge by calving, indicating an average annual freshwater flux from the Helheim Glacier catchment of ~31.8 km3 y-1. The overall average annual flux to Sermilik Fjord was ~35.2 km3 y-1. Only **~4%** of the freshwater flux from the Helheim sub-catchment originated from surface runoff, whereas **~14%** of the flux to Sermilik Fjord originated from surface runoff.

For Helheim, a linear regression between runoff and calving (R2=0.67) indicated that years with high runoff values correlate with high calving rates. However, a full understanding and description of the interacting processes that link climate to ice sheet dynamics and ice discharge are still incomplete.



Sermilik Fjord drainage area - runoff (1900-2008)



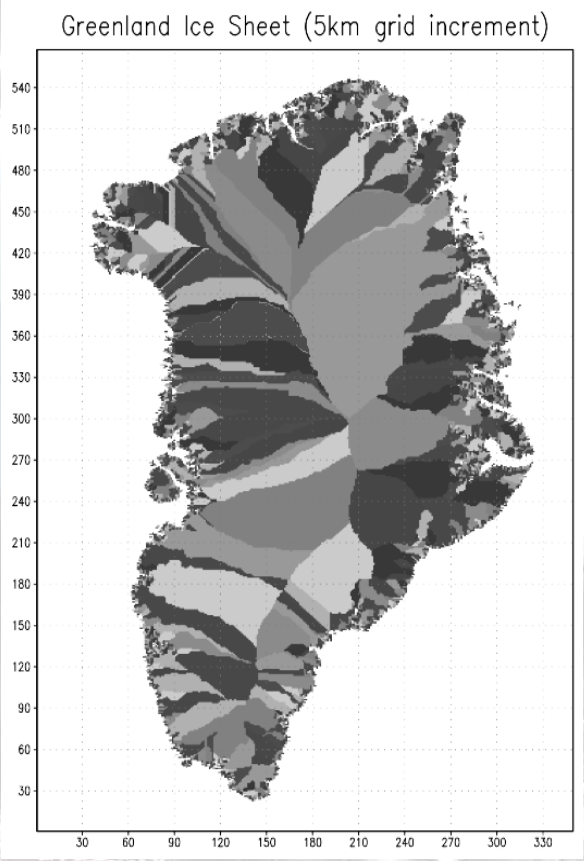
Mernild et al. in prep.

Ongoing/future work...

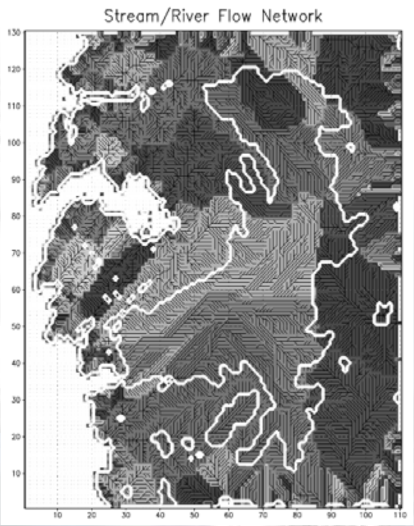
SnowModel (further modifications)

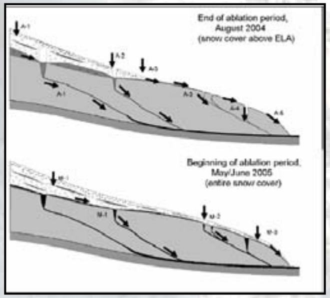
- Multi-Layer Snowpack Model
- IceHydro: Runoff Model - routing melt water/rain through the ice and landscape to the coast.

Step I



Step II





Route water through:
- Snow,
- Firn,
- ice.

Step III

Simulate runoff:
- hydrographs,
- spatial bottom distribution,
- terrestrial runoff at the coast line...

- Link SnowModel to a dynamic ice sheet model


Thank you...!!!