WS 1.1.B: Climate modeling in Mountain regions

Elevation-dependent warming in global climate model simulations at different spatial resolutions

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Background

EDW

The dependence of warming rates on elevation:

- Can be either positive or negative, but has to be statistically significant
- Can exhibit non-linear behaviour

Observations

- Are subject to **uncertainties** due to sparseness/ lack and biased distribution of in-situ stations
-Are in less agreement with each other than model simulations

Model studies

- Model resolution and imperfect parameterizations are **source of uncertainties**
- Based on both global and regional models, on both historical and future projections

Background and this study

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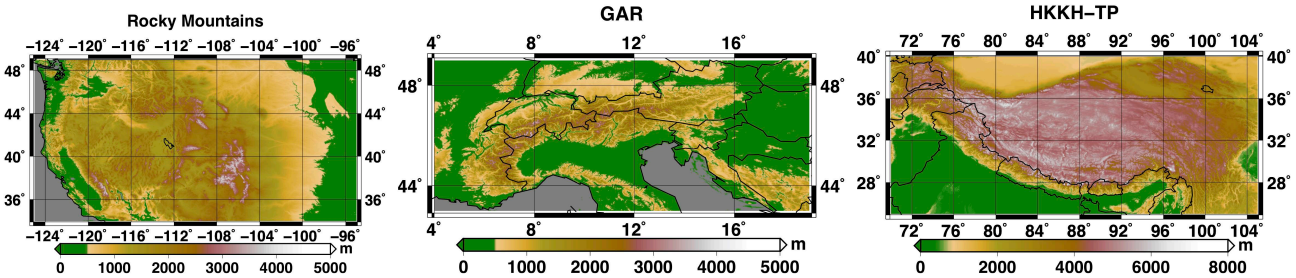


SPHINX

Ensemble of model simulations performed with the EC-Earth GCM, run at 125km, 80km, 40km, 25km, 16km, over three NH mid-latitude mountains.

- **Characteristics and linearity of the relashionship between warming rates and elevation**
- **Slope of the linear regression between warming rates and elevation**
- **EDW drivers**

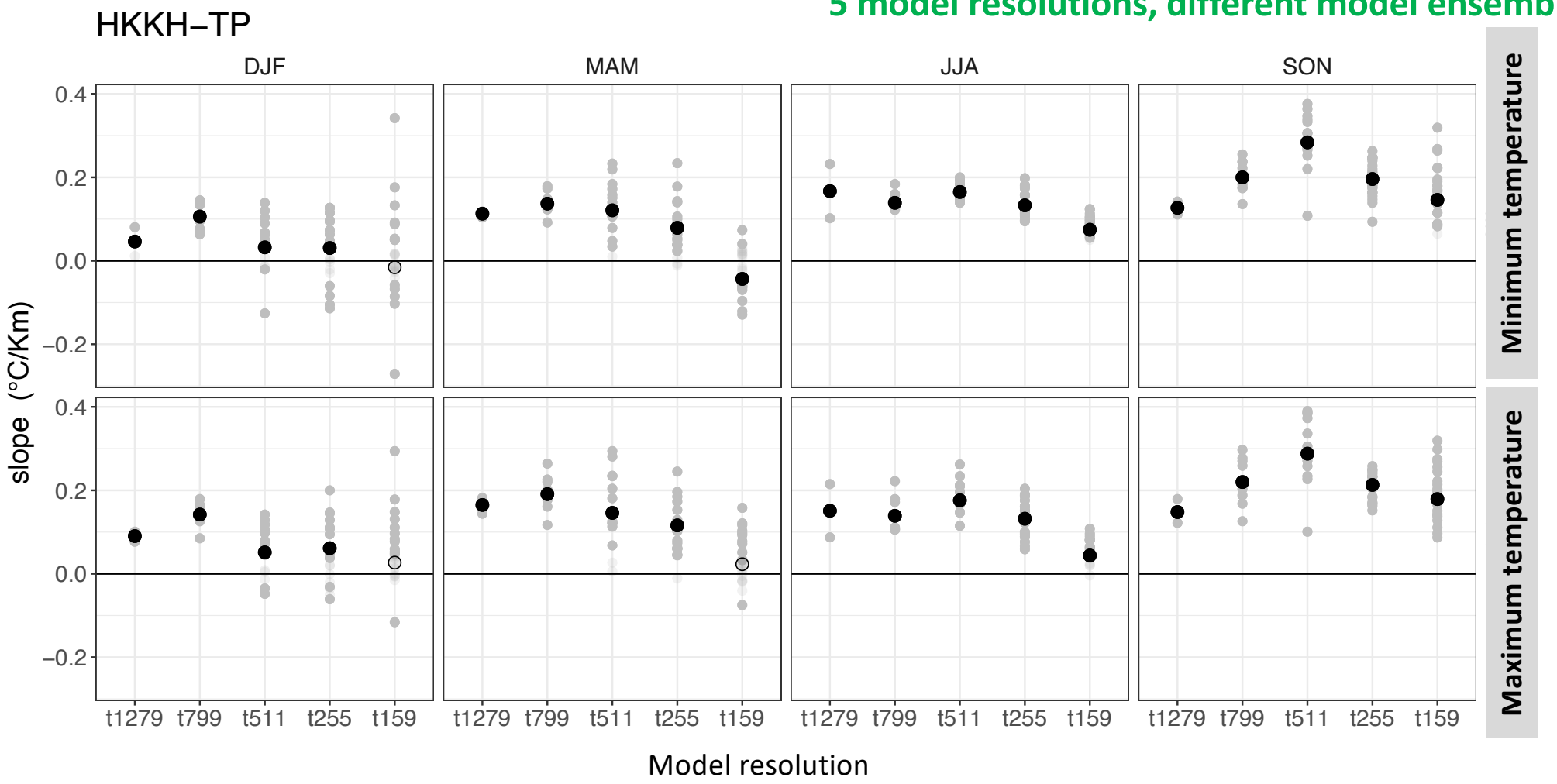
Does the model resolution play a role?

Slope of the linear regression

Himalaya-Tibetan Plateau

Minimum and maximum temperature, 4 seasons

5 model resolutions, different model ensemble



Slope of the linear regression

EDW signal is coherent throughout all model resolutions, though its intensity may be different and the model ensemble exhibits some spread

The region more prone to EDW is the HKKH-TP; the season showing the most striking evidence of EDW in all regions is autumn

		Tasmin					Tasmax				
		t1279	T799	T511	T255	T159	T1279	T799	T511	T255	T159
DJF	HKKH-TP	Y	Y	Y	Y	(N)	Y	Y	Y	Y	(Y)
	GAR	(N)	(N)	N	(N)	N	N	(N)	(N)	Y	Y
	Rockies	N	N	N	N	N	N	N	N	N	N
		T1279	T799	T511	T255	T159	T1279	T799	T511	T255	T159
MAM	HKKH-TP	Y	Y	Y	Y	N	Y	Y	Y	Y	(Y)
	GAR	(Y)	N	N	N	N	(N)	N	(N)	(Y)	Y
	Rockies	(N)	(N)	(N)	Y	Y	(Y)	(Y)	(Y)	Y	Y
		T1279	T799	T511	T255	T159	T1279	T799	T511	T255	T159
JJA	HKKH-TP	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	GAR	Y	Y	Y	(N)	(N)	Y	Y	Y	N	(N)
	Rockies	N	Y	(Y)	Y	Y	N	Y	(N)	(N)	Y
		T1279	T799	T511	T255	T159	T1279	T799	T511	T255	T159
SON	HKKH-TP	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
	GAR	Y	Y	Y	(Y)	Y	Y	Y	Y	N	(N)
	Rockies	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

Y = positive EDW (warming rates increase with elevation)
N = negative EDW
(Y/N) = slope not statistically significant

Drivers

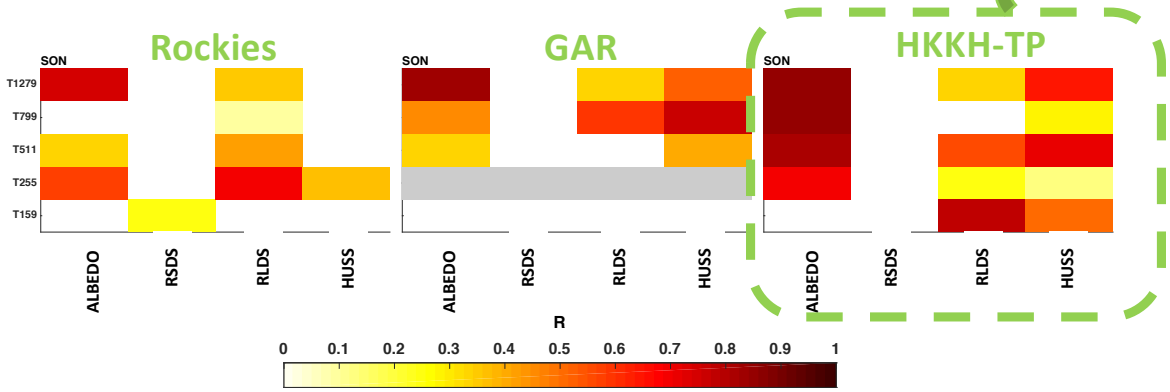
Temperature change at the surface is a response to the energy balance
→ **factors that increase the net flux of energy to the surface would lead to positive EDW**
→ **Δalbedo, Δhuss, Δrlds, Δrsds**

Multiple linear regression model

$$\Delta T_{min,max}(x) = a_0 + a_1 \Delta Albedo(x) + a_2 \frac{\Delta huss(x)}{huss_0(x)} + a_3 \frac{\Delta rlds(x)}{rlds_0(x)}$$

- They exhibit a dependence on elevation
- The sign of this dependence is consistent with positive EDW
- They are spatially correlated with the temperature change (when the dependence on elevation is removed)

All variables are "altitude-detrended" (i.e., the linear dependence on the altitude is removed) and standardized



HKKH–TP, SON

$\Delta(tasmin, tasmax) = a_1 \Delta albedo + a_2 \Delta huss/huss_0 + a_3 \Delta rlds/rlds_0$

	Rank	Δtasmin				
		$\Delta albedo$	$\frac{\Delta huss}{huss_0}$	$\frac{\Delta rlds}{rlds_0}$	R^2	AICc
		a_1	a_2	a_3		
T1279	1	− 0.793	0.147	0.508	0.664	− 0.554
	2	− 0.748	–	0.605	0.657	− 0.532
	3	− 0.848	0.556	–	0.554	− 0.270
	4	− 0.568	–	–	0.323	0.147
	5	–	− 0.363	0.655	0.204	0.310
	6	–	–	0.382	0.200	0.379
	7	–	0.130	–	0.080	0.520

Conclusions, issues, perspectives

- **Overall, the model resolution plays a crucial role in small areas such as the Alps**, where a too coarse resolution would lead to an underrepresentation of the highest altitudes.

- Enhancing the spatial resolution in climate models may be crucial especially in complex topography, but also improvements in model **parameterizations**, particularly those **involving surface processes, the snow-albedo and cloud-radiation feedbacks**, may allow for a better simulation of EDW in the models.

Palazzi, E., Mortarini, L., Terzago, S. et al. Clim Dyn (2019) 52: 2685. https://doi.org/10.1007/s00382-018-4287-z