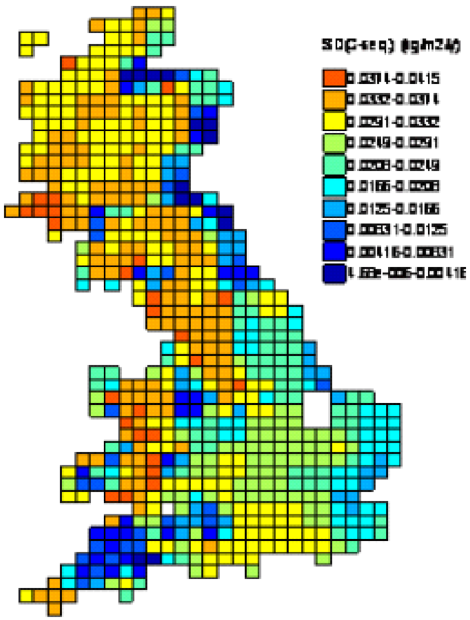
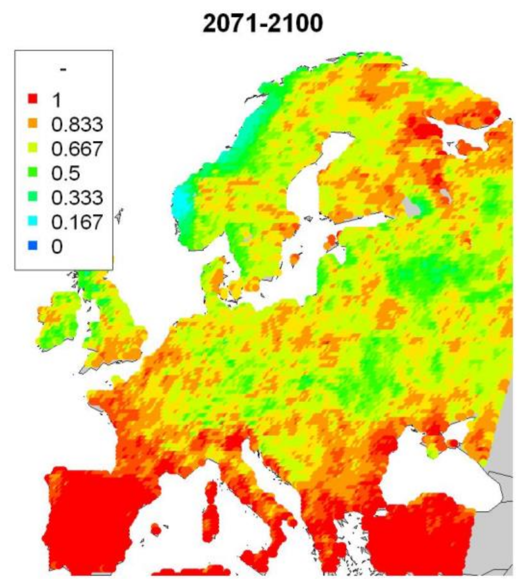
Methods for <u>spatial upscaling</u> and <u>risk analysis</u> of process-based models

Experiences from projects GREENHOUSE and Carbo-Extreme

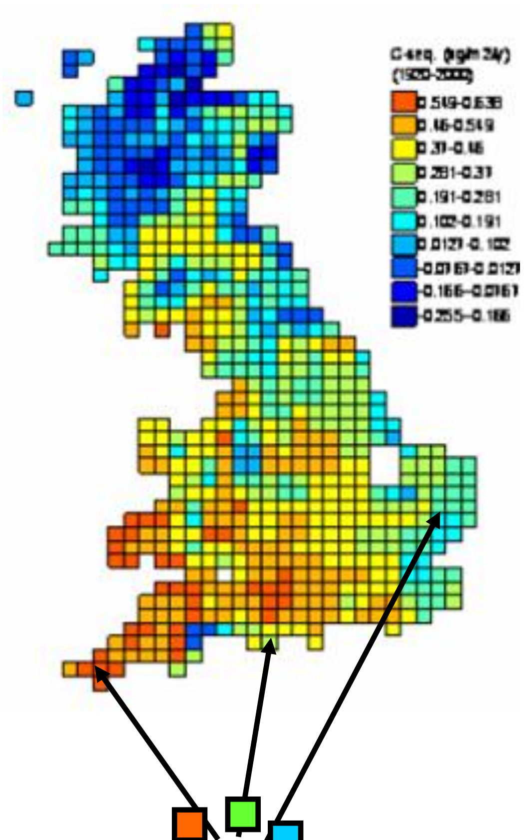




Marcel van Oijen, David Cameron, Peter Levy (CEH-Edinburgh),
and colleagues in GREENHOUSE and Carbo-Extreme

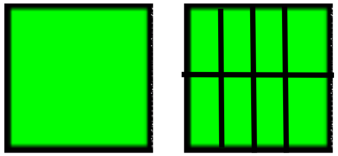
Reading, 9 Apr 2015

Spatial upscaling methods used for process-based models



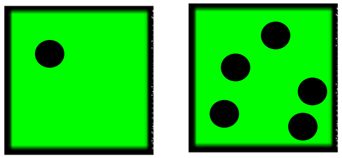
Individual grid cells ("regions") are large → What is the model output uncertainty for each cell ?

UPSCALING METHOD



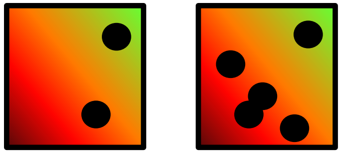
Input aggregation

$$\bar{y} = f(\bar{x})$$



Point selection

$$\bar{y} = \frac{1}{n}\sum^{n} y_i$$

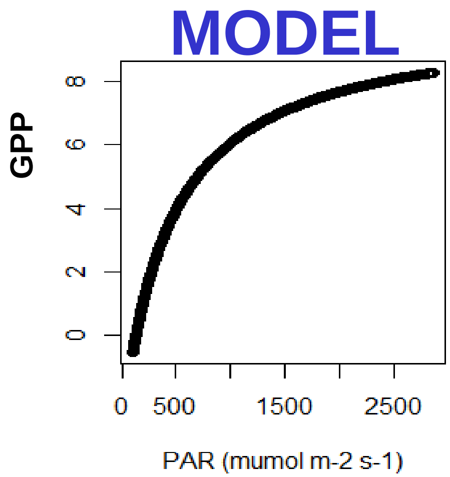


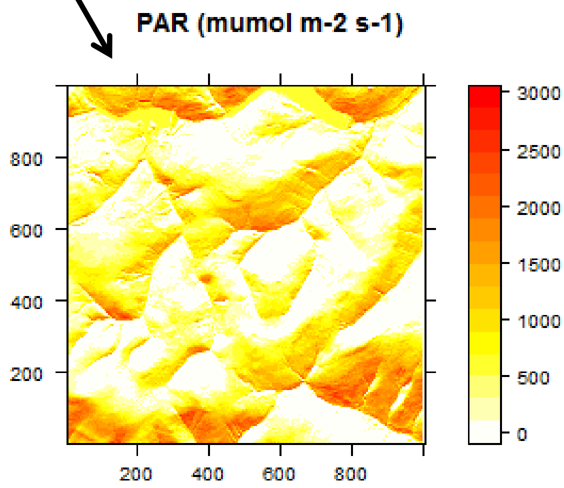
Interpolation (e.g. geostatistics)

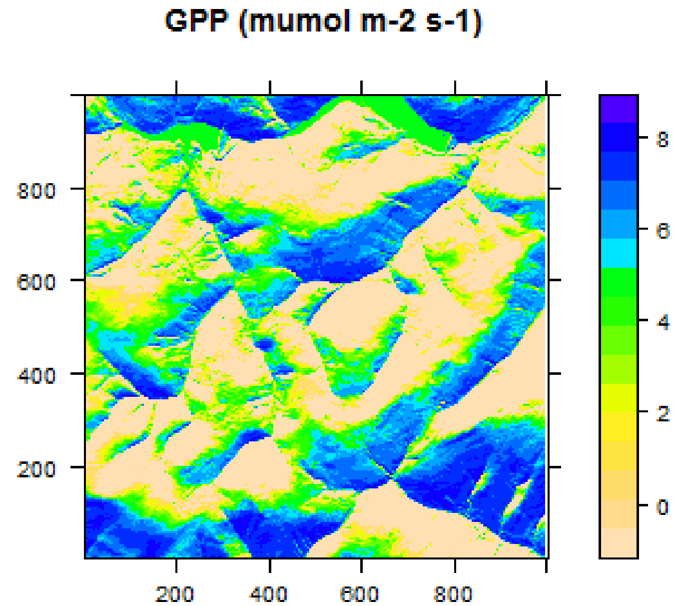
$$p(\bar{y}|\{y_i\}) = \int p(\bar{y}|\theta,\{y_i\})\, p(\theta|\{y_i\})\, d\theta$$

Θ = Spatial hyperparameters (variance, correlation length)

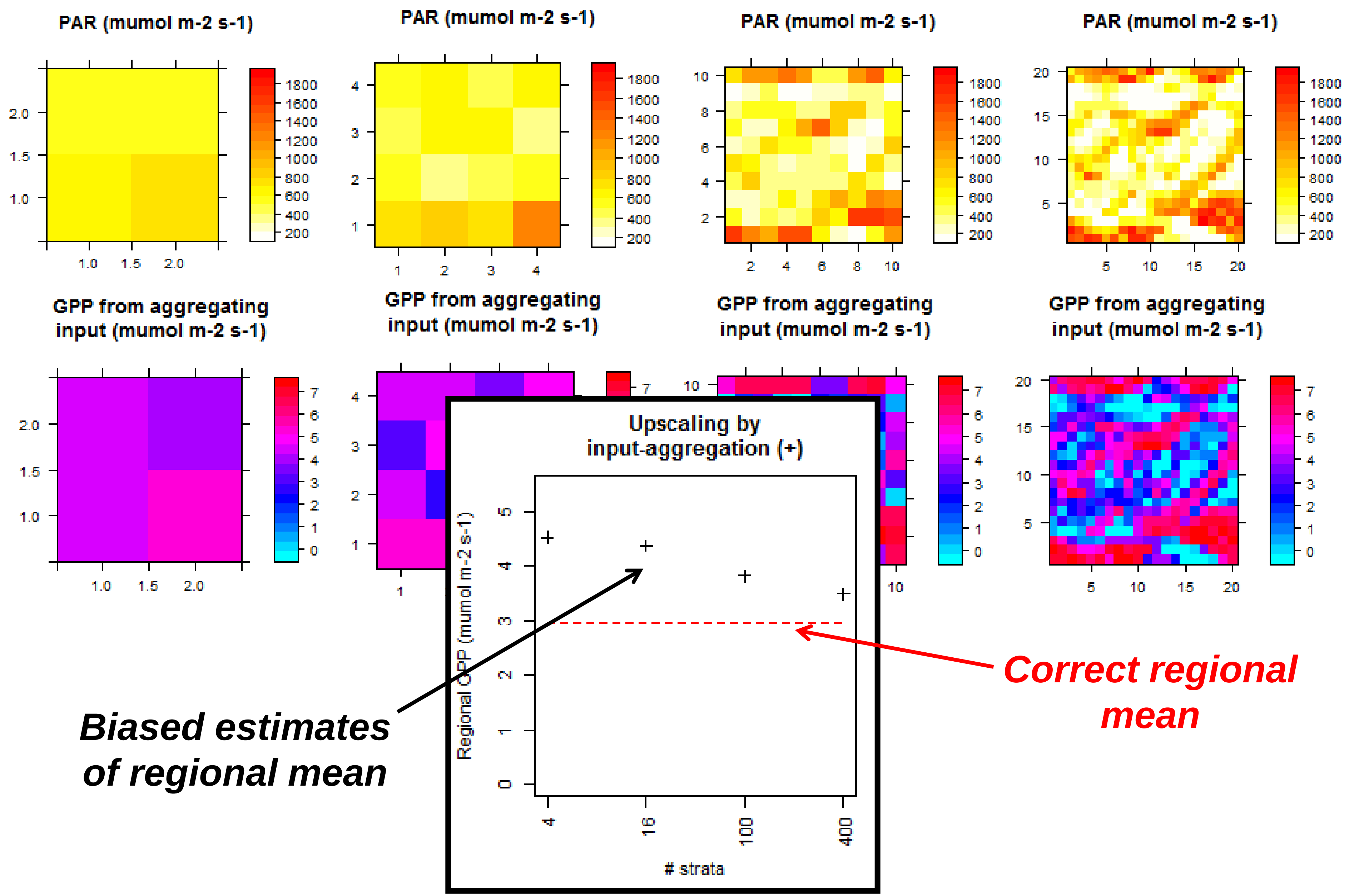
Example: region 5 x 5 km



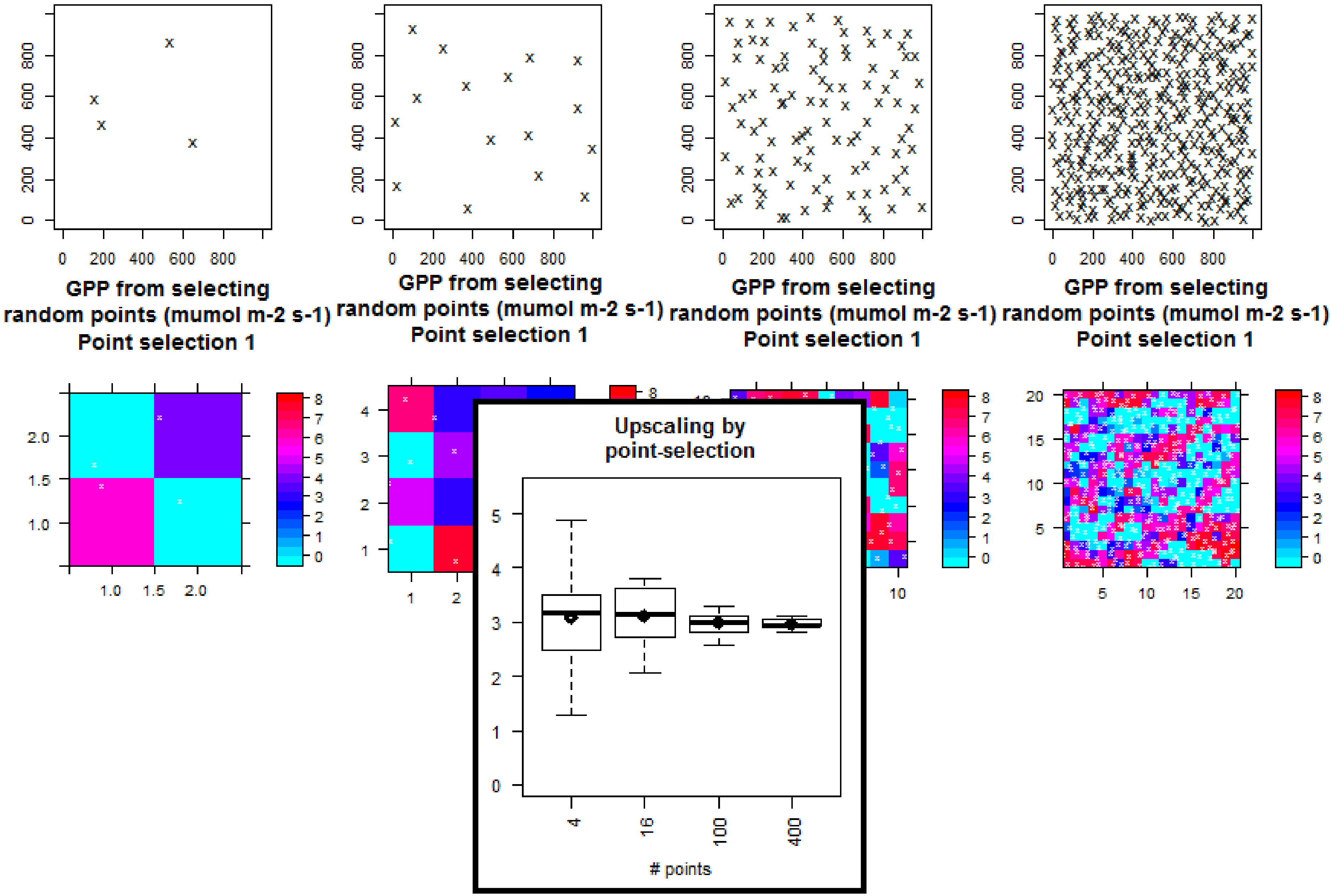




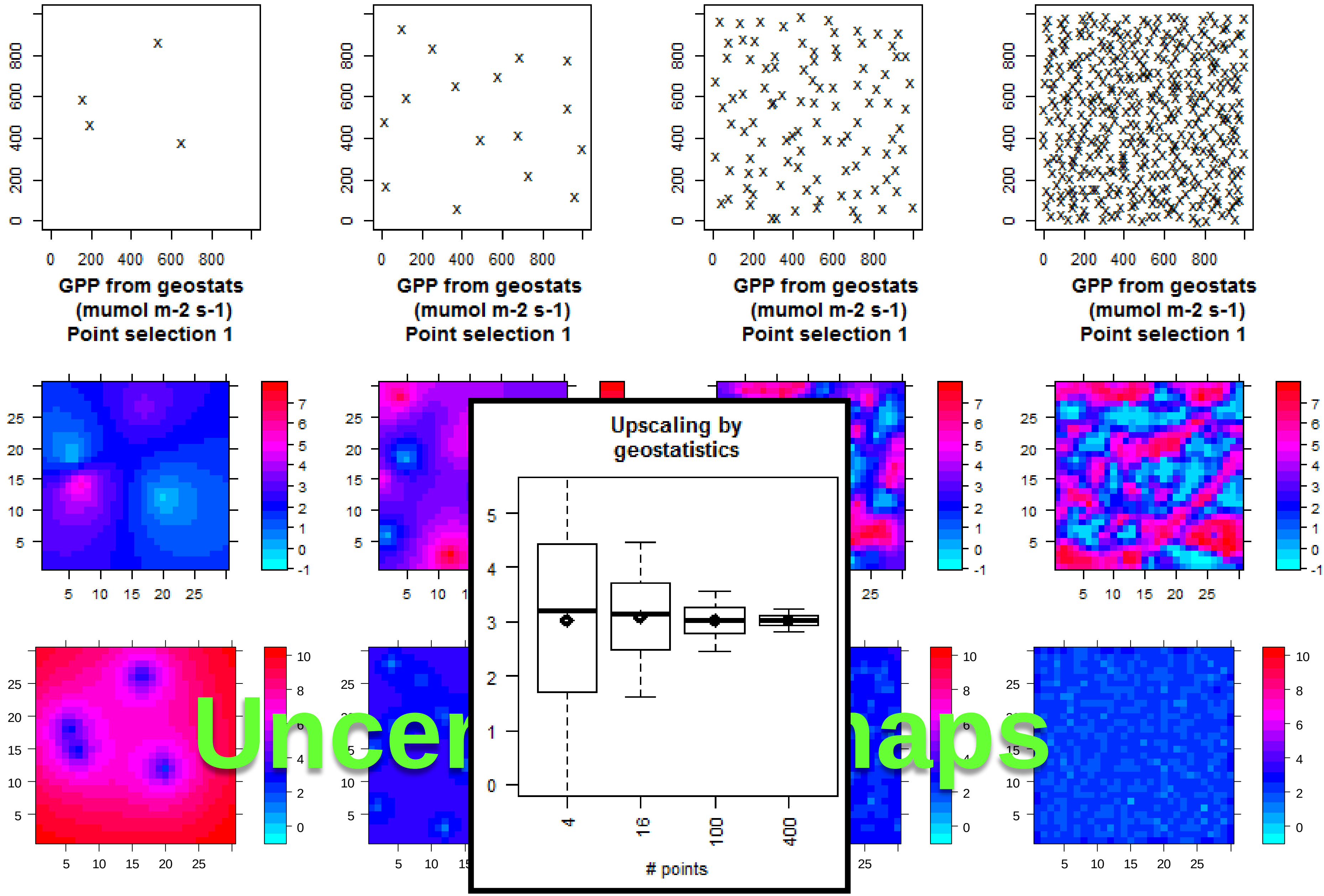
UPSCALING METHOD 1: Input Aggregation



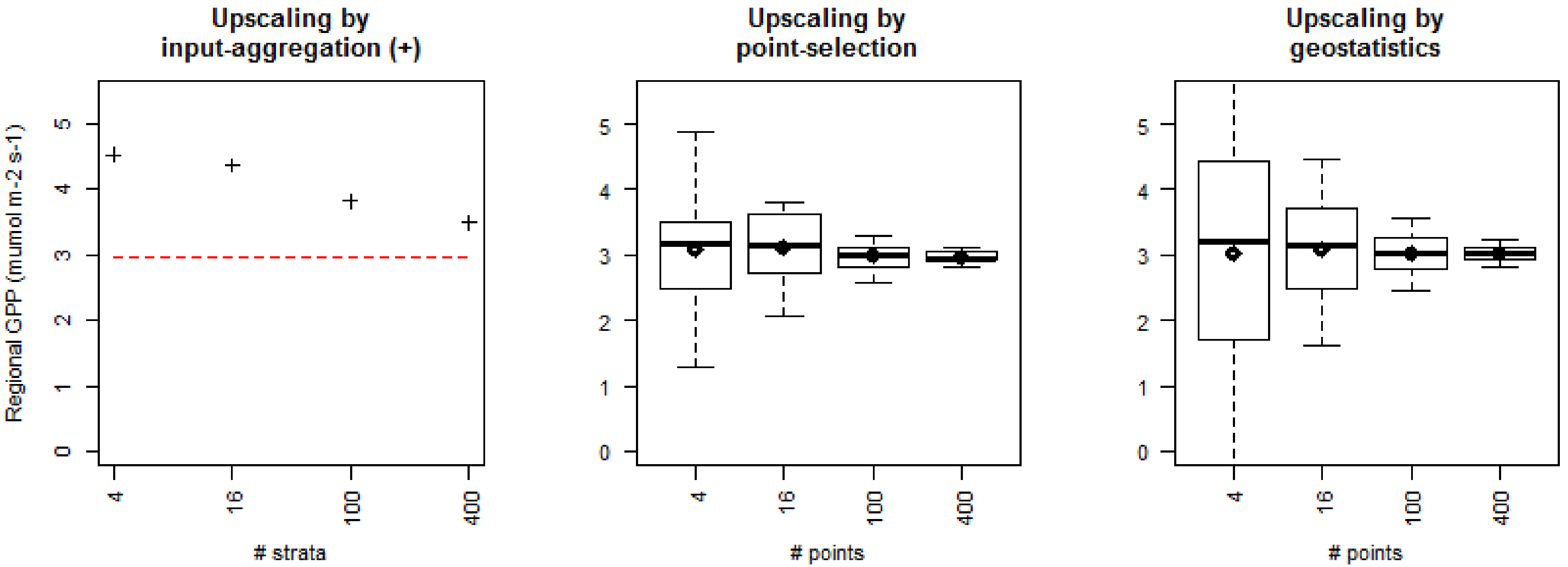
UPSCALING METHOD 2: Point Selection



UPSCALING METHOD 3: Bayesian Kriging



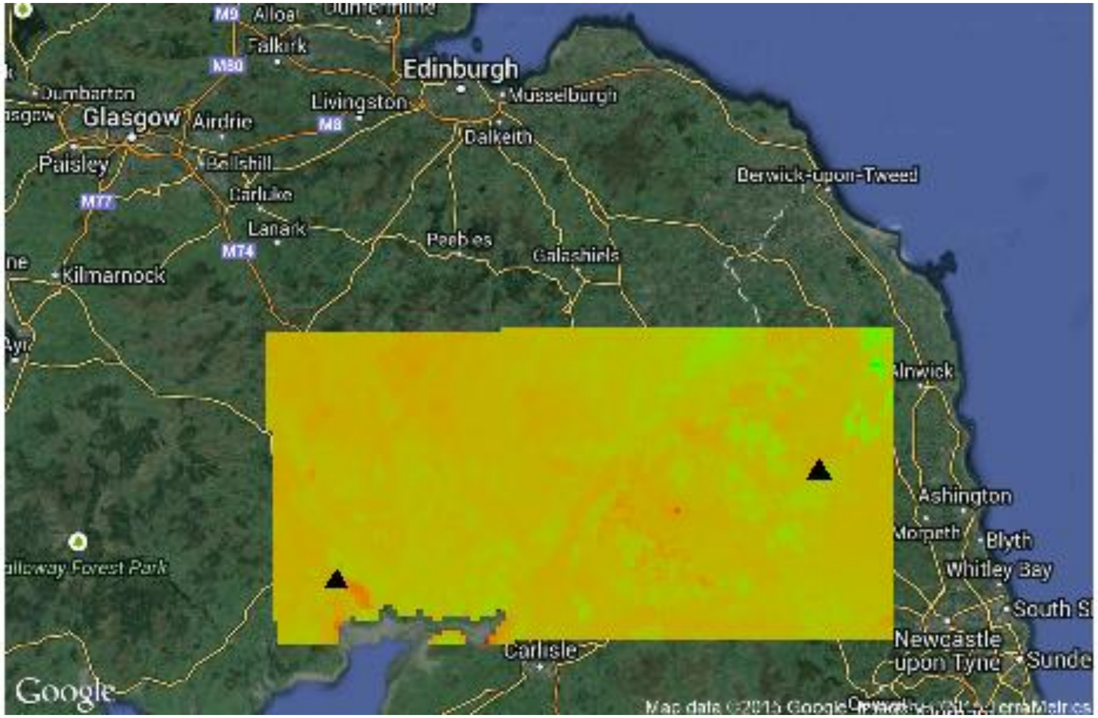
EXAMPLE 1: Comparison of methods



Biased method

Unbiased methods

Example region: 128 x 64 km



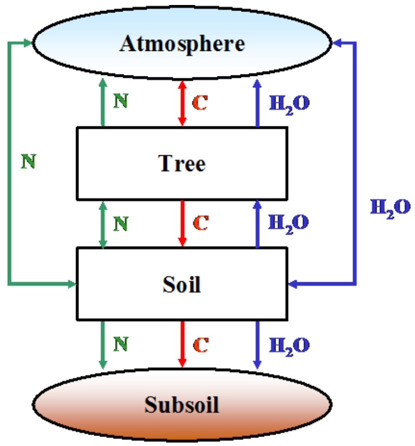
Model BASECO

Atmospheric drivers

N-deposition
CO_2
Radiation
Temperature
Rain
Humidity
Wind speed

Parameters & initial constants vegetation

Parameters & initial constants soil

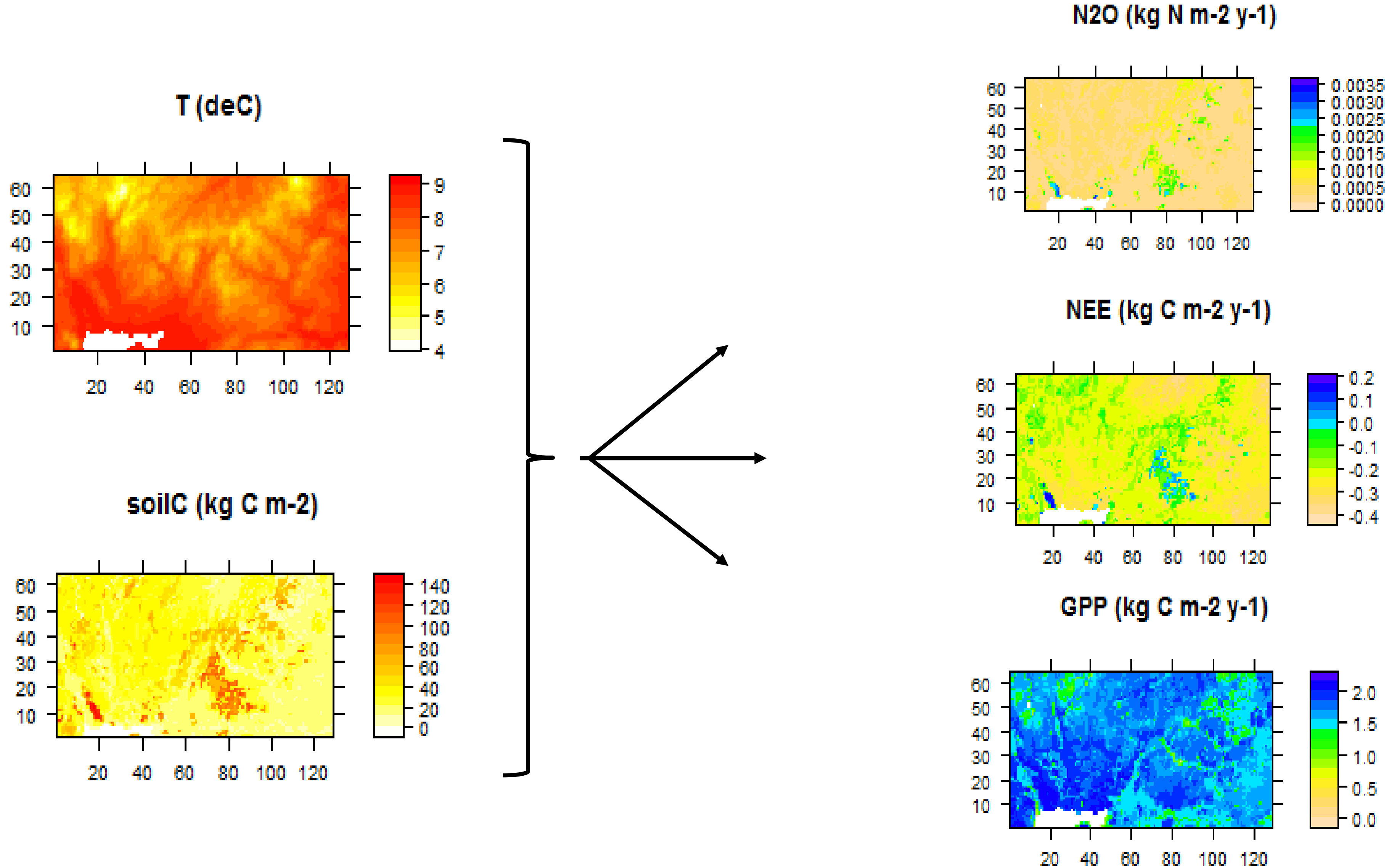


Output

Input

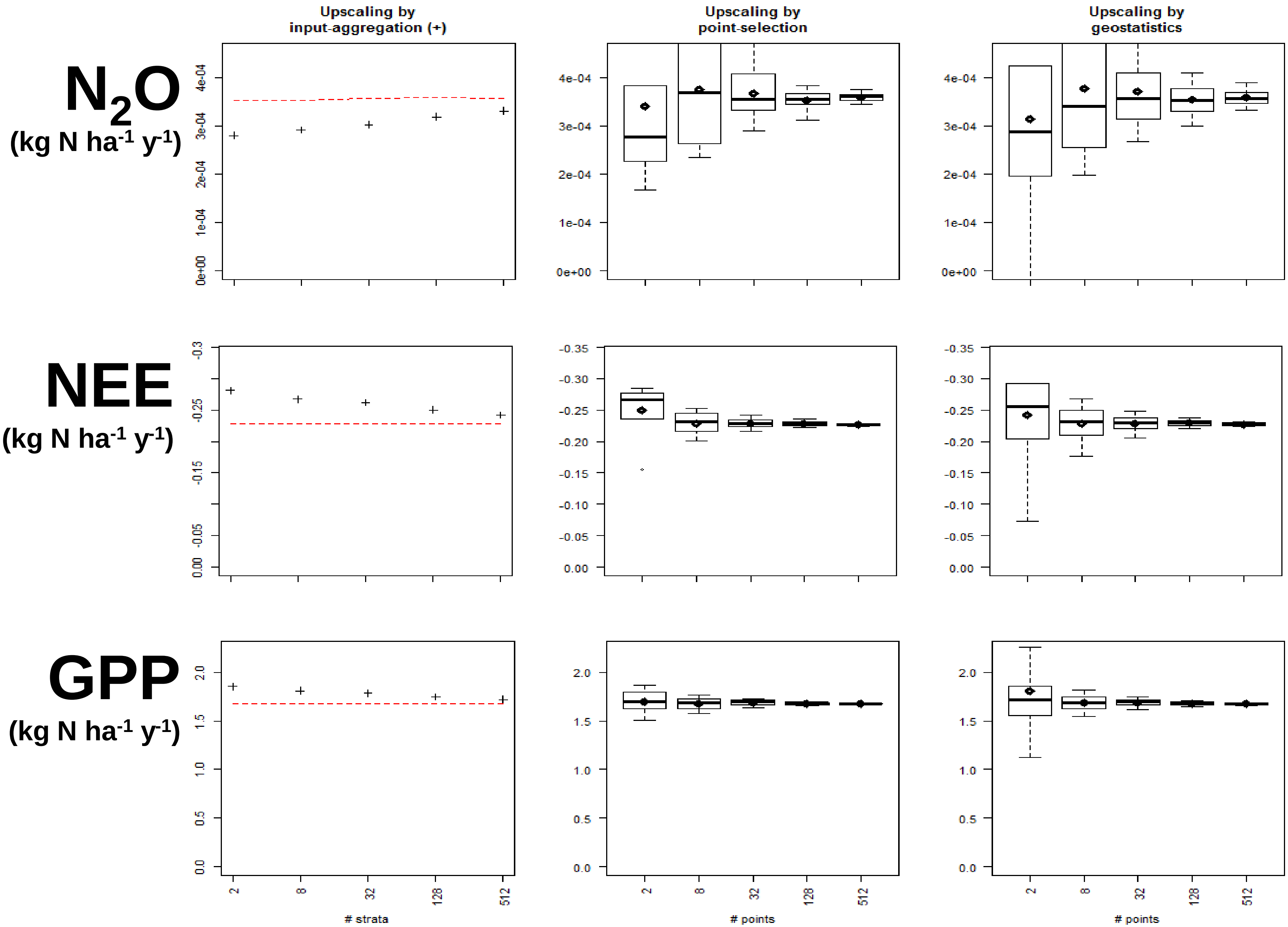
Model

Some inputs and outputs of BASECO

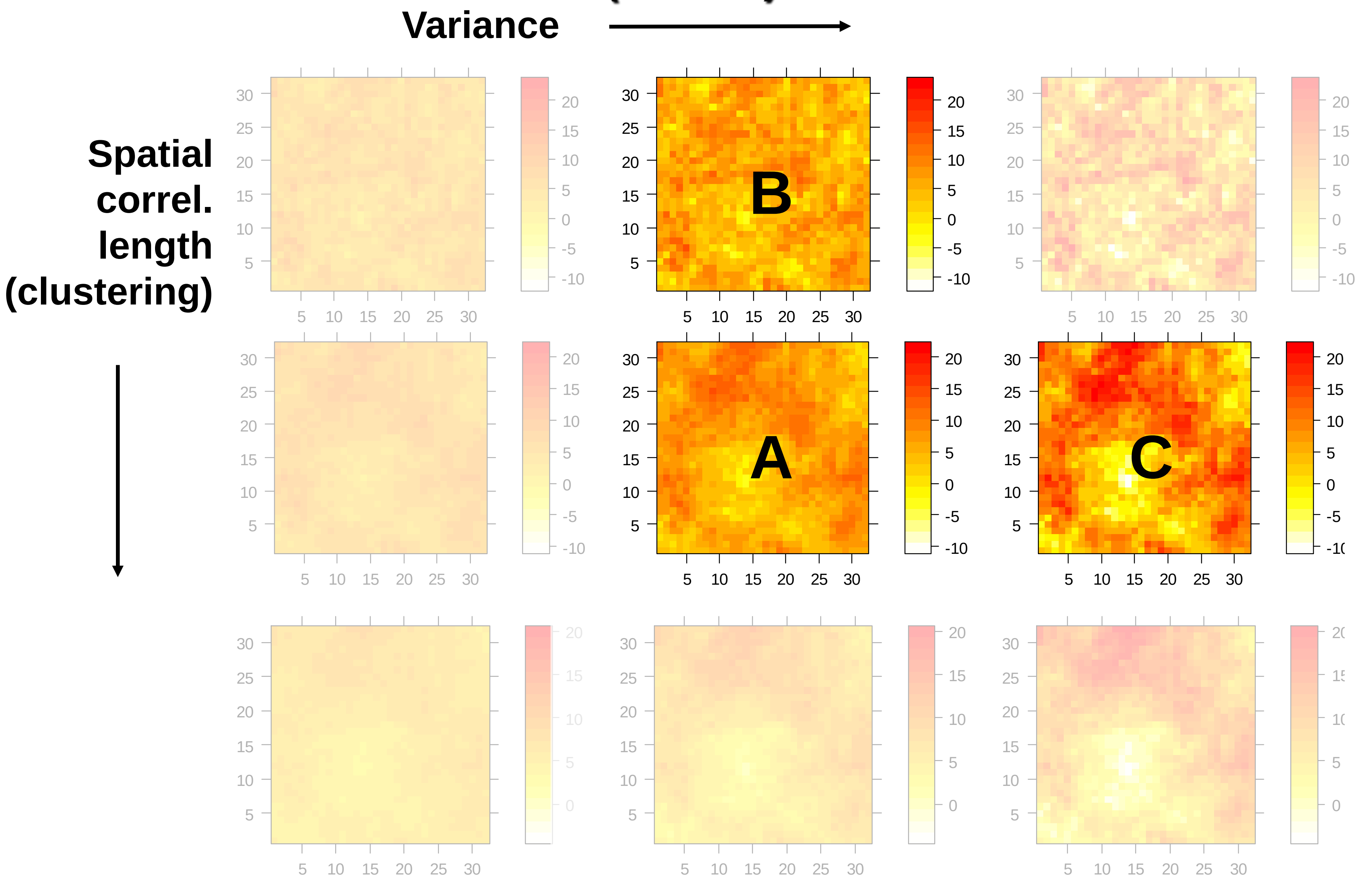


Input Model Output

EXAMPLE 2: Comparison of methods



Spatial heterogeneity: Gaussian Random Fields (GRFs)

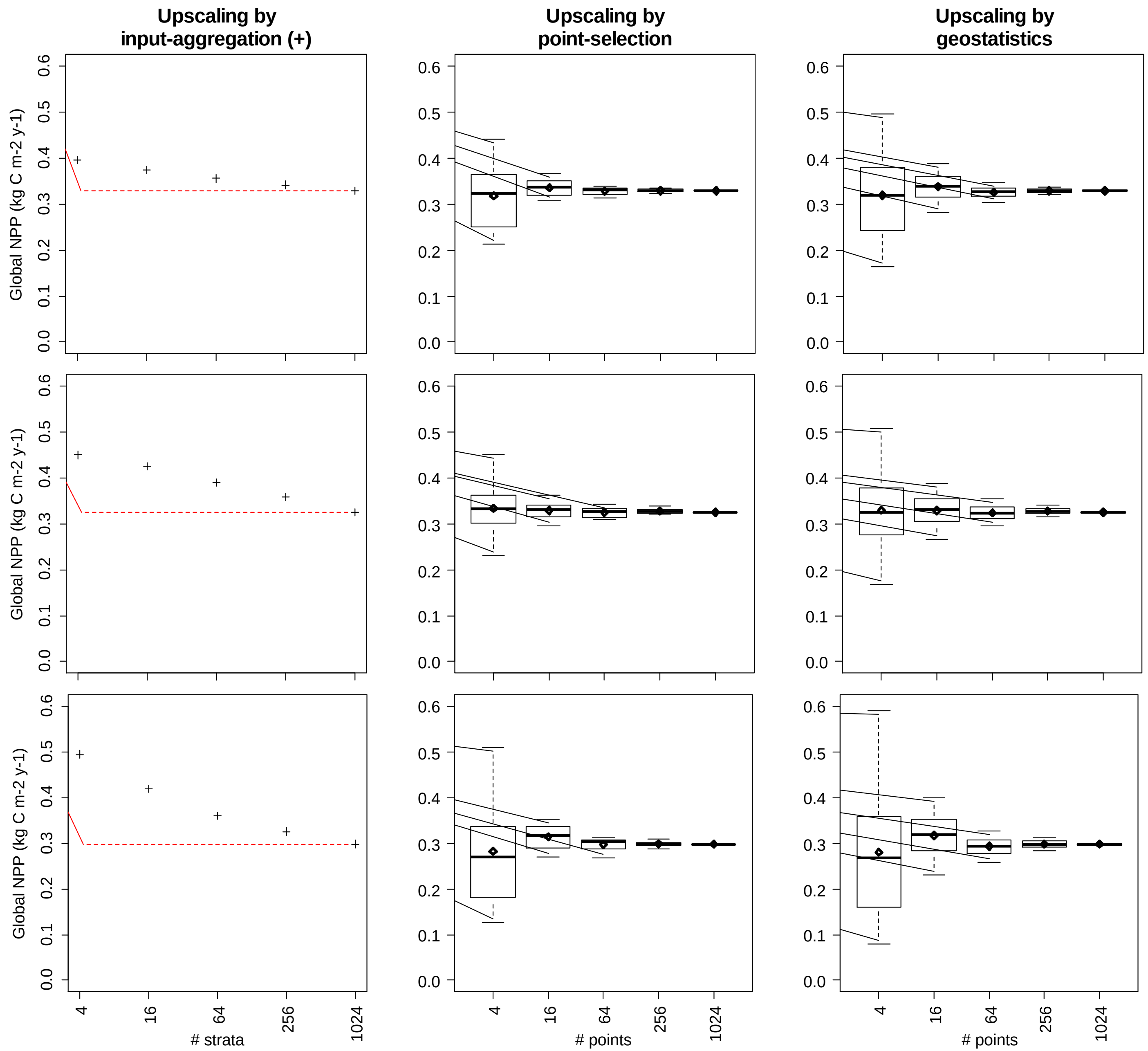


Impact of spatial correlation & variance on upscaling

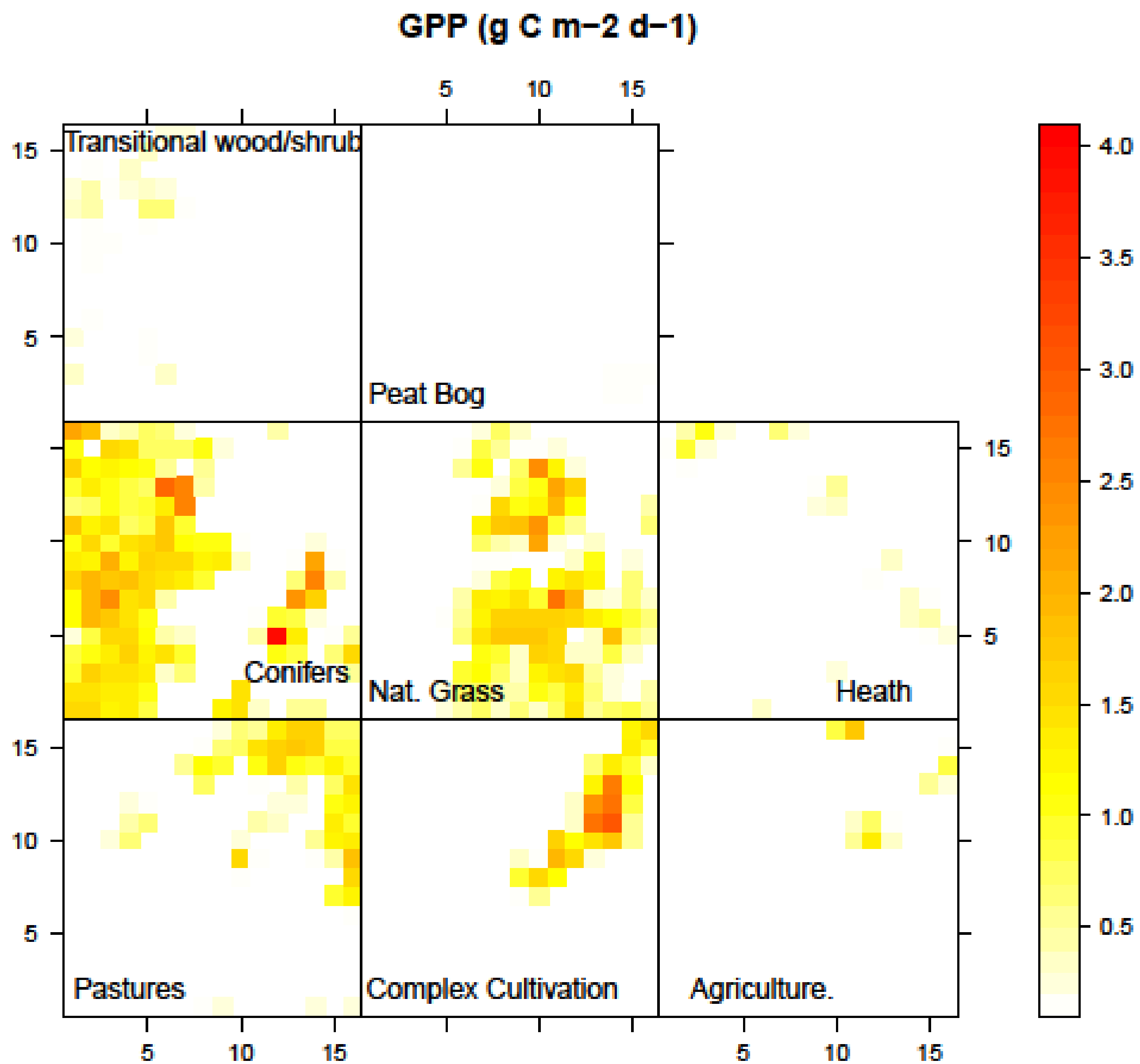
A.

B.
Smaller spatial correlation length (less clustering)

C.
Greater variance



Current work: upscaling for multiple land-use types



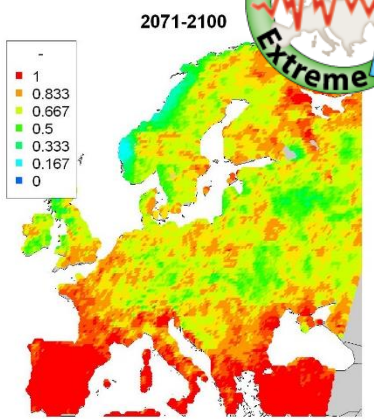
Upscaling methods: Discussion

- Upscaling errors depend on:
  - sampling intensity and spatial distribution
  - output variable
  - variance & autocorrelation length

- Input Aggregation gives biased estimates of the regional mean; the other methods are unbiased

- Uncertainty estimation is part of (geostatistical) Interpolation; the other methods require data from representative regions

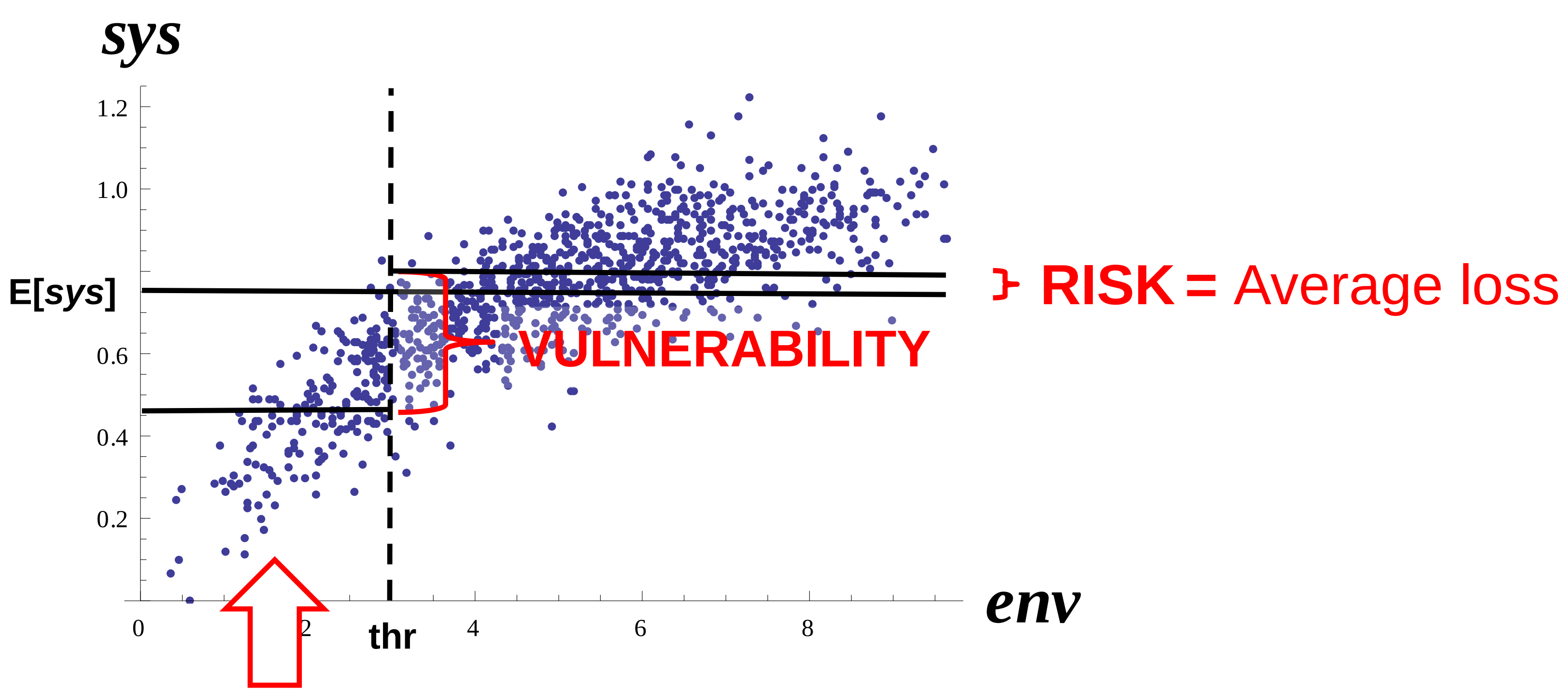
Risk analysis
in
project Carbo-Extreme



Theory: Van Oijen, M., Beer, C., Cramer, W., Rammig, A., Reichstein, M., Rolinski, S., Seneviratne, S. & Soussana, J.-F. (2013). A novel probabilistic risk analysis to determine the vulnerability of ecosystems to extreme climatic events. Environmental Research Letters 8: 015032. http://iopscience.iop.org/1748-9326/8/1/015032

Application: Van Oijen, M., Balkovič, J., Beer, C., Cameron, D., Ciais, P., Cramer, W., Kato, T., Kuhnert, M., Martin, R., Myneni, R., Rammig, A., Rolinski, S., Soussana, J.-F., Thonicke, K., Van der Velde, M. & Xu, L. (2014). Impact of droughts on the C-cycle in European vegetation: A probabilistic risk analysis using six vegetation models. Biogeosciences 11: 6357-6375. http://www.biogeosciences.net/11/6357/2014/bg-11-6357-2014.html

How does the analysis work?



P(Hazardous) =
frequency *env* < thr

RISK =
VULNERABILITY * P(Hazardous)

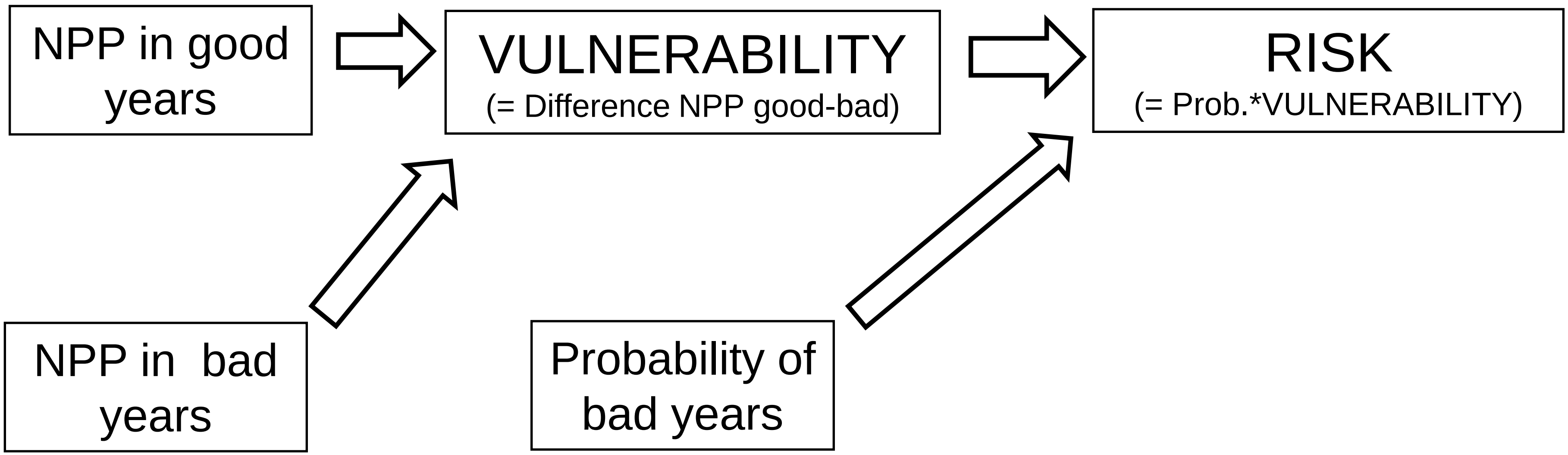
Risk analysis carried out in Carbo-Extreme

- **Time periods:** **1971-2000, 2071-2100**
- ***sys*:** **NPP, NEP, R_h, SWC, ET**
- ***env*:** **Drought (*)**
- **Models:**

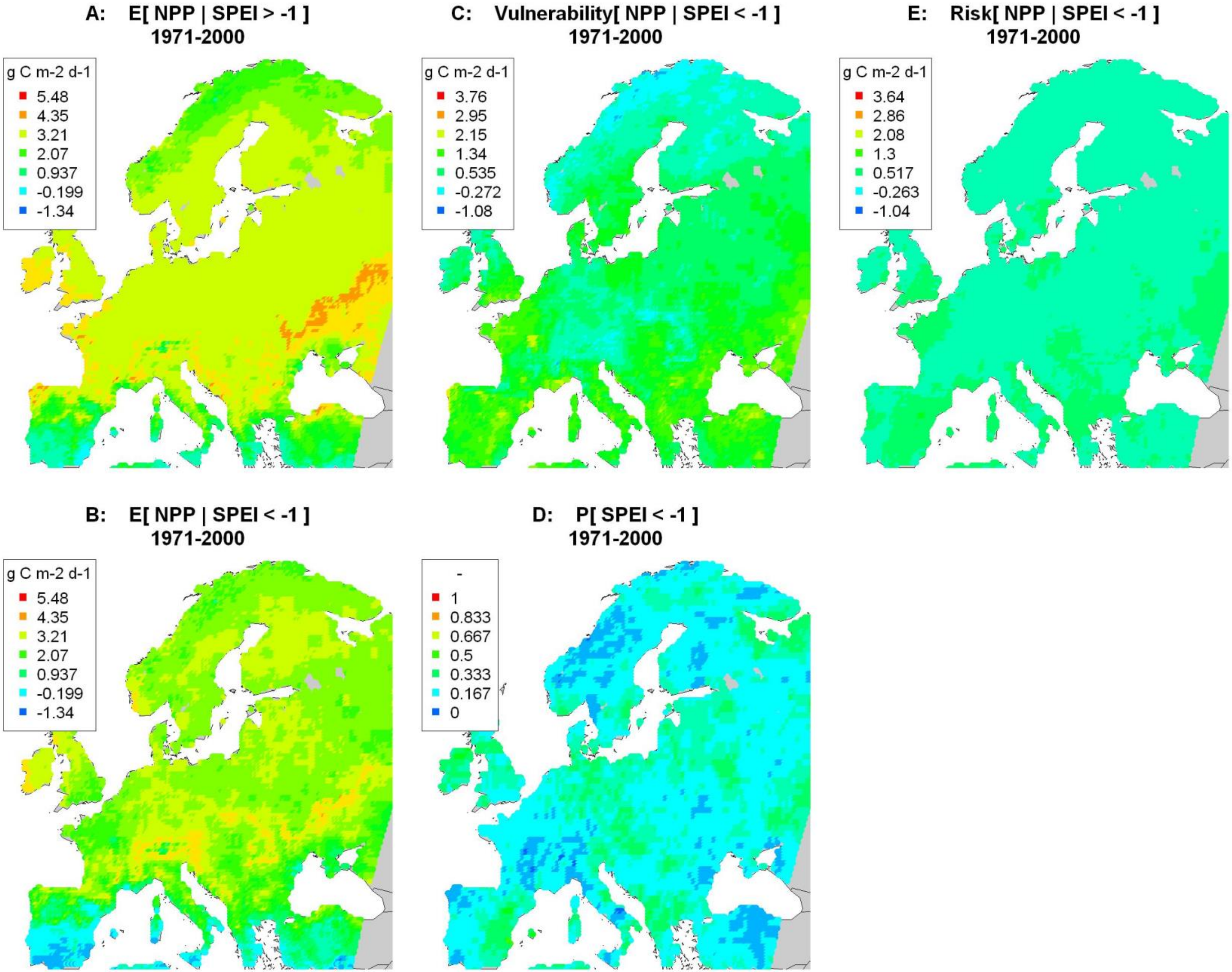
Group	Model	Ecosystem
PIK	LPJ	generic
LCSE	ORCHIDEE	generic
MPI	JSBACH	generic
CEH	BASFOR	forest
IIASA	EPIC	crops
INRA	PASIM	grassland

(*) Threshold: Standardized Precipitation Evapotranspiration Index (SPEI) < -1

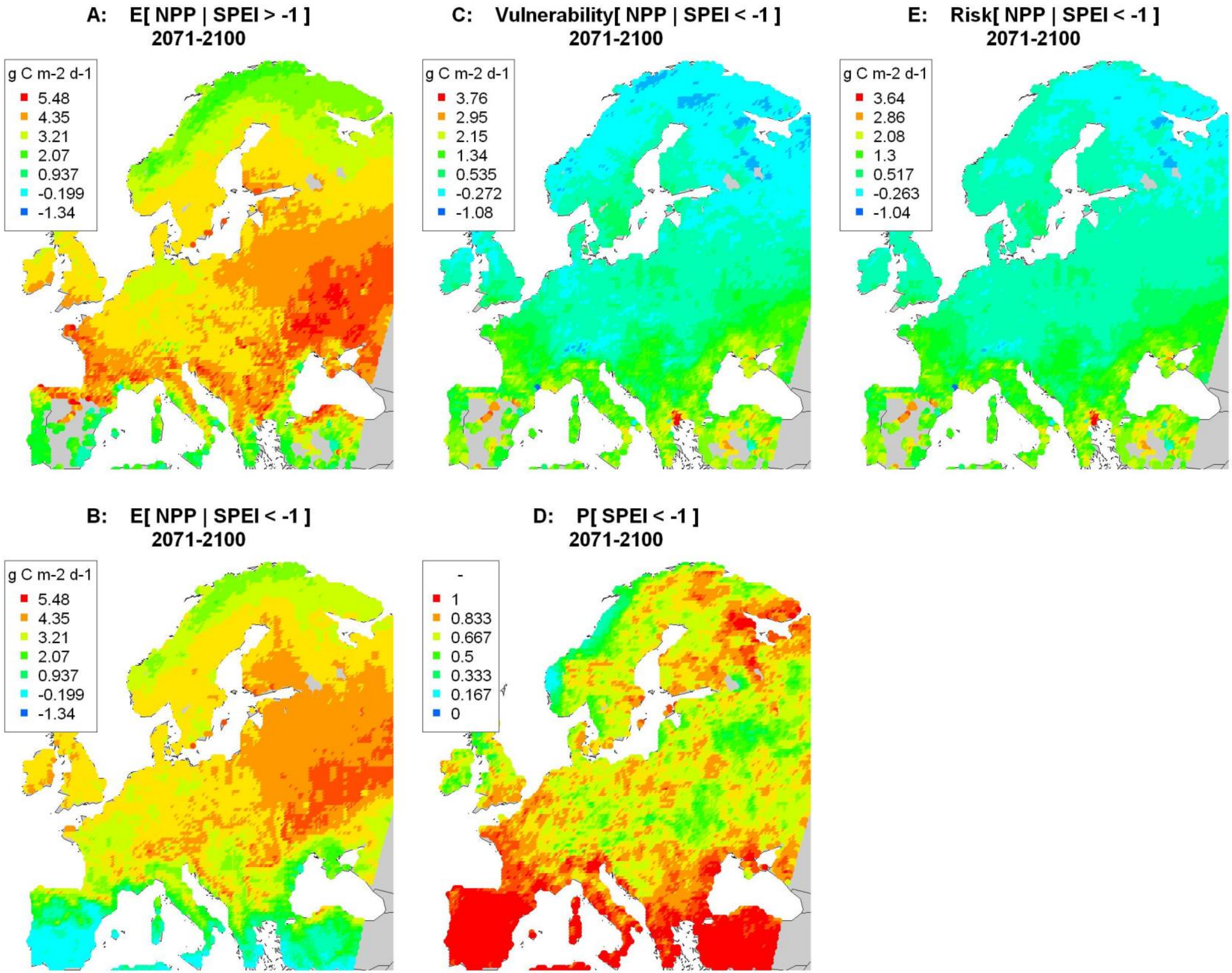
Example: Risk analysis for NPP



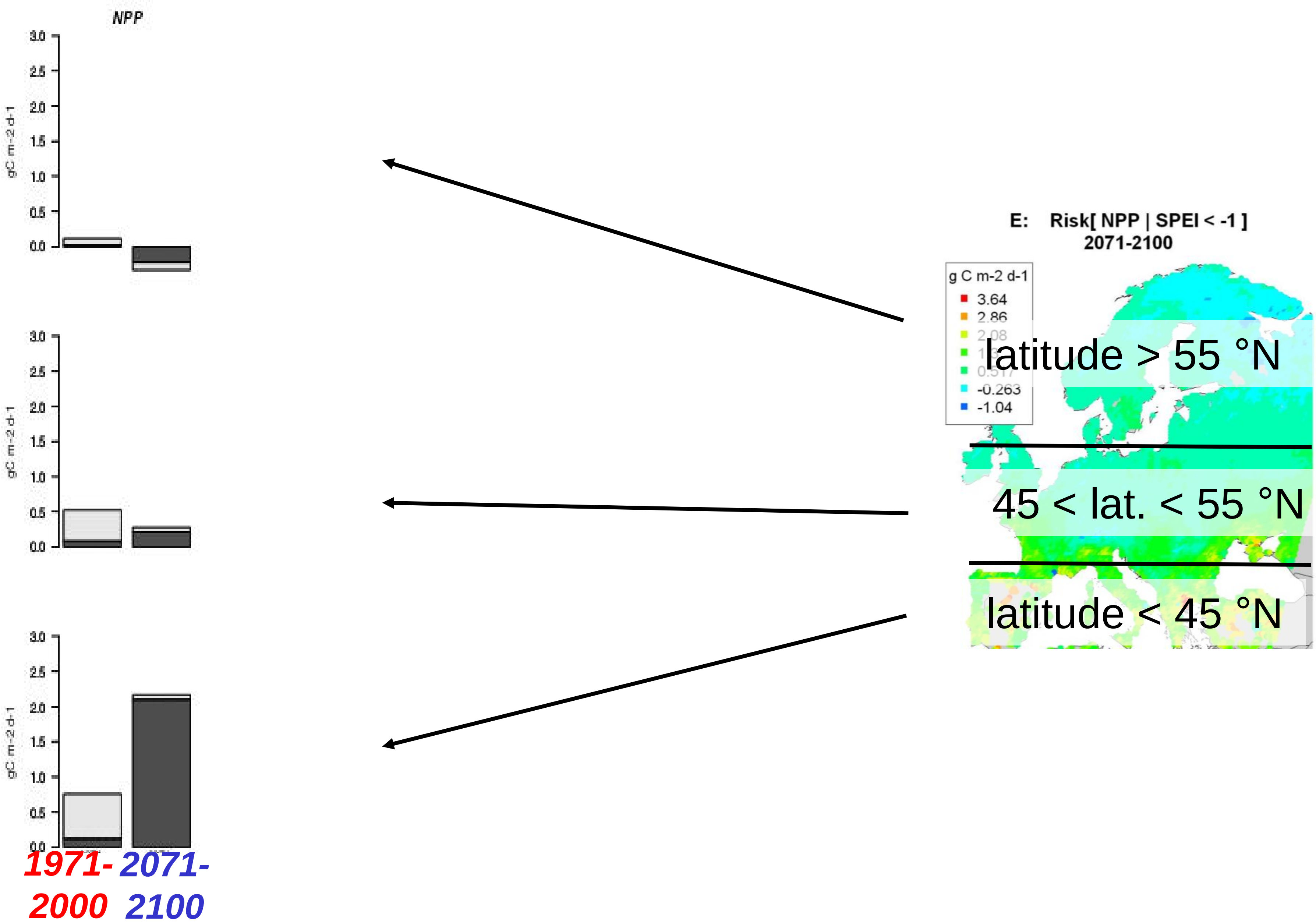
Risk analysis NPP (model PIK) 1971-2000



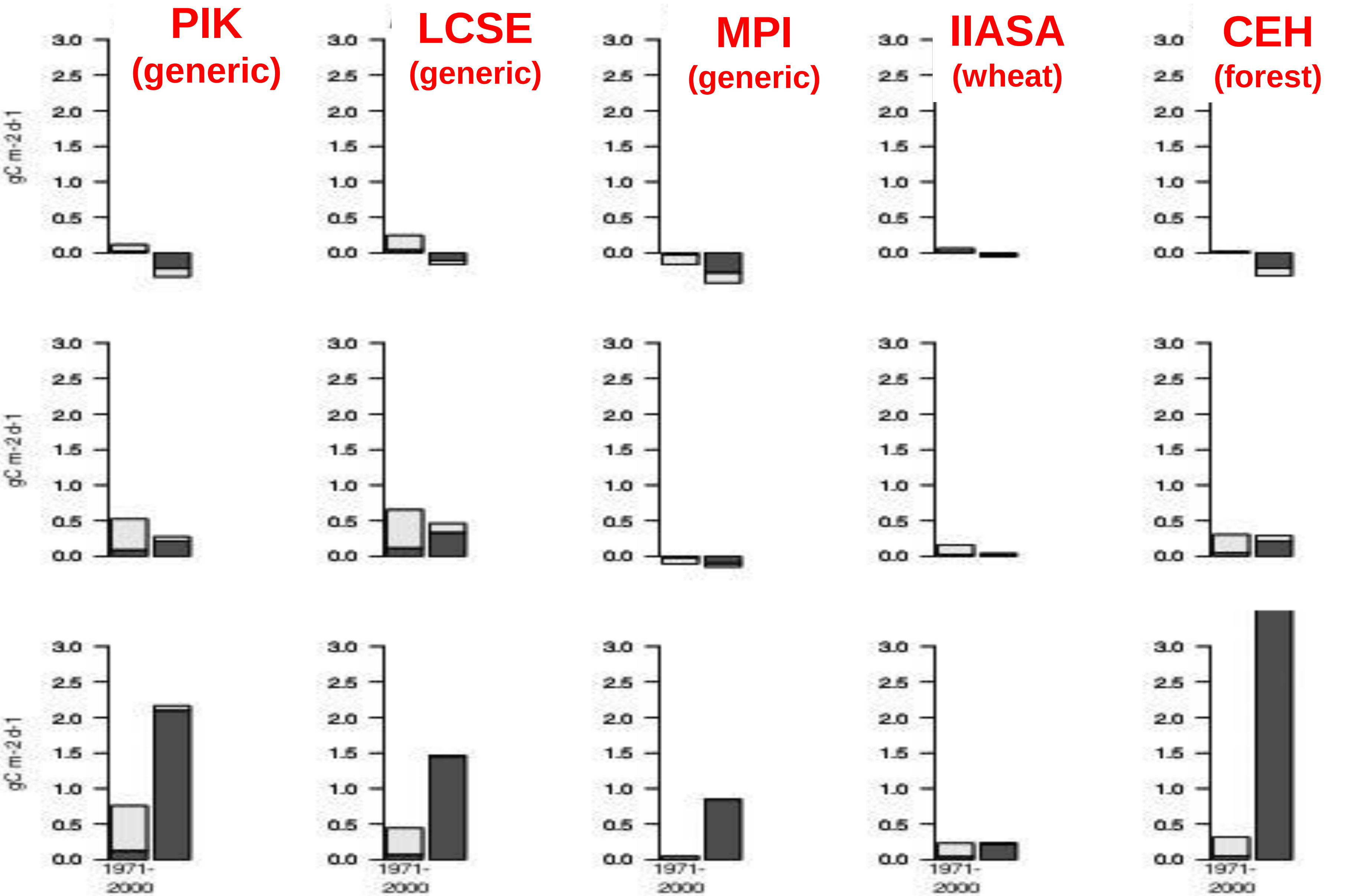
Risk analysis NPP (model PIK) 2071-2100



Risk analysis NPP (model PIK) per latitudinal band



Risk analysis NPP: model comparison



Risk analysis: Discussion

- Definitions of risk (R), vulnerability (V) and probability of hazard (P(H)) allow decomposition: R = V * P(H)

- Analysis method is applicable to data as well as to model outputs

- For drought, both V and R expected to increase in the south, but large model (vegetation) differences