# RECENT CLIMATE CHANGE IN LATVIA

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# SURFACE OBSERVATION DATA USED FOR THE ANALYSIS

**Meteorological parameters**:

- Minimum, maximum and mean air temperature
- Precipitation amount
- Wind speed
- Wind direction

**Time period covered**:

- 1961-2010
- 1966-2010 for wind speed

**Time steps of observation data:**

- Daily data
- SYNOP observation time data for wind direction

**Area coverage – 49 weather stations:**

- 48 WS for precipitation
- 22 WS for temperature parameters
- 22 WS for wind parameters


**Location of the meteorological observation stations used for the analysis**

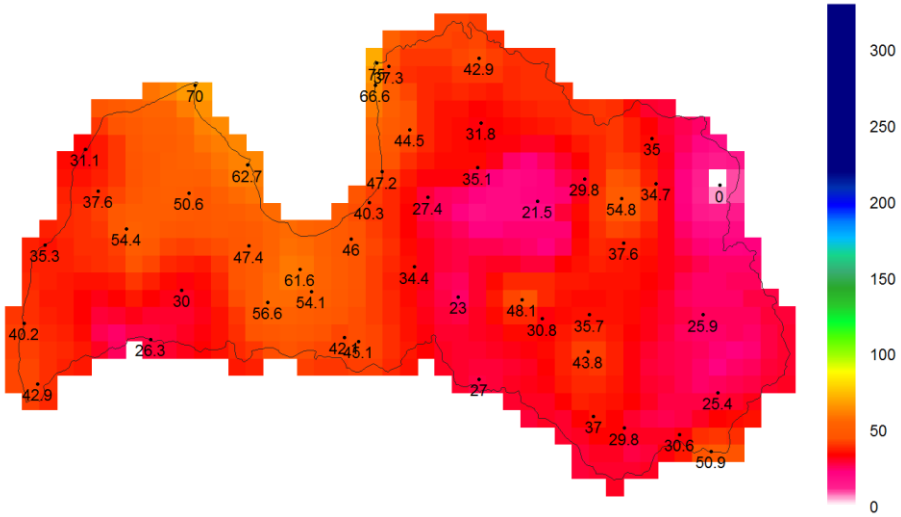
# QUALITY CONTROL OF ARCHIVED OBSERVATION DATA

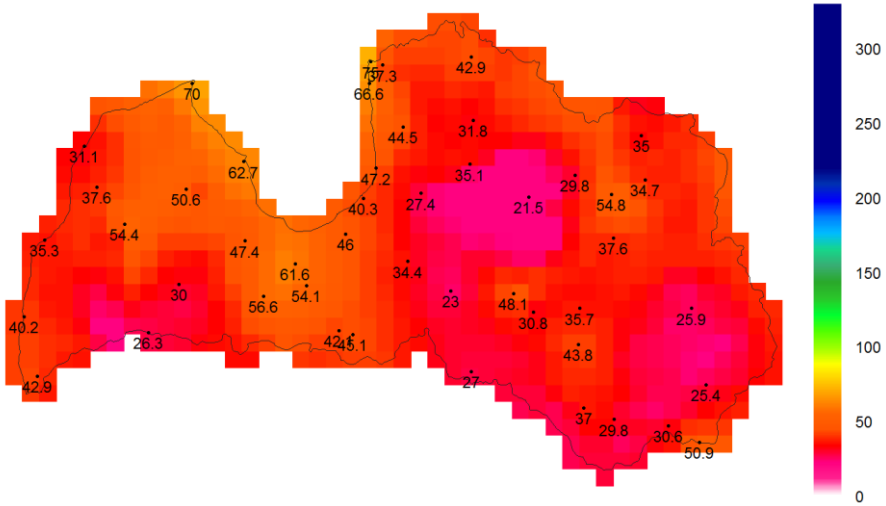
Archived observation data have been put under extensive quality control performed on different levels of the analysis:

1. Initial manual quality control of the data performed by in-house experts
2. Data homogenization for the data series containing meteorologically unexplainable shifts or jumps
3. Final data quality control and bias assessment of the interpolated values against E-OBS gridded observation dataset performed by the experts from the FMI

# QUALITY CONTROL: 1. Initial QC and blacklisting

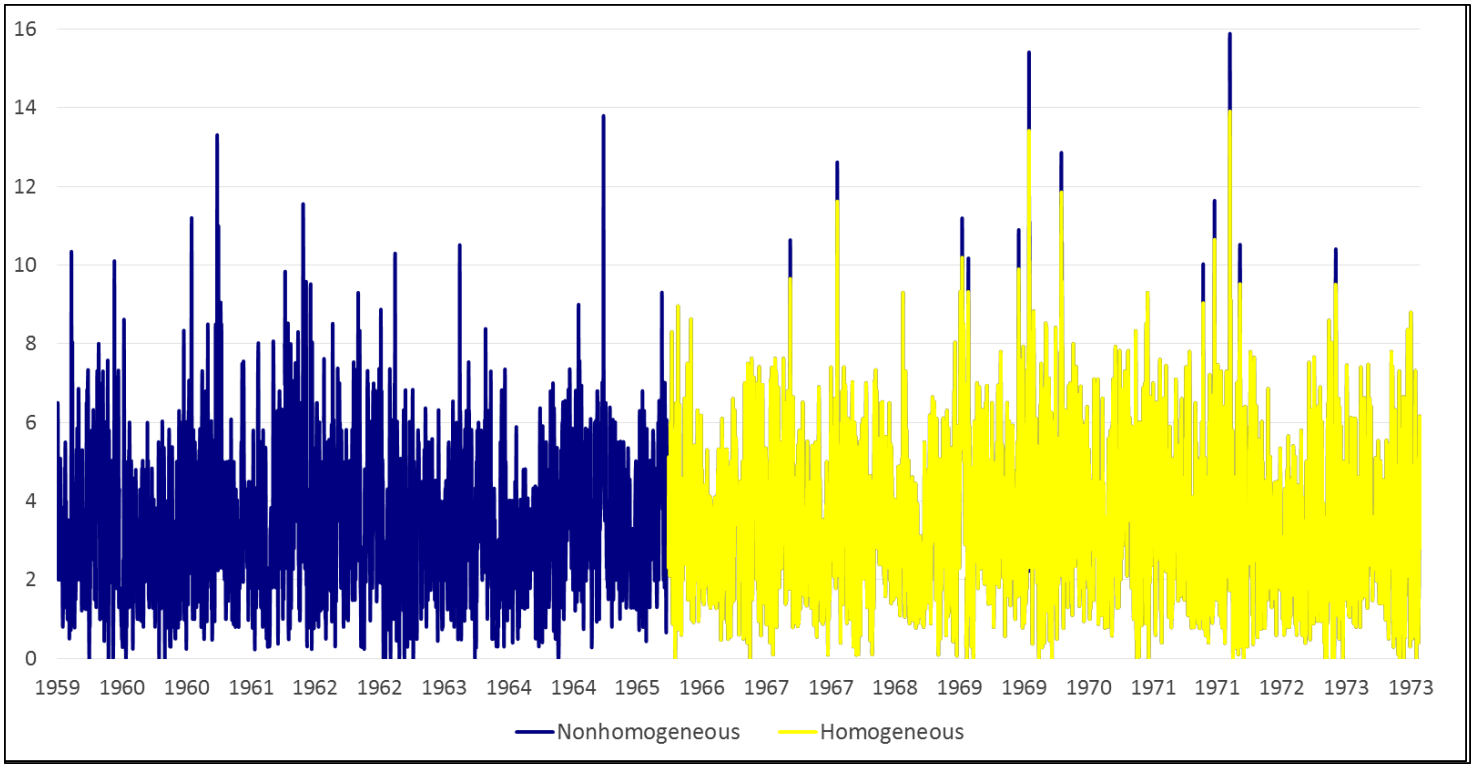
During data extraction from the electronic observation archive database several issues with data quality have been detected and corrected for



# QUALITY CONTROL: 2. Data homogenization

Due to changes in observation methods and instruments over time, shifts and jumps in wind speed observation data have been detected → a simple homogenization of the data series has been performed



# QUALITY CONTROL: 3. Comparison to the E-OBS dataset

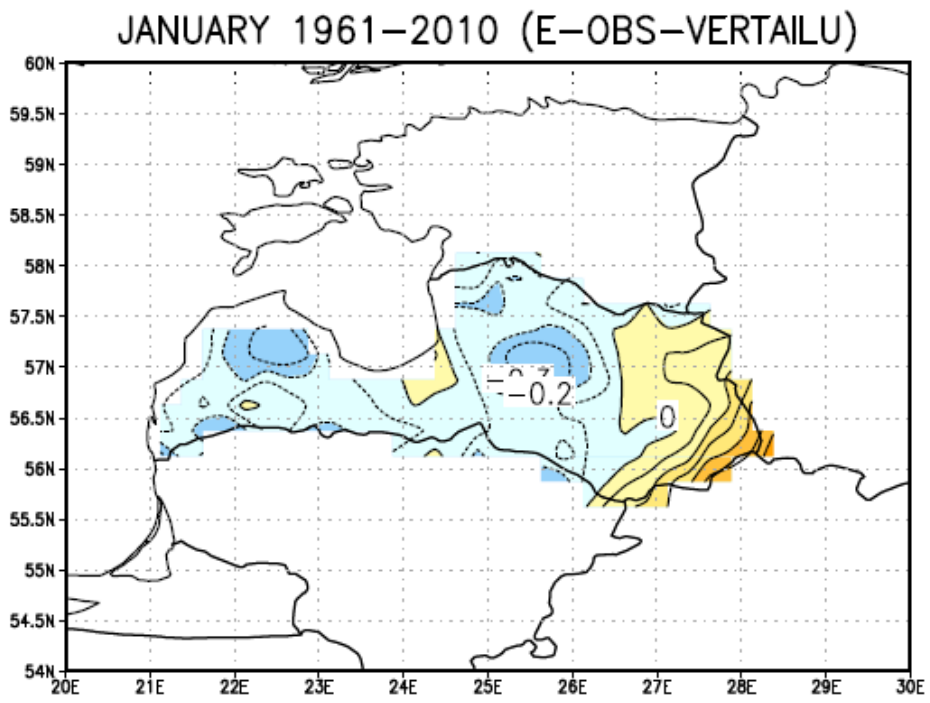
The corrected and homogenized data have been compared to the E-OBS gridded observation dataset for Europe.

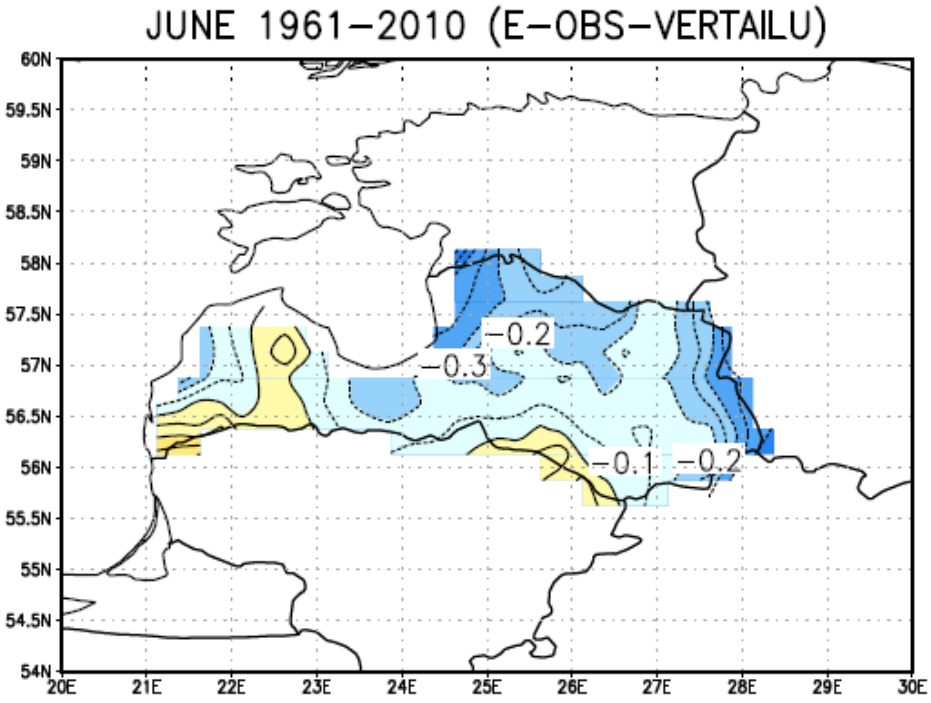
Main conclusions from the comparison of temperature parameters:

- The differences are generally quite gentle, of the order of magnitude of 0-0.3 °C. The analyses are generally of a good quality.
- More geographical details can be seen from LEGMC data, which is due to the larger number of observations utilized.

# QUALITY CONTROL: 3. Comparison to the E-OBS dataset

Larger differences occurring near the eastern boundary of the country might be artefacts: in winter the values are by 0.5 °C warmer than the E-OBS estimates, but in summer negative anomalies of a similar magnitude can be observed.



# CLIMATE INDICES

For the assessment of extreme climate events and their changes under the conditions of recent climate change, several climate indices following the recommendations of ECA&D have been calculated from the daily observation data

- 20 temperature indices
- 10 precipitation indices
- 12 wind indices

# CLIMATE INDICES

| Temperature indices | |
|---|---|
| **FD** | Frost days |
| **SU** | Summer days |
| **ID** | Ice days |
| **TR** | Tropical nights |
| **GSL** | Growing season length |
| **TN10p** | Cold nights |
| **TX10p** | Cold day-times |
| **TG10p** | Cold days |
| **TN90p** | Warm nigts |
| **TX90p** | Warm day-times |
| **TG90p** | Warm days |
| **TGn** | Minimum of the daily mean temperature |
| **TGx** | Maximum of the daily mean temperature |
| **TNn** | Minimum of the daily minimum temperature |
| **TNx** | Maximum of the daily minimum temperature |
| **TXn** | Minimum of the daily maximum temperature |
| **TXx** | Maximum of the daily maximum temperature |
| **WSDI** | Warm-spell duration indicator |
| **CSDI** | Cold-spell duration indicator |
| **DTR** | Diurnal temperature range |

| Precipitation indices | |
|---|---|
| **RX1day** | Maximum 1-day precipitation amount |
| **RX5day** | Maximum 5-day precipitation amount |
| **SDII** | Simplified daily intensity index |
| **R10** | Number of days with heavy precipitation |
| **R20** | Number of days with very heavy precipitation |
| **CDD** | Number of consecutive dry days |
| **CWD** | Number of consecutive days with precipitation |
| **R95p** | Very wet days |
| **R99p** | Extremely wet days |
| **PRCPTOT** | Total annual precipitation on wet days |

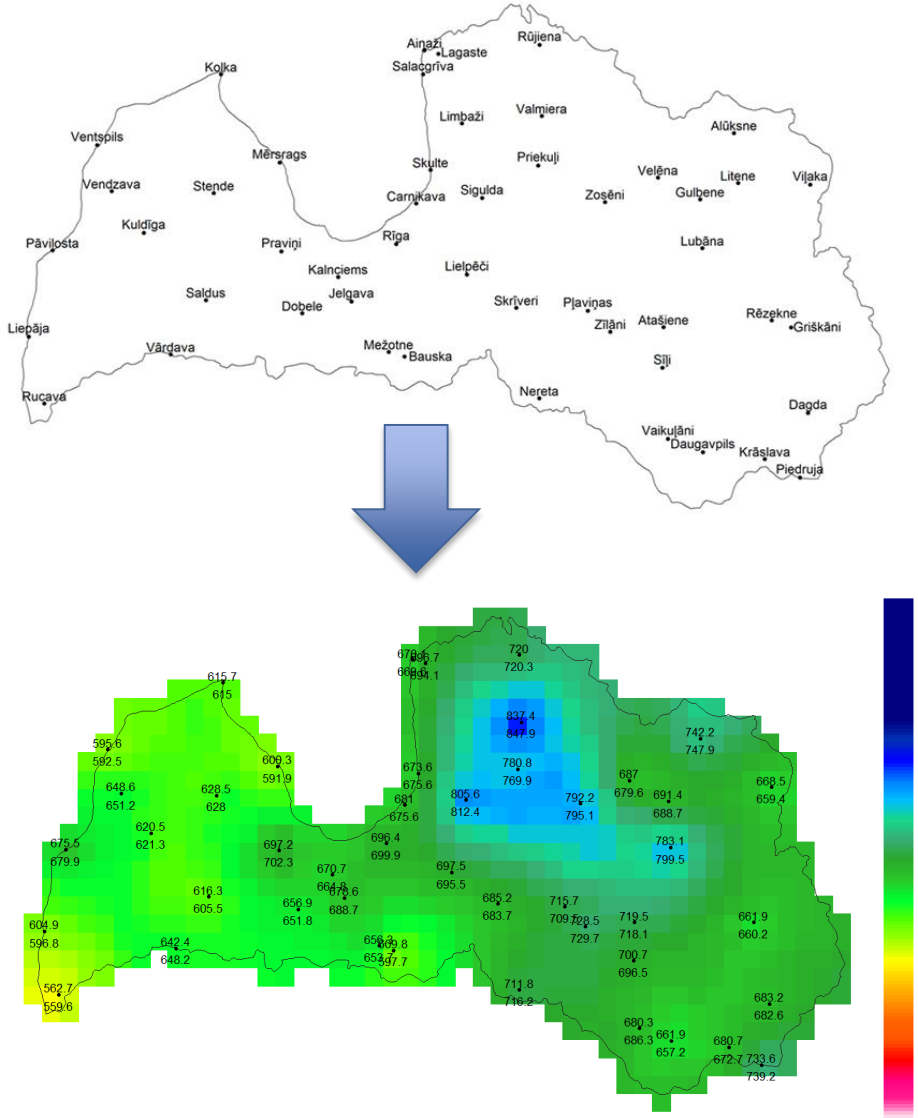
| Wind indices | |
|---|---|
| **FG** | Annual mean wind speed |
| **FGCalm** | Number of days with calm winds |
| **FG6Bft** | Number of days with strong winds |
| **FXx** | Annual maximum wind gusts |
| **DDnorth** | Number of days with prevailing northerly winds |
| **DDsouth** | Number of days with prevailing southerly winds |
| **DDwest** | Number of days with prevailing westerly winds |
| **DDeast** | Number of days with prevailing easterly winds |
| **DMnorth** | Number of days with maximum wind speed observed with northerly direction winds |
| **DMsouth** | Number of days with maximum wind speed observed with southerly direction winds |
| **DMwest** | Number of days with maximum wind speed observed with westerly direction winds |
| **DMeast** | Number of days with maximum wind speed observed with easterly direction winds |

The calculation of indices has been performed by using the RClimDex tool recommended by the ECA&D project team.

Indices have been calculated from quality-checked daily observation data, following a built-in routine of the tool.

# STATION DATA VS GRIDDED DATA

- Official meteorological observations performed only in fixed points – official meteorological observation stations
- Scientifically sound interpolation of data obtained from the meteorological weather stations performed in order to provide information also in points not covered by the observation network



# BASIC STATISTICAL ANALYSIS

Descriptive statistics and quality control taking into account WMO recommendations:

- Monthly, yearly means, minimums, maximums and sums
- Multi-year monthly and yearly means, minimums and maximums

$$\bar{T}_m = \frac{\sum_{i=1}^{n} T_{d_i}}{n} \qquad \bar{T}_y = \frac{\sum_{i=1}^{12} T_{m_i}}{12}$$

*Monthly mean values calculated only if:*

- *no more than 10 daily values missing*
- *5 or more consecutive daily values are missing*

*Yearly mean values calculated only if:*

- *no monthly values missing*

$$\bar{P}_m = \sum_{i=1}^{n} P_{d_i} \qquad \bar{P}_y = \sum_{i=1}^{n} P_{m_i}$$

*Monthly and yearly sums calculated only if:*

- *no daily values missing*

# BASIC STATISTICAL ANALYSIS

## Detection of trends:

- Mann-Kendall test

$$Z = \begin{cases} \frac{S-1}{\sqrt{Var(S)}} & \text{if } S > 0 \\ 0 & \text{if } S = 0 \\ \frac{S+1}{\sqrt{Var(S)}} & \text{if } S < 0 \end{cases}$$

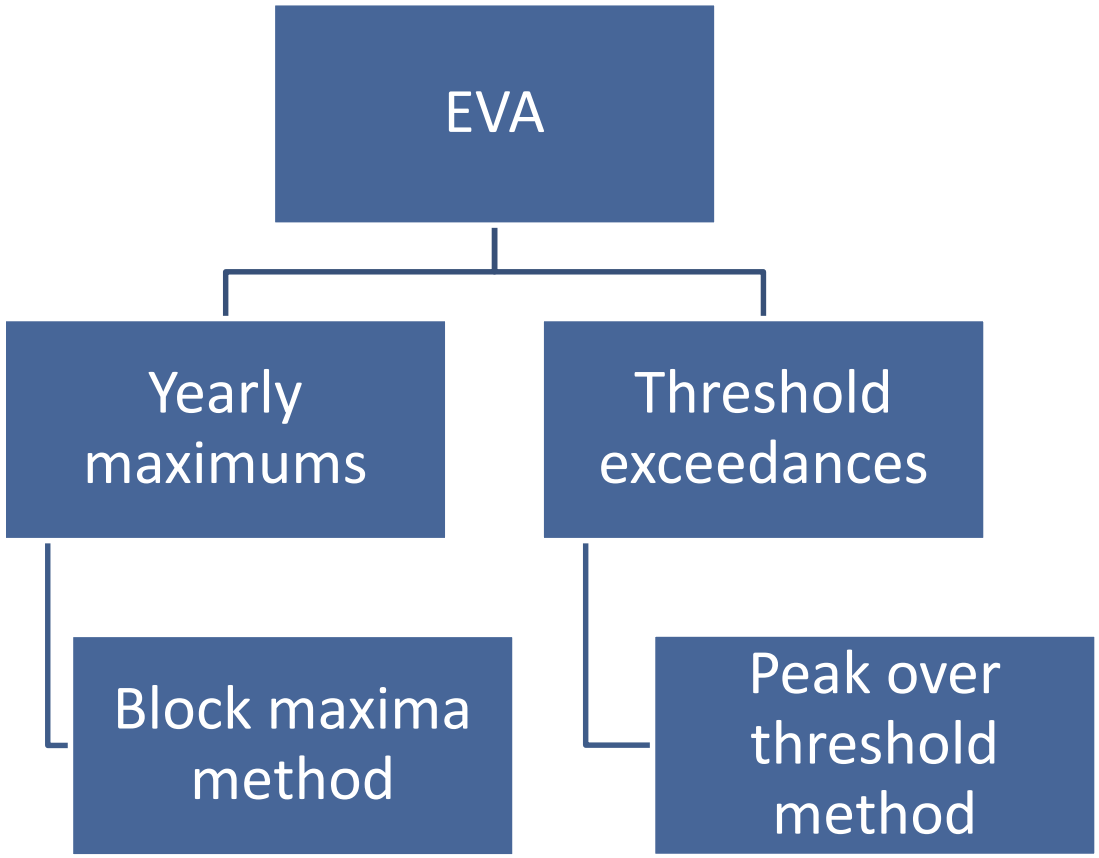
- Linear regression slope estimation

$$b = \frac{\sum_{i=1}^{N}(x_i - \bar{x})(y_i - \bar{y})}{\sum_{i=1}^{N}(x_i - \bar{x})^2}$$

- Coefficient of determination

$$R^2 = 1 - \frac{SS_{RES}}{SS_{TOT}}$$

# EXTREME VALUE ANALYSIS



# EXTREME VALUE ANALYSIS

## Block maxima method:

- Generalized extreme value distribution fits the data

$$G(x) = \begin{cases} \exp\left\{-\left[1+\xi\left(\frac{x-\mu}{\sigma}\right)\right]^{\frac{-1}{\xi}}\right\} & \text{if } \xi \neq 0 \\ \exp\left\{-\exp\left[-\left(\frac{x-\mu}{\sigma}\right)\right]\right\} & \text{if } \xi = 0 \end{cases}$$

- Parameters estimation, hypothesis testing
- Return levels – amounts that might be exceeded once in T years

$$x_T = \begin{cases} \mu - \frac{\sigma}{\xi}\left[1-\{-\log(1-1/T)\}^{-\xi}\right] & \text{if } \xi \neq 0 \\ \mu - \sigma\log\{-\log(1-1/T)\} & \text{if } \xi = 0 \end{cases}$$

# EXTREME VALUE ANALYSIS

## Peak over threshold method:

- Generalized Pareto distribution fits the data

$$H_{\xi,\sigma}(y) = \begin{cases} 1 - \left(1 + \frac{\xi}{\sigma} y\right)^{-1/\xi} & \text{if } \xi \neq 0 \\ 1 - e^{-\frac{y}{\sigma}} & \text{if } \xi = 0 \end{cases}$$

- Parameters estimation, hypothesis testing
- Return levels – amounts that might be exceeded once in N years

$$x_N = \begin{cases} u + \frac{\sigma}{\xi}\left[\left(N n_y \zeta_u\right)^{\xi} - 1\right] & \text{if } \xi \neq 0 \\ u + \sigma \log\left(N n_y \zeta_u\right) & \text{if } \xi = 0 \end{cases}$$

# DATA INTERPOLATION

## Kriging with external drift

- Spatial dependencies can be expressed as deterministic trend and stochastic component

$$Z(s) = \mu(s) + \varepsilon(s)$$

- Linear trends using explanatory variables

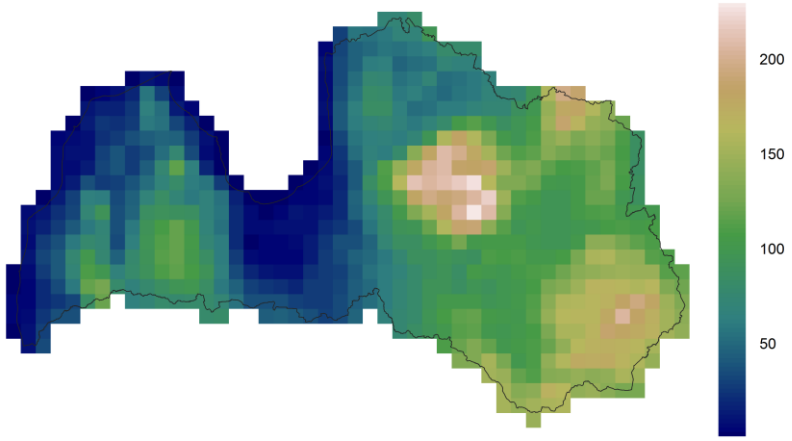
$$Z(x, y, h, c_t) = \beta_0 + \beta_1 x + \beta_2 y + \beta_3 x^2 + \beta_4 y^2 + \beta_5 xy + \beta_6 h + \beta_7 c_t$$

$$Z(x, y, h, c_p) = \beta_0 + \beta_1 x + \beta_2 y + \beta_3 x^2 + \beta_4 y^2 + \beta_5 xy + \beta_6 h + \beta_7 c_p$$

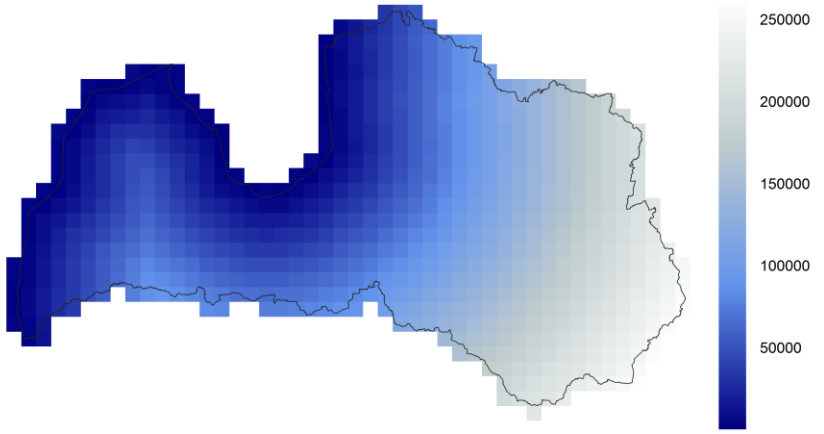
$$Z(x, y, h, d) = \beta_0 + \beta_1 x + \beta_2 y + \beta_3 x^2 + \beta_4 y^2 + \beta_5 xy + \beta_6 h + \beta_7 d$$

# DATA INTERPOLATION

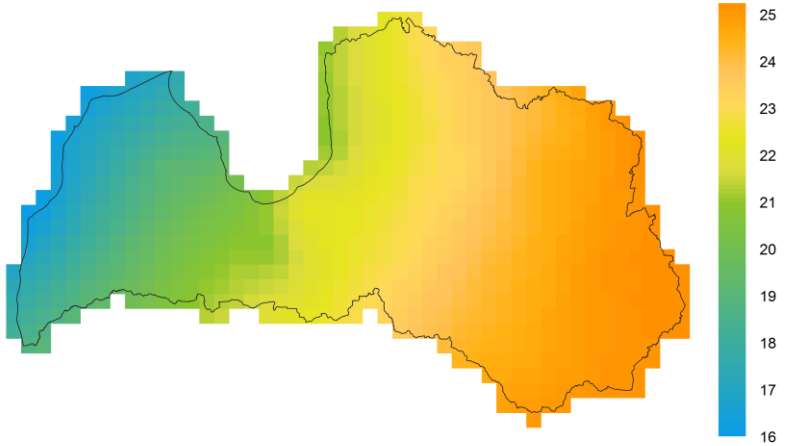
## Explanatory variables



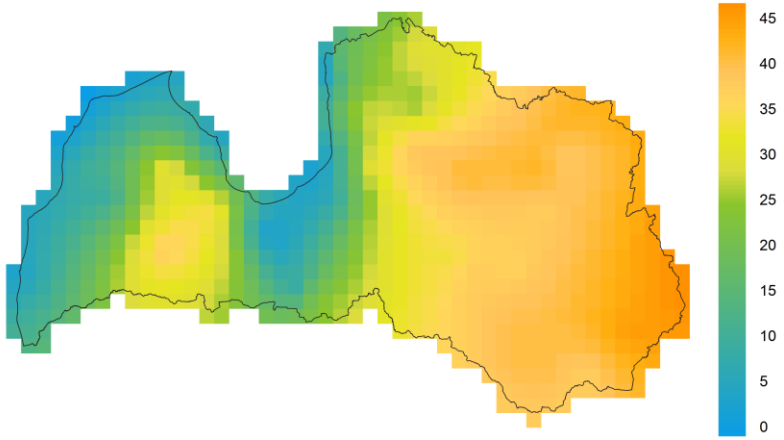

Mean elevation




Distance from the Baltic Sea and the Gulf of Riga




Gorczynski continentality

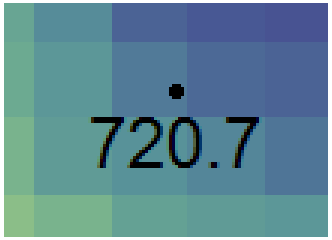



Gams' continentality

# DATA INTERPOLATION

## Validation:

– statistical indicators of the differences between predicted values and the values actually observed

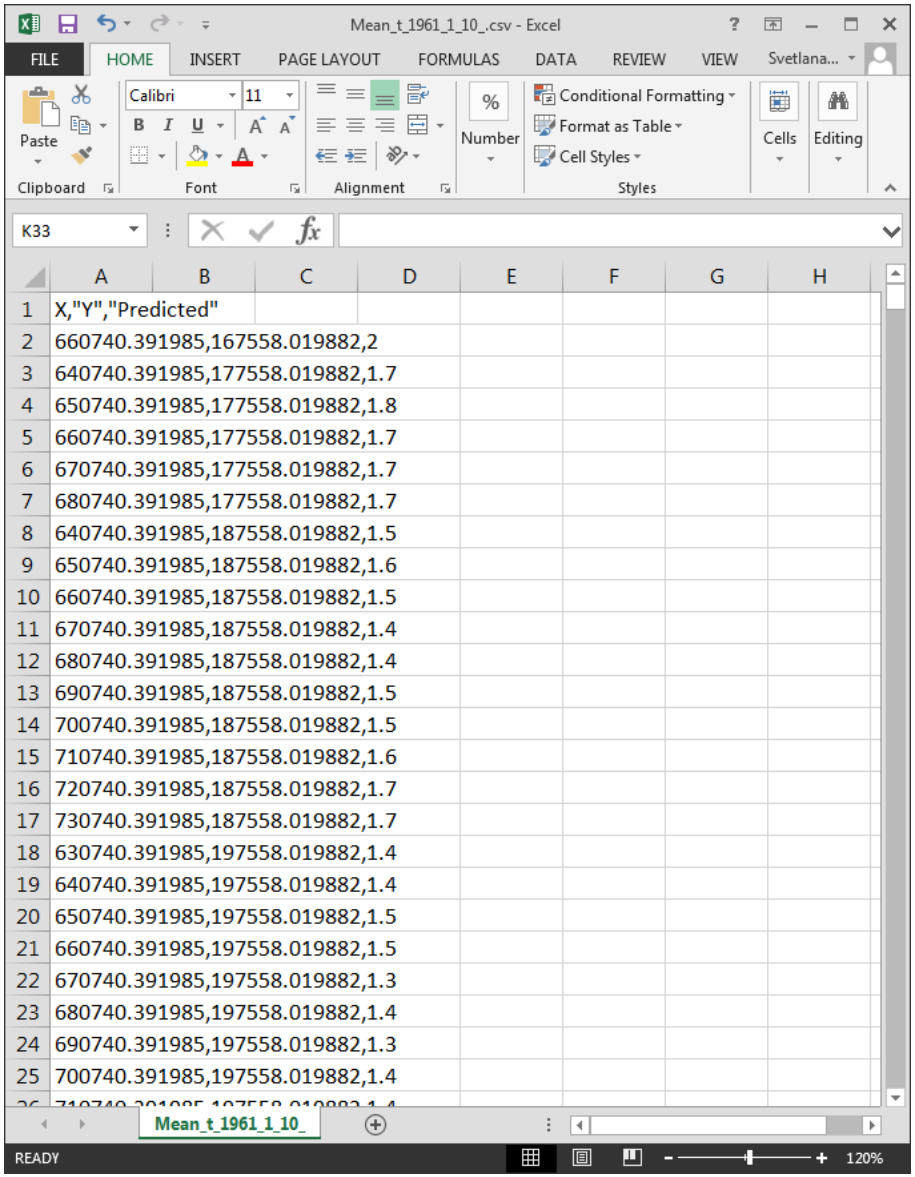



| | Temperature | | | Precipitation | Wind | |
|---|---|---|---|---|---|---|
| | Mean | Min | Max | Sum | Mean | Gusts |
| **Mean error** | 0.00 | 0.00 | 0.00 | -0.27 | 0.01 | 0.02 |
| **MAB** | 0.01 | 0.04 | 0.02 | 7.91 | 0.05 | 0.08 |
| **RMSE** | 0.03 | 0.07 | 0.04 | 10.58 | 0.08 | 0.12 |

# DATA INTERPOLATION

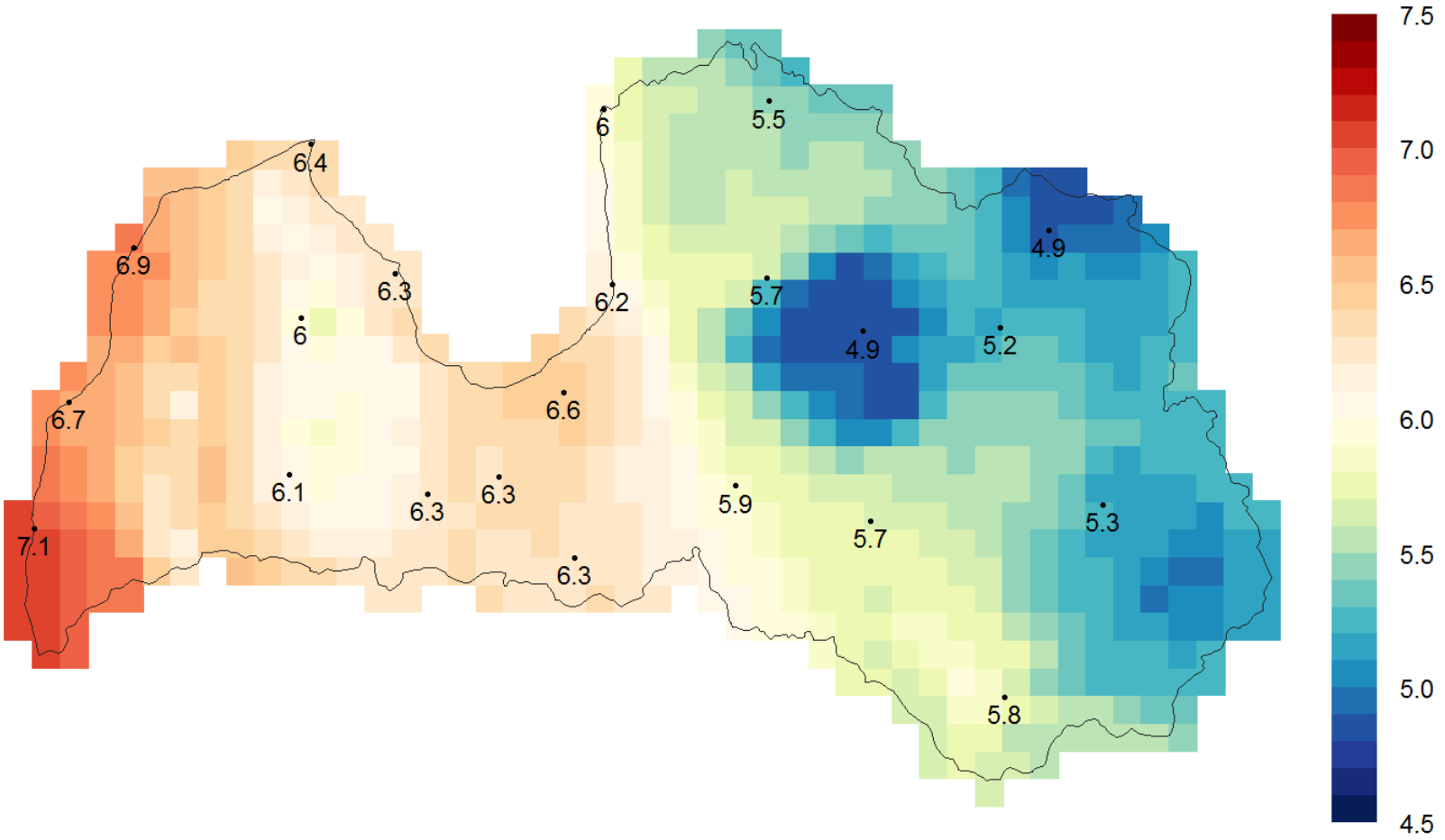
## Output files

- 739 grid cells
- Cell's coordinates in metric LKS-92 system
- Parameter value



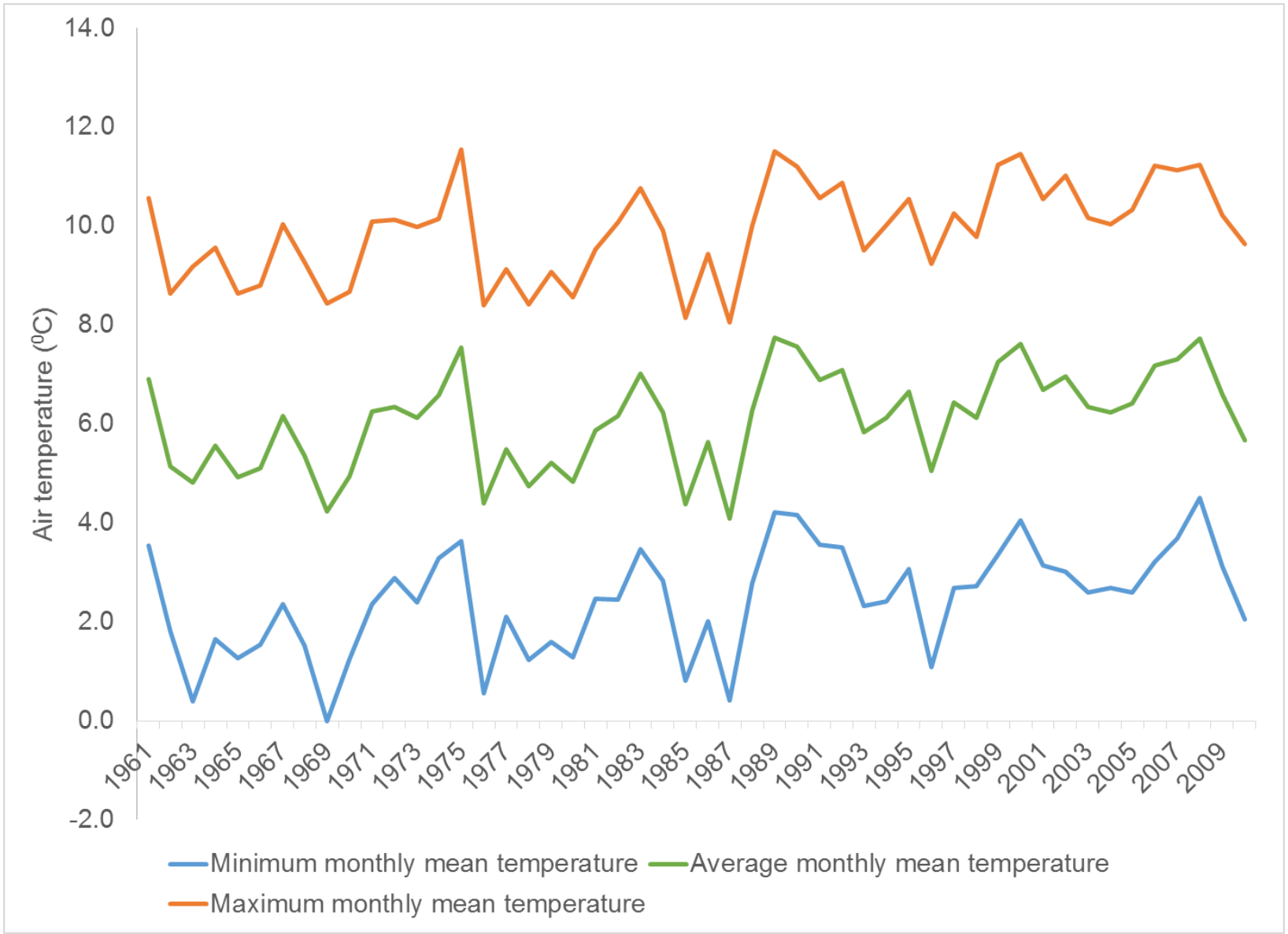
# RECENT CLIMATE CHANGE IN LATVIA

# AIR TEMPERATURE




**Annual mean air temperature (°C) over the period 1961-2010**

# AIR TEMPERATURE



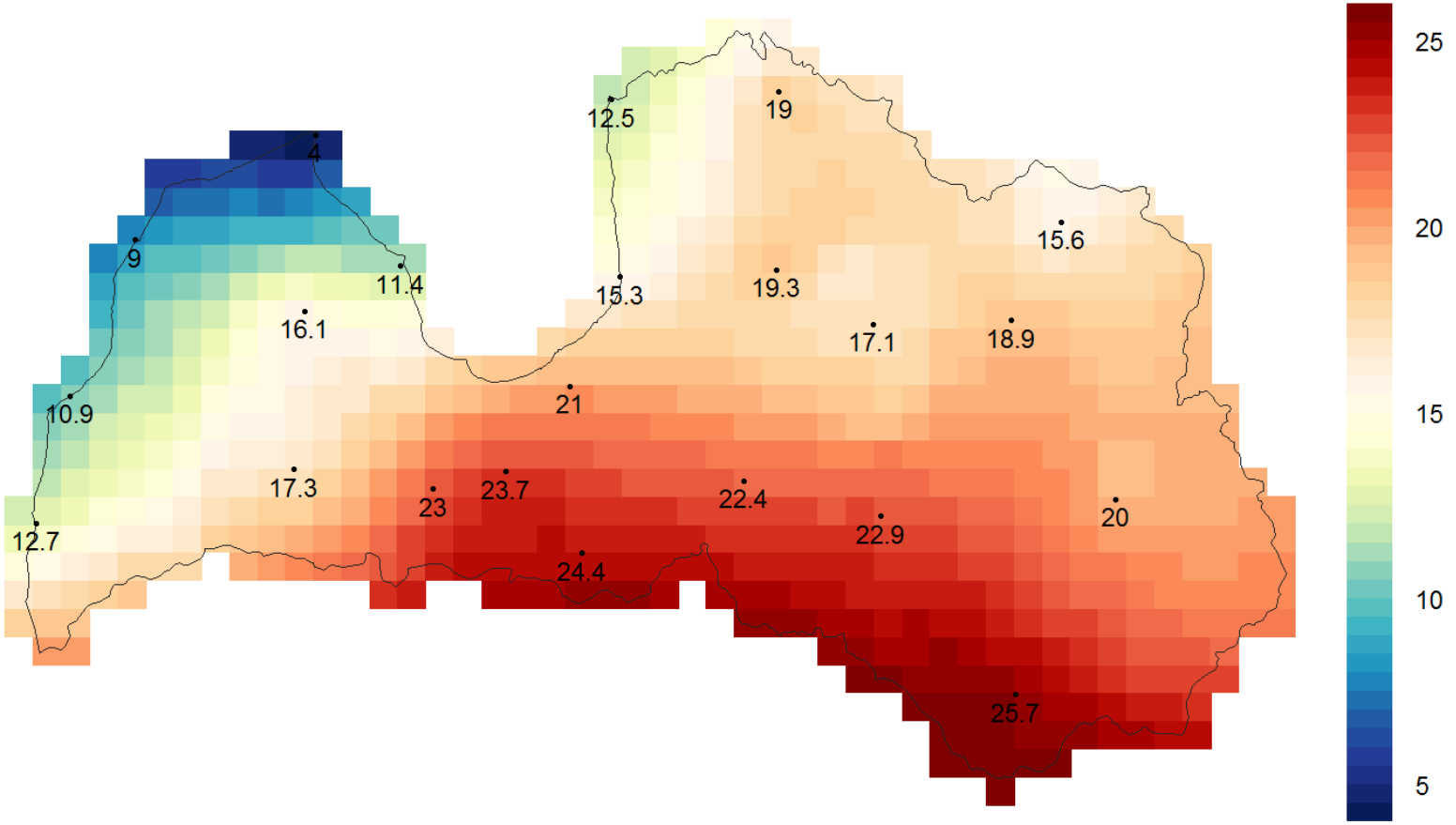
# OBSERVED TRENDS IN TEMPERATURE VARIABLES

| Index or variable | MK test statistics | Index name | MK test statistics | Index name | MK test statistics |
|---|---|---|---|---|---|
| TNmean | 3.22 | TGmean | 3.48 | TXmean | 3.35 |
| TNn | 1.33 | TGn | 1.29 | TXn | 1.13 |
| TNx | 2.87 | TGx | 1.58 | TXx | 1.61 |
| FD | -2.38 | DTR | 0.07 | SU | 1.56 |
| ID | -2.21 | GSL | 0.45 | TR | 2.48 |
| CSDI | -2.25 | | | WSDI | 2.92 |

Very significant tendency of increase (Mann-Kendall test statistics ≥ 3.3)
Significant tendency of increase (Mann-Kendall test statistics ≥ 2.6)
Substantial tendency of increase (Mann-Kendall test statistics ≥ 1.6)

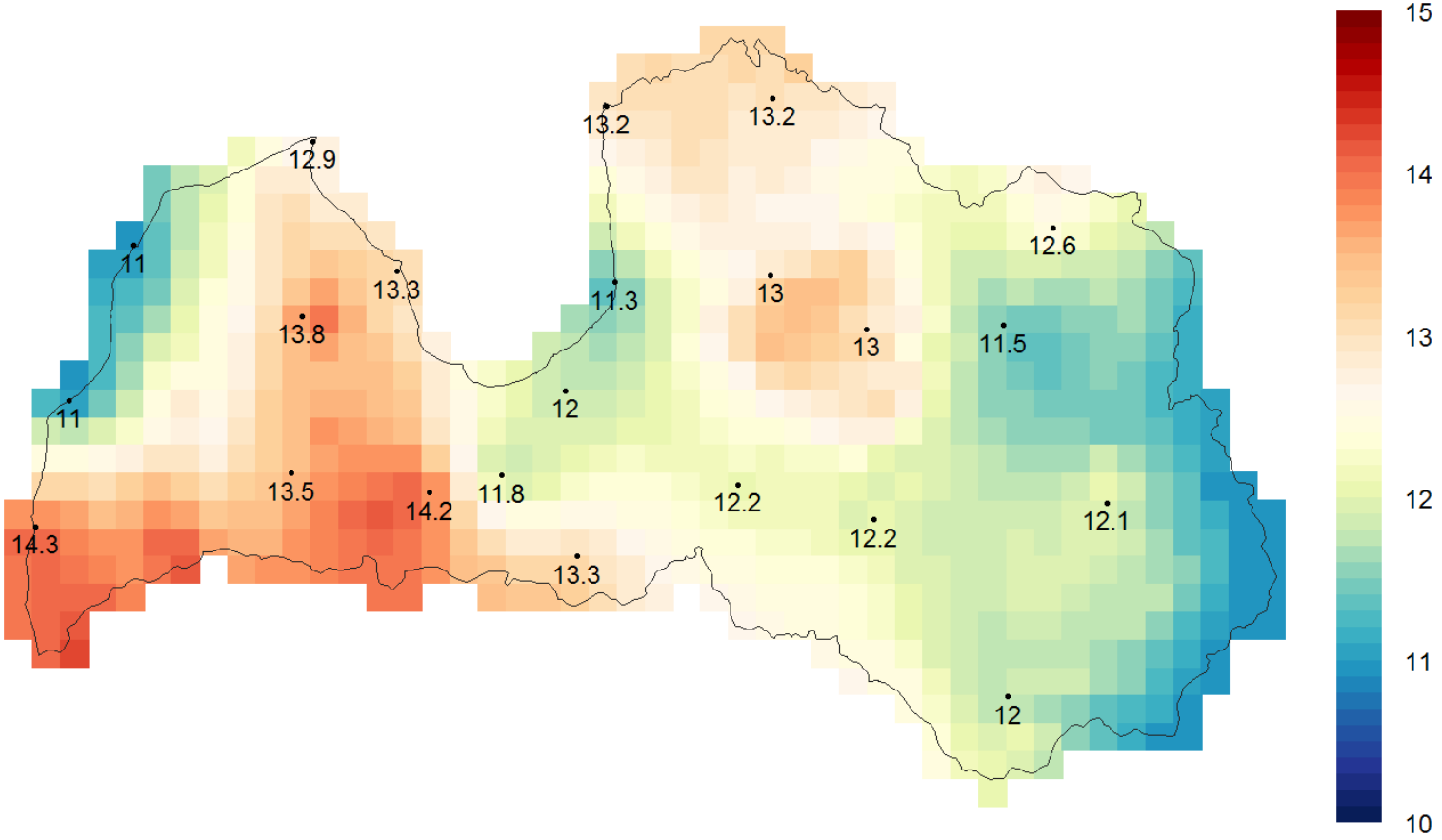
Very significant tendency of decrease (Mann-Kendall test statistics ≤ -3.3)
Significant tendency of decrease (Mann-Kendall test statistics ≤ -2.6)
Substantial tendency of decrease (Mann-Kendall test statistics ≤ -1.6)

# SUMMER DAYS



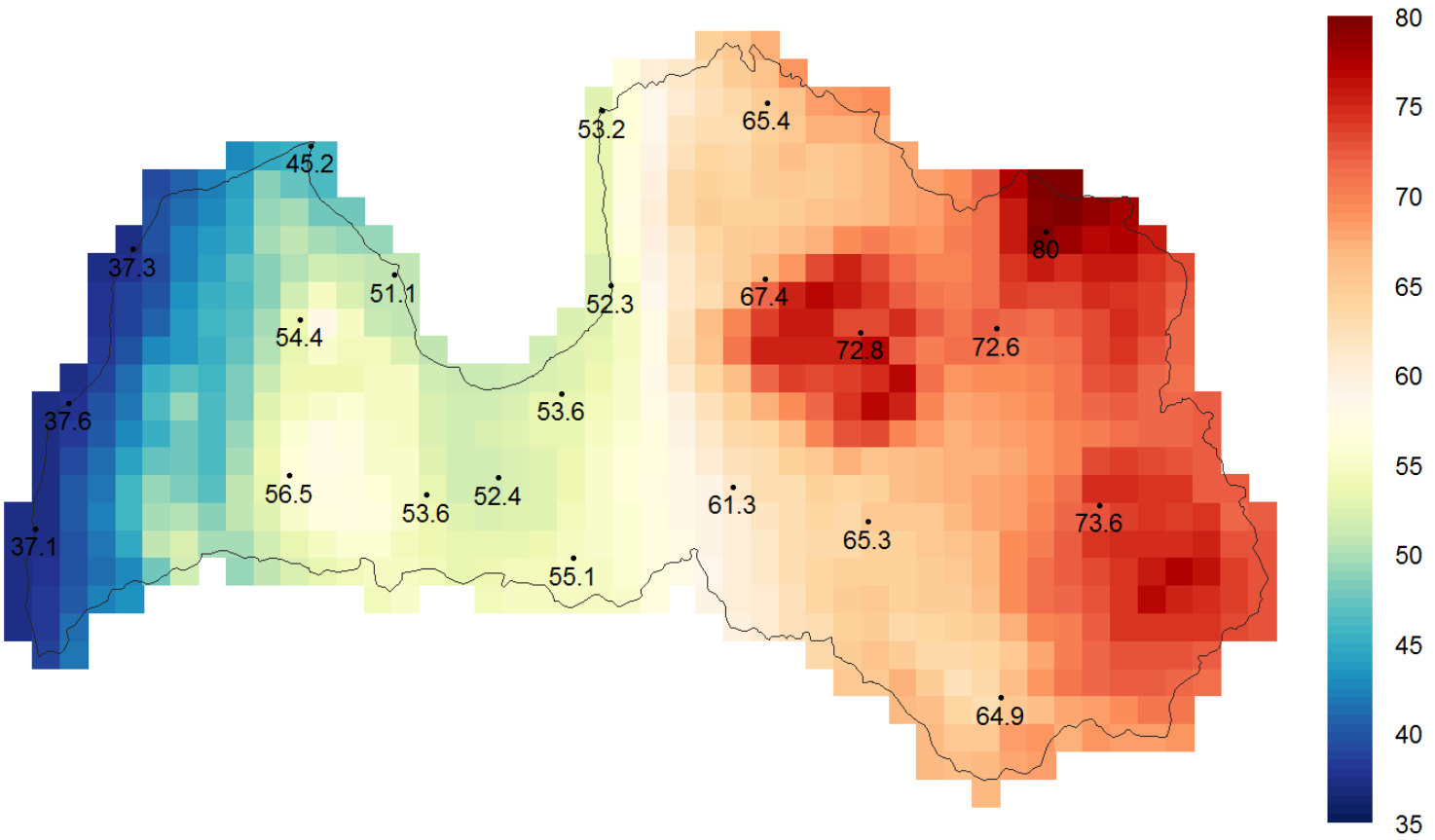

**Mean number of summer days (maximum air temperature > +25°C) over the period 1961-2010**

# WARM SPELL DURATION



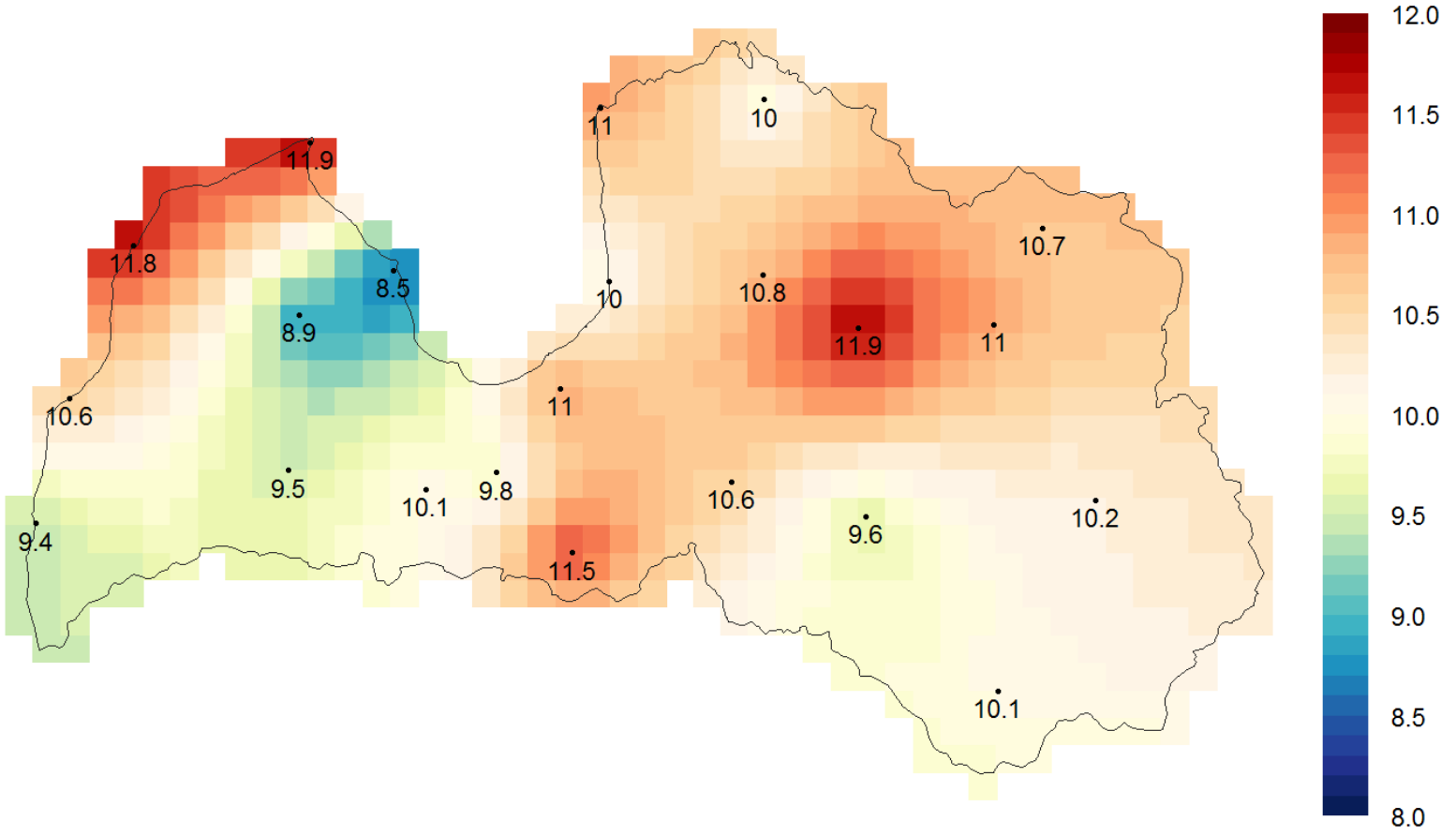

**Mean length of the observed warm spells (at least 6 consecutive days with maximum temperature above the 90$^{th}$ percentile of the reference period) over the period 1961-2010**

# ICE DAYS



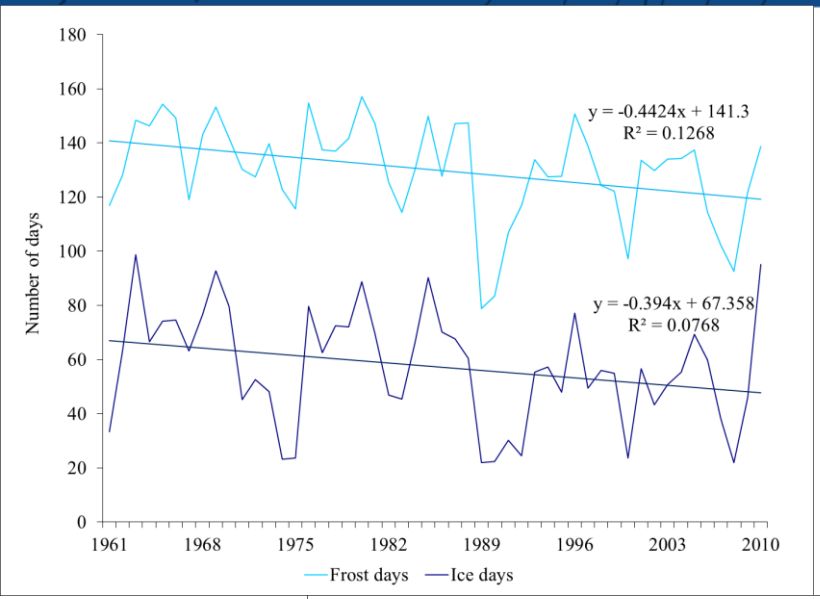

**Mean number of ice days (maximum air temperature < 0°C) over the period 1961-2010**

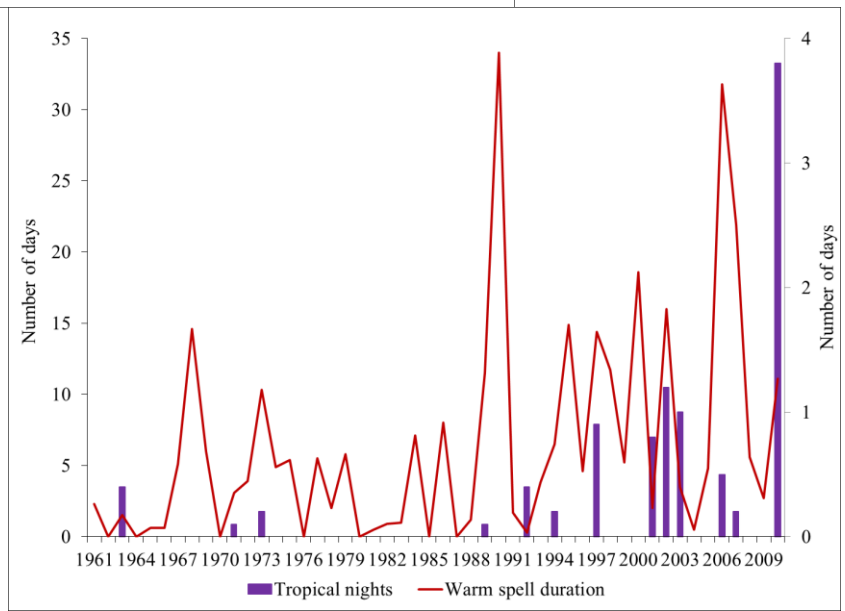
# COLD SPELL DURATION




**Mean length of the observed cold spells (at least 6 consecutive days with minimum temperature below the 10th percentile of the reference period) over the period 1961-2010**

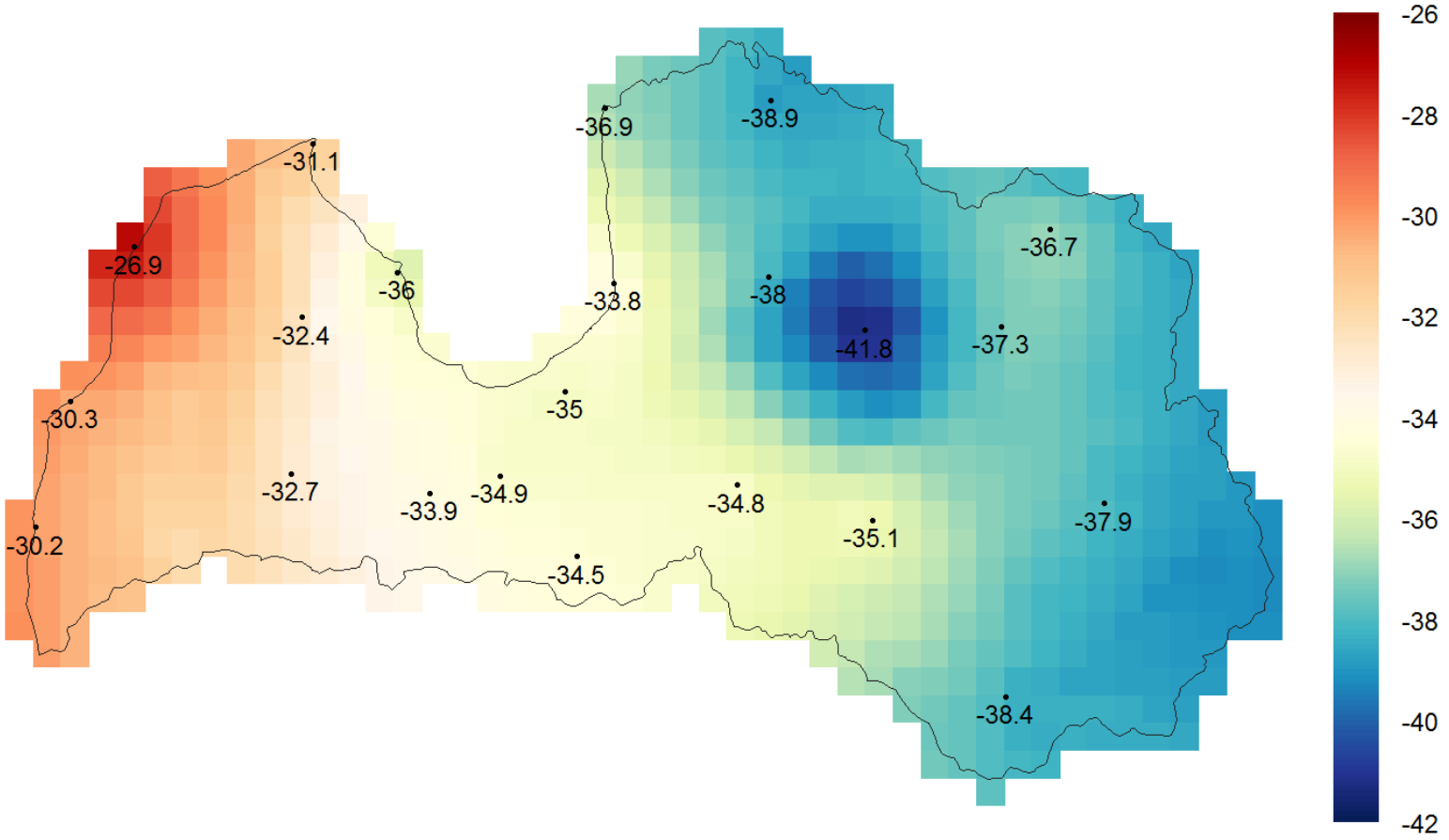
# OBSERVED TRENDS IN TEMPERATURE VARIABLES



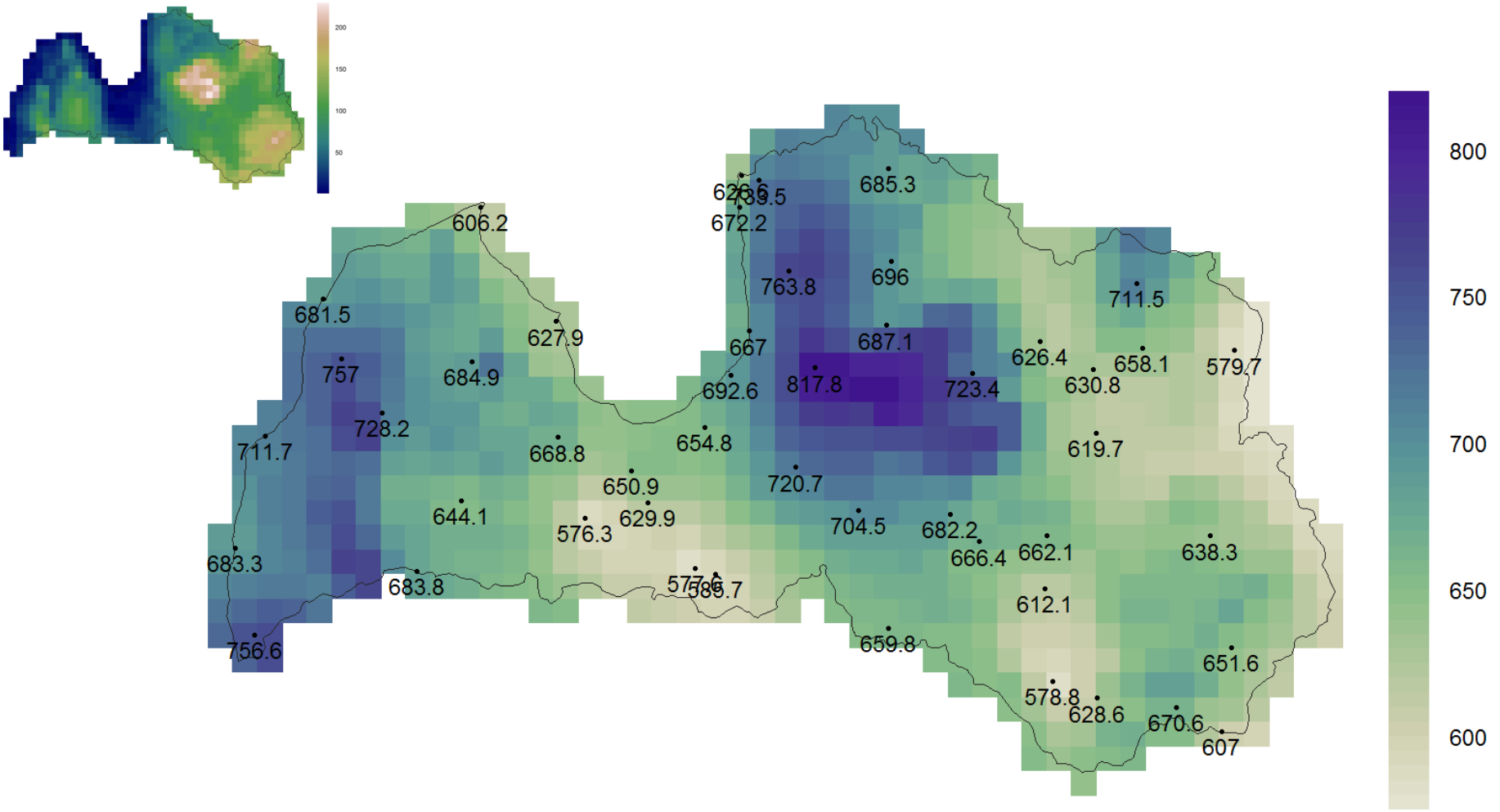

| Observation station | Frost days | Ice days | Tropical nights | Warm spell duration |
|---|---|---|---|---|
| Ainazi | -1.64 | -1.83 | 2.53 | 1.24 |
| Aluksne | -3.24 | -2.14 | 1.73 | 2.8 |
| Bauska | -2.2 | -2.02 | 2.35 | 0.25 |
| Daugavpils | -1.81 | -1.87 | 2.16 | 2.99 |
| Dobele | -2.94 | -2.37 | 1.78 | 3.31 |
| Gulbene | -2.53 | -2.49 | 2 | 2.83 |
| Jelgava | -1.11 | -2.32 | 3.09 | 1.97 |
| Kolka | -2.43 | -1.81 | 2.34 | 3.15 |
| Liepaja | -1.71 | -1.85 | 2.51 | 3.08 |
| Mersrags | -1.29 | -1.93 | 1.01 | 3.61 |
| Pavilosta | -2.54 | -2.05 | 1.8 | 2.93 |
| Priekuli | -3.05 | -2.48 | 2.43 | 2.14 |
| Rezekne | -2.6 | -2.17 | 2.45 | 2.68 |
| Riga | -3.82 | -2.04 | 2.15 | 2.34 |
| Rujiena | -2.25 | -2.24 | 2.25 | 1.84 |
| Saldus | -2.19 | -2.07 | -0.27 | 2.06 |
| Skriveri | -2.19 | -2.23 | 1.74 | 2.99 |
| Skulte | -2.23 | -2.2 | 3.29 | 1.62 |
| Stende | -1.33 | -1.93 | -0.54 | 1.9 |
| Ventspils | -2.65 | -2.25 | 3.1 | 2.25 |
| Zilani | -2.26 | -2.2 | 1.11 | 2.85 |
| Zoseni | -3.22 | -1.7 | 1.22 | 1.94 |

# RETURN LEVELS OF EXTREME TEMPERATURE VALUES



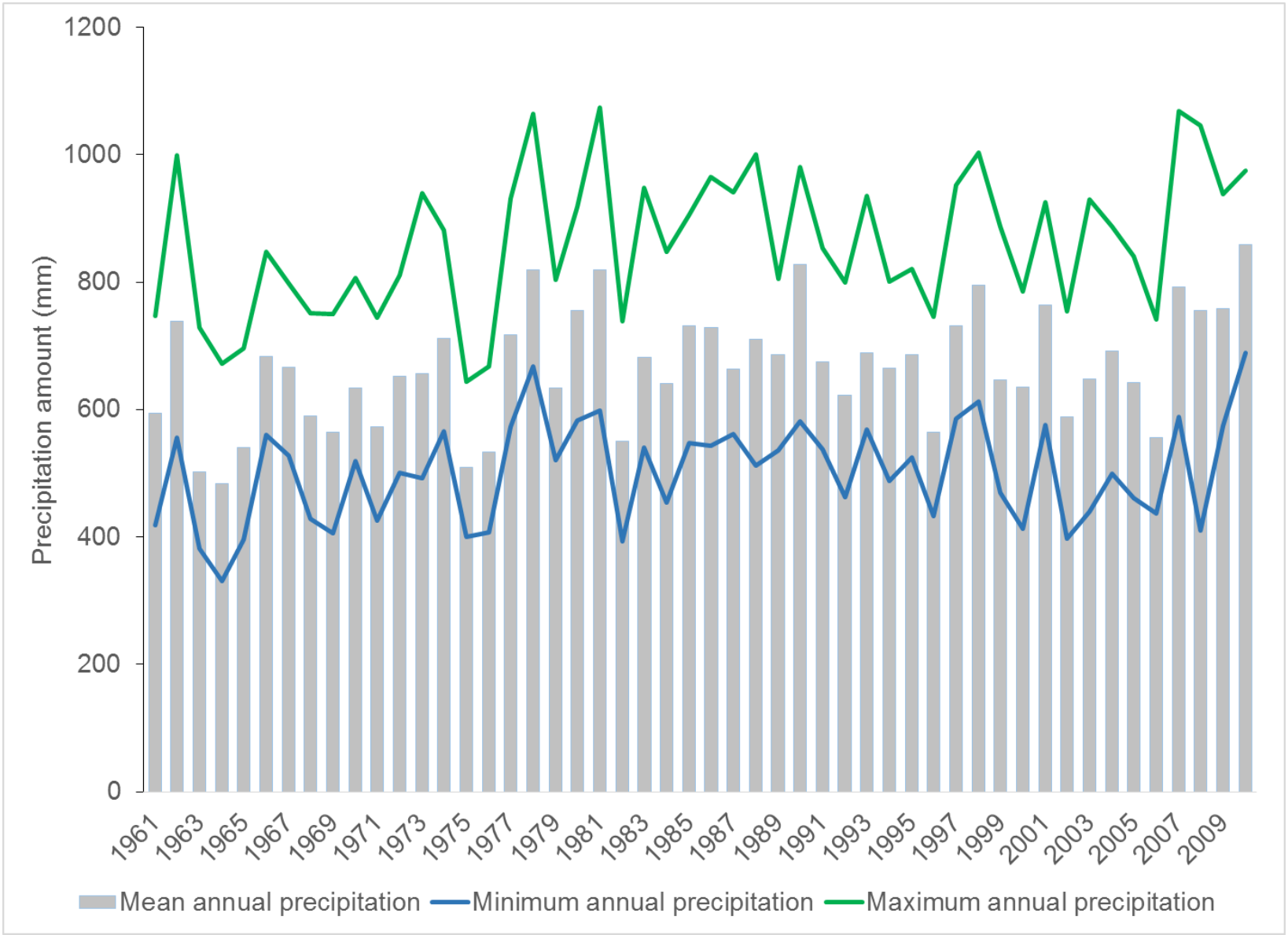

**Daily minimum air temperature return levels calculated over the period 1961-2010 – the temperature value that might be exceeded once in 100 years**

# PRECIPITATION




**Annual mean precipitation amount (mm) over the period 1961-2010**

# PRECIPITATION



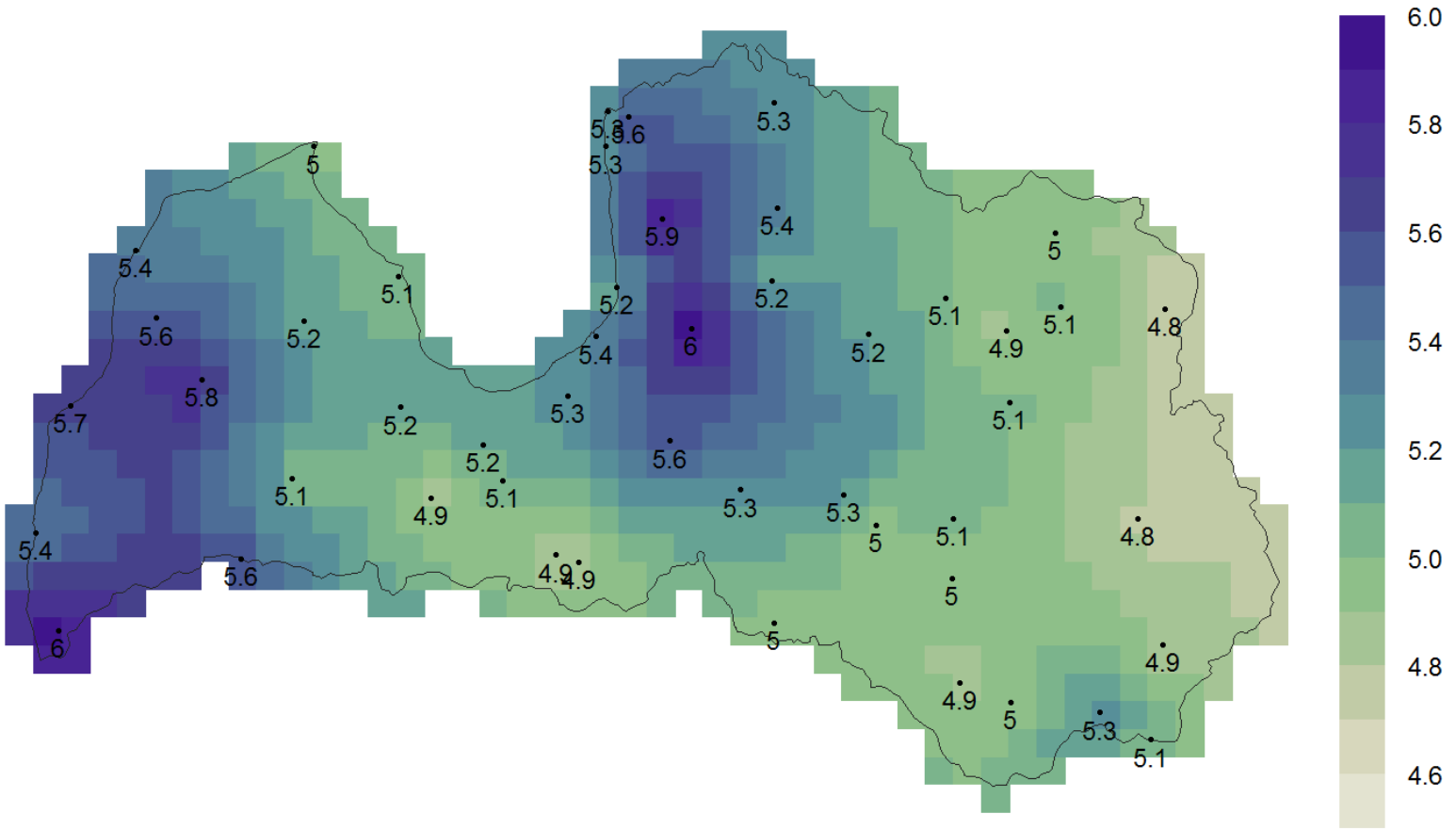
# OBSERVED TRENDS IN PRECIPITATION VARIABLES

| Index name | MK test statistics | Index name | MK test statistics |
|---|---|---|---|
| **CDD** | 0.39 | **R10** | 2.69 |
| **CWD** | 1.6 | **R20** | 2.83 |
| **PRCPTOT** | 2.3 | **R95p** | 2.91 |
| **SDII** | 3.01 | **R99p** | 2.02 |
| | | **Rmax1day** | 1.31 |
| | | **Rmax5day** | 1.66 |

Very significant tendency of increase (Mann-Kendall test statistics ≥ 3.3)
Significant tendency of increase (Mann-Kendall test statistics ≥ 2.6)
Substantial tendency of increase (Mann-Kendall test statistics ≥ 1.6)

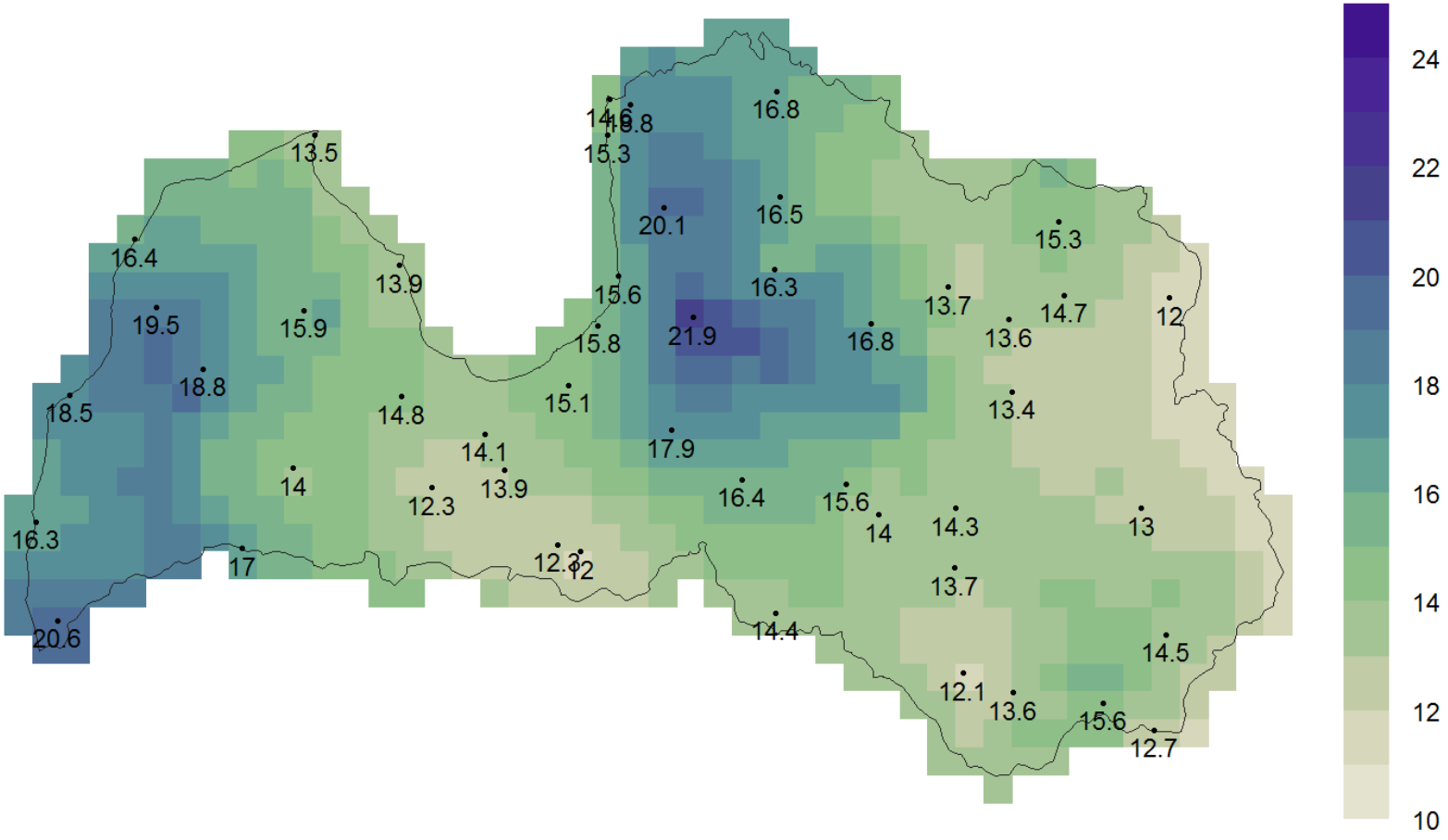
Very significant tendency of decrease (Mann-Kendall test statistics ≤ -3.3)
Significant tendency of decrease (Mann-Kendall test statistics ≤ -2.6)
Substantial tendency of decrease (Mann-Kendall test statistics ≤ -1.6)

# PRECIPITATION INDICES – DAILY INTENSITY



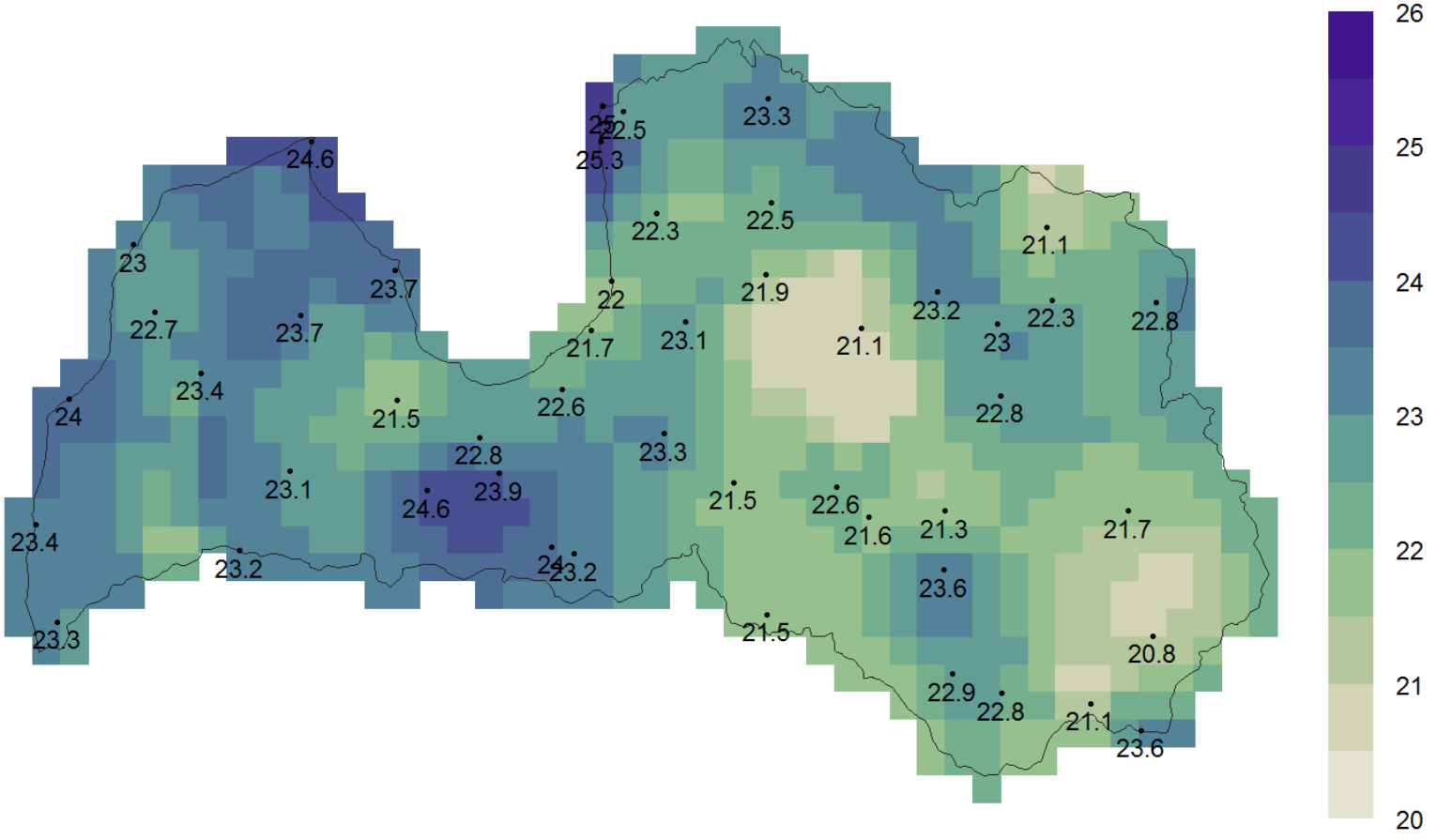

**Mean value (mm/day) of the simplified daily intensity index (SDII) in the period 1961-201**

# PRECIPITATION INDICES – HEAVY PRECIPITATION



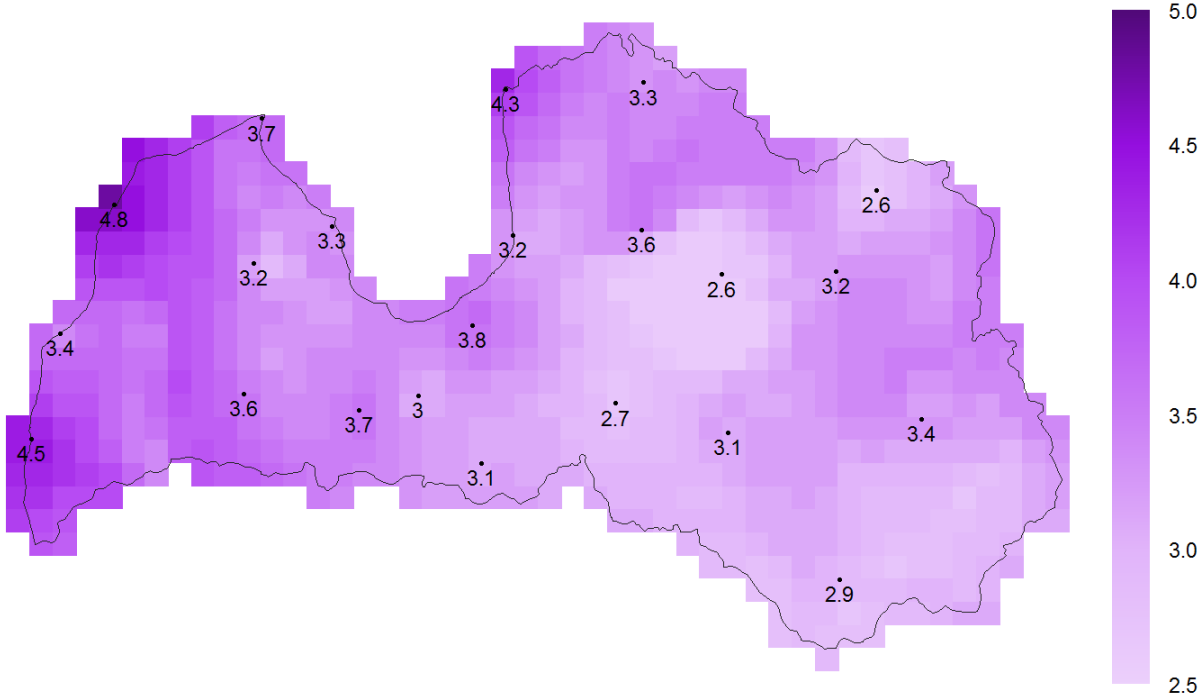

**Mean number of days with heavy precipitation (R10) in the period 1961-2010**

# PRECIPITATION INDICES – DRY PERIODS

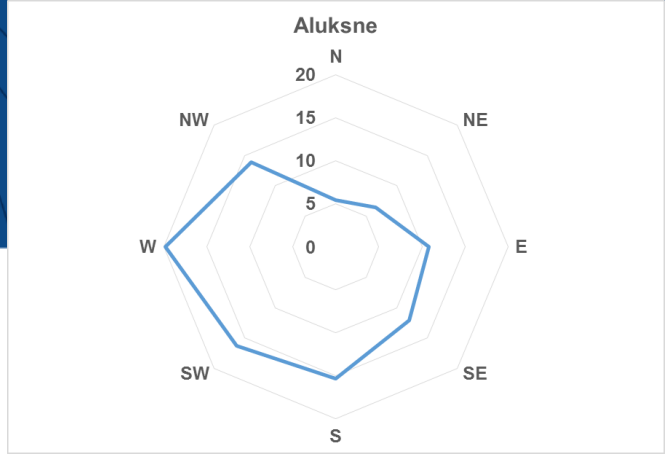


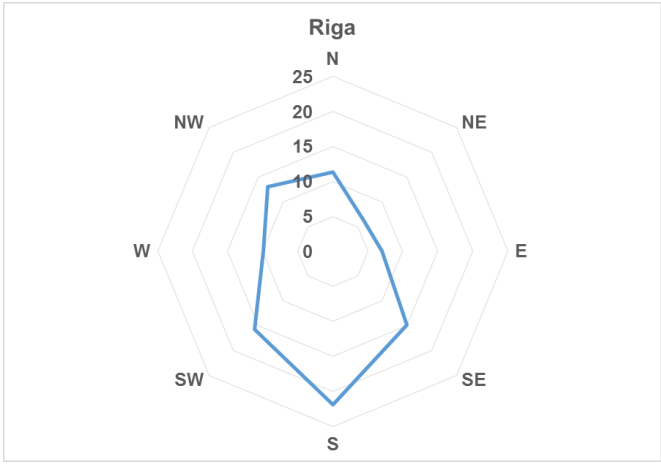

**Mean number of consecutive dry days (CDD) in the period 1961-2010**

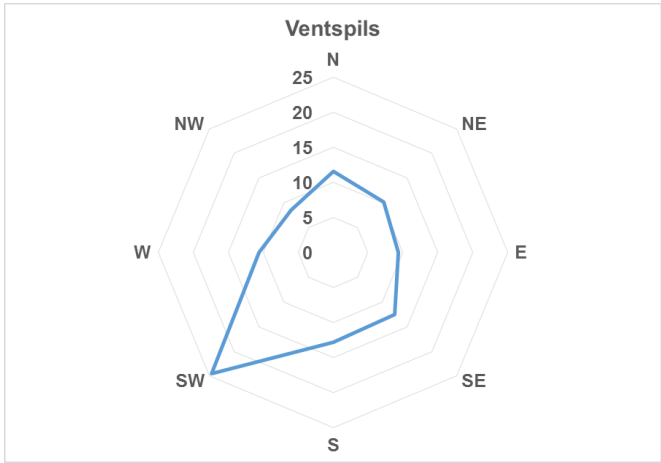
# WIND SPEED AND DIRECTION



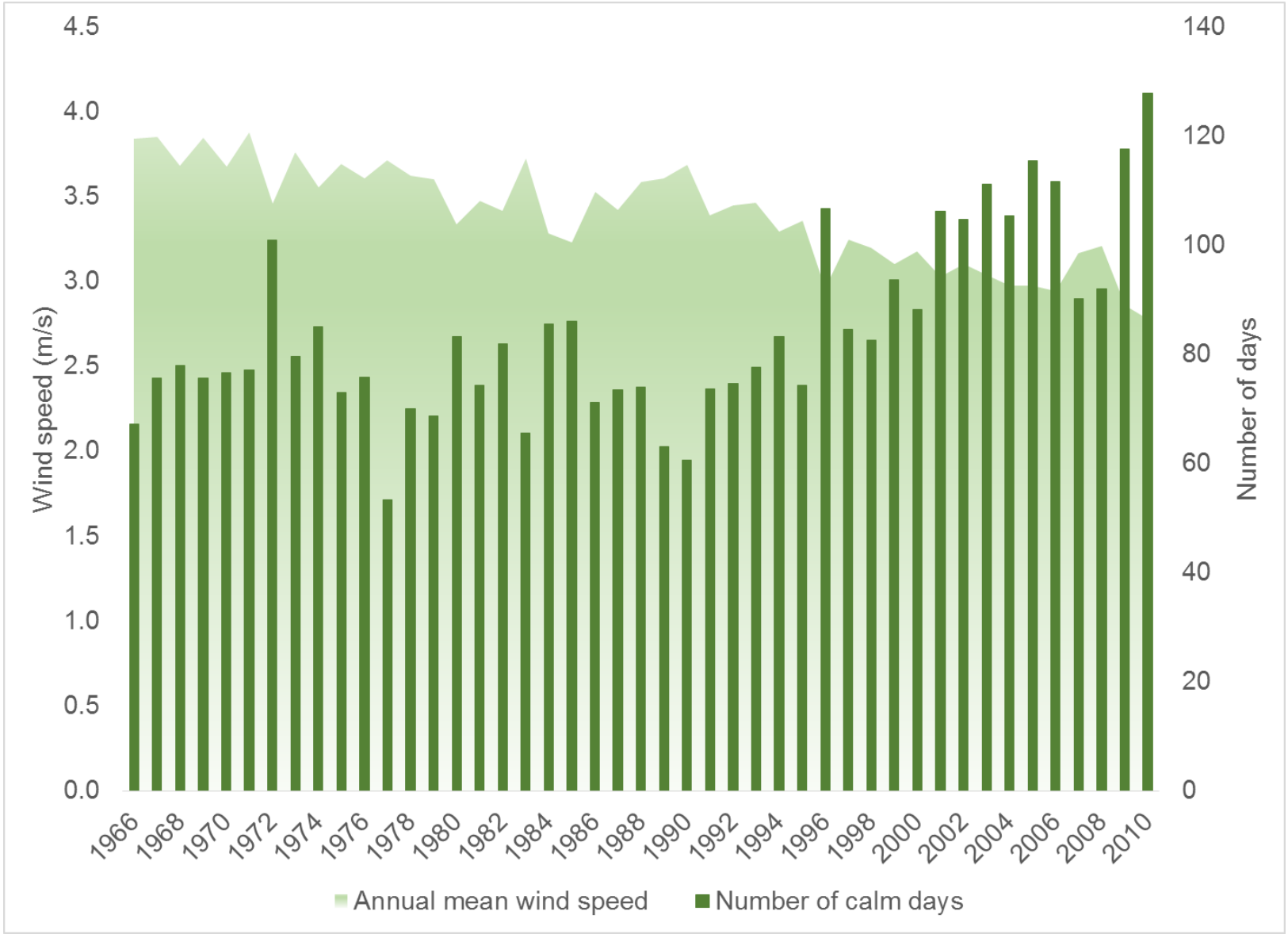

**Annual mean wind speed (m/s) and prevailing wind directions in the period 1961-2010**



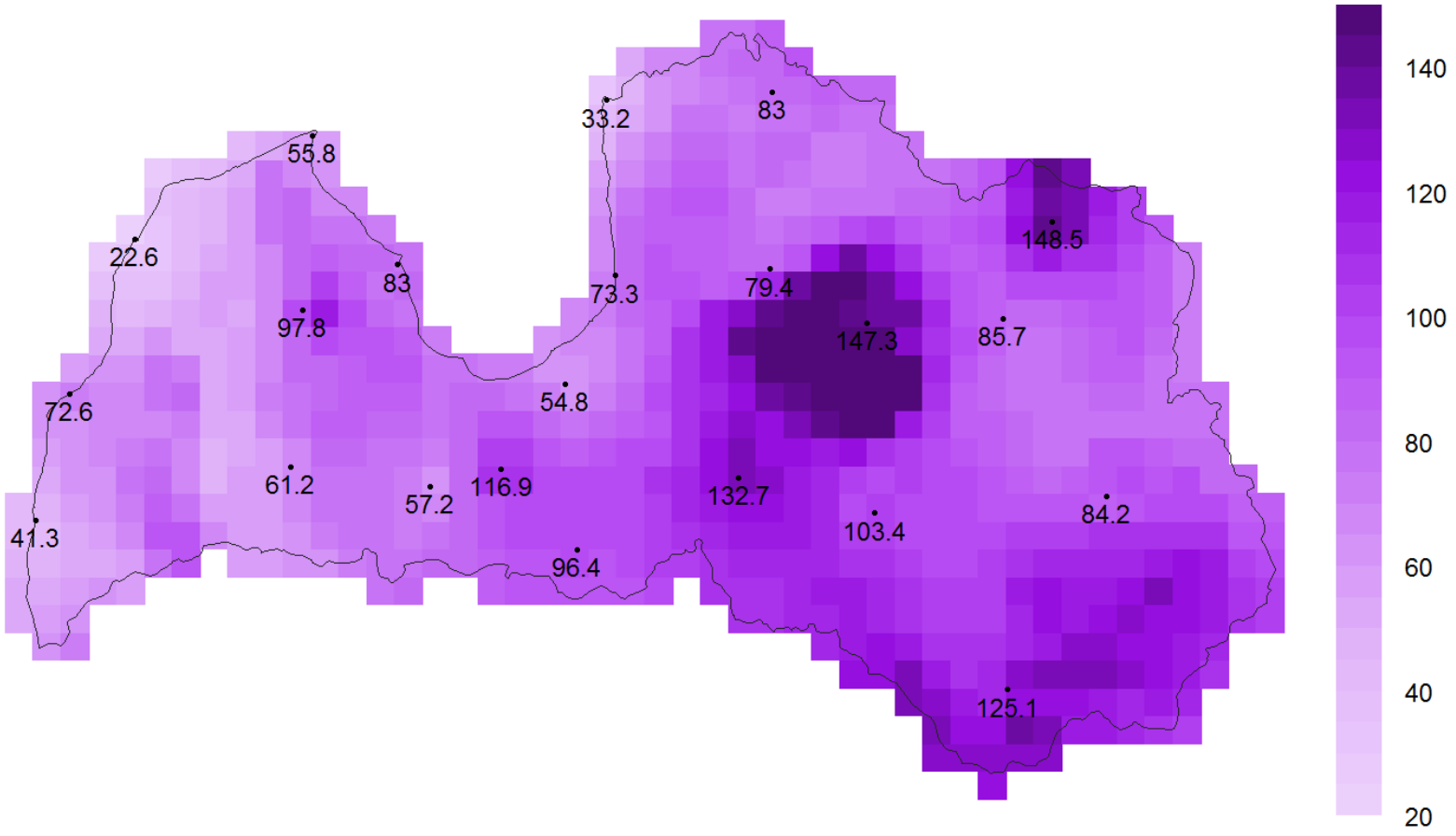



# WIND SPEED

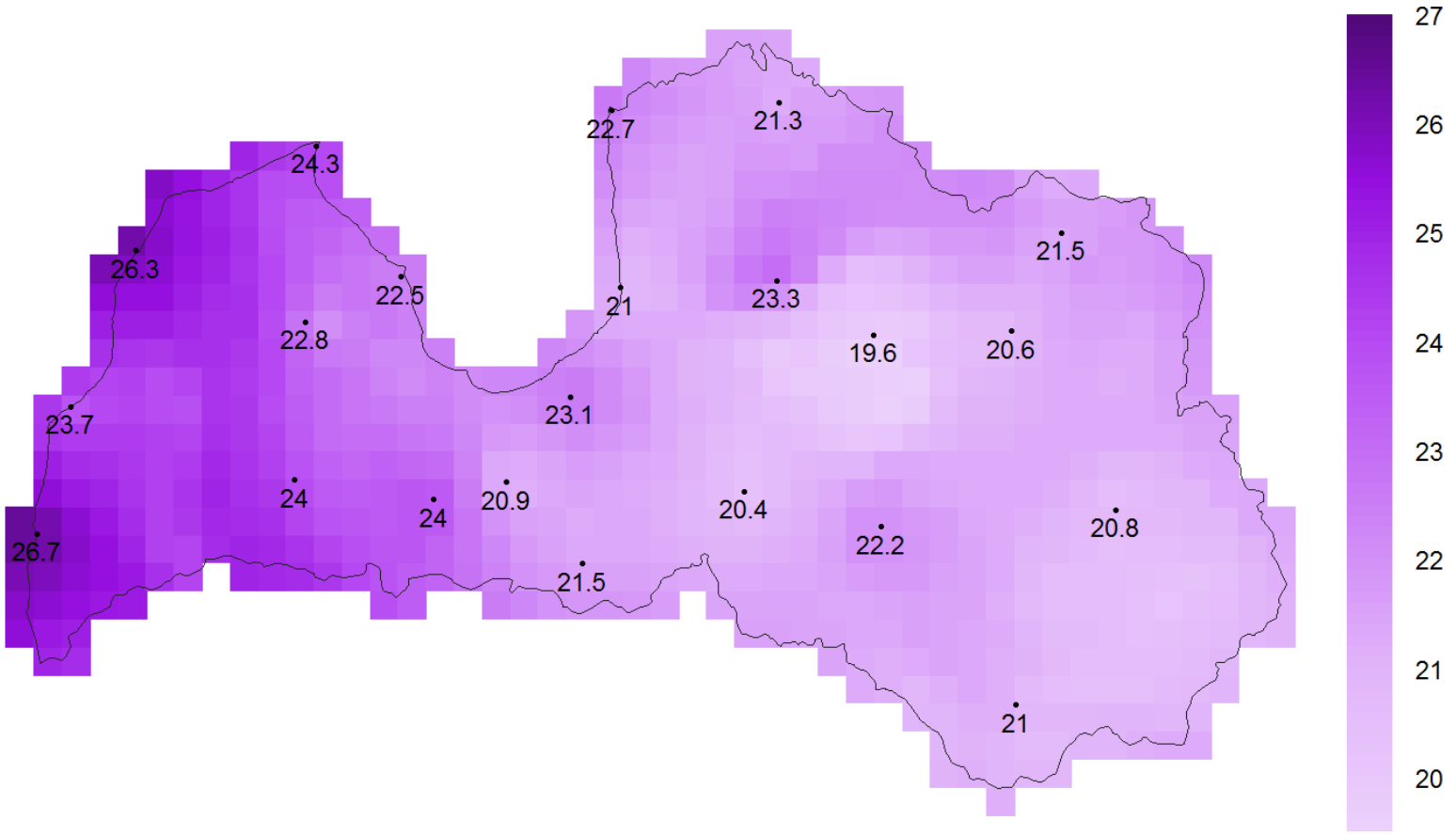

4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Wind speed (m/s)
140
120
100
80
60
40
20
0
Number of days
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
Annual mean wind speed
Number of calm days

# DAYS WITH CALM WIND




**Mean number of calm days (FGcalm) in the period 1961-2010**

# MAXIMUM WIND GUSTS




**Averaged annual maximum wind gusts in the period 1961-2010**

# OBSERVED TRENDS IN WIND VARIABLES

| Index name | MK test statistics | Index name | MK test statistics | Index name | MK test statistics |
|---|---|---|---|---|---|
| **FG** | **-6.8** | **DDeast** | -0.55 | **DMeast** | 0.23 |
| **FGcalm** | **4.37** | **DDsouth** | -0.87 | **DMsouth** | 0.48 |
| **FG6Bft** | **-3.84** | **DDwest** | 1.18 | **DMwest** | **1.72** |
| **FXx** | -0.05 | **DDnorth** | -0.42 | **DMnorth** | -0.84 |

Very significant tendency of increase (Mann-Kendall test statistics ≥ 3.3)
Significant tendency of increase (Mann-Kendall test statistics ≥ 2.6)
Substantial tendency of increase (Mann-Kendall test statistics ≥ 1.6)

Very significant tendency of decrease (Mann-Kendall test statistics ≤ -3.3)
Significant tendency of decrease (Mann-Kendall test statistics ≤ -2.6)
Substantial tendency of decrease (Mann-Kendall test statistics ≤ -1.6)

# FURTHER WORK WITHIN THE PROJECT

- All observation data and indices representing recent climate change submitted to the experts
- Finalization of return value calculation
- Calculation of future projections in absolute terms and future climate indices
- Participation in adaptation monitoring system development
- Written report and analysis on recent climate change and projected changes in the future