CHR-Workshop, 26-27 November 2015 , Viktorsberg, Austria

Snow and glacial melt runoff contributions to discharge in the River Rhine and its tributaries against the background of climate change

Monitoring of snow water resources in Switzerland

Integrating observational data with advanced modelling approaches

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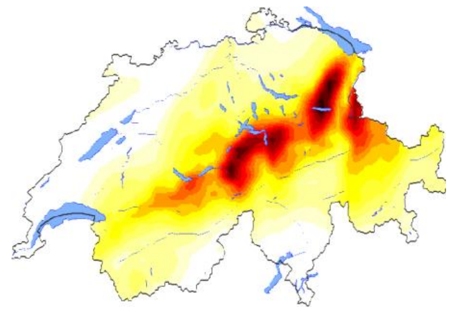
Operational snowmelt modelling in Switzerland

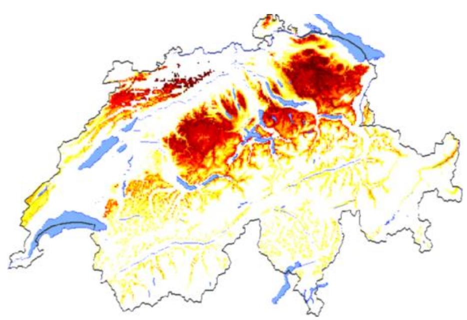
- Methods and models
- SWE reference dataset (daily, 1km, 1972-2014)

SWE Monitoring

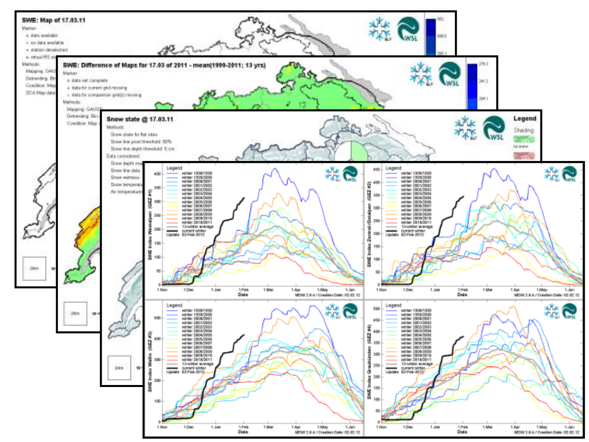


Meteo + Forecast

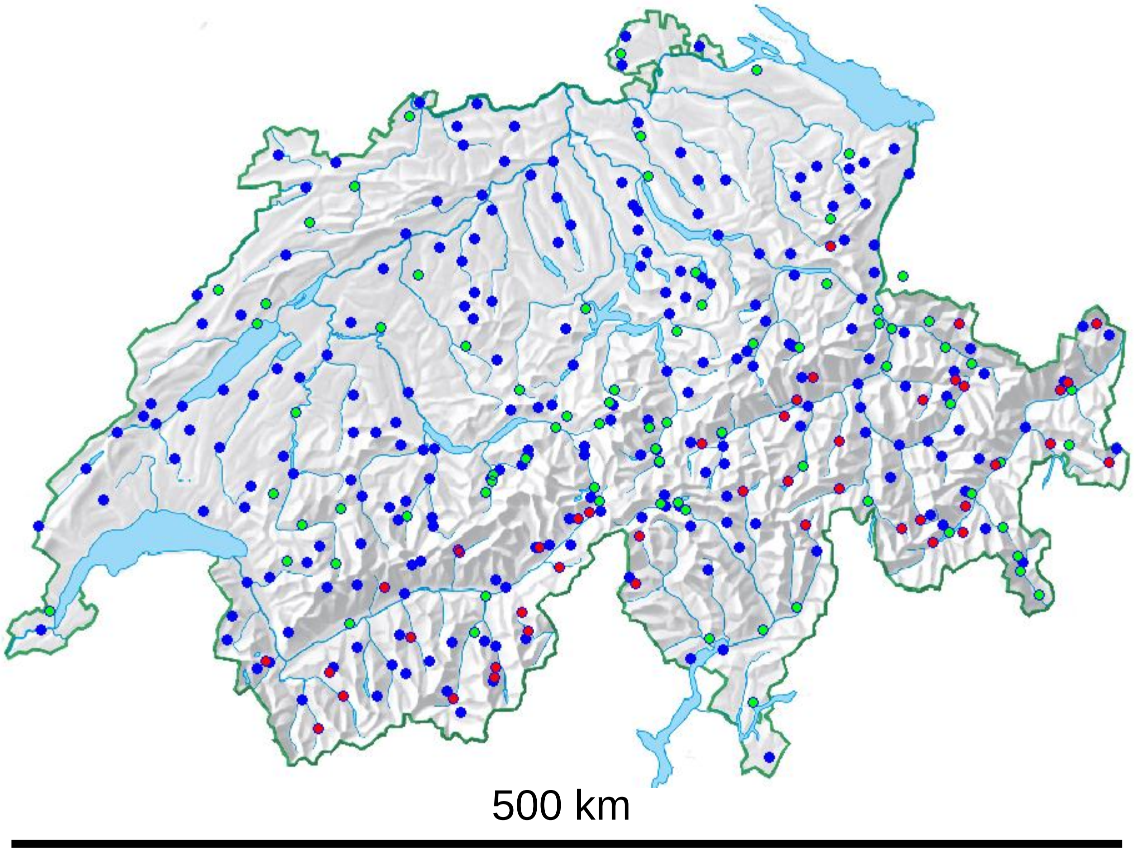
Snowmelt Model



Operational Products



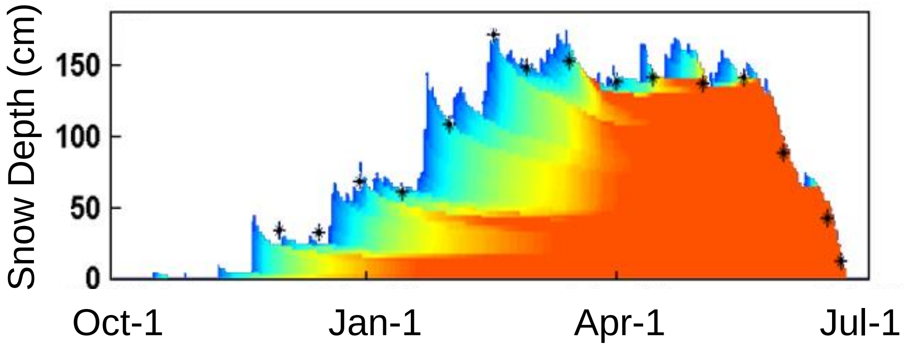
Snow monitoring / available data



- Snow depth (HS), daily, since 1998 ~400 sites
- Snow water equivalent (SWE), biweekly ~40 sites
- Longterm stations, since 1971 ~100 sites

Snow density model / convert HS to SWE

- Using daily HS data as main input
- Condition: many sites lack corresponding meteo data



Concept / key elements

#1) New snow density function

$\rho_{layer,\ t=0}$ = f(elevation, season)

#2) Densification function

$\rho_{layer,\ t} = f(\rho_{layer,\ t-1}, age_{layer})$

#3) Assimilation algorithm

If $HS_{observed} >> HS_{modeled}$ add new snow layer

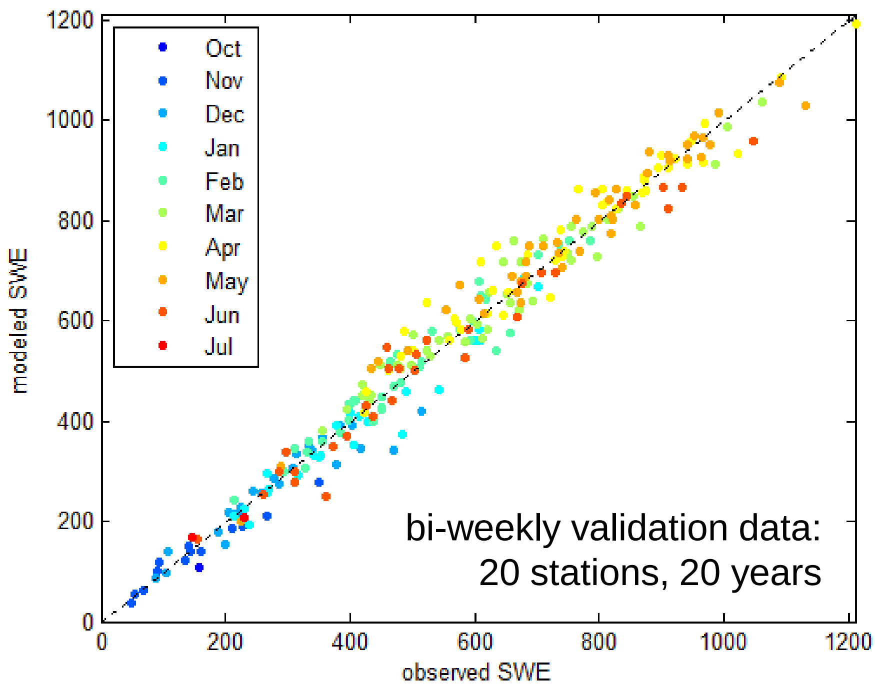
If $HS_{observed} <> HS_{modeled}$ increase / decrease densification until fit

If $HS_{observed} << HS_{modeled}$ melt snow

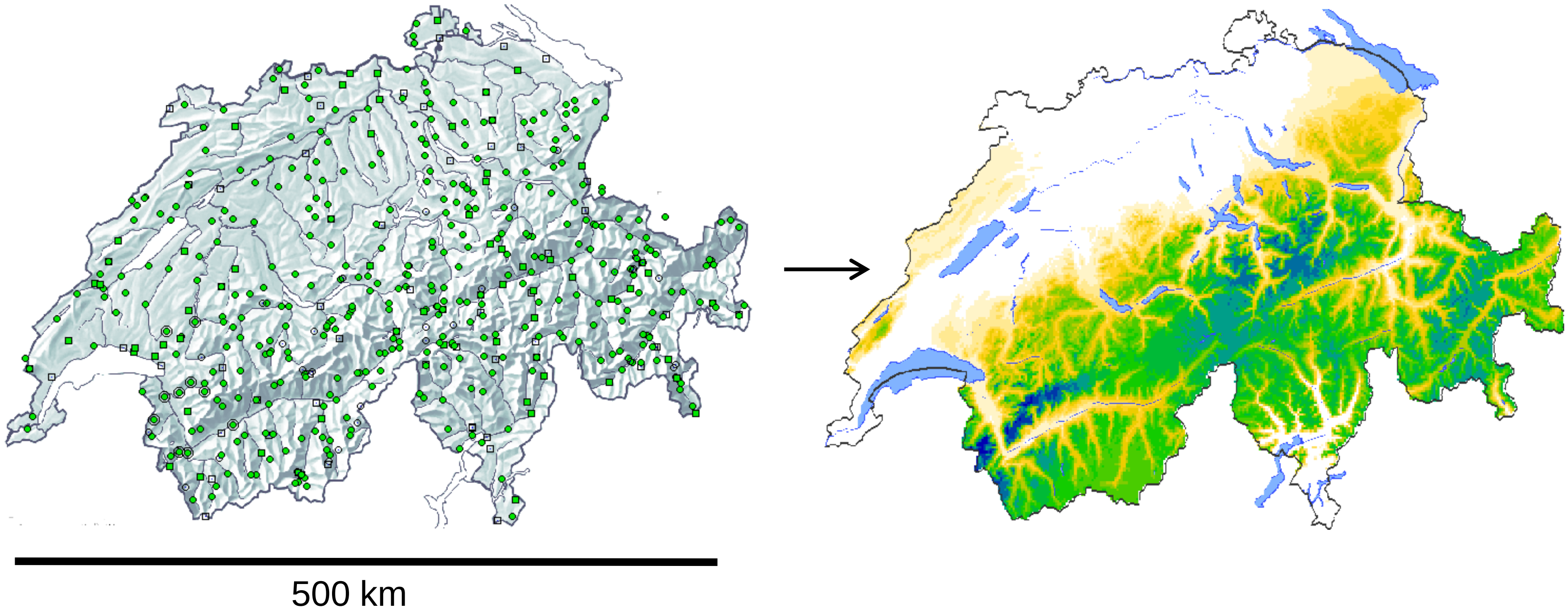
Snow density model / verification

- Using daily HS data as main input
- Condition: many sites lack corresponding meteo data

- Very robust performance
- Can deal with ephemeral snow



Snow melt model / overview



- Model #1: enhanced T-index / hourly meteo data preprocessing
- Model #2: energy balance / simplified snowpack structure (max. 3 layers)
- Output resolution: 1km / daily (#1) + hourly (#2)
- Model resolution: 1km (grid) + 25m (subgrid)

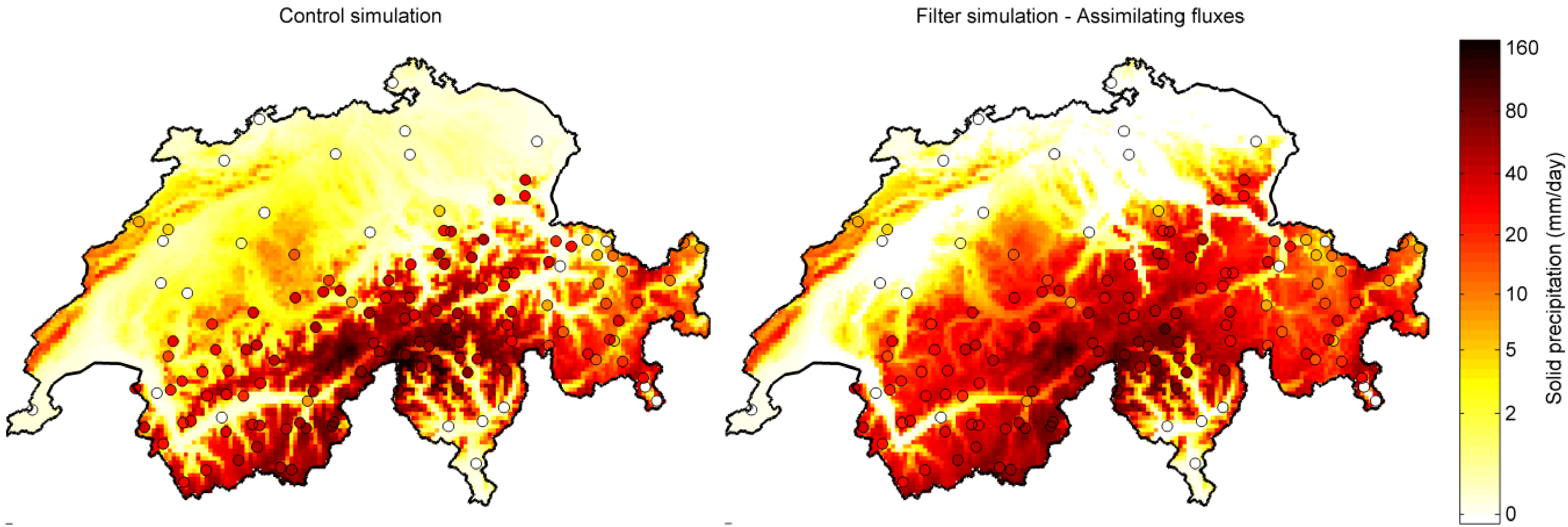
Model validation + intercomparison (#1/#2) ► Magnusson et al, 2015, WRR

Data assimiliation / integrating monitoring data and model

- Two-step assimilation of dSWE/dt (flux assimilation)

  a) Calculating precip. and precip. phase using Optimal Interpolation
  input: precipitation, temperature, observed dSWE/dt

  b) Enhance modelled snowmelt rates using Ensemble Kalman Filter
  input: observed dSWE/dt

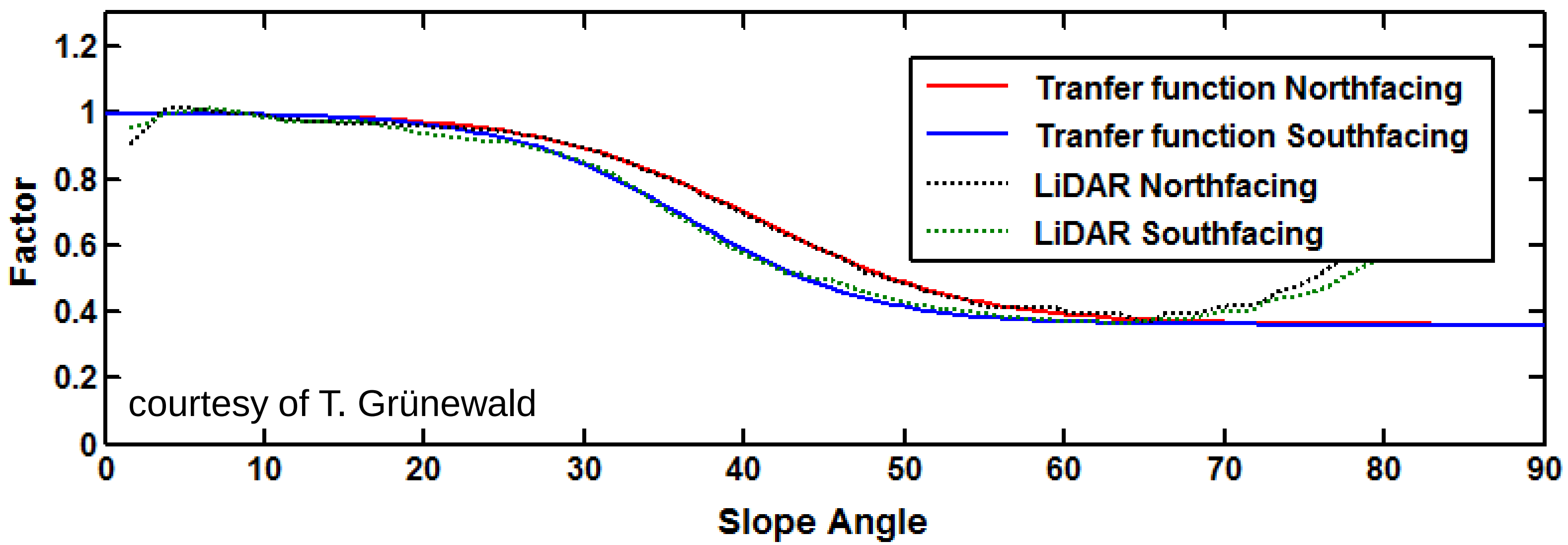


Subgrid functions / integrating terrain effects

- Necessary to account for terrain / landuse
- Implementation of transfer functions at 25m subgrid scale

Example: accounting for preferential deposition of snowfall

- Transfer function based on LiDAR-data (mid winter flights)
- Application on snowfall rates at 25m spatial resolution



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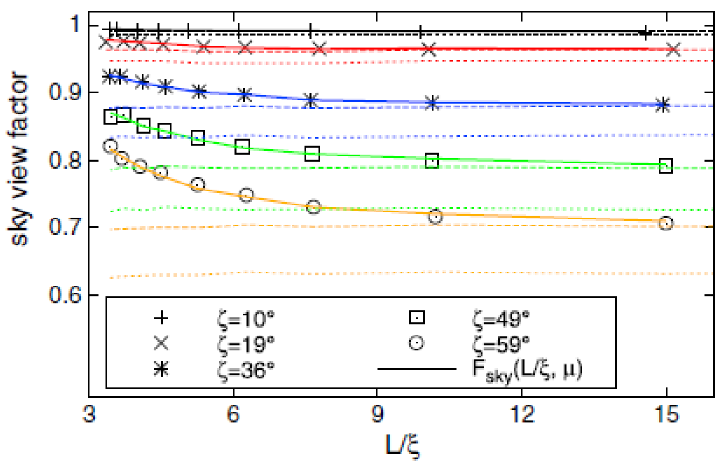
An other examples

- Terrain shading effects on short wave radiation input



Variability of snow distribution

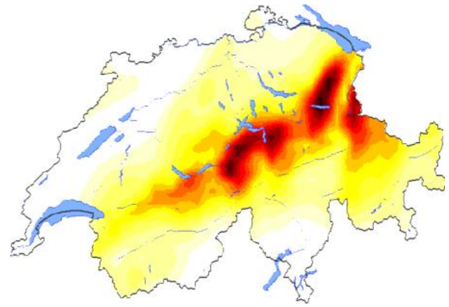
Spatial scale	large	→			small
Driver of variability	elevation	weather	aspect	slope	micro-topo
Interannual variability	strong	→			weak
Implementation in model	resolved / data		||		parameterized

2010

2011

Operational framework: integration of both snow melt models

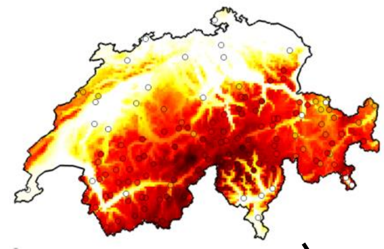
SWE Monitoring

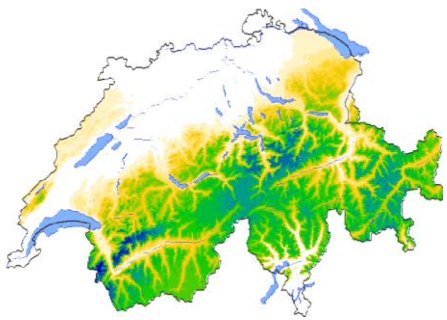


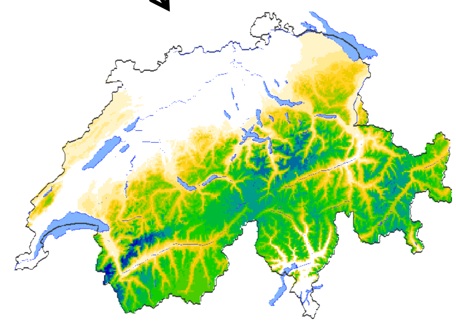
Meteo + Forecast

Updated Precip

Data assimilation







T-Index model

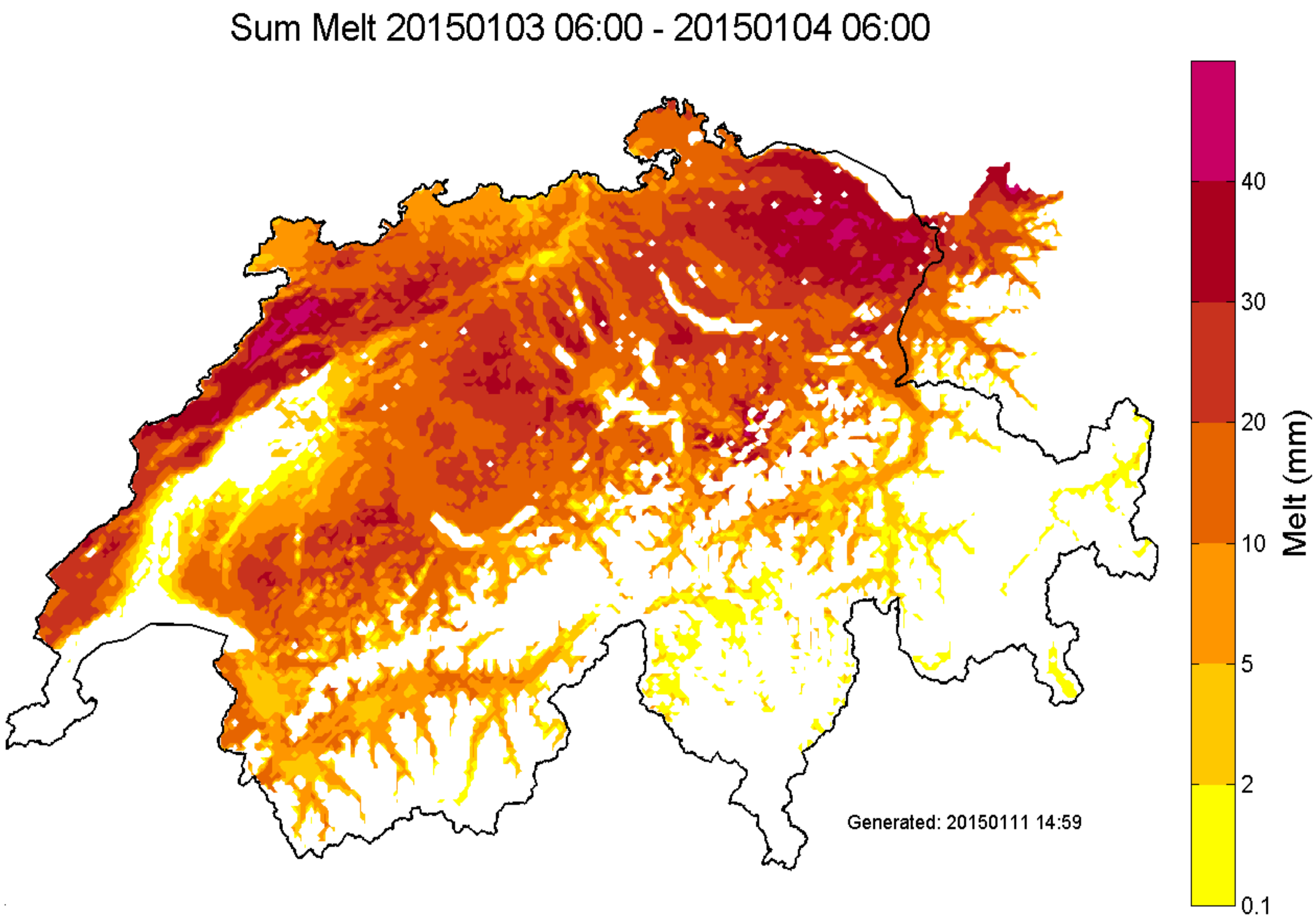
longterm / climatology / SWE

E-Balance model

forecast / event analysis / dSWE

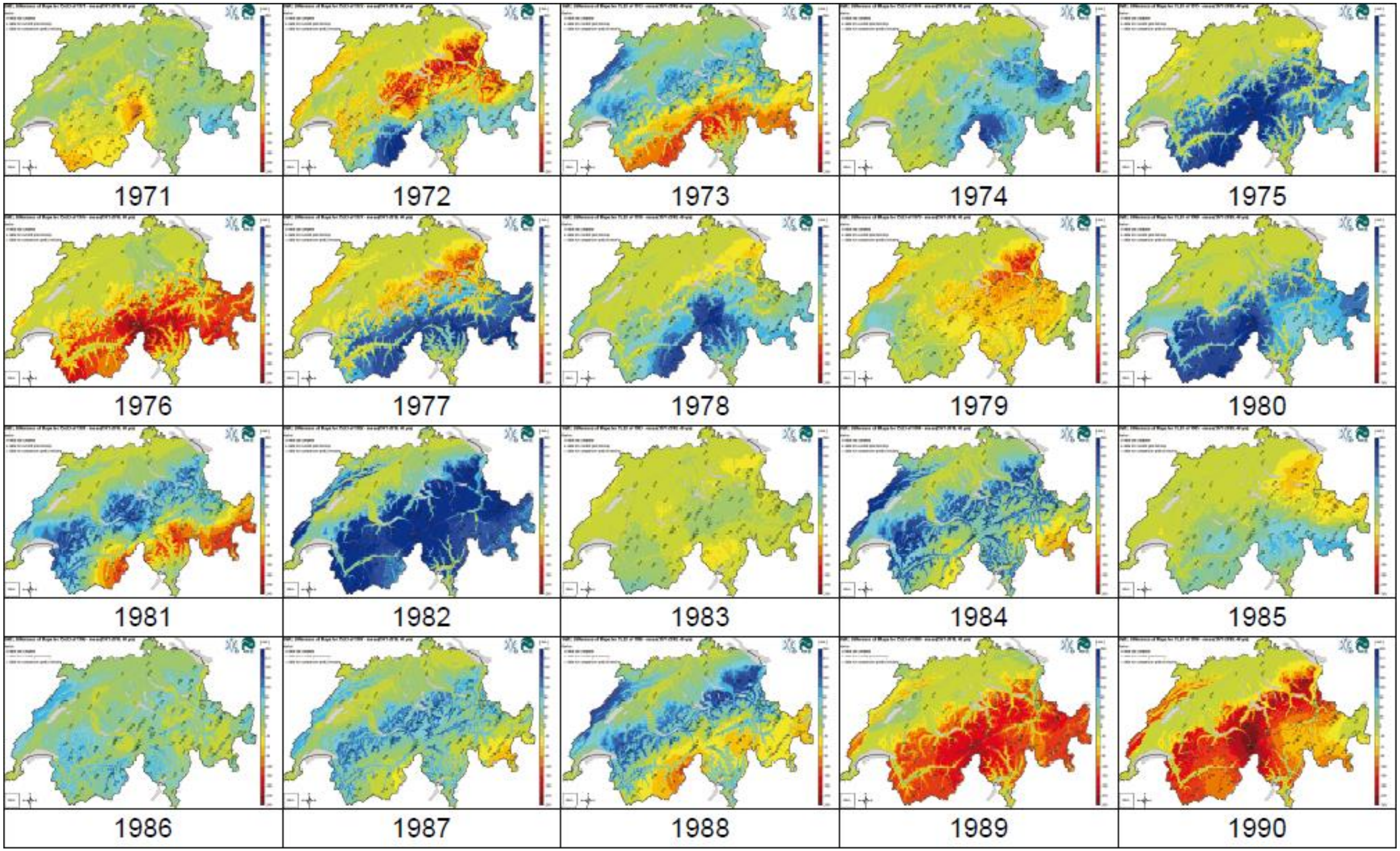
Model output for a rain-on-snow event on Jan-3 2015

- Very warm and windy conditions, rain in NE+NW Switzerland
- Energy balance model



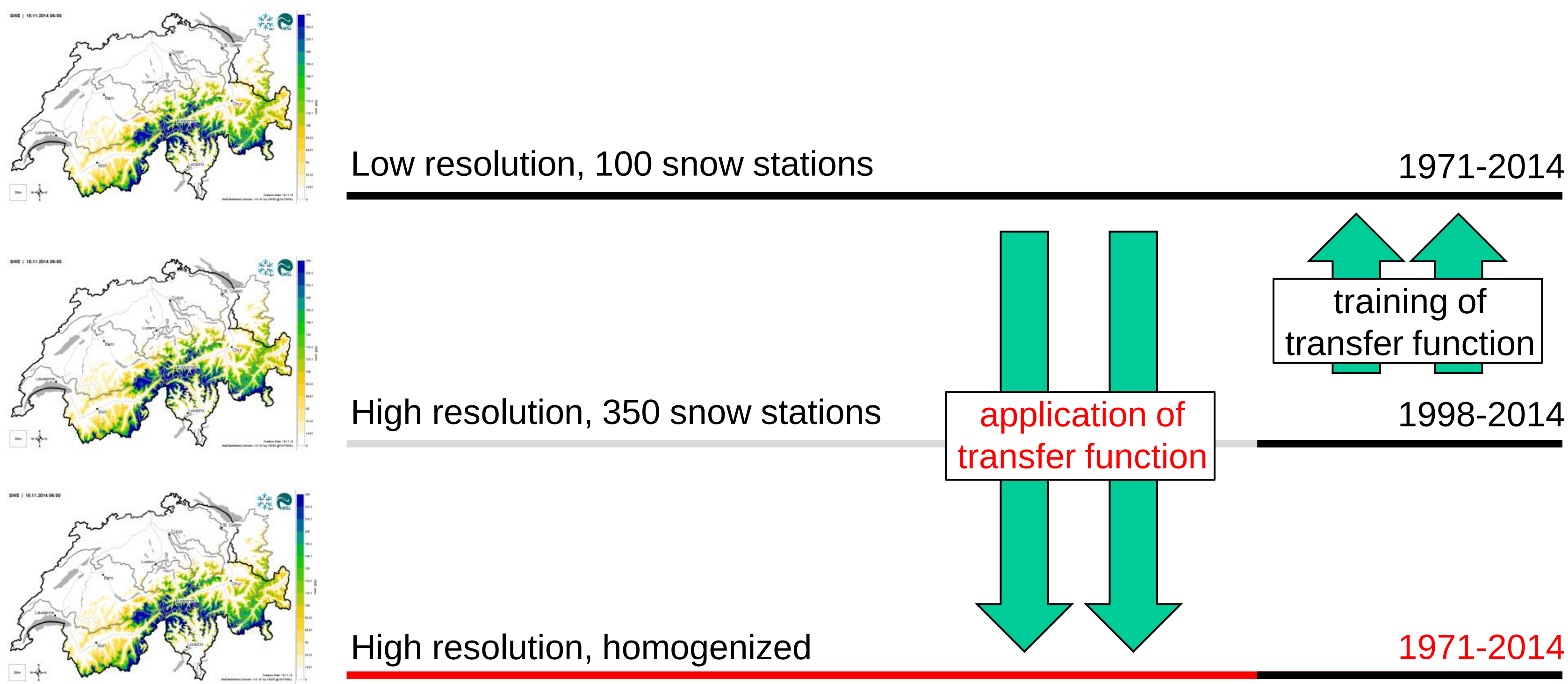
Model output for March-15

- Relative to longterm mean 1971-2014
- Temperature index model

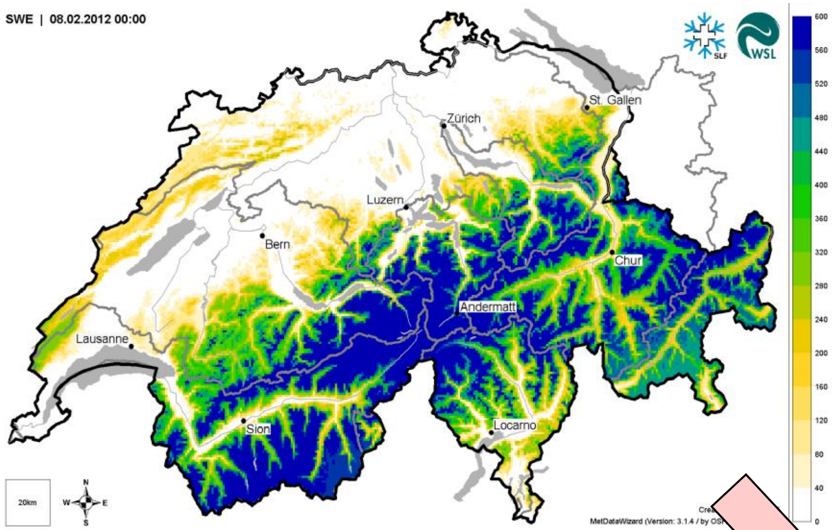


Extended SWE reference dataset 1971-2014

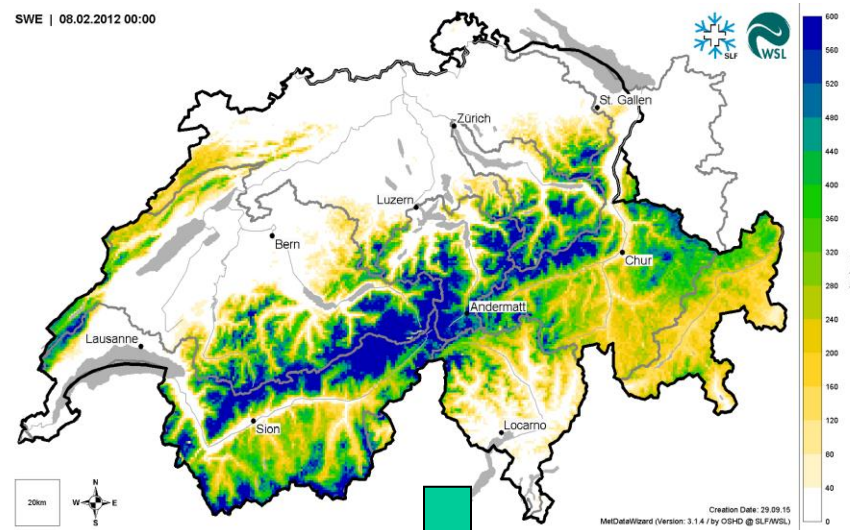
- Accounting for changes in monitoring network densities
- Spatially explicit data homogenization
- Homogenization method: quantile mapping using local CDFs



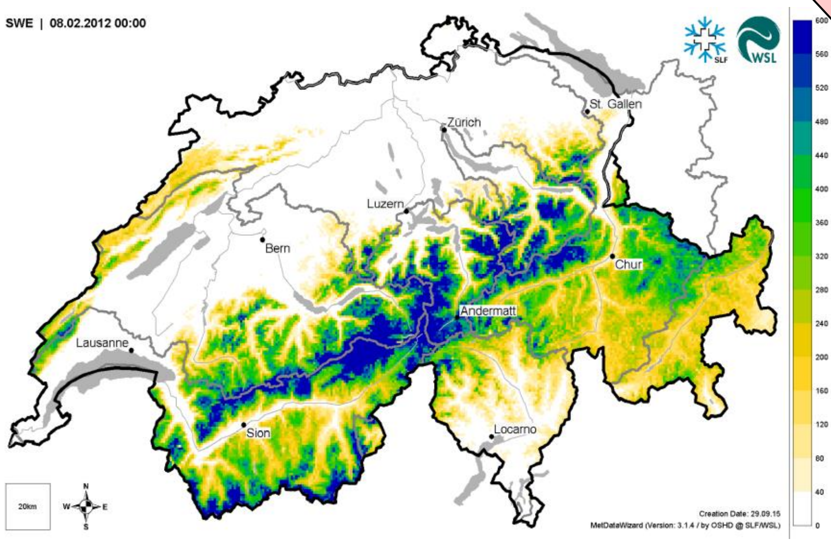
Quantile mapping homogenization



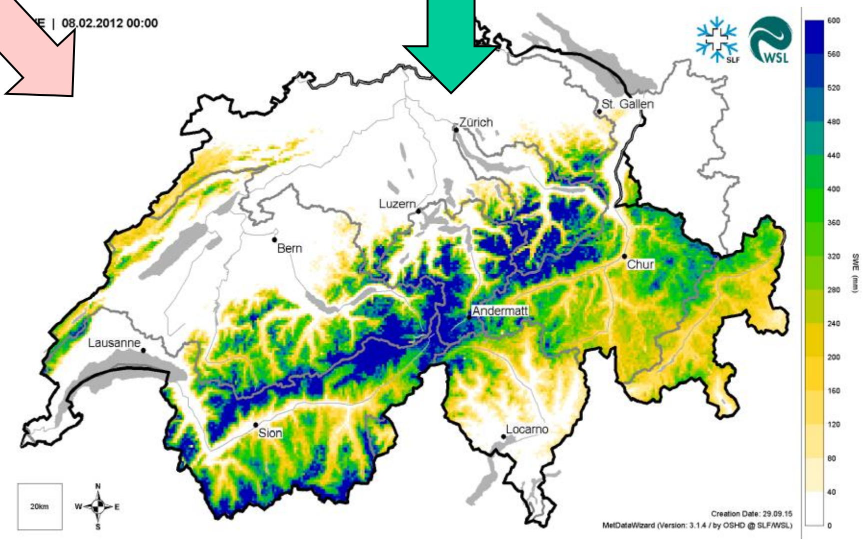
LoRes – Interpolation



LoRes – Modelling



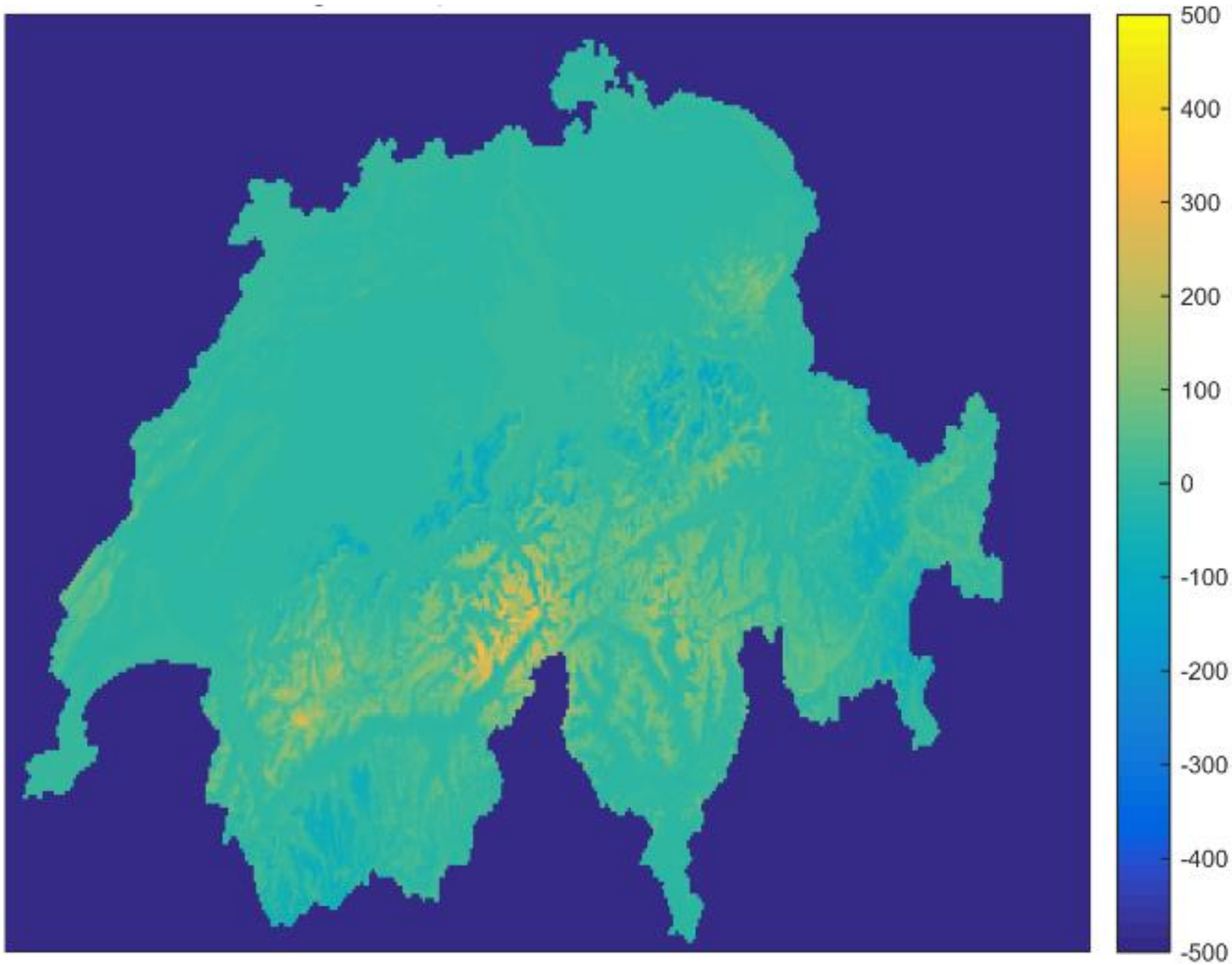
LoRes – Modelling – homogenized



HiRes – Modelling

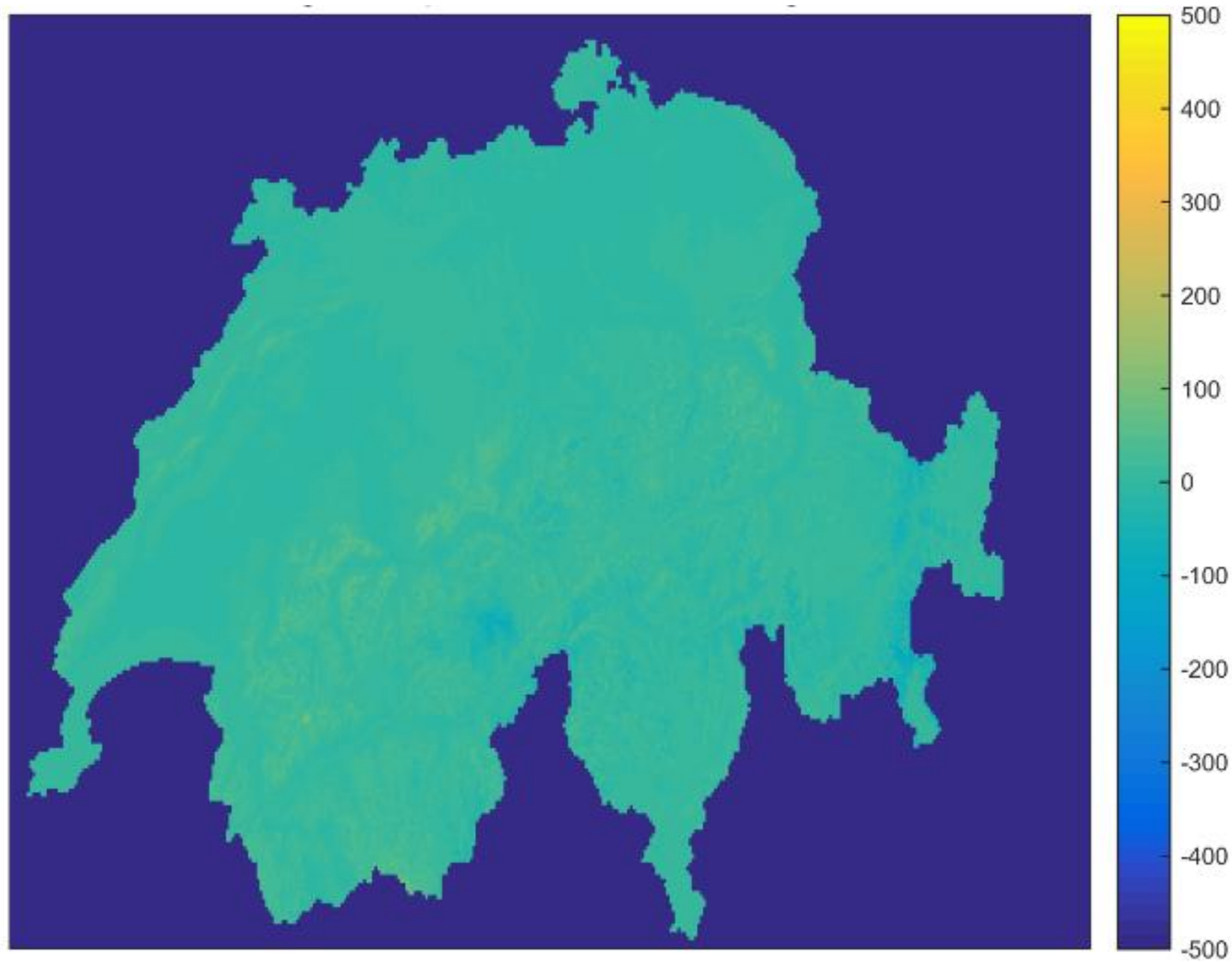
data ► snow density model ► snow melt model ► data assimilation ► subgrid functions ► final integration ► SWE climatology

Quantile mapping homogenization



Mean difference April-15 ► LoRes – HiRes

Quantile mapping homogenization



Mean difference April-15 ► LoRes homogenized – HiRes

Take home message

- Using a dedicated snow bulk density model to convert HS to SWE data
- Deploying 2 different snow melt models in parallel

  an enhanced T-Index model (CPU efficient)

  an E-Balance model with simplified snowpack structure
- Integration of monitoring data with snow melt models using a two-step data assimilation framework
- Using subgrid transfer functions to account for small-scale processes
- Accounting for changes in monitoring network densities by applying spatially-explicit homogenization methodology