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Determining weather types for statistical-dynamical downscaling for the urban climate of Hamburg, Germany

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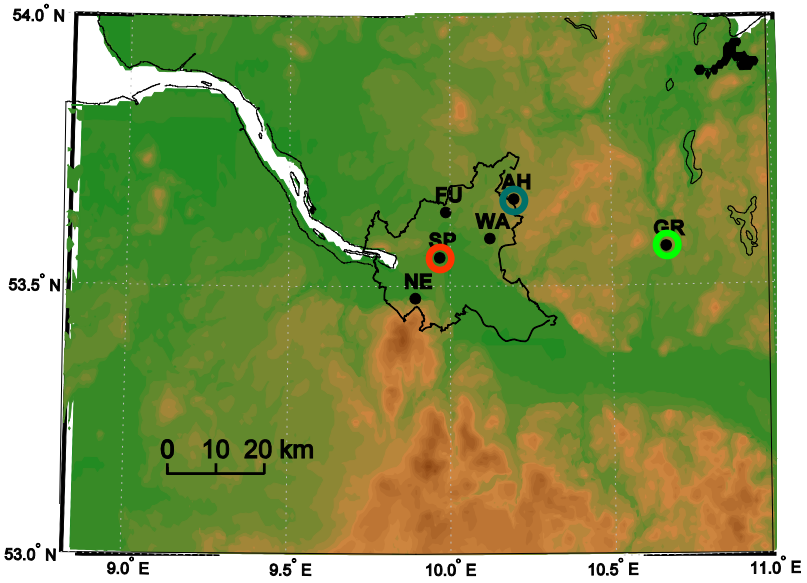
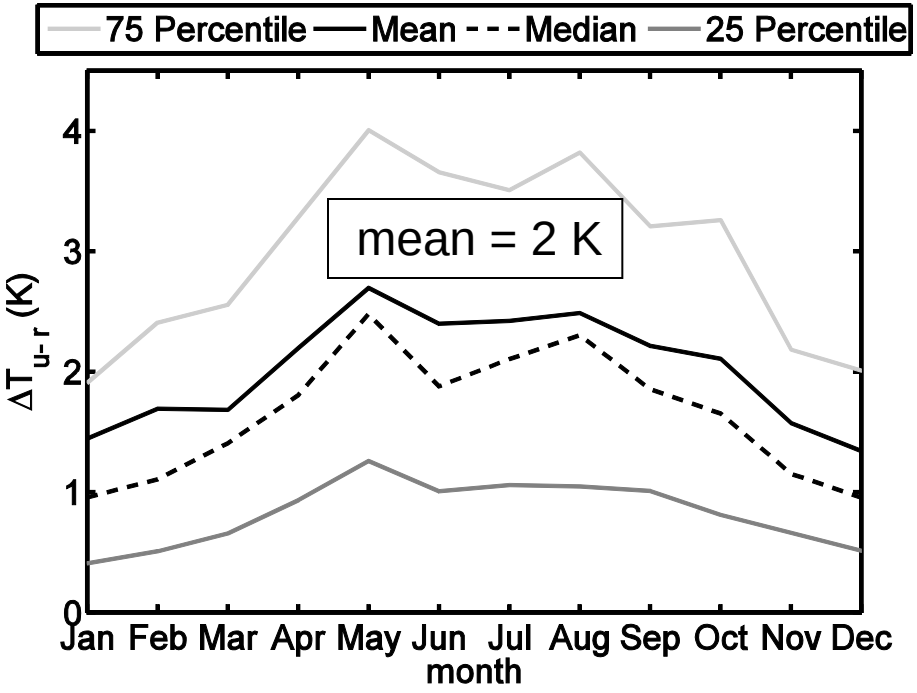
Motivation
Urban Heat Island of Hamburg

- **Definition:**

daily minimum temperature (1985-1999):

UHI = St.-Pauli (○) – (Grambek (○) + Ahrensburg (○))/2



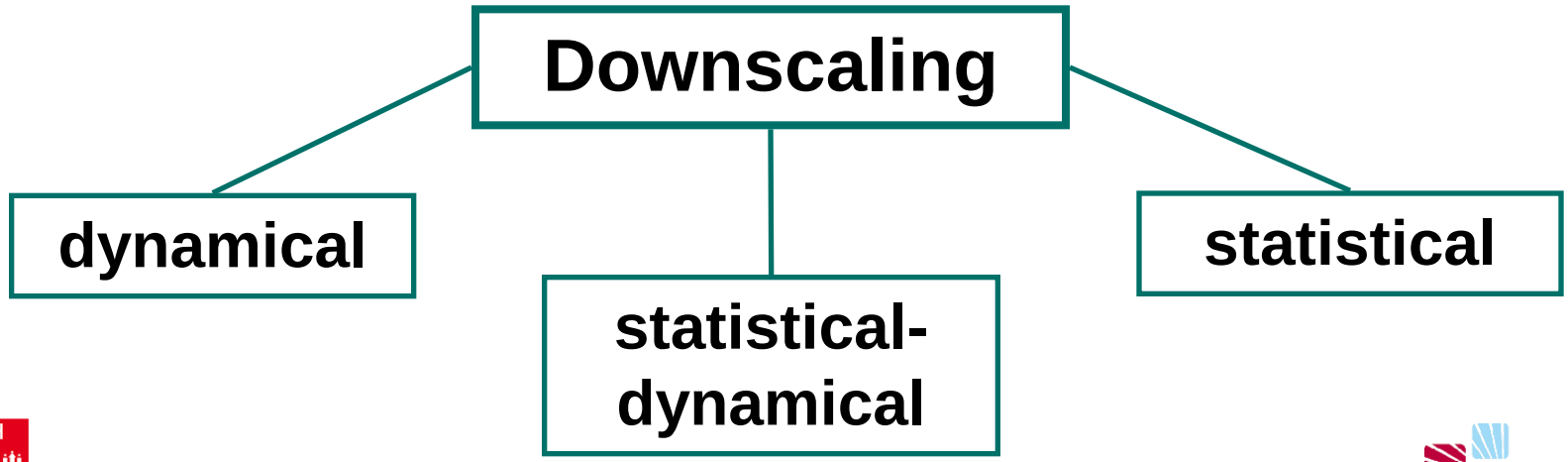


Motivation
Question

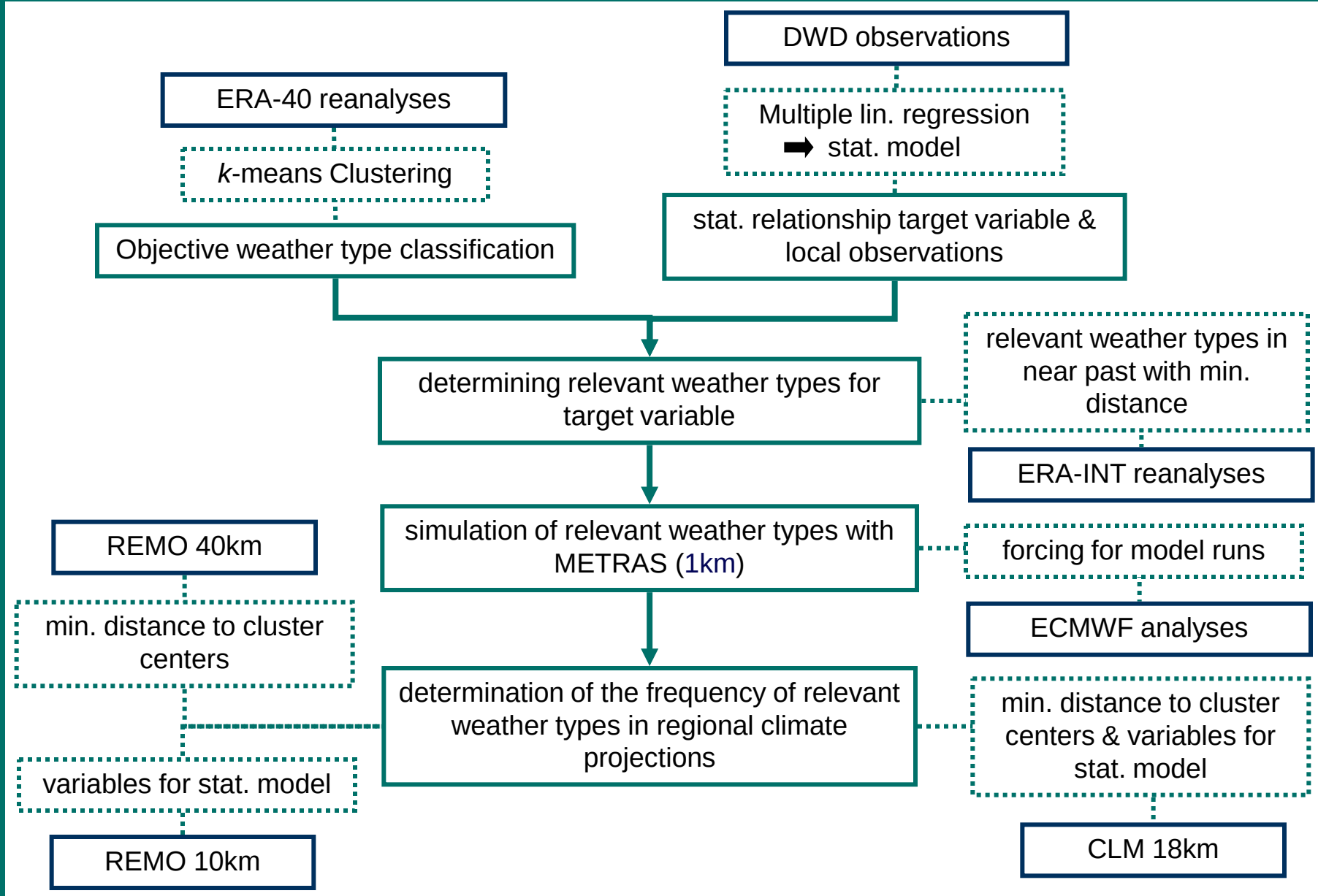
Does the urban heat island (UHI) change in a future climate?

- **resolution of current climate models ~ 10 km**
- **cannot resolve the UHI well**

climate projections have to be downscaled

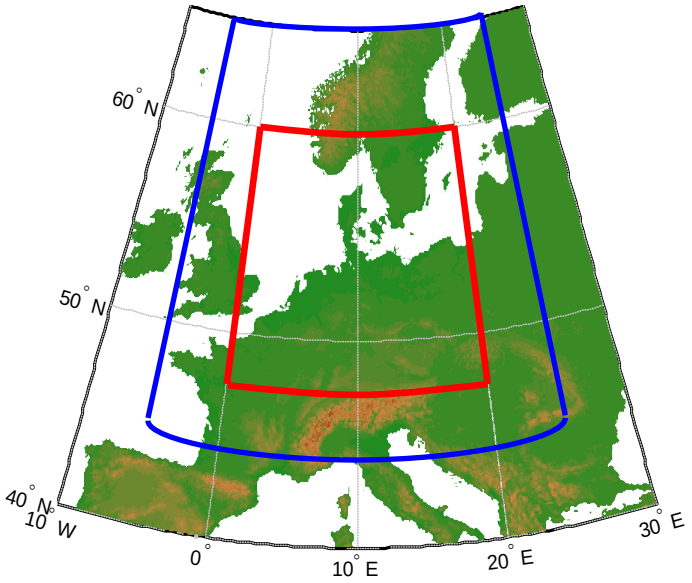


Statistical-Dynamical Downscaling method



Weather type classification
data

- **Data: ERA-40 reanalyses**
- **Variables:**
  - geopotential height in 700 hPa
  - relative humidity in 700 hPa
- **Period:**
  - 1960-2001
- **Domains:**
  - 0-20° East, 5° West-25° East
  - 47,5-60° North, 45-65° North



- **Questions:**
  - daily averaged fields or fields at given time of day
  - which method to use
  - number of weather types
  - best domain

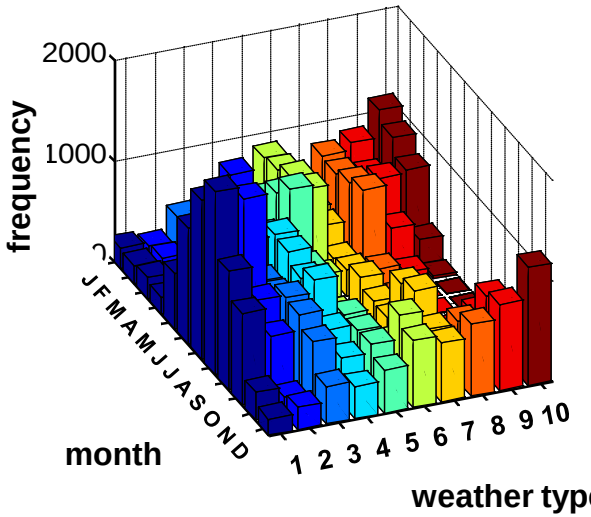
Weather type classification
seasons & output time

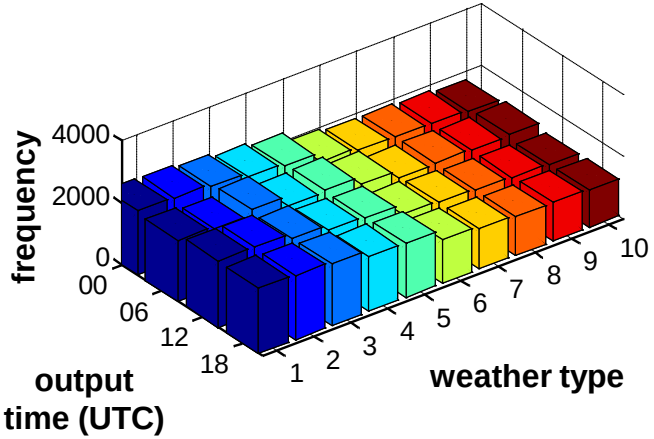
- *k*-means with 10 cluster & 4 output times of ERA-40
- different weather types in different seasons
- not useful for downscaling

➡ clustering for each season separately

- 86 % of days have the same weather type at 3-4 output times

➡ 12 UTC fields are used for clustering





Weather type classification
cluster algorithm

- **COST733 classification software to compute cluster analyses**
  - *k*-means
  - DKmeans
  - SANDRA
- **Comparison measure**
  - explained cluster variance (ECV)
  - mean of ECV over results with different cluster number (2-23)
- ***k*-means and SANDRA have nearly the same mean ECV**
- **dkmeans performance is slightly weaker**

***k*-means for weather type classification**

Optimal cluster number
DVindex (Shen et al., 2005)

- **obtain the overall best intra-compact clusters (IntraRatio) & inter-separated clusters (InterRatio)**

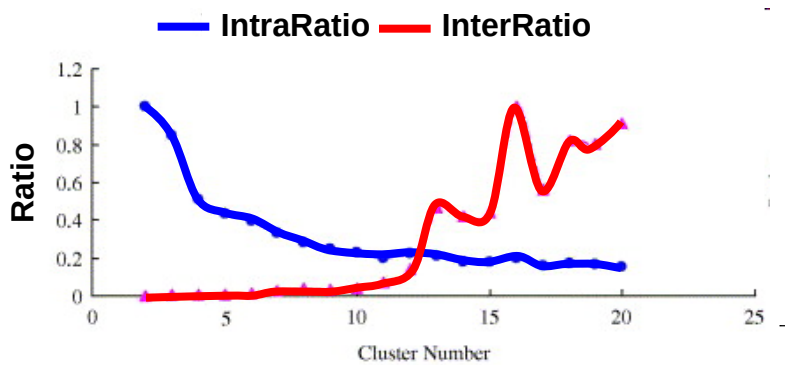
$$DVindex = IntraRatio(k) + \gamma \cdot InterRatio(k)$$

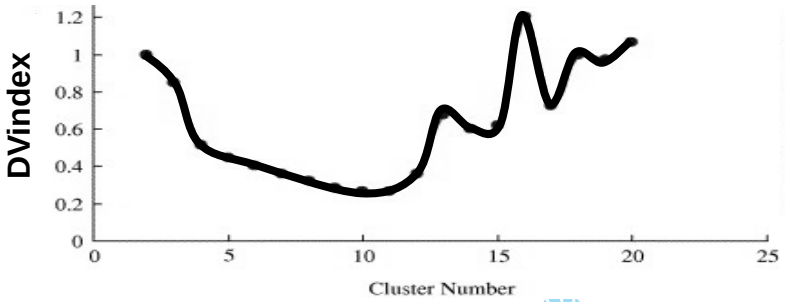
$$IntraRatio(k) = \frac{Intra(k)}{Max(Intra)}$$

$$InterRatio(k) = \frac{Inter(k)}{Max(Inter)}$$

$$Intra(k) = \frac{1}{N}\sum_{i=1}^{k}\sum_{x \in C_i}\left\|x - z_i\right\|^2$$

$$Inter(k) = \frac{Max_{i,j}\left(\left\|z_i - z_j\right\|^2\right)}{Min_{j \neq i}\left(\left\|z_i - z_j\right\|^2\right)} \cdot \sum_{i=1}^{k}\left(\frac{1}{\sum_{i=1}^{k}\left(\left\|z_i - z_j\right\|^2\right)}\right)$$





Shen et al. (2005)

Cluster number
Other measures

- **Validity Index after Ray and Turi (1999)**
  - similar to DVindex
  - easier to calculate
  - has problems with noisy data

$$Validity = \frac{Intra}{\min_{i \neq j}\left(\left\|z_i - z_j\right\|^2\right)}$$

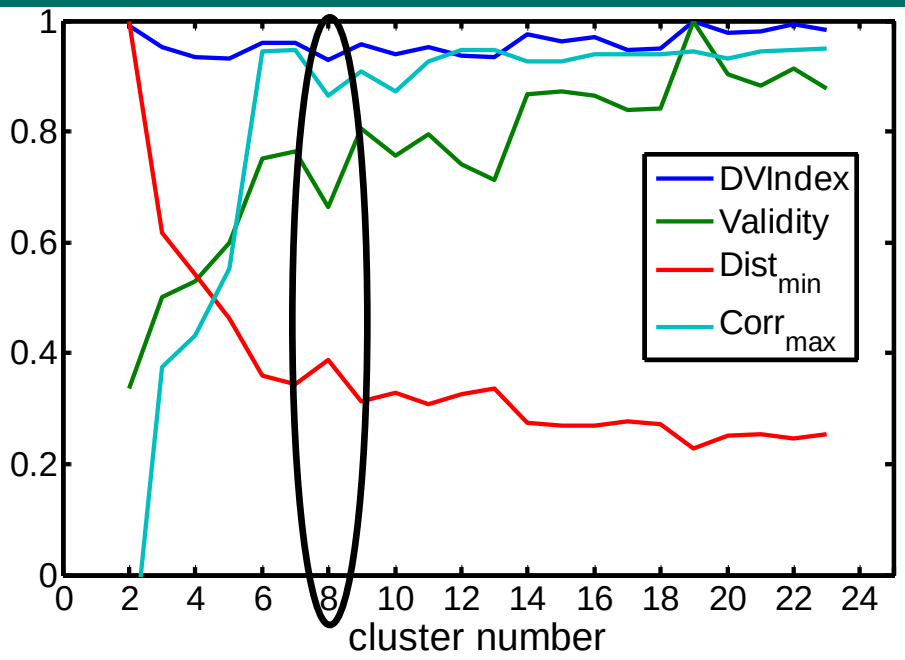
- **smallest distance between the cluster centers (maximum)**

$$Dist_{\min} = \min_{i \neq j}\left(\left\|z_i - z_j\right\|^2\right)$$

- **highest correlation between the cluster centers (minimum)**

$$Corr_{\max} = \frac{\mathrm{cov}(z_i, z_j)}{\mathrm{var}(z_i) \cdot \mathrm{var}(z_j)}$$

Cluster number
Results

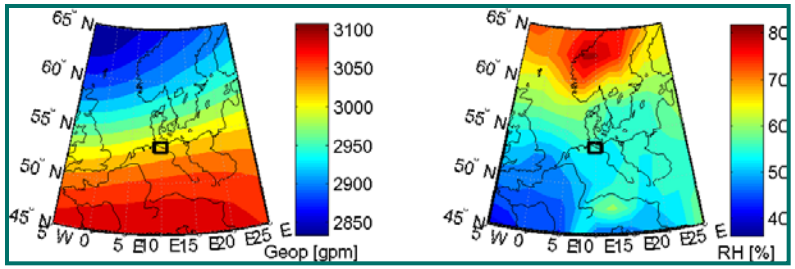


- **no clear identification of cluster number for small domain ➡ weather type classification with large domain**
- **Different number of weather types per season:**

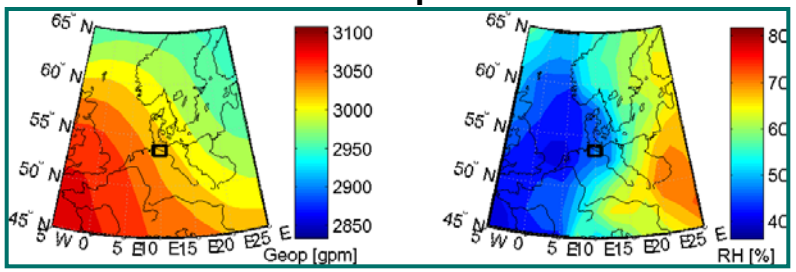
season	MAM	JJA	SON	DJF
weather types	8	7	6	8

Weather type classification
Results: weather types summer

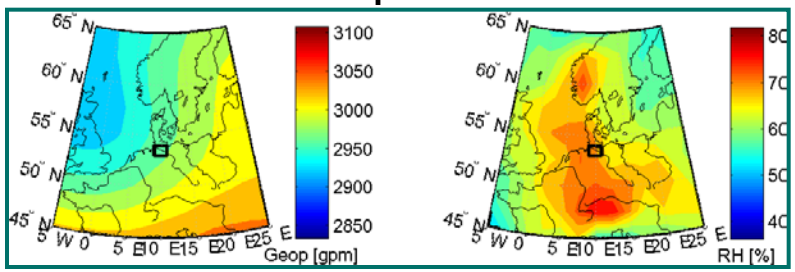
WT 1 Freq = 16.8%



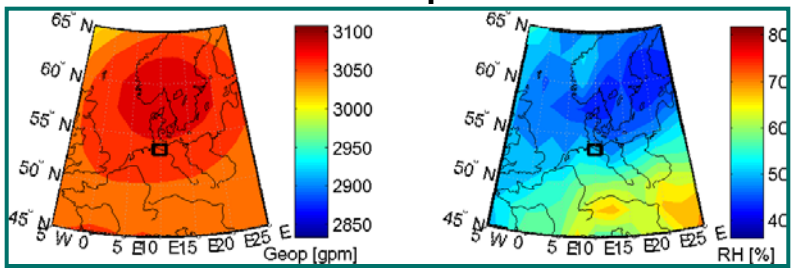
WT 2 Freq = 14.6%



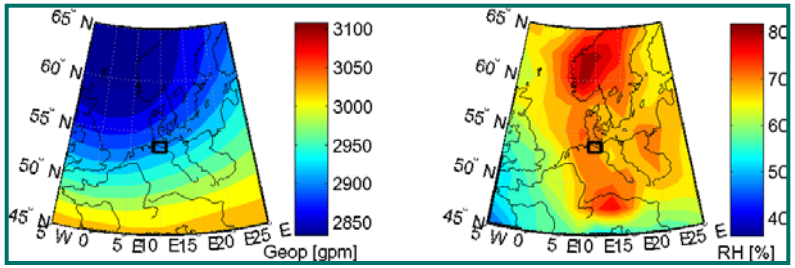
WT 3 Freq = 14.6%



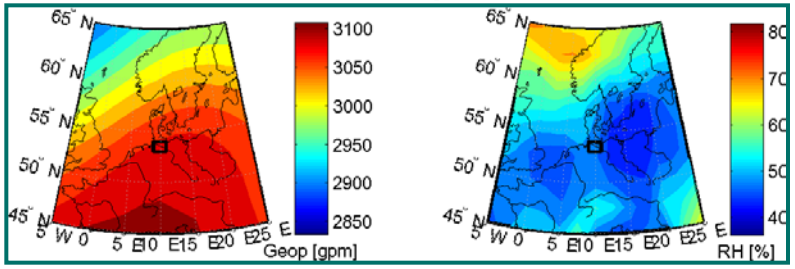
WT 4 Freq = 14.4%



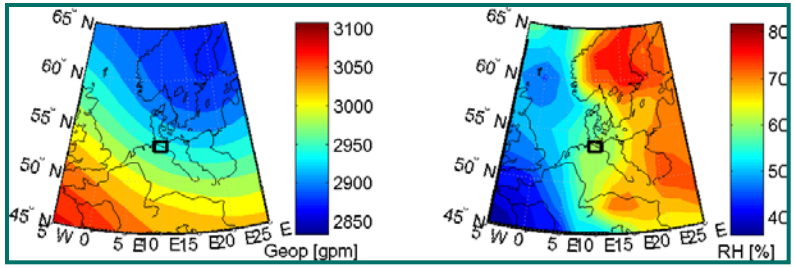
WT 5 Freq = 14.3%



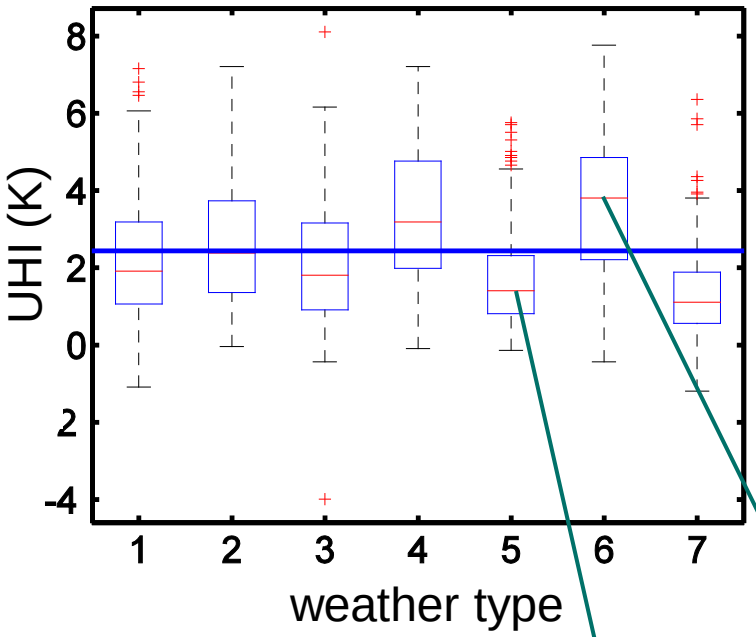
WT 6 Freq = 13.2%



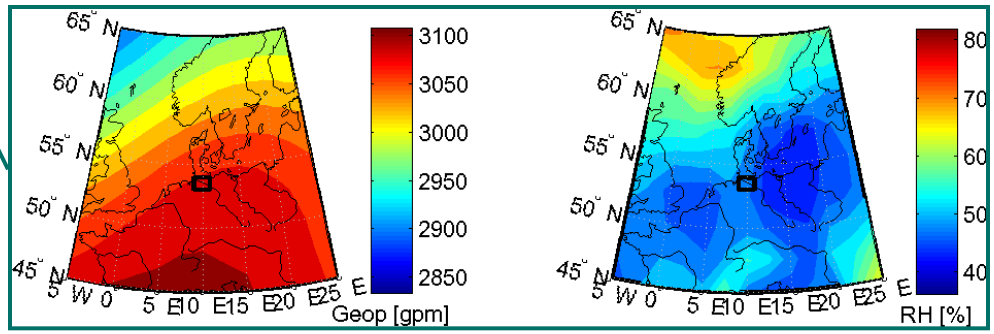
WT 7 Freq = 12.1%

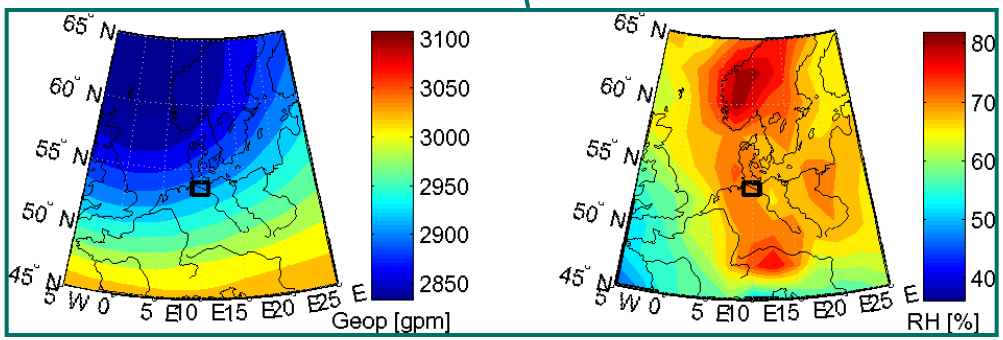


UHI per weather type



simulating cluster center is insufficient





Relevant days

- **per weather type linear model for UHI with cloud cover, relative humidity and wind speed as predictors (Hoffmann et al., 2010)**

$$UHI = a\,FF + b\,CC + c\,RH + d$$

- **defining strong UHI days: UHI > 4 K**
- **relevant day = day which is closest to days with UHI = 4 K & day which has the maximum UHI (for each weather type)**
- **simulation of these days with mesoscale model METRAS (1 km)**

➡ **Calculating mean strong UHI as linear combination of the simulated days**

Summary

- **method for statistical dynamical downscaling**
- **weather type classification**
  - *k*-means clustering of 700hPa geopotential height & relative humidity
  - clustering for each season separately
  - several statistical measures to determine cluster number
  - cluster number could be determined only for large domain
  - different number of weather types for different seasons
  - simulating cluster center is insufficient
- **statistical model for each weather type**
  - strong UHI days (>4 K)
  - linear combination to get mean strong UHI
- **simulations with mesoscale model METRAS are in progress**