ZAMG
Zentralanstalt für Meteorologie und Geodynamik

Extreme snow depth in Austria: Smooth spatial modelling with extremal coefficients

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- Two established spatial modeling approaches are compared and combined in a new model
- New modelling approach outperforms the other two in terms of CRPS
- Spatial modelling reduces uncertainty compared to local estimations

1. Motivation and Data

- Spatially coherent maps of extreme snow depths are useful in planning of buildings
- Simple interpolation after pointwise estimation of extremes leads to inaccurate results lacking the possibility to infer uncertainties
- Two existing approaches compete for accuracy and spatial dependency: smooth spatial modelling (SSM, Blanchet and Lehning, 2010) and max-stable processes (MSP, Blanchet and Davison, 2011)
- Mixing those two approaches better accounts for spatial dependencies of extremes by keeping accuracy high
- Improvement is achieved by taking spatial dependency of extremes as additional covariate (extremal coefficients)
- 421 daily snow depth measurements (winter seasons from 1941 – 2012)
- Randomly chosen 211 model fitting and 210 verification stations

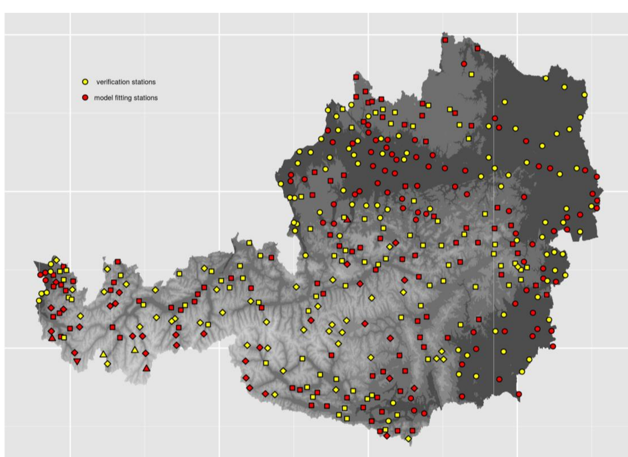

Figure 1: Topography of Austria with model fitting stations (red) and verification stations (yellow)

2. Extremal coefficients

- Extremal coefficient (ec) describes probability, that block maxima at two locations do not exceed a threshold (=spatial dependency)
- ec=1 corresponds to complete dependence, ec=2 complies with independence
- 200 ec's between all pairs of observations → decrease to reasonable number of ec's
- Cluster stations by their extremes (Bernard et al., 2013) and selecting most significant station leads to 8 ec's ($ec_1, \ldots, ec_8$) (Figure 2, left)

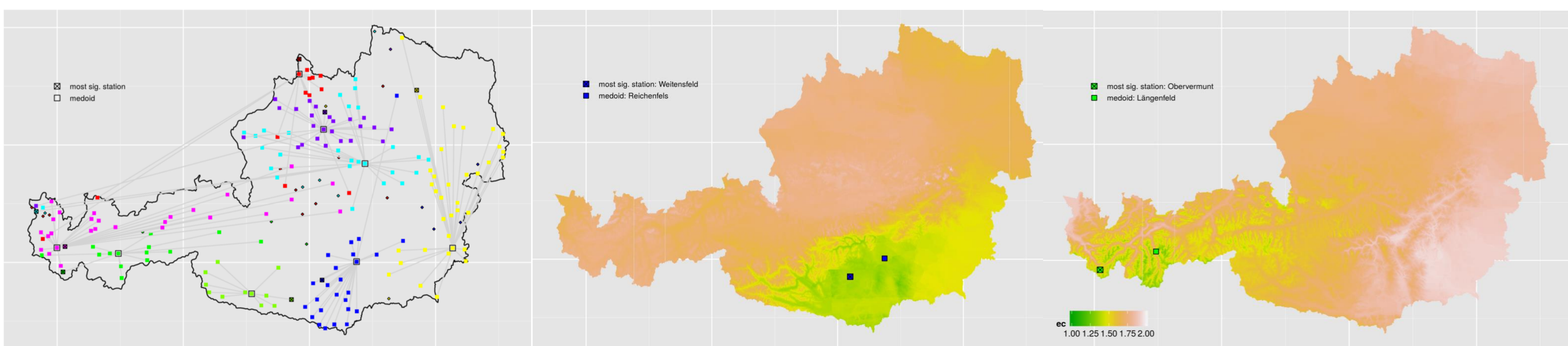

Figure 2: Left: 8 Clusters. Right: Extremal coefficients and medoid for stations in the mountains and in flatlands

3. Method

Smooth spatial modelling with extremal coefficients (SSM-EC)

- i.i.d seasonal snow depth maxima are realisations of GEV
- GEV parameters are modelled as linear functions of lon, lat, alt, mean max. snow depth and extremal coefficients (48 different combinations)
- Maximising station-wise summed log-likelihood functions and taking combination with lowest TIC leads to the "best spatial model" for extreme snow depths in Austria:

$$\mu \propto lon, lat, mean\ max.snow\ depth, ec_1, \ldots, ec_8$$
$$\sigma \propto alt, mean\ max.snow\ depth$$
$$\xi \propto lon, lat, alt, ec_1, \ldots, ec_8$$

- Verification with Continuous Ranked Probability Score (CRPS)

3. Results

- New modeling approach SSM-EC models snow depth extremes realistically (Figure 6)
- SSM-EC outperforms SSM and MSP approaches in terms of CRPS
- SSM-EC reproduces fine spatial shape parameter pattern of MSP model by keeping accuracy of margins (Figures 3 and 4)
- Spatial estimation reduces uncertainty (Figure 5)

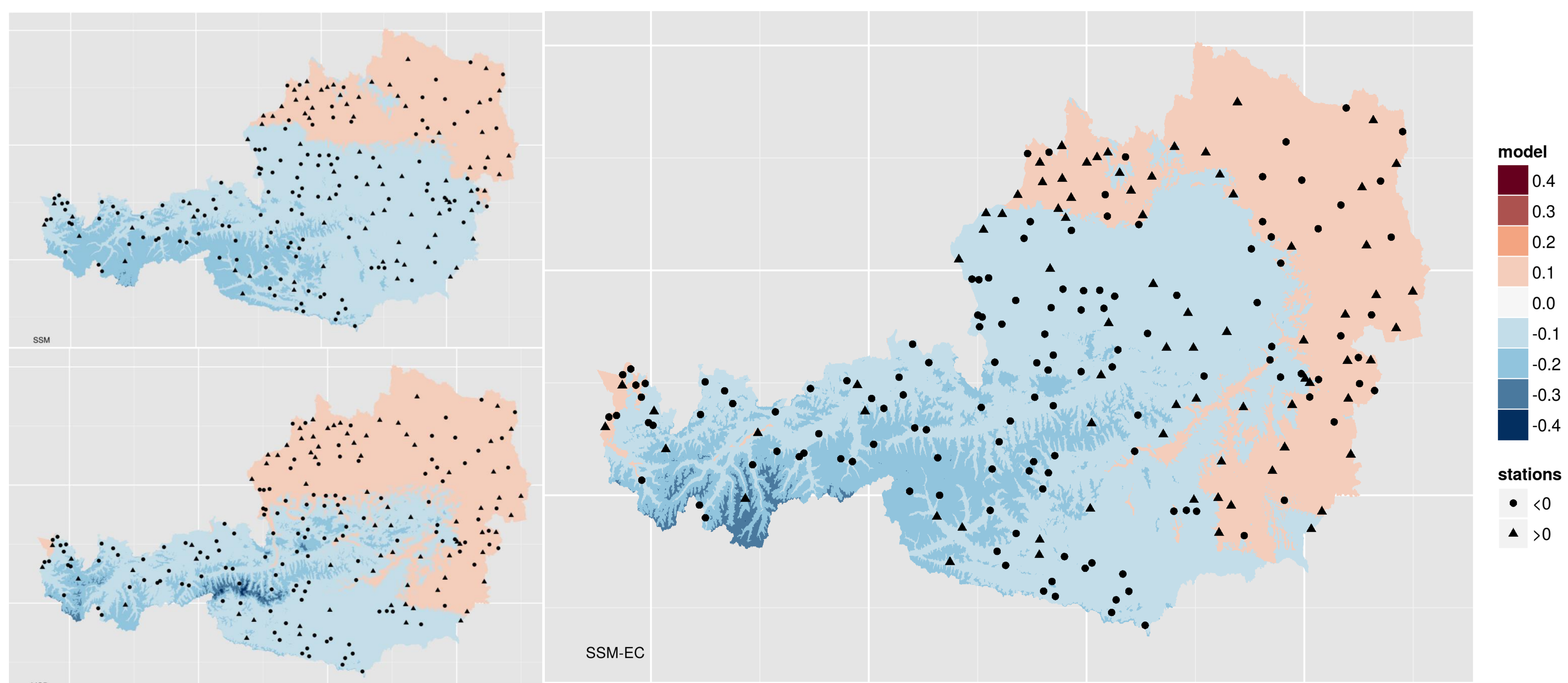

Figure 3: Estimation of GEV shape parameter of the different modelling approaches: SSM (smooth spatial modelling), MSP (max-stable processes), SSM-EC (SSM with extremal coefficients).

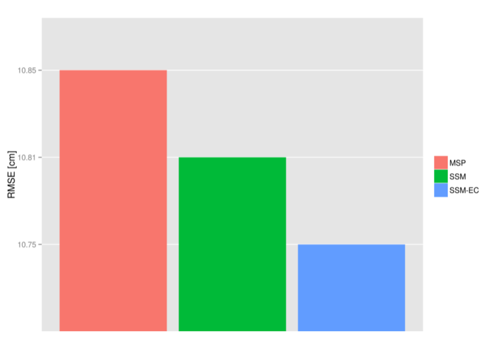

Figure 4: RMSE of location parameter μ.

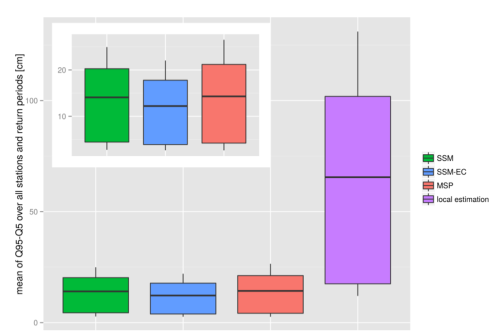

Figure 5: 95-5% interquantile mean. All models reduce uncertainty, SSM-EC the most.

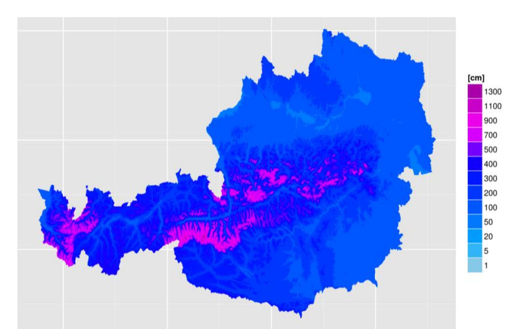

Figure 6: Snow depth with return period of 100 years, computed with model SSM-EC.

4. Conclusions and Outlook

- Smooth spatial modelling with extremal coefficients provides a way to better implement spatial dependency of extremes
- New modelling approach is flexible to be adapted to other parameters
- Currently spatial models are developed for rain, windspeed and snowload
- All models are implemented in EVA+ web platform of ZAMG

References

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