Effects of climate input data aggregation on modelling regional crop yields

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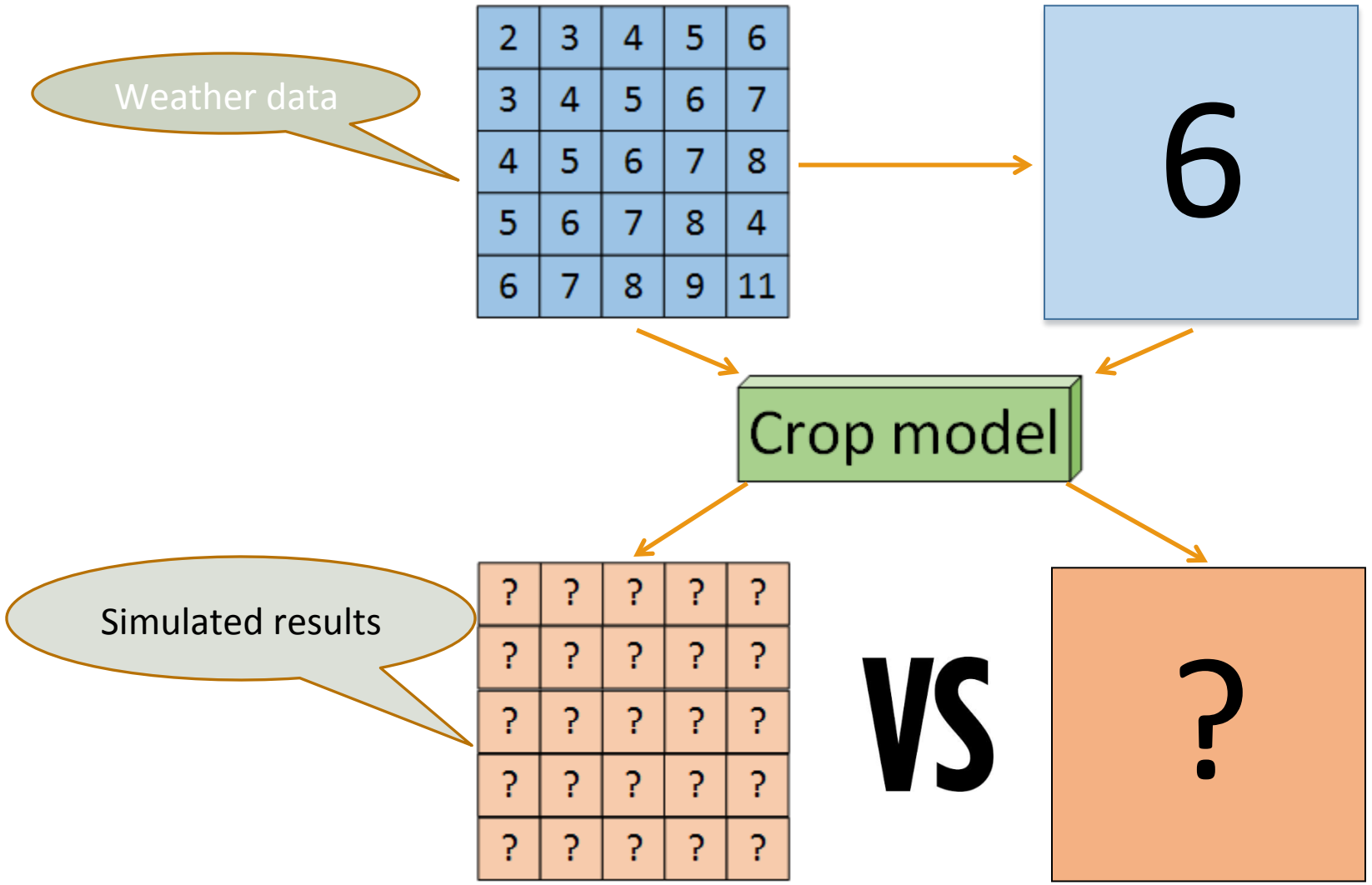
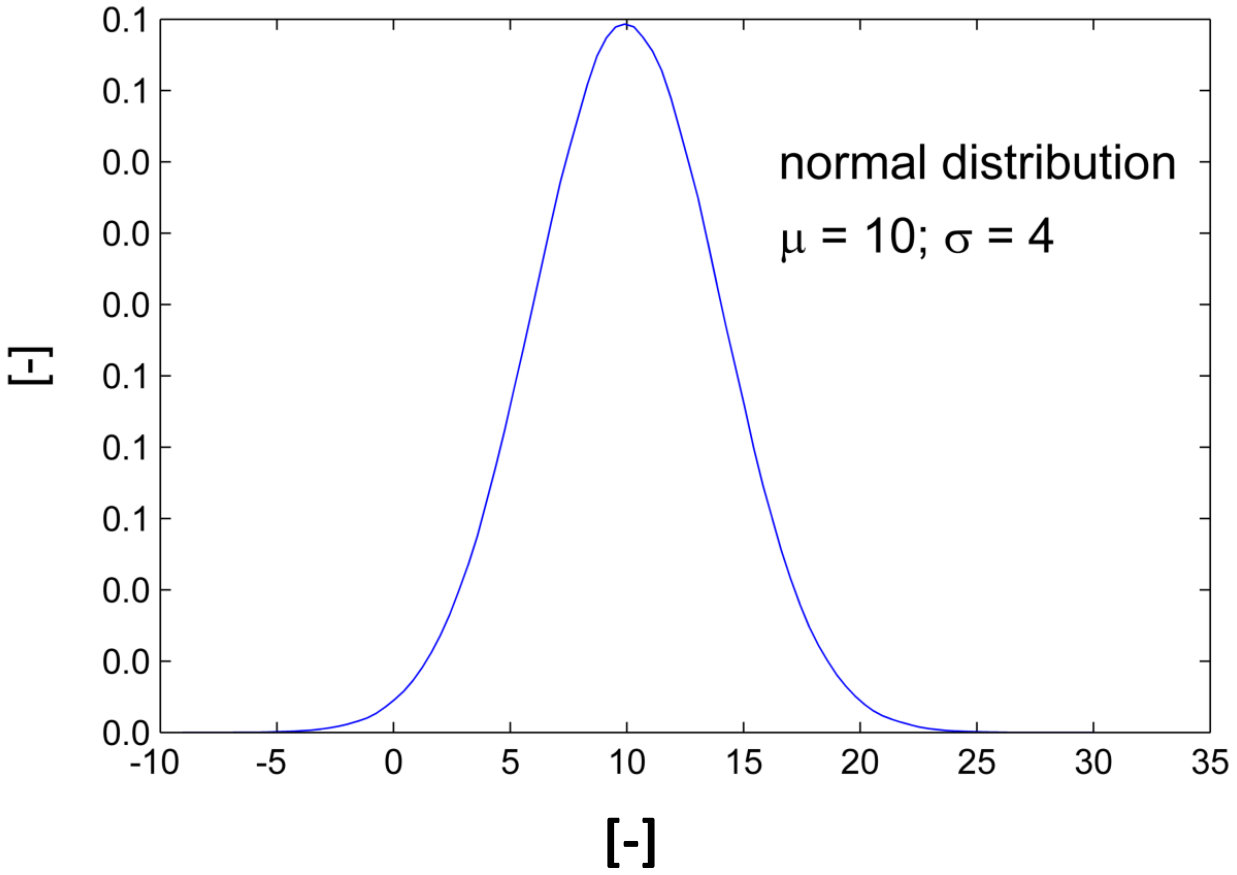
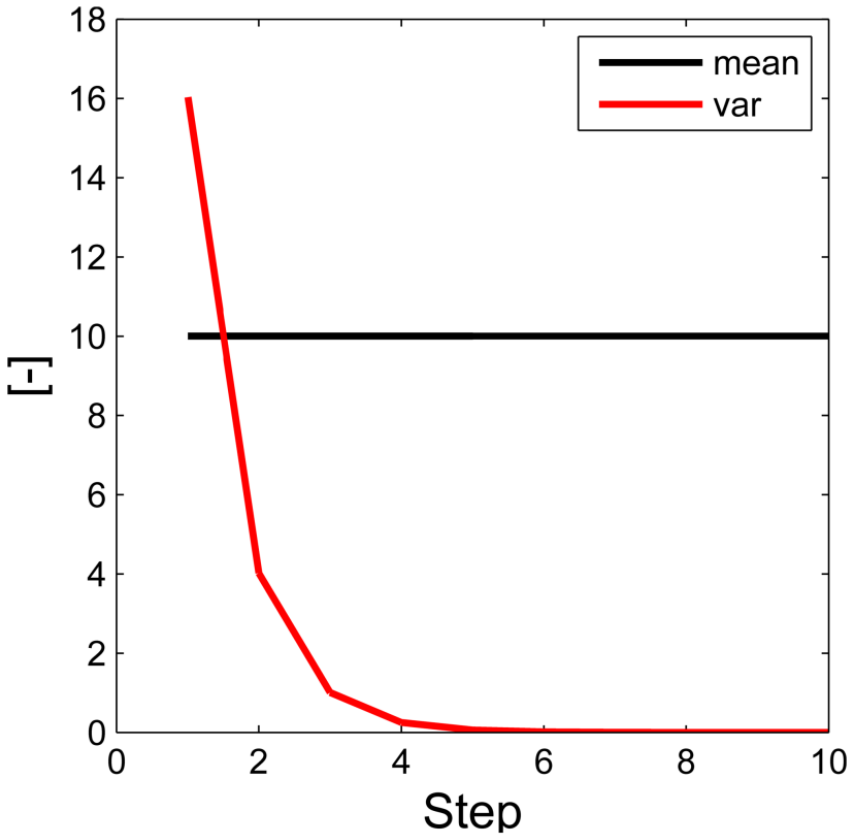
Data aggregation and crop modelling



Zhao et al., 2014

Data aggregation and crop modelling: theoretical consideration



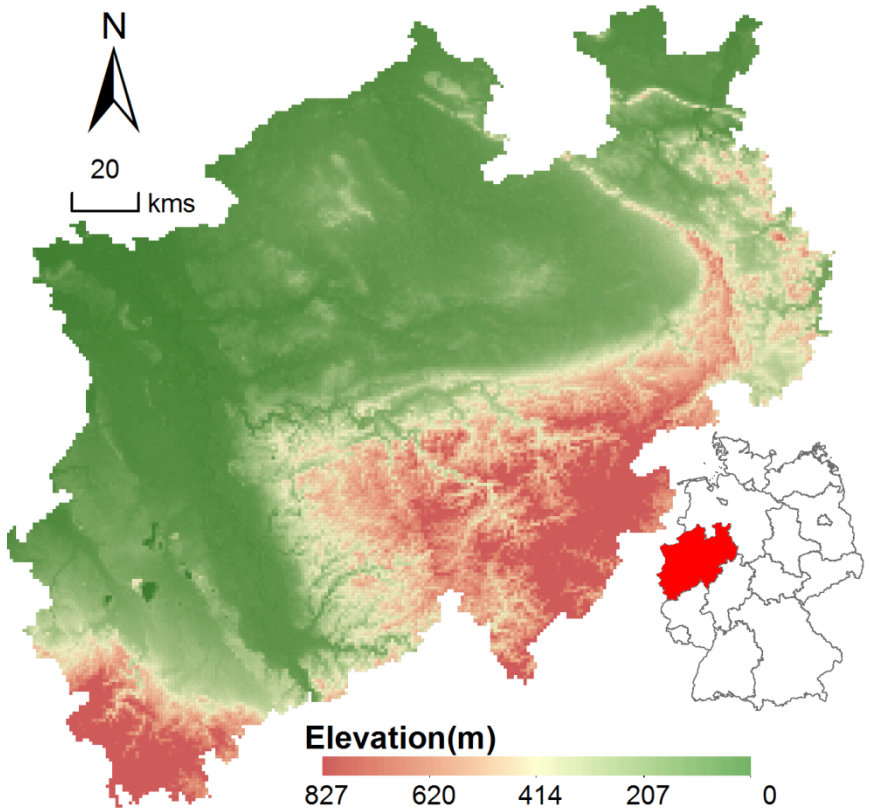


Motivation and Objectives

Rasche & Del Diego 2014
What do we know? ➔ Hansen & Jones 2000, Angulo et al. 2013, Nendel et al. 2013…

1. To what extent are crop model outputs affected by input aggregation?
2. Do the effects of scaling methods depend on the model?
3. Do the effects of scaling methods depend on the output type (yield, ET, soil carbon, N_2O, …)?
4. ...

Methodology



- Weather data: Tmin, Tmax, precipitation, radiation, wind speed
- Soil: single soil profile for all grid cells
- 13 crop models: APSIM, APSIM$_{(modified)}$, HERMES, MONICA, STICS, SIMPLACE<LINTUL5>, COUP, EPIC, LandscapeDNDC, DailyDaycent, MCWLA, RothC, N_2O-Mode
- Crops: Winter wheat and silage maize
- Calibration: Minimum
- Production systems: potential, water limited, and N limited

Methodology

Climate data aggregation levels

Resolution (km)	No. of grid cells
1	34168
10	410
25	80
50	24
100	9

~ 79,823,991 years

- Weather data: Tmin, Tmax, precipitation, radiation, wind speed
- Soil: single soil profile for all grid cells
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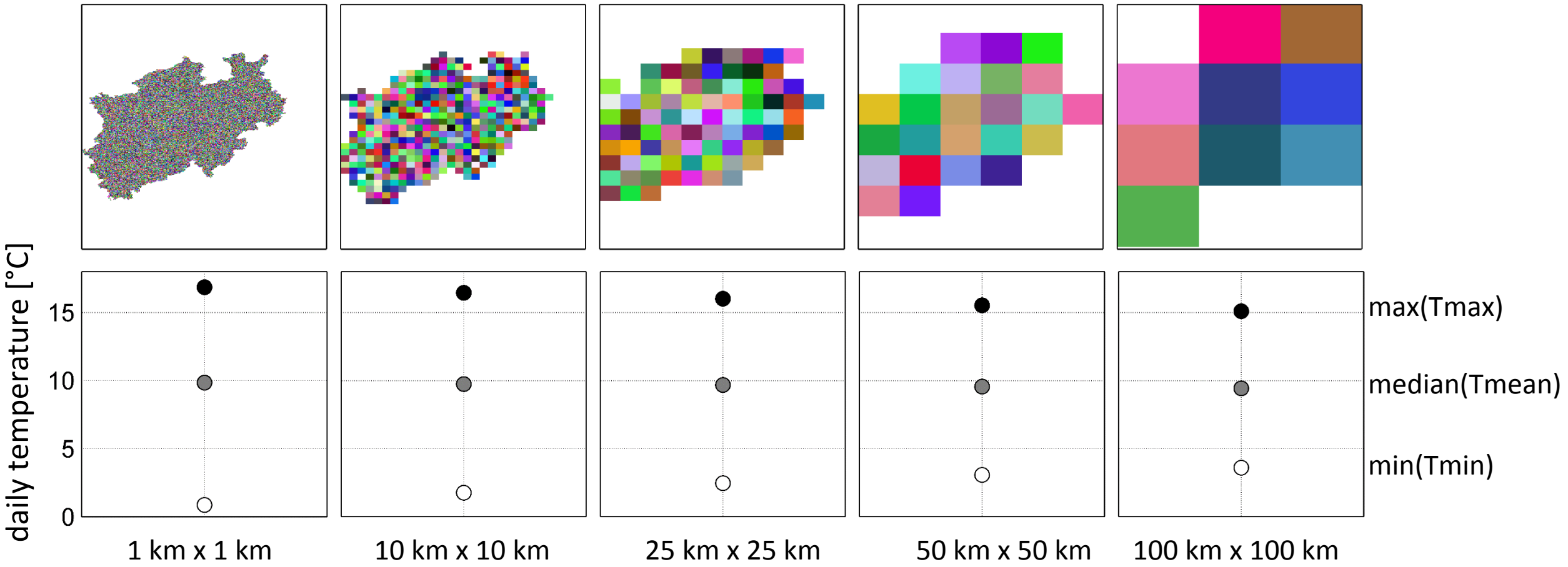
Effect of spatial aggregation on daily temperature



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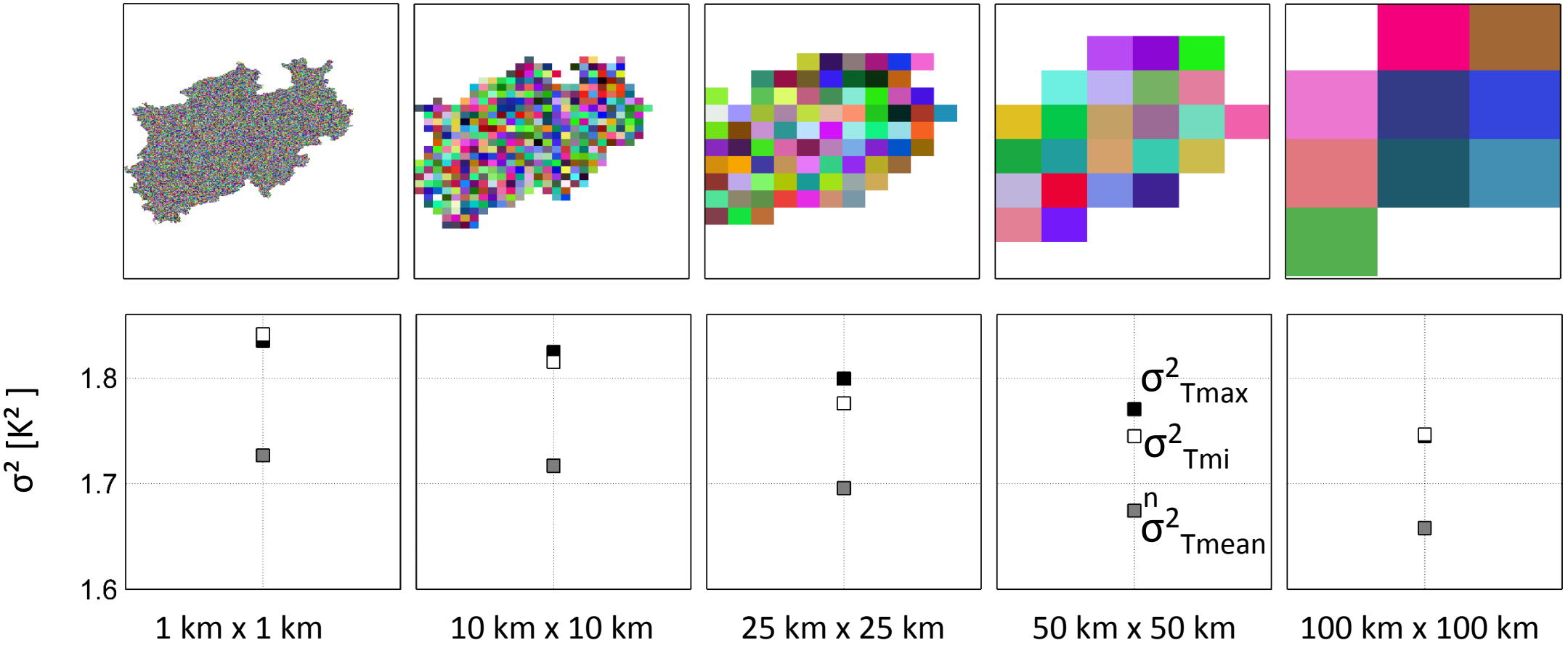
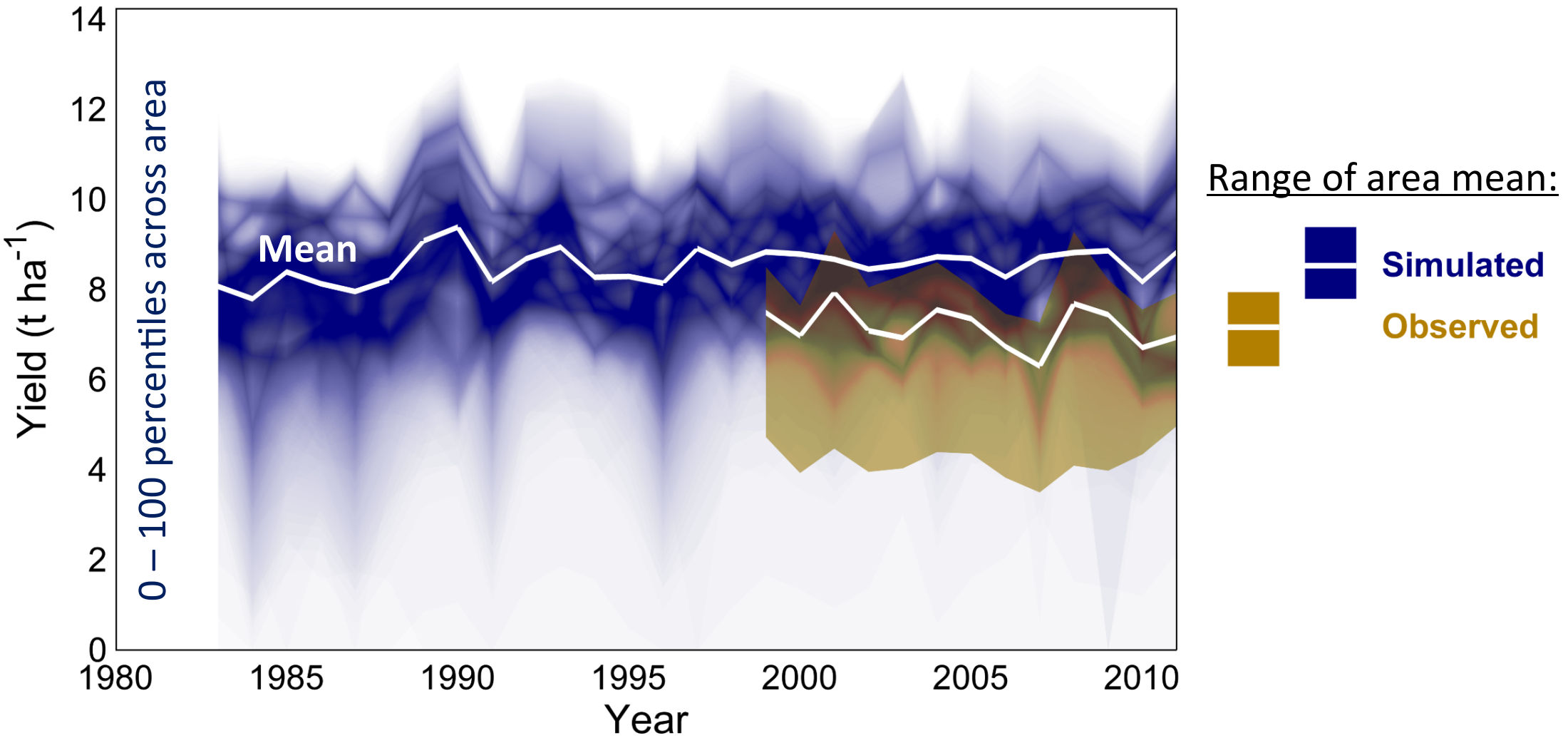


Model concordance for simulated yield of winter wheat (potential growth, 1 km x 1 km)



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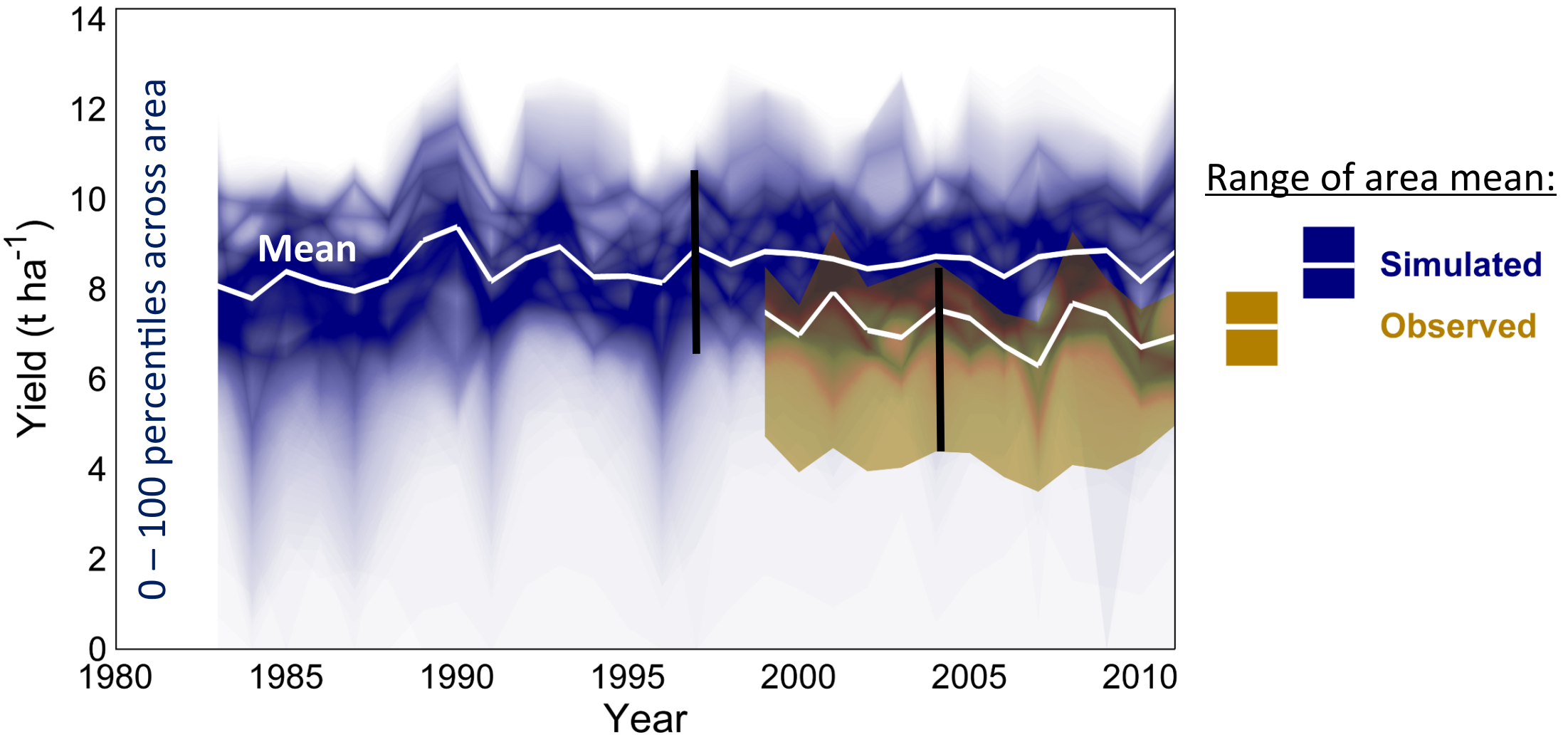

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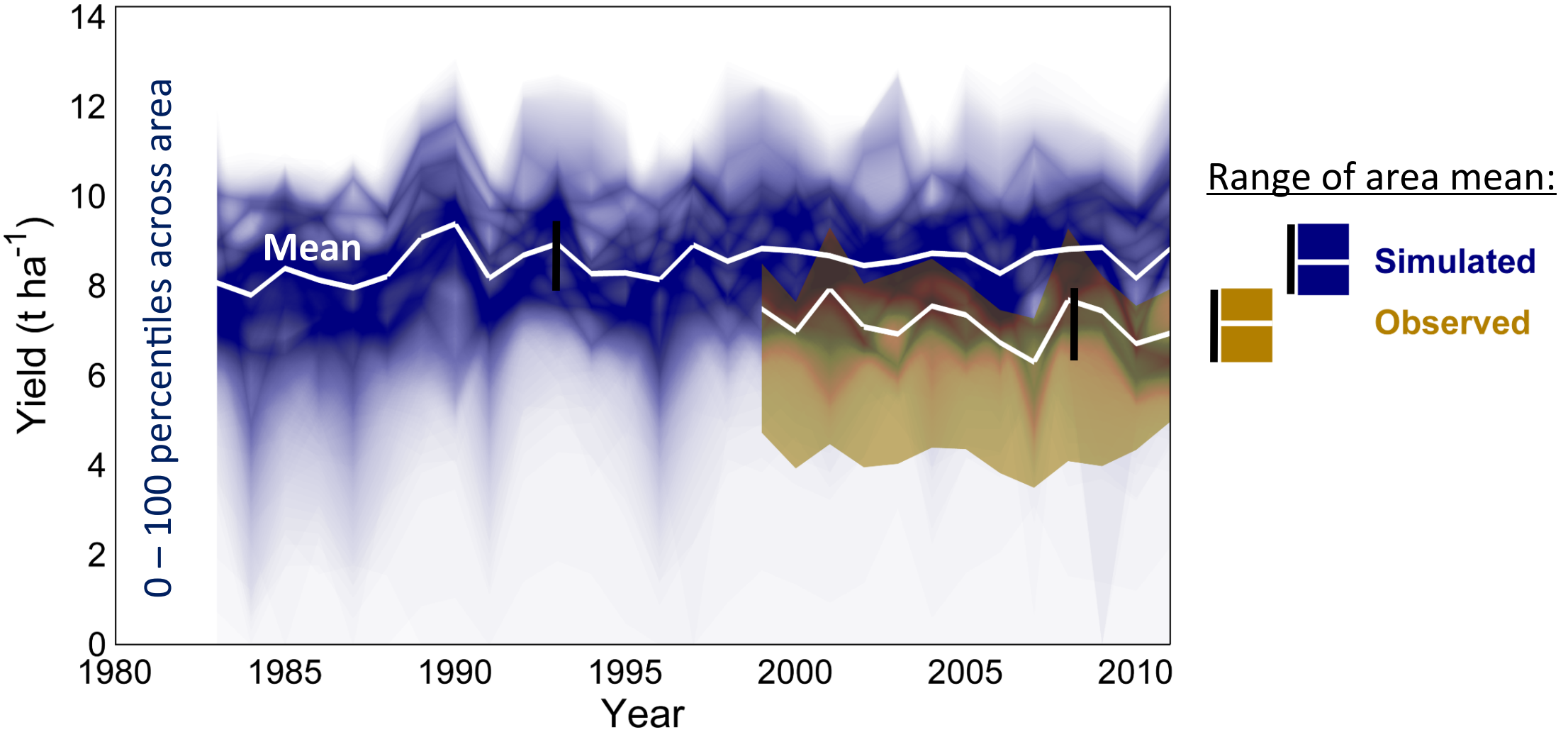

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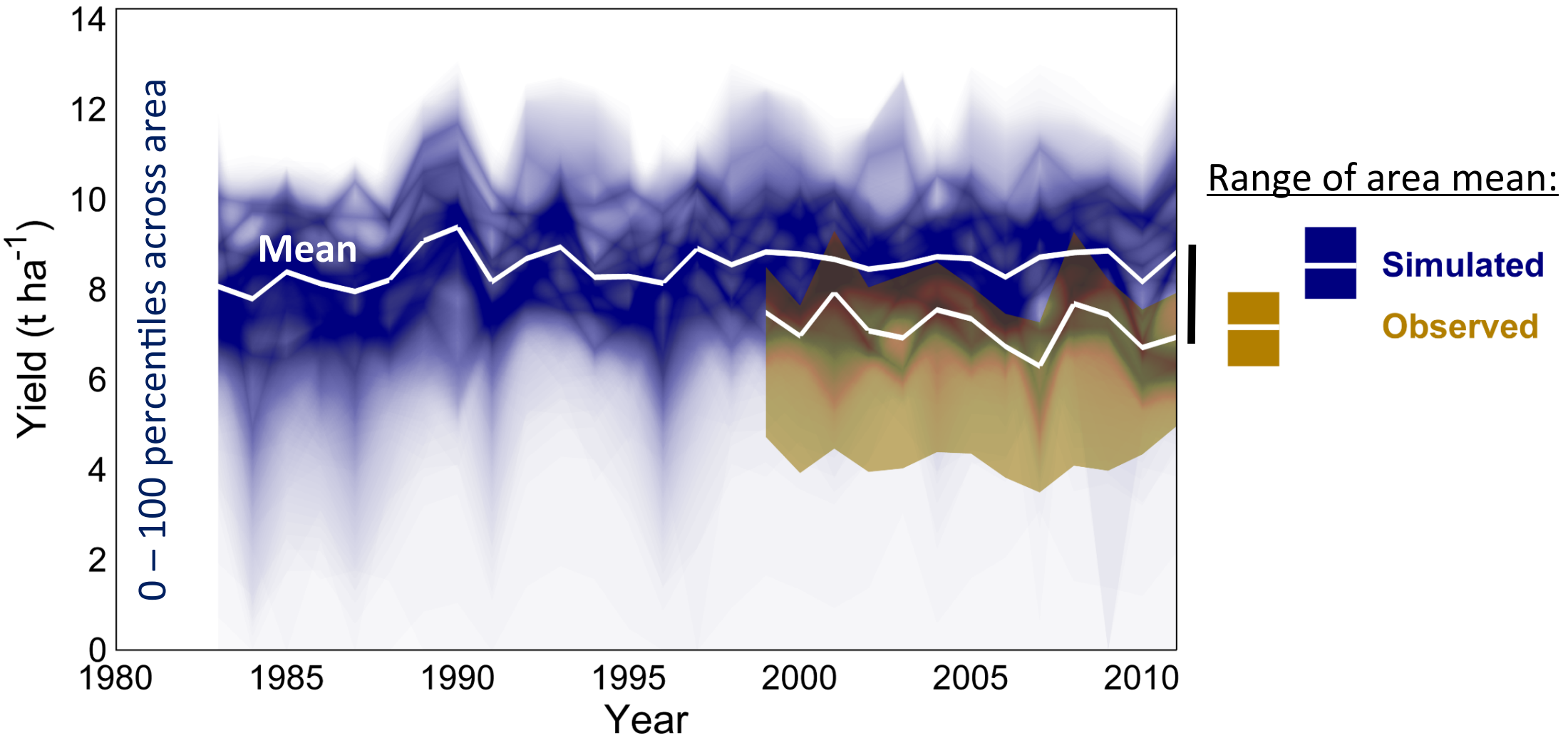
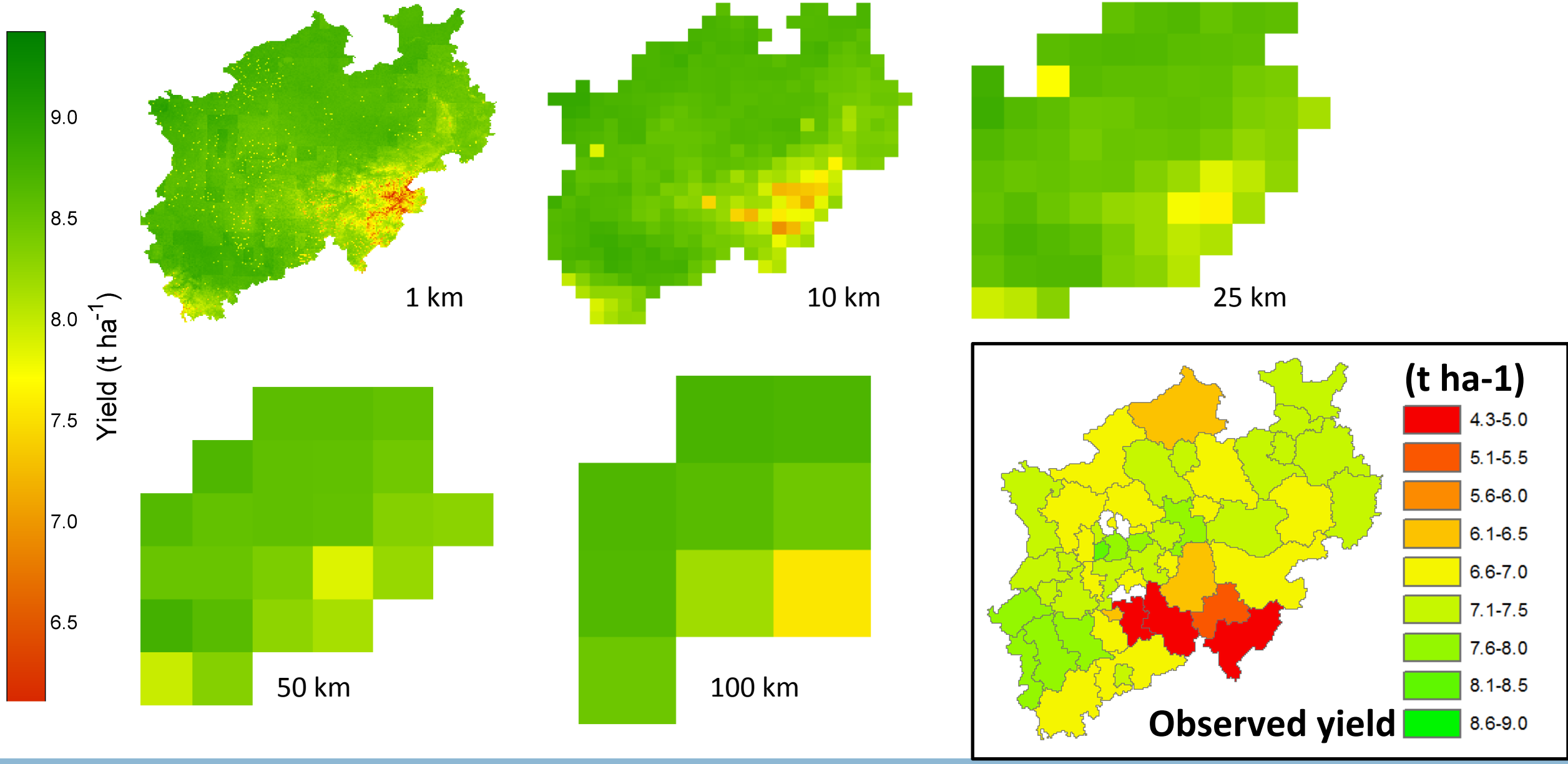
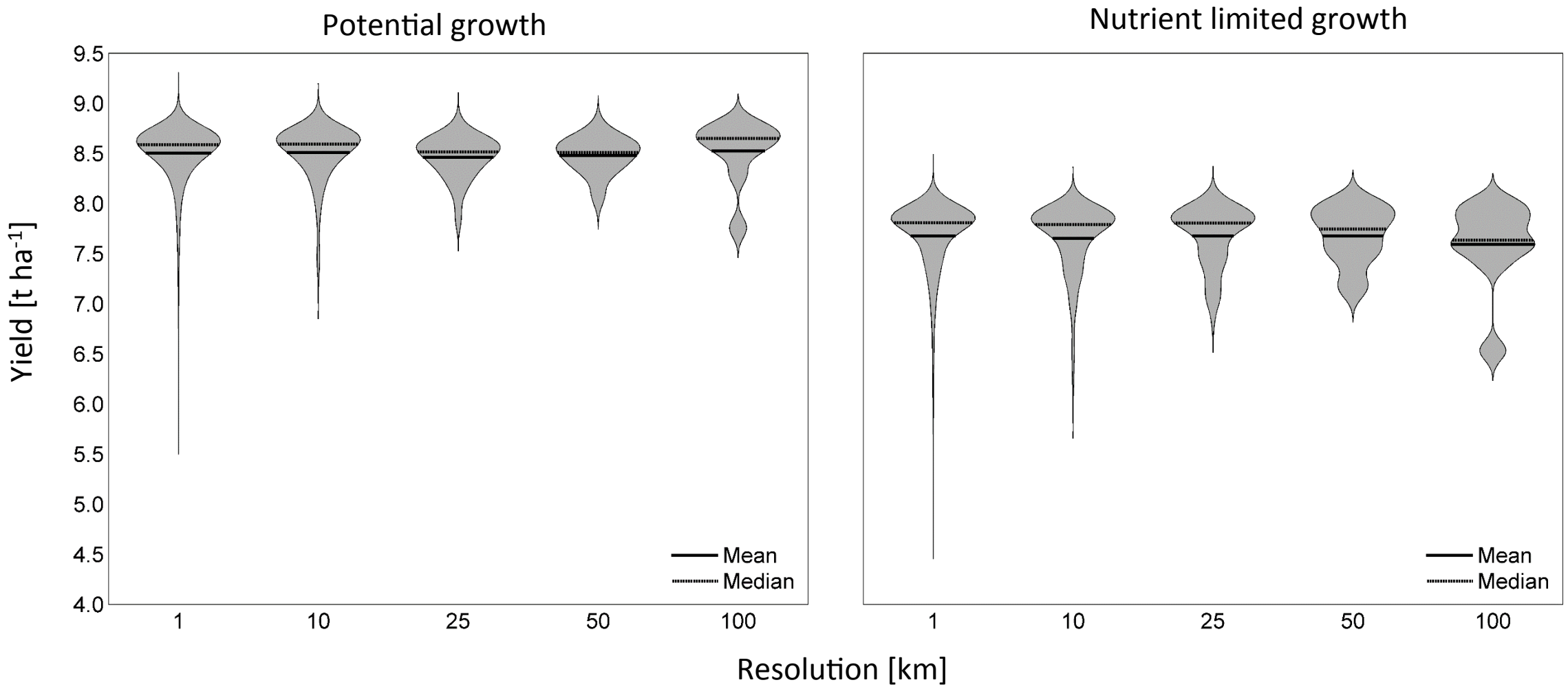


Simulated potential (ensemble mean) and observed yield of winter wheat



Effect of spatial aggregation on simulated on winter wheat yield (ensemble mean)

(ensemble mean, mean of years)



Effect of spatial aggregation on simulated grain yield and biomass

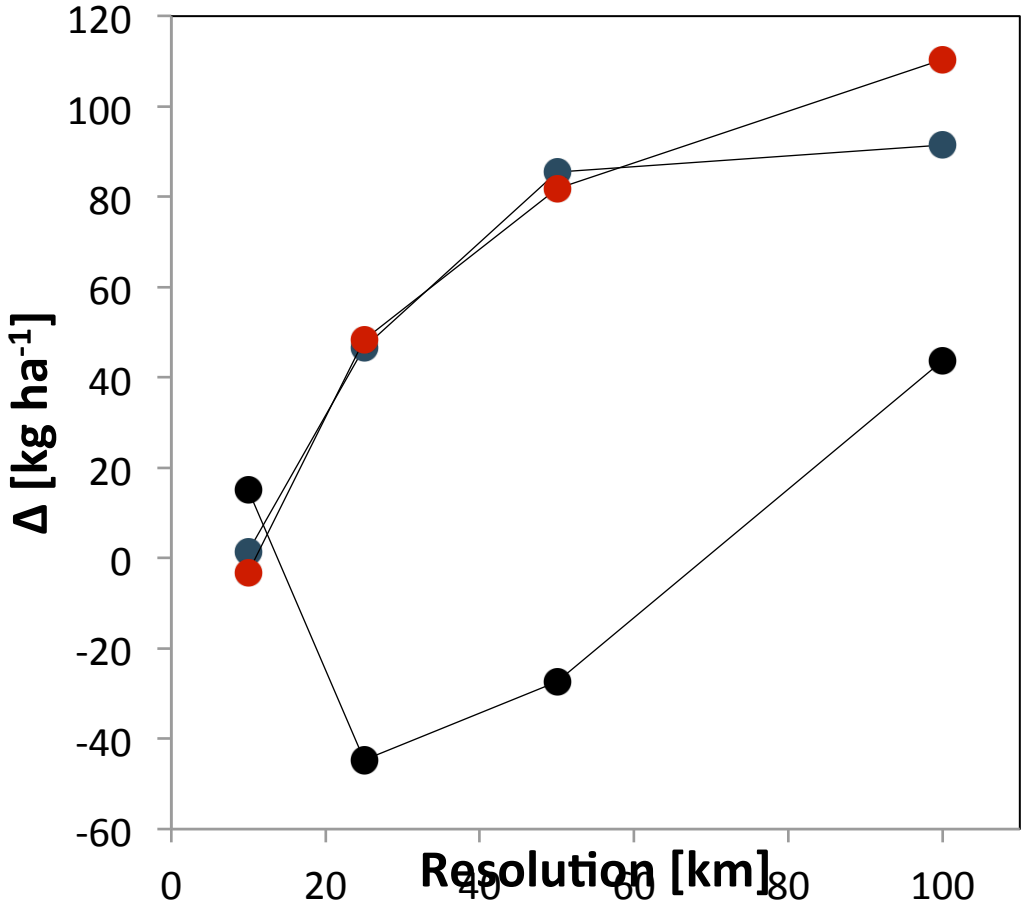
$$\bar{y} = \frac{1}{n_a \cdot n_c \cdot n_m} \sum_{a,c,m}^{n_a \cdot n_c \cdot n_m} y_{a,c,m} \qquad \bar{\sigma}^2 = \frac{1}{n_a n_c} \sum_{a=1}^{n_a} \sum_{c=1}^{n_c} \left(\left(\frac{1}{n_m} \sum_{m}^{n_m} y_{a,c,m} \right) - \left(\frac{1}{n_s n_m} \sum_{s=1}^{n_s} \sum_{m=1}^{n_m} y_{a,s,m} \right) \right)^2$$

with:
$\bar{y}$: mean yield
$\bar{\sigma}^2$: mean yield variance
m: model
s, c: grid point
a: year

Resolution	Winter Wheat grain yield $\bar{y}$, ($\bar{\sigma}^2$) [t ha^{-1} , (t^2 ha^{-2})]			Silage Maize above ground biomass $\bar{y}$, ($\bar{\sigma}^2$) [t ha^{-1} , (t^2 ha^{-2})]		
(km)	Potential	Water-limited	Nutrient-limited	Potential	Water-limited	Nutrient-limited
1	8.2 (0.17)	7.9 (0.17)	7.6 (0.24)	17.7 (1.79)	17.1 (1.43)	15.1 (1.24)
10	8.3 (0.16)	7.9 (0.17)	7.5 (0.24)	17.7 (1.58)	16.7 (1.01)	15.0 (1.02)
25	8.2 (0.11)	7.9 (0.13)	7.5 (0.19)	17.7 (1.35)	16.7 (0.86)	15.0 (0.74)
50	8.2 (0.09)	7.9 (0.12)	7.6 (0.17)	17.7 (1.02)	16.7 (0.65)	15.1 (0.54)
100	8.3 (0.17)	7.9 (0.20)	7.5 (0.31)	17.8 (0.59)	16.8 (0.39)	15.1 (0.33)

Actual mean yield: 7.2 t ha^{-1} Actual mean biomass: 14.3 t ha^{-1}

Effect of spatial aggregation on simulated grain yield (selected cell c0 r4)



Nutrient limited

Water limited

Potential

$$\Delta = \frac{1}{n_a n_c n_m n_r} \sum_{a,c,m,r}^{n_a n_c n_m n_r} \left(y_{a,s,m,r \geq 10} - y_{a,c,m,r=1} \right)$$

y: yield
m: model
c: grid point
a: year
r: resolution [km]

Conclusion and Ongoing work

1. To what extent does input data aggregation affect crop model output?
2. Do the effects of scaling methods depend on the model?

$$\text{‘Aggr. Effect‘} = f(\mu(X), \sigma(X), \tau \sim \hat{\gamma}(h), M(\theta, ...))$$

μ(X), σ(X): Input data mean, variance; τ: resolution; $\hat{\gamma}(h)$: semivariance; M: Model; θ: parameters

Conclusion: Crop model input data aggregation effects depend on model sensitivity, modelled crop sensitivity and the spatial variance of the input data.
➔ Need for investigation at higher spatial variance / at ‘stress’
➔ Need for detailed assessment at the level of model structure

Ongoing: + soil information, +higher resolution (spatial, temporal), +region, +management

Conclusion and Ongoing work

Conclusion: Crop model input data aggregation effects are a function of the model sensitivity, the modelled crop sensitivity and the spatial variance of the climate data.

➔ Need for investigation at higher spatial variance

➔ Need for further investigation at stress

➔ Need for detailed assessment at the level of model structure

Thank you

‘Aggr. Effect‘ $= f(\mu(X), \sigma(X), \tau \sim \hat{\gamma}(h), M(\theta, ...))$

μ(X), σ(X): Input data mean, variance; τ : resolution $\hat{\gamma}(h)$: semivariance; M: Model; θ: parameters