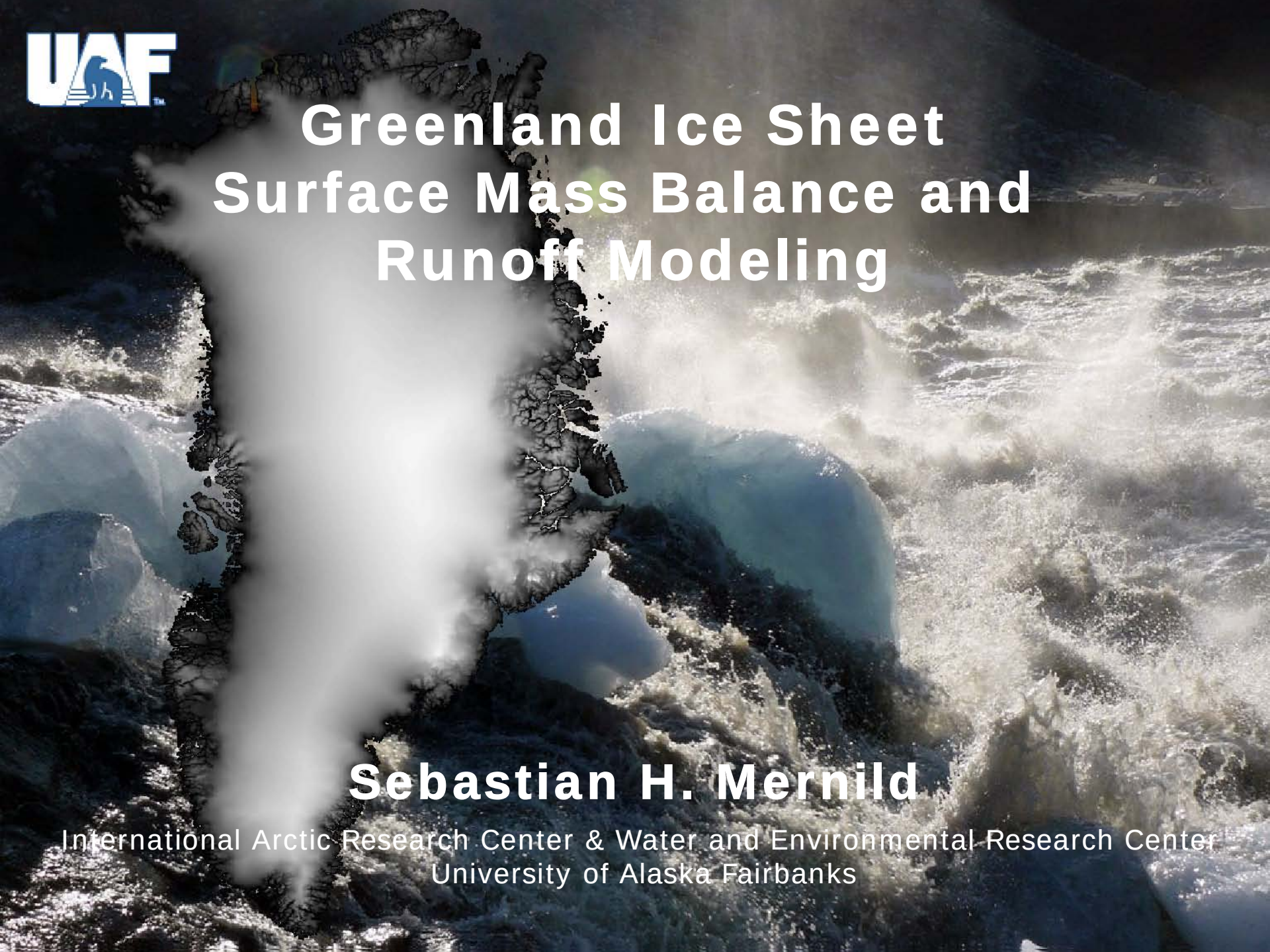

Greenland Ice Sheet Surface Mass Balance and Runoff Modeling

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Resent research:

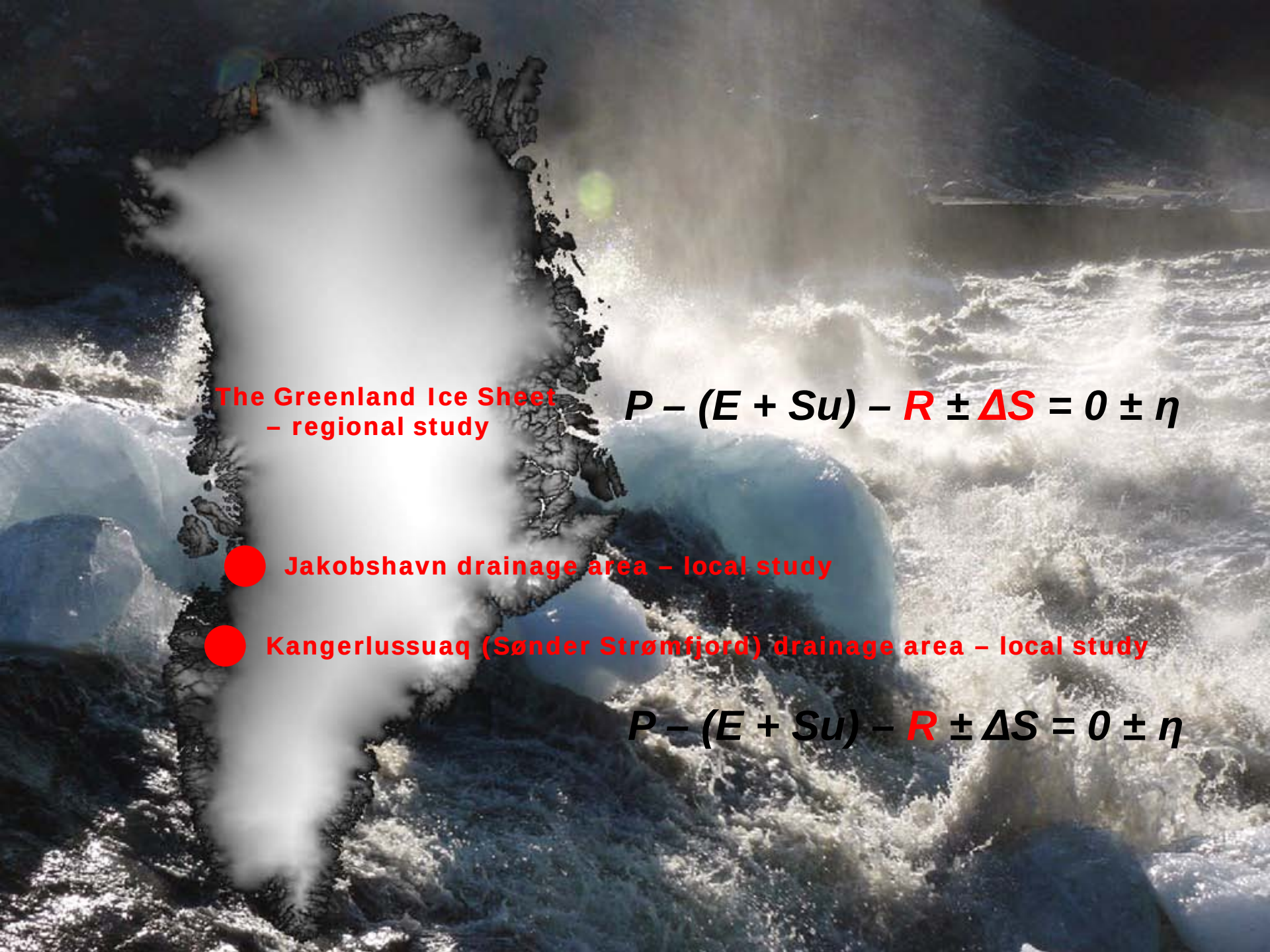
the purpose is to investigate…

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

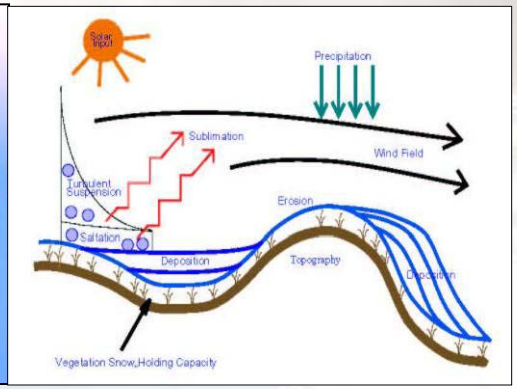
The water balance:

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

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
$P - (E + Su) - R \pm \Delta S = 0 \pm \eta$
Jakobshavn drainage area – local study
Kangerlussuaq (Sønder Strømfjord) drainage area – local study
$P - (E + Su) - R \pm \Delta S = 0 \pm \eta$

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, 2007*)

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

Air temperature inversion routines in coastal areas (*Mernild & Liston in review*)

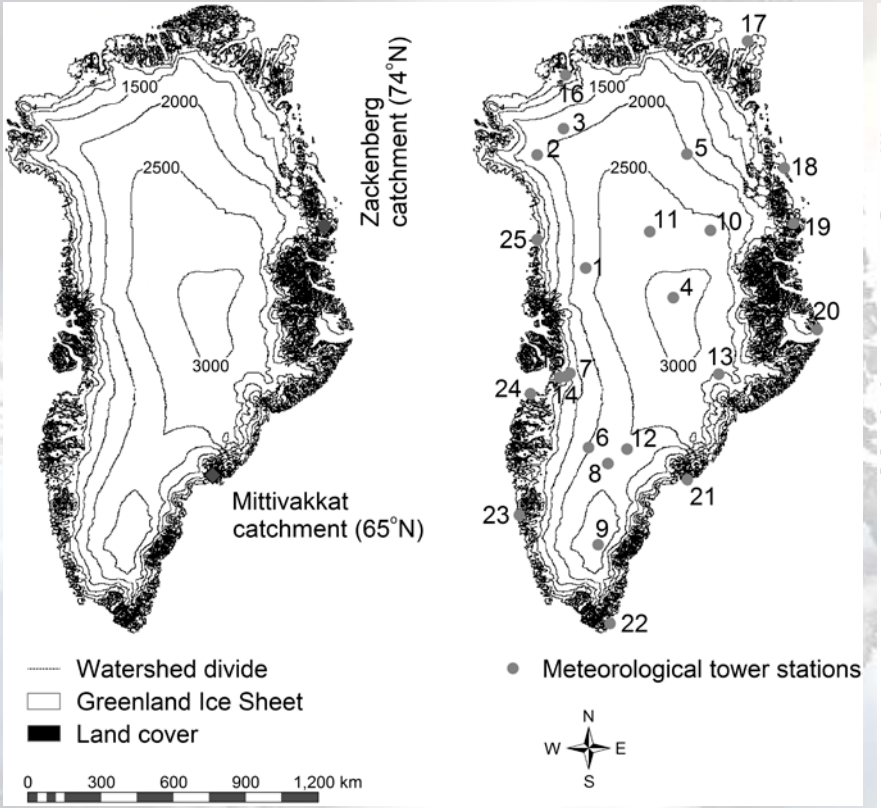
Variable albedo (*Mernild et al. in review*)

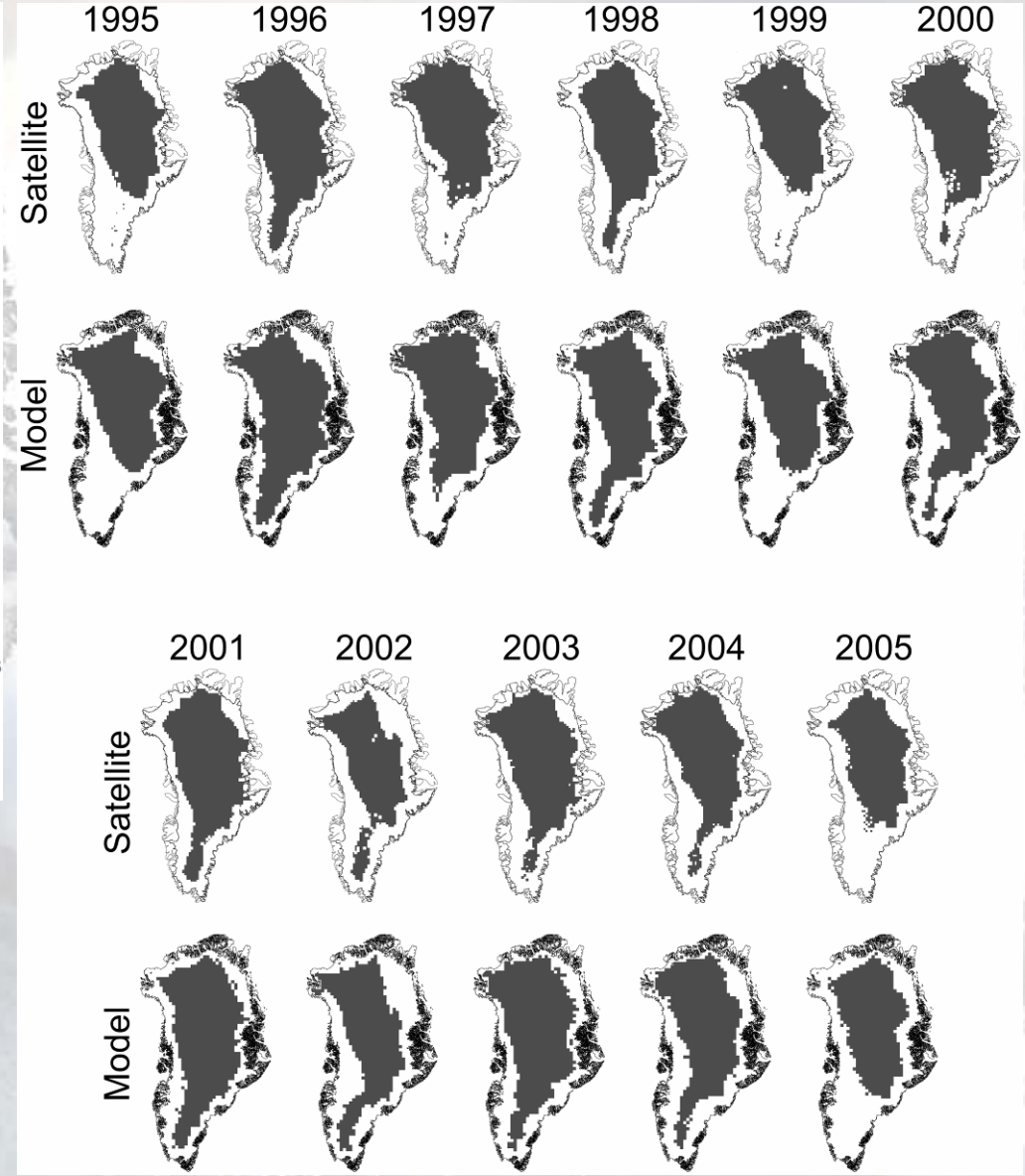
Linked to runoff models (*Mernild et al 2006b, 2007*): TimeArea, MikeShe – Future: IceHydro.

SnowModel *was tested at the:*

Mittivakkat Catchment, SE Greenland,
Zackenberg Catchment, NE Greenland.
Greenland Ice Sheet (regional/local scale)

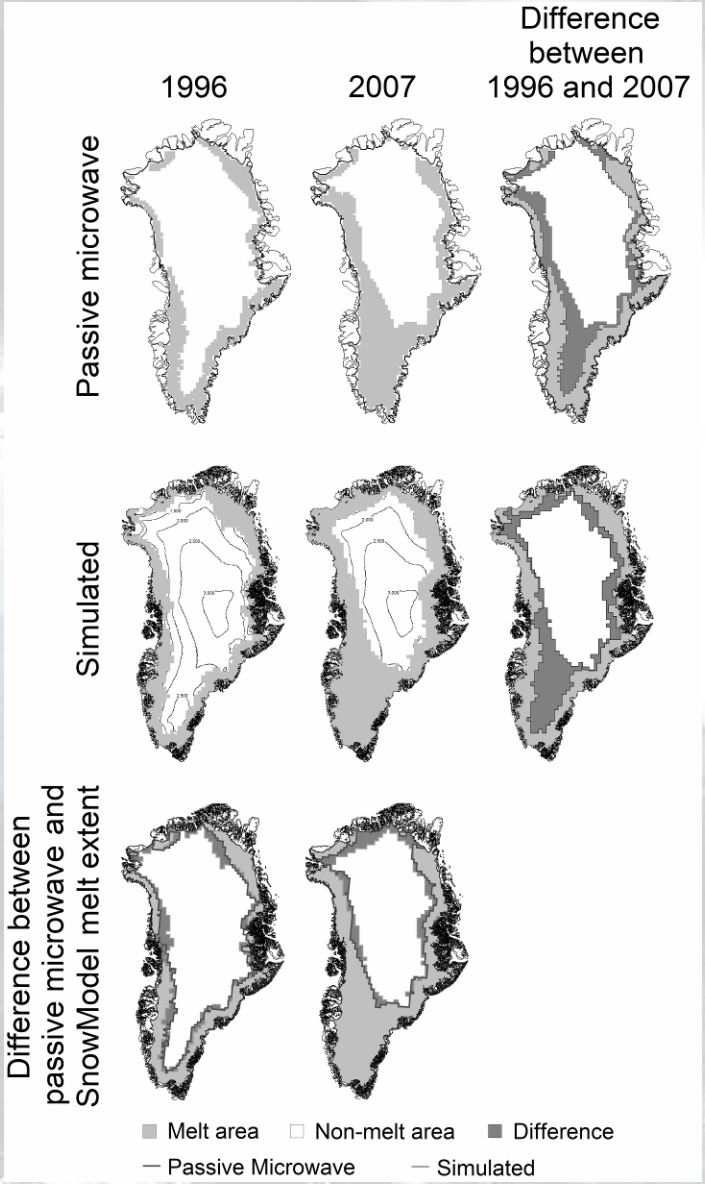
The GrIS for present time based on observed met data…



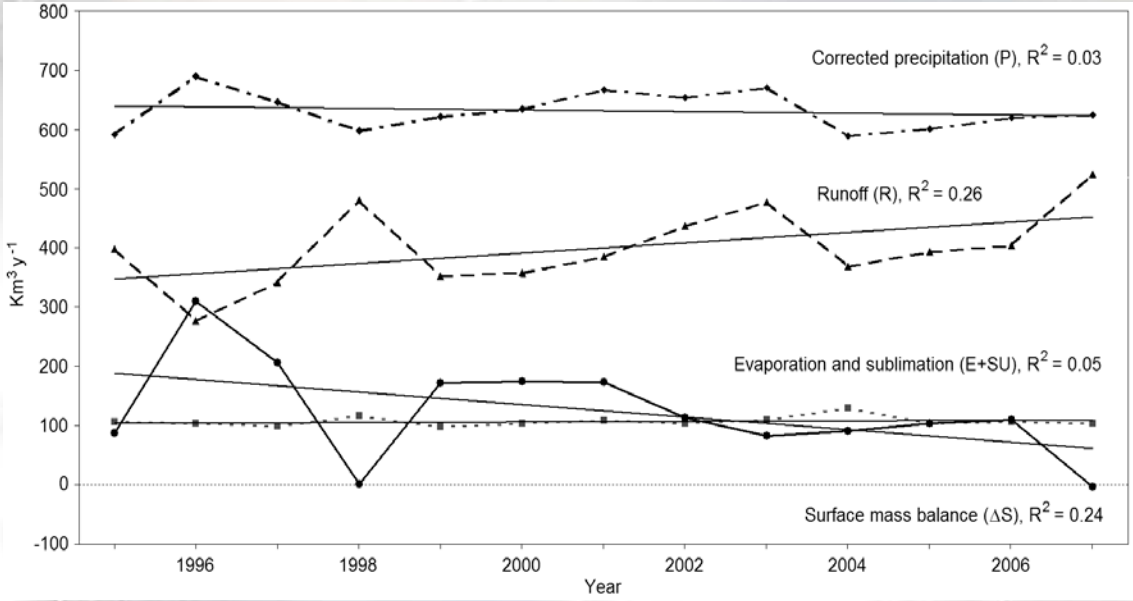


Mernild et al. 2008c

The GrIS for present time…



Mernild et al. 2009b

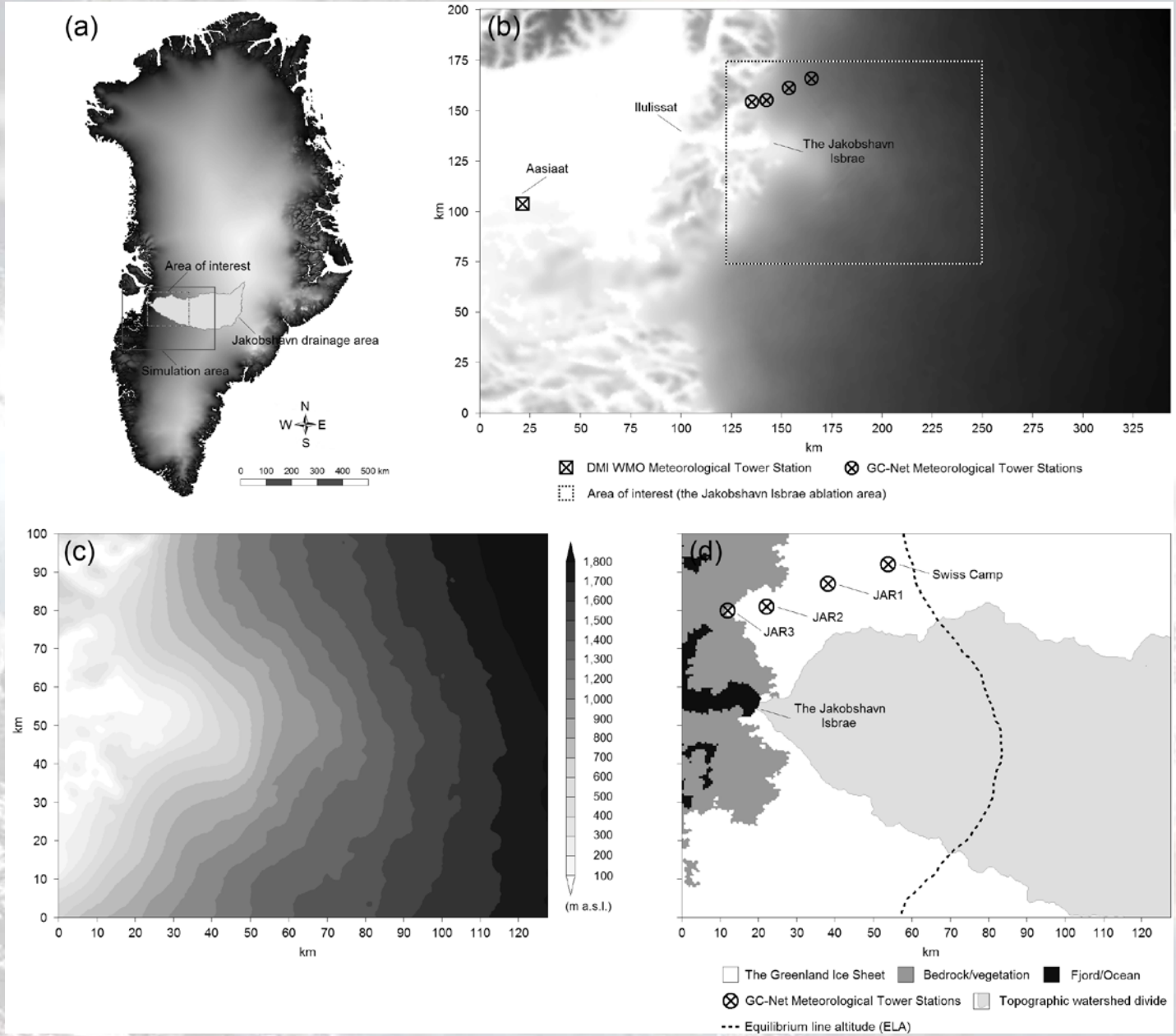


Rank-ordered GrIS precipitation (P), runoff (R), surface mass-balance (ΔS), and air temperature anomaly for 1995 through 2007

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

Jakobshavn drainage area - runoff (2000-2007)



Mernild et al. submitted

Jakobshavn drainage area - runoff (2000-2007)

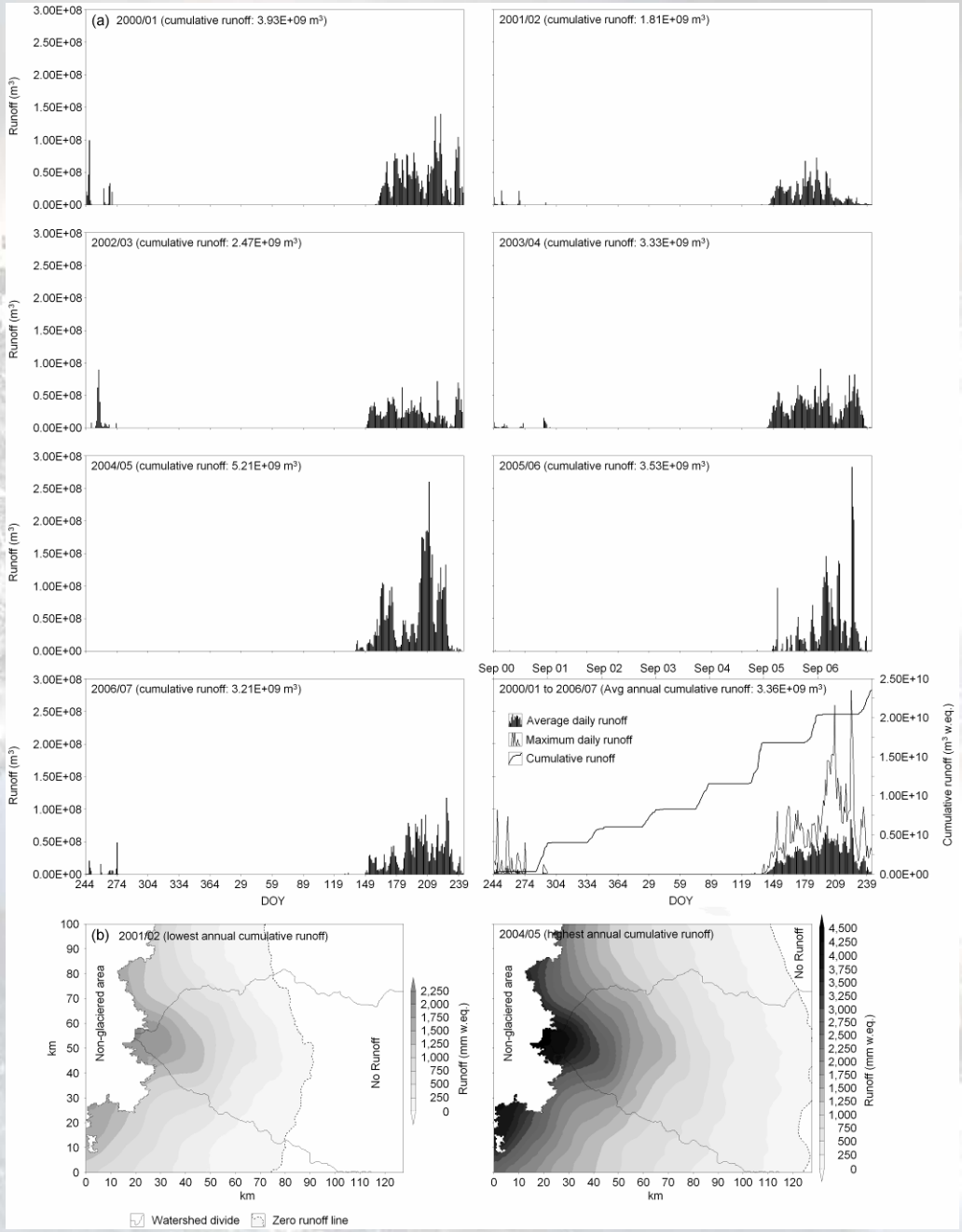
Simulated annual surface melt varied from as low as 3.83×109 m3 (2001/02) to as high as 8.64×109 m3 (2004/05).

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

The SnowModel meltwater retention and refreezing routines considerably reduce the amount of meltwater available as ice sheet runoff; without these routines the Jakobshavn surface runoff would be overestimated by an average of 80%.

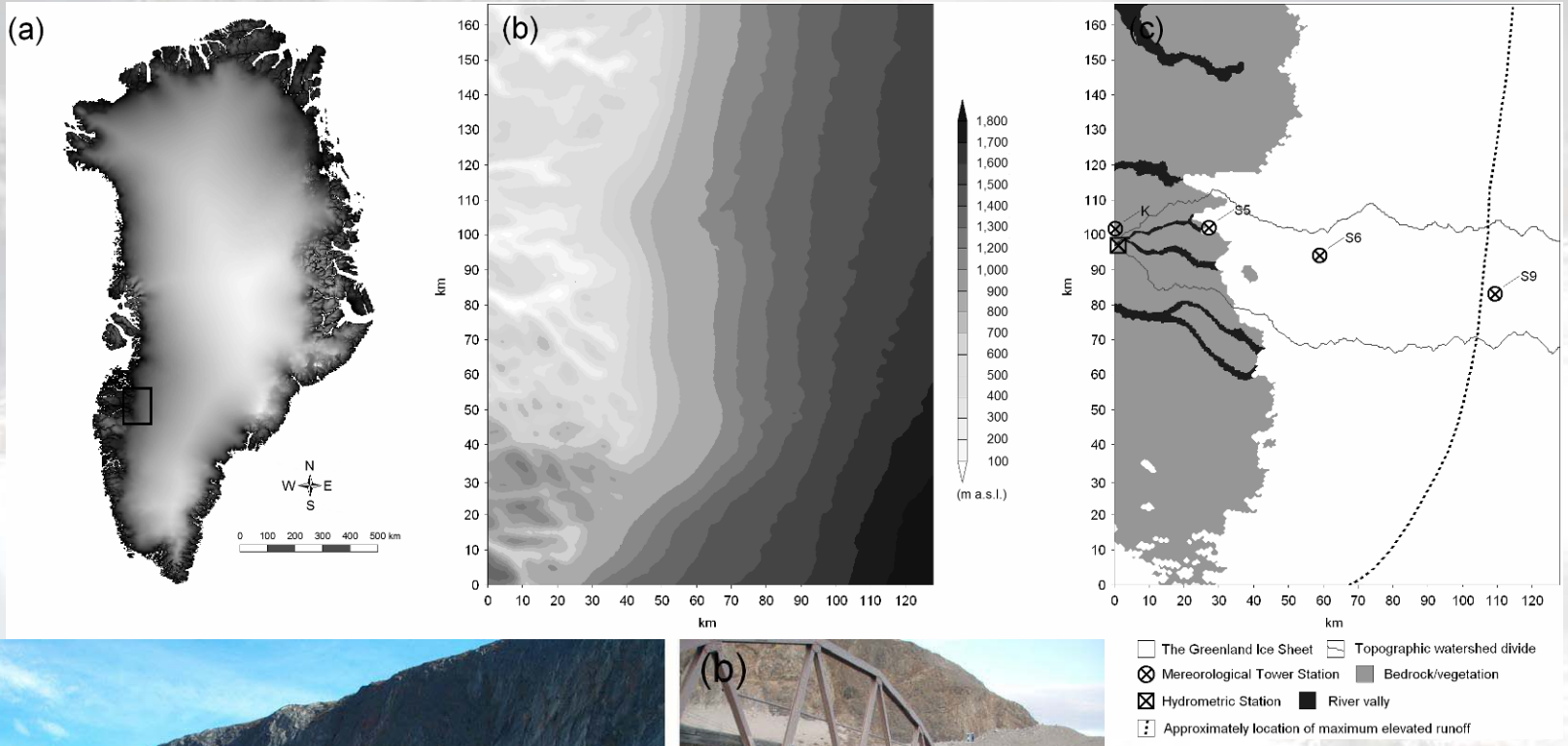
Cumulative runoff at the Jakobshavn glacier terminus of ~2.25 m w.eq. to ~4.5 m w.eq., respectively.

The average modeled Jakobshavn runoff of ~3.4 km3 y-1 was merged with previous estimates of Jakobshavn ice discharge to quantify the freshwater flux to Illulissat Icefiord. This study suggests that ~13% of the average annual freshwater flux of 27.0 km3 y-1 originates from the surface runoff.



Mernild et al. submitted

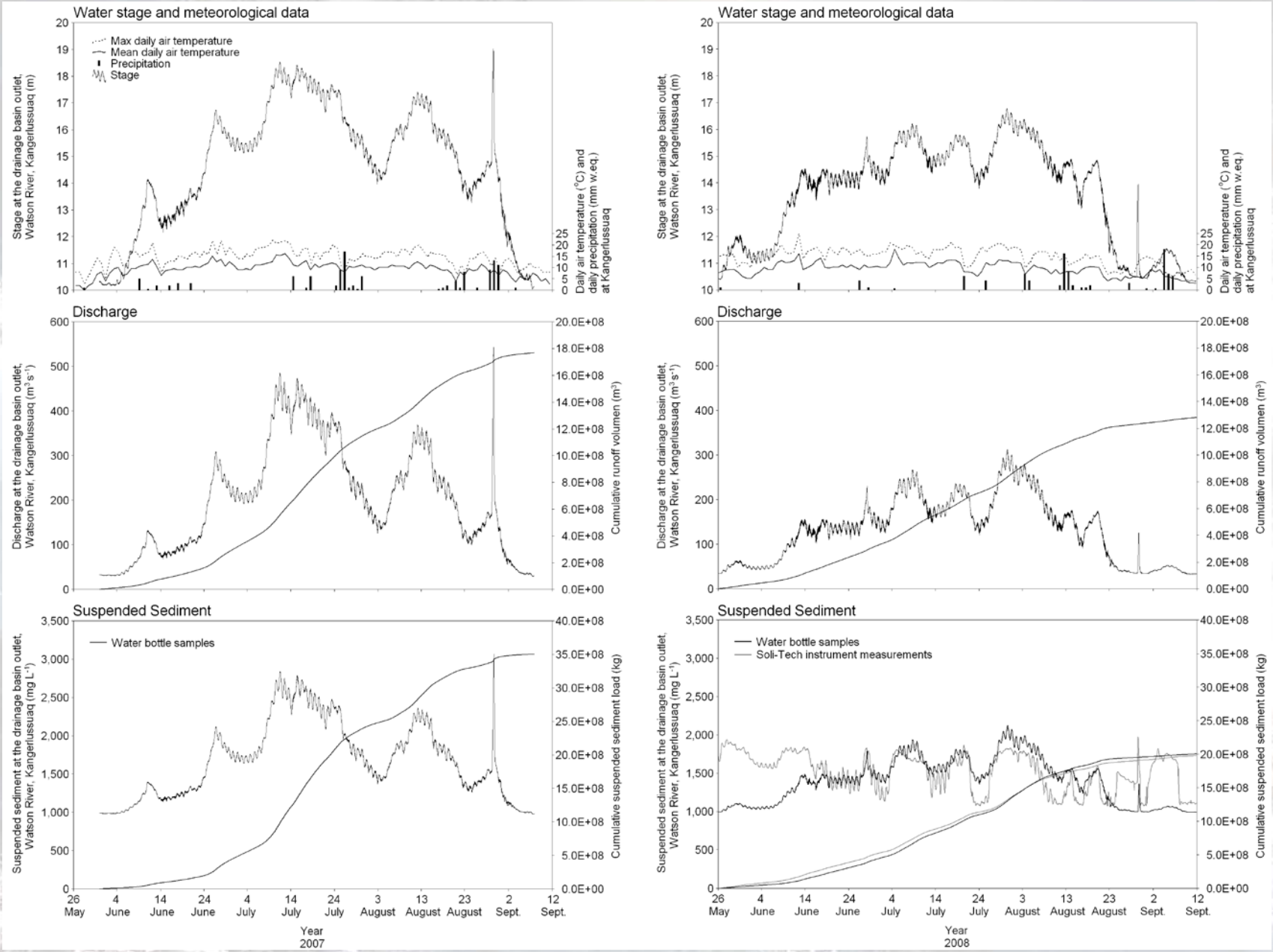
Kangerlussuaq drainage area - runoff (2007-2008)



Mernild et al. in prep.

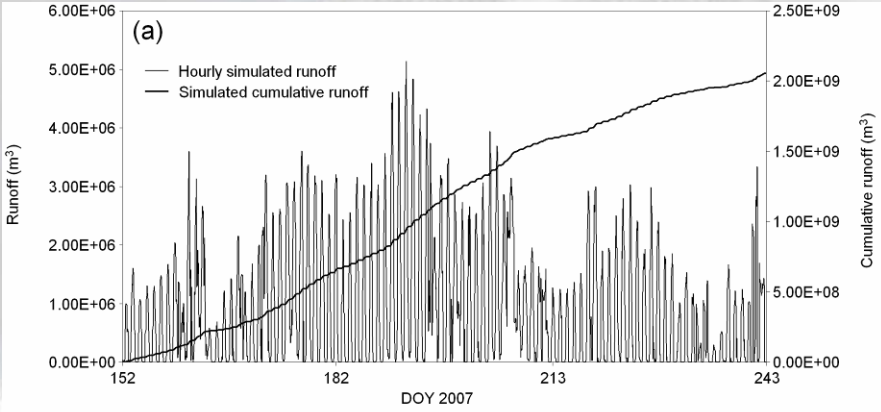
Hasholt and Mernild 2009

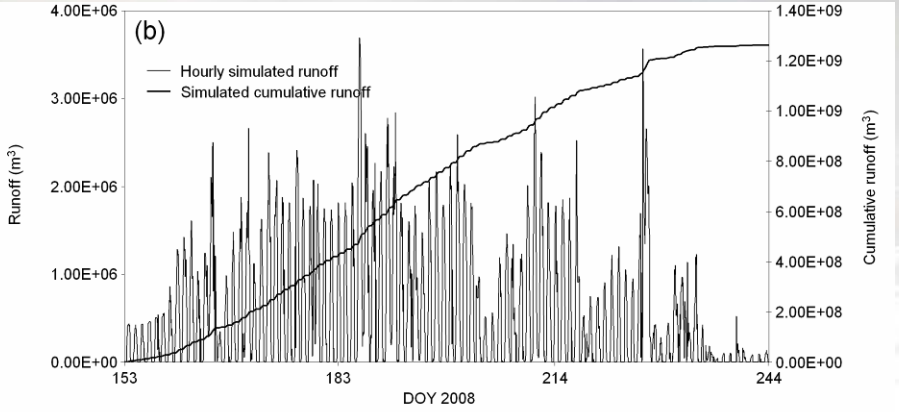
Kangerlussuaq drainage area - runoff (2007-2008)

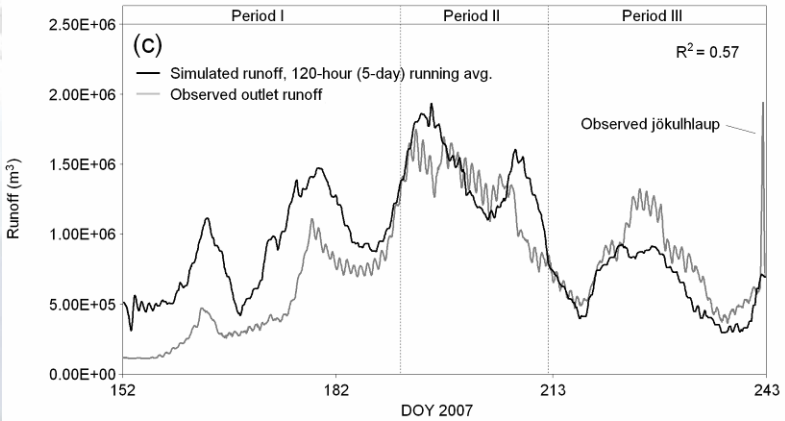


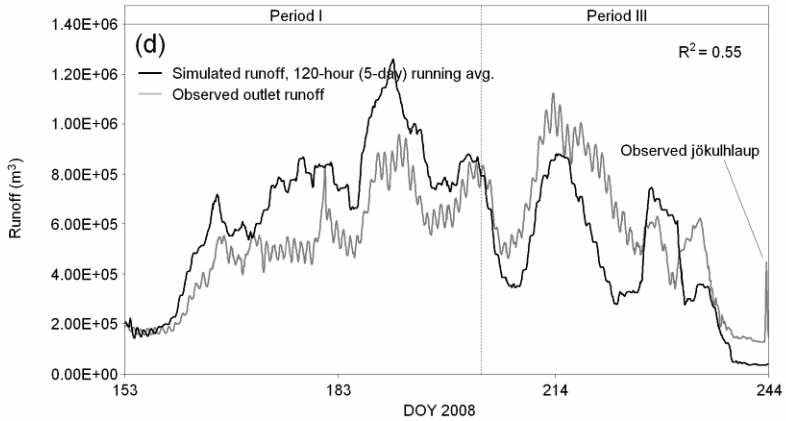
Mernild and Hasholt submitted

Kangerlussuaq drainage area - runoff (2007-2008)

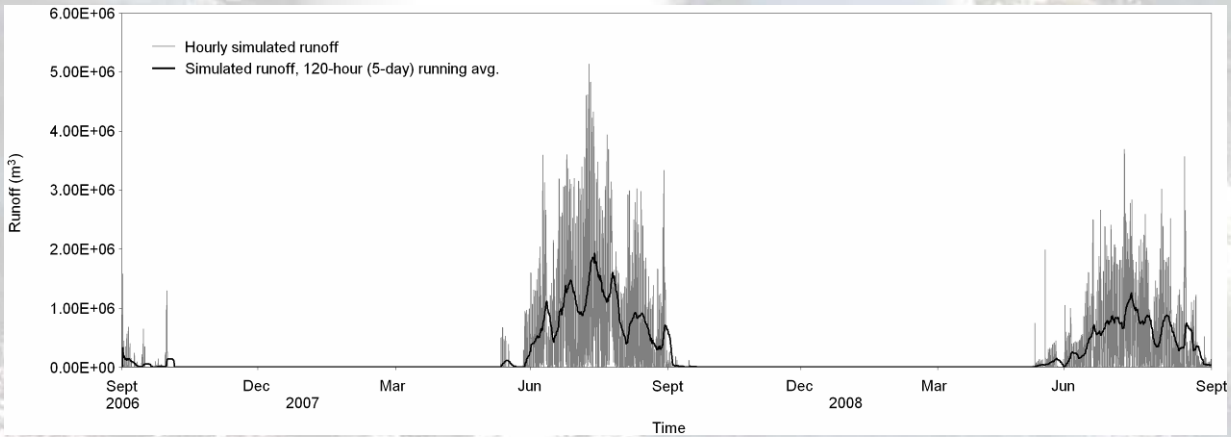




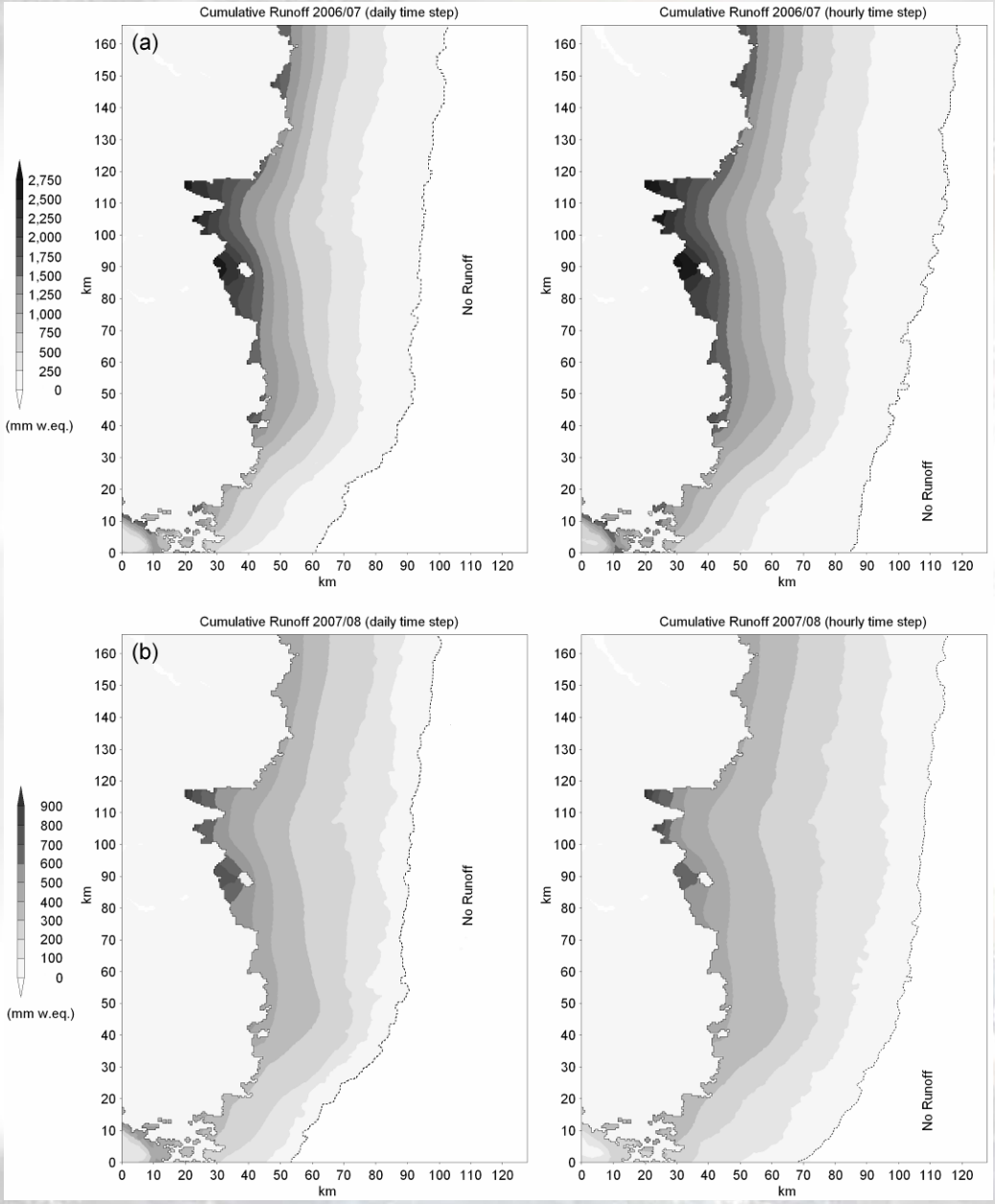




Mernild et al. in prep.



Kangerlussuaq drainage area - runoff (2007-2008)

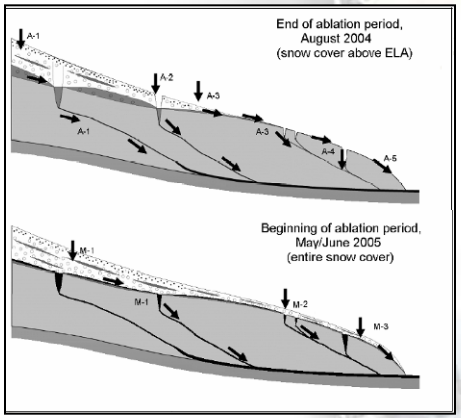


Mernild et al. in prep.

Ongoing/future work…

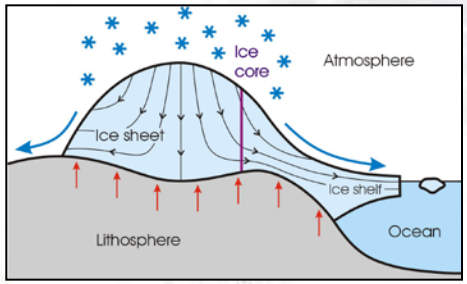
SnowModel (further modifications)

- Multi-Layer Snowpack Model
- IceHydro



IceHydro: Runoff Model - runoff model routing melt water/rain through the ice and landscape to the coast.

- Link SnowModel to a dynamic ice sheet model



Simulations

- Kangerlussuaq, 1996-present, future
- Helheim area, East Greenland
- GrIS, 1950-2080 (IPCC scenario A1B modeled in the HIRHAM4 RCM (using boundary conditions from ECHAM5 AOGCM).


Thank you...!!!