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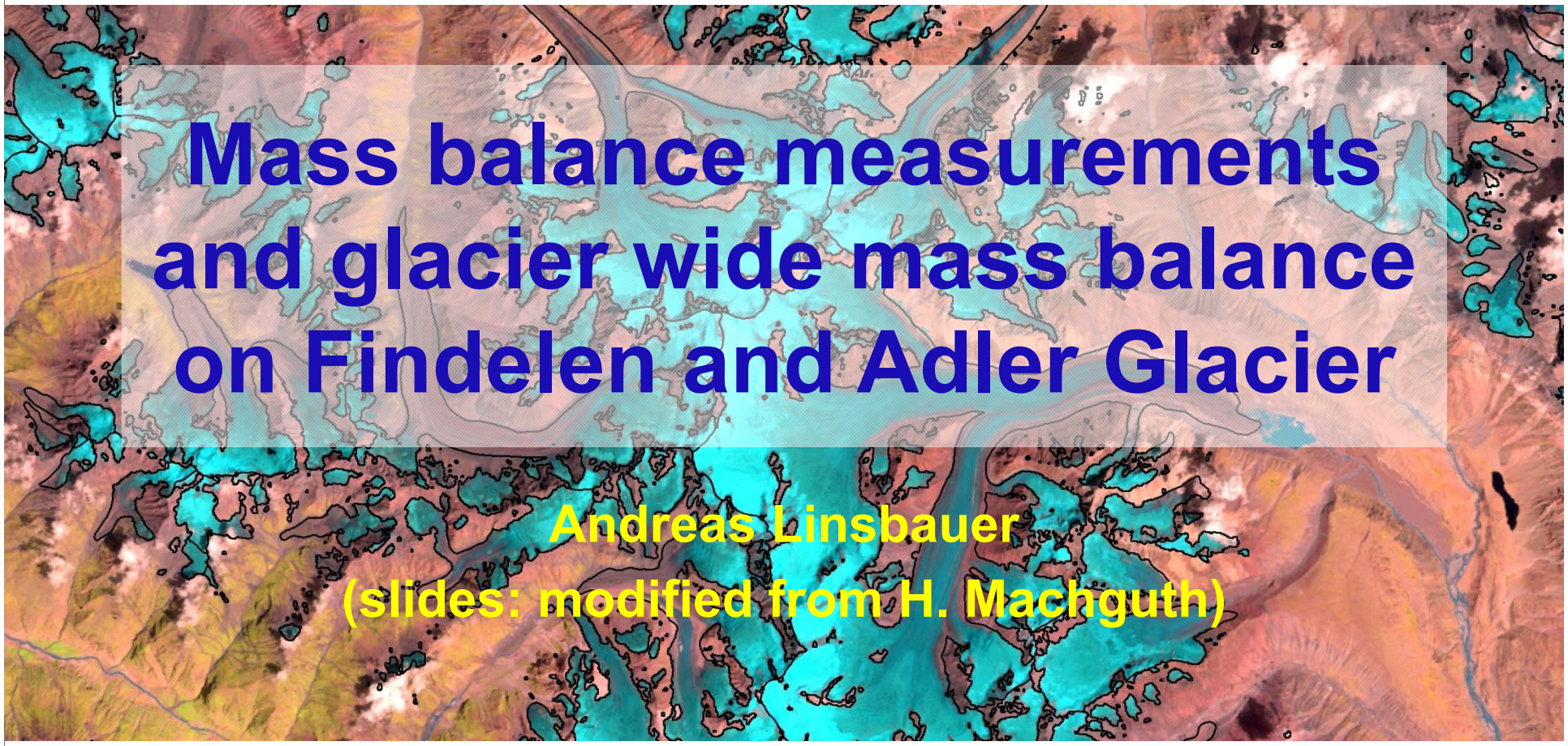


Mass balance measurements and glacier wide mass balance on Findelen and Adler Glacier

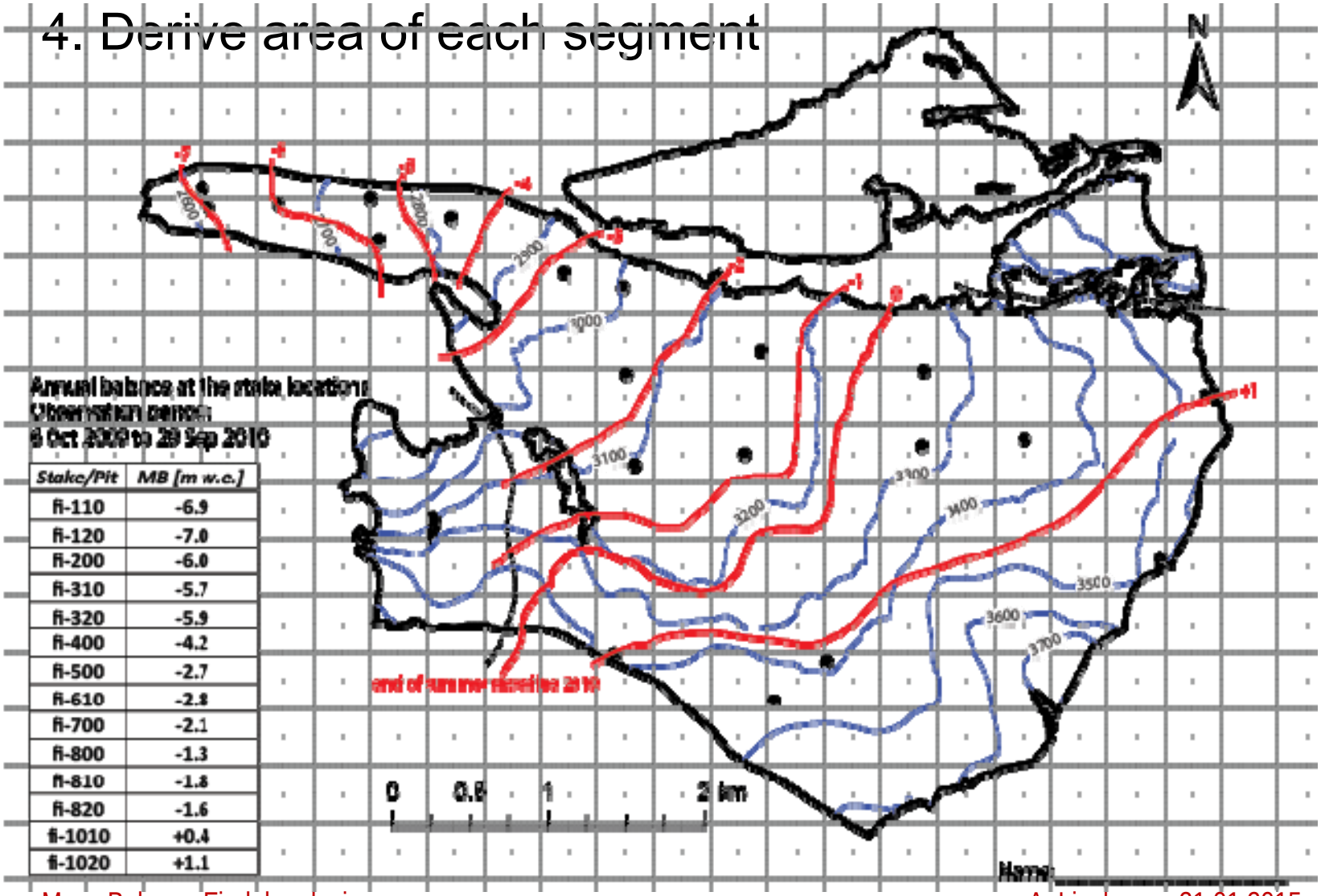
Andreas Linsbauer

(slides: modified from H. Machguth)

IHCAP – Indian Himalayas Climate Change Adaptation Programme
Capacity building programme “Cryosphere” Level-2 (Jan 5 – Feb 13, 2015)

Mass Balance exercise – level 1

4. Derive area of each segment



Annual balance at the stake locations
Observation period:
6 Oct 2009 to 29 Sep 2010

Stake/Pit	MB [m w.e.]
fi-110	-6.9
fi-120	-7.0
fi-200	-6.0
fi-310	-5.7
fi-320	-5.9
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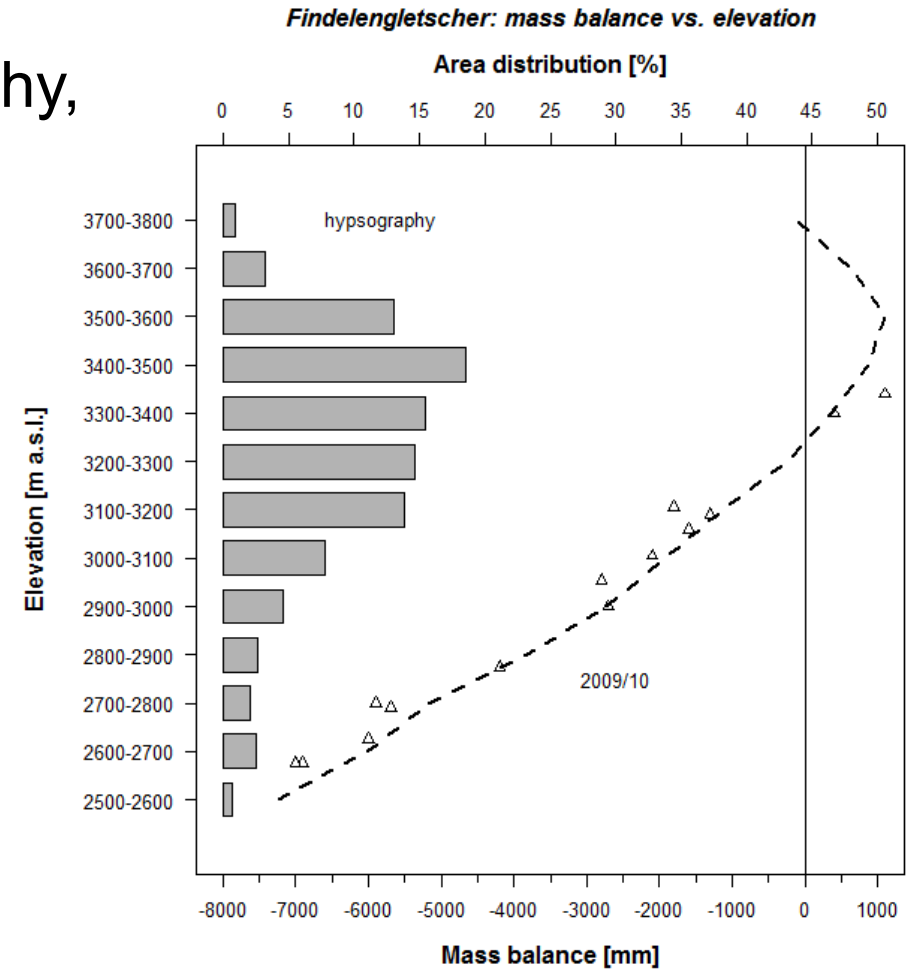
fi-500	-2.7
fi-610	-2.8
fi-700	-2.1
fi-800	-1.3
fi-810	-1.8
fi-820	-1.6
fi-1010	+0.4
fi-1020	+1.1

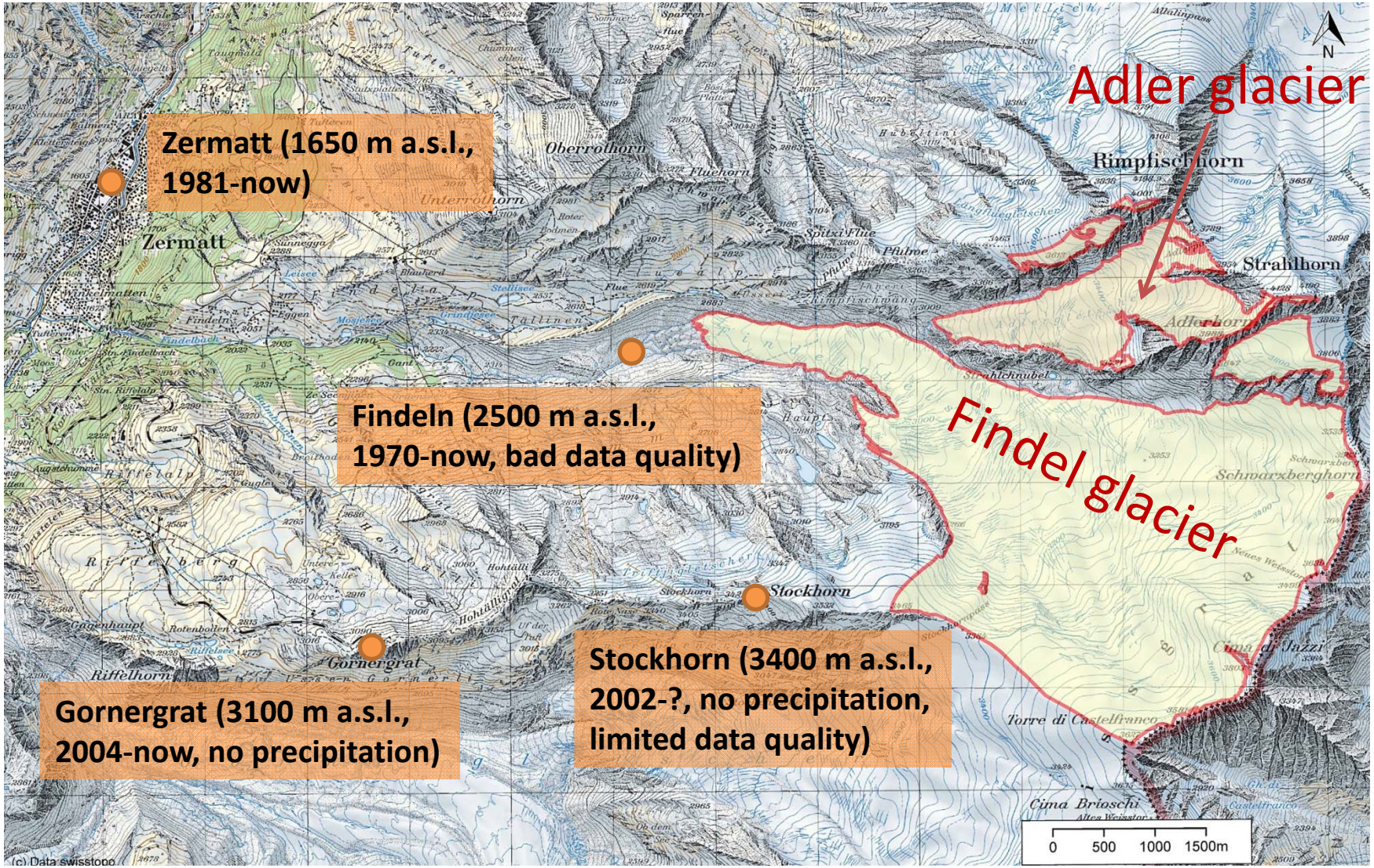
Mass Balance exercise – level 1

5. plot into one figure:

- the glacier hypsography,
- mass balance vs. altitude for elevation bins of 100 m,
- and the point observations.



Geographical setting of Findel glacier



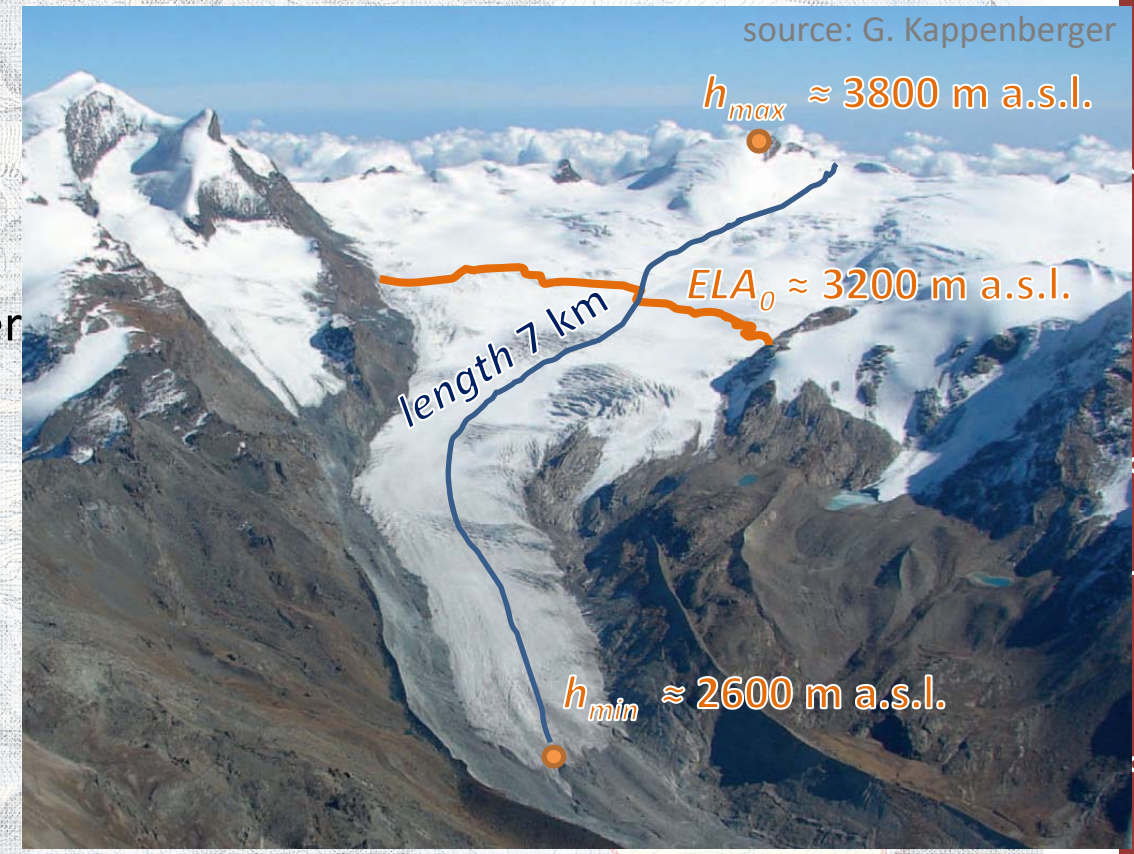
Geographical and climatological setting

Findel glacier characteristics

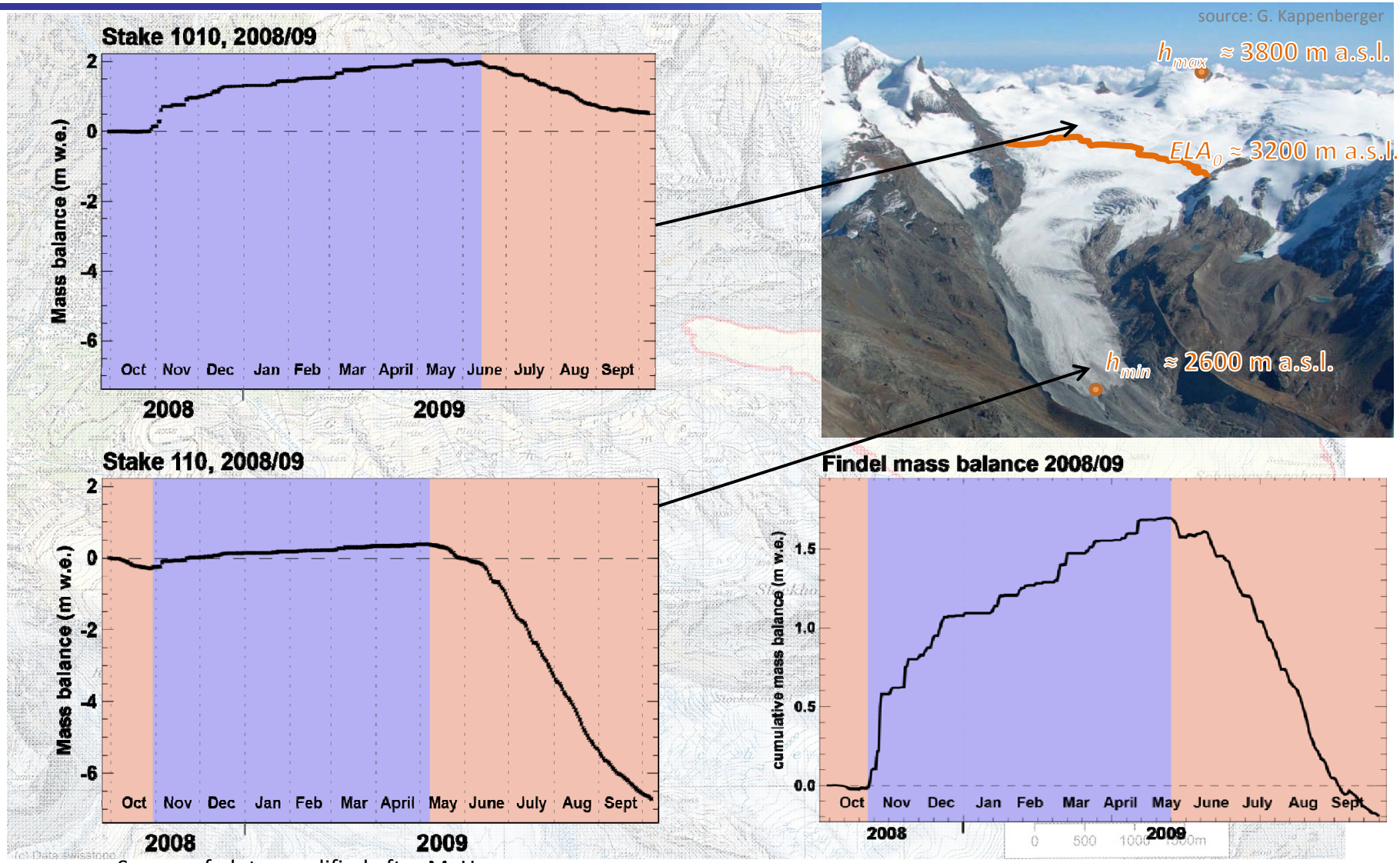
- area 13.4 km^2 (roughly #15 in the Alps)
- debris free valley-type glacier

Climate and glacier

- temperate climate, no rainy and dry season
- clear seasonal temperature cycle
- temperate glacier (ice and firn mostly at 0 °C)
- clearly seperable accumulation and ablation seasons



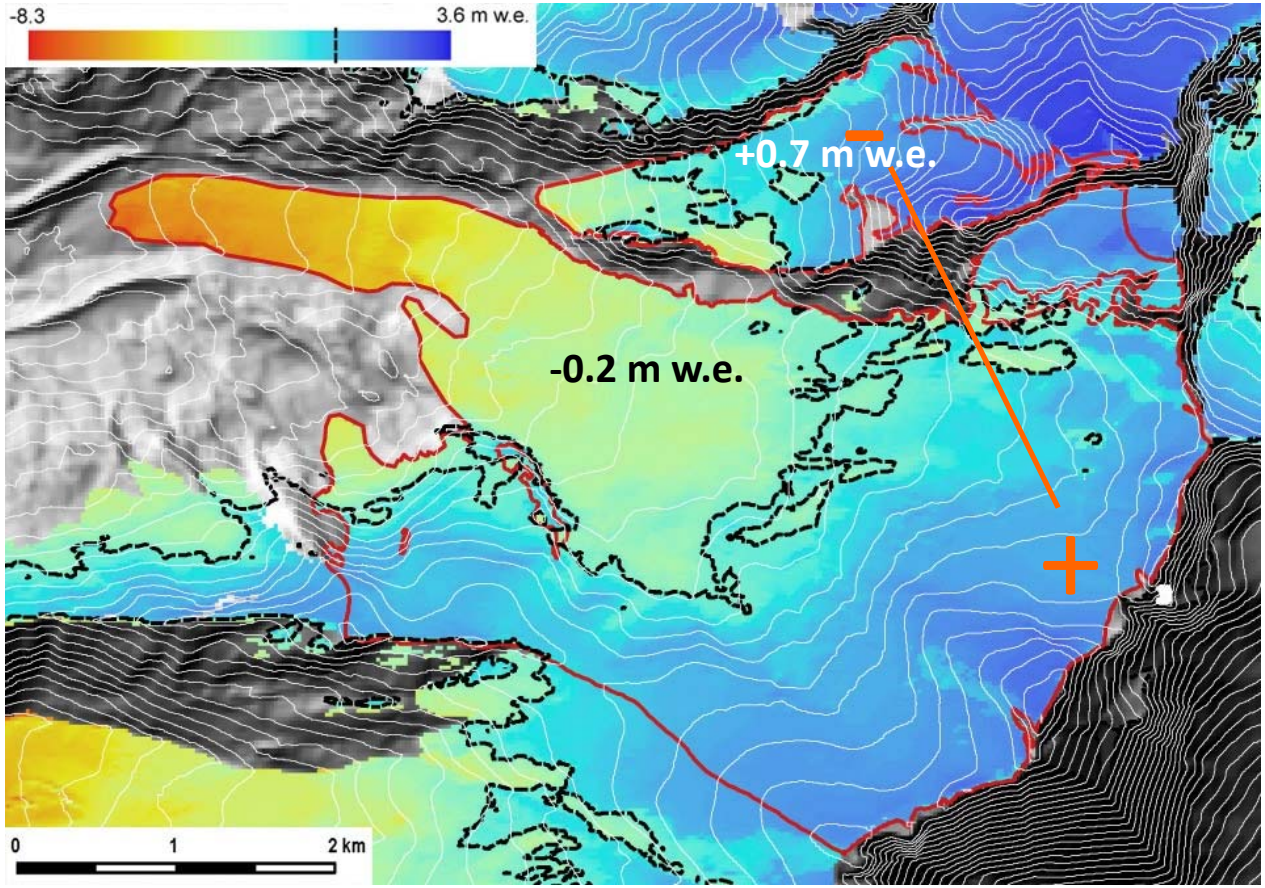
Geographical and climatological setting



Source of plots: modified after M. Huss

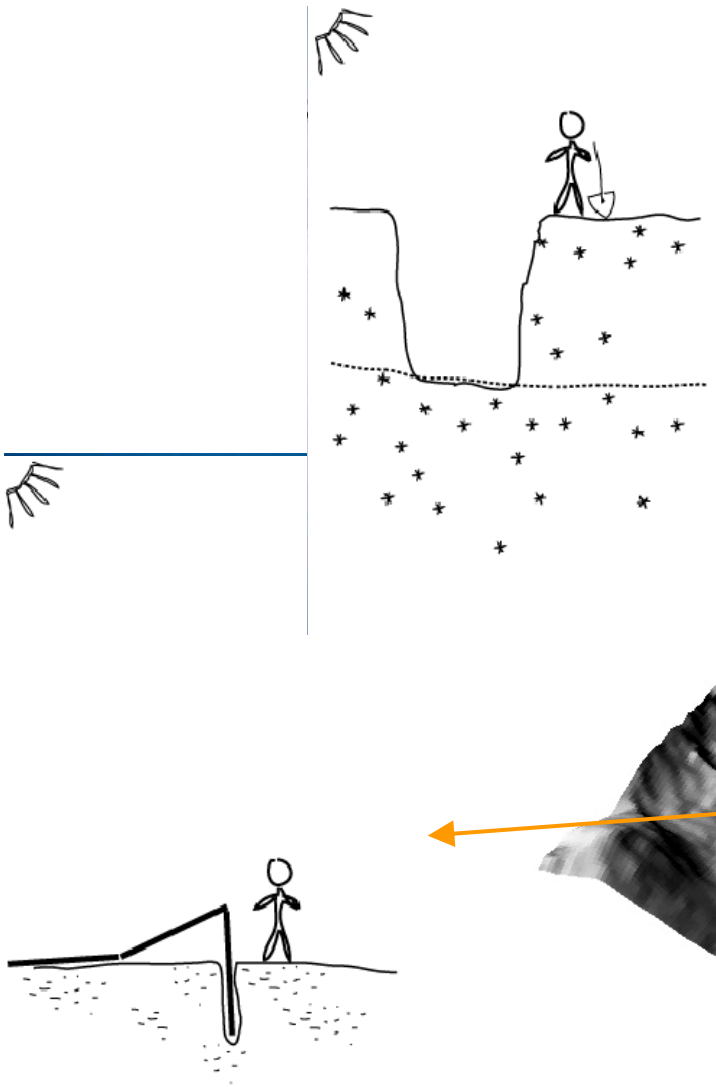
Why Findelen galcier?

- Initially **not a mass balance glacier**, only measured for ground truthing in a modelling study
- Investigation of a presumed horizontal precipitation gradient



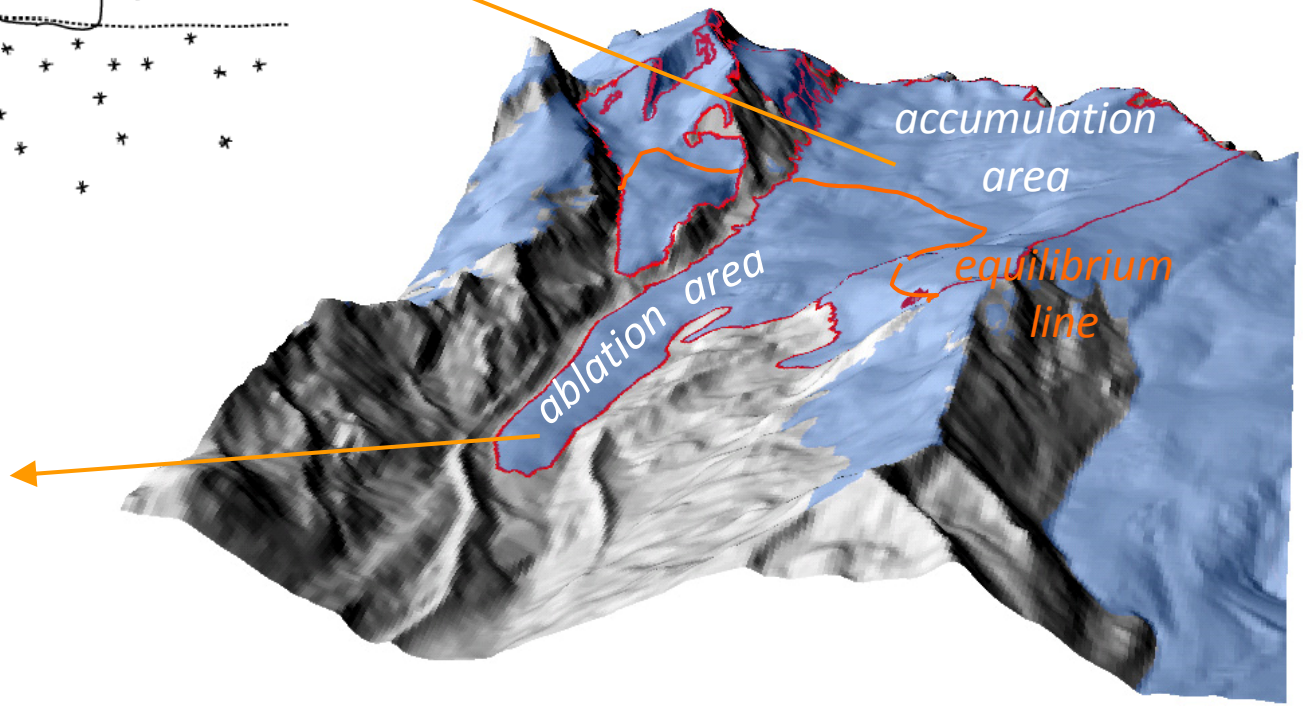
modelled mass balance distribution Findel and Adler glacier

How do we measure on Findelen?



Annual field surveys are carried out close to the beginning of the *hydrological year*. […] The duration of the *mass-balance year* varies in the floating-date system. (Cogley et al., 2011)

Findel glacier: direct glaciological method, *floating date system*



How do we measure on Findelen?

Photo: N. Salzmann

Photo: S. Bircher

Stake drilling / Stake readings

How do we measure on Findelen?

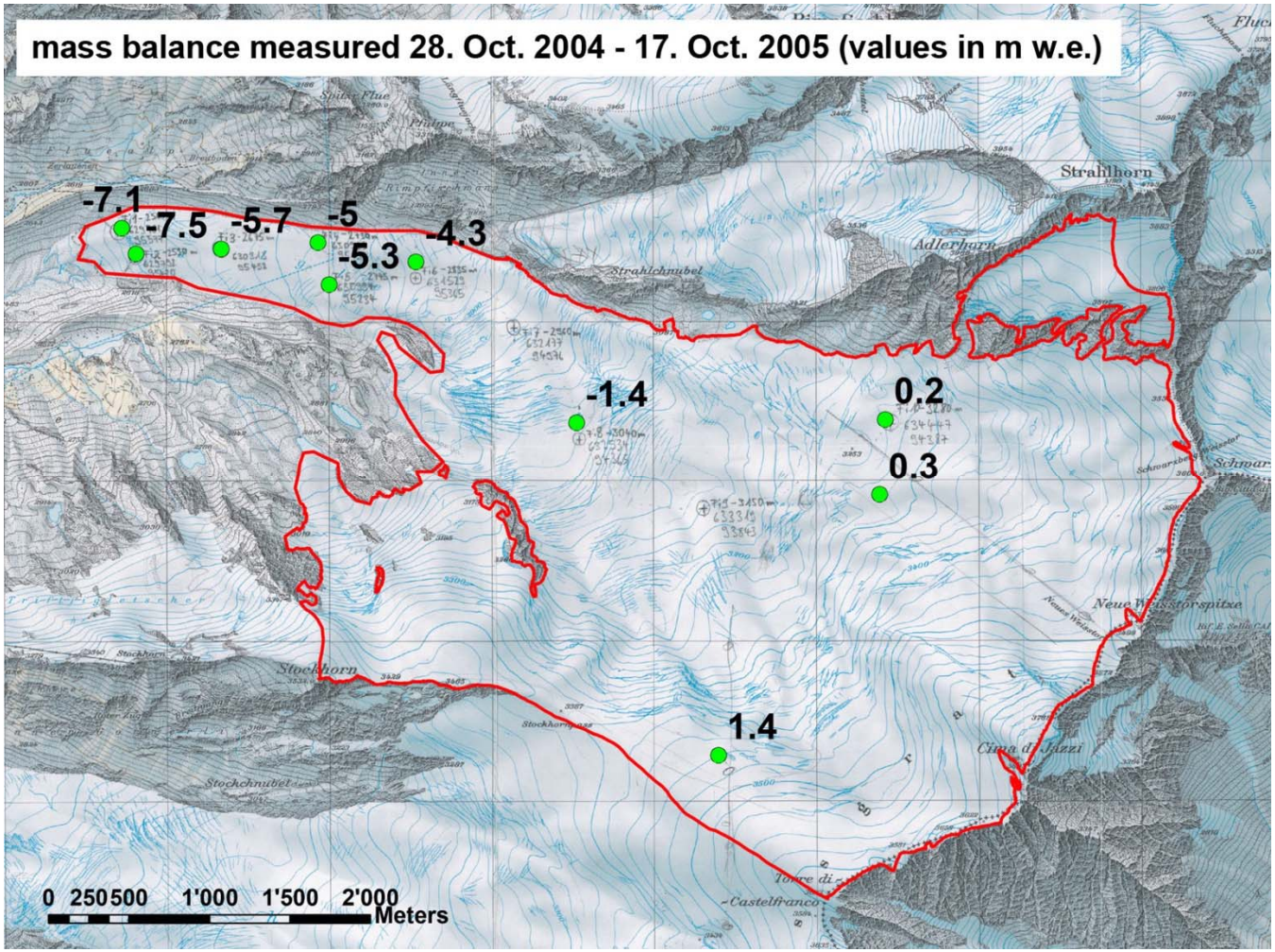
Photo: H. Machguth

Photos: N. Salzmann

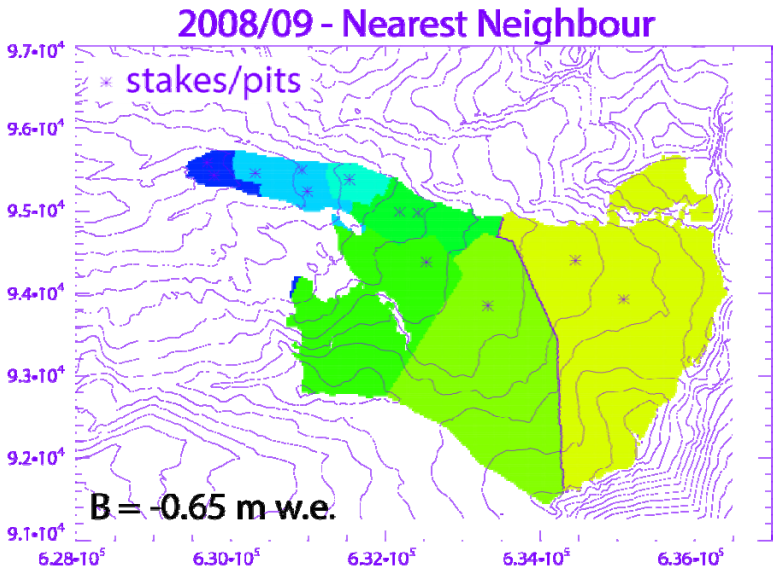
Snow pits

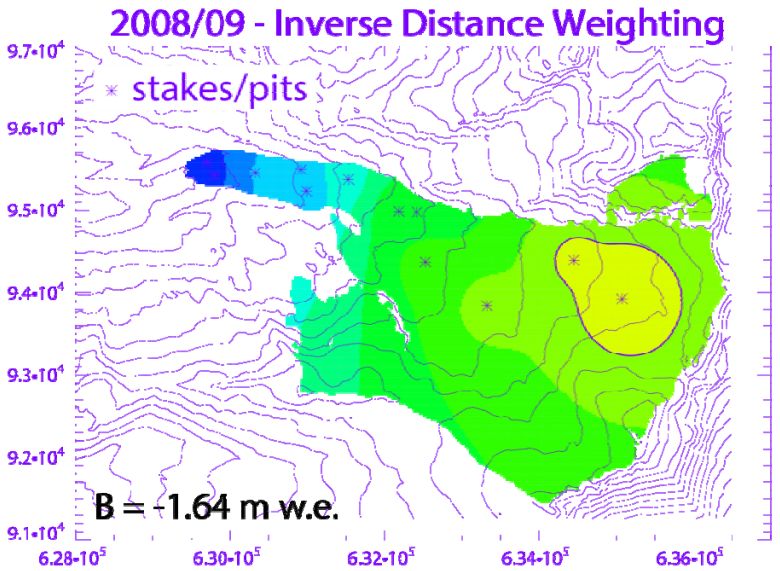
The usual starting point

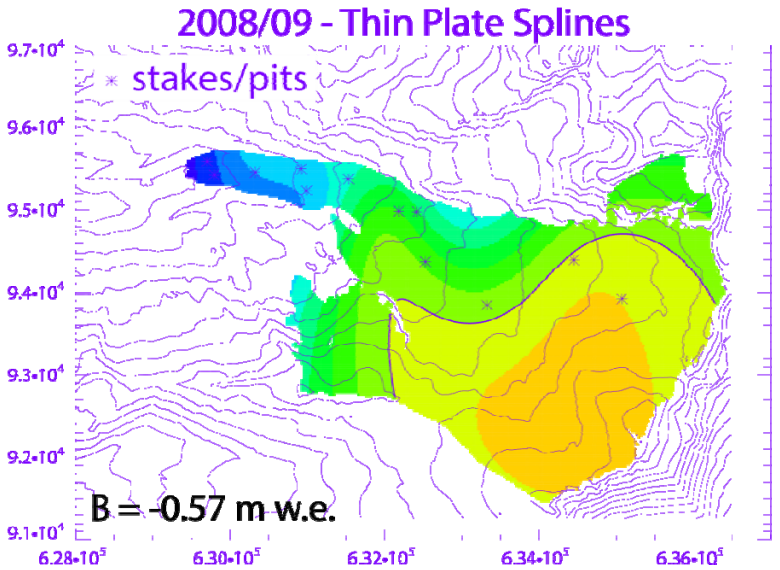
Some random stake readings



Interpolation approaches







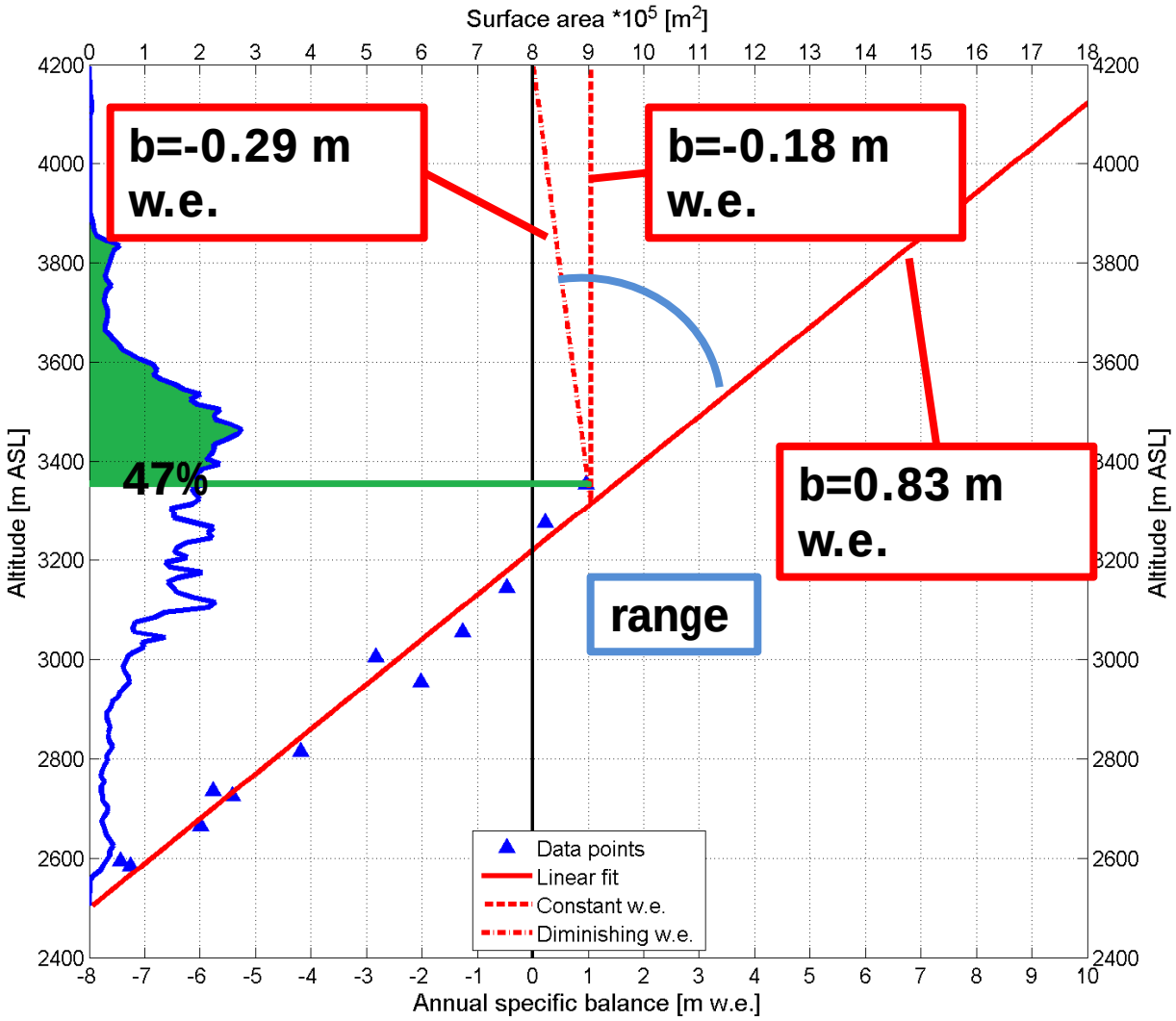
Submitted to WGMS:

0.1±0.5 m w.e.

Profile method

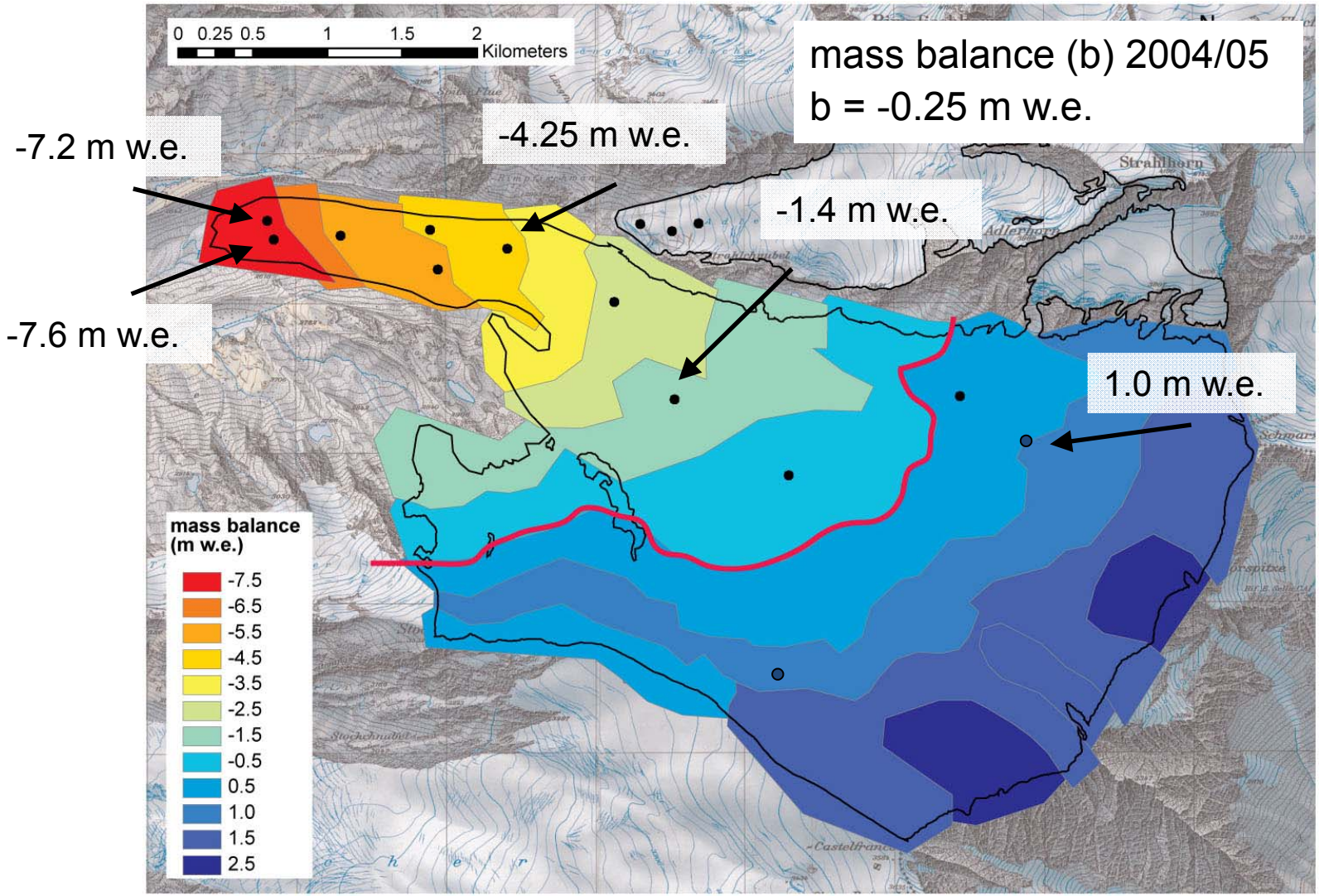
b = f(h)

Example: 2008 - 2009



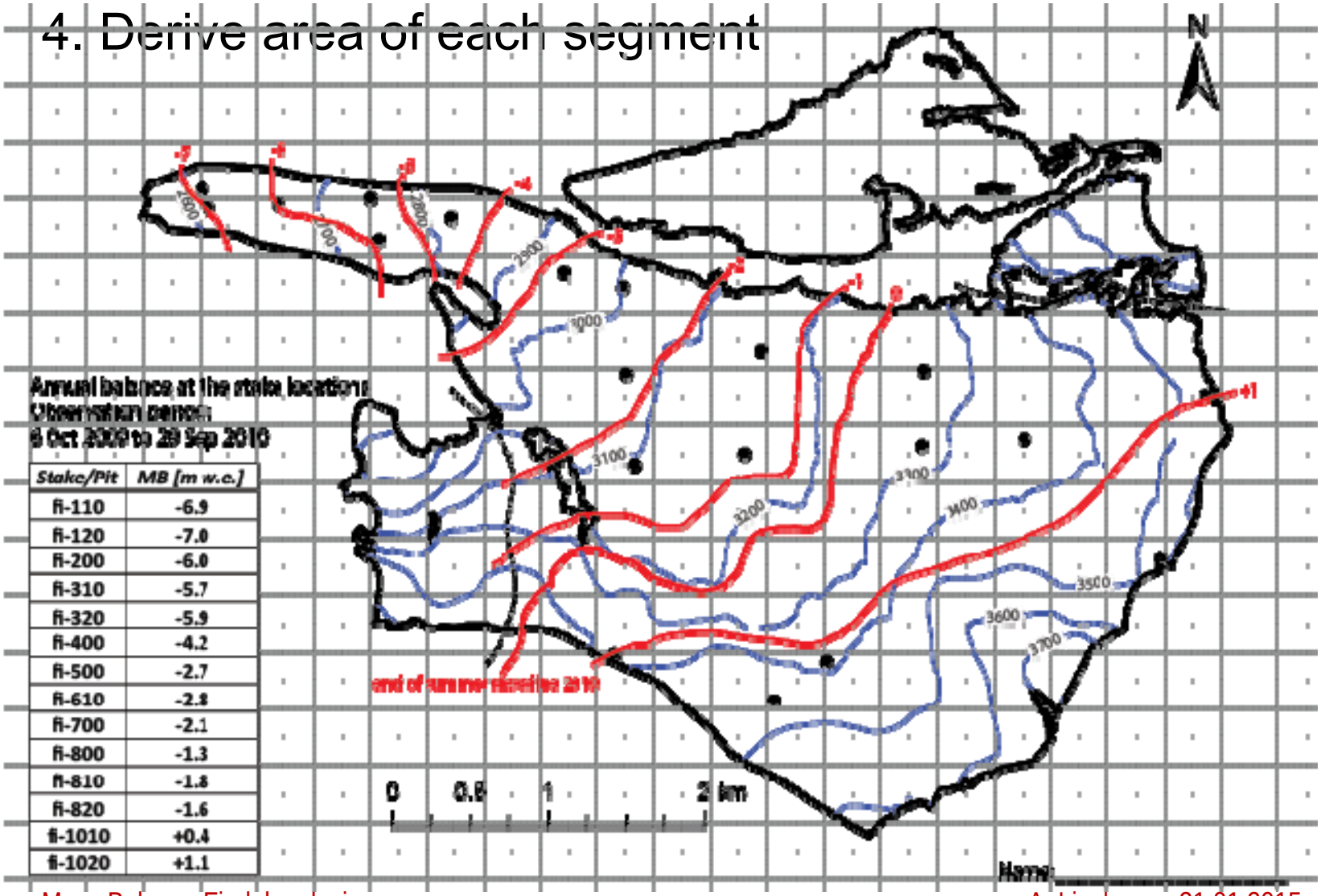
source: P. Joerg, unpublished

Contour line method



Mass Balance exercise – level 1

4. Derive area of each segment



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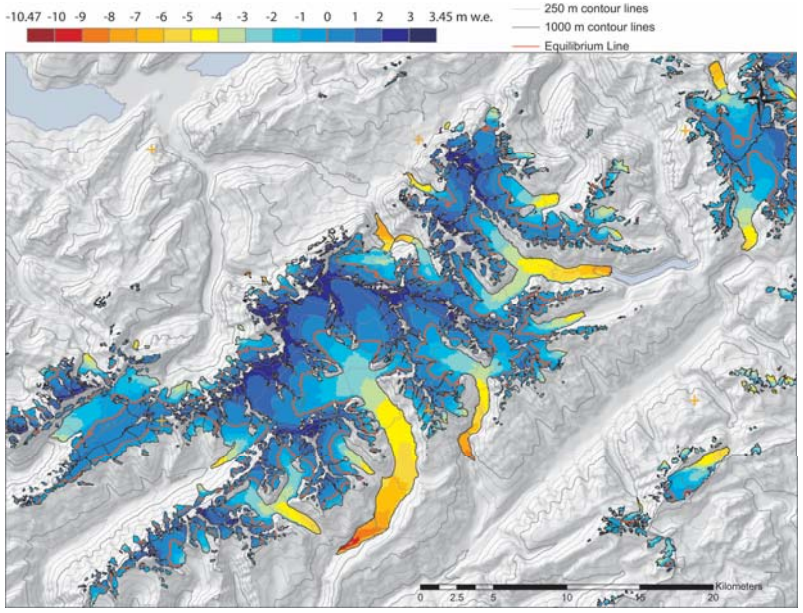
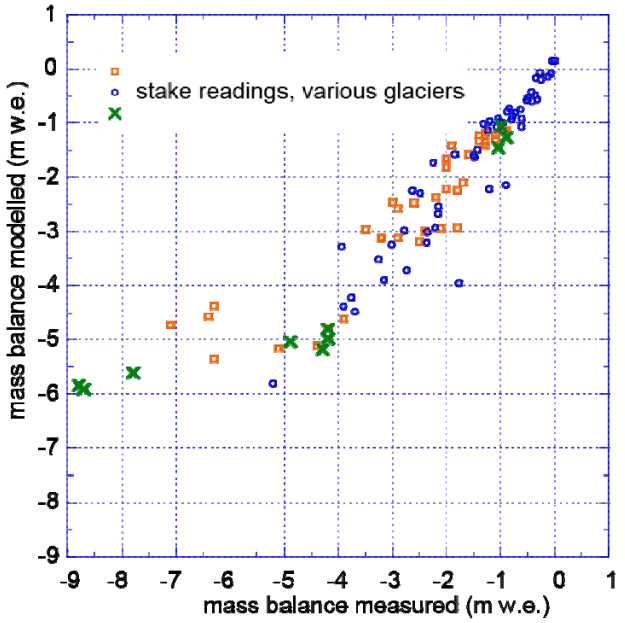
fi-1020	+1.1

Calculated mass balance is never final!

- Re-analysis using geodetic mass balance
- Extrapolation methods are subject to improvements
- The way mass balance data are used is changing …





Conclusions

- Understanding and addressing the relevant processes is the key to good quality mass balance data
- Adapt methods to climatological and glacier characteristics
- Extrapolation is the key to total mass balance
- In most cases it is best to either work manually or use process-based extrapolation (see talks on Friday)
- Publish/submit complete meta data and stake readings

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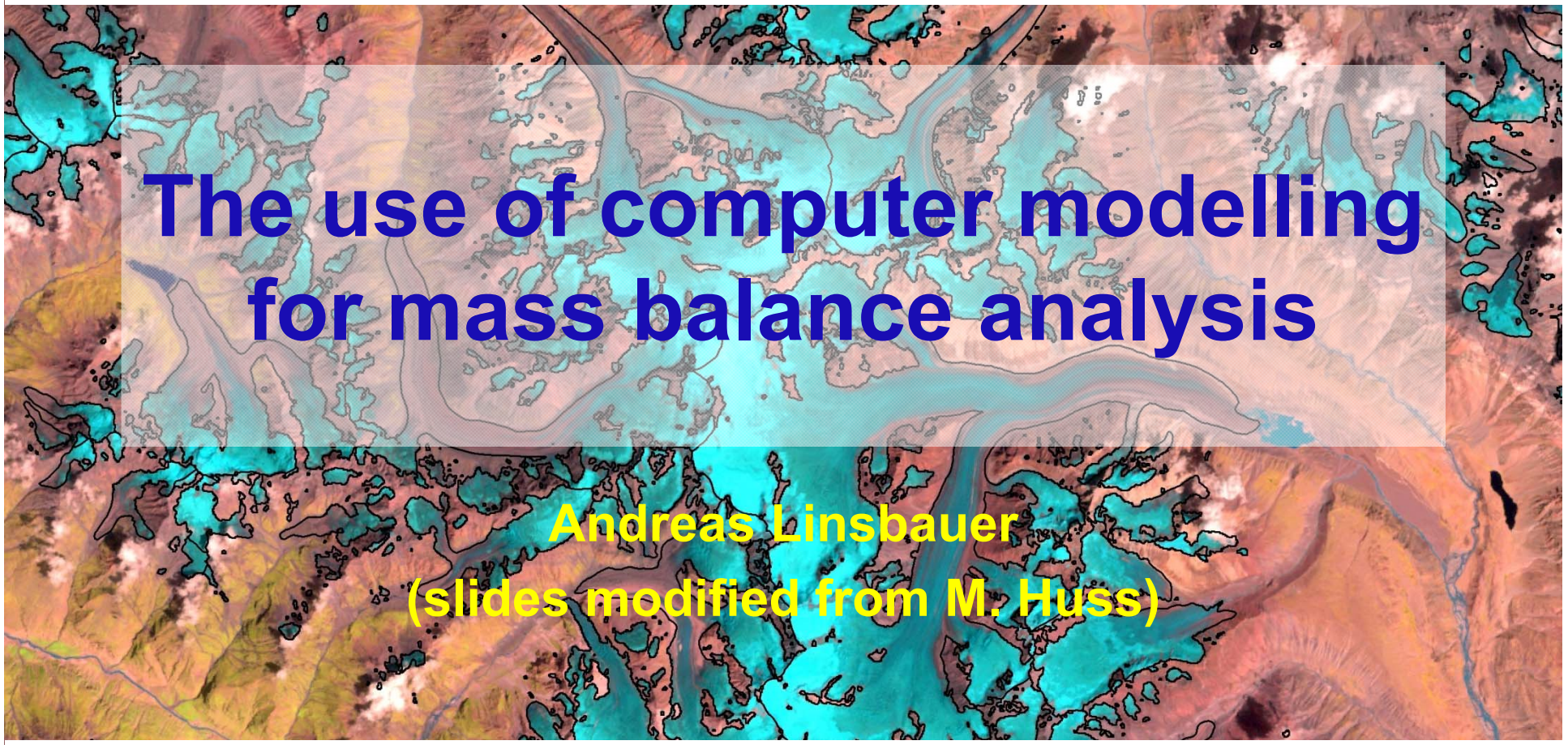


The use of computer modelling for mass balance analysis

Andreas Linsbauer
(slides modified from M. Huss)

IHCAP – Indian Himalayas Climate Change Adaptation Programme
Capacity building programme “Cryosphere” Level-2 (Jan 5 – Feb 13, 2015)

Three systems to evaluate mass balance:

Measurement period

Between field surveys

"practicable"

Fixed date

Hydrological year

$\overline{b_{\mathrm{net}}}$ Oct 1 - Sept 30

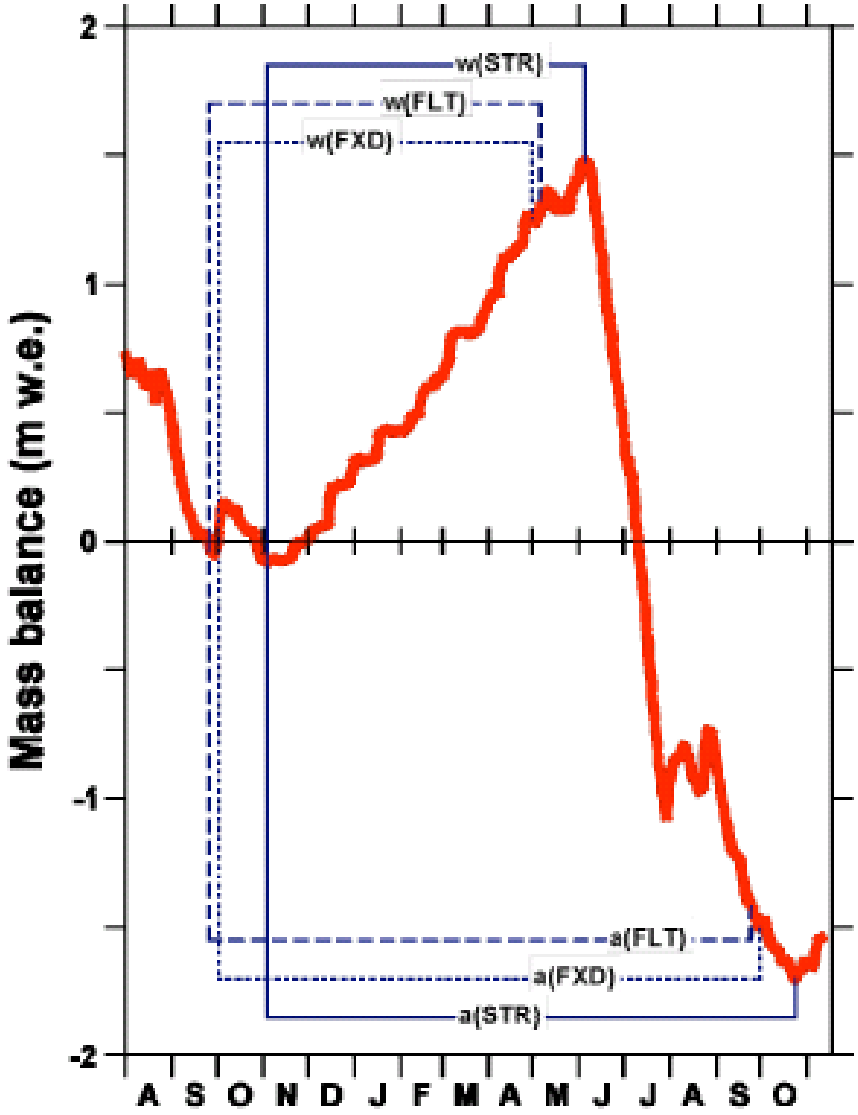
$\overline{b_{\mathrm{win}}}$ Oct 1 - April 30

"comparable"

Stratigraphic

Change in glacier mass between annual minima and maxima

"theoretical"



Mass balance model

Basic approach:

- Extrapolate point mass balance in SPACE and TIME using physical relations
- Analyze seasonal to annual mass balance data using a daily mass balance model (temperature, precipitation).
  - Melt: **Distributed temperature-index / energy balance model** including potential radiation (Hock, 1999; erlemans, 2001)
    → 3 parameters
  - Acc.: Extrapolation of precipitation
    → 1 parameter

Two steps:

- 1. Fit model to winter accumulation data
- 2. Fit model to annual data

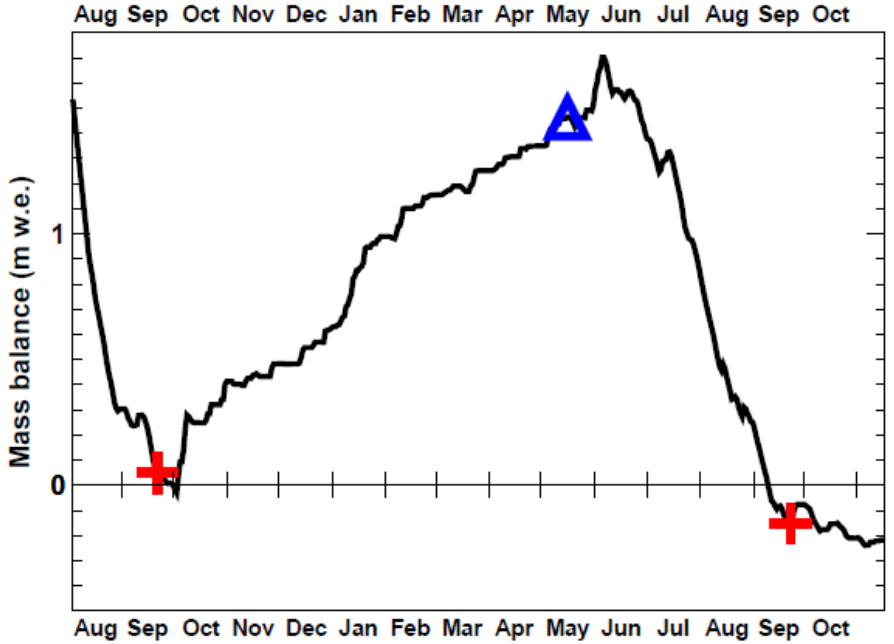
Model adjustment

Downscaling of seasonal mass balance observations using daily weather data:

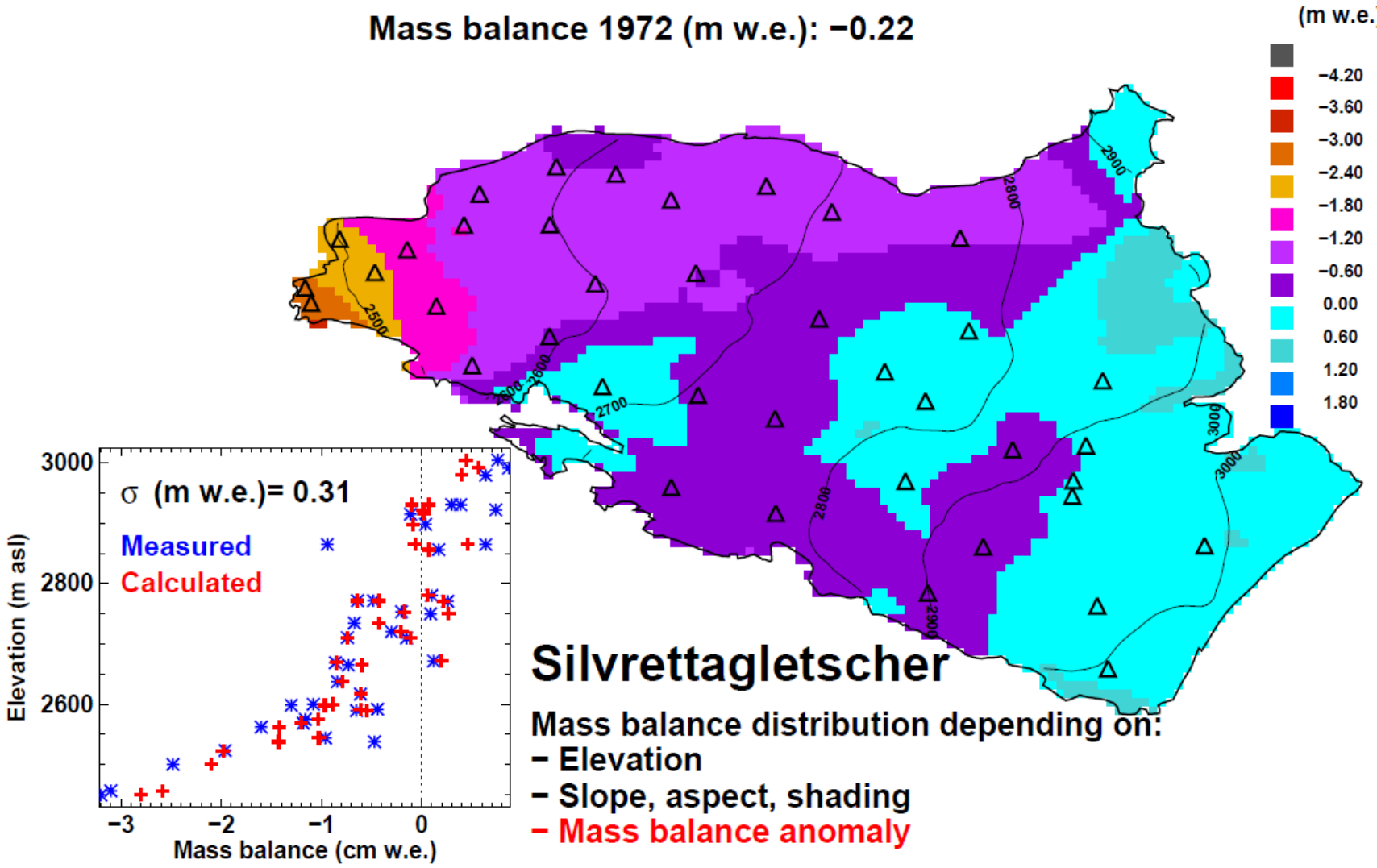
- Winter measurements constrain accumulation parameters
- Annual balance measurements constrain melt parameters

Spatial distribution:

- Slope, aspect, shading
- Wind drift



Model adjustment: Spatial distribution

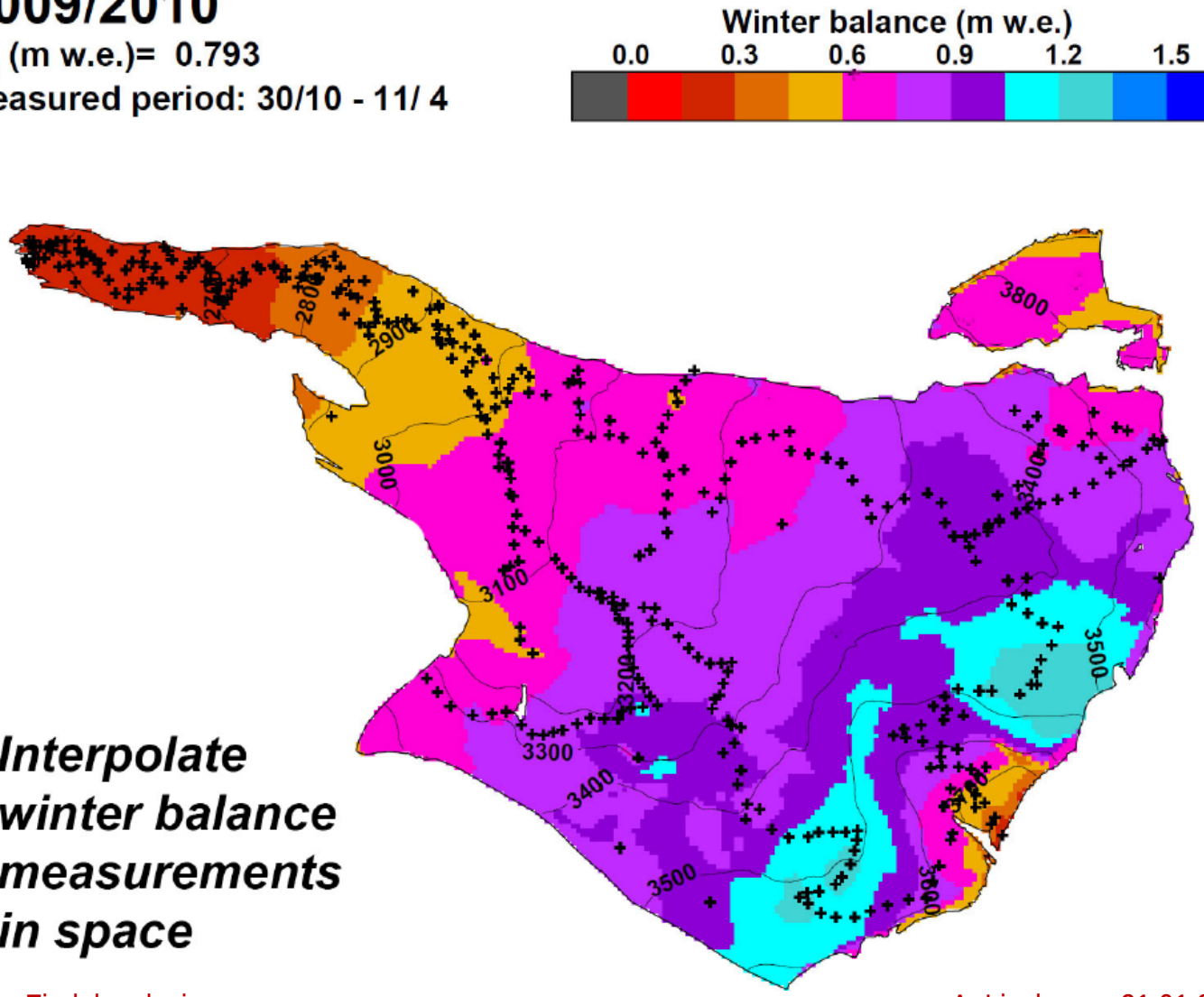


Step 1: Winter accumulation

2009/2010

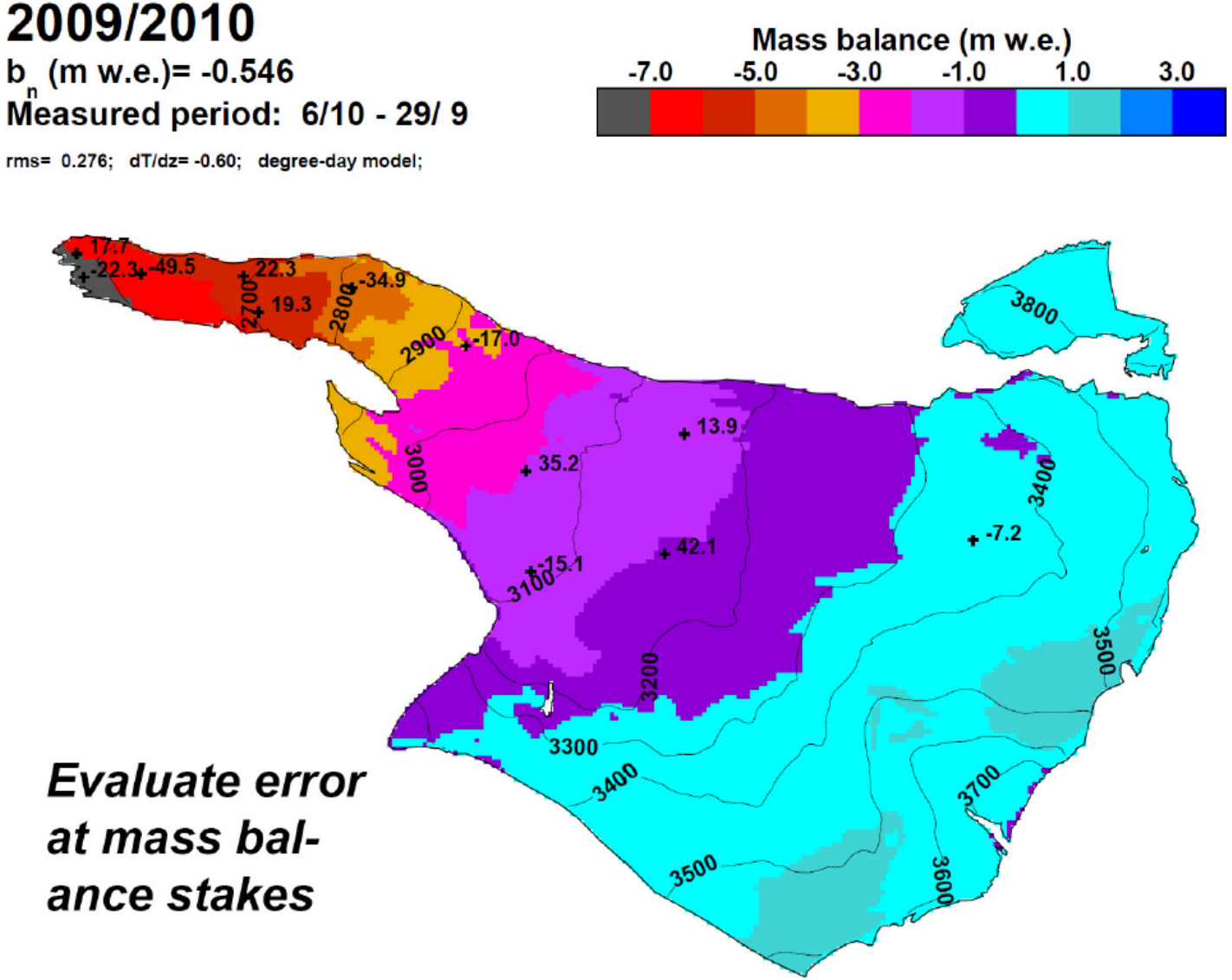
b_w (m w.e.)= 0.793

Measured period: 30/10 - 11/ 4

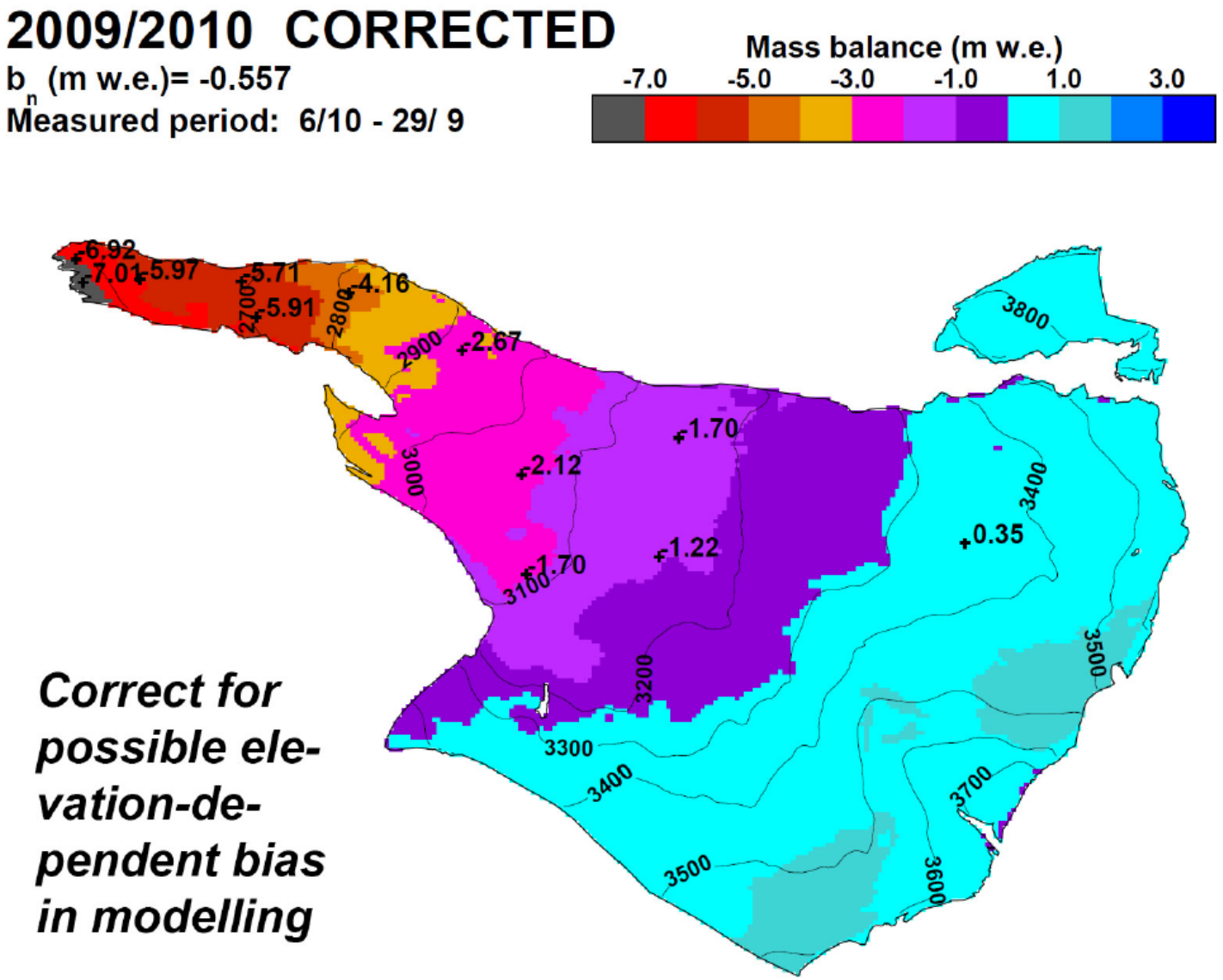


Interpolate winter balance measurements in space

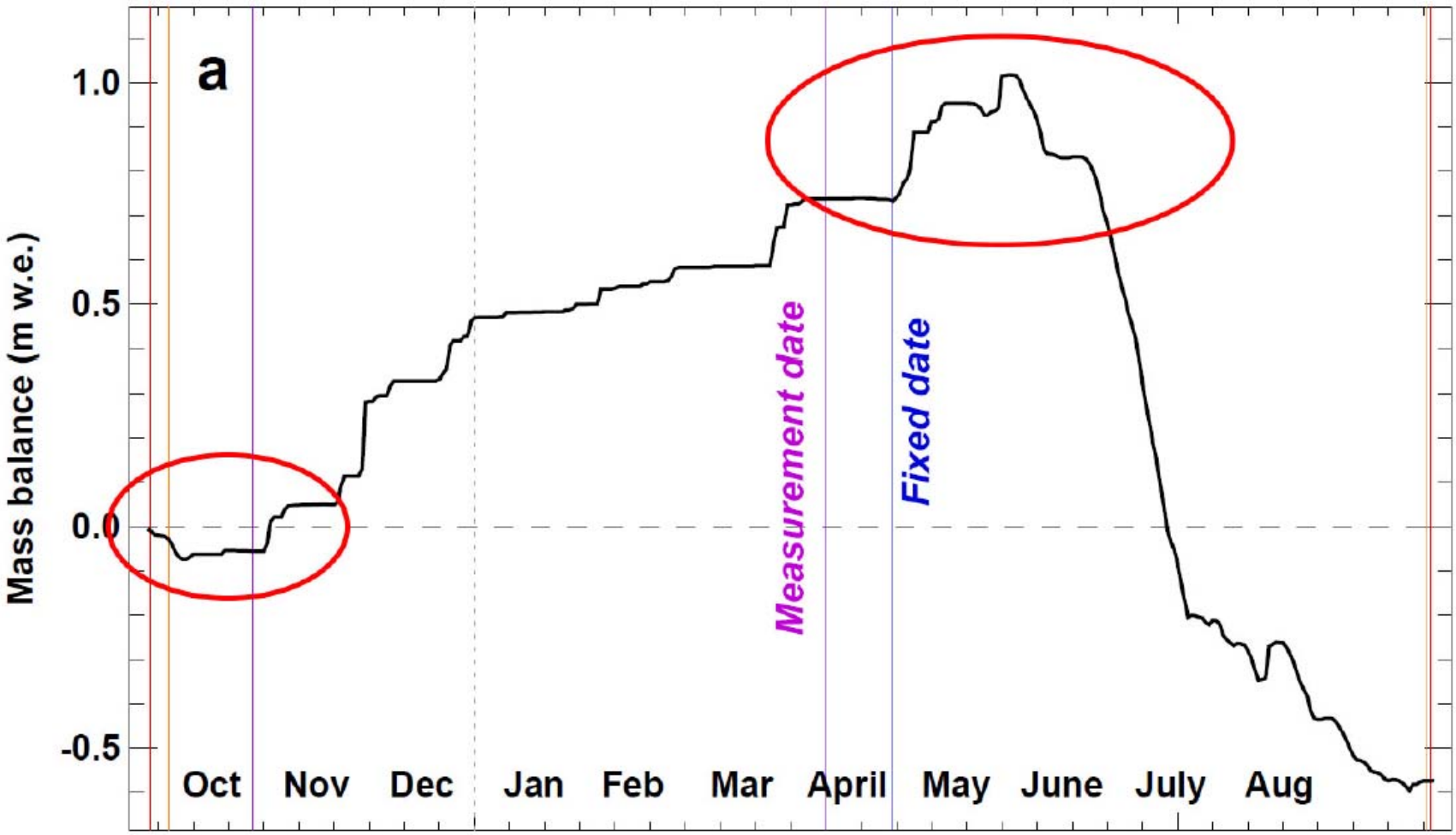
Step 2: Annual mass balance



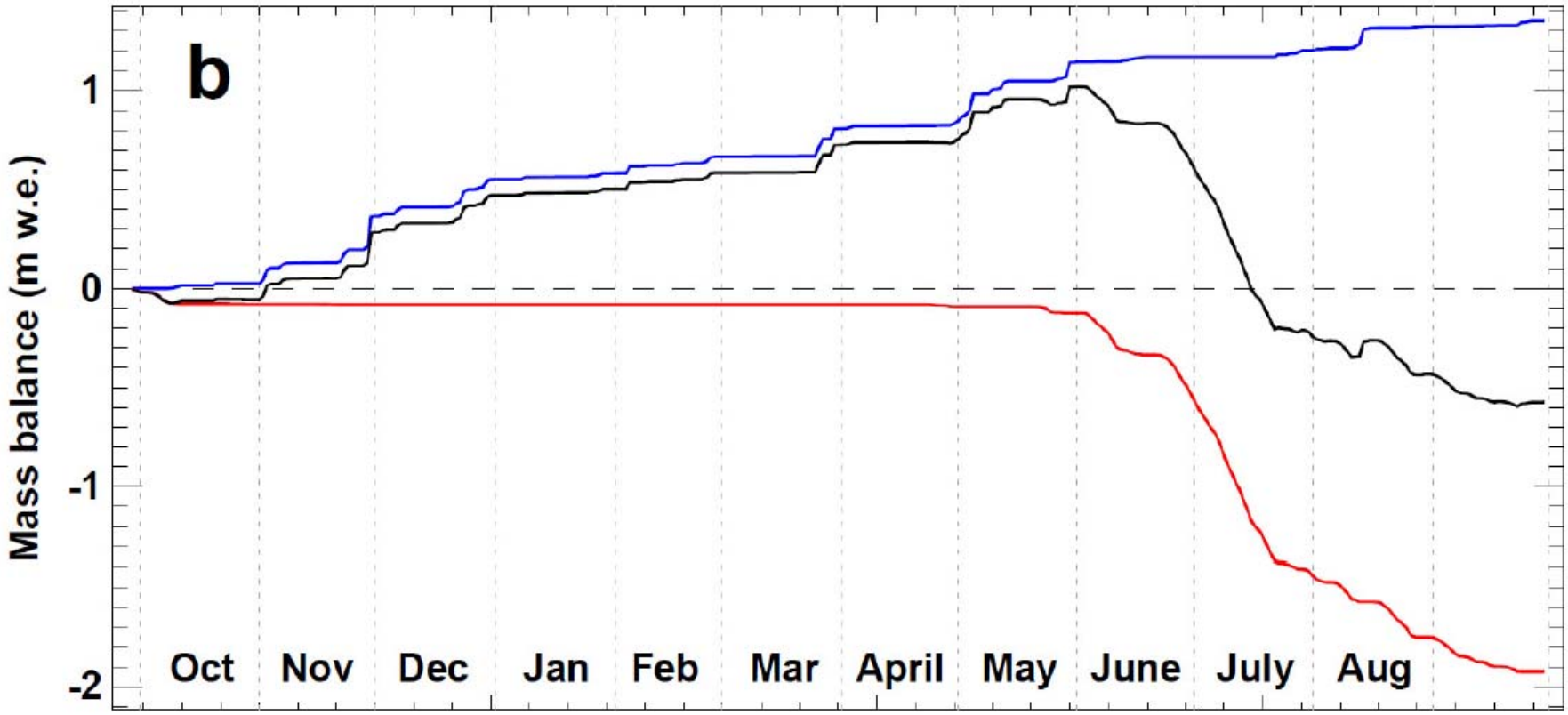
Final correction



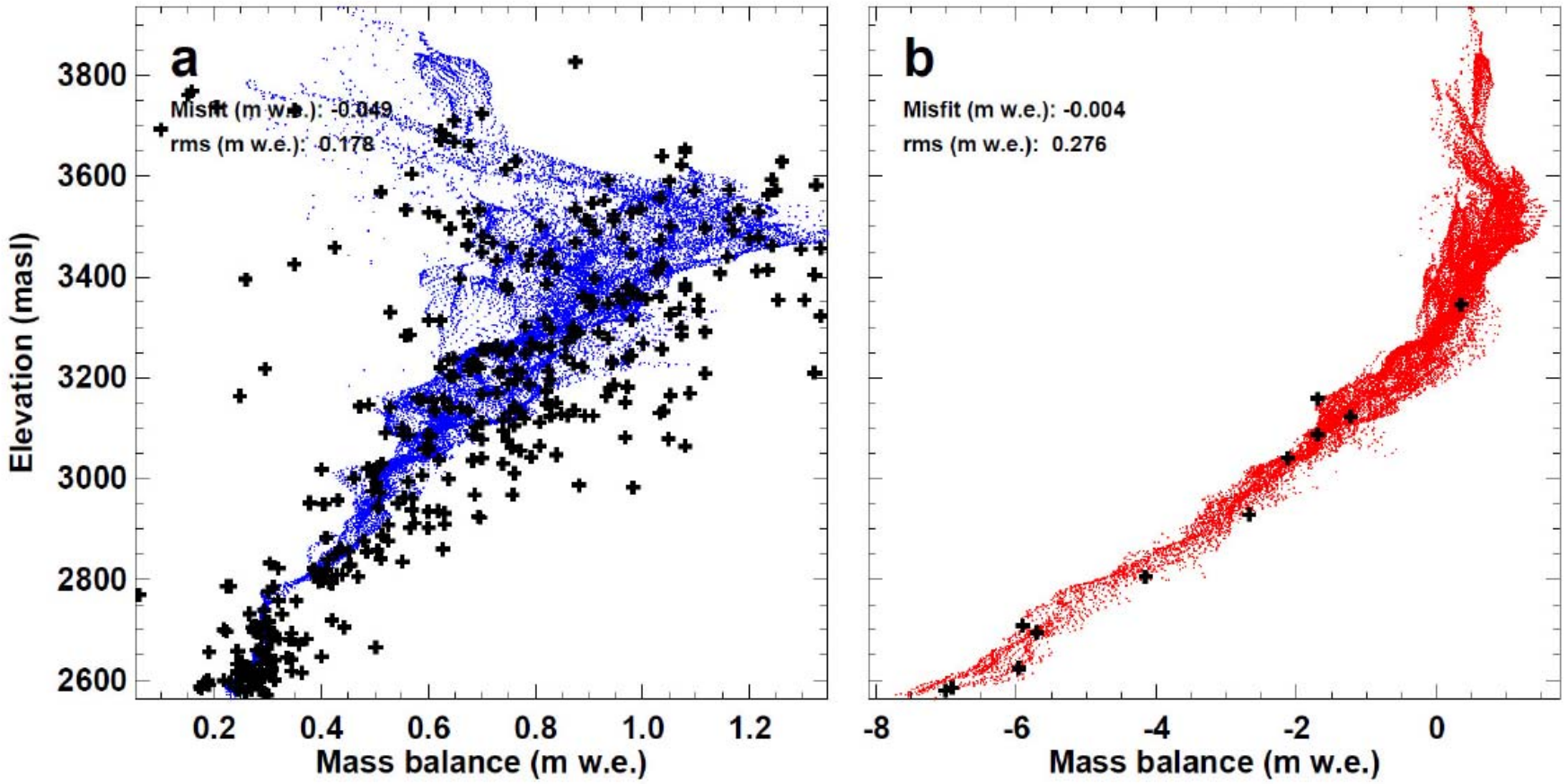
Inferred daily mass balance series



Separation of mass balance components



Elevation distribution of mass balance



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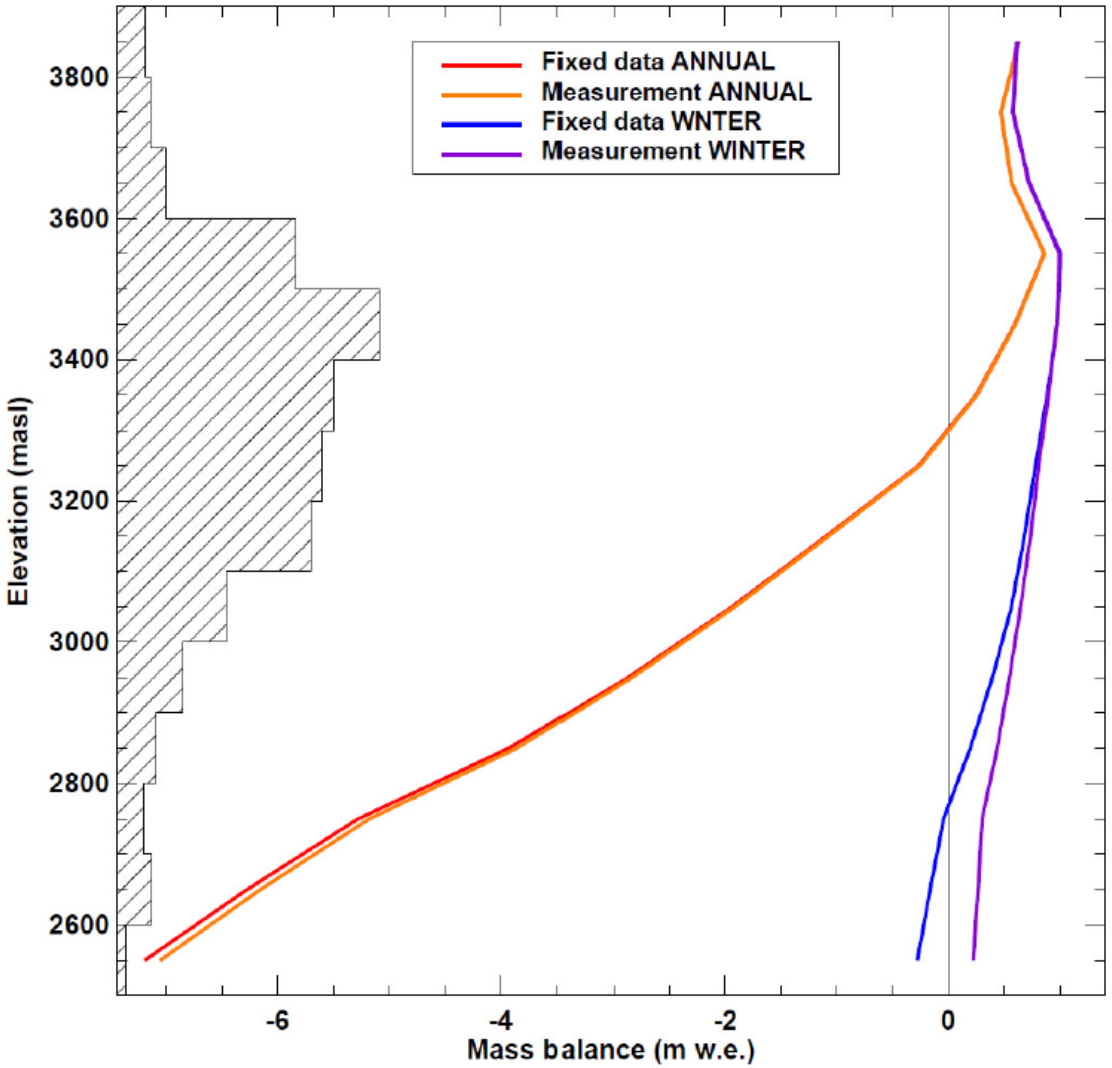

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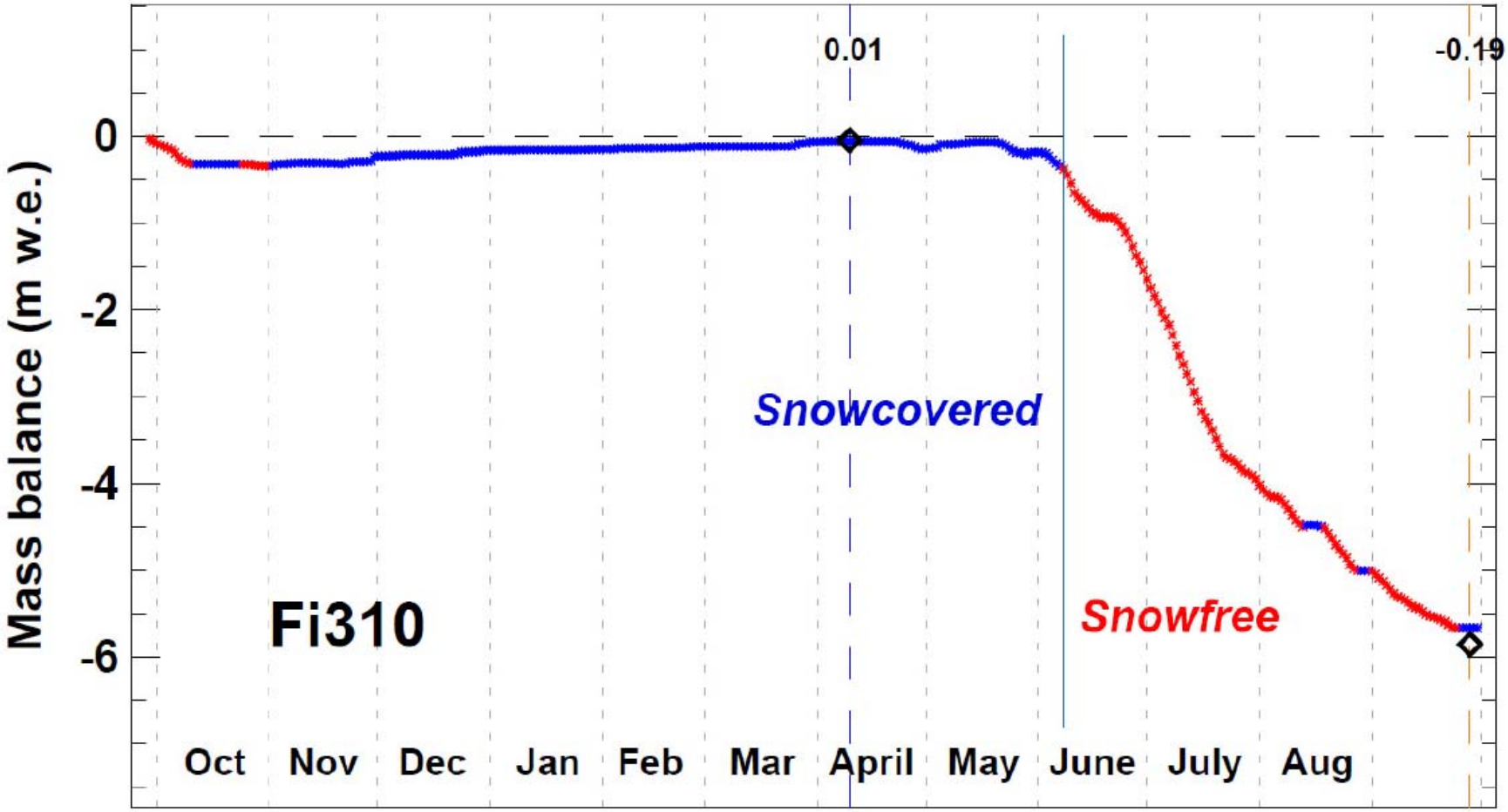

Conclusion

- Evaluation of mass balance using a consistent, automated method
- Important advantages compared to traditional evaluation:

→ Extrapolation using physical relations

→ Use information contained in winter snow measurements

→ Daily resolution from seasonal surveys, correct varying periods

- BUT: (1) Requires nearby meteorological measurements, (2) does not allow integration of the observers' knowledge