



CRAMPON - α

Cryospheric Monitoring and Prediction Online –
Alpha phase (ramp-up)

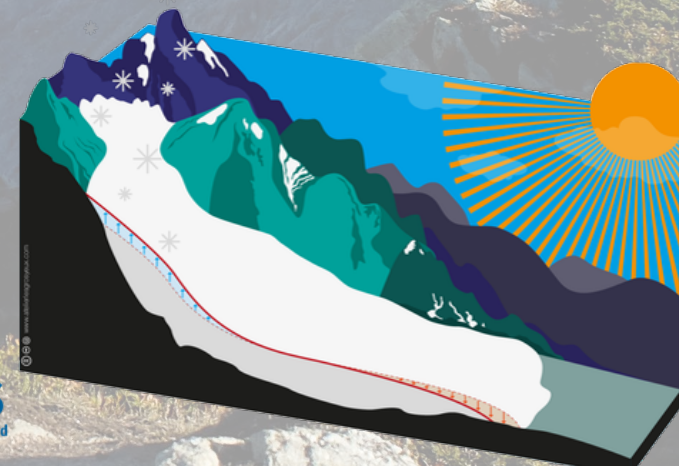
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Christophe Ogier, Leo Sold, Lea Geibel, Daniel Farinotti



ETH zürich



Laboratory of Hydraulics,
Hydrology and Glaciology

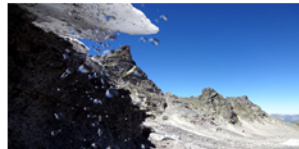


Motivation: No water in the hot summer months?



- Countrywide, daily glacier mass balance estimates could help to better manage water resources in future dry spells
- Frequent observations are essential to support mass balance models in giving frequent estimates, but field work is expensive

Near-Real Time Mass Balance = Model + Data Assimilation



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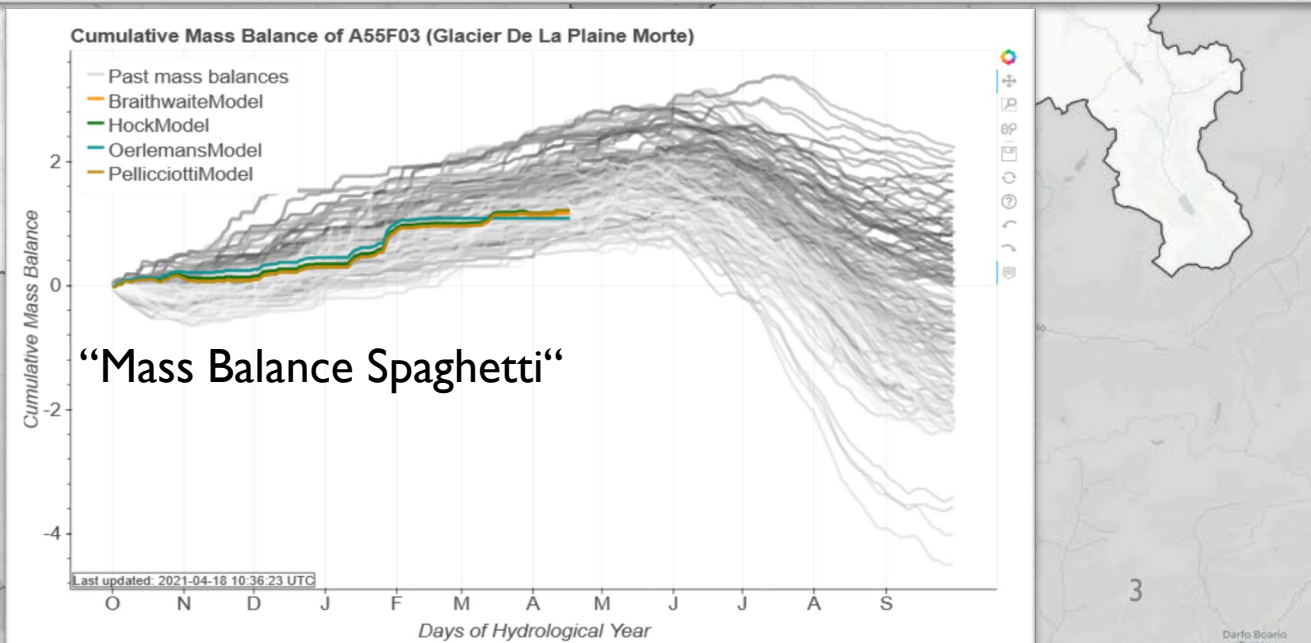
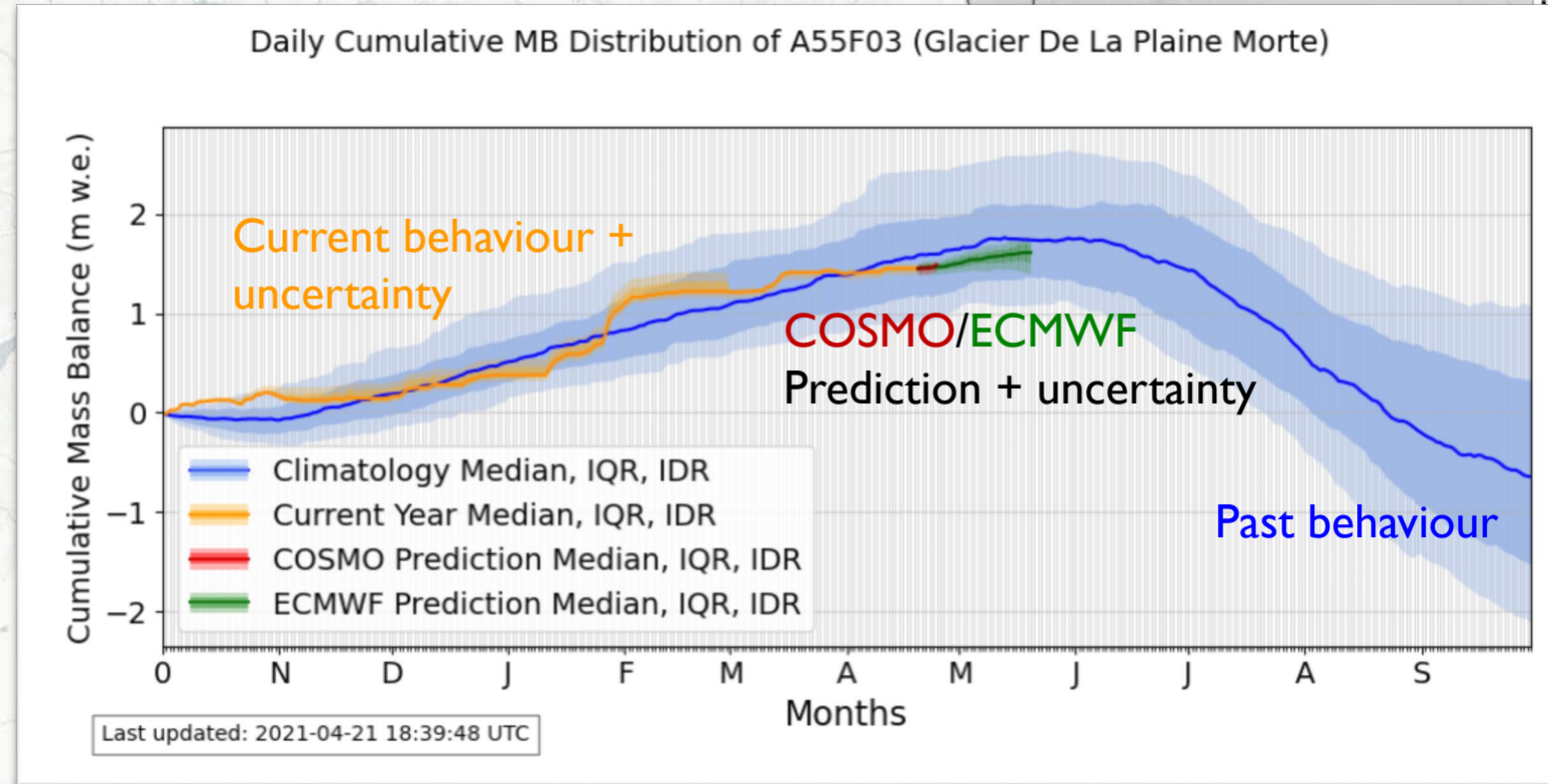
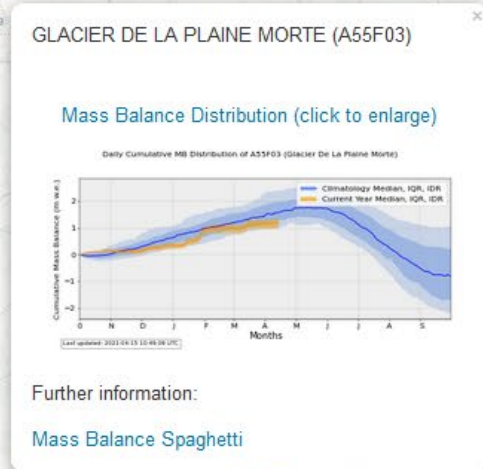
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IDEA:

- 1) Take all easy-to-acquire observations together,
- 2) assimilate them into a mass balance model ensemble, and
- 3) create a web platform for near real-time glacier mass balances, their predictions and uncertainties

Platform Overview

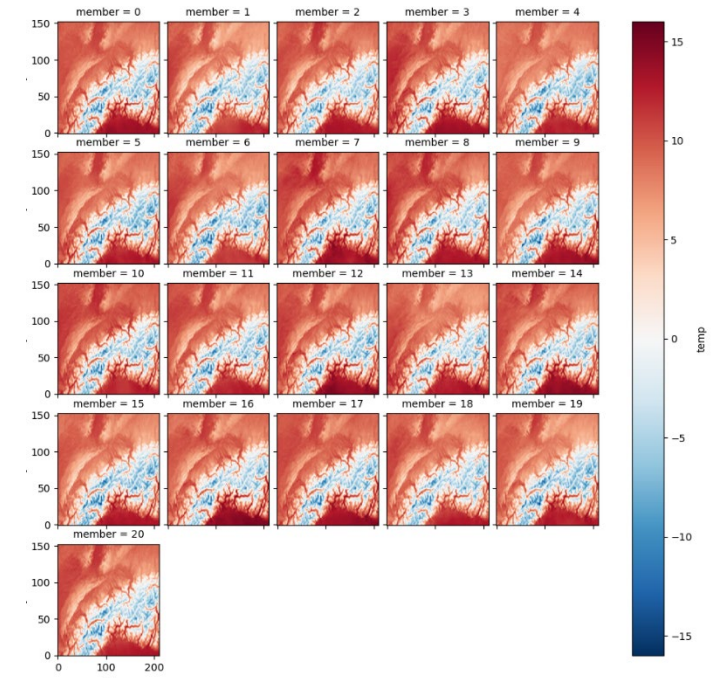
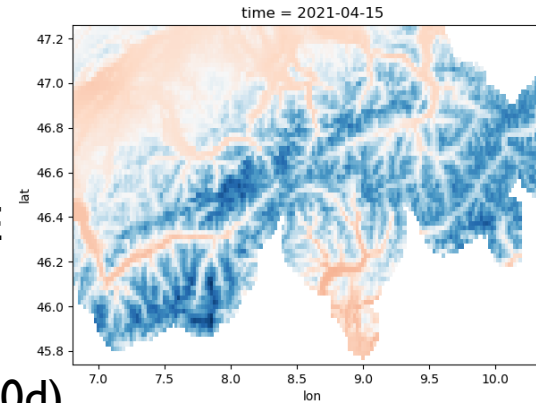


PRODUCT: A map of Switzerland, where it is possible to query near real-time glacier mass balance analyses and predictions

Meteorological Input

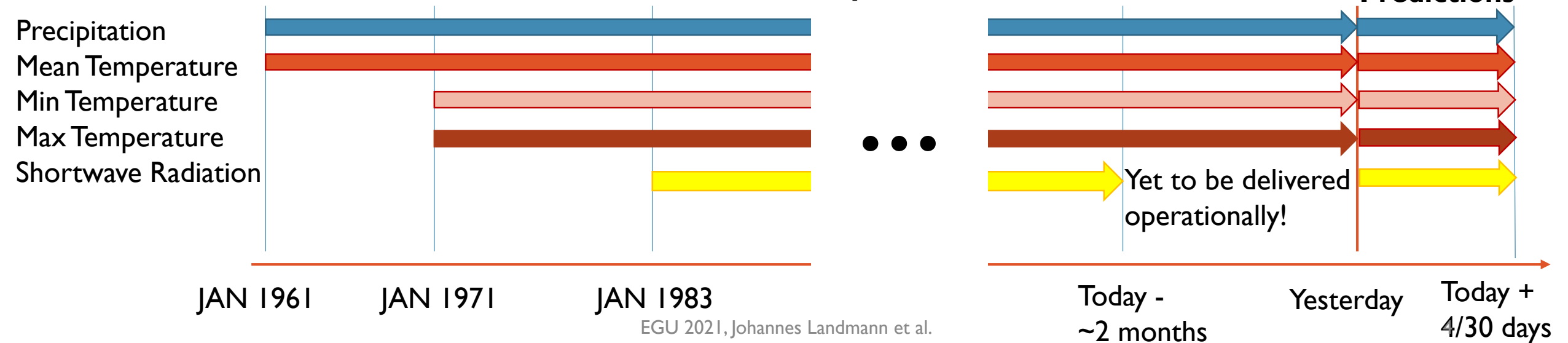
ANALYSES: ~2km gridded, daily products from MeteoSwiss, including error estimates

FORECASTS: ~2km gridded product from COSMO-E with 21 runs, aggregated to daily scale (lead time 5d); 0.5 deg extended range ECMWF forecast (50 runs, lead time ~30d)



Gridded Analyses , MeteoSwiss

COSMO/ECMWF Predictions



Ensemble modeling

Mass balance is calculated based on model ensembles

Mass Balance

Ensemble of four temperature index / simplified energy balance models:

- 1) **Braithwaite 1989** (temperature only)
- 2) **Hock 1999** (temperature & potential irradiation)
- 3) **Pellicciotti 2005** (temperature and shortwave radiation)
- 4) **Oerlemans 2001** (temperature and shortwave radiation)

=> two more coming up

Snow

No explicit model ensemble, but ensemble resulting from the mass balance and albedo ensembles

Albedo

Ensemble of three aging parametrizations:

- 1) **Brock 2000** (temperature and precipitation)
- 2) **Oerlemans 1998** (time and precipitation)
- 3) **(Dutra 2010; yet to be applied)** (precipitation)

The ensembles are generated through:

- 1) Different physical models
- 2) Uncertain meteorological input
- 3) Uncertain input parameters

=> A multi-model mass balance ensemble

Glacier categories by observations

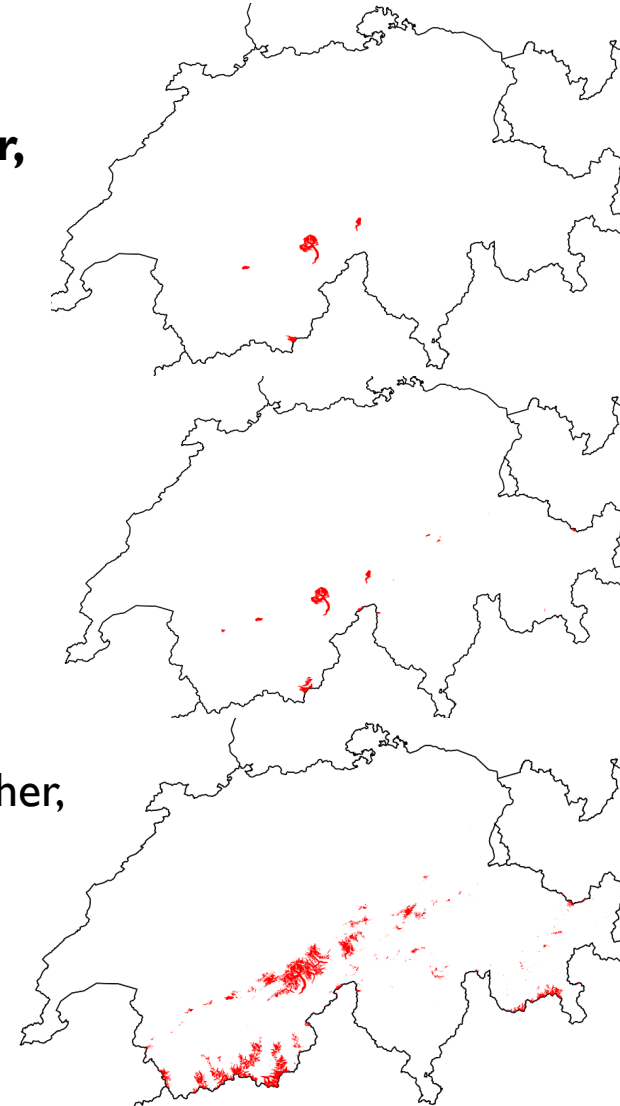
(bold=already operational)

Cat. III	   	Cameras, satellite observations, seasonal observations volume changes Total number: 4
Cat. II	  	Satellite observations, seasonal observations, volume changes Total number: 17
Cat. I	 	Satellite observations, volume changes, Total number: ~1900

Rhonegletscher, Gr.Aletschgletscher,
Findelengletscher,
Glacier de la Plaine Morte

Silvrettagletscher, Allalin, Basòdino,
Tsanfleuron + 13 others

Hüfifirn, Gornergletscher, Unteraargletscher,
Vadret da Roseg + ~ 1900 others

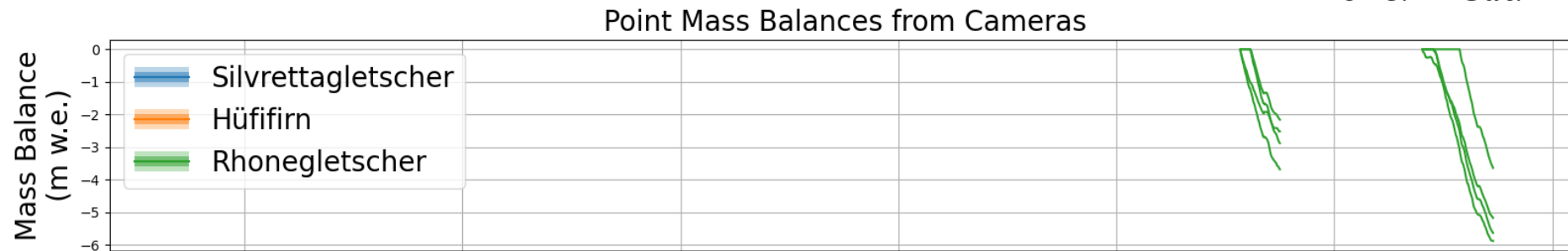


Example observations since the year 2015

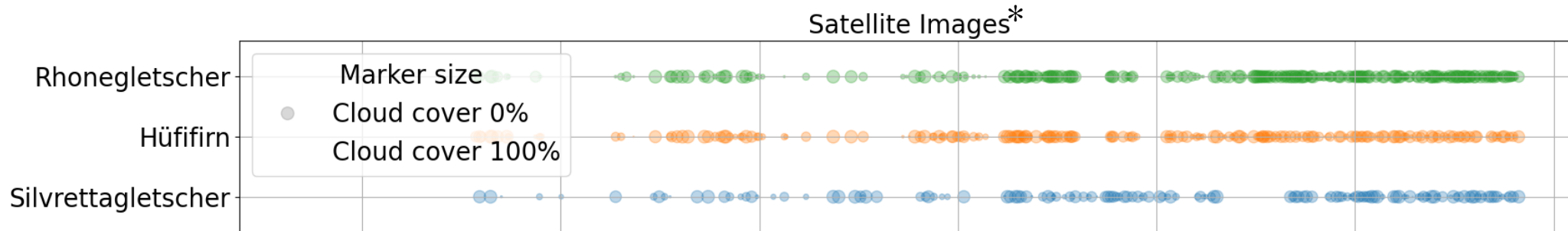
Hüfifirn: Cat. I
Silvretta: Cat. II
Rhone: Cat. III

Cameras

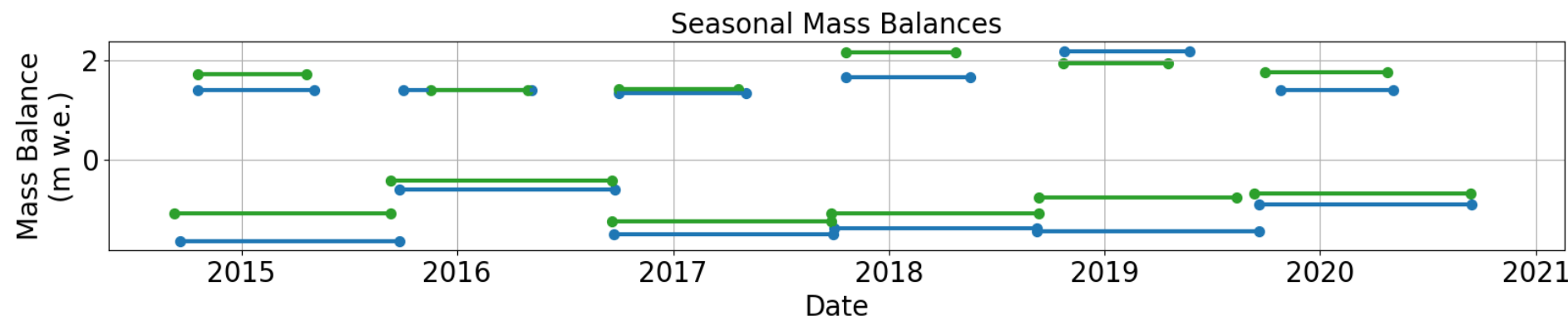
see also [contribution by Sold et al.](#)



Satellites (Sentinel-2)



Glac. Method + Interpolation

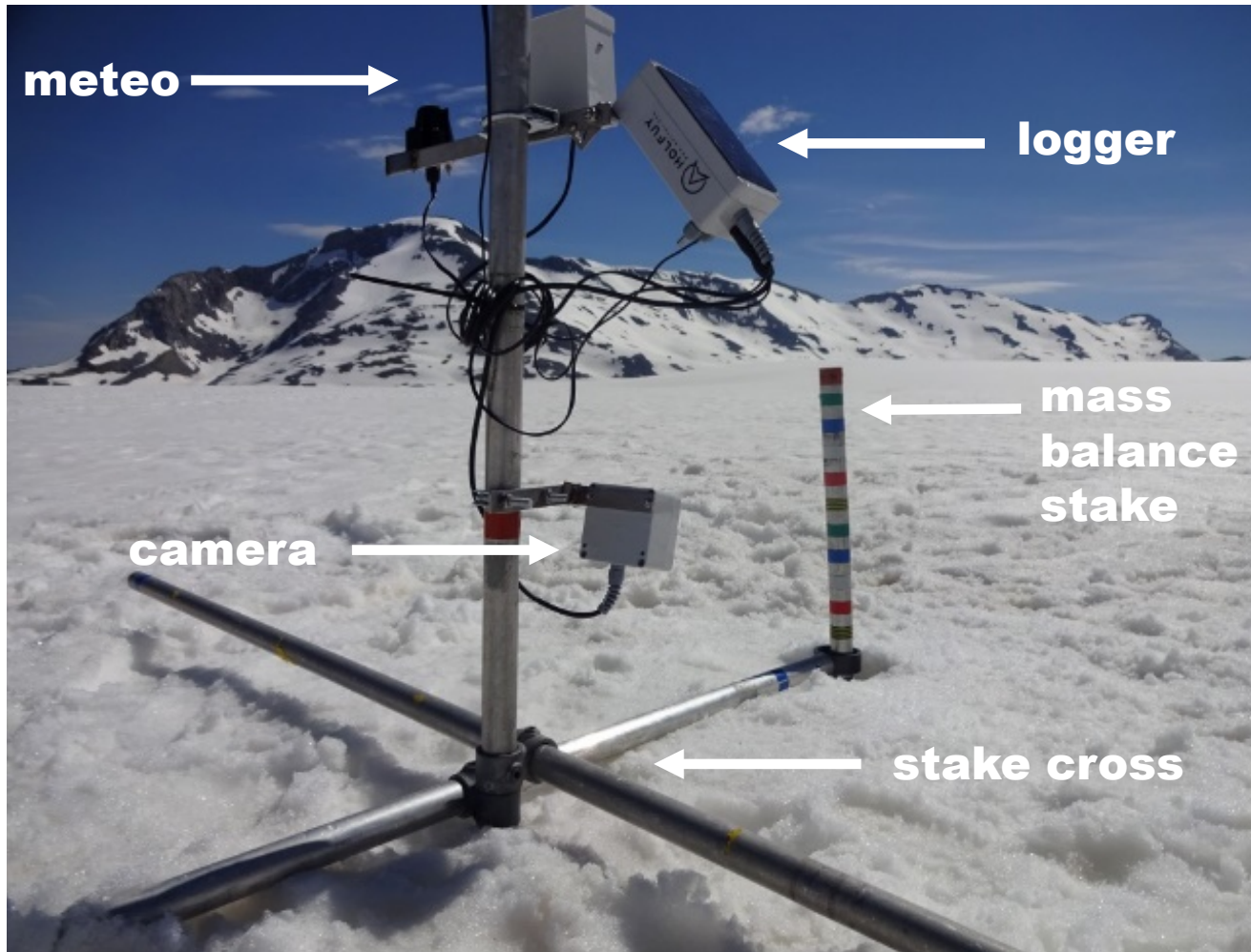


All glaciers have volume changes in the past

EGU 2021, Johannes Landmann et al.

*Image processing between 2015-07 and 2018-03 not complete due to technical issues on the data provider side

OBS: Real-time cameras



Click on the links for external resources:

If you want to know how we read these camera observations with **computer vision**, click [here](#)

If you want to see **live pictures** from our cams: Right now we have cams out on [Grosser Aletsch](#), [Findelen](#), and [Rhône](#)

To watch **time lapse videos of an entire season**, go to [this](#) page



- low maintenance
- daily melt estimates
- low cost!

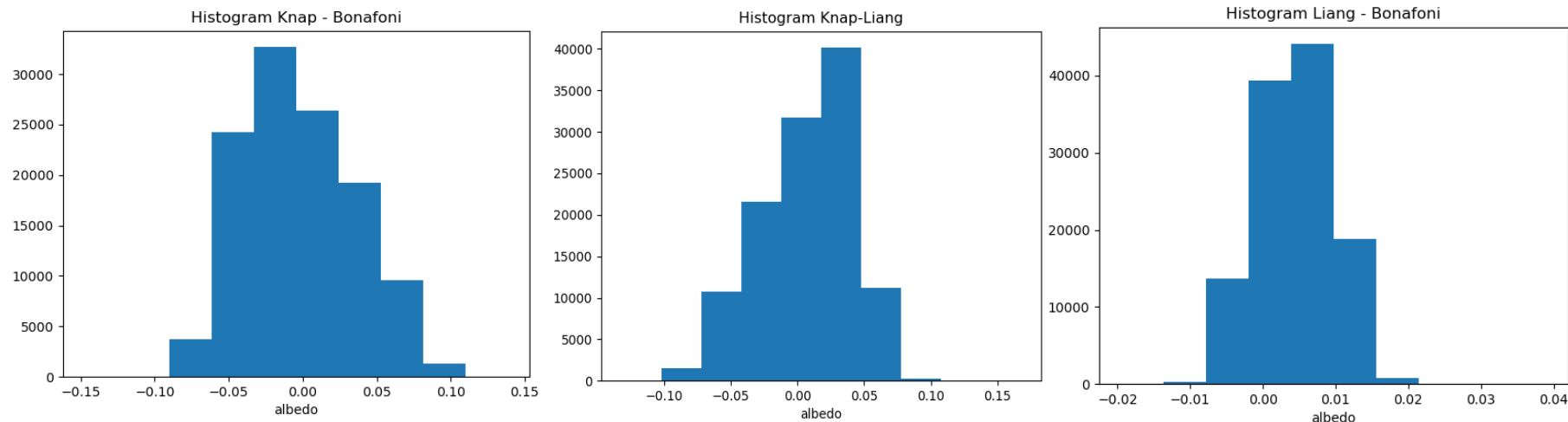
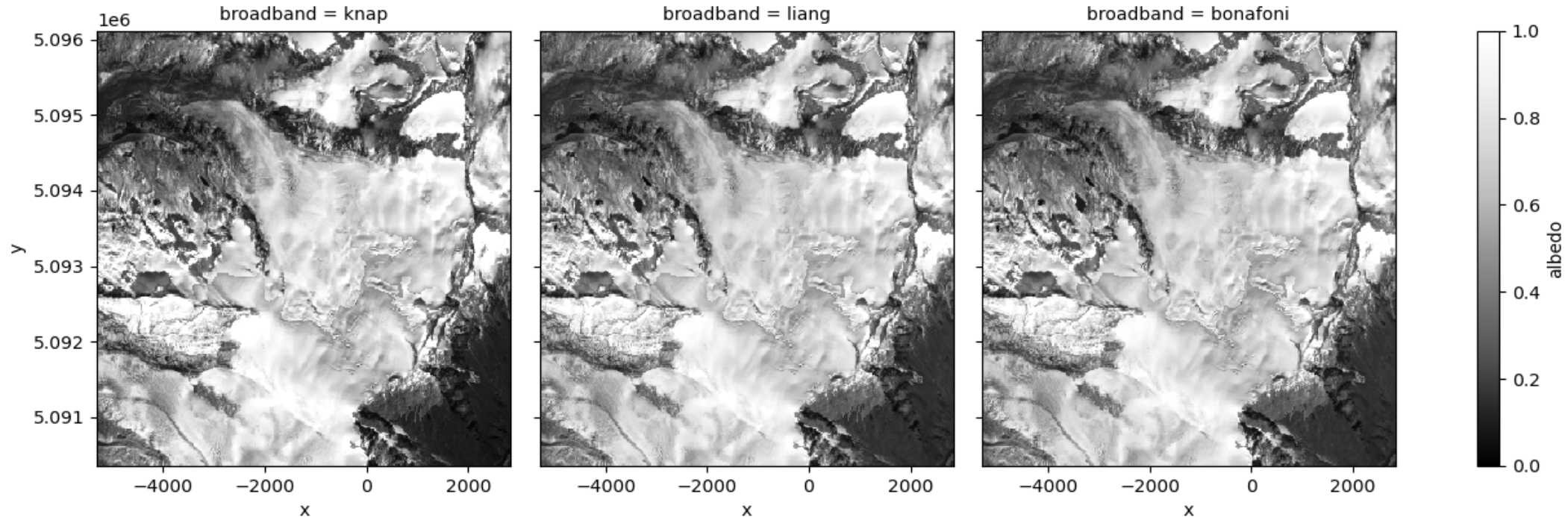


- accumulation measurements are challenging
- indirect estimate of melt



OBS: Albedo

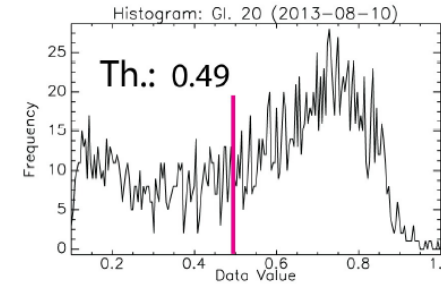
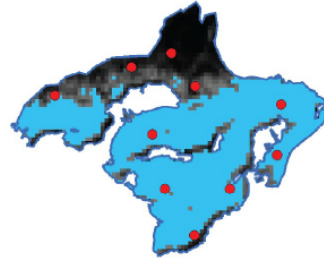
Processing using three different narrow-to-broadband conversion algorithms



Algorithms agree reasonably well, differences help to estimate the uncertainties

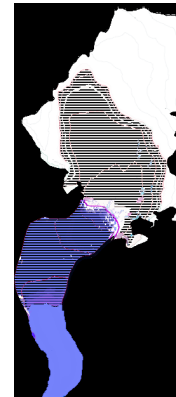
OBS: Transient Snow Line Algorithms

1) Rastner et al. (2019)



Otsu thresholding of near-infrared histogram

2) Naegeli et al. (2019)



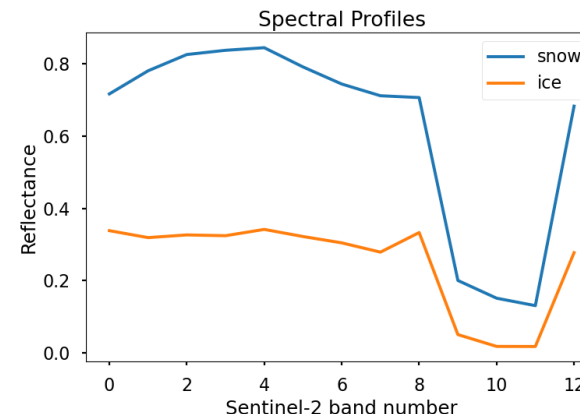
Classifying broadband albedo & evaluating its elevation gradient in the „ambiguous area“

3) Naegeli et al. (2019) „alternate“

$$\frac{\partial \alpha}{\partial z}$$

4) Linear Spectral Unmixing

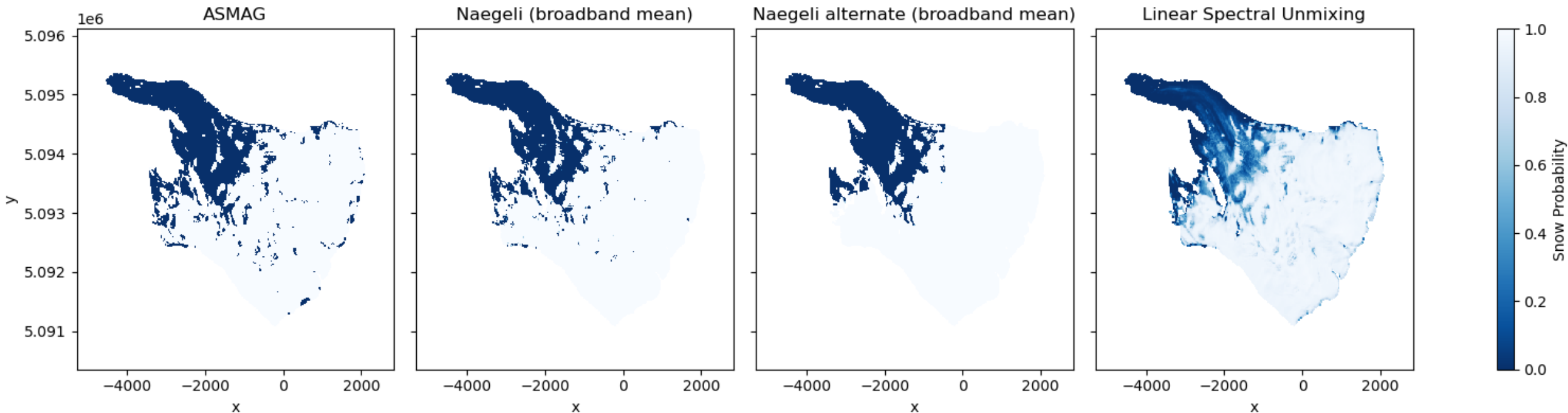
similar to Kneib et al. (2021), but with custom endmember detection algorithm



Matching spectral profiles of template classes snow/ice (“endmembers”)

OBS: Snow Line Results

Example method comparison on 2020-08-07, Findelengletscher region



Very robust method if the glacier has a snow line. Tends to fail when glacier is fully snow covered or only bare ice.

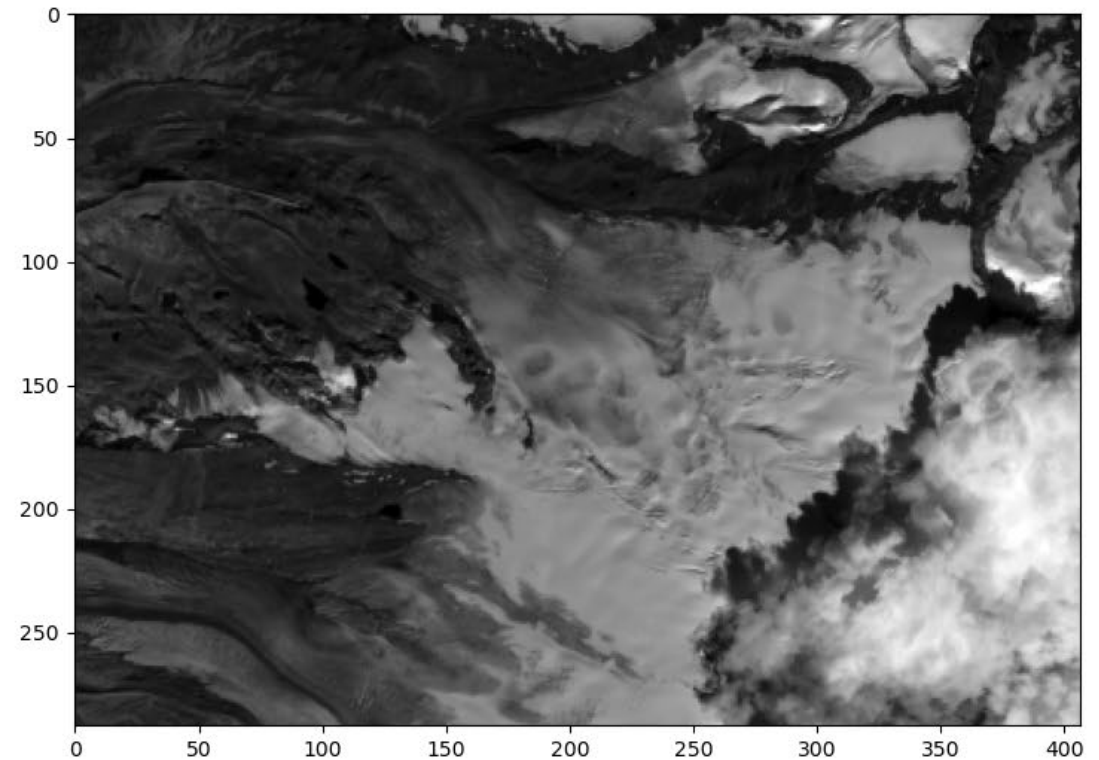
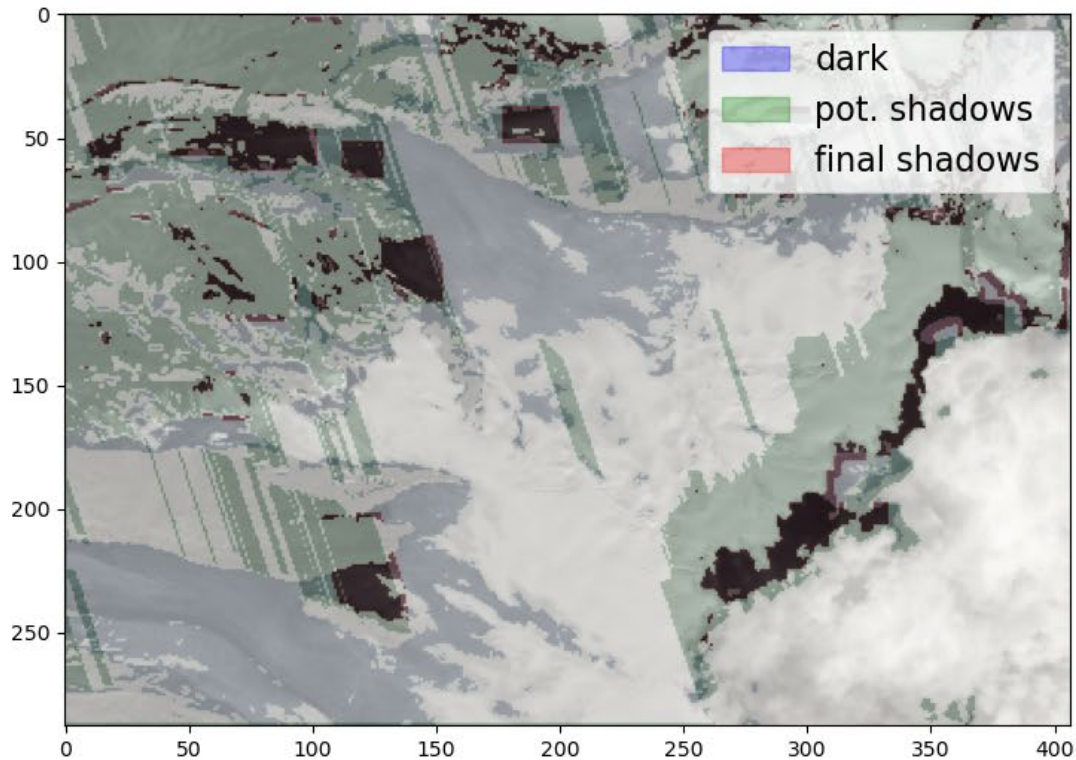
Works in all cases. Somewhat arbitrary choice of critical radius and sometimes problems with finding steepest albedo gradient.

Like Naegeli, but with individual critical radius and iterative gradient detection. Removes clutter. Computationally a little more expensive.

Gives an actual probability for each pixel to belong to either of the endmembers. Very sensitive to false cloud/cloud shadows classifications.

OBS: Additional cloud/cloud shadow removal

Necessary to remove false negative cloud (shadow) classifications in ESA product

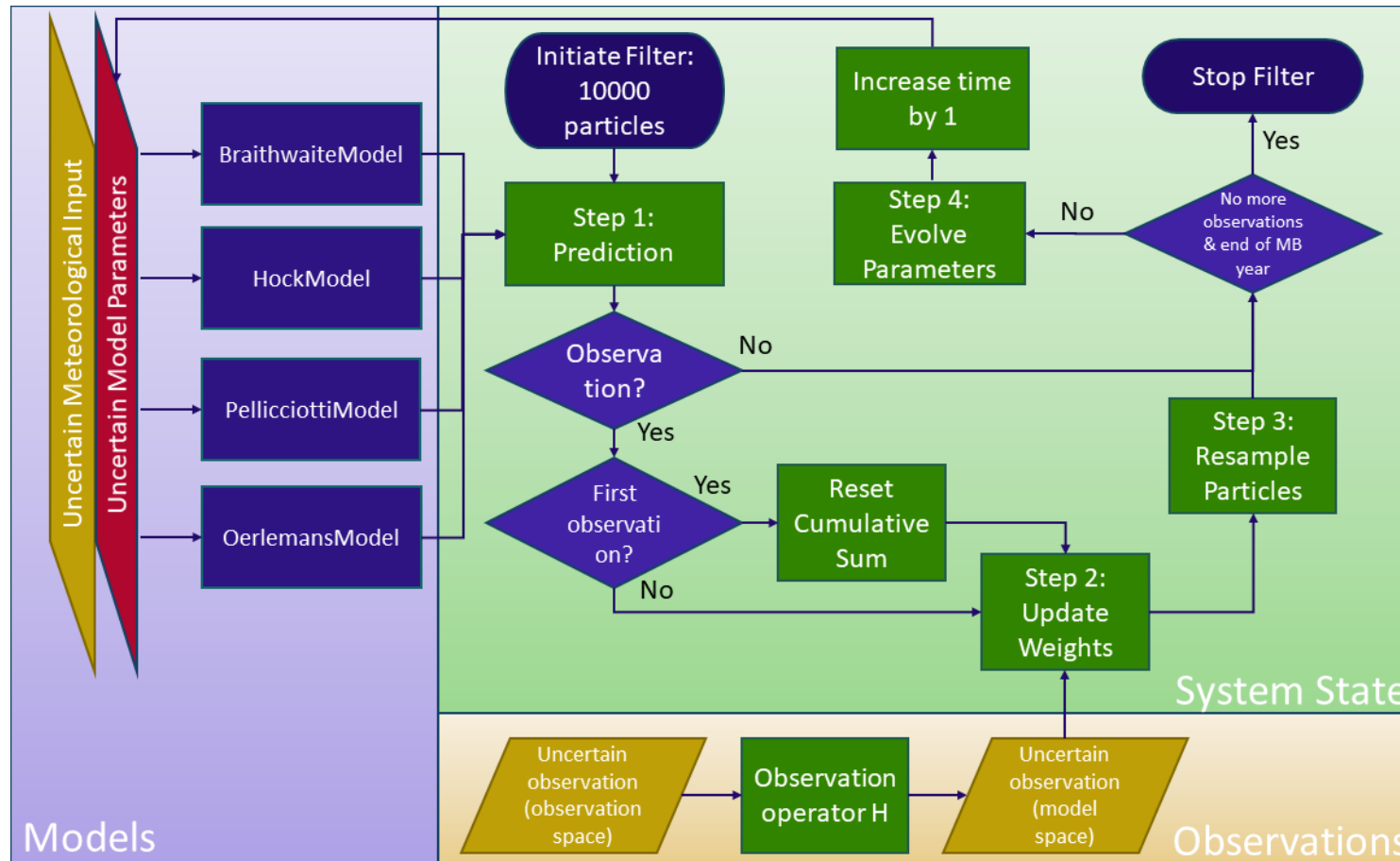


ESA cloud mask/scene classification contains a lot of false negatives: we want to be conservative!

- 1) Classify clouds with a stricter thresholding (modified from [geeguide](#))
- 2) Track cloud shadows onto the glacier (modified after G. Donchyts, Deltares, NL)

Data assimilation scheme overview

Augmented State Ensemble Particle Filter with custom Resampling



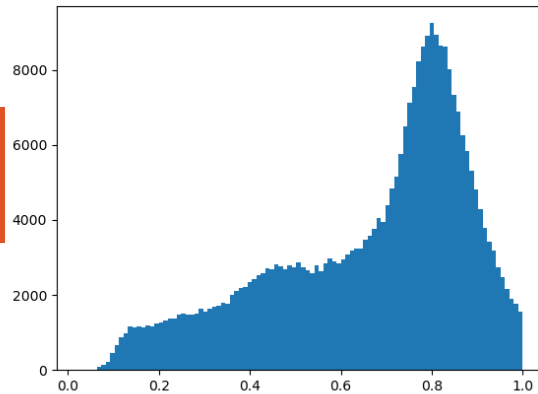
This is valid for the direct assimilation of mass balances. For assimilating albedo, we are testing to run a separate filter.

For a detailed description on how the assimilation scheme works, see our paper in [The Cryosphere Discussions](#)

Albedo Assimilation scheme (prov.)

Albedo distribution, Findelengletscher, Switzerland, 2020-08-07

Real albedo distribution

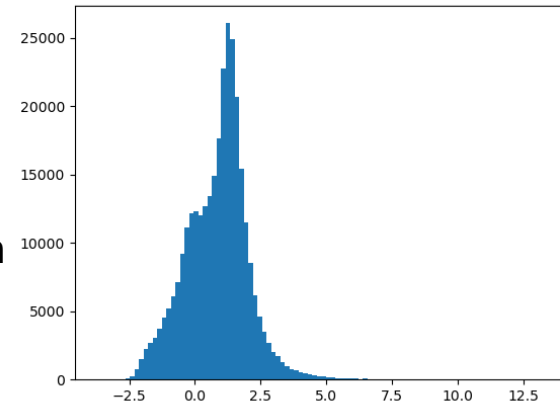


Albedo
Observation

Gaussian Anamorphosis

Logit-normal transformation

Transformed distribution

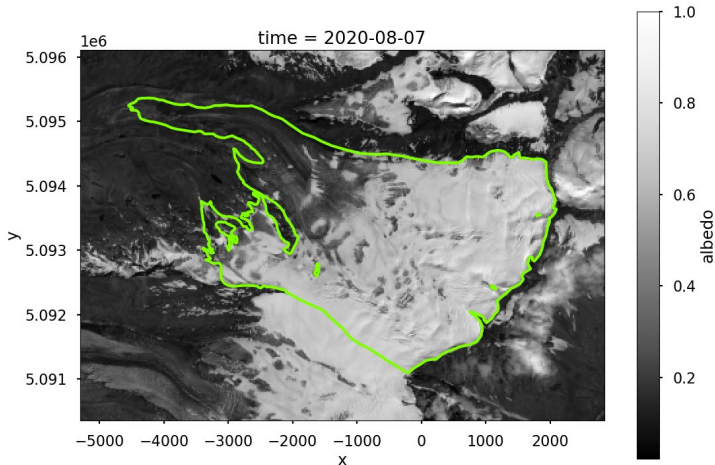


Albedo Ensemble
Prediction

Gaussian
Anamorphosis

Particle Weights
Update

Particle Resampling



Current glacier status

Overall status of all 19 operational glaciers (2021-04-20):

TOP

100

80

60

40

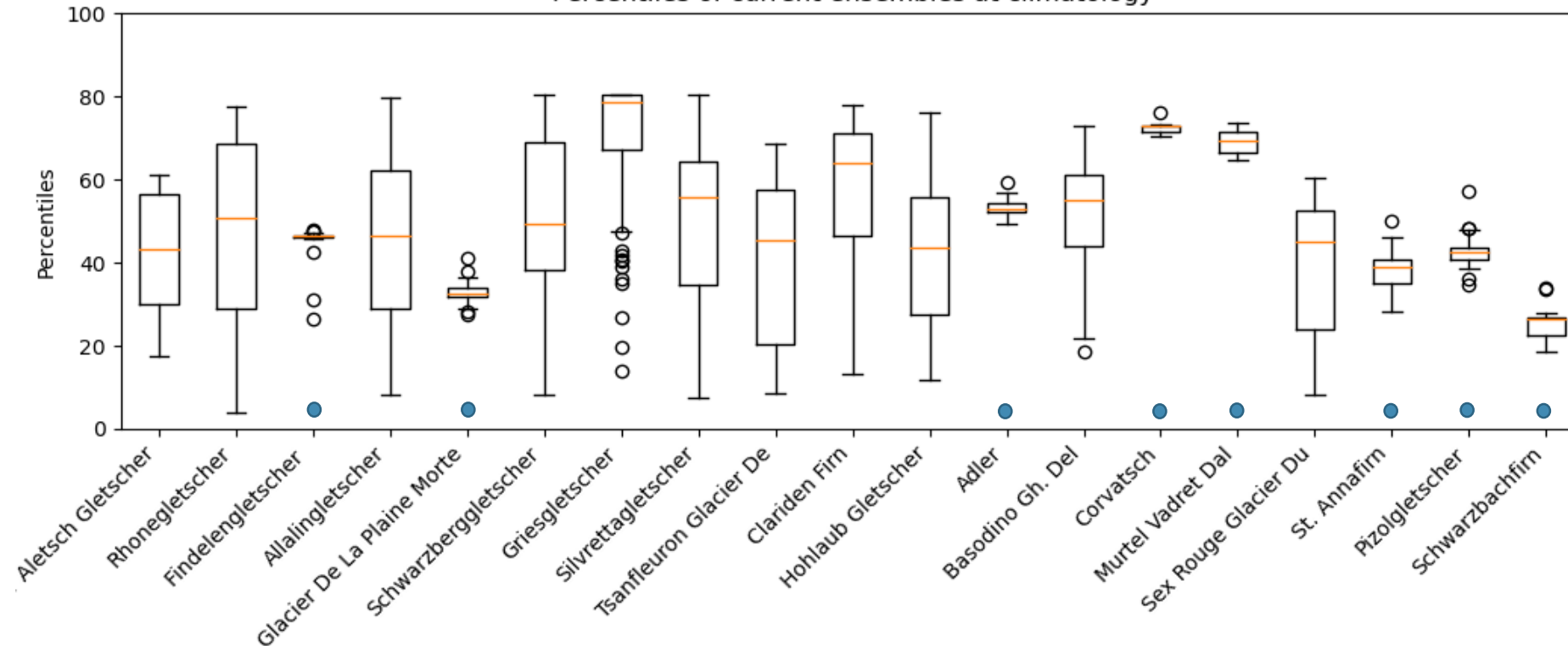
20

0

We're average!
(median=50.0,
std=18.7)

FLOP

Percentiles of current ensembles at climatology



Last updated: 2021-04-20

•: winter mass balance 2020/2021 already included

Coming up...

- Integrate all Cat. I glaciers into the platform
- Integrate/process all albedo observations
- Work on snow line assimilation scheme
- Extend the prediction phase (given access to seasonal predictions)
- Finalize web site content and style
- Auto-integrate machine-read camera observations
- Prepare first public online data release in Summer 2021



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