Evaluation of the regional climate model RegCM4.7 over the Carpathian region for very wet and average years

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Motivation

- Model-based projections of climate change impacts across multiple sectors suggest that the Carpathian region will be among the **hotspot** regions with the highest number of severely affected sectors in Europe (Ceglar, 2018)

- In recent decades, an **increase** has been detected in frequency and severity of **extreme** events (e.g. drought, extreme precipitation and heat wave) (Spinoni et al., 2013)

- Climate across the Carpathian region is influenced by oceanic, continental, and Mediterranean effects, as well as by orographic factors

- **PannEx** project, which aims to achieve a better understanding of the Earth system components and their interactions in the Pannonian Basin

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Main objectives:

- To reproduce the historical precipitation pattern through testing the parameterization of surface processes with RegCM4.7 over Carpathian region

- How do the land-surface and planetary boundary layer parameterizations affect the precipitation?

- To study multi-scale processes and interactions

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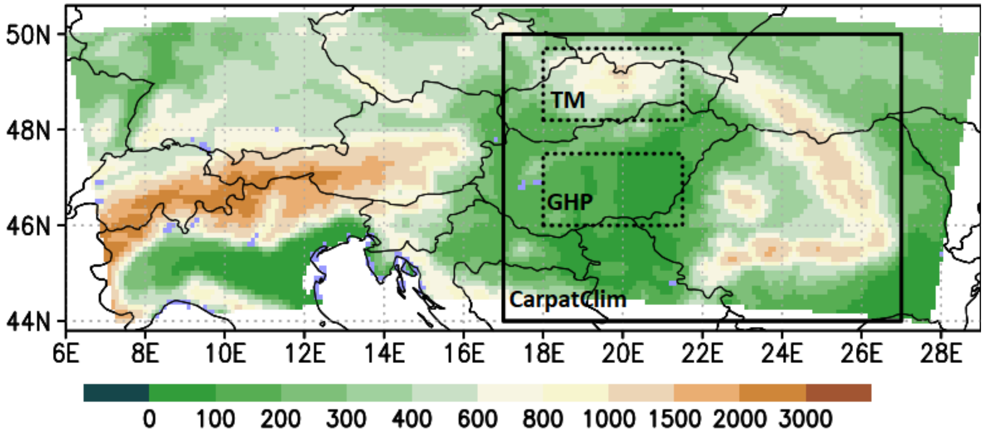
Characteristics of Simulations

Period: 1981 (normal year) / 2010 (the wettest year in Hungary)
Boundaries: ERA-Interim (0.75°)
Horizontal resolution: 10 km

	BATS_HO	BATS_UW	CLM_HO	CLM_UW
Large scale prec scheme	Modified SUBEX scheme (Torma et al., 2011)			
Convective scheme	Tiedtke (Tiedtke, 1989)			
Land Surface Models	BATS (Dickinson et al. 1993)		CLM4.5 (Oleson, 2013)	
PBL Scheme	Holtslag (Holtslag et al., 1990)	UW (Bretherton et al., 2004)	Holtslag	UW

Database for validation

- CarpatClim
  - Climatological grids: 44°N - 50°N, 17°E - 27°E
  - Period: 1961-2010
  - Temporal resolution: 1 day
  - Horizontal resolution: 0.1°
  - Used variables for the studies:
    - Temperature
    - Precipitation



TM: Tatra Mountain
GHP: Great Hungarian Plain

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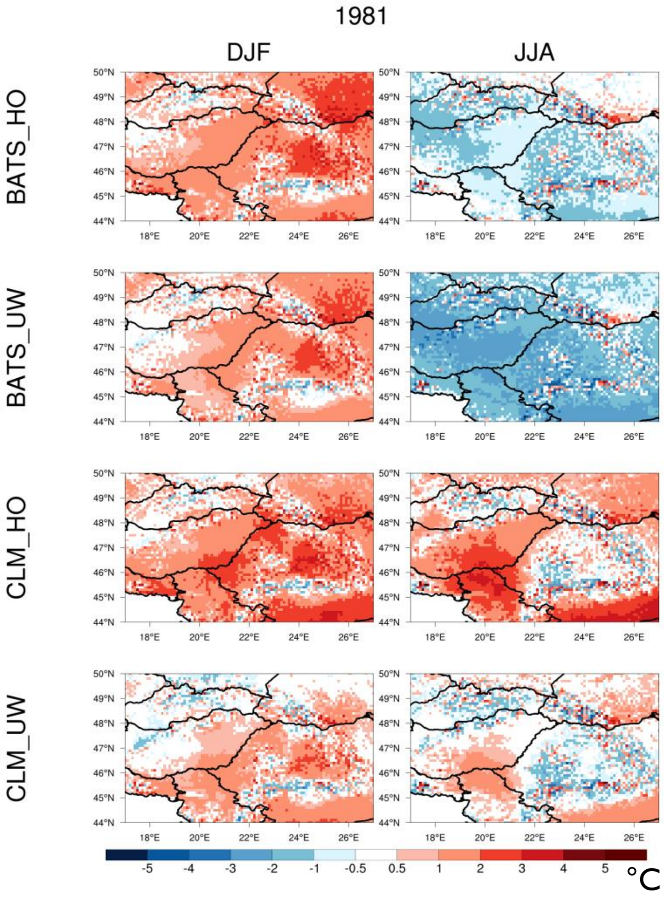
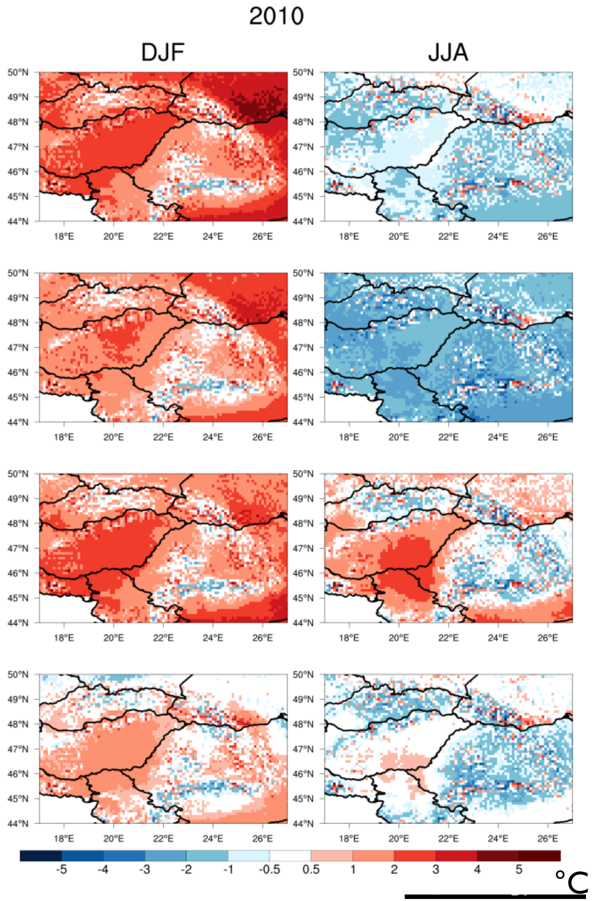
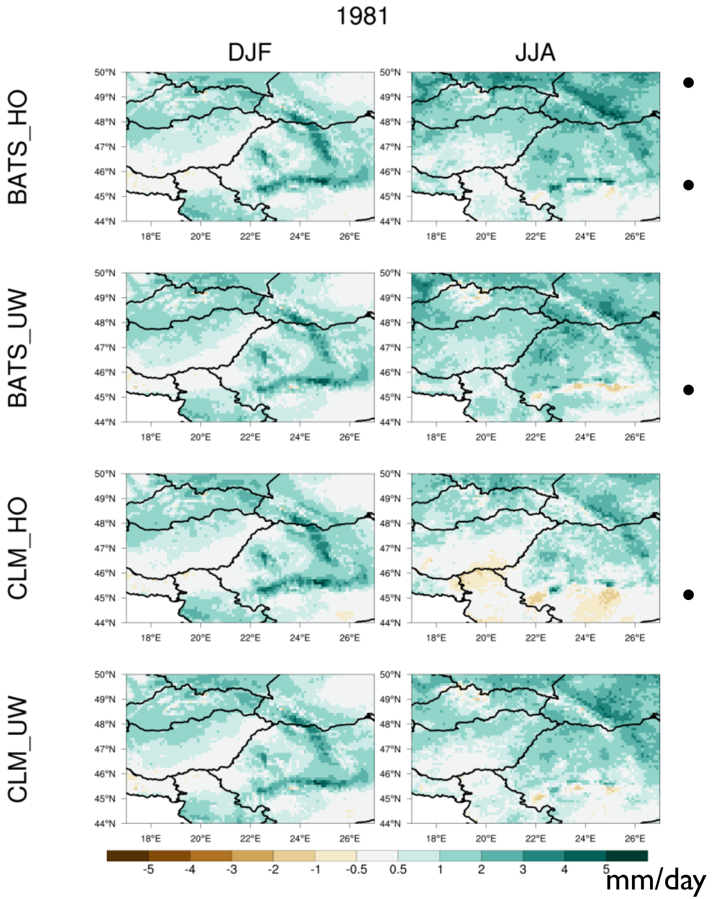
Model validation: temperature



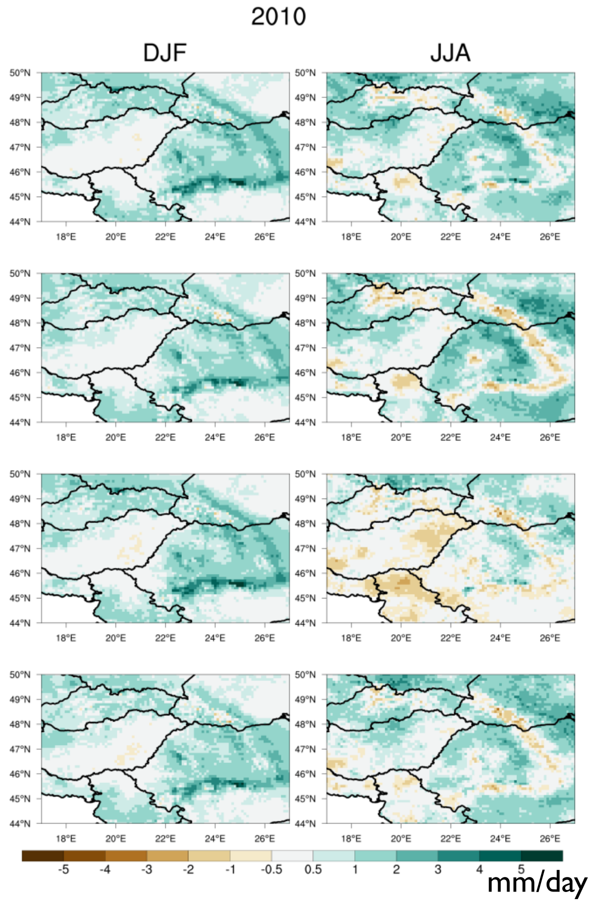
- Overestimation in winter (~2-3 °C)
- BATS scheme produces negative biases in summer
- UW scheme produces cooler climate
- Bias patterns are similar in both year
- CLM_UW seems to be the best in all season

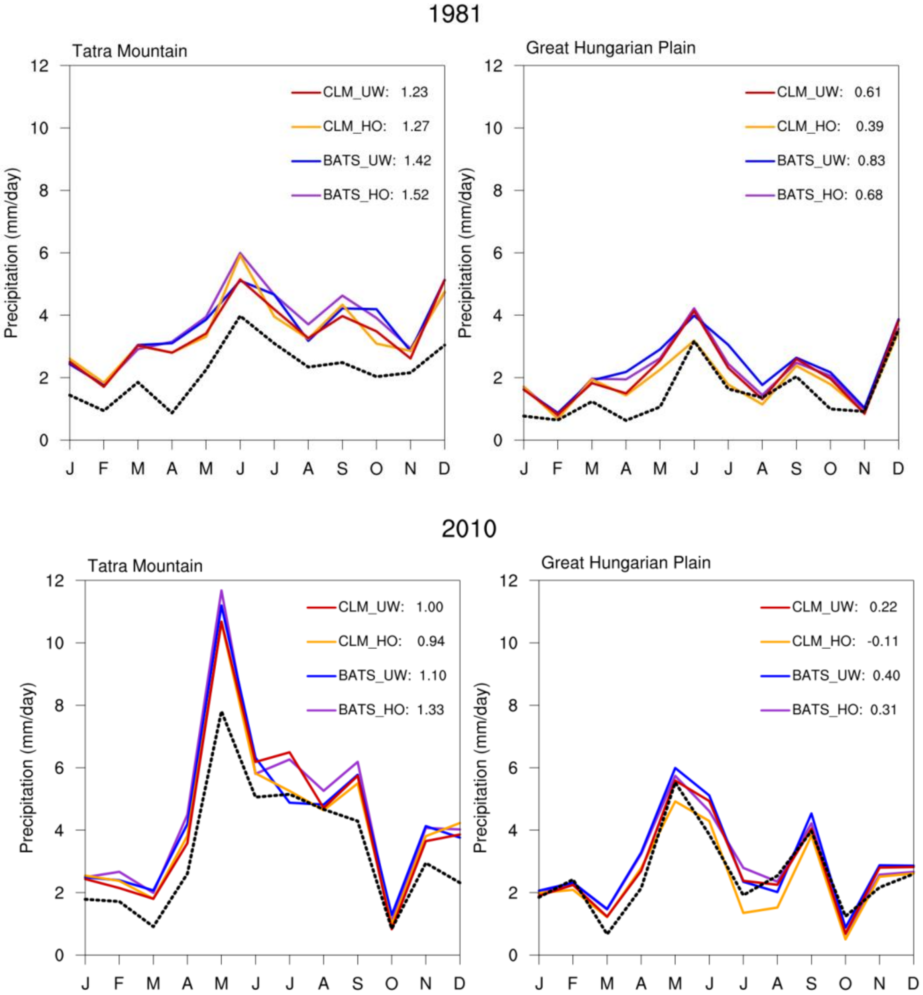


Model validation: precipitation



- In general: overestimation
- There is no substantial difference between the simulations
- The largest biases are over mountains
 (4-5 mm/day) in 1981
- Negative biases occur only in JJA in small subregions, especially in 2010





Model validation: precipitation

- All simulations overestimate precipitation over all subregions (1-2 mm/day), mainly over the mountains
- The annual cycle is well captured
- The different land and PBL schemes do not have substantial effect on precipitation
- CLM_HO results in the smallest biases

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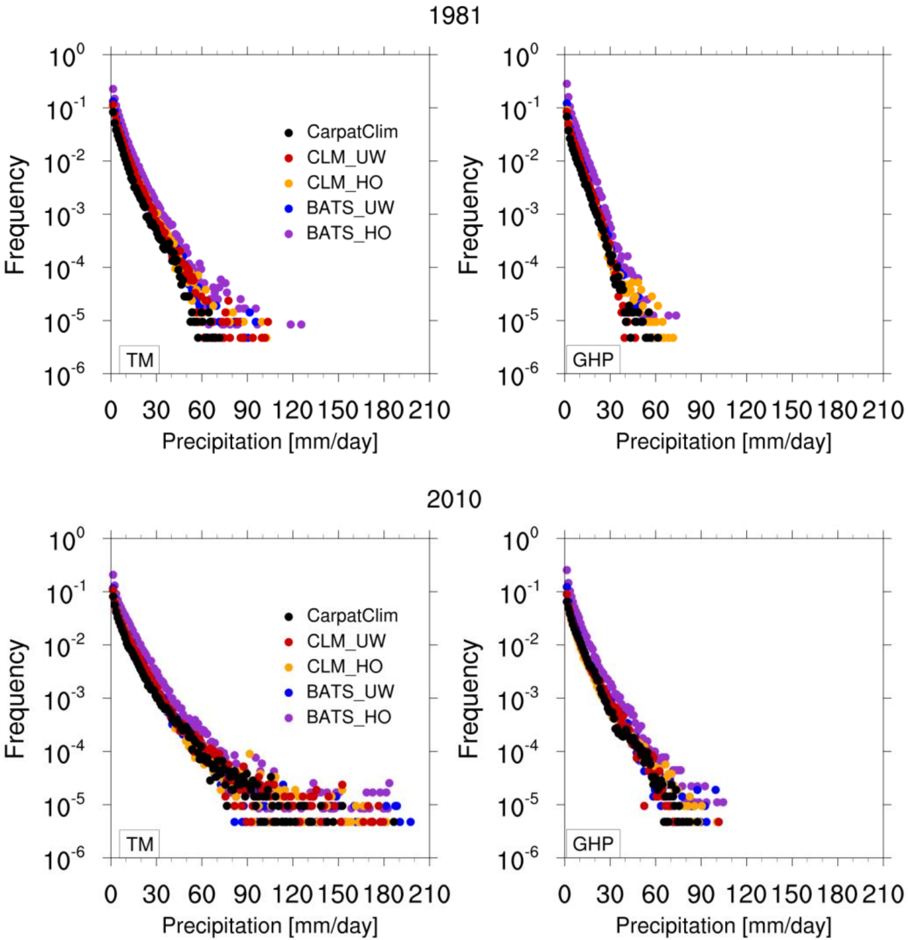
Model validation: precipitation



- PDF's (probability density function) of daily precipitation over the subregions
- In general, the simulations overestimate the high intensity events, especially over the mountainous area
- There are only slight differences between the simulations

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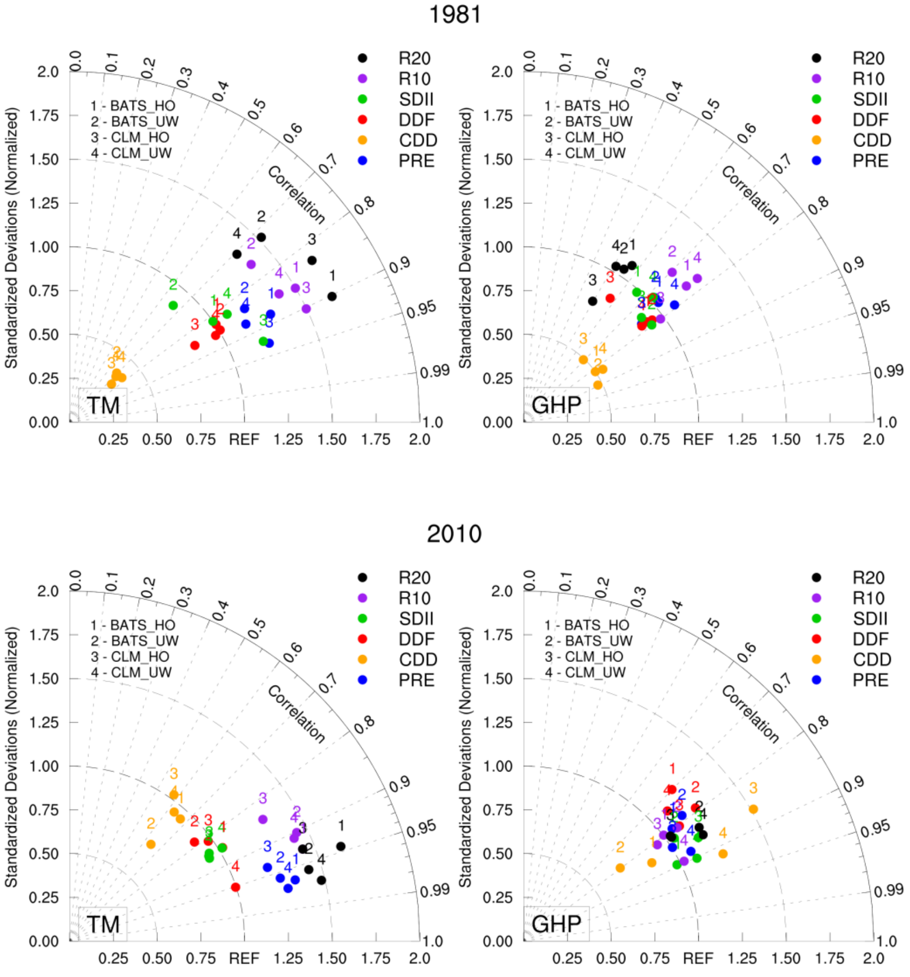
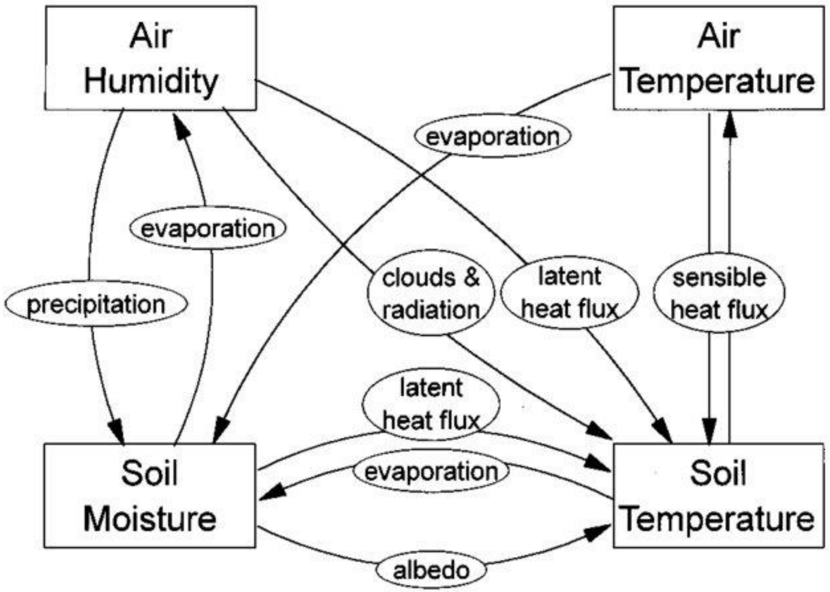
Model validation: precipitation



- Different precipitation indices for the subregions
- CDD (consecutive dry days): underestimation
- DDF (dry days frequency),
  SDII (simple daily intensity index): SDs are the closest to the reference among the indices
- R10 and R20 (very wet days with precipitation exceeding 10 and 20 mm, respectively): The difference between them is the highest over the mountainous area
- The results are better in 2010

Multi-scale processes and interactions



Brubaker and Entekhabi (1996)

- Interactions between the land surface and the atmosphere play an essential role in the weather and climate system (Knist et al., 2017)

- A key variable of the land-atmosphere system is soil moisture, which controls the flux partitioning between sensible and latent heat to a large extent (Seneviratne et al., 2010)

Surface energy budget

- Precipitation is strongly linked to the energy budget in the atmosphere

$$NR + SH + LH + G + SM = 0$$

NR: net radiation
SH: sensible heat flux
LH: latent heat flux
G: ground heat flux
SM: heat flux from snow melt

$$EF = \frac{LH}{(NR - G - SM)}$$

$$EF = \frac{LH}{(SH + LH)}$$

EF: evaporative fraction plays an important role in interpreting the components of surface available energy

Global mean (Wm^{-2})

$SW\downarrow$	$SW\uparrow$	$LW\downarrow$	$LW\uparrow$	SH	LH
185	25	342	398	21	82

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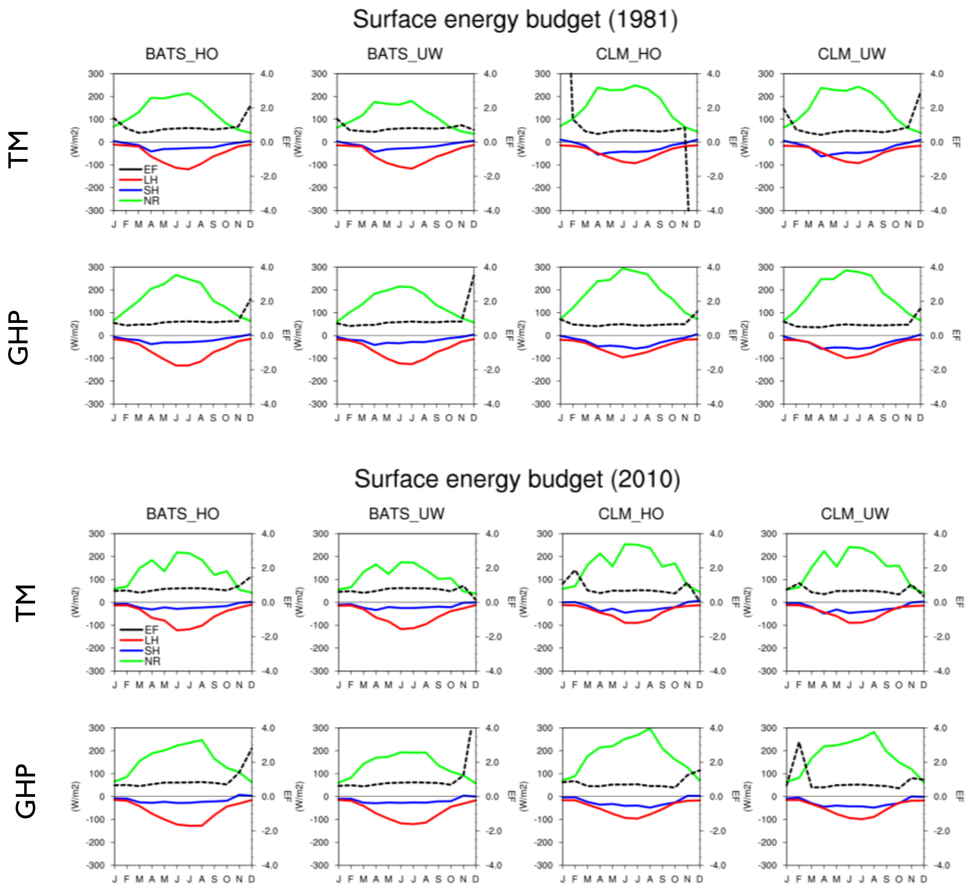
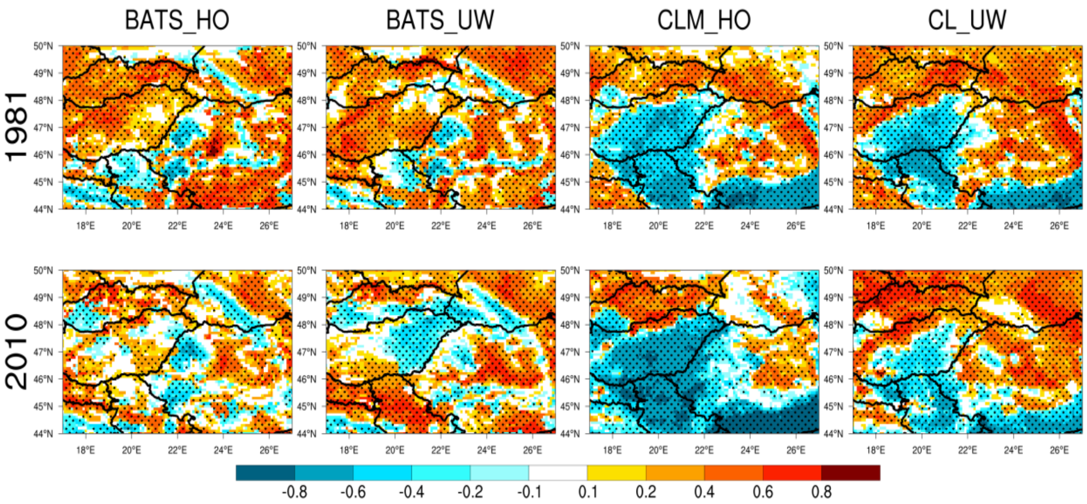
Surface energy budget



NR, LH, SH, EF

- Positive SH values: atmosphere is warmer than the surface in winter
- Simulations with BATS contain bigger negative SH in summer
- Higher LH appears with BATS simulations (contains more soil moisture than CLM simulations)
- The lower NR values with BATS are caused by the overestimation of cloud cover
- The EF has a strong link with available soil moisture, which is the limiting factor of latent heat flux, and it is essentially controlled by water availability in the root zone

Land-Atmosphere Coupling Metric



Correlation between LH and SH computed from 5 days of non-overlapping means in summer (JJA)

(Dotted areas show where correlation is significant at a 95% confidence level)

- The soil moisture-temperature coupling can be assessed by the correlation between SH and LH
- Positive correlation → weak coupling
- On the regional scale, much of the spatial heterogeneity in coupling strength can be related to orography, its influences of more precipitation, more cloud cover and colder temperatures (Knist et al., 2017)
- With CLM, the coupling is much stronger over lowland

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Conclusions

- **Temperature:**
  - BATS simulations are cooler than CLM simulations
  - UW scheme reduces the warm bias, but increases the cold bias
- **Precipitation**
  - The lower daily precipitation intensities (< 40 mm) are close to the observation
  - The extreme indices are underrepresented, especially in 1981
- **Energy budget**:
  - For the BATS simulations, the PBL scheme has more important role compared to the CLM simulations
- **Land-Atmosphere Coupling Metric**
  - CLM has stronger coupling

→ CLM with UW PBL scheme seems the best combination in both years

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References

- Bretherton, C.S., McCaa, J.R. and Grenier, H., 2004. A new parameterization for shallow cumulus convection and its application to marine subtropical cloud-topped boundary layers. Part I: Description and 1D results. *Monthly weather review*, *132*(4), pp.864-882.
- Brubaker, K.L. and Entekhabi, D., 1996. Analysis of feedback mechanisms in land-atmosphere interaction. *Water Resources Research*, *32*(5), pp.1343-1357.
- Ceglar, A., Croitoru, A.E., Cuxart, J., Djurdjevic, V., Güttler, I., Ivančan-Picek, B., Jug, D., Lakatos, M. and Weidinger, T., 2018. PannEx: The Pannonian Basin Experiment. *Climate Services*, *11*, pp.78-85.
- Dickinson, S.C., US Secretary of Navy, 1993. *Antenna erector for a towed buoyant cable*. U.S. Patent 5,272,486.
- Holtslag, A.A.M., De Bruijn, E.I.F. and Pan, H.L., 1990. A high resolution air mass transformation model for short-range weather forecasting. *Monthly Weather Review*, *118*(8), pp.1561-1575
- Knist, S., Goergen, K., Buonomo, E., Christensen, O.B., Colette, A., Cardoso, R.M., Fealy, R., Fernández, J., García-Díez, M., Jacob, D. and Kartsios, S., 2017. Land-atmosphere coupling in EURO-CORDEX evaluation experiments. *Journal of Geophysical Research: Atmospheres*, *122*(1), pp.79-103.
- Oleson, K., 2013. Technical description of version 4.5 of the Community Land Model (CLM) p 420. *NCAR Technical Note*.
- Seneviratne, S.I., Corti, T., Davin, E.L., Hirschi, M., Jaeger, E.B., Lehner, I., Orlowsky, B. and Teuling, A.J., 2010. Investigating soil moisture–climate interactions in a changing climate: A review. *Earth-Science Reviews*, *99*(3-4), pp.125-161.
- Spinoni, J., Antofie, T., Barbosa, P., Bihari, Z., Lakatos, M., Szalai, S., Szentimrey, T. and Vogt, J., 2013. An overview of drought events in the Carpathian Region in 1961-2010. *Advances in Science and Research*, *10*, p.21.
- Tiedtke, M., 1989. A comprehensive mass flux scheme for cumulus parameterization in large-scale models. *Monthly weather review*, *117*(8), pp.1779-1800.
- Torma, C., Coppola, E., Giorgi, F., Bartholy, J. and Pongrácz, R., 2011. Validation of a high-resolution version of the regional climate model RegCM3 over the Carpathian basin. *Journal of Hydrometeorology*, *12*(1), pp.84-100.

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