Monitoring Energy Balance of Icelandic Glaciers for 25 years

Icelandic Glacier Automated Weather Stations Program – ICE-GAWS

27th IUGG General Assembly

C01b - Glacier Monitoring from In-Situ and Remotely Sensed Observations, including Aspects of the History of Cryospheric Sciences

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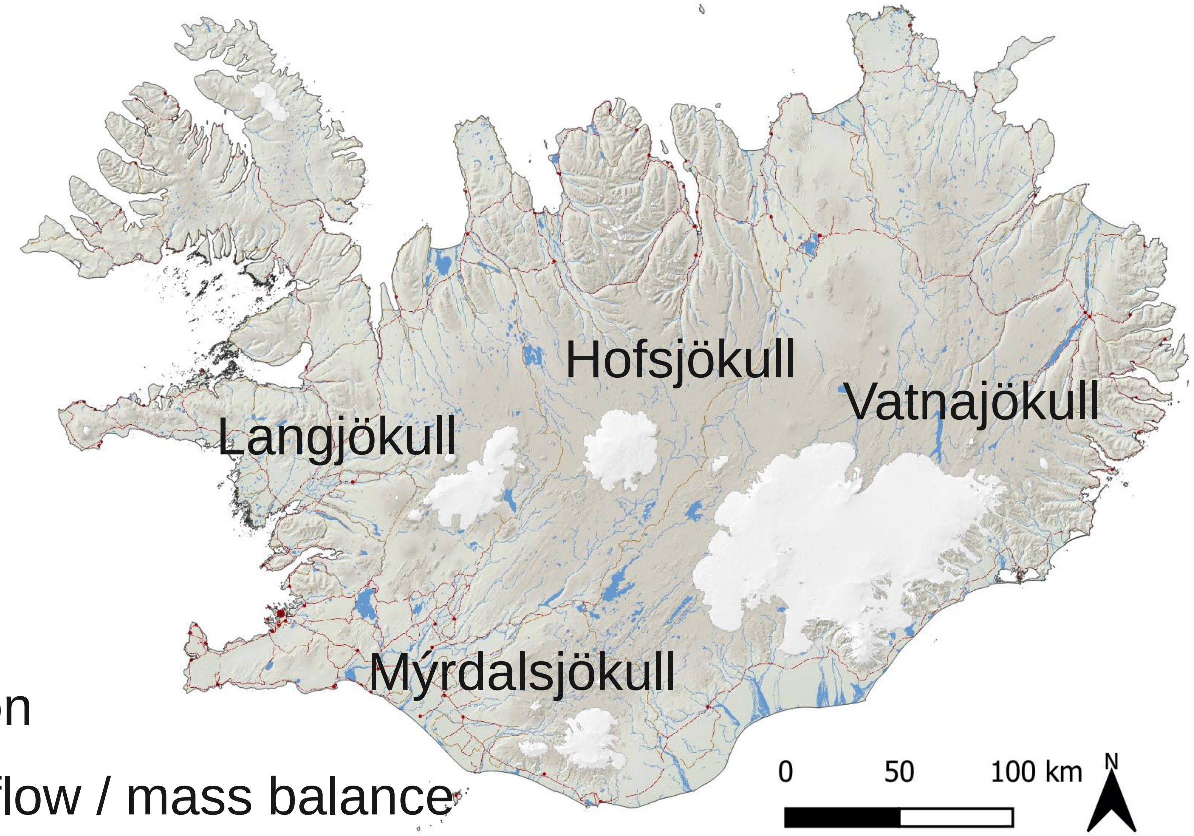
Introduction

- Glaciers in Iceland
  - 10% of Iceland covered by glacier
  - Area: 10.000 km^2 / Volume: 3500 km^3
  - 1 cm contribution to sea level rise
- Why glaciers are important in Iceland
  - Water resources → ~50% of inflow energy
  - Civil Protection → Glacier Outburst Floods
  - Volcanic activity → melt enhancement/isolation
  - Changes in climate → Long term changes in flow / mass balance

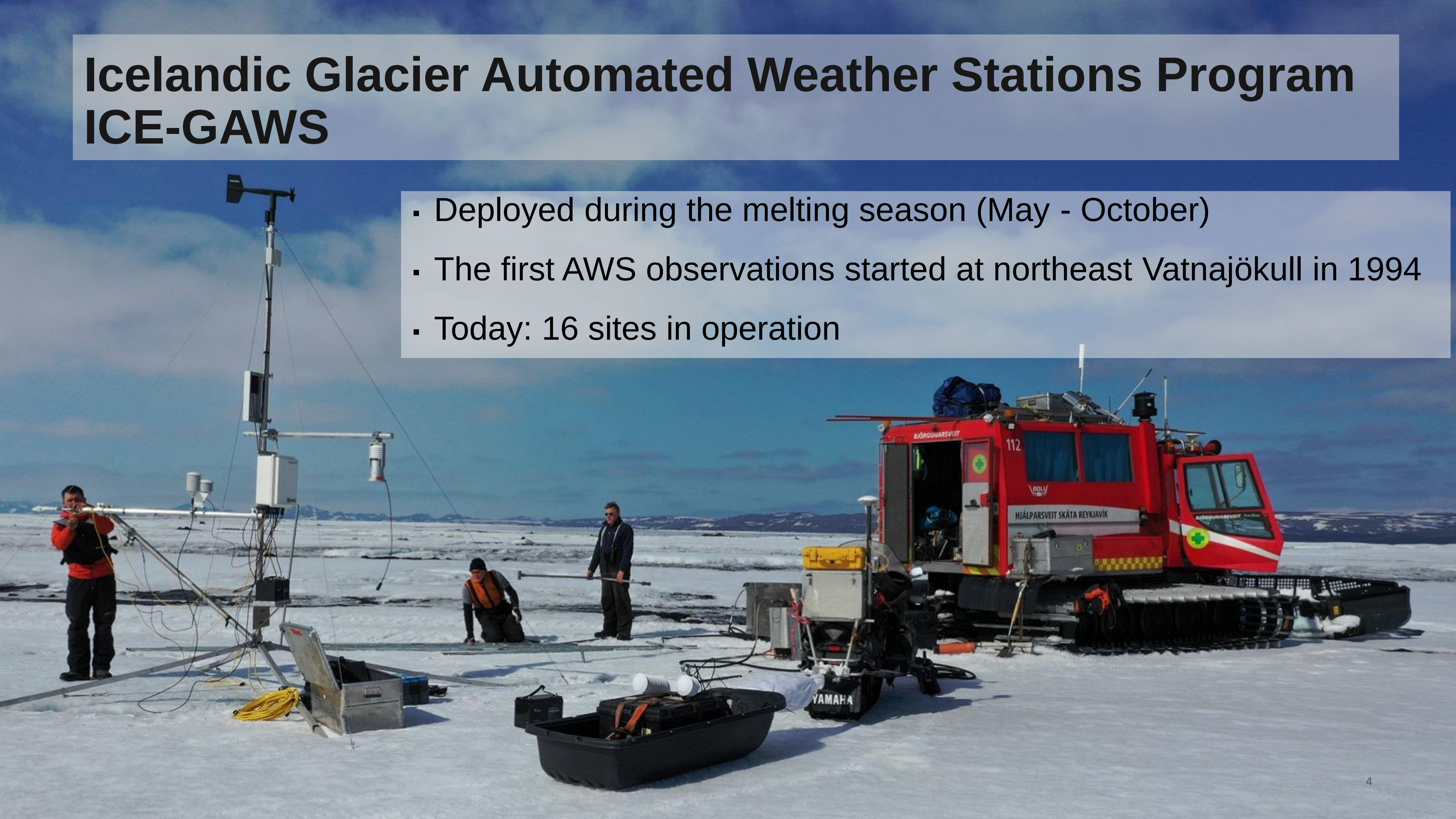


Introduction

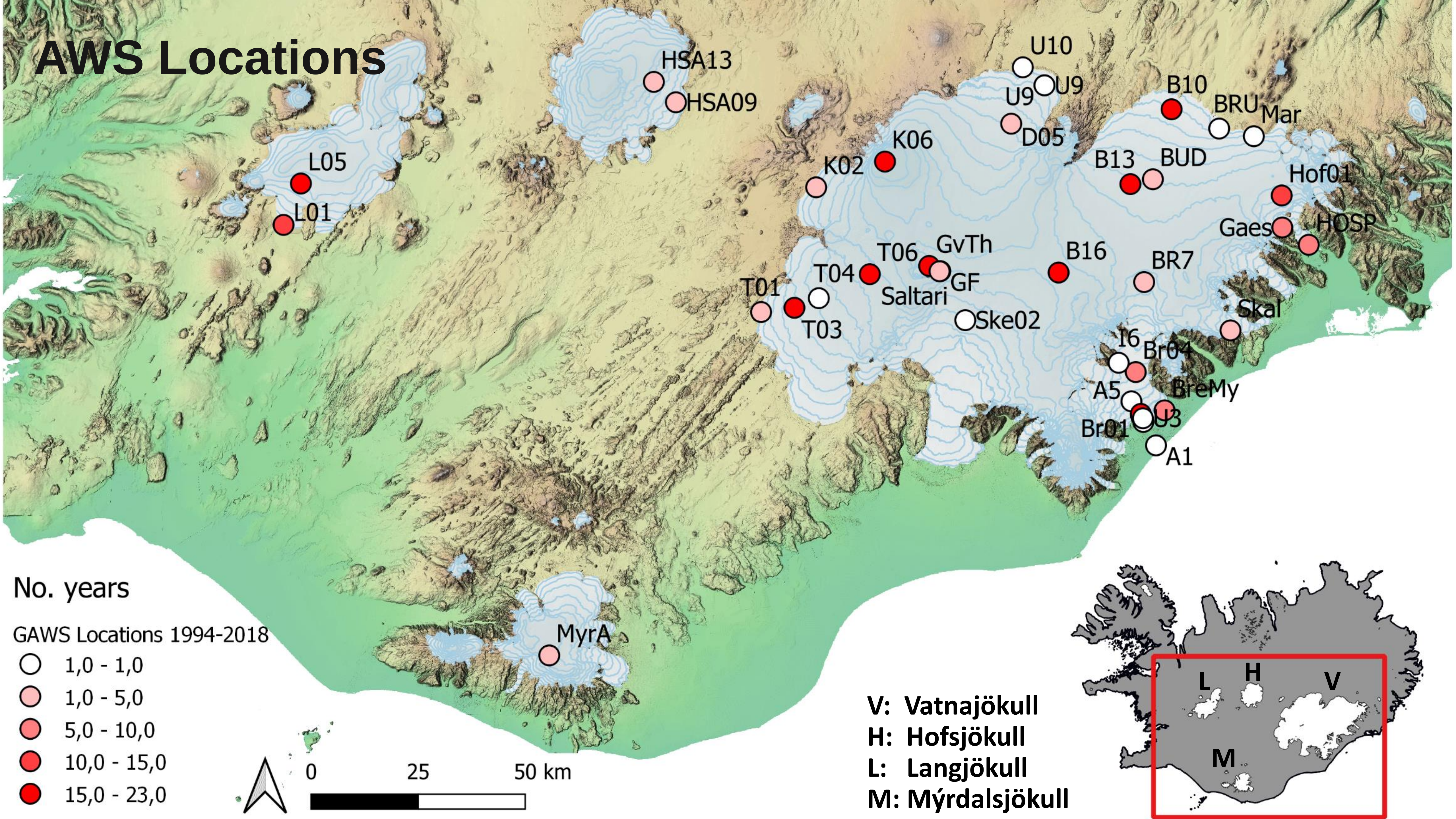
- Mass- and energy balance of Icelandic glaciers is systematically surveyed annually by a network of collaborators.
- A program of systematic glacier monitoring was started for Vatnajökull by the **Institute of Earth Sciences at the University of Iceland** and the **National Power Company of Iceland** in 1992 and 1998 for Langjökull
- Main objectives
  - to improve our understanding of surface mass balance
  - runoff from glaciers
  - energy balance of glacier surface → **Automatic Weather Stations**
  - provide long-term observations of mass and energy balance
- **IMO** operates the mass balance program at Hofsjökull since 1988
- **IGS** operates mass balance for Mýrdalsjökull and selected points at Vatnajökull

Icelandic Glacier Automated Weather Stations Program ICE-GAWS

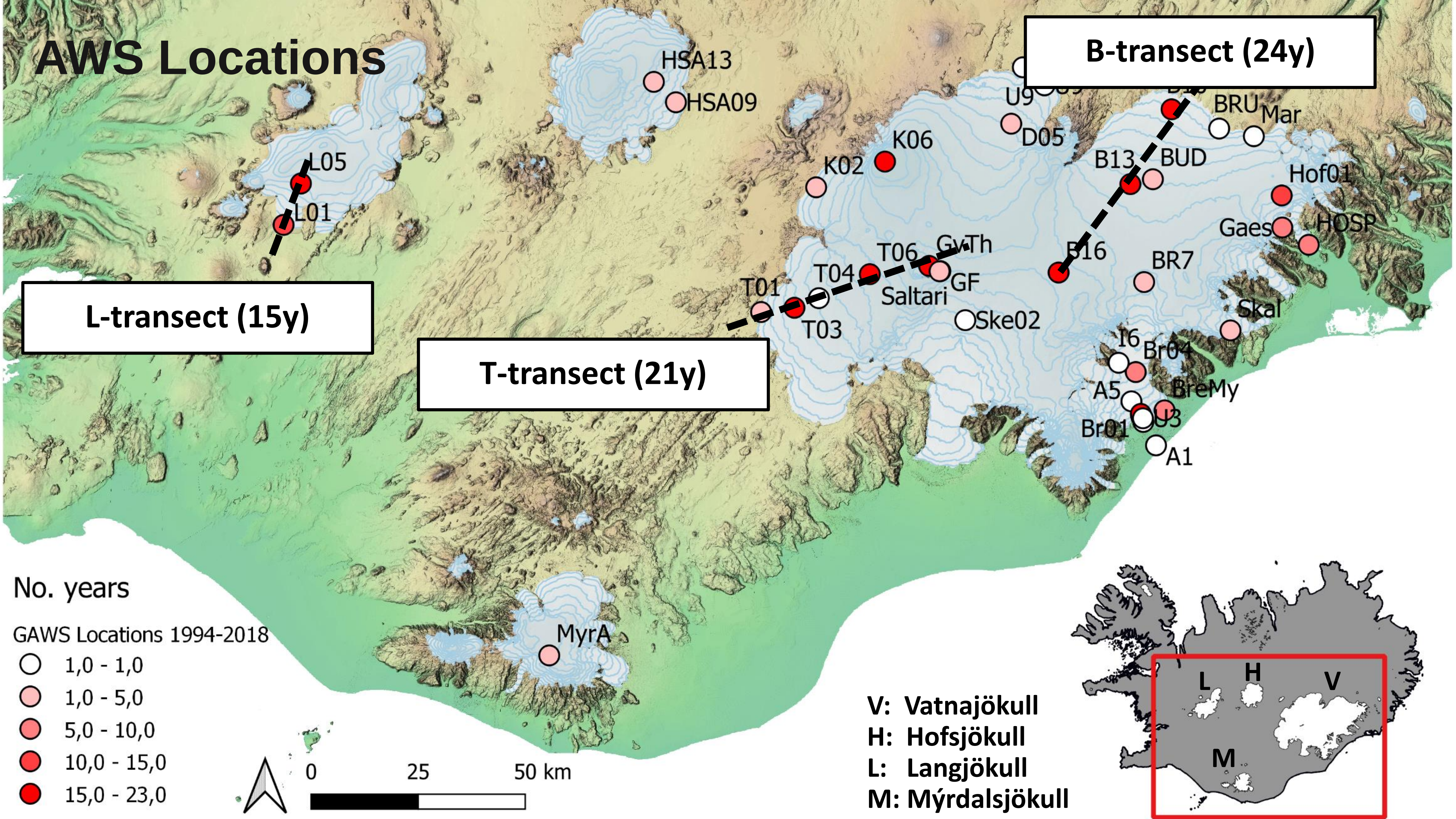
- Deployed during the melting season (May - October)
- The first AWS observations started at northeast Vatnajökull in 1994
- Today: 16 sites in operation



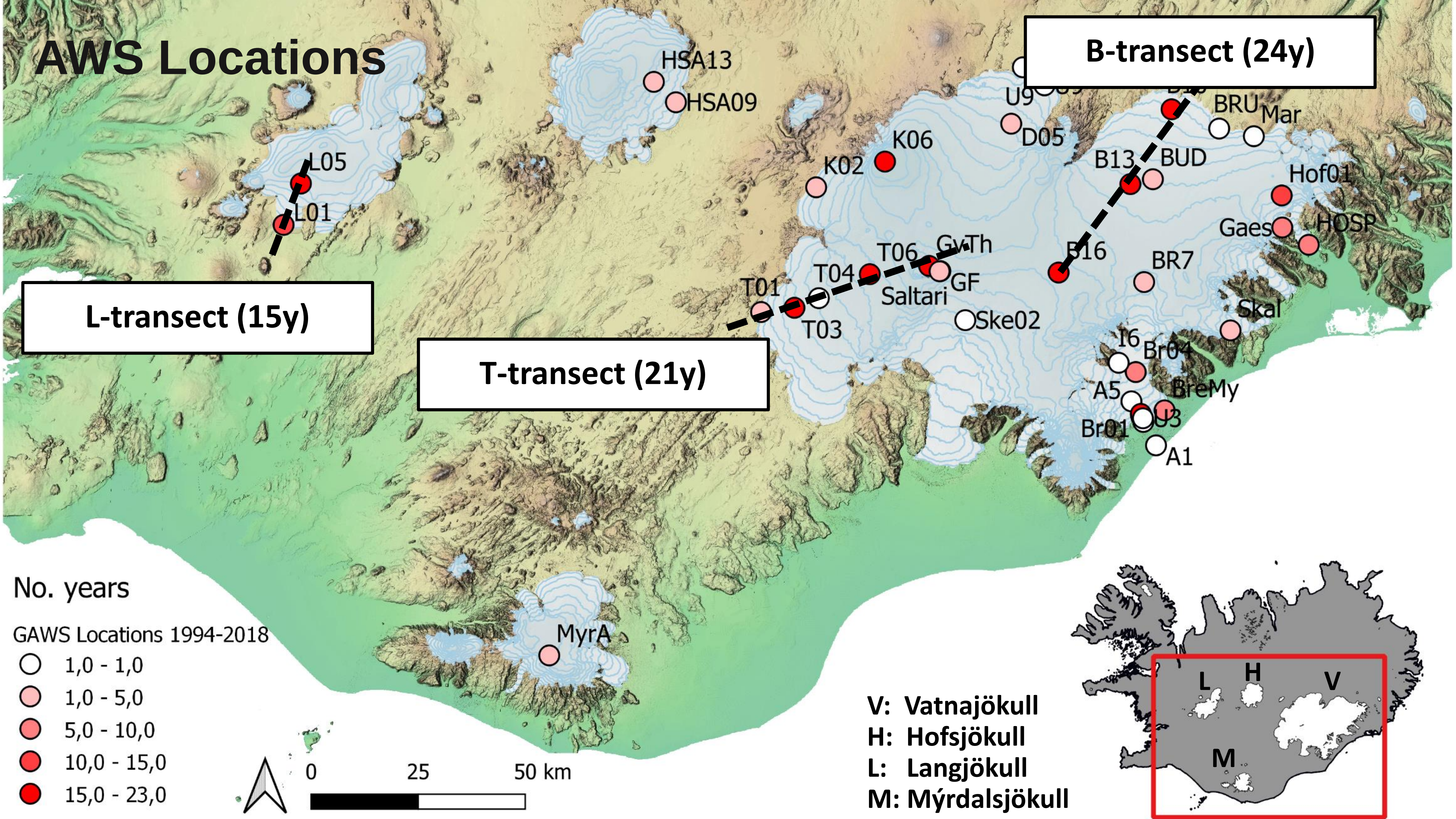
AWS Locations



V: Vatnajökull
H: Hofsjökull
L: Langjökull
M: Mýrdalsjökull



AWS Locations
B-transect (24y)
L-transect (15y)
T-transect (21y)
HSA13
HSA09
U9
D05
K06
K02
BRU
Mar
B13
BUD
Hof01
L05
L01
Gaes
HOSP
T06
GvTh
B16
BR7
T04
GF
T01
Saltari
T03
Ske02
Skal
I6
Br04
A5
BreMy
U3
Br01
A1
MyrA
No. years
GAWS Locations 1994-2018
1,0 - 1,0
1,0 - 5,0
5,0 - 10,0
10,0 - 15,0
15,0 - 23,0
0
25
50 km
V: Vatnajökull
H: Hofsjökull
L: Langjökull
M: Mýrdalsjökull
L
H
V
M



AWS Locations
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HSA13
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V: Vatnajökull
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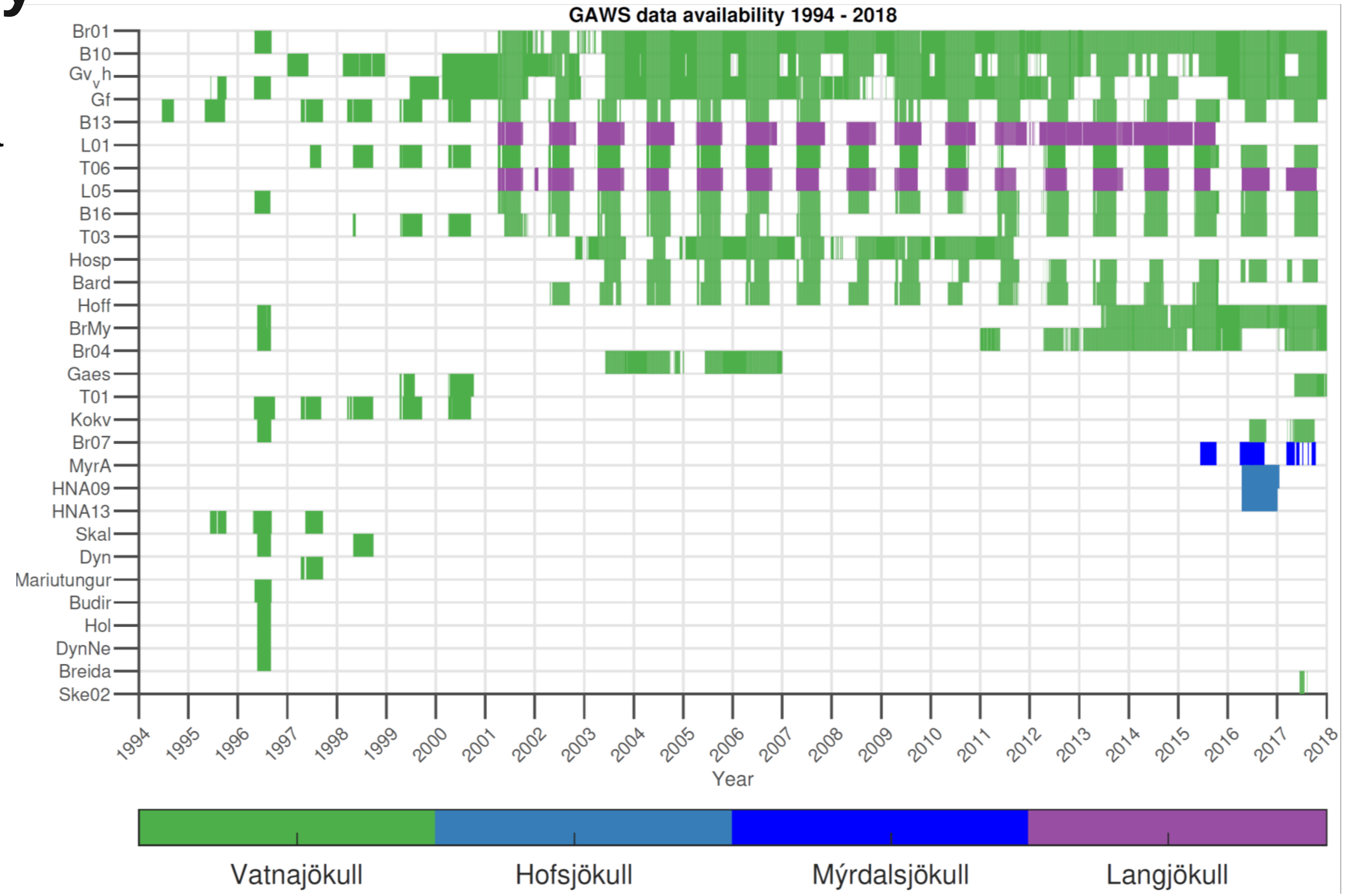
L
H
V
M

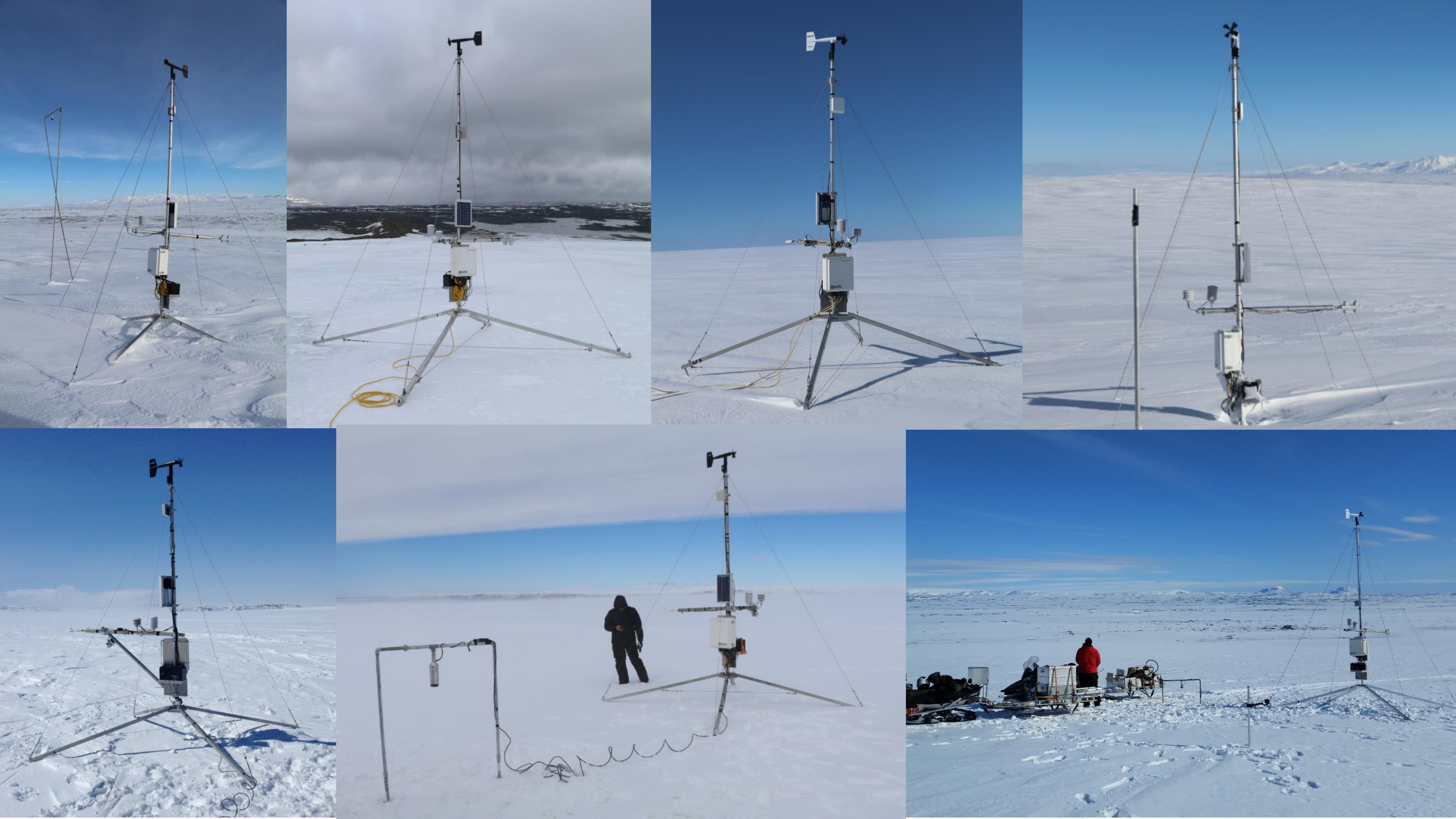
Data availability

- 83.500 days of data
- Observations since:
  - 1994 at Vatnajökull
  - 2001 at Langjökull
  - 2015 at Mýrdalsjökull
  - 2016 at Hofsjökull
- Volcanic eruptions
- Positive SMB in 2015



First installation:
Brúarjökull - B13 Summer 1994


Brúarjökull - B13 Summer 2019



Instrumentation

Temperature
Humidity
Wind speed / direction
Barometric pressure

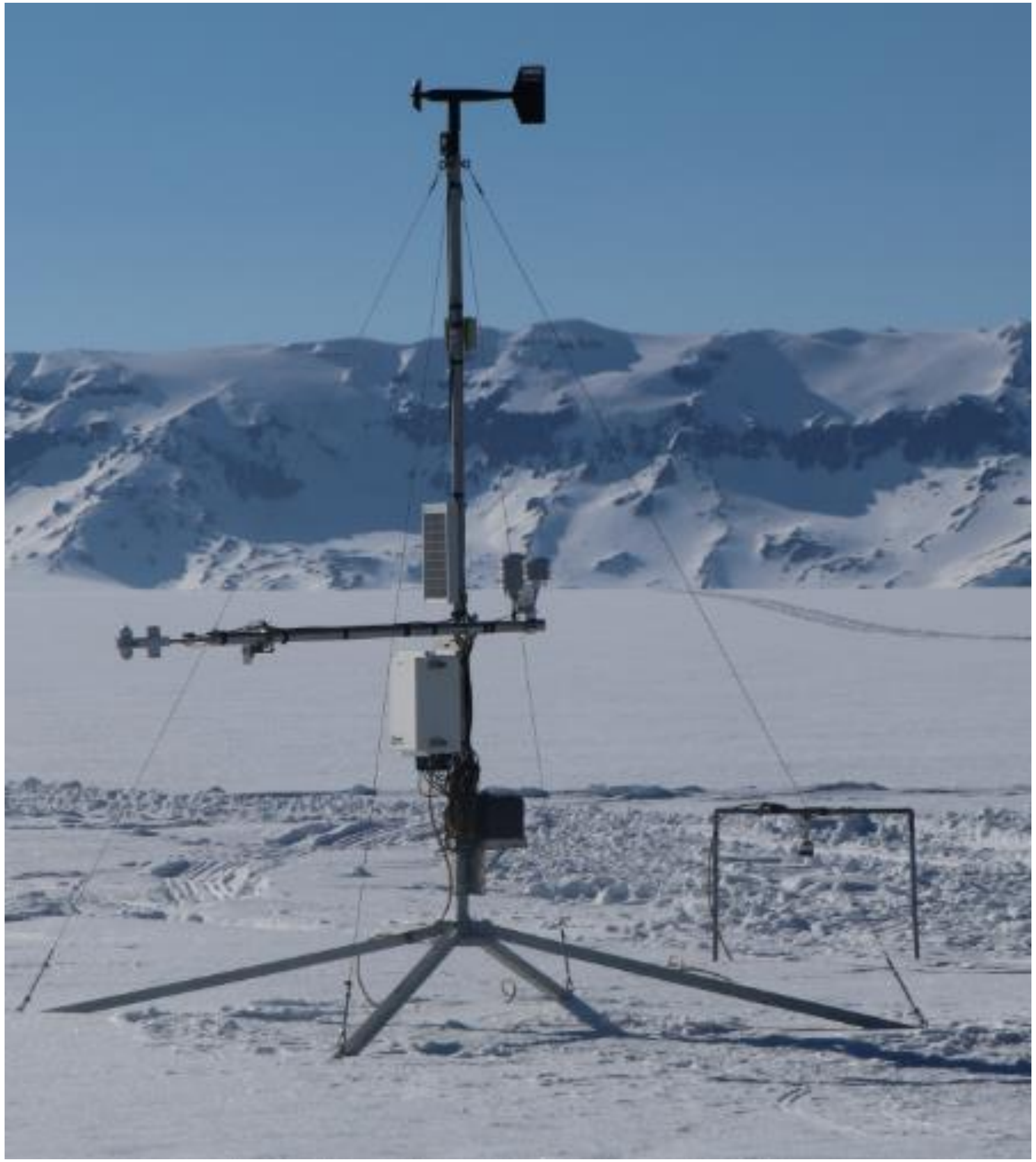
➡ Turbulent fluxes

Radiation components → albedo

$SW\downarrow + SW\uparrow + LW\downarrow + LW\uparrow$

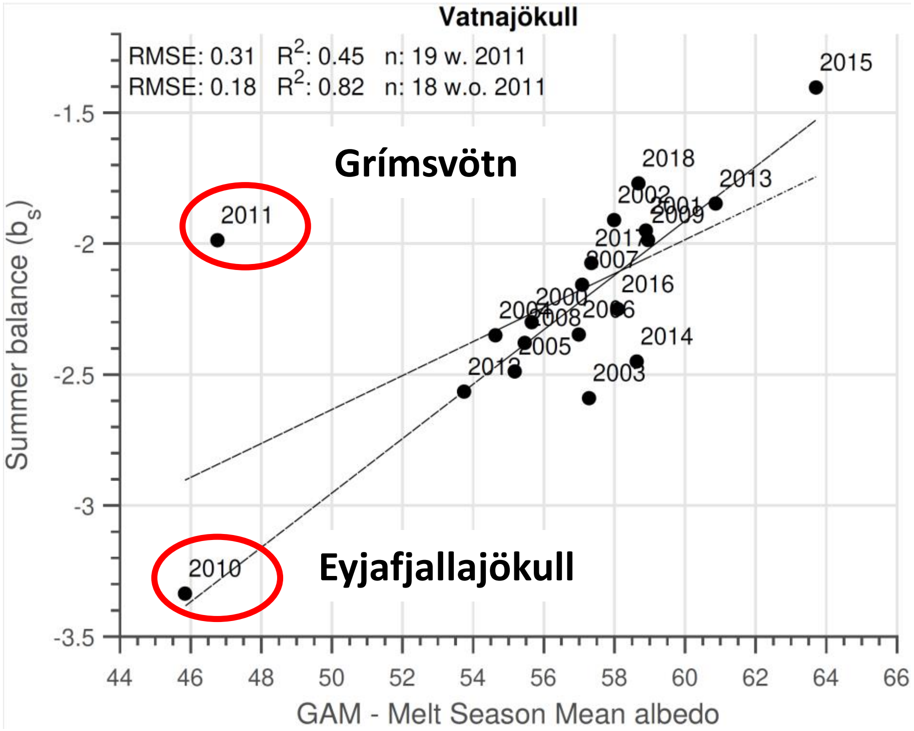
Surface elvation change (Snow height)

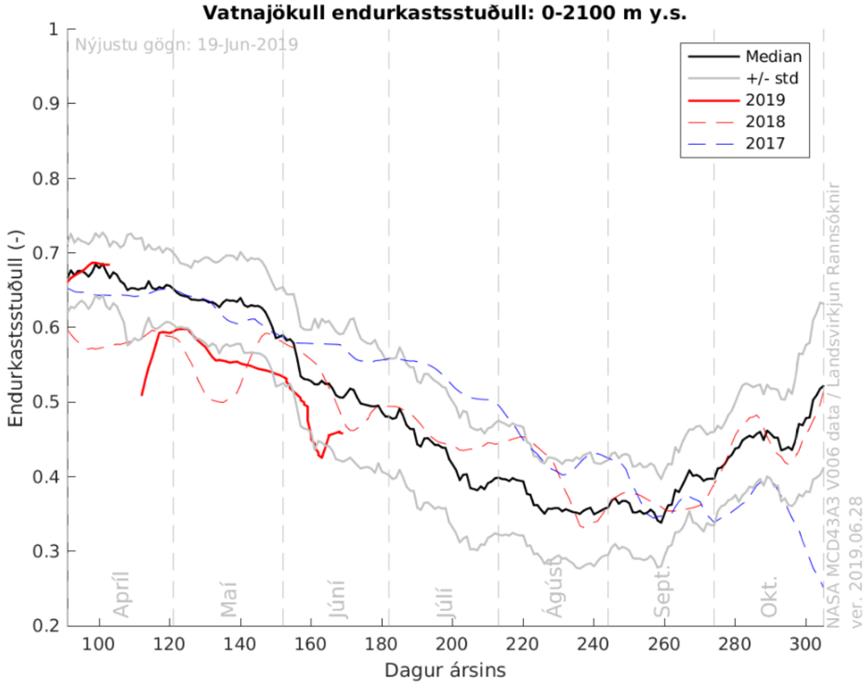
Web cams
Surface temperature
GPS
Tilt



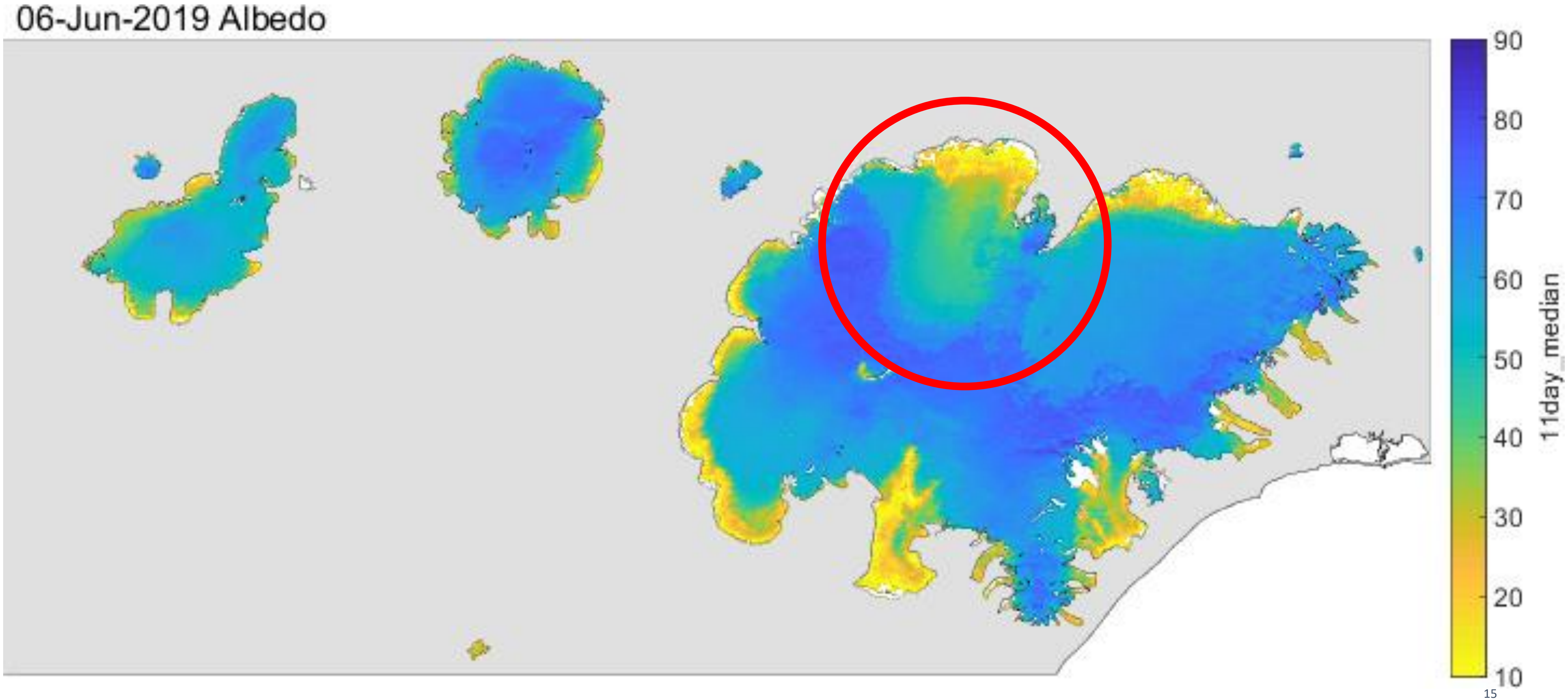
Applications of GAWS data
Remotely sensed albedo

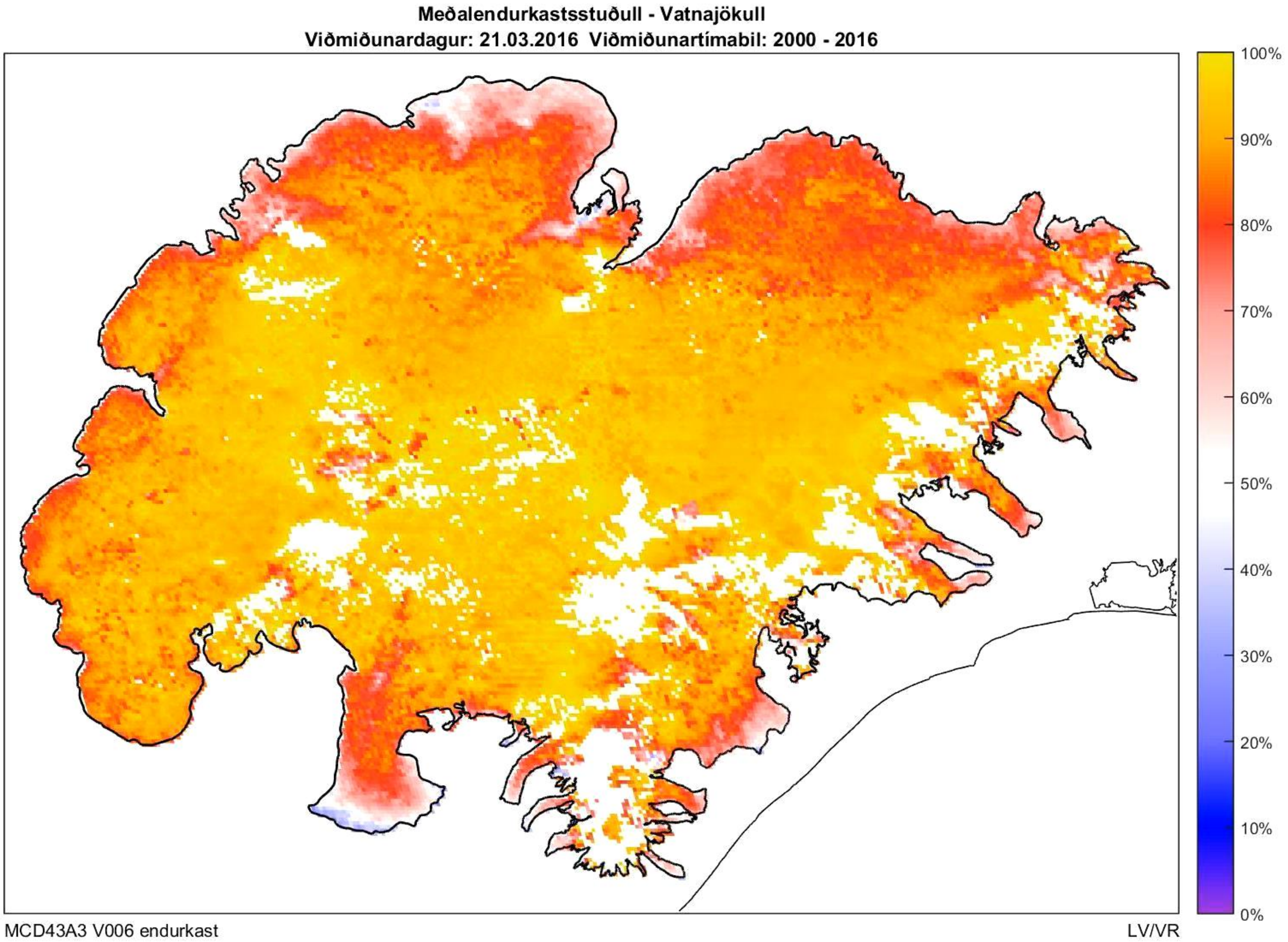
- Incoming short wave radiation dominating for melting → albedo
- Validation of M*D10A1 and MCD43A3 products
- „Gap filled“ daily products





Applications of GAWS data
Remotely sensed albedo





Meðalendurkaststuðull - Vatnajökull
Viðmiðunardagur: 21.03.2016 Viðmiðunartímabil: 2000 - 2016
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
MCD43A3 V006 endurkast
LV/VR

Summary

- GAWS In-situ data has played a key role in
  - understanding the response of glaciers to climate change
  - calibration/validation of remotely sensed products
  - validation and calibration of hydrological models (short/medium/long range)
- Currently testing assimilation of GAWS data (Temp + Albedo)
- GAVEL (QAQC) system in development
- Overview of project hopefully online soon!

Thank you

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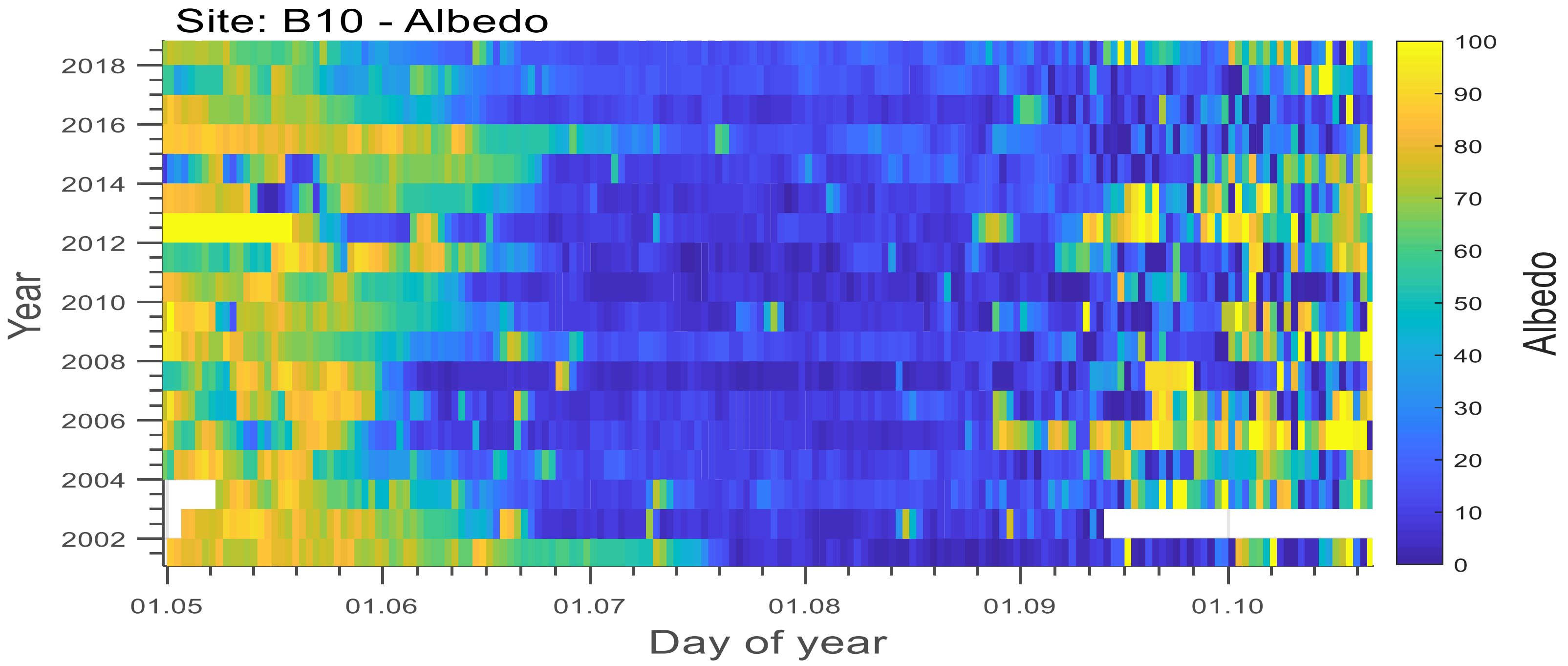
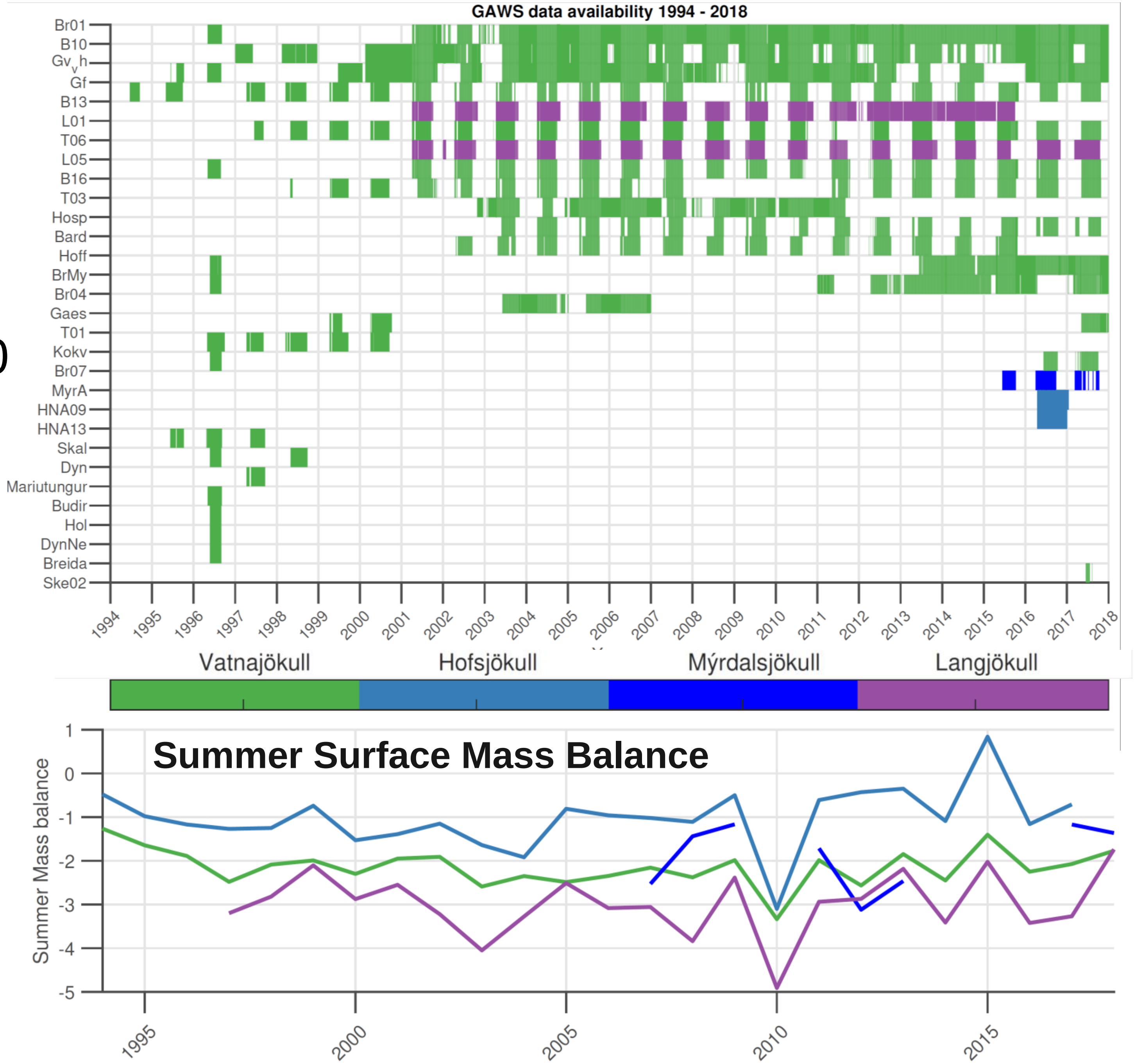
Applications of GAWS data
Inflow forecasting

- Calibration of short and long term hydrological models
- Currently testing assimilation of GAWS data
  - Bias correction of temperature / Albedo validation

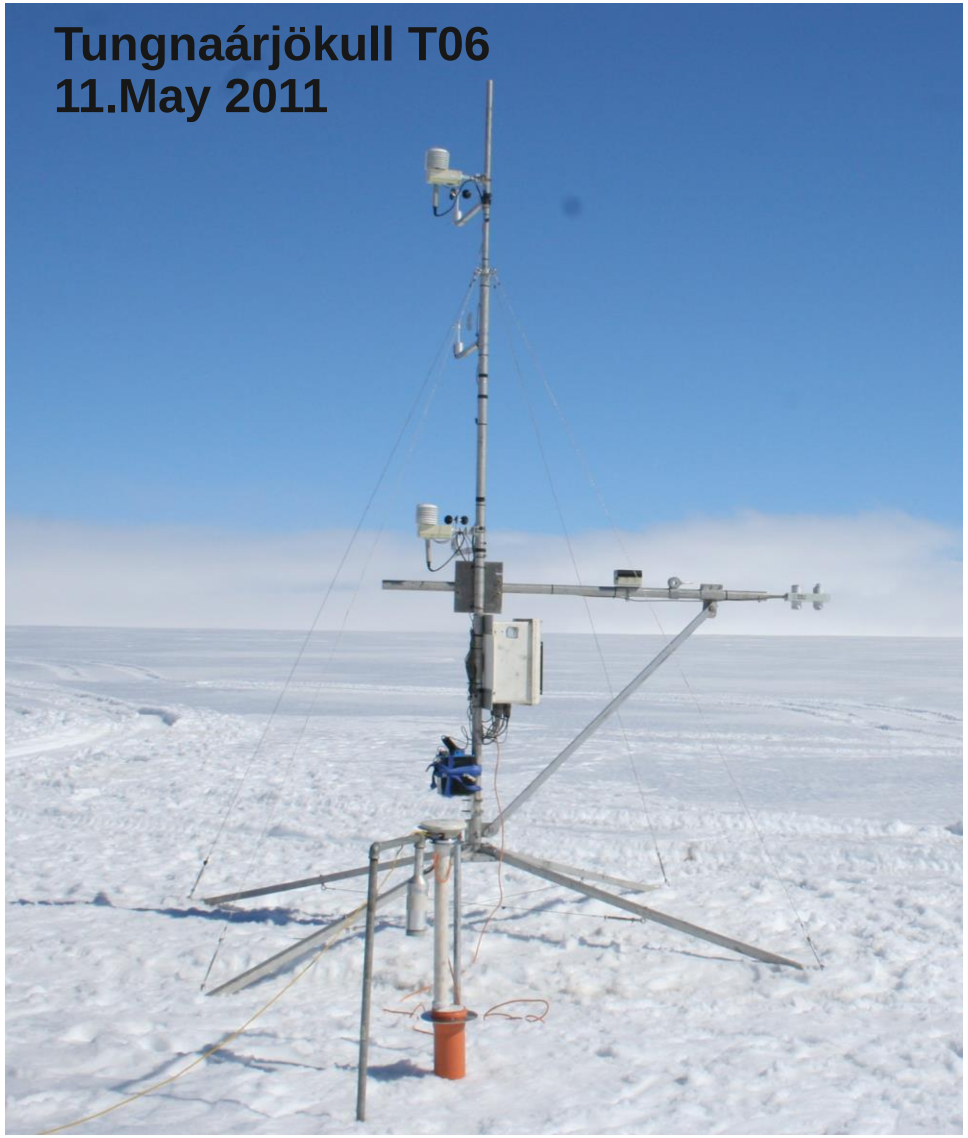


Data availability

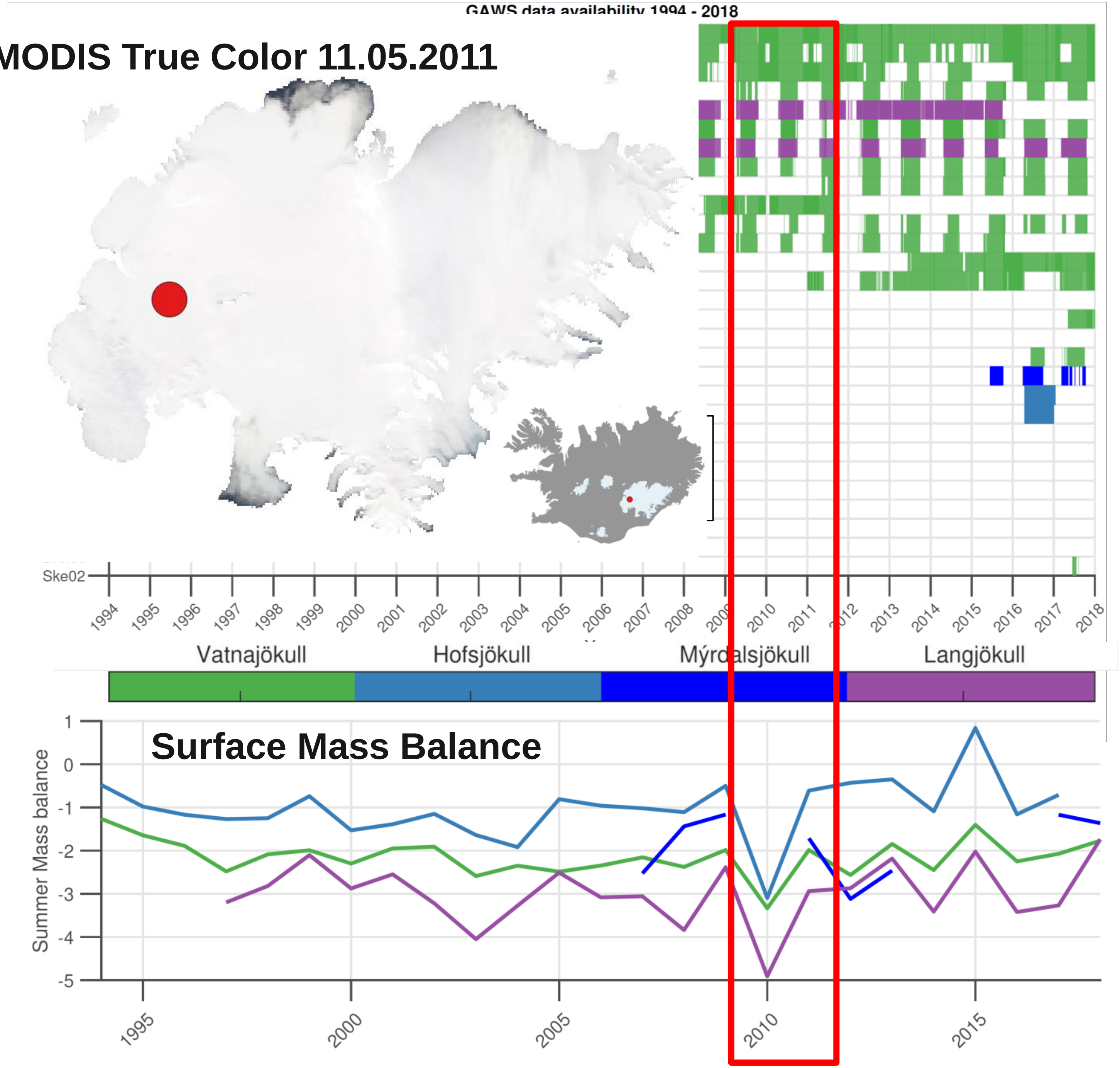
- 83.500 days of observations
- Eruptions in 1998, 2004, 2010 and 2011
- Cold Spring/Summer 2015
- Observations since:
  - 1994 at Vatnajökull
  - 2001 at Langjökull
  - 2015 at Mýrdalsjökull
  - 2016 at Hofsjökull



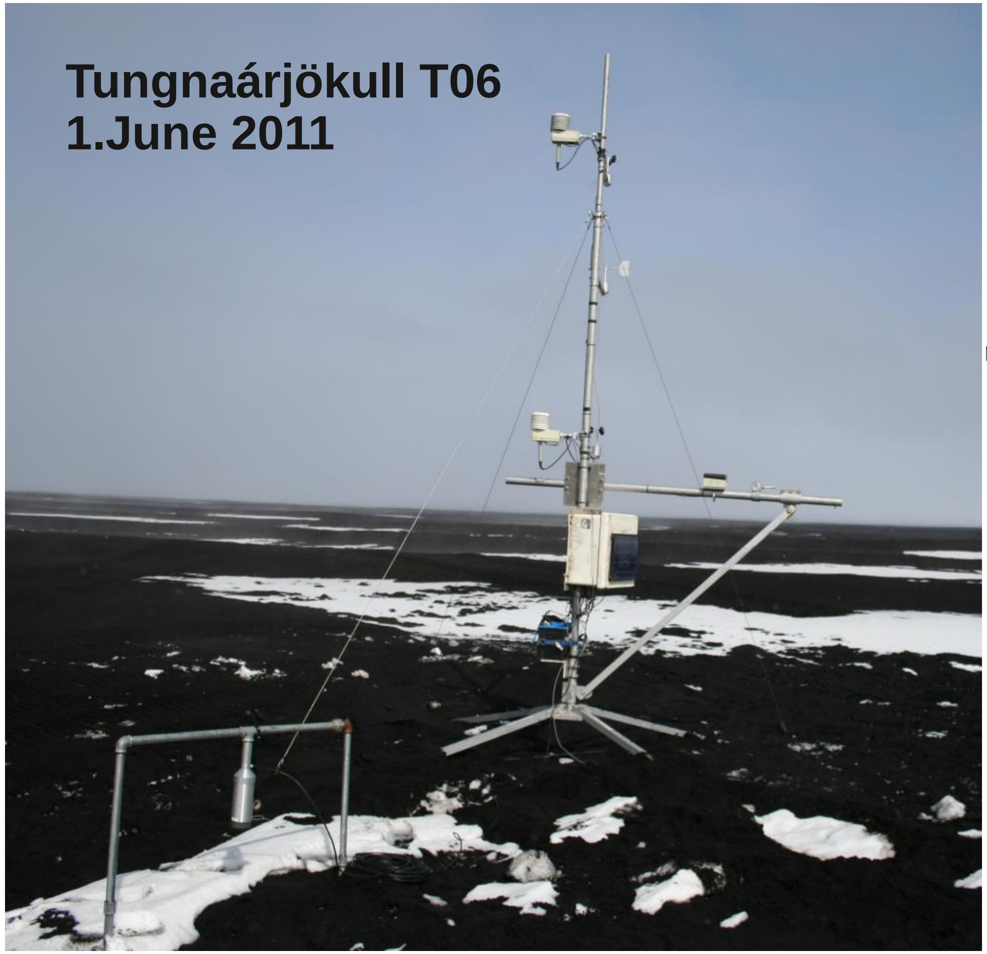
Data availability

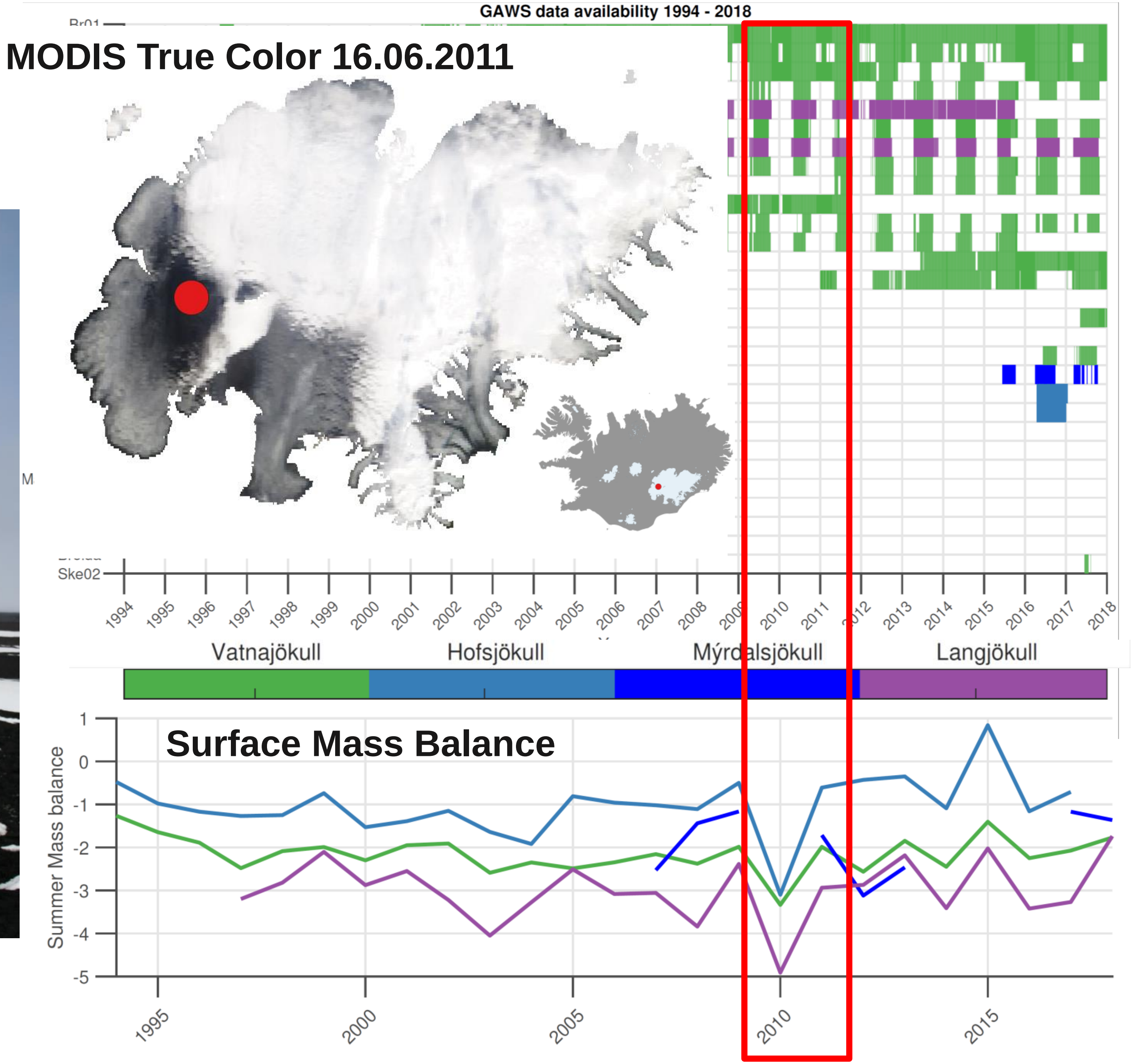


MODIS True Color 11.05.2011



Data availability





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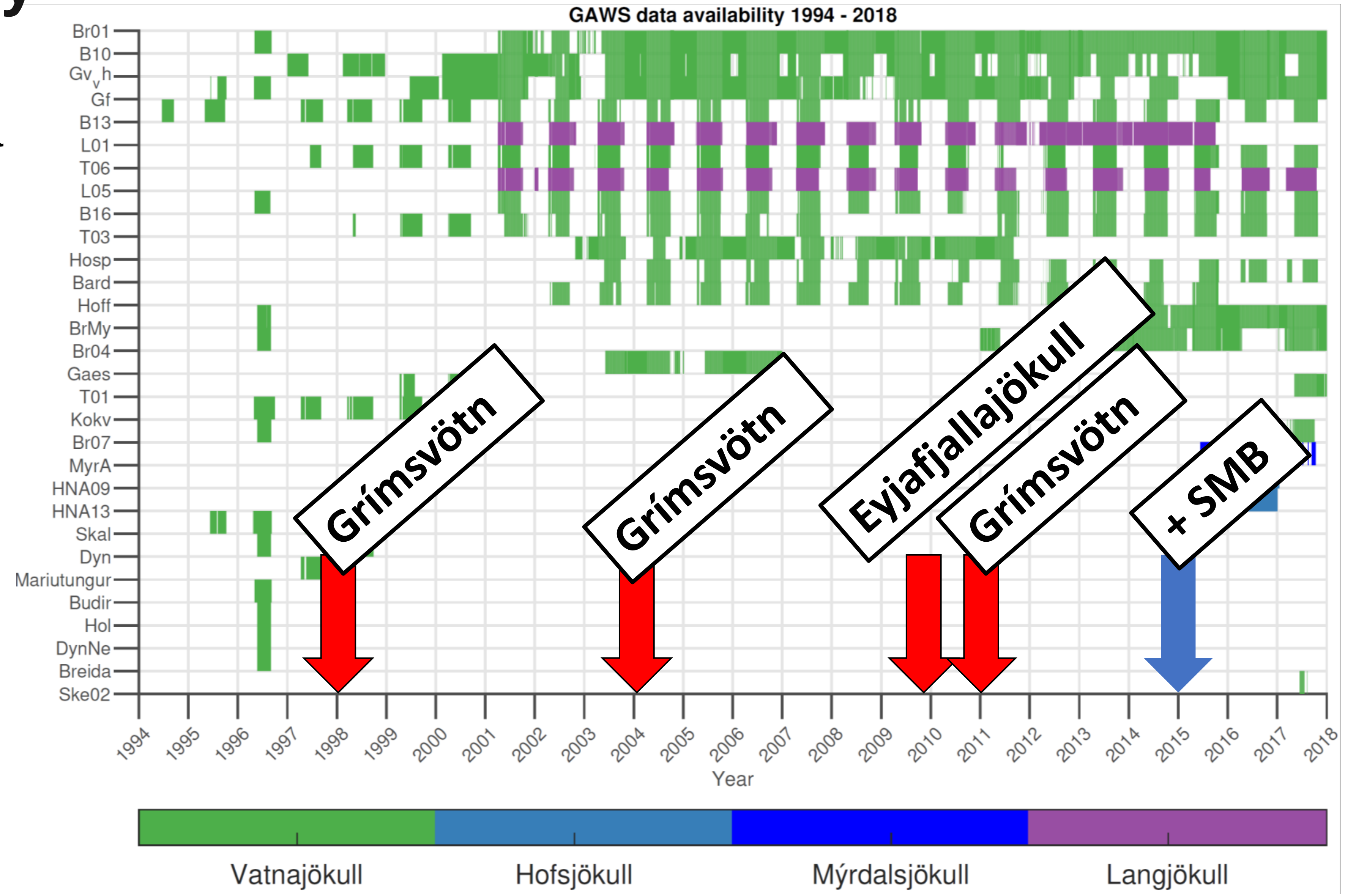
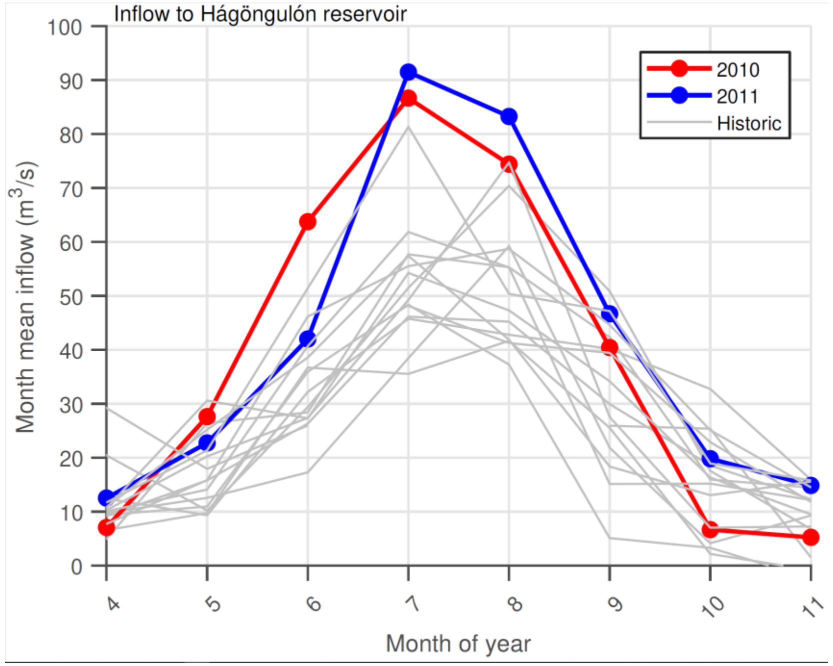
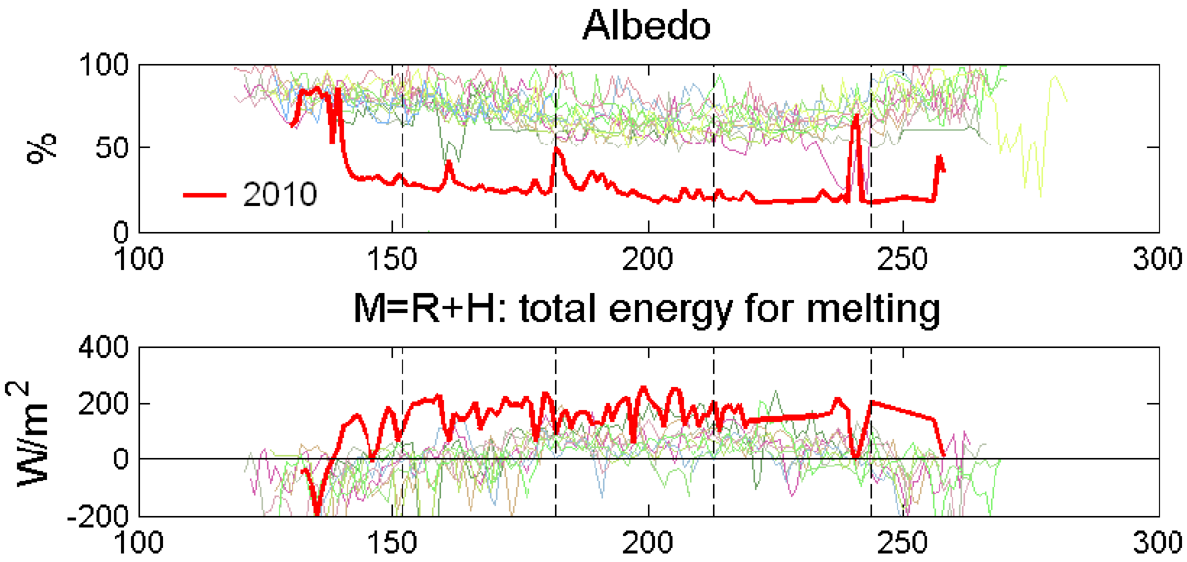
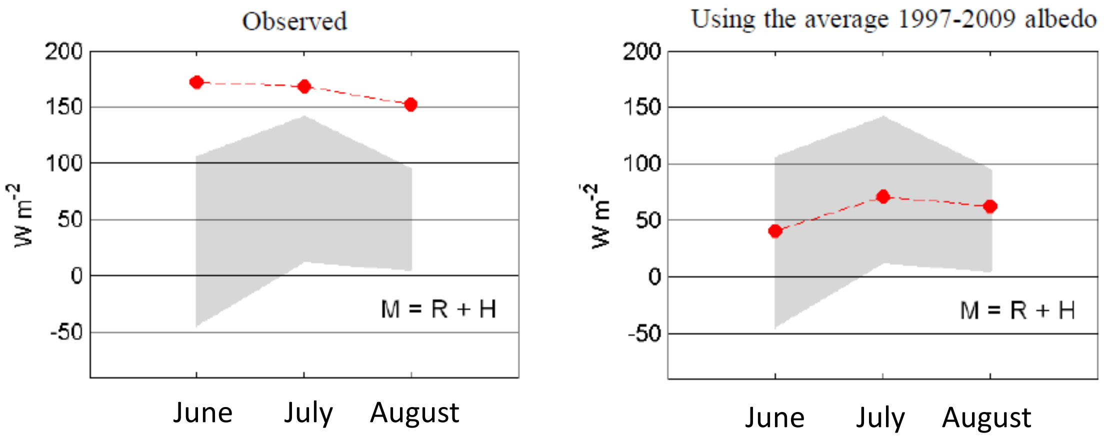


Applications of GAWS data
Influence of volcanic activity

- Volcancic ash and tephra can have great influence on energy balance
- Real time impact assesment for hydro power

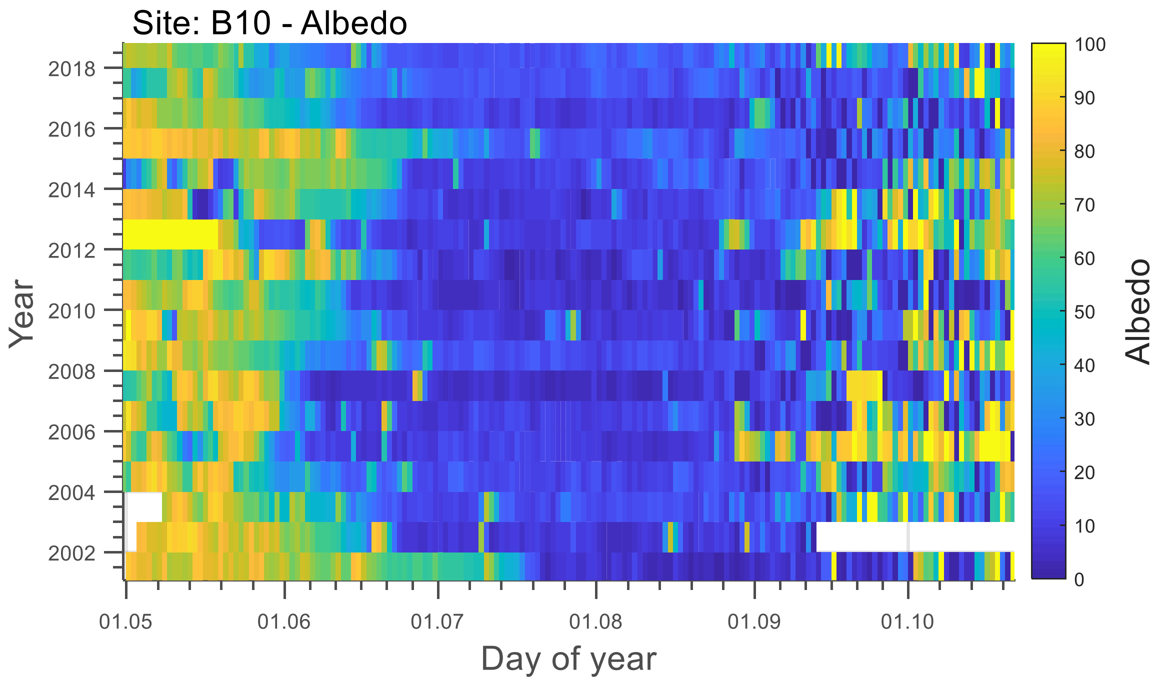


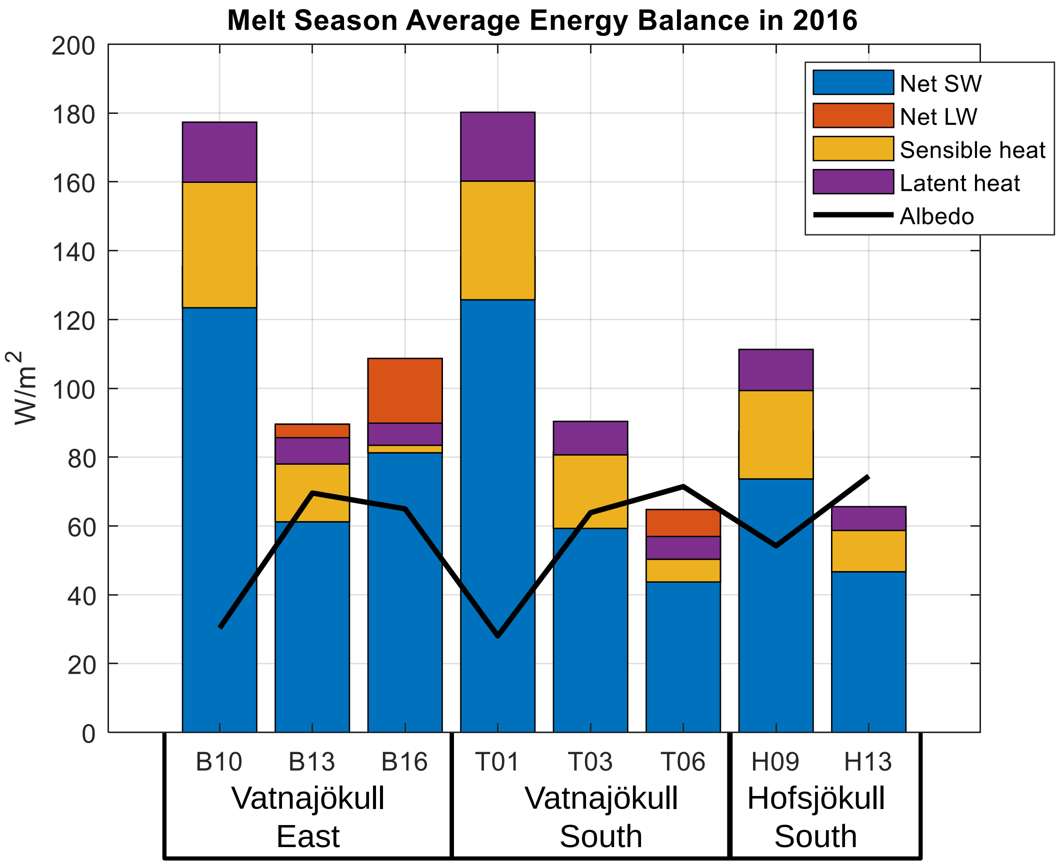


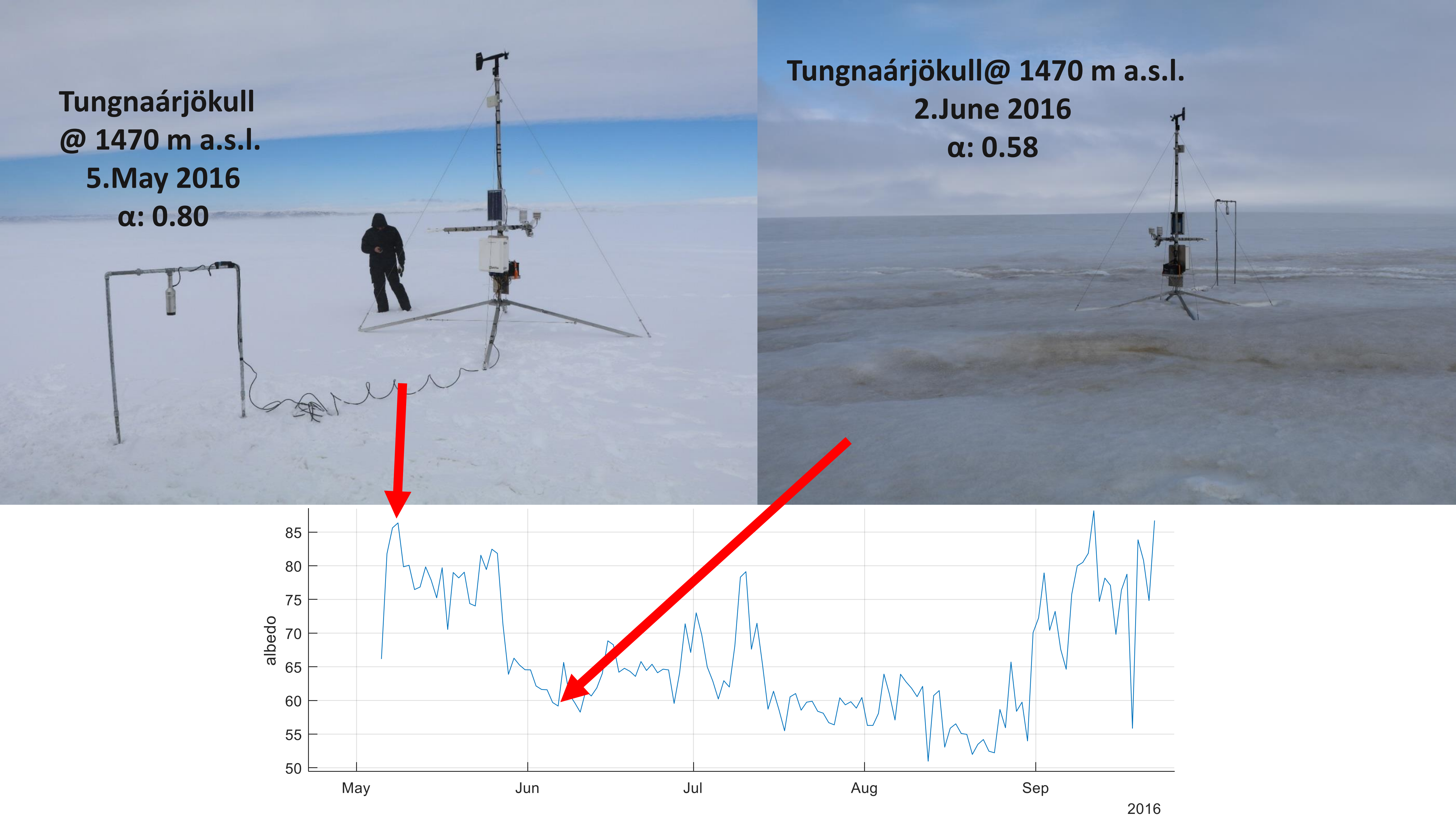


Applications of GAWS data
Inflow forecasting

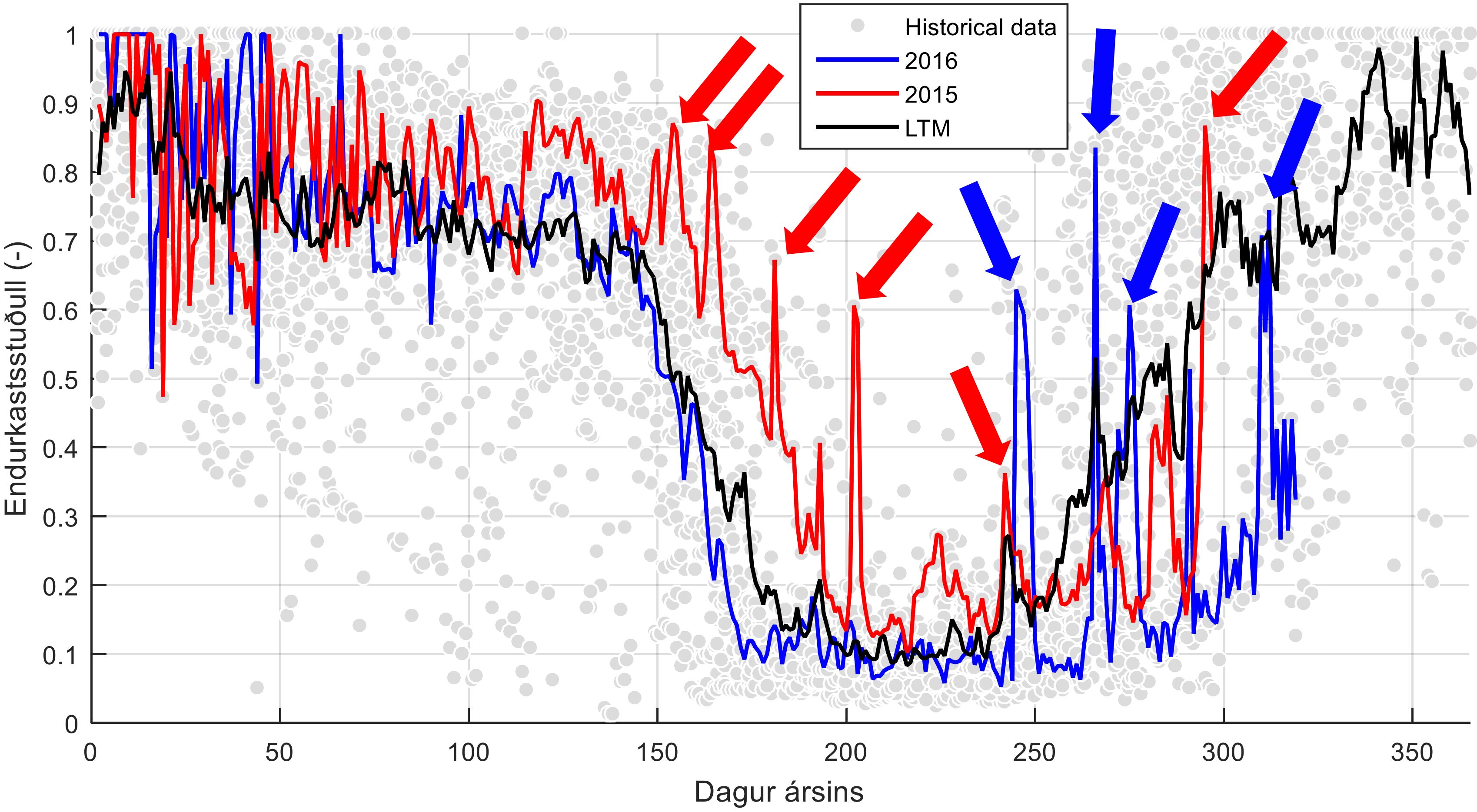
- Calibration of short and long term hydrological models
- Currently testing assimilation of GAWS data
  - Bias correction of temperature / Albedo validation






Tungnaárjökull
@ 1470 m a.s.l.
5.May 2016
α: 0.80
Tungnaárjökull@ 1470 m a.s.l.
2.June 2016
α: 0.58
albedo
85
80
75
70
65
60
55
50
May
Jun
Jul
Aug
Sep
2016

Snowfall events

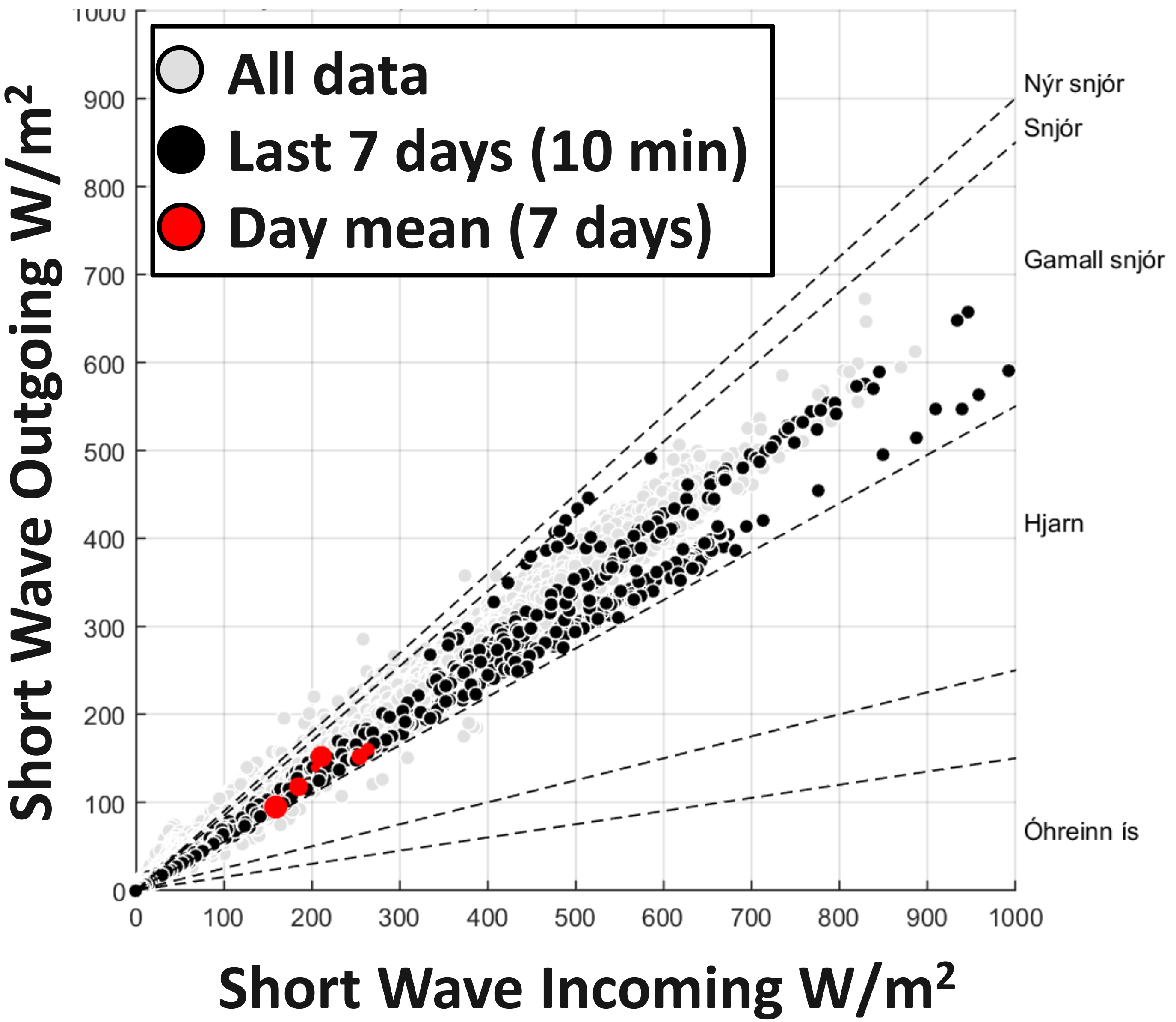



Tungnaárjökull@ 1470 m a.s.l.
1.May – 1.Oct.2017





AWS – B10 800 masl 1.1.2017 – 1.05.2017



New snow

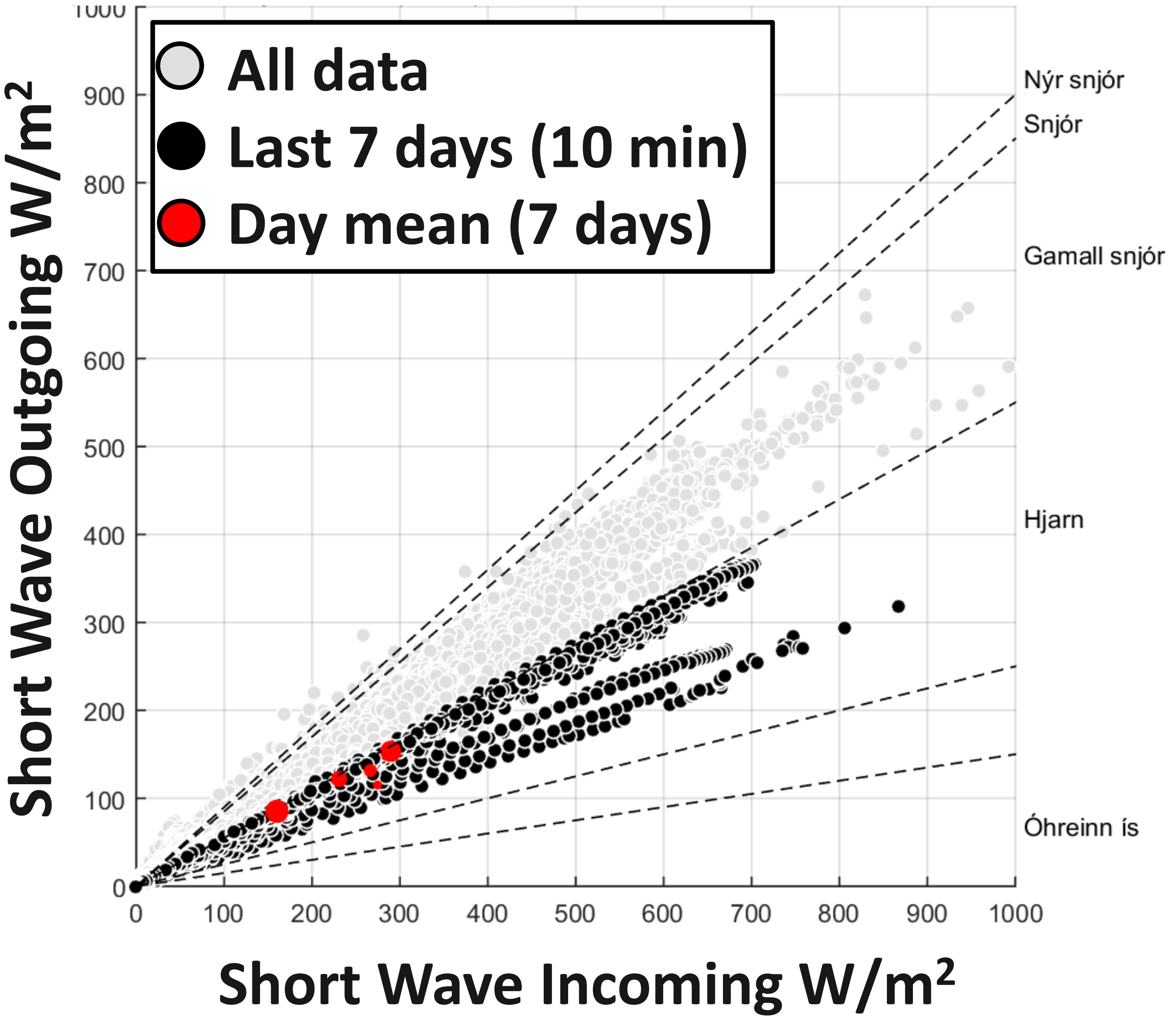
Old snow

Firn

Clean ice

Dirty ice

AWS – B10 800 masl **1.1.2017 – 10.05.2017**



New snow

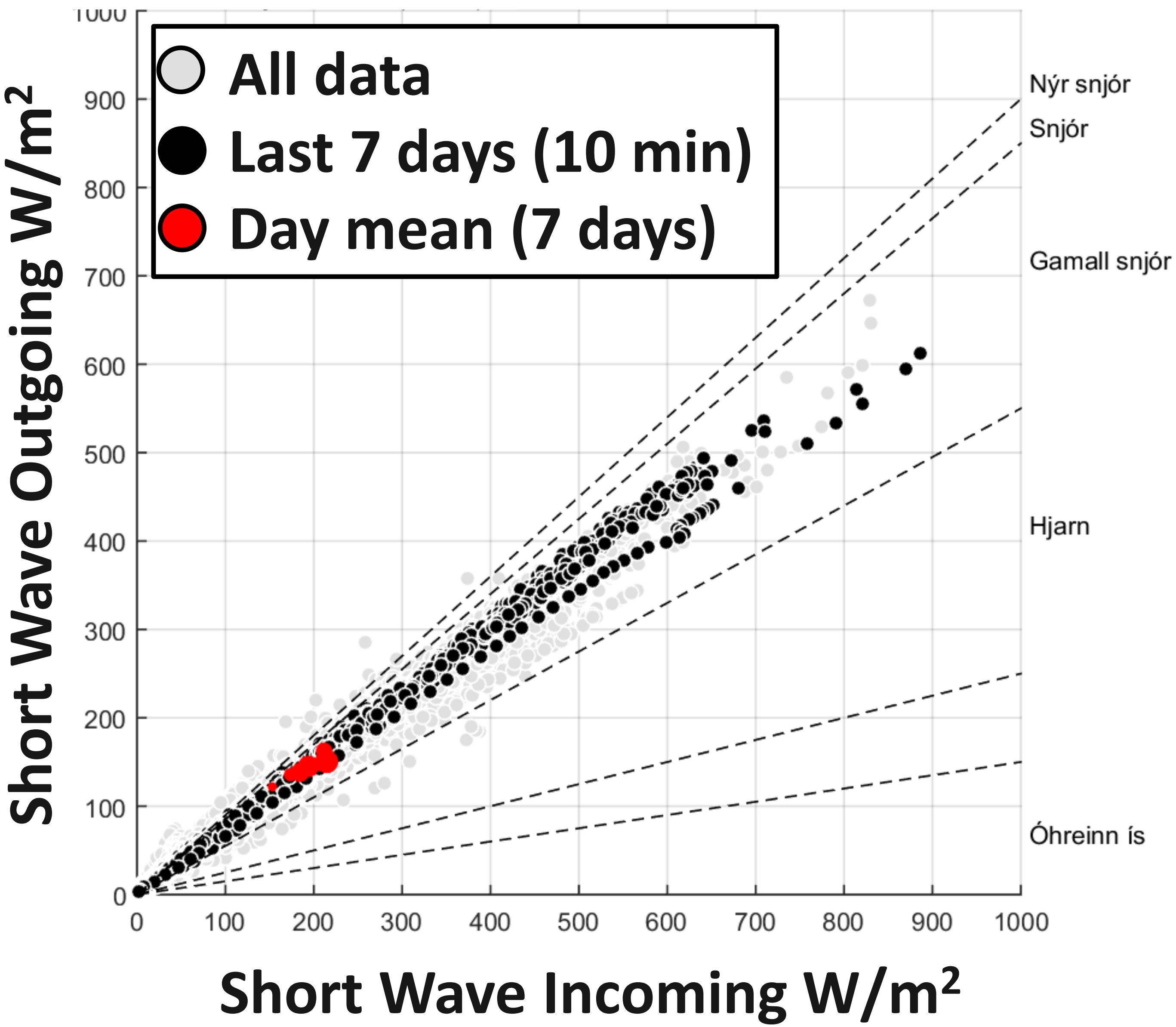
Old snow

Firn

Clean ice

Dirty ice

AWS – B10 800 masl 1.1.2017 – 20.05.2017



New snow

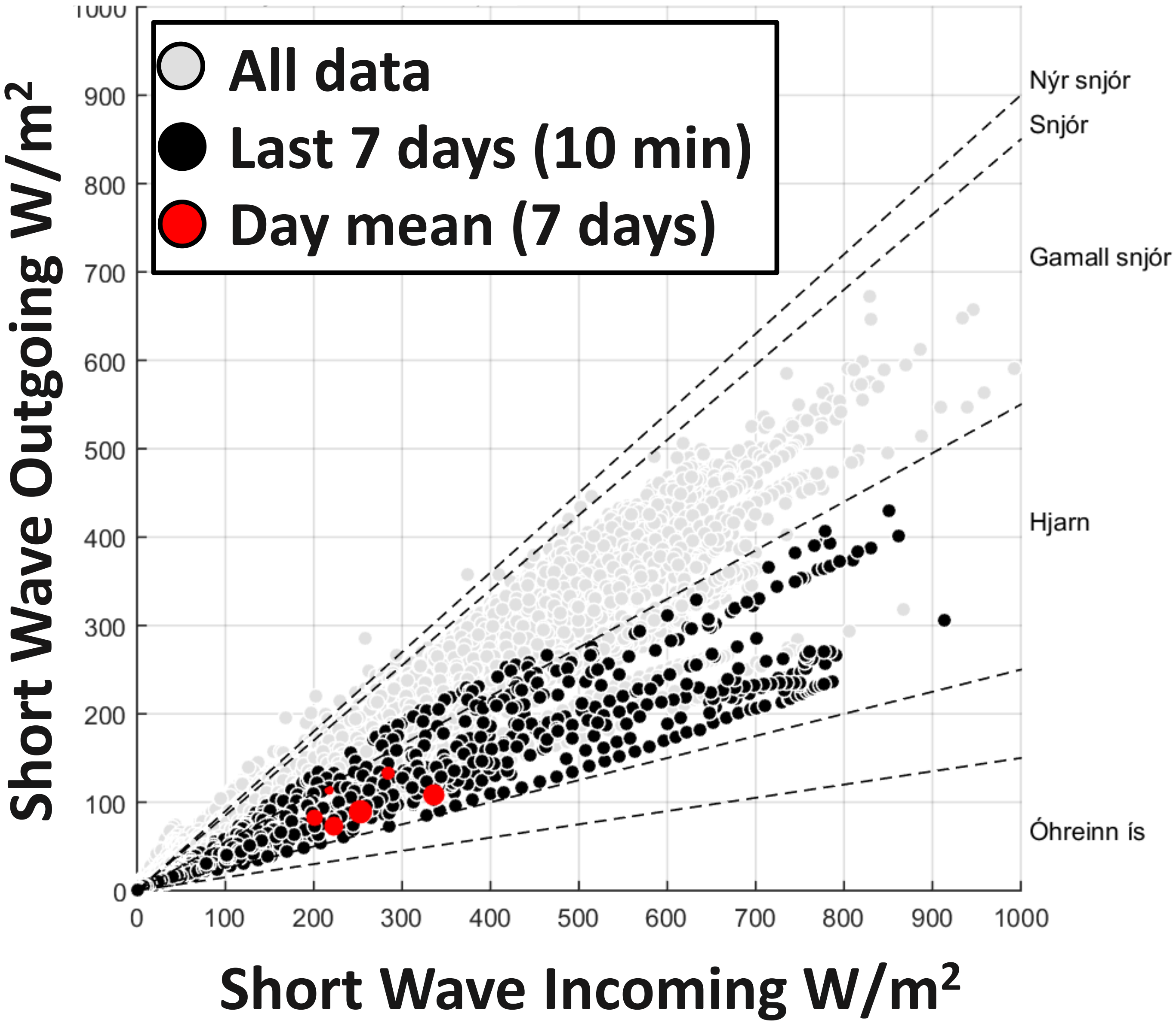
Old snow

Firn

Clean ice

Dirty ice

AWS – B10 800 masl 1.1.2017 – 29.05.2017



New snow

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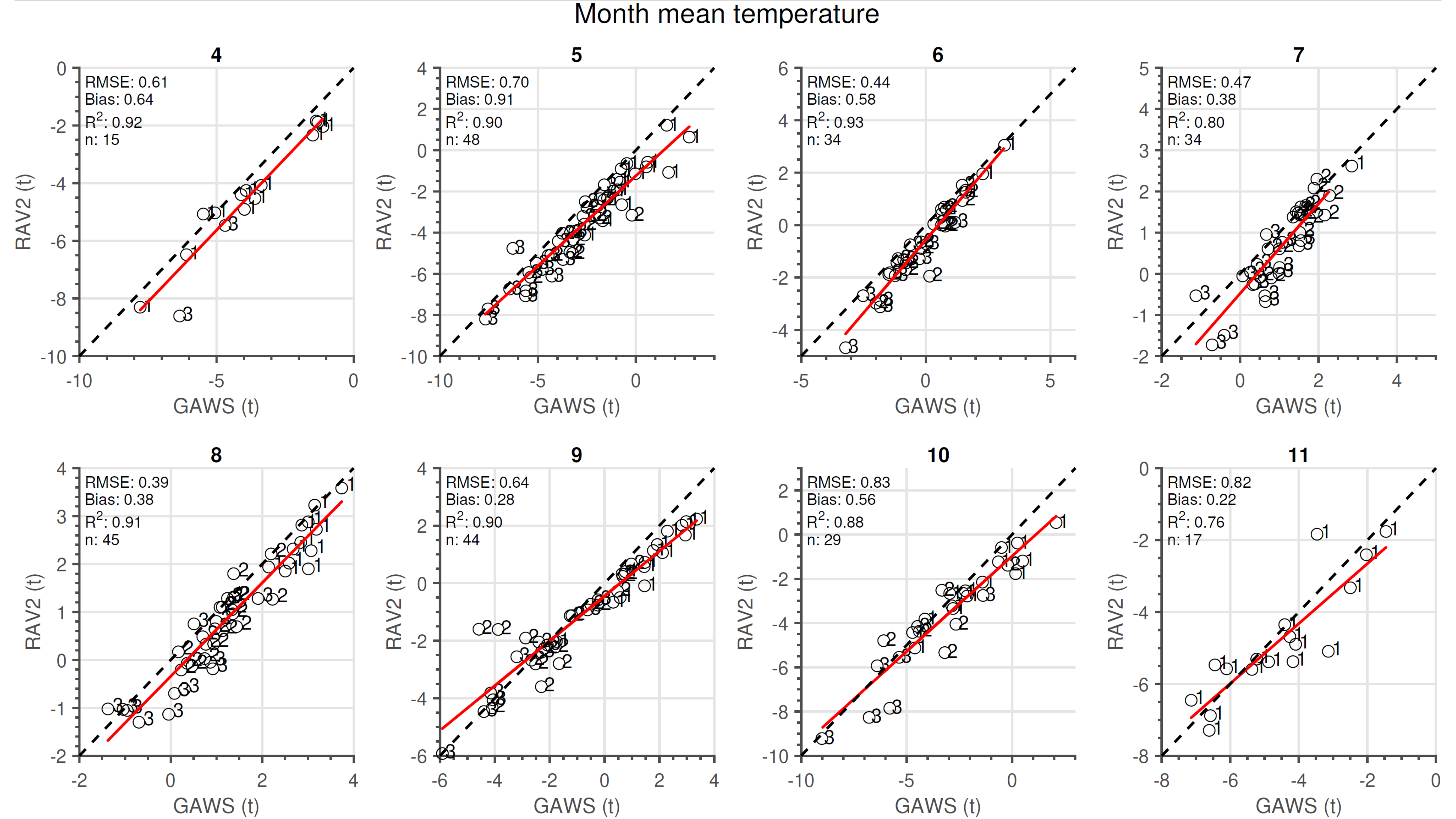
Month mean temperature
4
RMSE: 0.61
Bias: 0.64
R2: 0.92
n: 15
5
RMSE: 0.70
Bias: 0.91
R2: 0.90
n: 48
6
RMSE: 0.44
Bias: 0.58
R2: 0.93
n: 34
7
RMSE: 0.47
Bias: 0.38
R2: 0.80
n: 34
8
RMSE: 0.39
Bias: 0.38
R2: 0.91
n: 45
9
RMSE: 0.64
Bias: 0.28
R2: 0.90
n: 44
10
RMSE: 0.83
Bias: 0.56
R2: 0.88
n: 29
11
RMSE: 0.82
Bias: 0.22
R2: 0.76
n: 17
RAV2 (t)
GAWS (t)