Evaluation of regional simulations of snow cover over the Austrian Alps

Simon Dadson[1], Juraj Parajka[2]

- **Running JULES over Austrian Alps**
- **Evaluate results against observed archive of snow cover and snow depth 1975-2002**
- **Consider potential improvements to hydrological forecasting and modelling of snow extremes**

sjdad@ceh.ac.uk **parajka@hydro.tuwien.ac.at**

[1]NERC Centre for Ecology and Hydrology, Wallingford, UK
[2]Technical University, Wien, Austria

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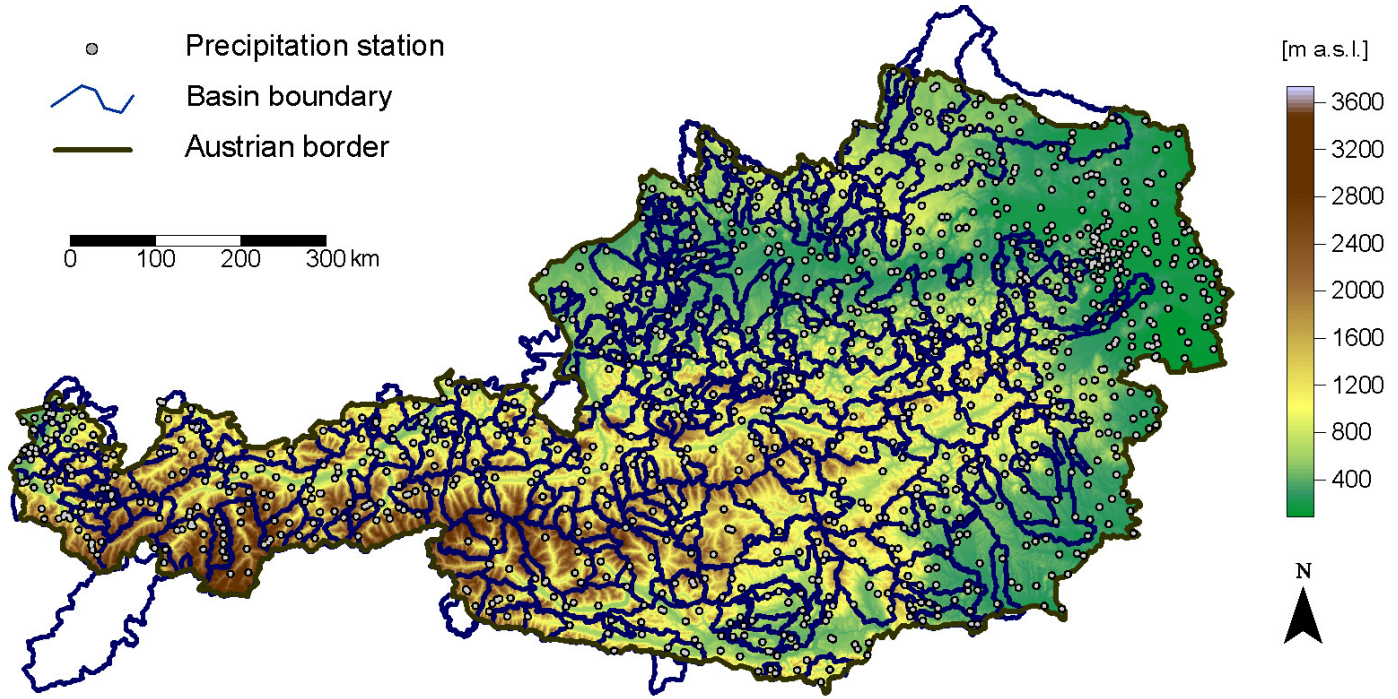
Motivation

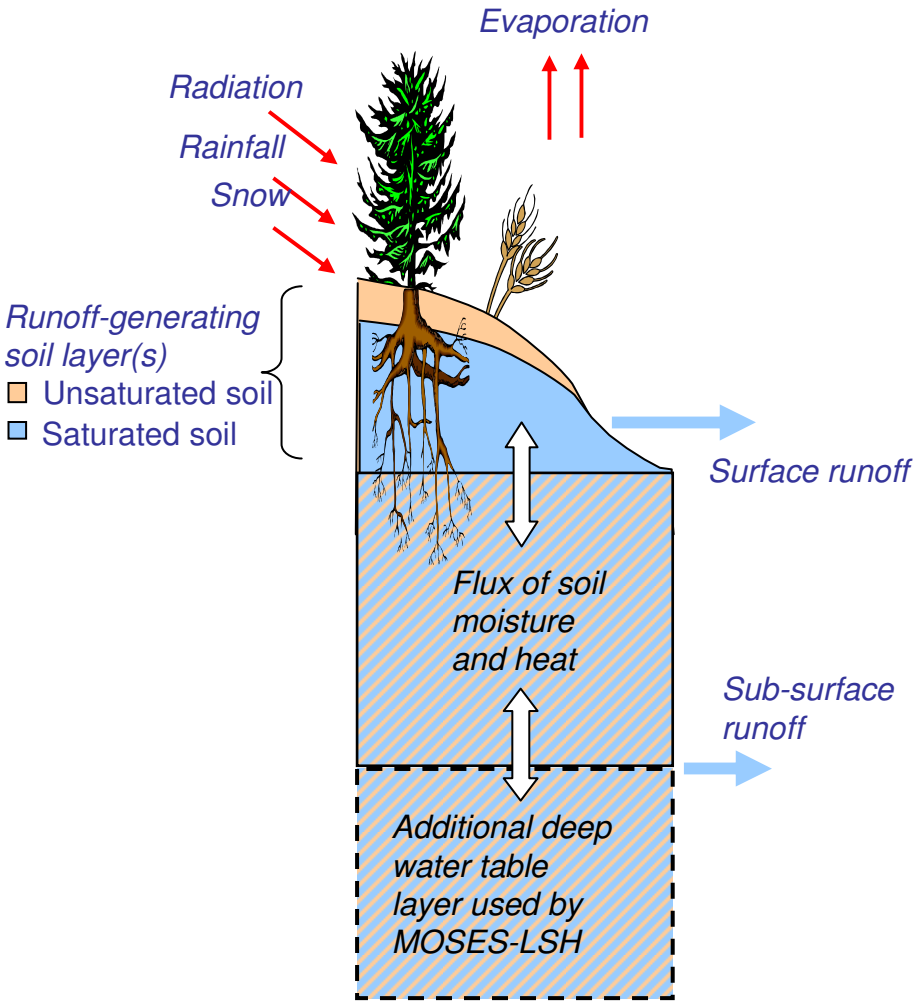
Using JULES together with CEH Grid-to-Grid flow routing algorithm to calculate river flows at continental scale

To model snowmelt-related flows in alpine catchments, it is critical to get snow cover correct

Here, we evaluate the performance of JULES snow model using observed data from Austria over the period 1975-2002

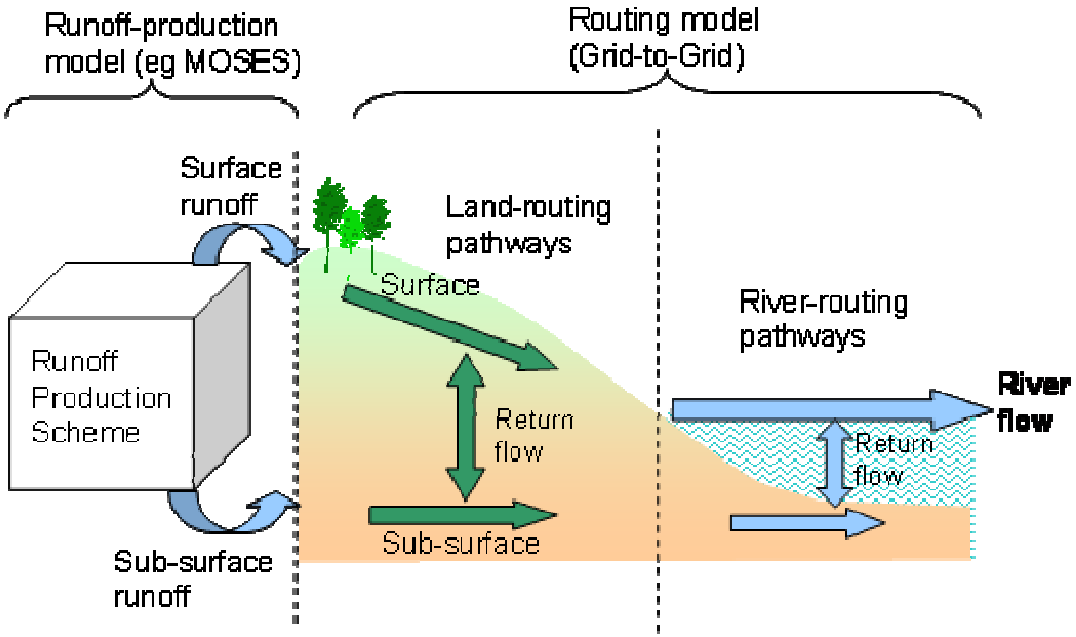


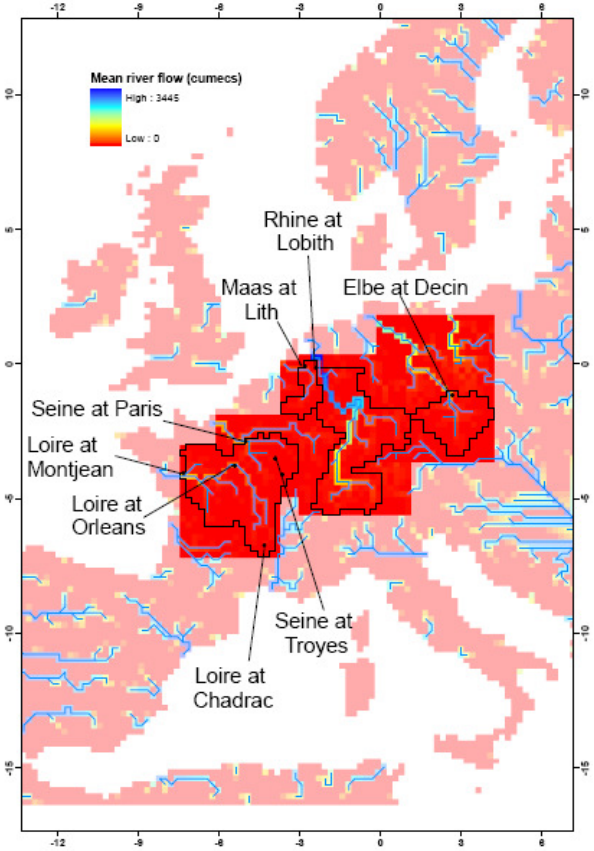
Hydrology in JULES



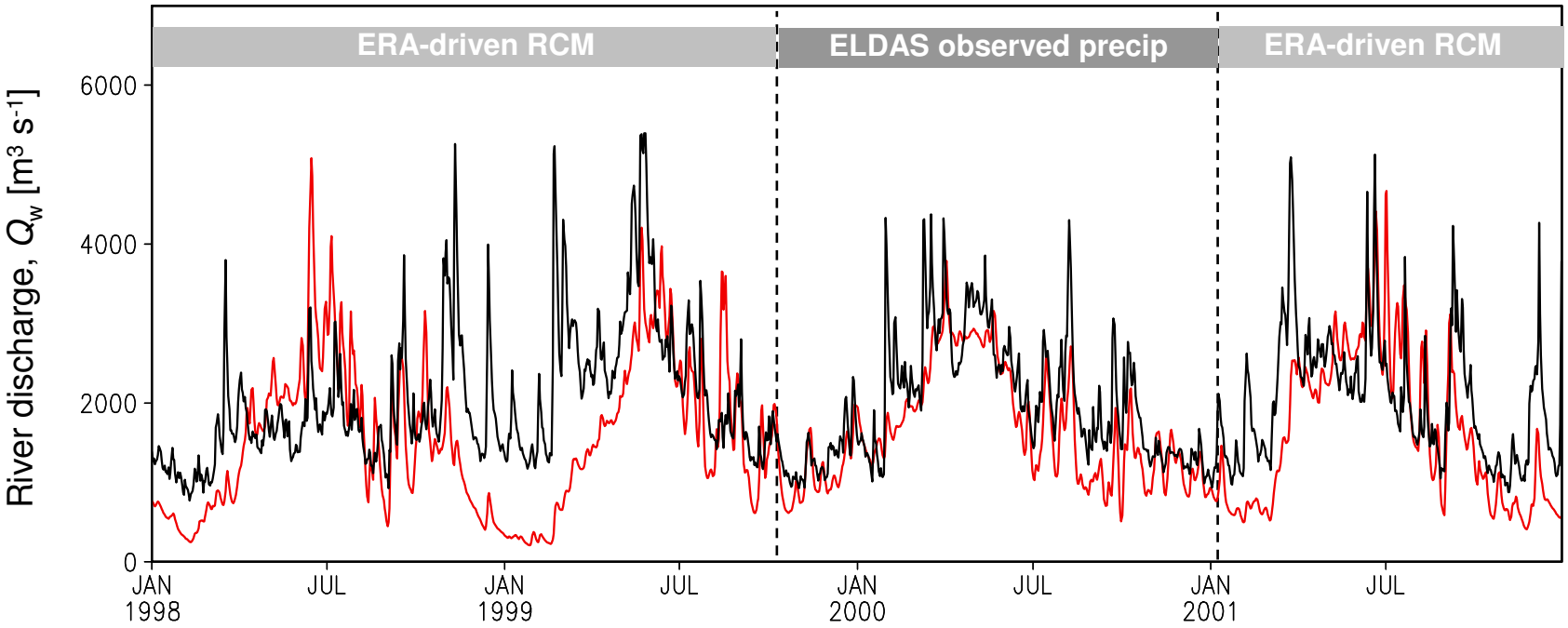
- JULES takes **temperature, wind speed, humidity, LW & SW radiation** and **precipitation** from RCM.
- Compute **evapotranspiration**, taking account of soil properties derived from IGBP soils data; dynamically account for **stomatal resistance**
- Broadband **albedo** diagnostic function of surface temperature
- Surface **energy balance** for composite of snow and snow-free surfaces
- Constant **snow density** (250 kg/m^3)
- Diagnose state of **soil moisture** by using a Pareto distribution of soil moisture store sizes
- Convert to **surface** and **subsurface flow**

Flow routing scheme for NW Europe



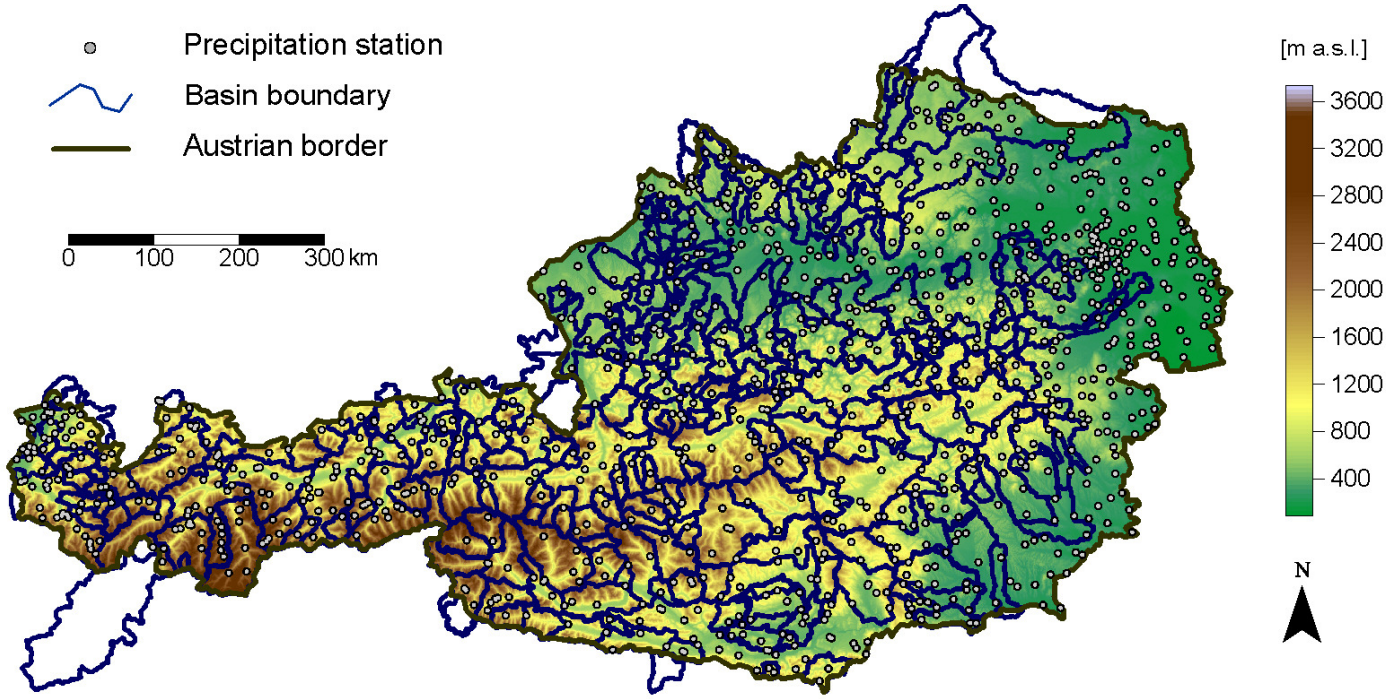


Danube at Kienstock



- **Model results (red line) for Danube compare well with observed river flow data (black)**
- **Better representation of snowmelt runoff may improve model performance in spring melt season**

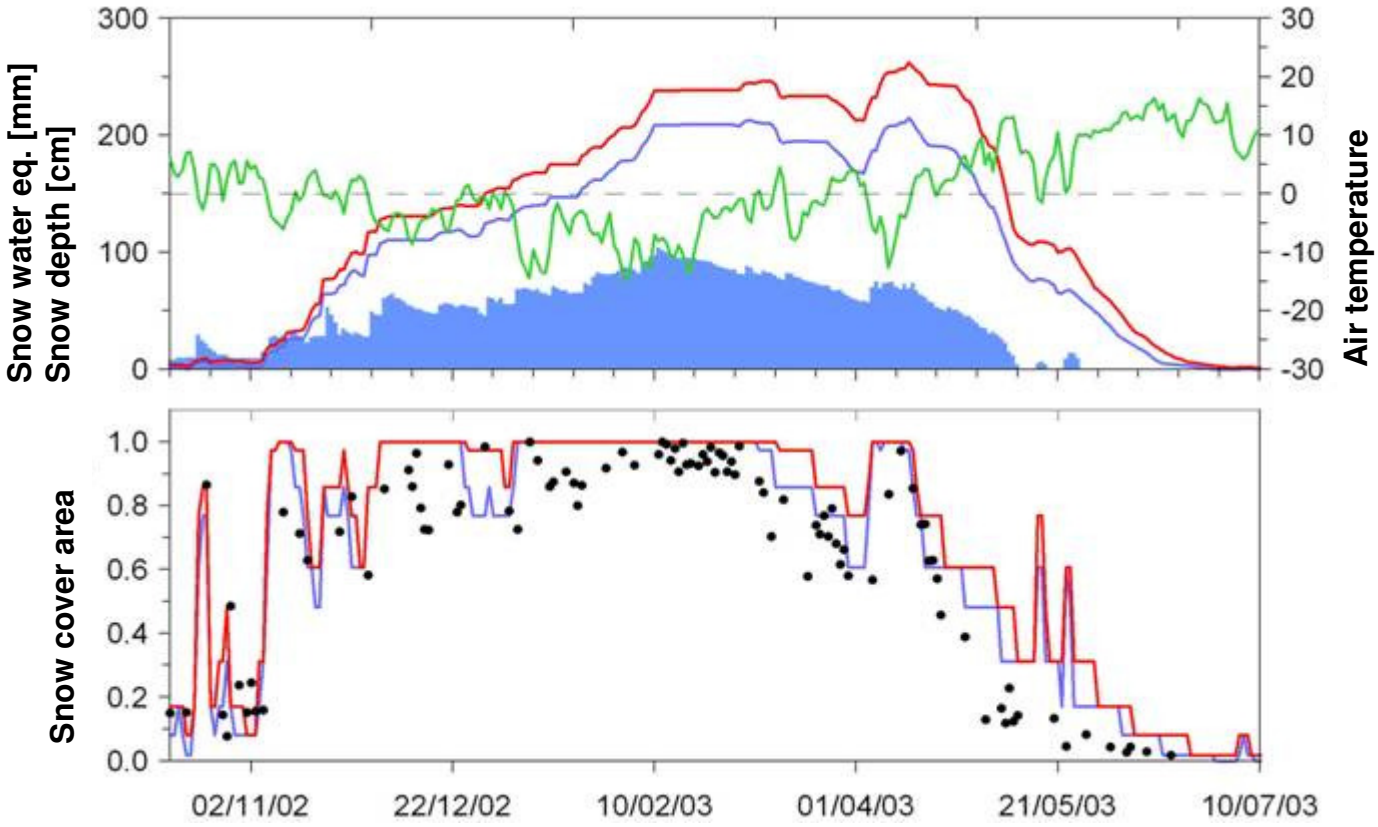
Austrian Precipitation Gauging Network



776 stations

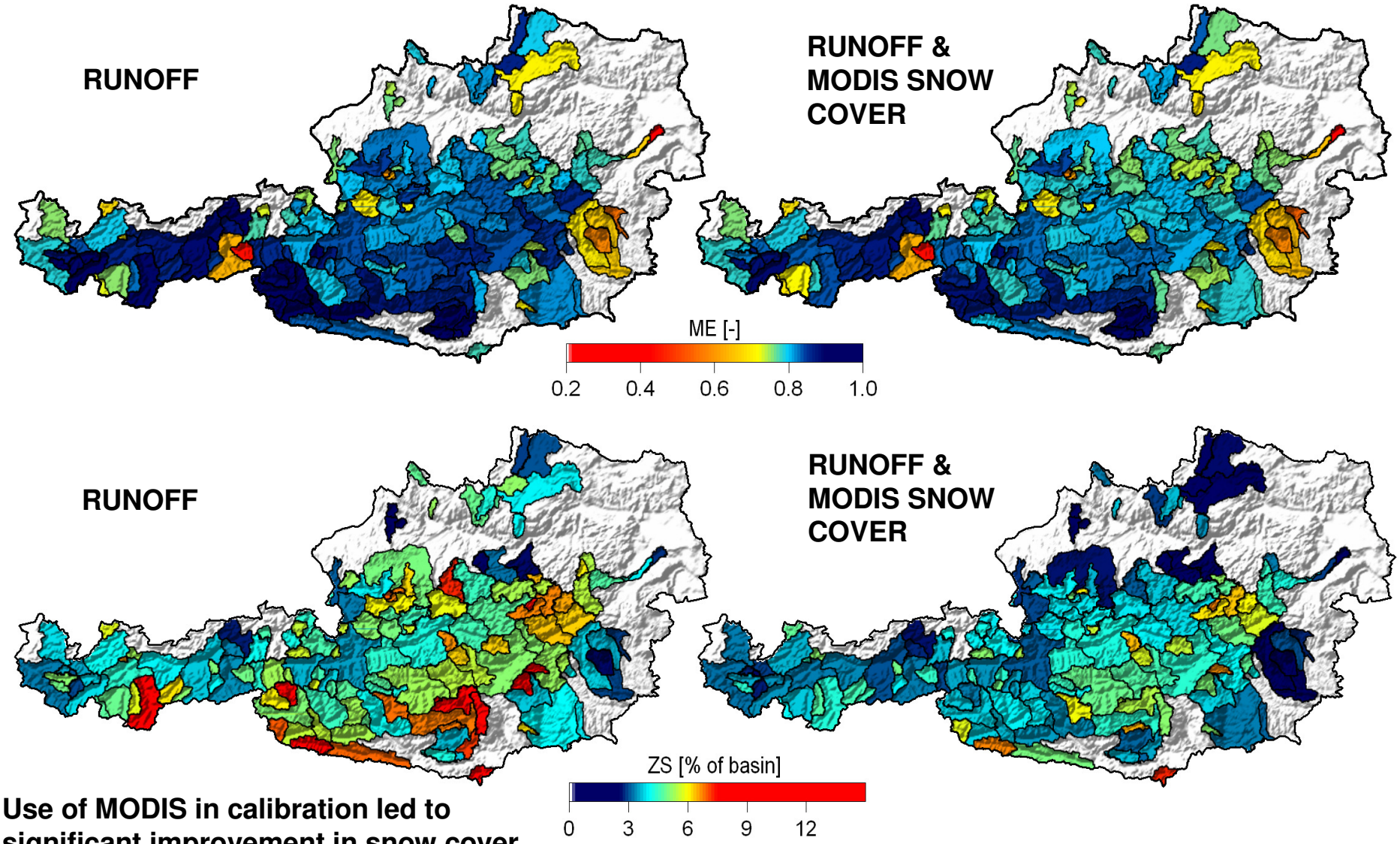
Snow cover, snow depth, and snow water equivalent measured daily between 1975-2002

Example results from catchment-based snow-melt model



Rainfall-runoff model with threshold air temperature used for snow accumulation and degree-days used for snowmelt

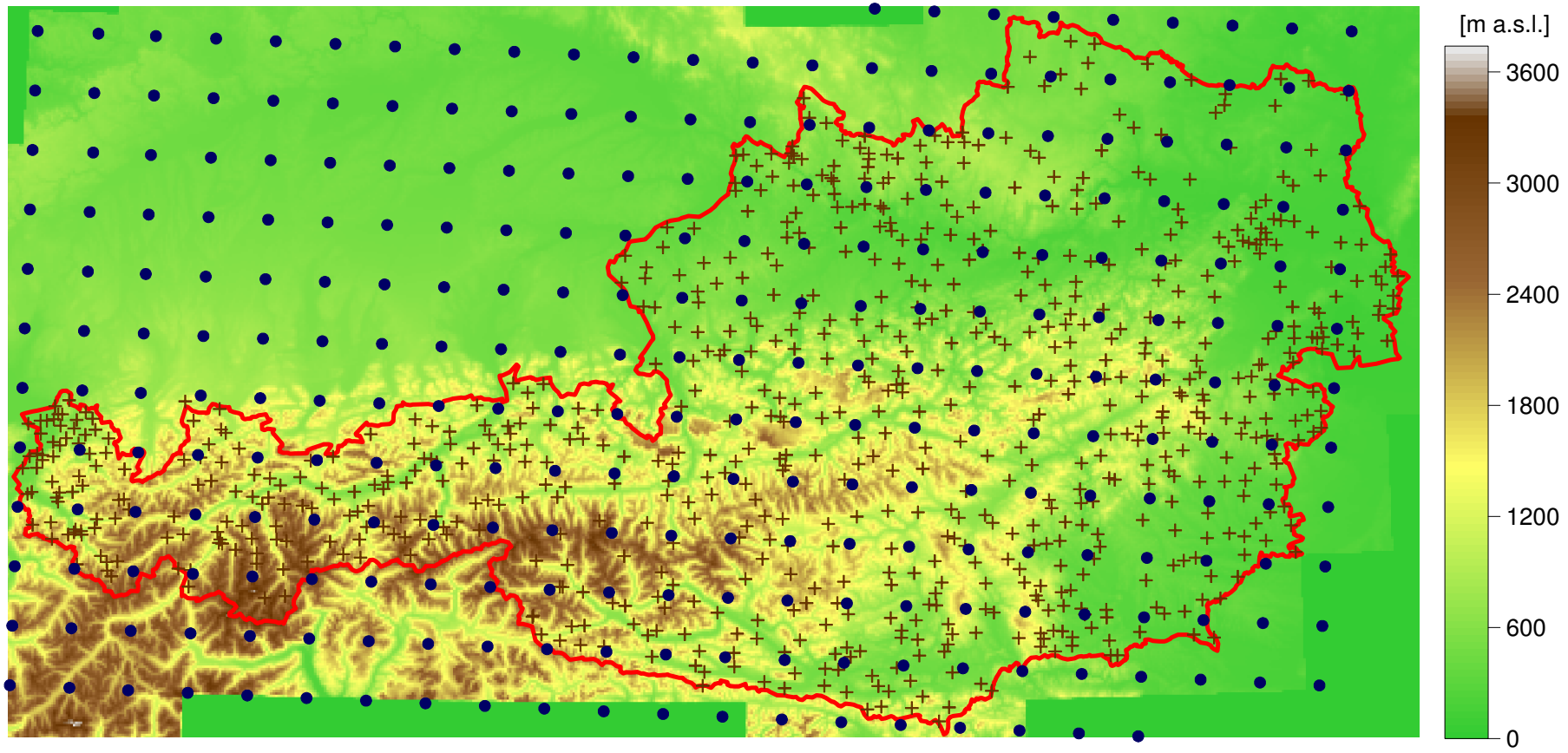
Model Efficiency for Runoff (top) and Snow Cover (bottom)



Use of MODIS in calibration led to significant improvement in snow cover simulation; less effect on runoff

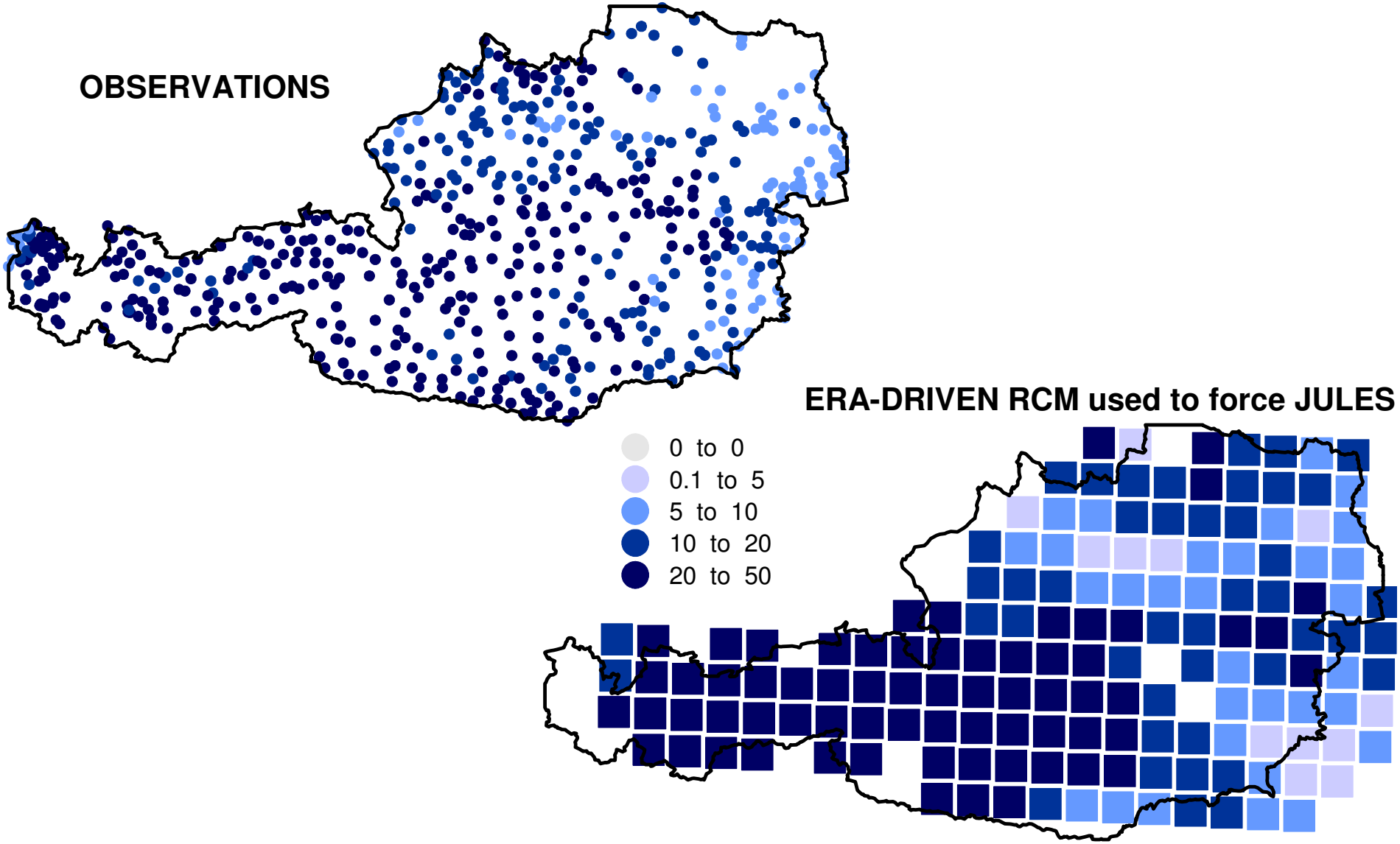
Parajka and Blöschl, 2008, *J. Hyd.*

Locations of climate stations and JULES gridpoints



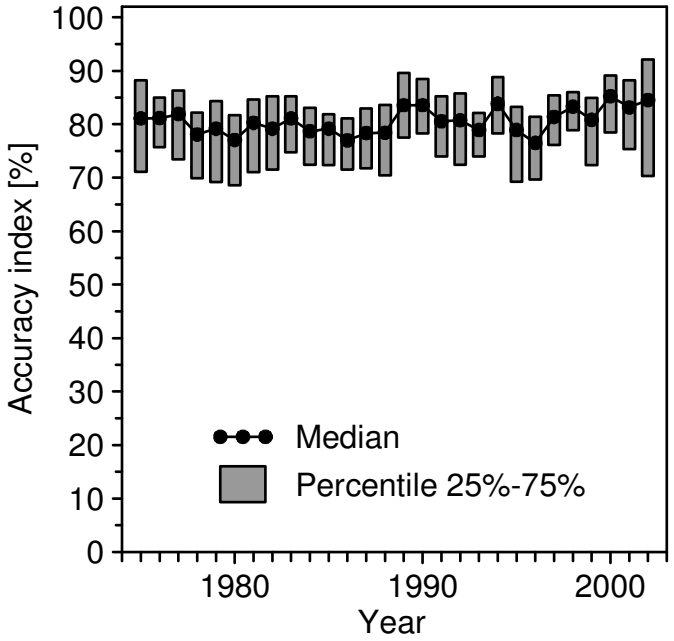
Topography of Austria and location of climate stations with daily snow depth observations (crosses) and centers of JULES gridpoints (circles).

Duration of snow cover (%) in the period 1975-2002

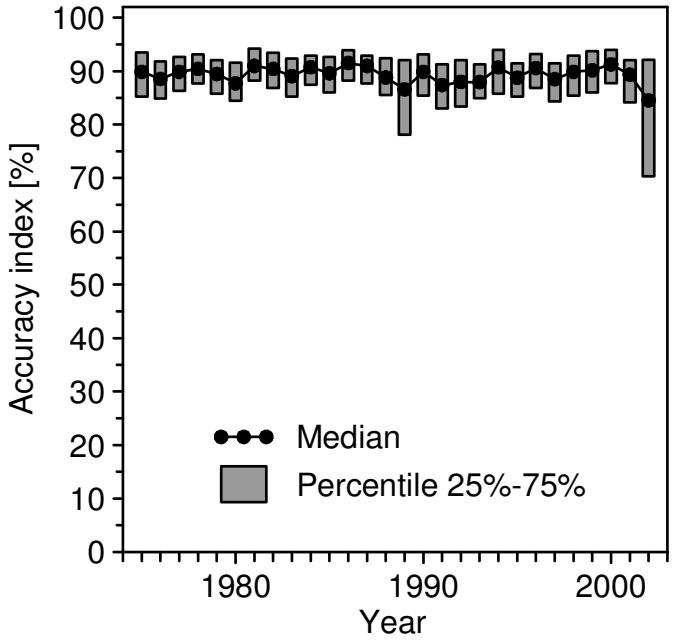


Inter-annual Accuracy

ERA-40-driven RCM & JULES



OBSERVED PPT & JULES



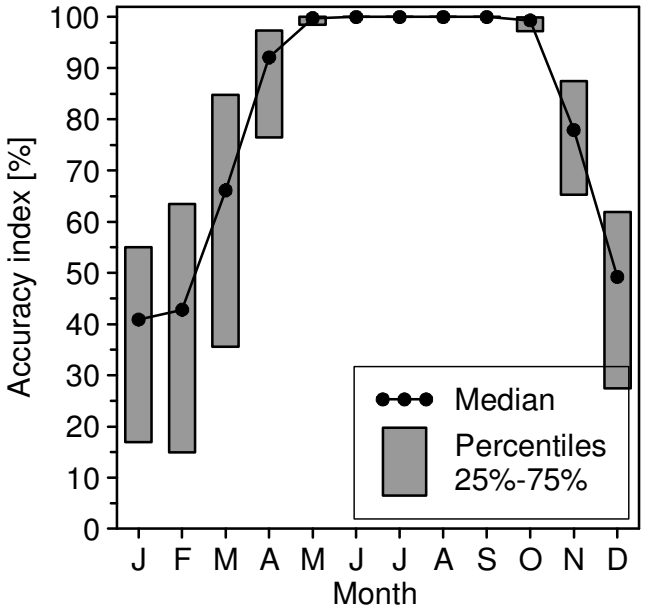
Sum of station-days	JULES: SNOW	JULES: NO-SNOW
Ground: SNOW	A	B
Ground: NO-SNOW	C	D

Accuracy index = (A + D) • 100 / (A + B + C + D)

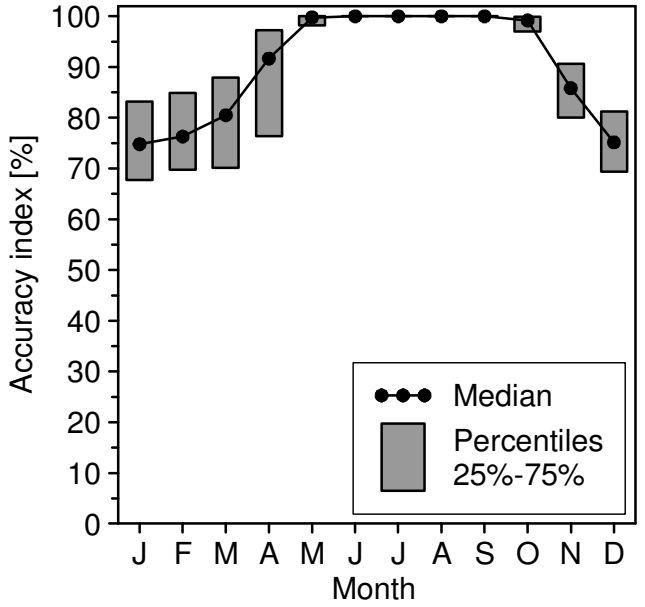
Median and 25-75% percentiles estimated over 776 climate stations in the period 1975-2002.

Seasonal Accuracy

ERA-40-driven RCM & JULES



OBSERVED PPT & JULES



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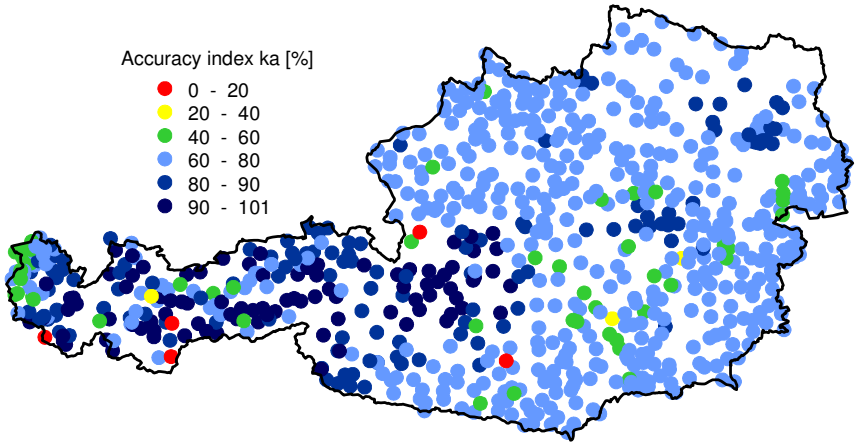
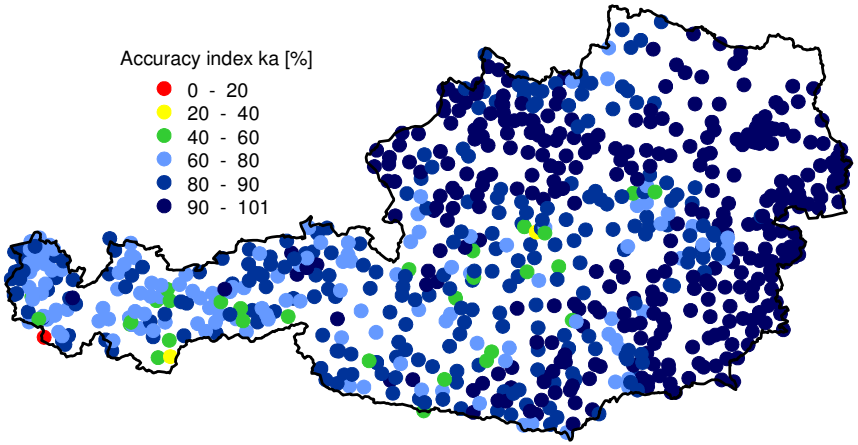
Accuracy of Snow Cover Simulations: Seasonal Variability

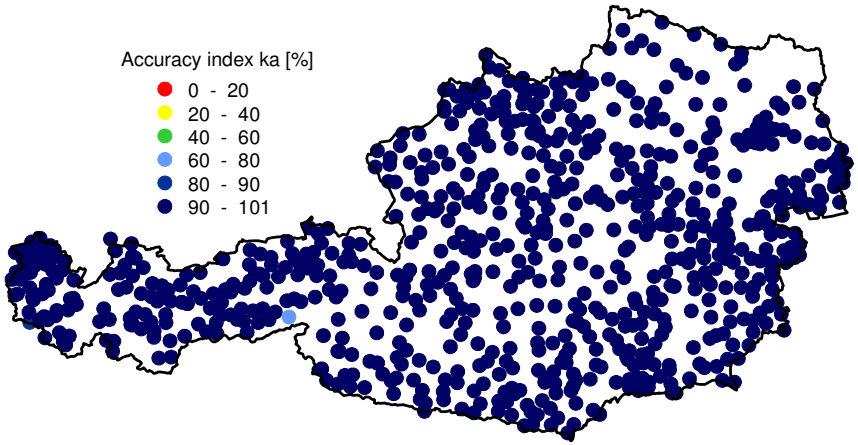
DEC-FEB



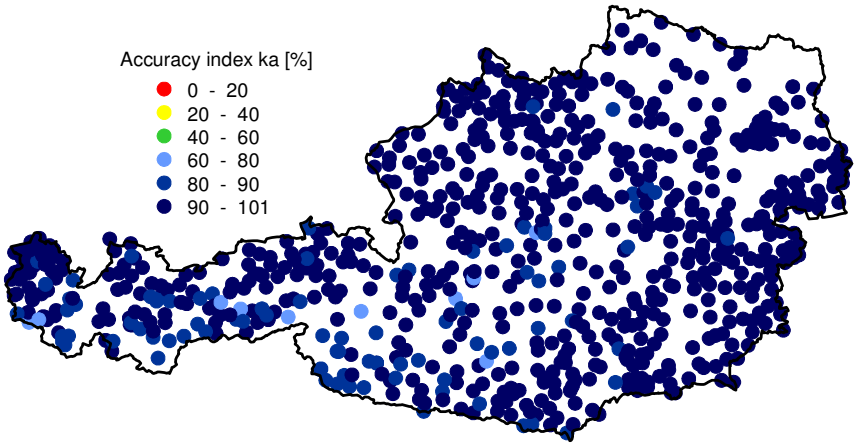
MAR-MAY



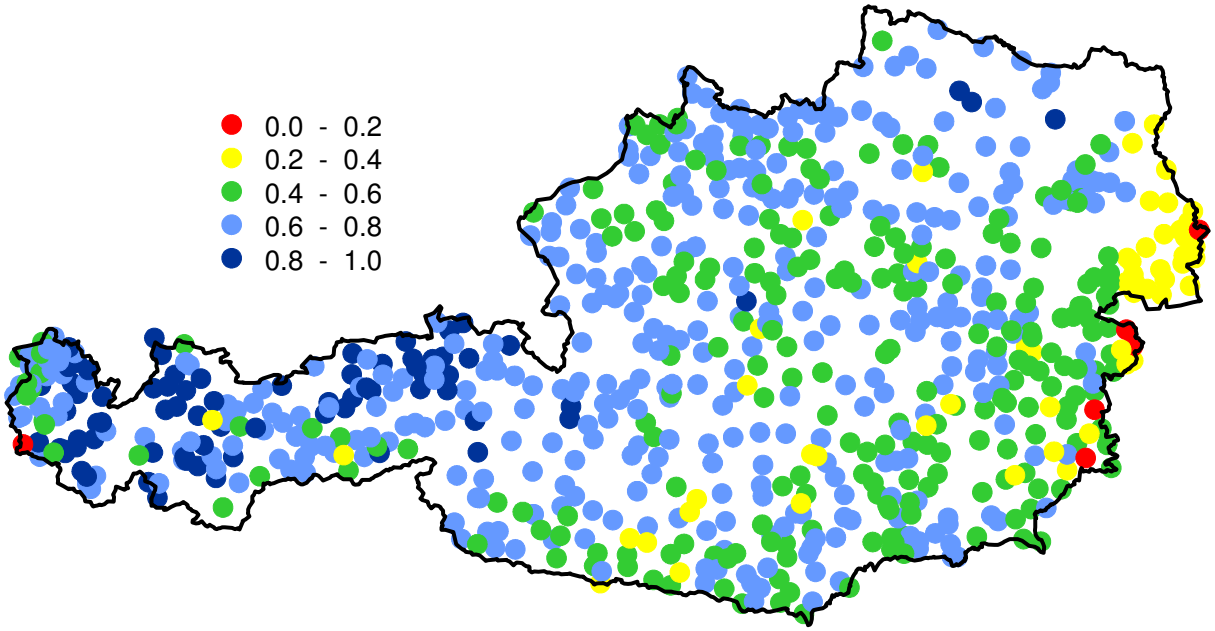
JUN-AUG



SEP-NOV



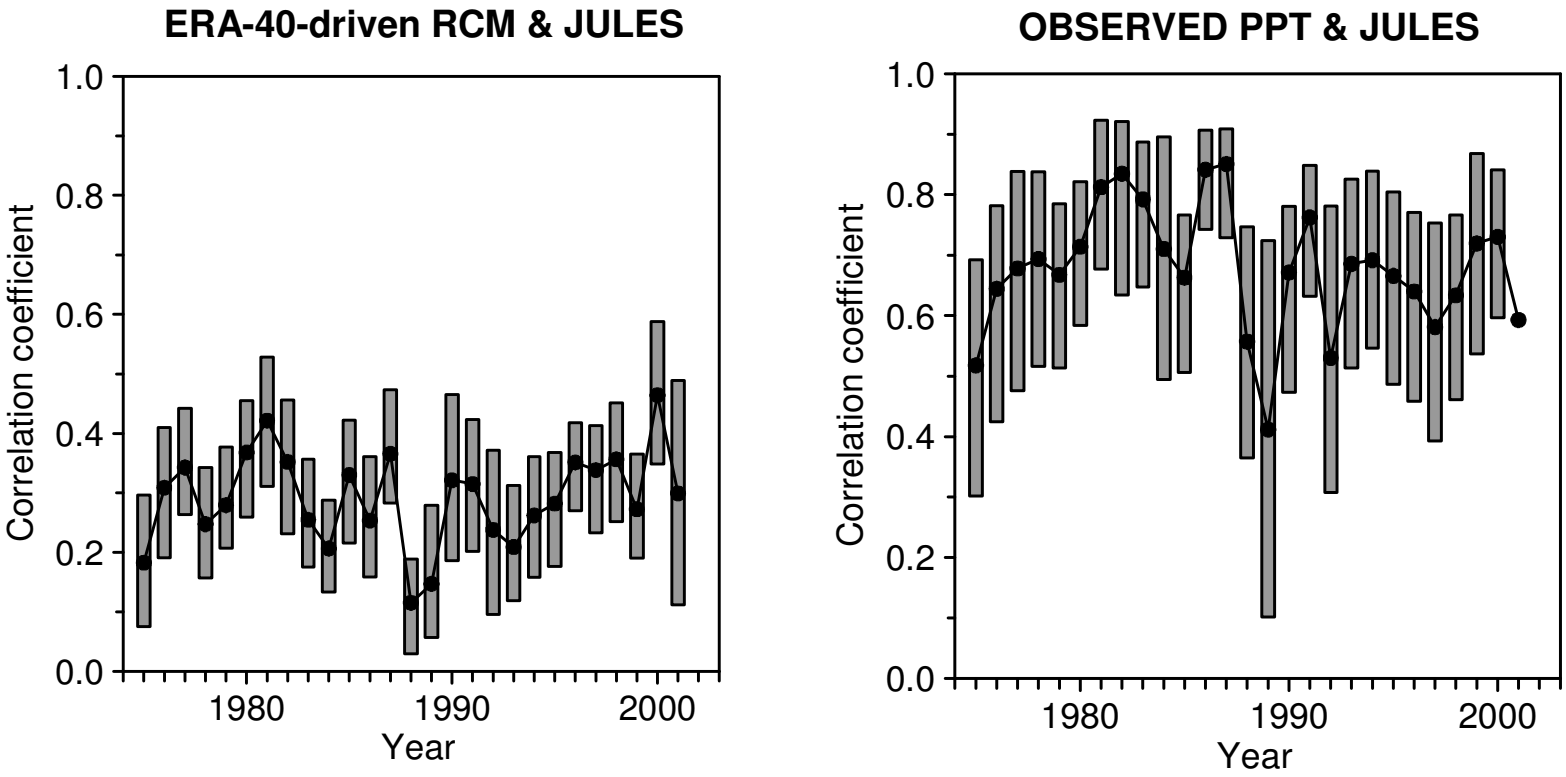
Spatial Variability in the Accuracy of Snowmelt Simulations



Spatial variability of the correlation coefficient between modelled snow water equivalent and observed snow depth in the period 1975-2002

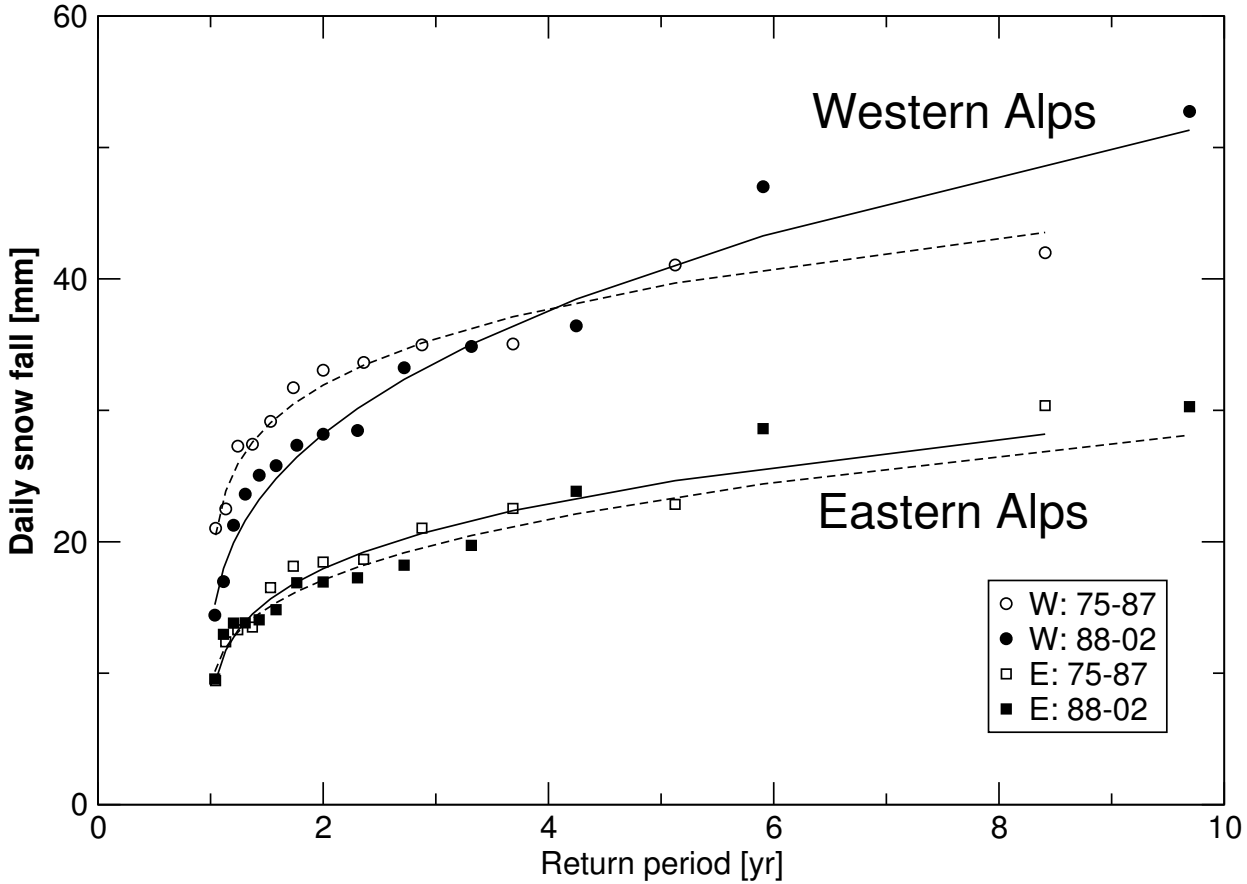
Accuracy is greatest in high-mountain regions and on NW flank of mountain range;poorest model performance in SE quadrant

Annual Variability in the Accuracy of Snowmelt Simulations



Annual variation of the correlation coefficient between JULES snow mass simulations and ground based snow depth data.

Future work: Frequency distribution of snowfall



temp (degC)	Western	Eastern
1975-1987	2.71	4.11
1988-2002	3.64	5.02

snow (mm/day)	Western	Eastern
1975-1987	1.15	0.61
1988-2002	0.95	0.52

Work in collaboration with
Carlo Buontempo and
Erasmo Buonomo (Met Office)

Mean temperature increased by ~1 degree; mean snow rate decreased by ~50 mm/year

But: extreme snowfall has increased by ~25 percent in frontal-dominated W. Alps.

Question: NAO or climate change?

Conclusions

• JULES predicts snow-cover days with average accuracy of 89% (DJF: 75%, MAM: 86%; JJA: 100%; SON: 94%).

•The model reproduces the spatial pattern of snow cover well in the Alps.

•We are investigating ways to improve the model's representation of sub-grid-scale hydrological processes.

Further Work

•Use of JULES 2.x and later versions of snow code.

•Explicit resolution of the way in which snow is distributed with elevation.

•Analysis of sensitivity to temperature threshold for snow accumulation.

•To investigate trends in observed data, especially statistics of extremes, and comparison with JULES.

•Scenarios for climate change: using JULES to project effects of climate change on snow cover and hydrology in the Alps.