DMI
Danish Meteorological Institute

Improving Snow and Ice Albedo in Climate and NWP Models

Ruth Mottram

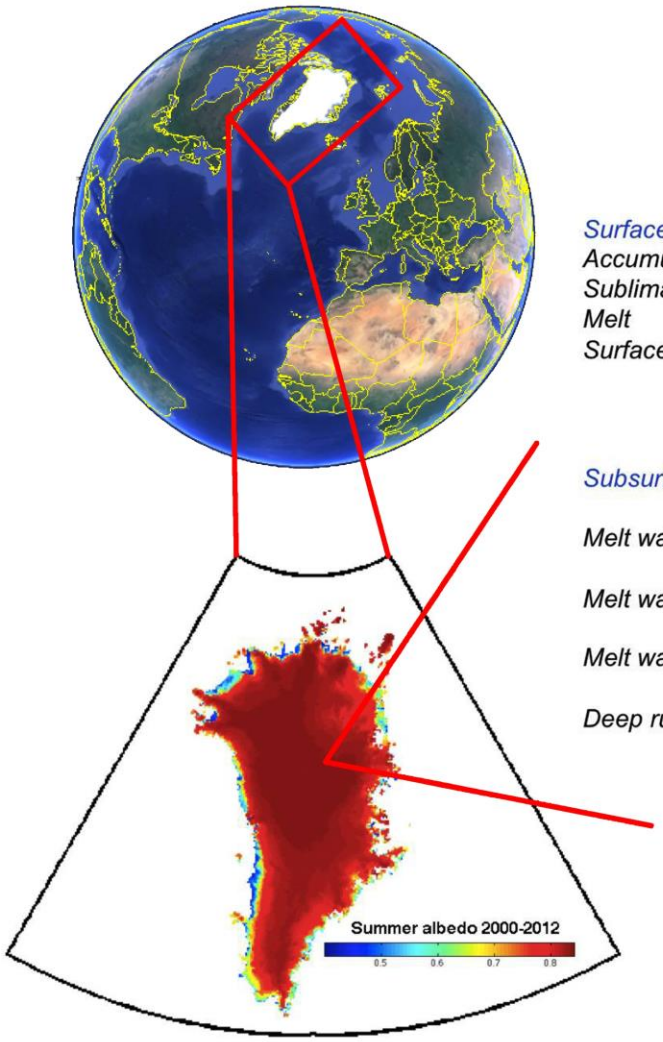
Arctic and Climate Research

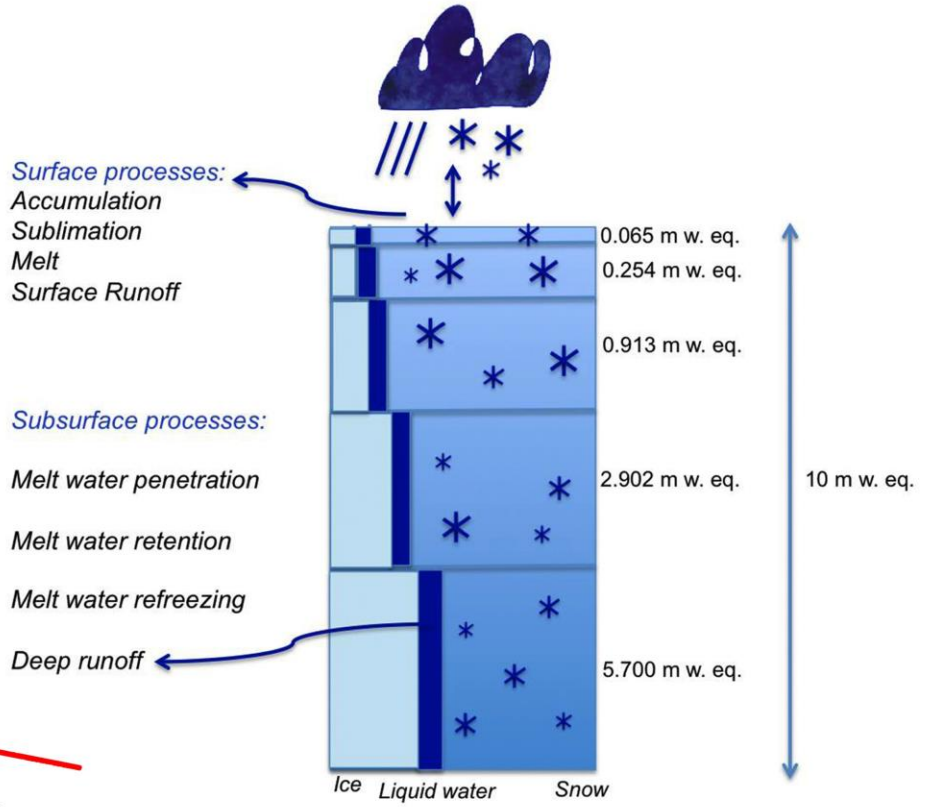
Danish Meteorological Institute

With Contributions from: Simon Gascoin, Peter Lang Langen, Pia Englyst Nielsen, Kristian Pagh Nielsen, Louise Steffensen Schmidt, Finnúr Pálsson, and Emily Gleeson

Climate modeling

HIRHAM5 – Regional Climate Model modified from **HIRLAM7** dynamics and **ECHAM5** physics, calculates Surface Mass Balance

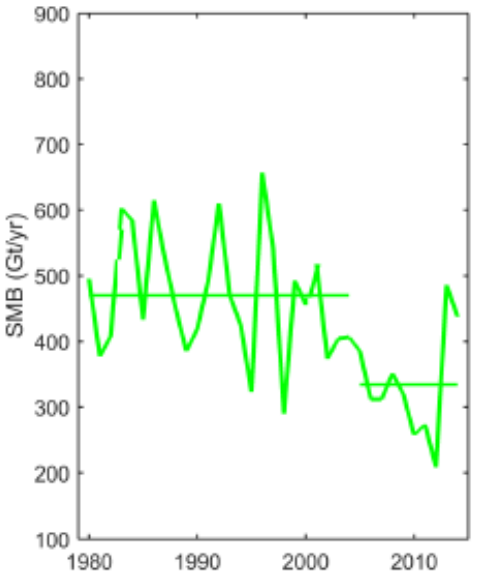


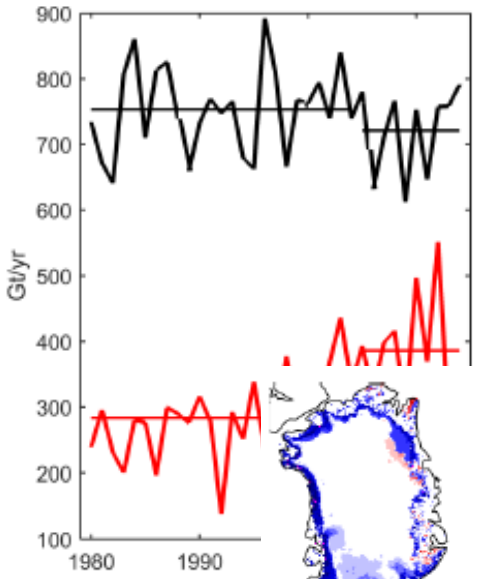


- 5.5 km horizontal resolution
- 31 levels in the vertical
- Time step of 90s

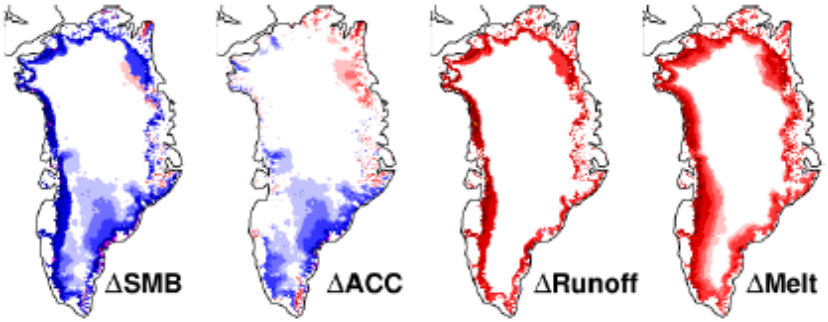
Forced by ERA-Interim on the boundaries

Surface Mass Balance of Greenland 1980 - 2014



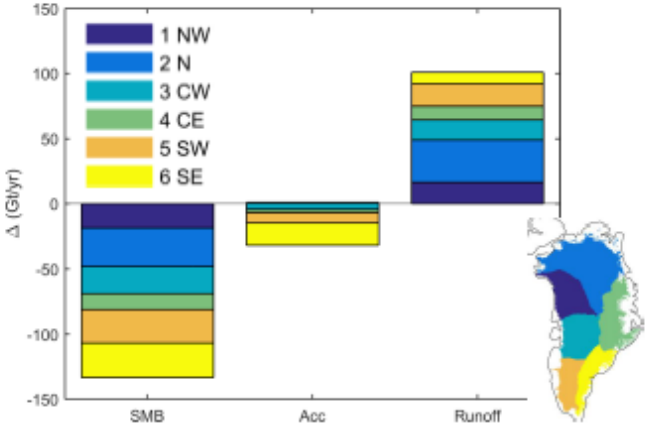


Over the period ice accumulation has remained constant but there has been a declining trend of SMB due to melt



What is the Surface Mass Balance of the Greenland Ice Sheet?

Roughly 300 Gt per year



Δ is the difference [2005:2014]-[1980:2004]

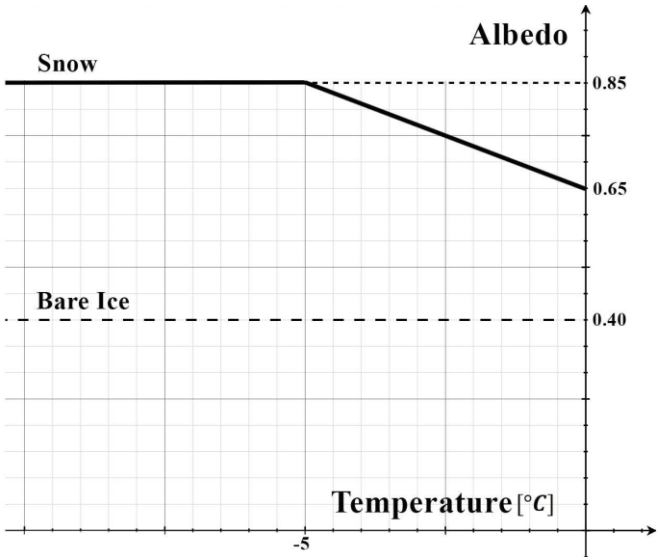
Simple Albedo parameterizations

Temperature dependent schemes

e.g. HIRHAM5

$$\begin{cases} \alpha_{min} = 0.65 & T = 0°C \\ \alpha_{sn} = linear\ change & \\ \alpha_{max} = 0.85 & T < -5°C \end{cases}$$

Including a smooth transition to bare ice conditions for small snow depths



Prognostic schemes

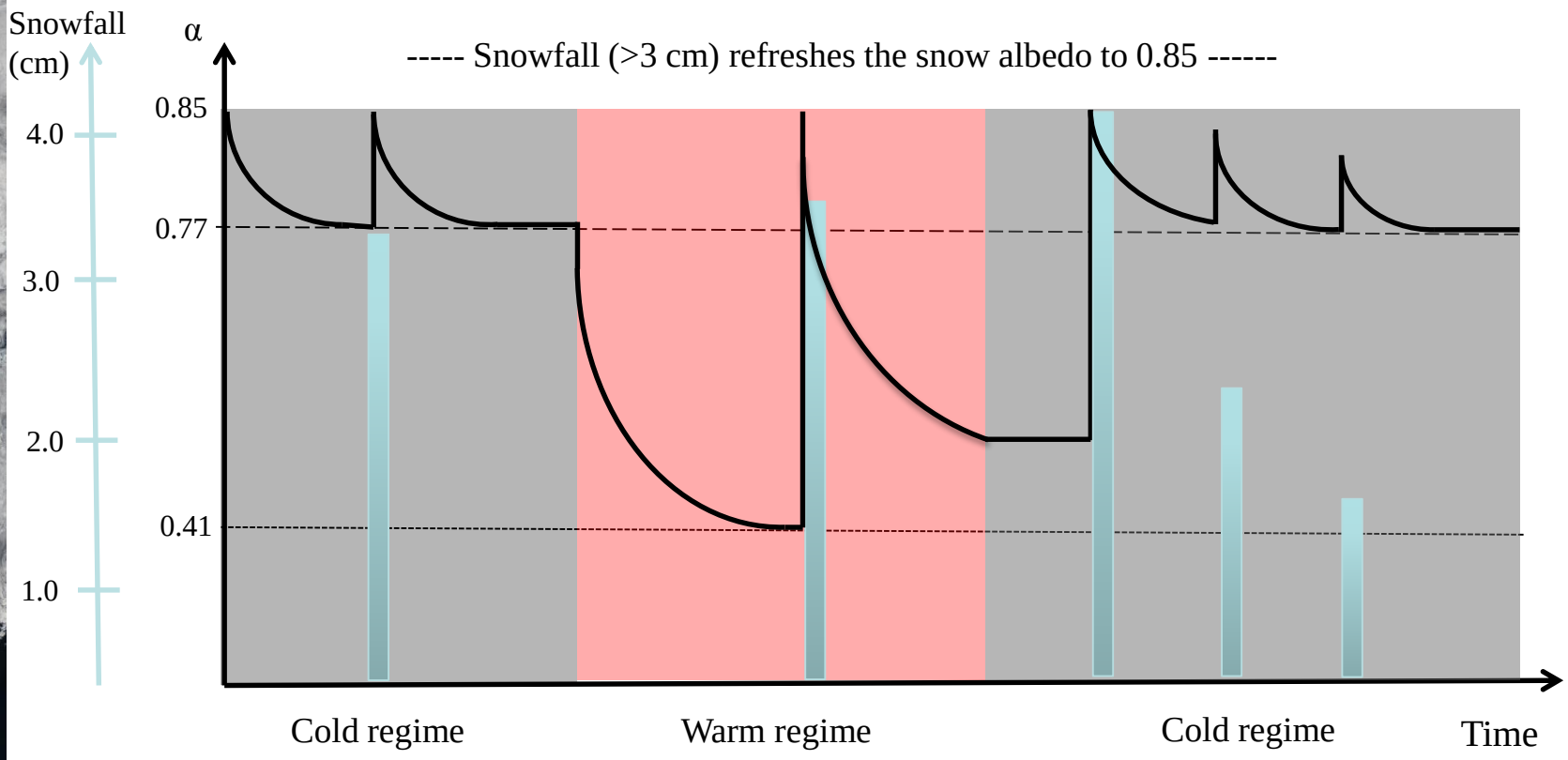
$$\alpha_{sn}^{t+1} = \begin{cases} \alpha_{sn}^{t} - \tau_d^{-1}\delta t \\ (\alpha_{sn}^{t} - \alpha_{min})exp(-\tau_m^{-1}\delta t) + \alpha_{min} \end{cases}$$

For snowfall $\alpha_{sn}^{t+1} = \alpha_{max}$

Complex schemes

Including snow grain size evolution, wavelength dependency etc.

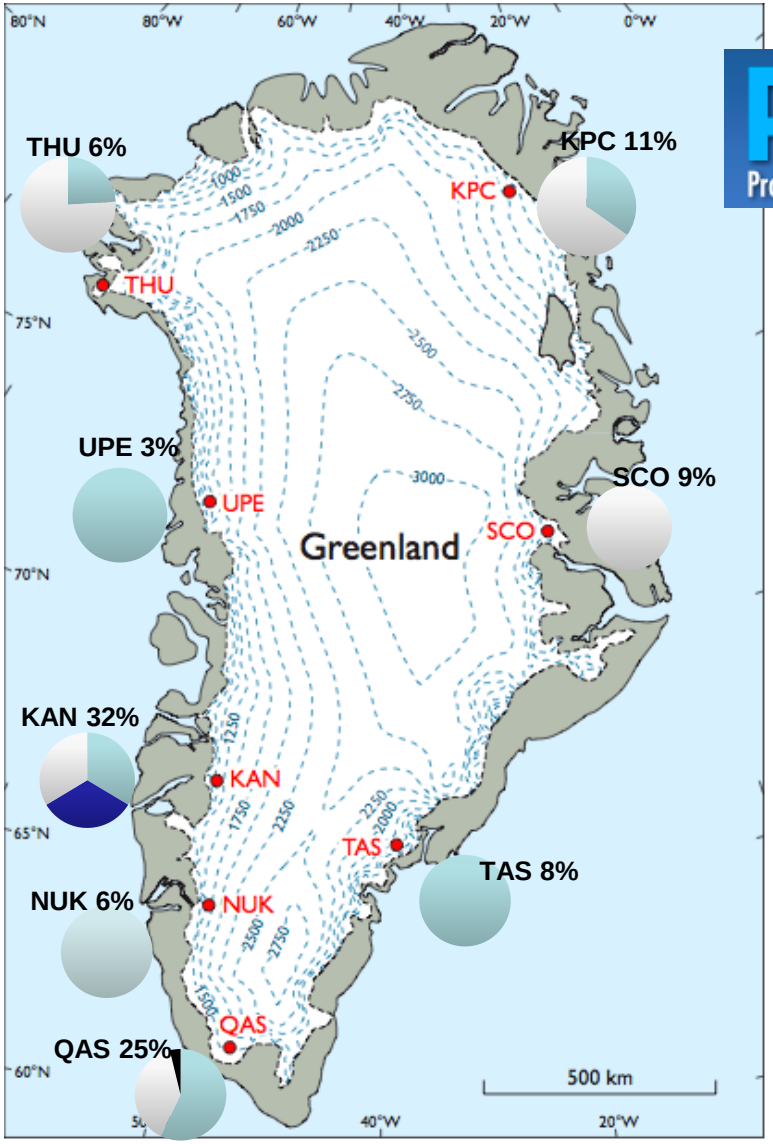
New albedo parameterization



Cold snow : $$\alpha_{snow}^{t+\delta t} = \alpha_d + (\alpha_{snow}^{t} - \alpha_d)\, exp\left(\frac{-\delta t}{\tau_d}\right)$$

Melting snow : $$\alpha_{snow}^{t+\delta t} = \alpha_m + (\alpha_{snow}^{t} - \alpha_m)\, exp\left(\frac{-\delta t}{\tau_m}\right)$$

Calibration



Credit: Fausto et al. [2012].

PROMICE
Programme for Monitoring of the Greenland Ice Sheet

14 stations

Input parameters

Temperature
Snow depth → Snow rate

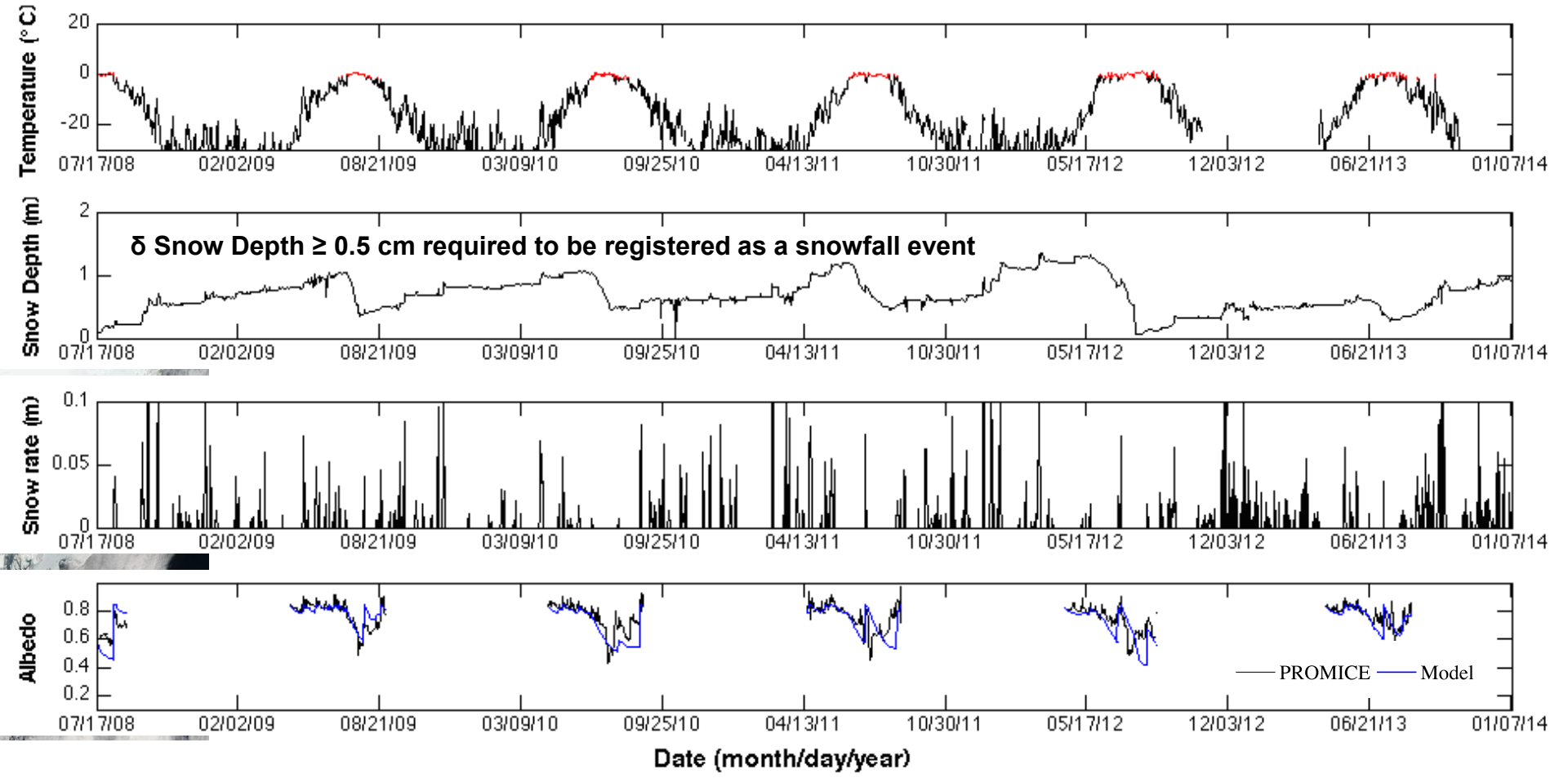
Albedo

Location of station:

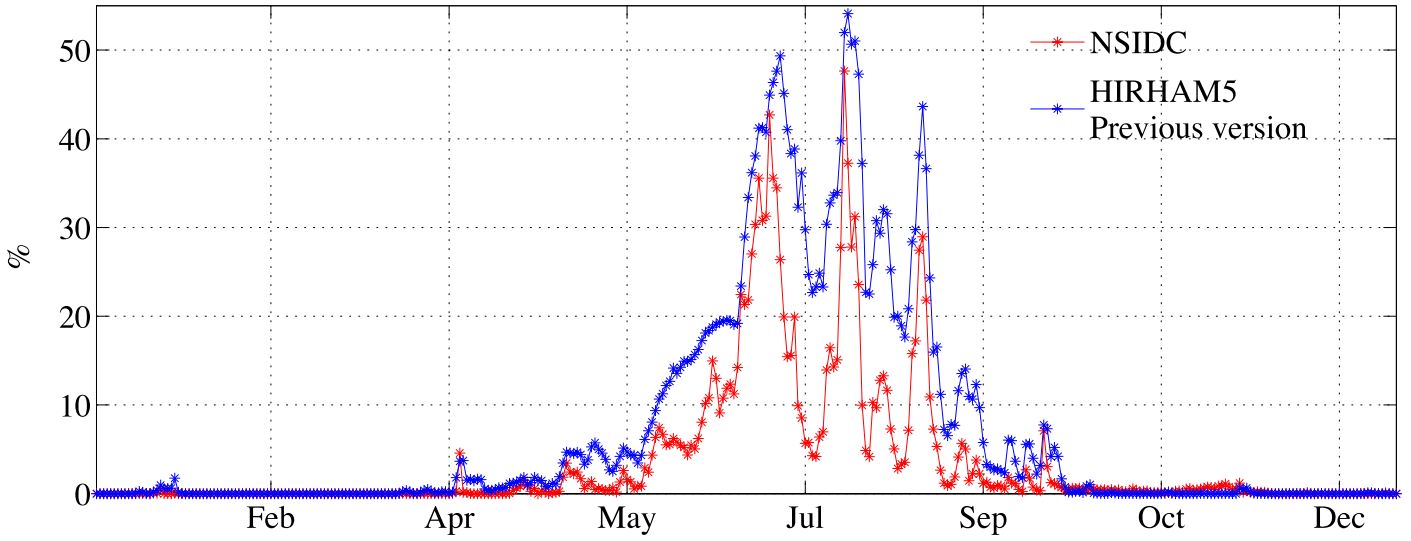
L M U A N

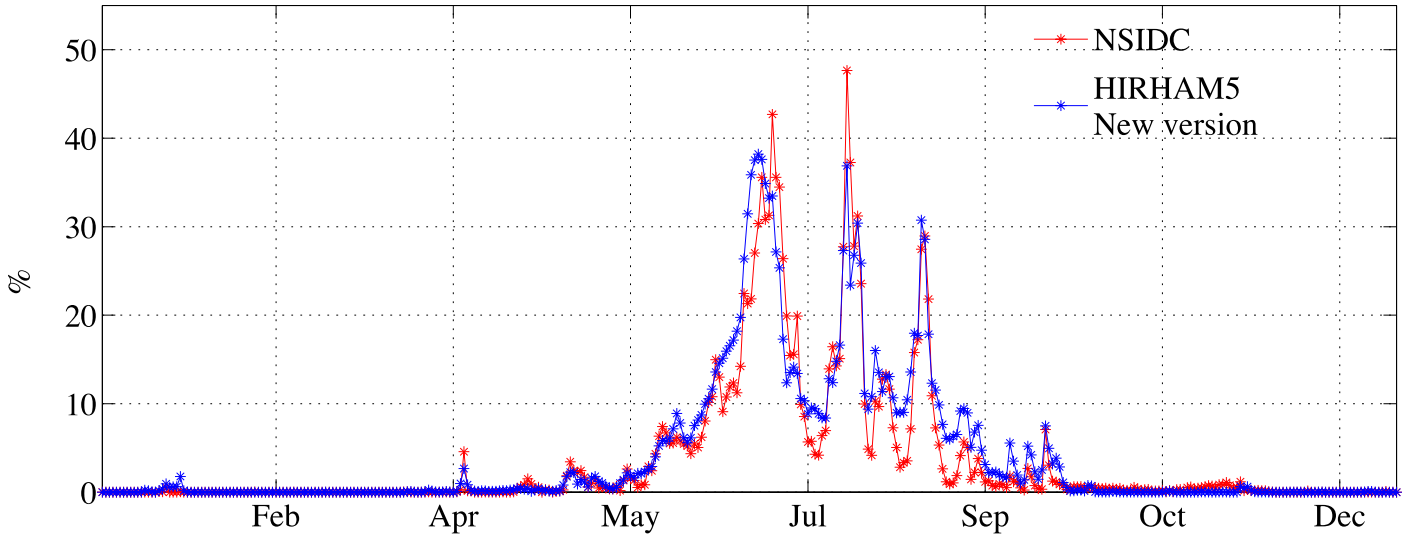
Example from KPC_U Station

Data from 17/7/2008 to 7/1/2014



Melt extent 2000





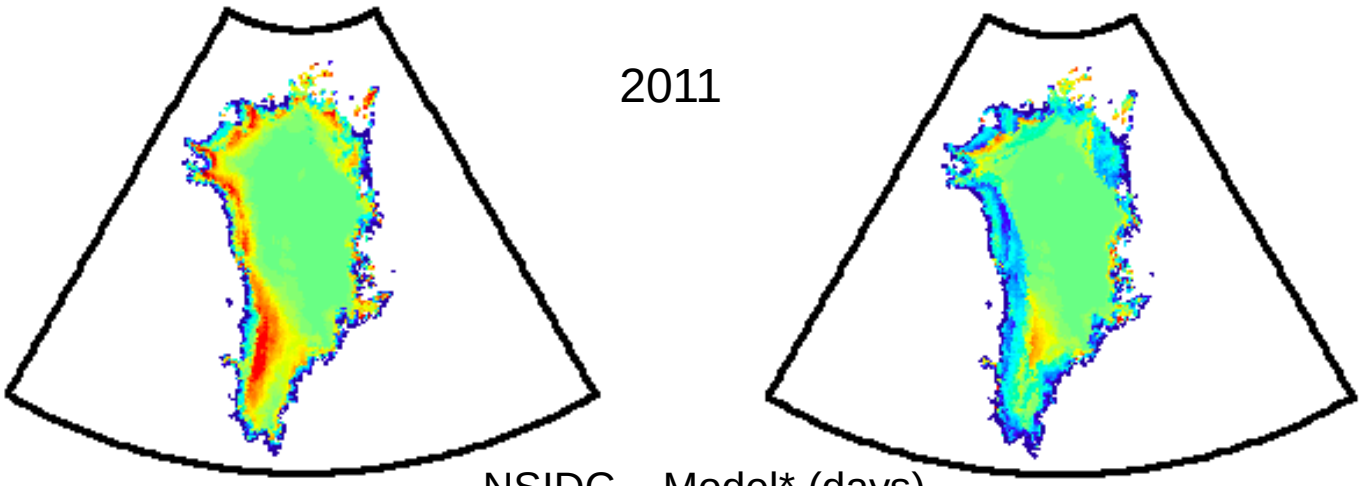
Melt days compared to NSIDC

NSIDC=NASA National Snow and Ice Data Center

New version

Previous version

2011



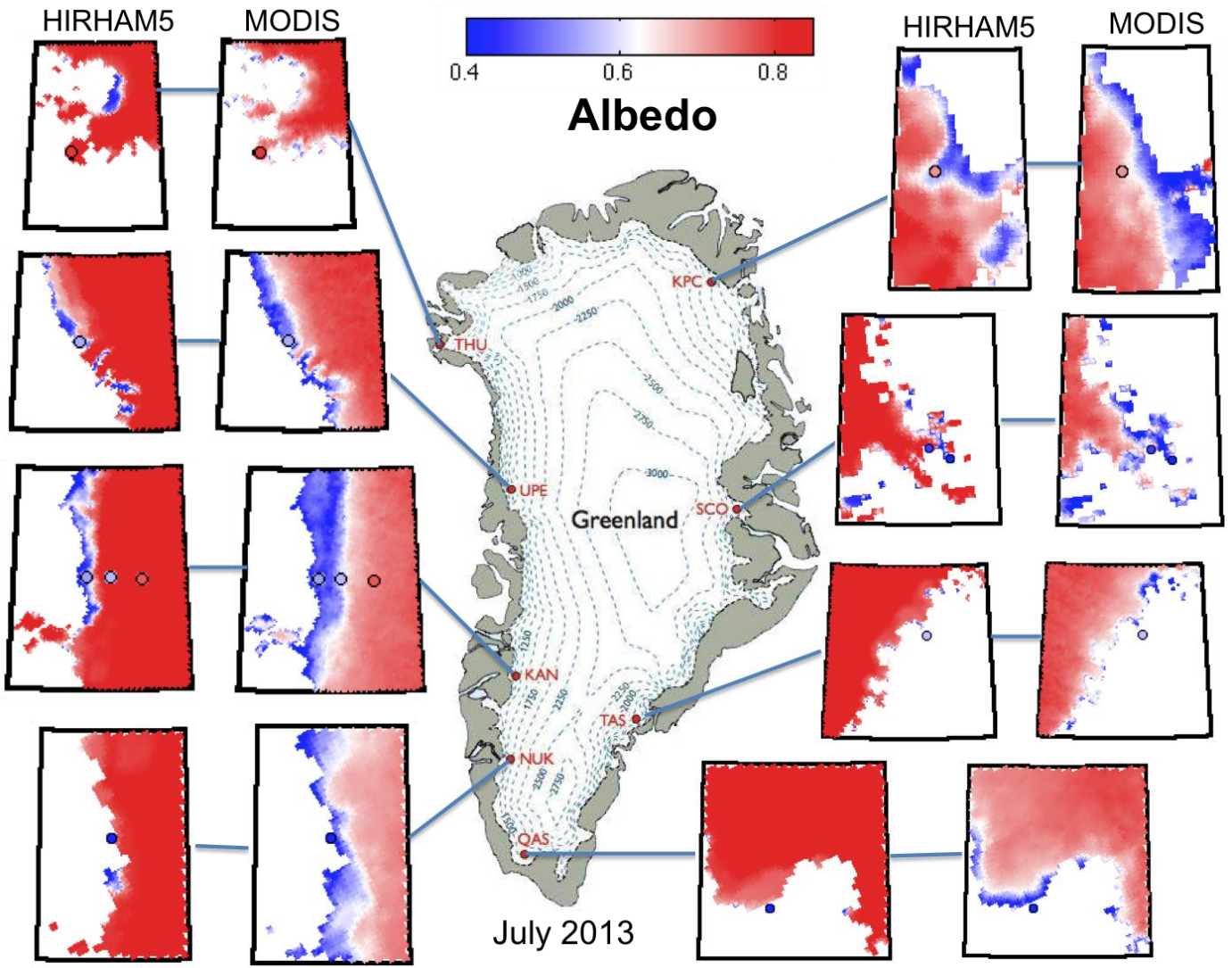
* Model melt day = melt production > 1 mm in HIRHAM5

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
# old	-13.09	-11.82	-14.66	-13.96	-14.60	-14.88	-13.54	-16.04	-13.36	-12.38	-15.01	-9.28	-17.93
# new	-1.79	0.38	1.19	-2.16	-0.46	-0.88	1.47	-0.79	-2.58	-3.66	-0.32	-0.11	-14.98

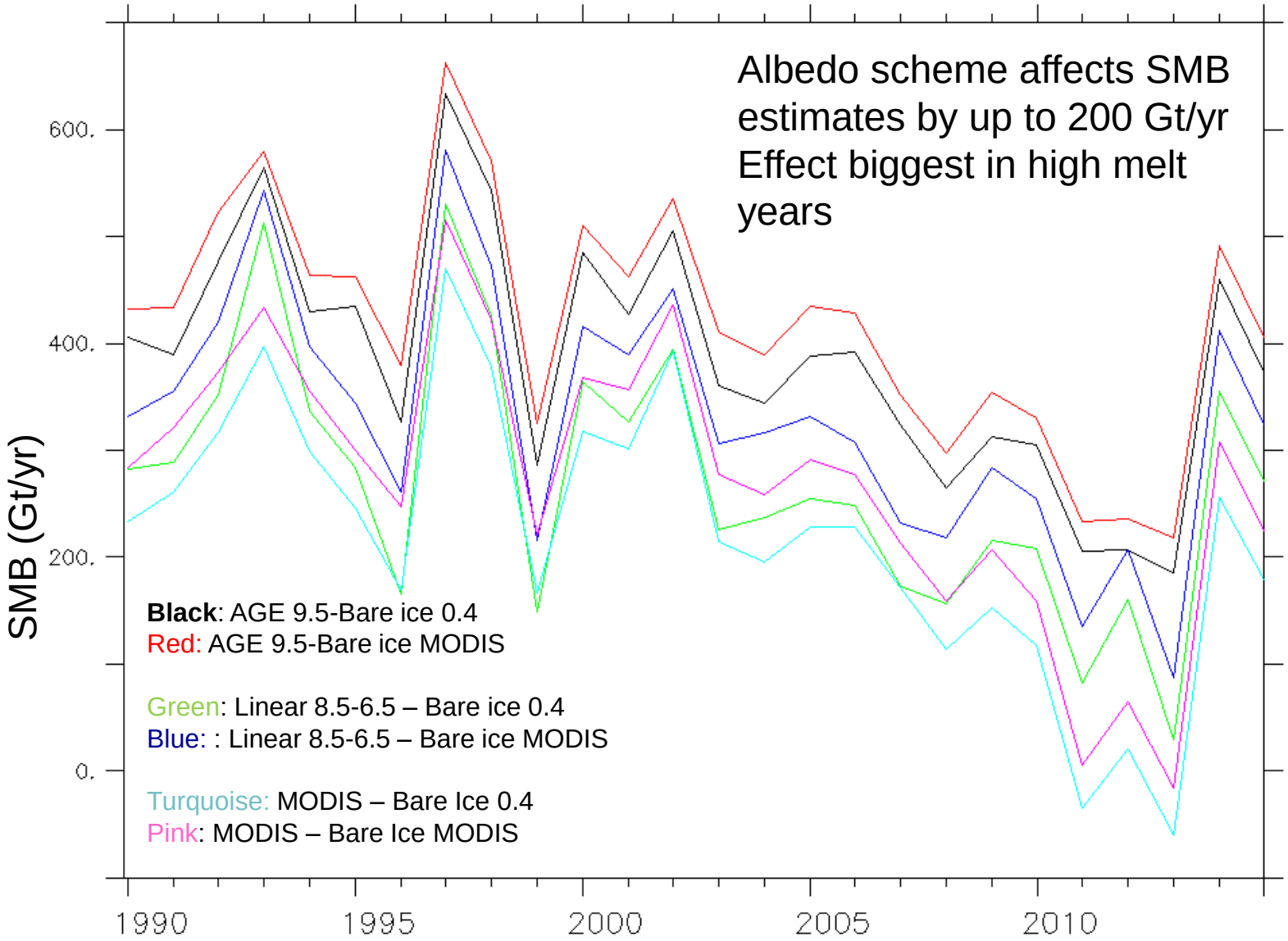
Old = 12.51 melt days more than NSIDC per year

New = 1.90 melt days more than NSIDC per year

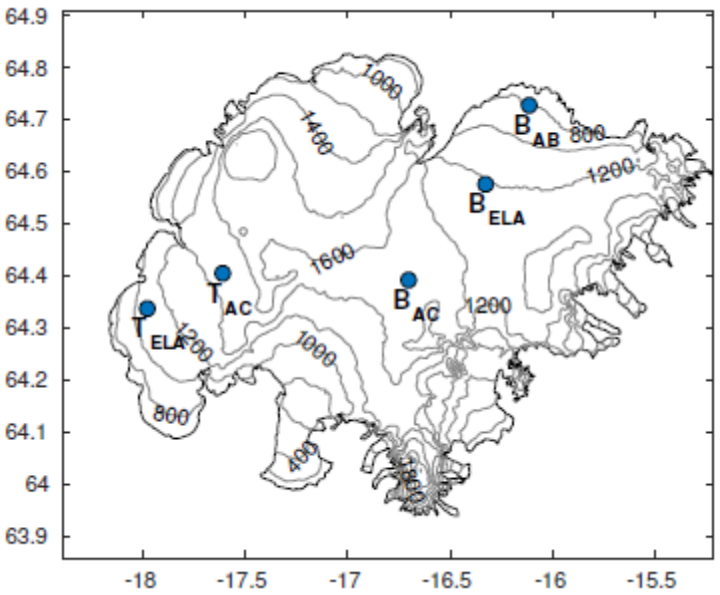
Comparison against MODIS and PROMICE

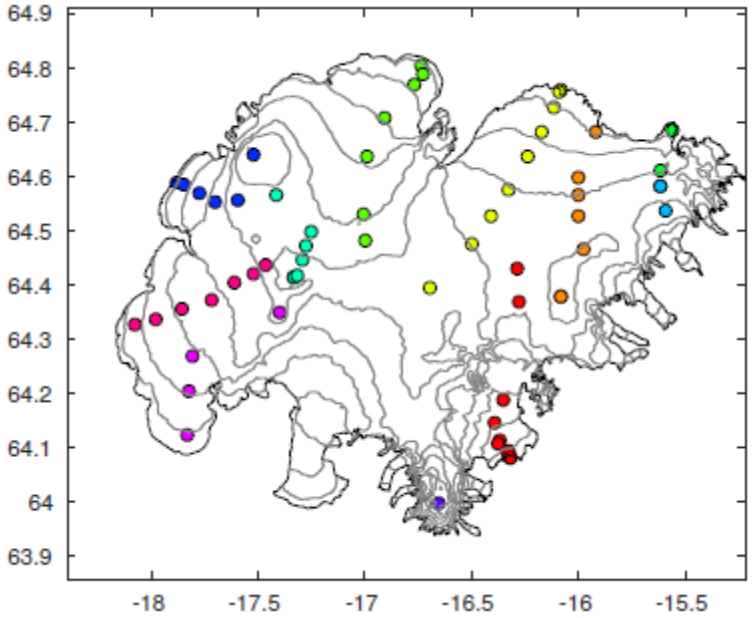


Impact of Albedo on Greenland Ice Sheet SMB



SMB studies on Vatnajökull

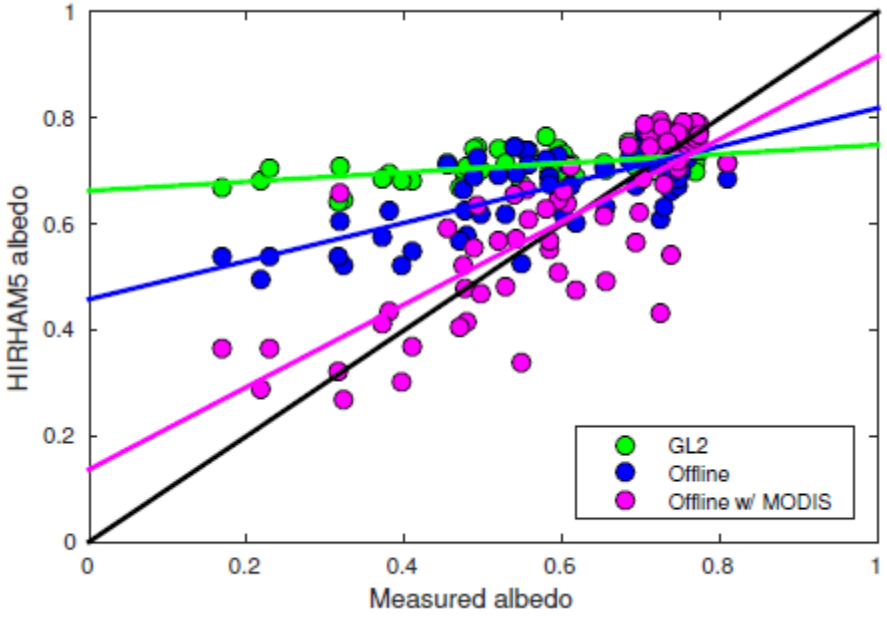


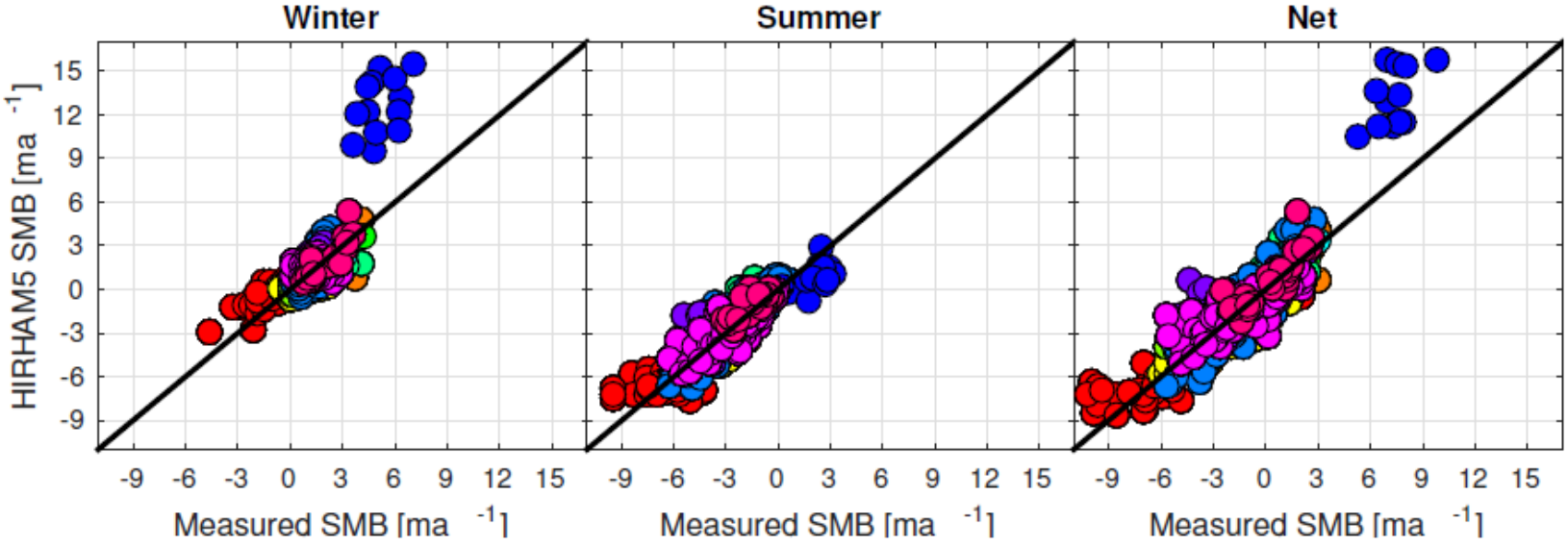


From: Simon Gascoin

Vatnajökull, Iceland

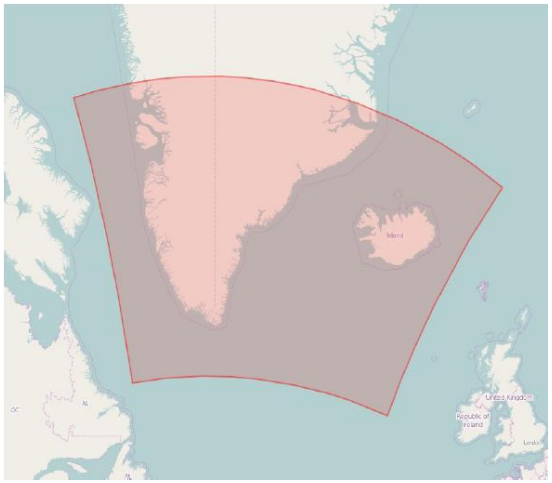
- MODIS albedo used as background albedo for bare ice
- New parameterisation used for rest of Vatnajokull

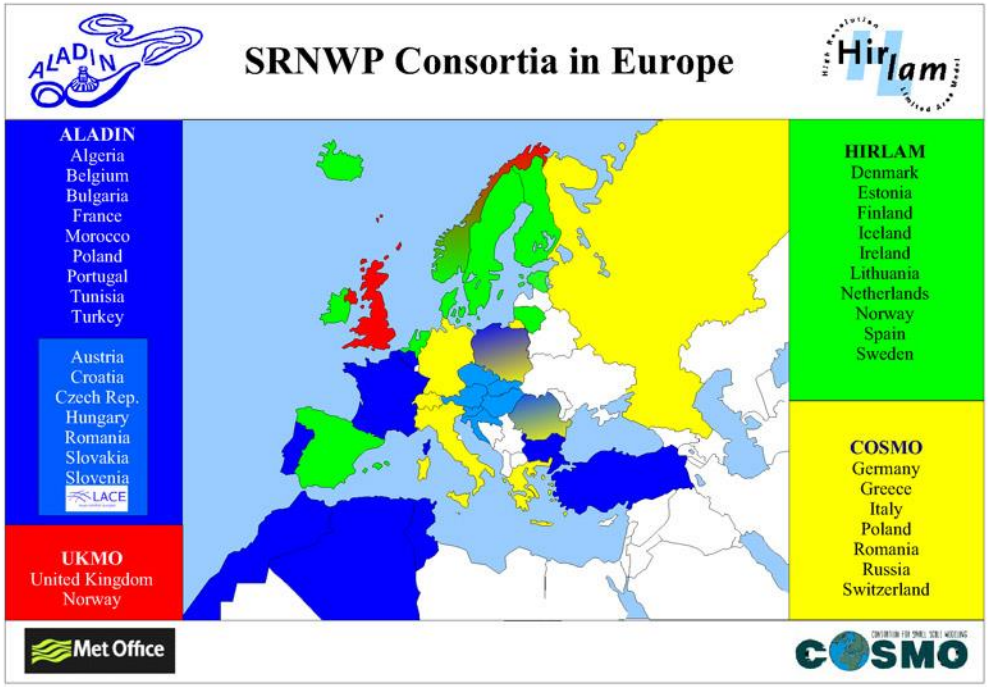




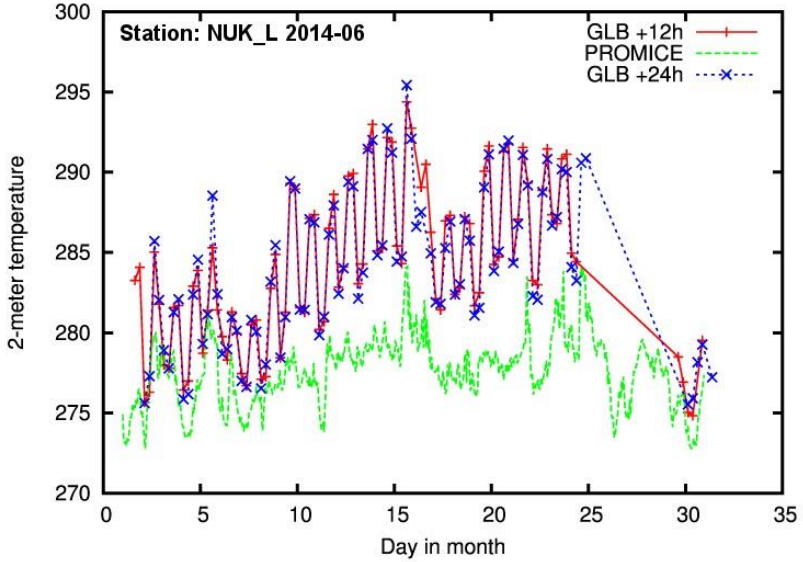
The Next Generation: Harmonie Climate

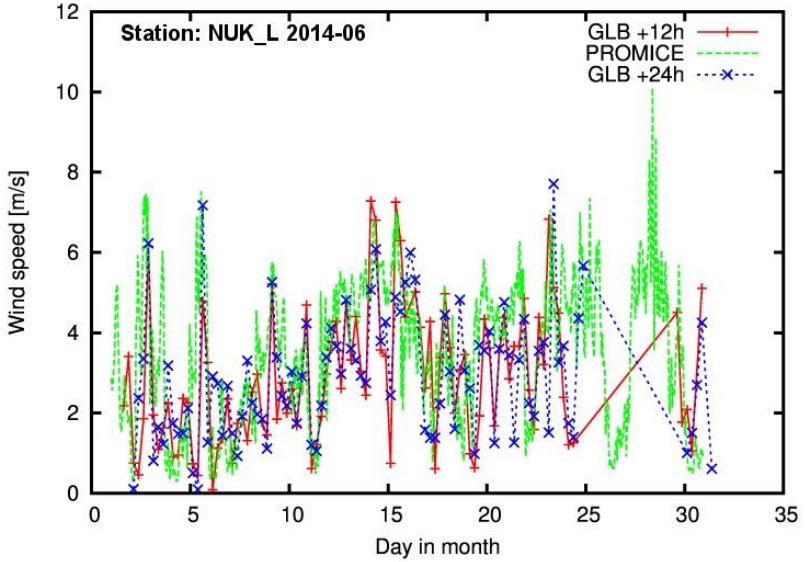
- Flexible single model for NWP and climate
- SURFEX surface scheme
- Arome physics for non-hydrostatic runs
- IFS or Alaro physics for lower resolution
- HCLIM in development for Greenland (already runs in for European domains)

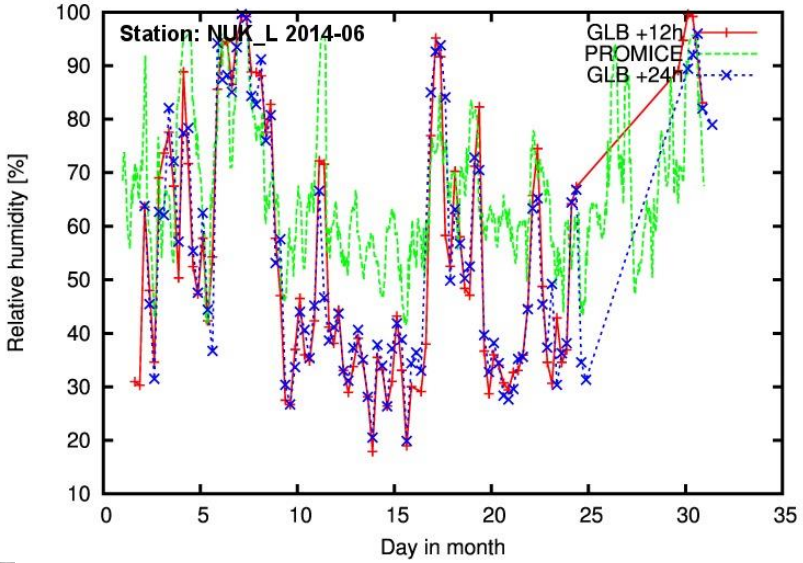


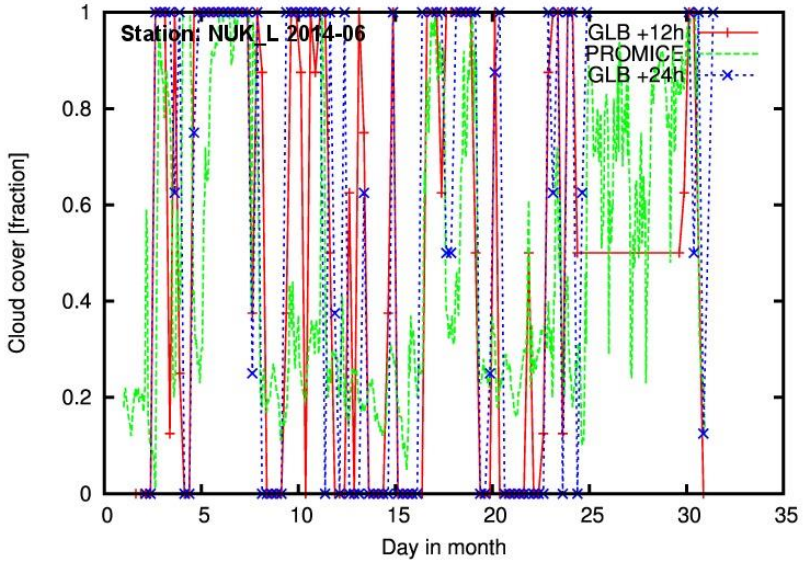


PROMICE NUK_L



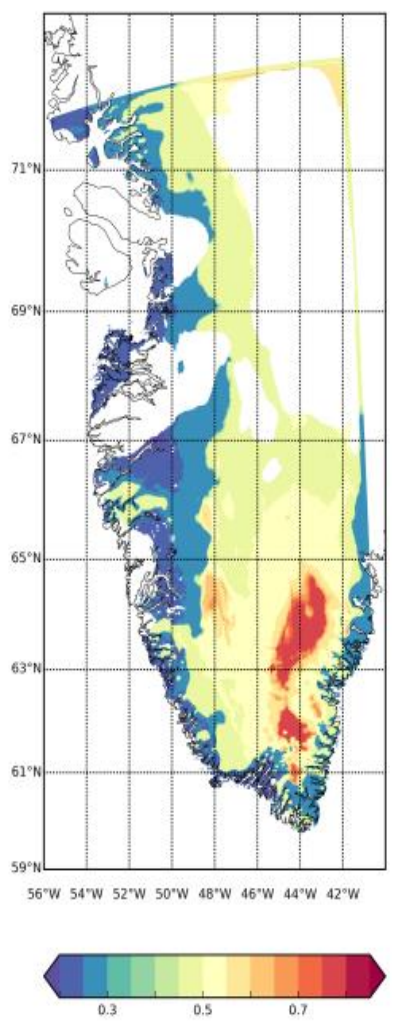


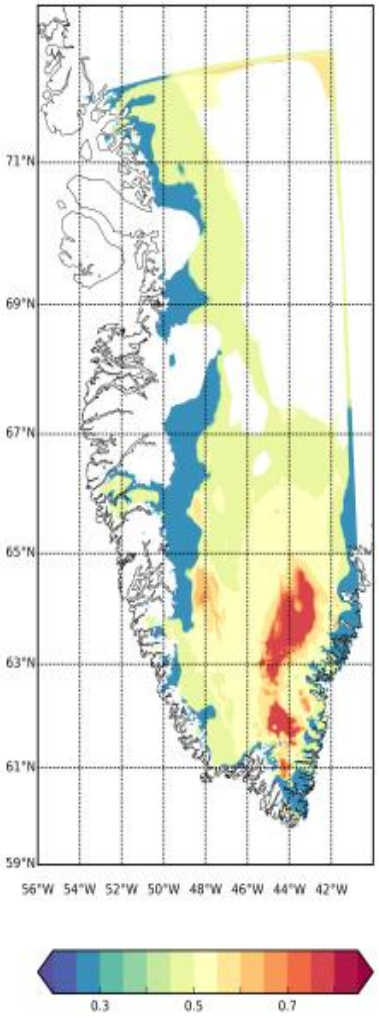


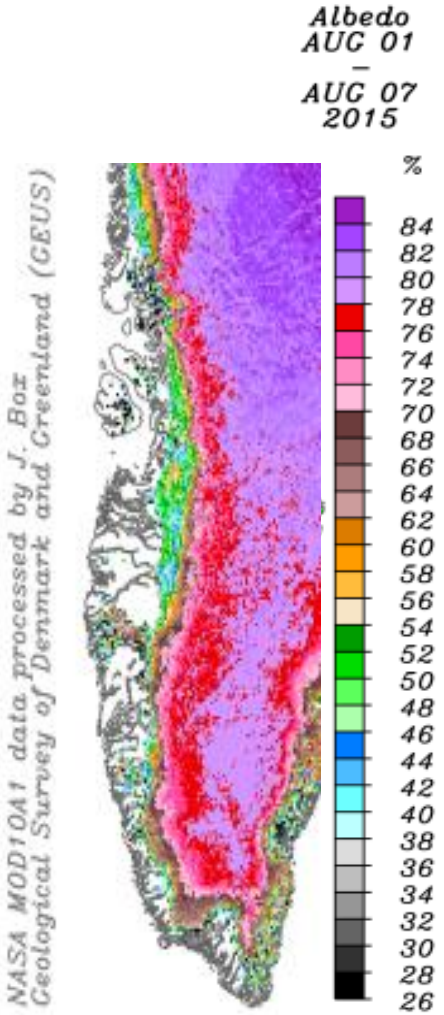


HARMONIE – NWP

Net Albedo 27th July 2015







Summary and Future Work

- Albedo is a fundamental control on the Surface Mass Balance of ice sheets and glaciers
- Albedo parameterisation is not simple, but it is a necessary step to better climate and weather models
- Assimilating albedo into models is complicated by coverage of satellite data products but can significantly improve model performance
- Using point observations to refine parameterisations is a necessary but not the only required step!
- As spectral albedo schemes become more common in models, evaluating results over different surfaces and different wavelengths is becoming more urgent

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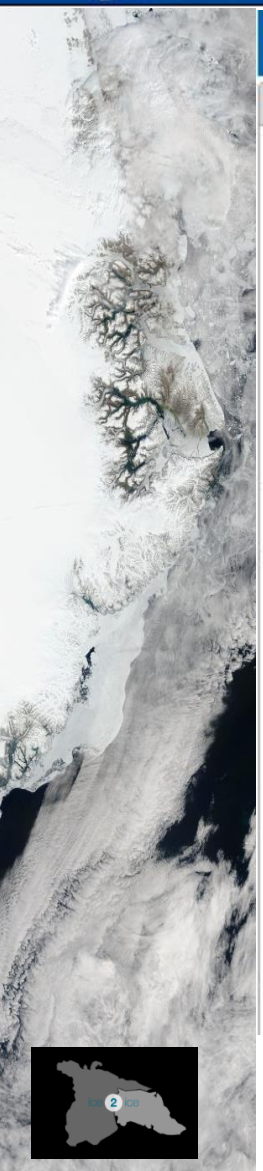
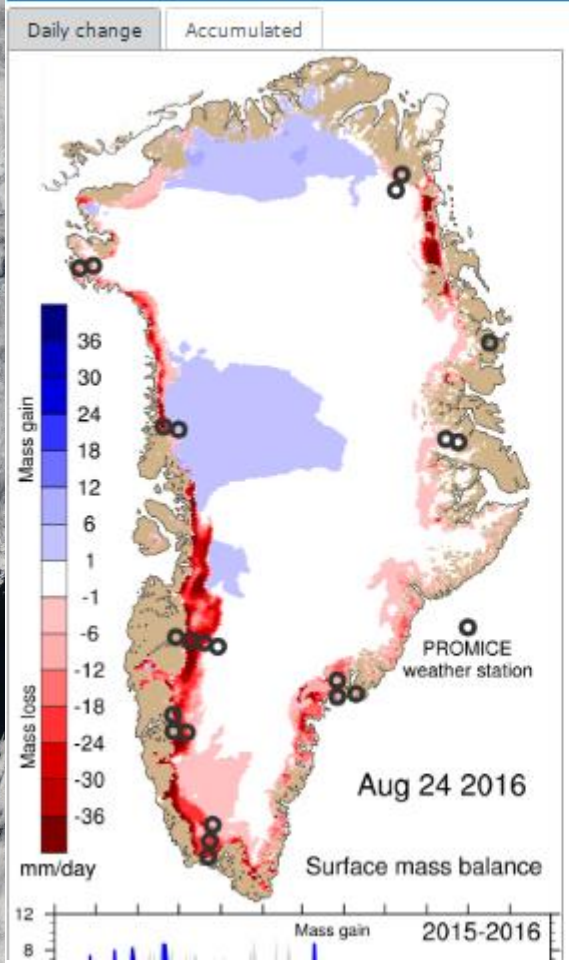
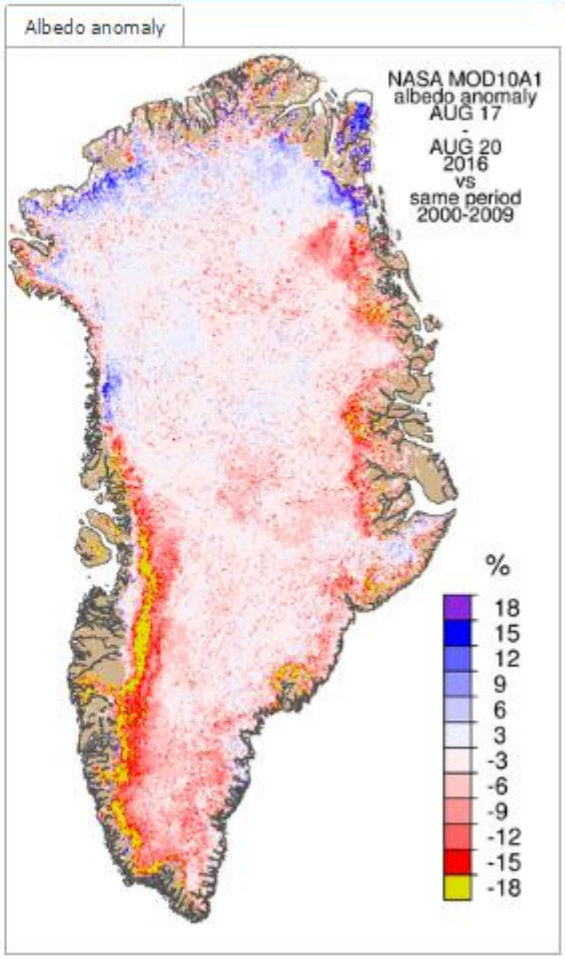


Surface conditions





Near Real-Time monitoring of the Arctic by Danish Institutions

Greenland ice sheet

Arctic sea ice area and thickness

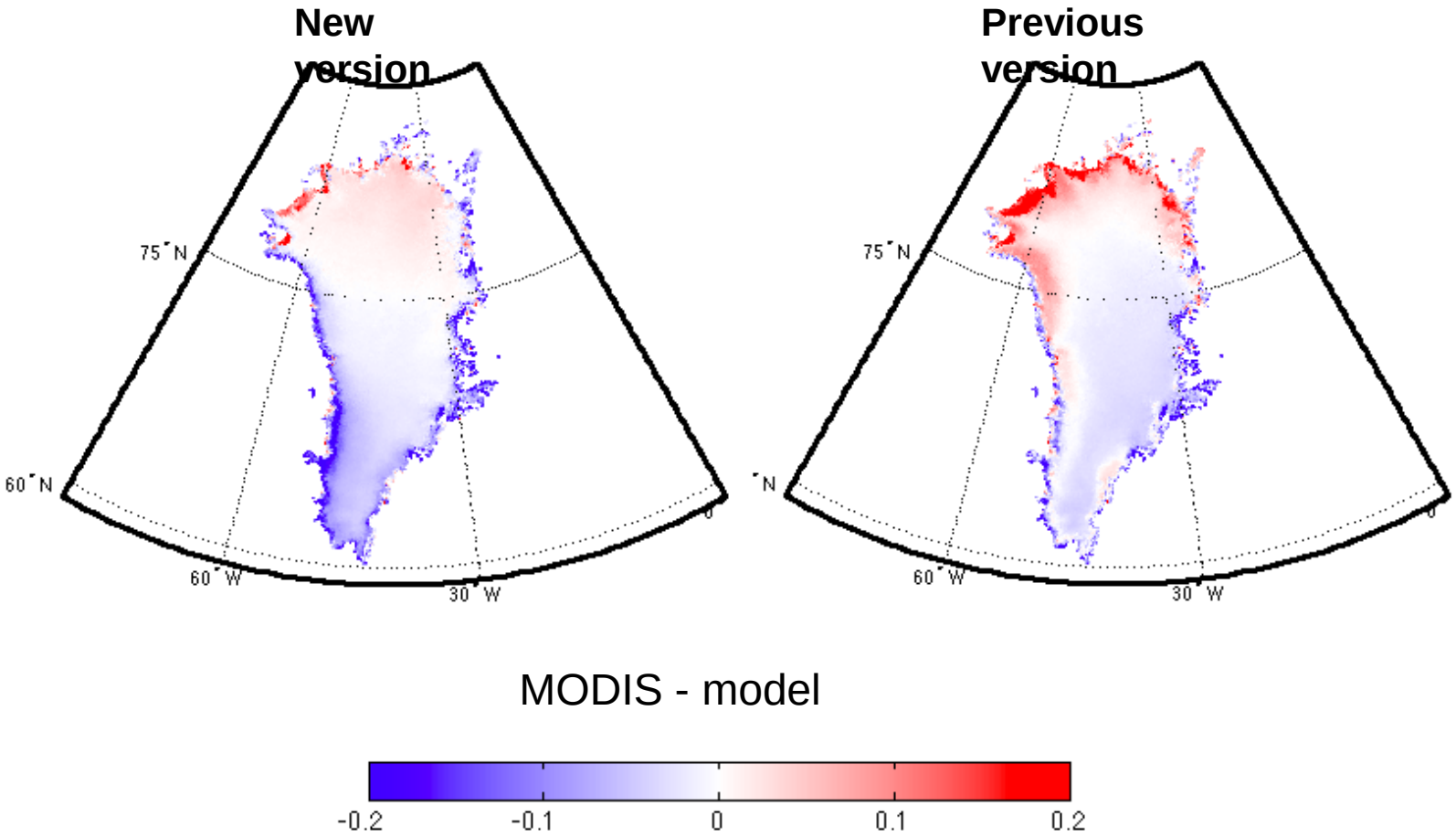
Weather

Coming soon: Permafrost

polarportal.dk/

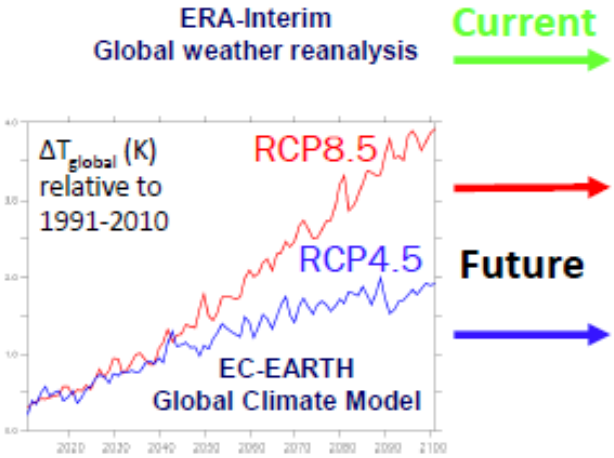
Comparison against MODIS

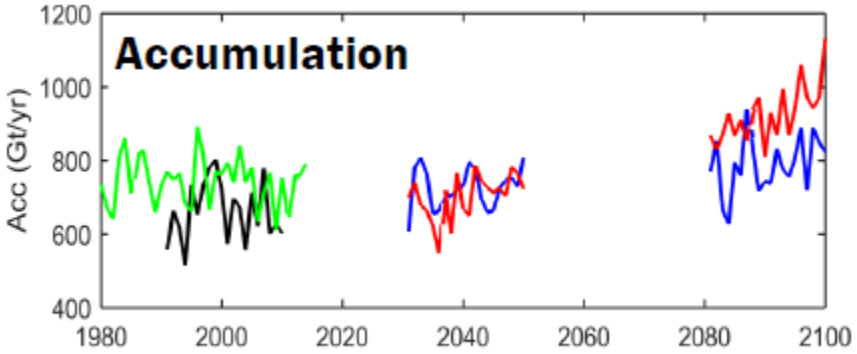
Mean summer albedo 2000-2013

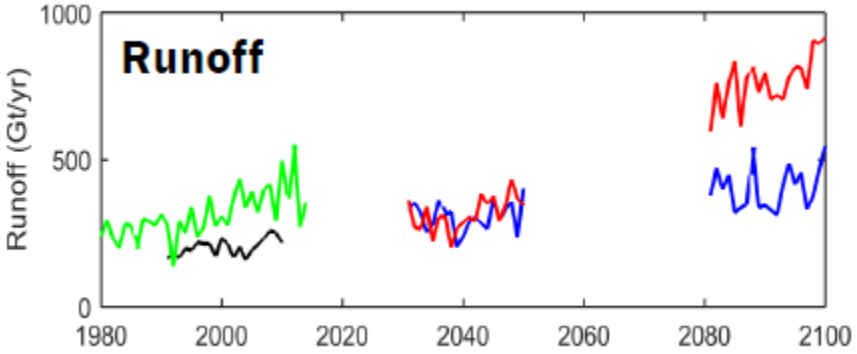


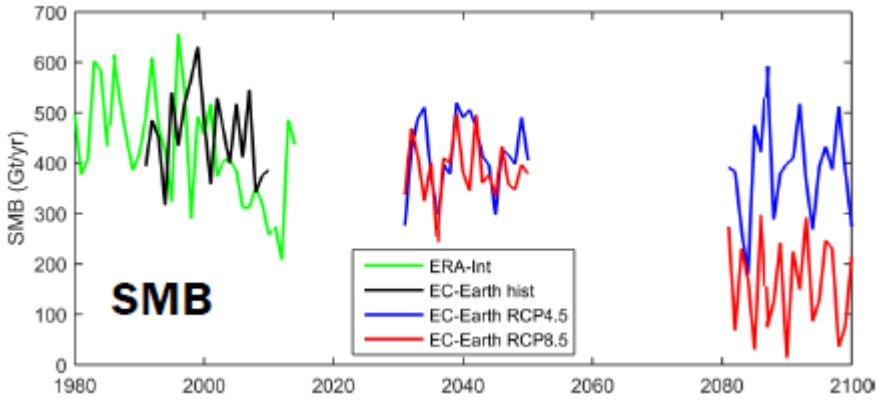
Future Surface Mass Balance of Greenland Ice Sheet

- Albedo Parameterisations are still necessary for future projections
- Many GCMs do not adequately parameterise albedo of ice sheets

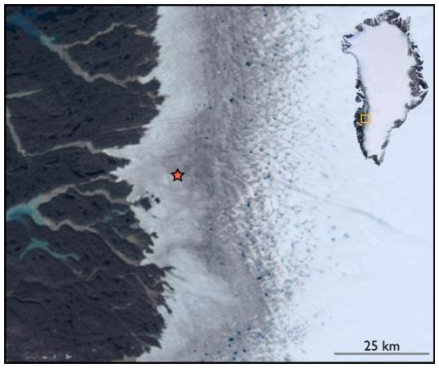


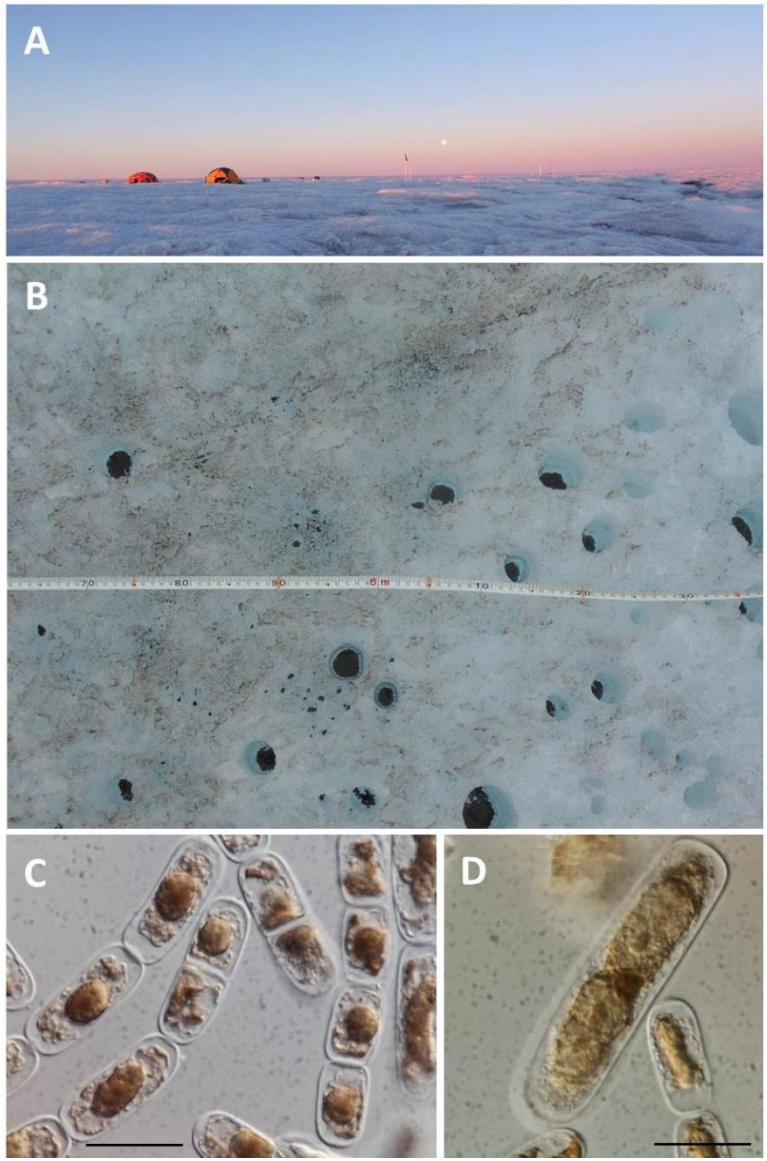




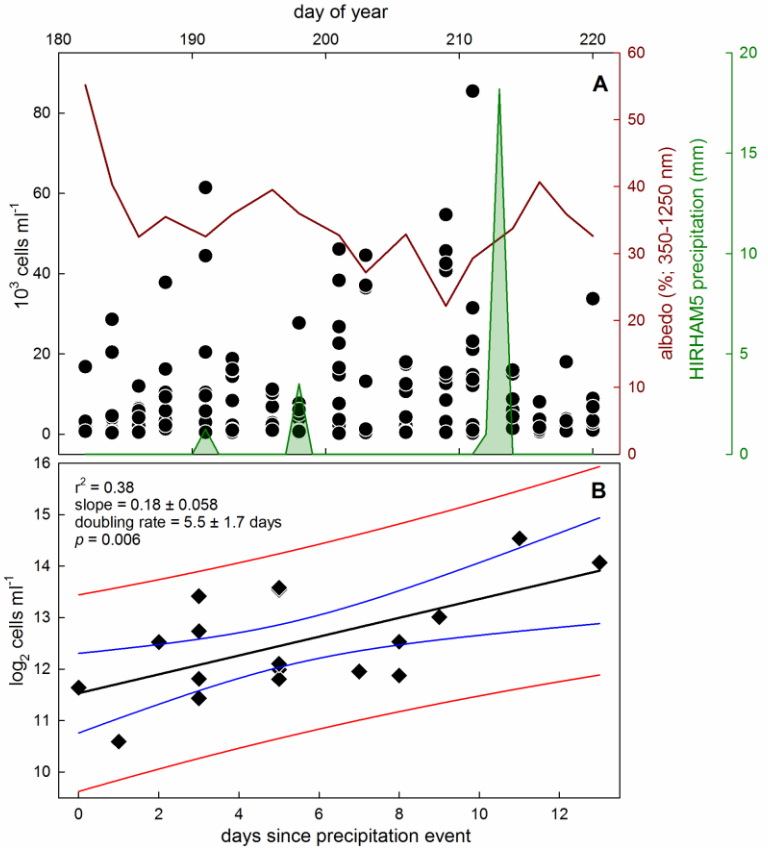


Surface Darkening





Snow algae growth
Rainfall reverses darkening by washing ice clean

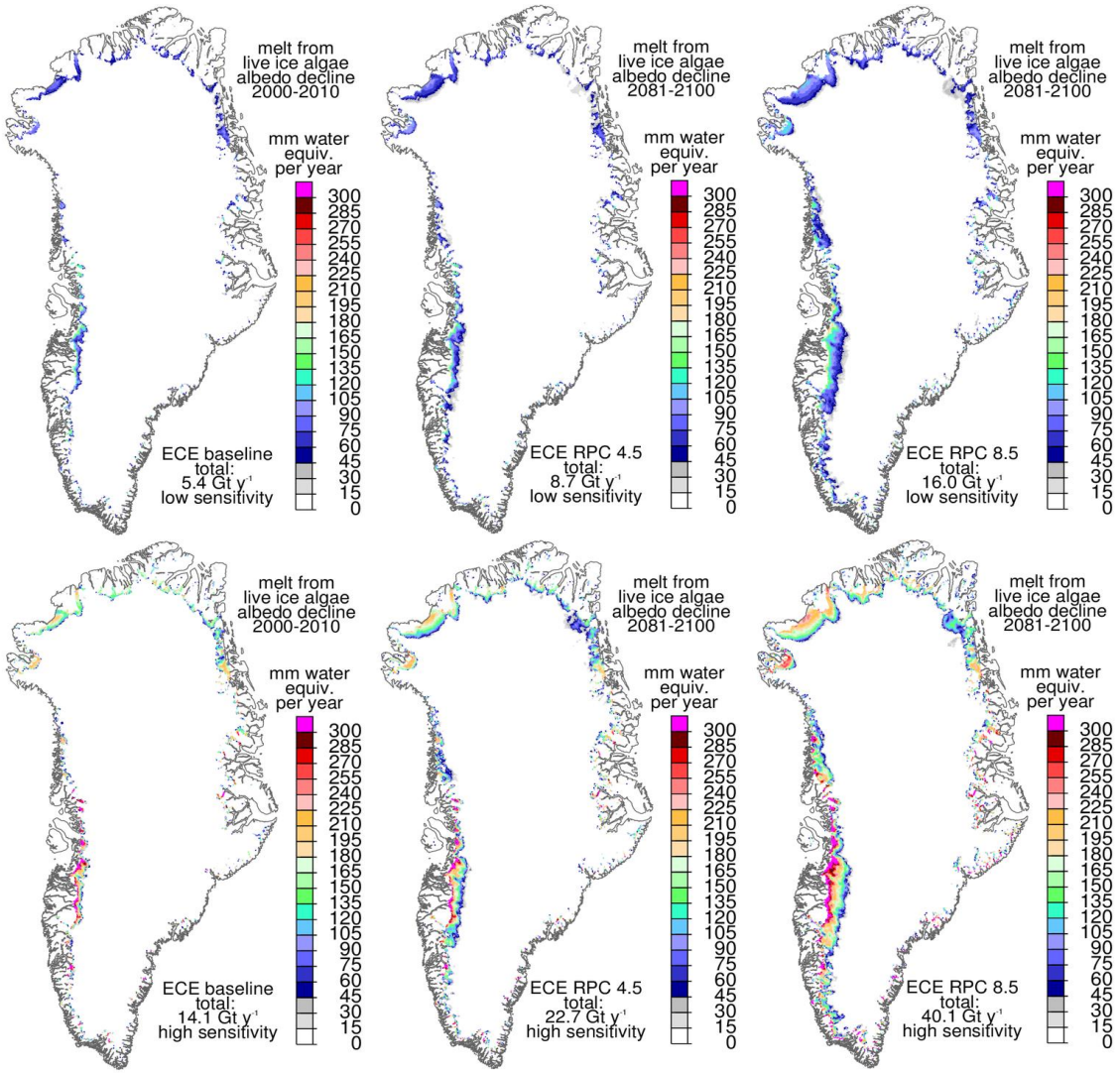


Future Algae-driven melt

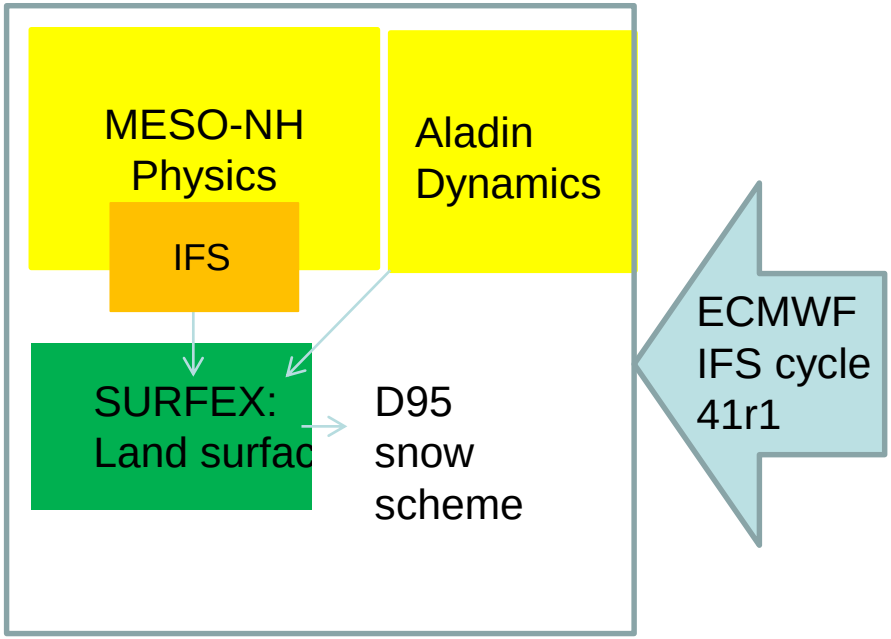
For 2000-2010, algae-driven melt component of 8.6 ± 7.7 Gt y^{-1} an additional 5 ± 1% melt.

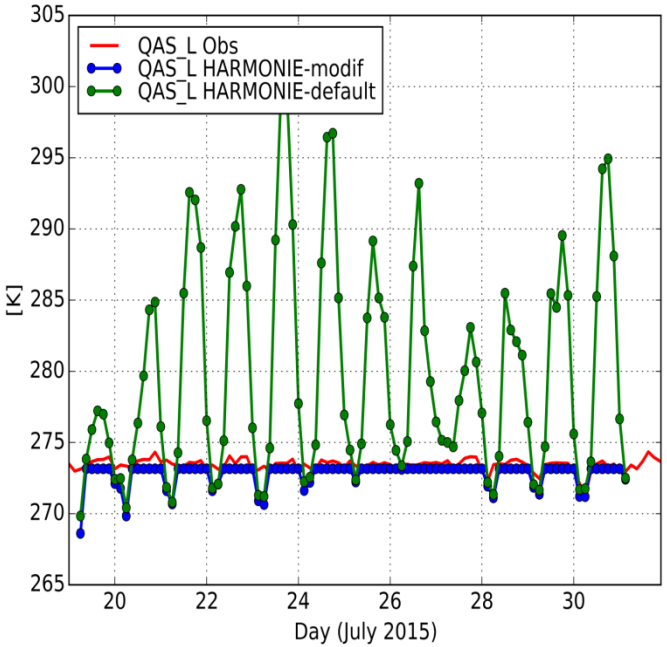
For 2081-2100 algae driven melt increases to 24.4 ± 12.1 Gt y^{-1}

Paper in review, Stibal + Box et al.



Modified HARMONIE over Glaciers





Snow Melt March – August 2015