Assignment 1 temperature

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Contents

1 Assignment 1

1.1 The data set

The considered data set has been generated by the Korean Meteorological Administration over the city of Seoul (SK), in the time period between 2013 and 2017, uploaded on the UC Irvine Machine Learning Repository. The data consists in the LDAPS (Local Data Assimilation and Prediction System) model's forecasts, the present-day minimum and maximum temperatures and other auxiliary variables, while the two output variables are the next-day maximum and minimum air temperatures.

1.2 Applied goals in studying the data

The aim of studying such data is to perform a bias correction of the future minimum and maximum air temperature forecasts of the Korean Meteorological Administration LDAPS model. Precise forecasts of maximum and minimum air temperatures are crucial to anticipate and prevent the possible damage caused by extreme meteorological events, such as heat waves and cold spells. Bias correction is a process used to address bias errors in the predictions of a Numerical Weather Prediction (NWP) climate model, that present some discrepancies when compared to observed data. These errors usually arise with extreme, but unusually occurring, rainfall intensities or temperatures, that are underestimated by NWP models, due to a variety of factors (e.g. a large grid size - which leads to a less detailed representation of the weather, due to a reduced spacial resolution - and the simplification of thermodynamic processes). Therefore, long-term data sets with a model's output and historic data from the same period are used to correct extreme temperatures with linear regressions: the adjusted future time series is then constructed with the updated regression parameters.

1.3 Exploratory analysis

The study area is the metropolitan city of Seoul (SK), which is located in a geographical region surrounded by four mountains and split in two by the Han River. Precipitation is particularly abundant in summer, due to the East Asian monsoon, therefore the period is characterized by temperatures above 30°C.

The data set is composed of data collected from the 30th of June 2013 to the 30th of August 2017 and it consists of the following variables: the ones produced by the LDAPS model for the forecasts are the next-day maximum and minimum air temperatures (°C), next-day maximum and minimum relative humidity (%), next-day average wind speed (m/s), next-day average latent heat flux (W/m2), next-day average cloud cover (%), next-day average precipitation (%). Additionally, the data collected in-situ comprises of the observed

next-day maximum and minimum air temperatures (°C) - used as target variables -, as well as the present max and min air temperatures, obtained from a grid with 25 automatic weather stations scattered around the city. Other auxiliary variables are the latitude and longitude (in coordinates), elevation and slope (grouped as topographic variables) and daily incoming solar radiation (wh/m2).

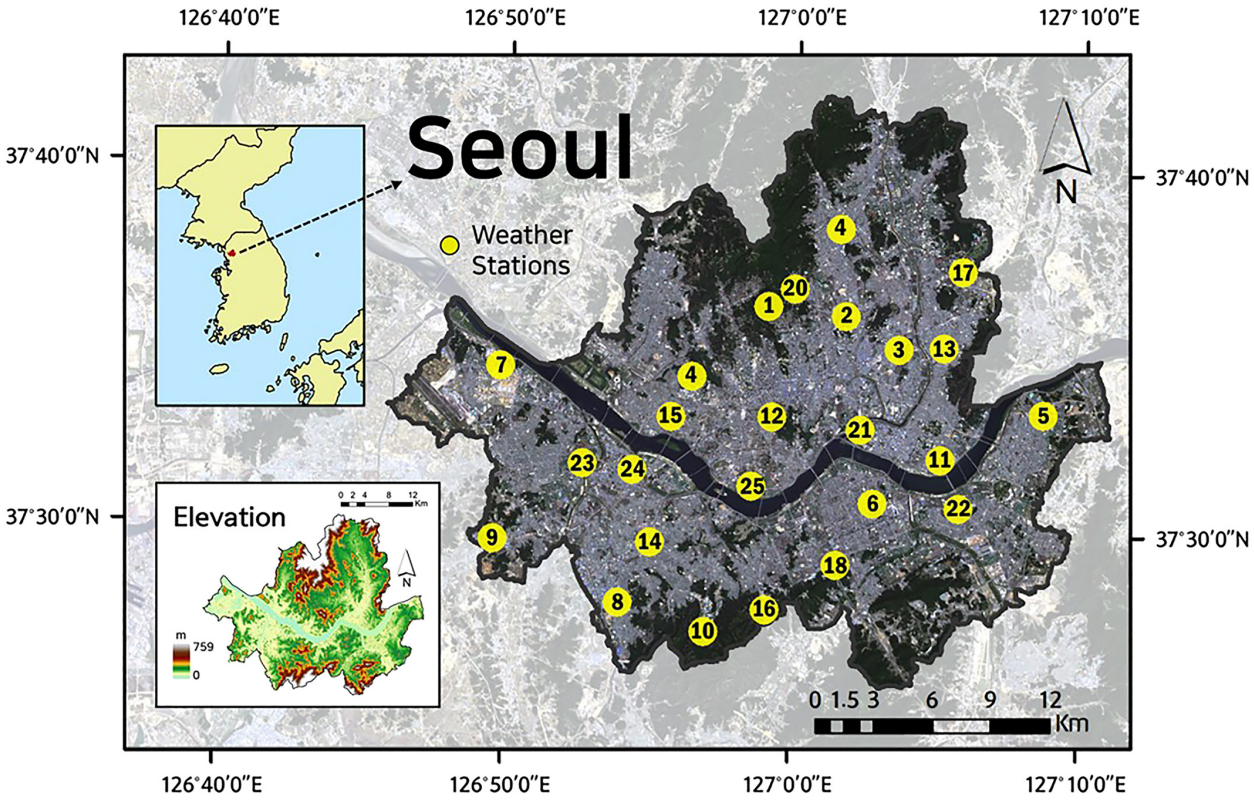

Figure 1: Location of automatic weather stations

We now read the data, remove the 1248 missing values and provide a summary of the data set. The number of data is 7752 and the regression variables are 25.

```
data = read.csv("Bias_correction.csv", header = T)
head(data)
```

```
##   station       Date Present_Tmax Present_Tmin    RHmin    RHmax Tmax_lapse
## 1       1 30/06/2013         28.7         21.4 58.25569 91.11636   28.07410
## 2       2 30/06/2013         31.9         21.6 52.26340 90.60472   29.85069
## 3       3 30/06/2013         31.6         23.3 48.69048 83.97359   30.09129
## 4       4 30/06/2013         32.0         23.4 58.23979 96.48369   29.70463
## 5       5 30/06/2013         31.4         21.9 56.17410 90.15513   29.11393
## 6       6 30/06/2013         31.9         23.5 52.43713 85.30725   29.21934
##   Tmin_lapse       WS        LH       CC1       CC2       CC3       CC4 PPT1
## 1   23.00694 6.818887  69.45181 0.2339475 0.2038957 0.1616969 0.1309282    0
## 2   24.03501 5.691890  51.93745 0.2255082 0.2517714 0.1594441 0.1277273    0
## 3   24.56563 6.138224  20.57305 0.2093437 0.2574694 0.2040915 0.1421253    0
## 4   23.32618 5.650050  65.72714 0.2163720 0.2260024 0.1611574 0.1342487    0
## 5   23.48648 5.735004 107.96554 0.1514069 0.2499953 0.1788925 0.1700210    0
## 6   23.82261 6.182295  50.23139 0.1852788 0.2808180 0.2328410 0.1463629    0
##   PPT2 PPT3 PPT4     lat     lon      DEM  Slope Solar.radiation Next_Tmax
## 1    0    0    0 37.6046 126.991 212.3350 2.7850        5992.896      29.1
```

```
## 2    0    0    0 37.6046 127.032  44.7624 0.5141        5869.312      30.5
## 3    0    0    0 37.5776 127.058  33.3068 0.2661        5863.556      31.1
## 4    0    0    0 37.6450 127.022  45.7160 2.5348        5856.965      31.7
## 5    0    0    0 37.5507 127.135  35.0380 0.5055        5859.552      31.2
## 6    0    0    0 37.5102 127.042  54.6384 0.1457        5873.781      31.5
##   Next_Tmin
## 1      21.2
## 2      22.5
## 3      23.9
## 4      24.3
## 5      22.5
## 6      24.0
```

```
sum(is.na(data))
```

```
## [1] 1248
```

```
data = na.omit(data)
data$Date = as.Date(data$Date, format = "%d/%m/%Y")
as.factor(data$station)
```

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## [6097] 23 25 1  2  3  4  5  6  7  8  9  10 11 12 13 14 15 16 17 18 19 20 21 22
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## [6577] 16 17 18 19 20 21 22 23 24 25 1  2  3  4  5  6  7  8  9  10 11 12 13 14
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## [7225] 24 25 1  2  3  4  5  6  7  8  9  10 11 12 13 14 15 16 17 18 19 20 21 22
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```

```
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## [7369] 20 21 22 23 24 25 1  2  3  4  6  7  8  9  10 11 12 13 14 15 16 17 18 19
## [7393] 20 21 22 23 24 25 1  2  3  4  6  7  8  9  10 11 12 13 15 16 17 18 19 20
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## [7441] 23 24 25 1  2  3  4  7  8  9  10 11 12 13 14 15 16 17 18 19 20 21 22 23
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## [7561] 23 24 25 1  2  3  4  5  6  7  8  9  10 11 12 13 14 15 16 17 18 19 20 21
## [7585] 22 23 24 25
## 25 Levels: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 ... 25
```

```r
summary(data)
```

```
##     station           Date              Present_Tmax    Present_Tmin
##  Min.   : 1.00   Min.   :2013-06-30   Min.   :20.00   Min.   :11.3
##  1st Qu.: 7.00   1st Qu.:2014-07-15   1st Qu.:27.80   1st Qu.:21.6
##  Median :13.00   Median :2015-07-29   Median :29.90   Median :23.4
##  Mean   :13.01   Mean   :2015-07-27   Mean   :29.75   Mean   :23.2
##  3rd Qu.:19.00   3rd Qu.:2016-08-14   3rd Qu.:32.00   3rd Qu.:24.8
##  Max.   :25.00   Max.   :2017-08-30   Max.   :37.60   Max.   :29.9
##      RHmin            RHmax          Tmax_lapse      Tmin_lapse
##  Min.   :19.79   Min.   : 58.94   Min.   :17.62   Min.   :14.27
##  1st Qu.:45.96   1st Qu.: 84.20   1st Qu.:27.67   1st Qu.:22.09
##  Median :55.02   Median : 89.78   Median :29.71   Median :23.76
##  Mean   :56.72   Mean   : 88.36   Mean   :29.62   Mean   :23.51
##  3rd Qu.:67.12   3rd Qu.: 93.74   3rd Qu.:31.71   3rd Qu.:25.16
##  Max.   :98.52   Max.   :100.00   Max.   :38.54   Max.   :29.62
##        WS               LH              CC1              CC2
##  Min.   : 2.883   Min.   :-13.60   Min.   :0.0000   Min.   :0.0000
##  1st Qu.: 5.675   1st Qu.: 37.21   1st Qu.:0.1465   1st Qu.:0.1403
##  Median : 6.548   Median : 56.90   Median :0.3157   Median :0.3117
##  Mean   : 7.094   Mean   : 62.49   Mean   :0.3685   Mean   :0.3555
##  3rd Qu.: 8.029   3rd Qu.: 84.24   3rd Qu.:0.5742   3rd Qu.:0.5572
##  Max.   :21.858   Max.   :213.41   Max.   :0.9673   Max.   :0.9684
##       CC3              CC4               PPT1               PPT2
##  Min.   :0.0000   Min.   :0.00000   Min.   : 0.00000   Min.   : 0.00000
##  1st Qu.:0.1009   1st Qu.:0.08149   1st Qu.: 0.00000   1st Qu.: 0.00000
##  Median :0.2618   Median :0.22746   Median : 0.00000   Median : 0.00000
##  Mean   :0.3175   Mean   :0.29827   Mean   : 0.58901   Mean   : 0.48074
##  3rd Qu.:0.4964   3rd Qu.:0.49813   3rd Qu.: 0.05259   3rd Qu.: 0.01774
##  Max.   :0.9838   Max.   :0.97471   Max.   :23.70154   Max.   :21.62166
##       PPT3                PPT4                lat             lon
##  Min.   : 0.000000   Min.   : 0.000000   Min.   :37.46   Min.   :126.8
##  1st Qu.: 0.000000   1st Qu.: 0.000000   1st Qu.:37.51   1st Qu.:126.9
##  Median : 0.000000   Median : 0.000000   Median :37.55   Median :127.0
##  Mean   : 0.275007   Mean   : 0.265373   Mean   :37.54   Mean   :127.0
##  3rd Qu.: 0.007855   3rd Qu.: 0.000017   3rd Qu.:37.58   3rd Qu.:127.0
##  Max.   :15.841235   Max.   :16.655469   Max.   :37.65   Max.   :127.1
##       DEM              Slope         Solar.radiation   Next_Tmax
##  Min.   : 12.37   Min.   :0.0985   Min.   :4330    Min.   :17.40
##  1st Qu.: 28.70   1st Qu.:0.2713   1st Qu.:5001    1st Qu.:28.20
##  Median : 45.72   Median :0.6180   Median :5442    Median :30.40
```

```
##  Mean   : 61.92   Mean   :1.2598   Mean   :5344    Mean   :30.24
##  3rd Qu.: 59.83   3rd Qu.:1.7678   3rd Qu.:5729    3rd Qu.:32.60
##  Max.   :212.34   Max.   :5.1782   Max.   :5993    Max.   :38.90
##    Next_Tmin
##  Min.   :11.30
##  1st Qu.:21.30
##  Median :23.10
##  Mean   :22.91
##  3rd Qu.:24.60
##  Max.   :29.80
```

```
str(data)
```

```
## 'data.frame':    7588 obs. of  25 variables:
##  $ station        : int  1 2 3 4 5 6 7 8 9 10 ...
##  $ Date           : Date, format: "2013-06-30" "2013-06-30" ...
##  $ Present_Tmax   : num  28.7 31.9 31.6 32 31.4 31.9 31.4 32.1 31.4 31.6 ...
##  $ Present_Tmin   : num  21.4 21.6 23.3 23.4 21.9 23.5 24.4 23.6 22 20.5 ...
##  $ RHmin          : num  58.3 52.3 48.7 58.2 56.2 ...
##  $ RHmax          : num  91.1 90.6 84 96.5 90.2 ...
##  $ Tmax_lapse     : num  28.1 29.9 30.1 29.7 29.1 ...
##  $ Tmin_lapse     : num  23 24 24.6 23.3 23.5 ...
##  $ WS             : num  6.82 5.69 6.14 5.65 5.74 ...
##  $ LH             : num  69.5 51.9 20.6 65.7 108 ...
##  $ CC1            : num  0.234 0.226 0.209 0.216 0.151 ...
##  $ CC2            : num  0.204 0.252 0.257 0.226 0.25 ...
##  $ CC3            : num  0.162 0.159 0.204 0.161 0.179 ...
##  $ CC4            : num  0.131 0.128 0.142 0.134 0.17 ...
##  $ PPT1           : num  0 0 0 0 0 0 0 0 0 0 ...
##  $ PPT2           : num  0 0 0 0 0 0 0 0 0 0 ...
##  $ PPT3           : num  0 0 0 0 0 0 0 0 0 0 ...
##  $ PPT4           : num  0 0 0 0 0 0 0 0 0 0 ...
##  $ lat            : num  37.6 37.6 37.6 37.6 37.6 ...
##  $ lon            : num  127 127 127 127 127 ...
##  $ DEM            : num  212.3 44.8 33.3 45.7 35 ...
##  $ Slope          : num  2.785 0.514 0.266 2.535 0.505 ...
##  $ Solar.radiation: num  5993 5869 5864 5857 5860 ...
##  $ Next_Tmax      : num  29.1 30.5 31.1 31.7 31.2 31.5 30.9 31.1 31.3 30.5 ...
##  $ Next_Tmin      : num  21.2 22.5 23.9 24.3 22.5 24 23.4 22.9 21.6 21 ...
##  - attr(*, "na.action")= 'omit' Named int [1:164] 226 272 301 451 465 628 832 857 882 914 ...
##   ..- attr(*, "names")= chr [1:164] "226" "272" "301" "451" ...
```

```
selected_variables <- c("Present_Tmax", "Present_Tmin", "RHmin", "RHmax", "Tmax_lapse", "Tmin_lapse", "
selected_data <- data[, selected_variables]
correlation_matrix <- cor(selected_data)
print(correlation_matrix)
```

```
##                Present_Tmax Present_Tmin       RHmin       RHmax  Tmax_lapse
## Present_Tmax     1.000000000   0.61520818 -0.20905865 -0.30694324  0.57377689
## Present_Tmin     0.615208176   1.00000000  0.12219987 -0.01857640  0.46790418
## RHmin           -0.209058645   0.12219987  1.00000000  0.57835786 -0.56957978
## RHmax           -0.306943243  -0.01857640  0.57835786  1.00000000 -0.37729261
## Tmax_lapse       0.573776885   0.46790418 -0.56957978 -0.37729261  1.00000000
## Tmin_lapse       0.628704554   0.77206103  0.08523684 -0.11896461  0.65342497
## WS              -0.125952332  -0.03877922  0.28942243  0.13126857 -0.31601080
```

```
## LH               0.134246486  -0.01281686 -0.07219513  0.23898592  0.04366273
## CC1             -0.316333001   0.08434794  0.61283130  0.43593663 -0.44087760
## CC2             -0.216976122   0.09003759  0.74477409  0.39062032 -0.52537969
## CC3             -0.146391153  -0.00471934  0.68806867  0.22473396 -0.54272826
## CC4             -0.143069385  -0.04669442  0.51393680  0.12724159 -0.42973910
## PPT1            -0.114916546   0.11157678  0.25903888  0.26801864 -0.11565947
## PPT2            -0.104779098   0.06620729  0.38957186  0.22758086 -0.24836865
## PPT3            -0.127247895  -0.05242821  0.23751206  0.13243636 -0.19374912
## PPT4            -0.107294512  -0.07039097  0.16731078  0.11810122 -0.17041549
## lat             -0.054133706  -0.08141654  0.08502748  0.19481965 -0.04405242
## lon              0.007694507  -0.04517409 -0.07758996  0.02556256  0.09156832
## DEM             -0.189438545  -0.25408359  0.10068442  0.17655730 -0.18143288
## Slope           -0.107079402  -0.14842304  0.12245405  0.21943629 -0.16389116
## Solar.radiation -0.022114328   0.05976502  0.24216837  0.14662206  0.04741393
## Next_Tmax        0.610356613   0.46352292 -0.44682411 -0.28978793  0.83572903
## Next_Tmin        0.621048410   0.79697478  0.09324949 -0.07641549  0.58996315
##                   Tmin_lapse           WS           LH          CC1
## Present_Tmax     0.628704554 -0.125952332  0.134246486 -0.316333001
## Present_Tmin     0.772061034 -0.038779221 -0.012816863  0.084347945
## RHmin            0.085236844  0.289422426 -0.072195133  0.612831303
## RHmax           -0.118964608  0.131268569  0.238985920  0.435936625
## Tmax_lapse       0.653424970 -0.316010798  0.043662729 -0.440877597
## Tmin_lapse       1.000000000 -0.134651681 -0.139674730  0.008713542
## WS              -0.134651681  1.000000000  0.004426528  0.285348577
## LH              -0.139674730  0.004426528  1.000000000 -0.148314260
## CC1              0.008713542  0.285348577 -0.148314260  1.000000000
## CC2              0.046536557  0.257226197 -0.265381931  0.779510001
## CC3             -0.044998320  0.238154536 -0.246709265  0.516698171
## CC4             -0.079535786  0.218869842 -0.173156106  0.362670096
## PPT1             0.034956109  0.141502506 -0.018707932  0.446929869
## PPT2            -0.002743111  0.181633685 -0.084375307  0.389367961
## PPT3            -0.093116424  0.147199395  0.009495158  0.166763283
## PPT4            -0.103540878  0.134428080  0.012371860  0.088896522
## lat             -0.099451729  0.033025192  0.133309349 -0.010267692
## lon             -0.024702519 -0.063008633  0.024475724 -0.007962488
## DEM             -0.198395839  0.188539918  0.056361555 -0.017377763
## Slope           -0.187864337  0.169222835  0.087516874 -0.023892750
## Solar.radiation  0.157763236  0.120629731 -0.044955505  0.218285237
## Next_Tmax        0.592118965 -0.351106889  0.156779046 -0.459704617
## Next_Tmin        0.886512767 -0.102021255 -0.060392495 -0.012876541
##                         CC2          CC3          CC4         PPT1
## Present_Tmax    -0.216976122 -0.146391153 -0.143069385 -0.114916546
## Present_Tmin     0.090037594 -0.004719340 -0.046694424  0.111576782
## RHmin            0.744774092  0.688068671  0.513936801  0.259038884
## RHmax            0.390620323  0.224733962  0.127241586  0.268018642
## Tmax_lapse      -0.525379690 -0.542728256 -0.429739103 -0.115659470
## Tmin_lapse       0.046536557 -0.044998320 -0.079535786  0.034956109
## WS               0.257226197  0.238154536  0.218869842  0.141502506
## LH              -0.265381931 -0.246709265 -0.173156106 -0.018707932
## CC1              0.779510001  0.516698171  0.362670096  0.446929869
## CC2              1.000000000  0.724546065  0.527333079  0.304441603
## CC3              0.724546065  1.000000000  0.794463222  0.154952486
## CC4              0.527333079  0.794463222  1.000000000  0.115967791
## PPT1             0.304441603  0.154952486  0.115967791  1.000000000
```

```
## PPT2             0.479510983  0.336253550  0.286265945  0.367922364
## PPT3             0.238179029  0.337345684  0.265709306  0.012846918
## PPT4             0.157194397  0.303787107  0.380596989  0.004376576
## lat             -0.002642199  0.003826780 -0.010611835 -0.005840691
## lon             -0.004757250  0.013947591 -0.004455768 -0.004375157
## DEM             -0.016249366 -0.001249168 -0.010239794  0.005412335
## Slope           -0.021173255 -0.005903459 -0.017890555  0.010340376
## Solar.radiation  0.169346323  0.116691186  0.114267925  0.084803769
## Next_Tmax       -0.498294901 -0.523060771 -0.454038585 -0.125954218
## Next_Tmin        0.030357996 -0.056489533 -0.086197216  0.018031316
##                         PPT2         PPT3         PPT4          lat
## Present_Tmax    -0.104779098 -0.127247895 -0.107294512 -0.054133706
## Present_Tmin     0.066207289 -0.052428208 -0.070390969 -0.081416543
## RHmin            0.389571855  0.237512064  0.167310782  0.085027482
## RHmax            0.227580863  0.132436360  0.118101224  0.194819648
## Tmax_lapse      -0.248368650 -0.193749119 -0.170415485 -0.044052417
## Tmin_lapse      -0.002743111 -0.093116424 -0.103540878 -0.099451729
## WS               0.181633685  0.147199395  0.134428080  0.033025192
## LH              -0.084375307  0.009495158  0.012371860  0.133309349
## CC1              0.389367961  0.166763283  0.088896522 -0.010267692
## CC2              0.479510983  0.238179029  0.157194397 -0.002642199
## CC3              0.336253550  0.337345684  0.303787107  0.003826780
## CC4              0.286265945  0.265709306  0.380596989 -0.010611835
## PPT1             0.367922364  0.012846918  0.004376576 -0.005840691
## PPT2             1.000000000  0.205285257  0.121936971  0.015198224
## PPT3             0.205285257  1.000000000  0.288093165  0.031821763
## PPT4             0.121936971  0.288093165  1.000000000  0.008178147
## lat              0.015198224  0.031821763  0.008178147  1.000000000
## lon              0.016957509  0.018093874  0.041095055  0.289999101
## DEM              0.002411003  0.011345072 -0.009829926  0.029343775
## Slope            0.003702524  0.018372179 -0.008689008  0.071446200
## Solar.radiation  0.107620412 -0.057430108  0.033248768  0.036514051
## Next_Tmax       -0.186722283 -0.203553786 -0.190720113 -0.055367134
## Next_Tmin       -0.012461816 -0.068663981 -0.114899690 -0.085135814
##                         lon          DEM        Slope Solar.radiation
## Present_Tmax     0.007694507 -0.189438545 -0.107079402    -0.022114328
## Present_Tmin    -0.045174094 -0.254083591 -0.148423044     0.059765018
## RHmin           -0.077589959  0.100684418  0.122454049     0.242168370
## RHmax            0.025562558  0.176557304  0.219436293     0.146622063
## Tmax_lapse       0.091568315 -0.181432879 -0.163891155     0.047413934
## Tmin_lapse      -0.024702519 -0.198395839 -0.187864337     0.157763236
## WS              -0.063008633  0.188539918  0.169222835     0.120629731
## LH               0.024475724  0.056361555  0.087516874    -0.044955505
## CC1             -0.007962488 -0.017377763 -0.023892750     0.218285237
## CC2             -0.004757250 -0.016249366 -0.021173255     0.169346323
## CC3              0.013947591 -0.001249168 -0.005903459     0.116691186
## CC4             -0.004455768 -0.010239794 -0.017890555     0.114267925
## PPT1            -0.004375157  0.005412335  0.010340376     0.084803769
## PPT2             0.016957509  0.002411003  0.003702524     0.107620412
## PPT3             0.018093874  0.011345072  0.018372179    -0.057430108
## PPT4             0.041095055 -0.009829926 -0.008689008     0.033248768
## lat              0.289999101  0.029343775  0.071446200     0.036514051
## lon              1.000000000  0.006684501  0.037615582     0.005177649
## DEM              0.006684501  1.000000000  0.784179395     0.053240680
```

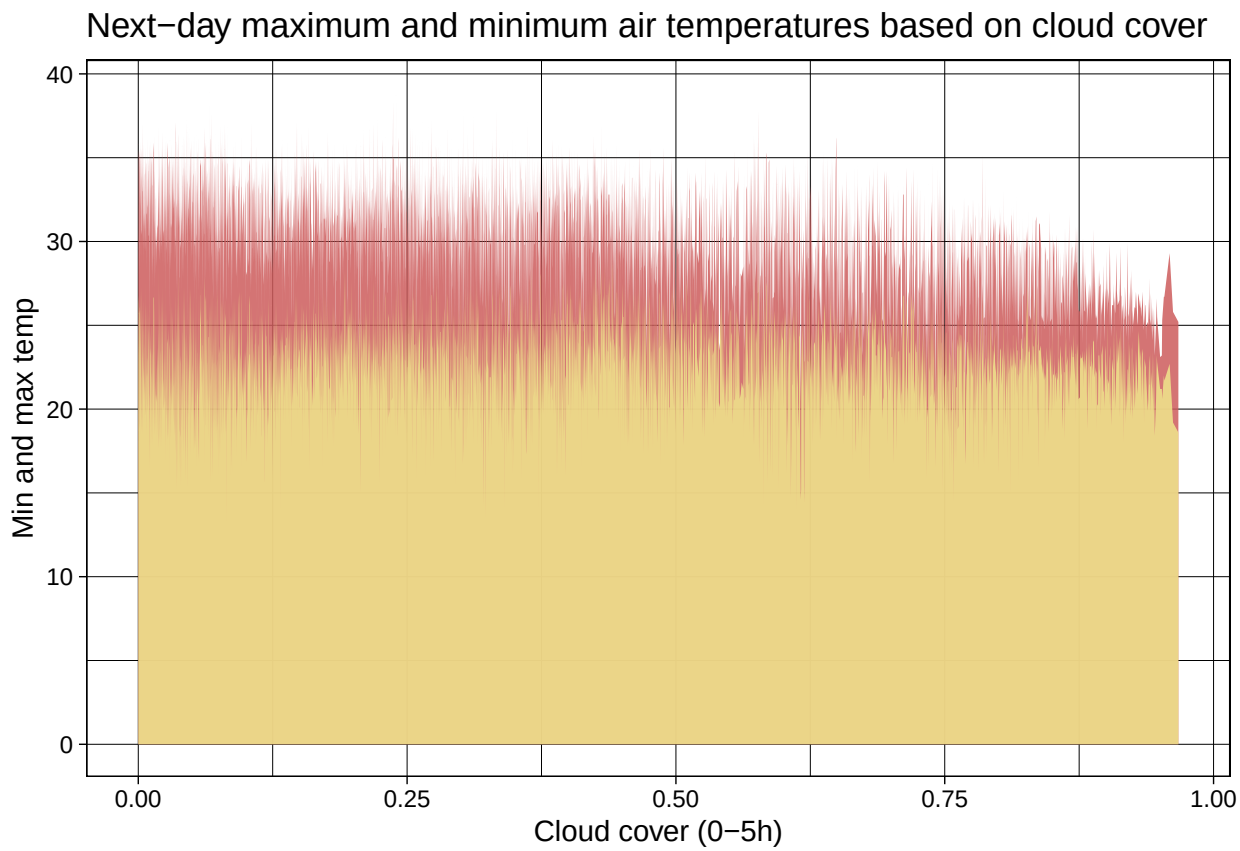
```
## Slope            0.037615582  0.784179395  1.000000000     0.025516575
## Solar.radiation  0.005177649  0.053240680  0.025516575     1.000000000
## Next_Tmax        0.003501996 -0.174577585 -0.104278815     0.016145245
## Next_Tmin       -0.045757947 -0.249303047 -0.148378803     0.125516826
##                    Next_Tmax   Next_Tmin
## Present_Tmax     0.610356613  0.62104841
## Present_Tmin     0.463522925  0.79697478
## RHmin           -0.446824108  0.09324949
## RHmax           -0.289787928 -0.07641549
## Tmax_lapse       0.835729028  0.58996315
## Tmin_lapse       0.592118965  0.88651277
## WS              -0.351106889 -0.10202126
## LH               0.156779046 -0.06039250
## CC1             -0.459704617 -0.01287654
## CC2             -0.498294901  0.03035800
## CC3             -0.523060771 -0.05648953
## CC4             -0.454038585 -0.08619722
## PPT1            -0.125954218  0.01803132
## PPT2            -0.186722283 -0.01246182
## PPT3            -0.203553786 -0.06866398
## PPT4            -0.190720113 -0.11489969
## lat             -0.055367134 -0.08513581
## lon              0.003501996 -0.04575795
## DEM             -0.174577585 -0.24930305
## Slope           -0.104278815 -0.14837880
## Solar.radiation  0.016145245  0.12551683
## Next_Tmax        1.000000000  0.61662918
## Next_Tmin        0.616629184  1.00000000
```

In order to inspect the features of the variables, we produce exploratory plots. The following code shows the relationship between the model forecast of next-day average cloud cover (in %) and the forecasts for the minimum and maximum temperature levels:

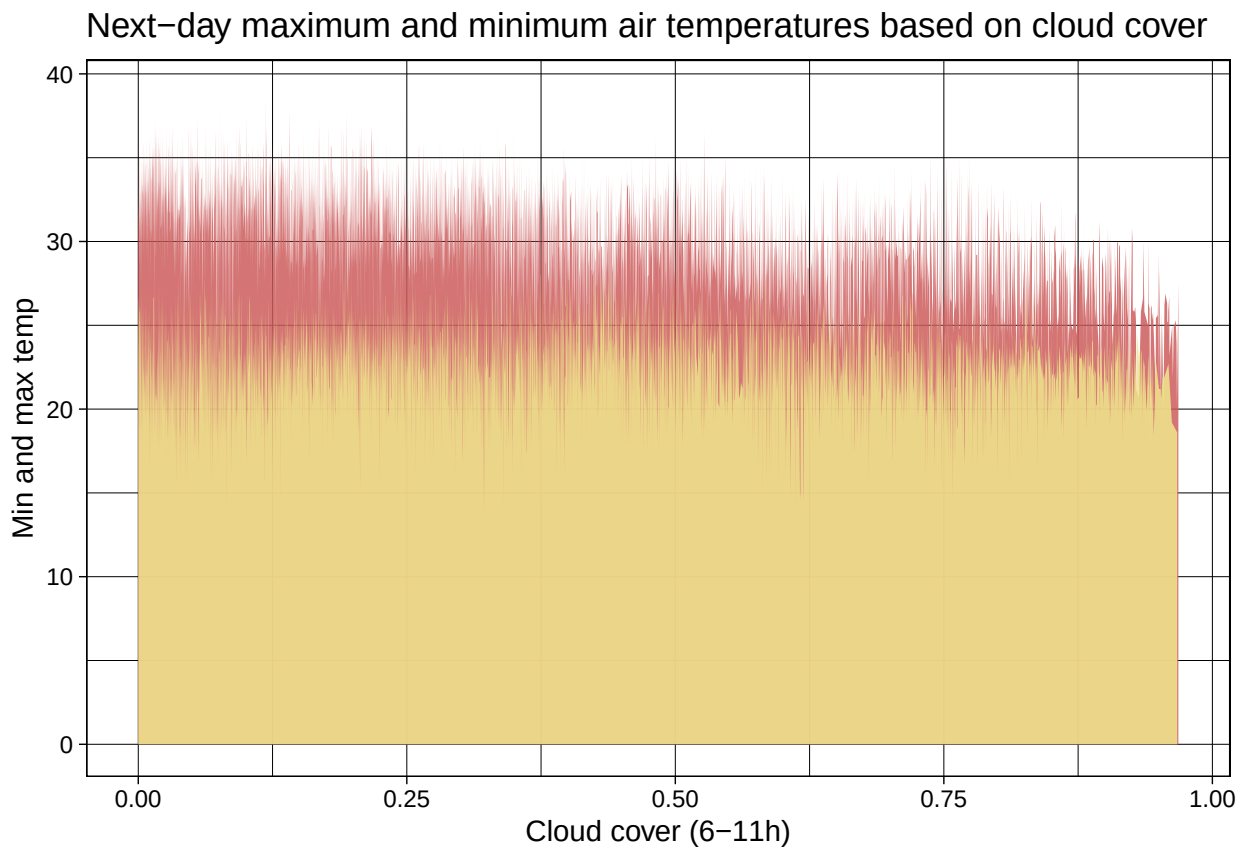
```
library(ggplot2)
```

```
## Warning: package 'ggplot2' was built under R version 4.2.3
```

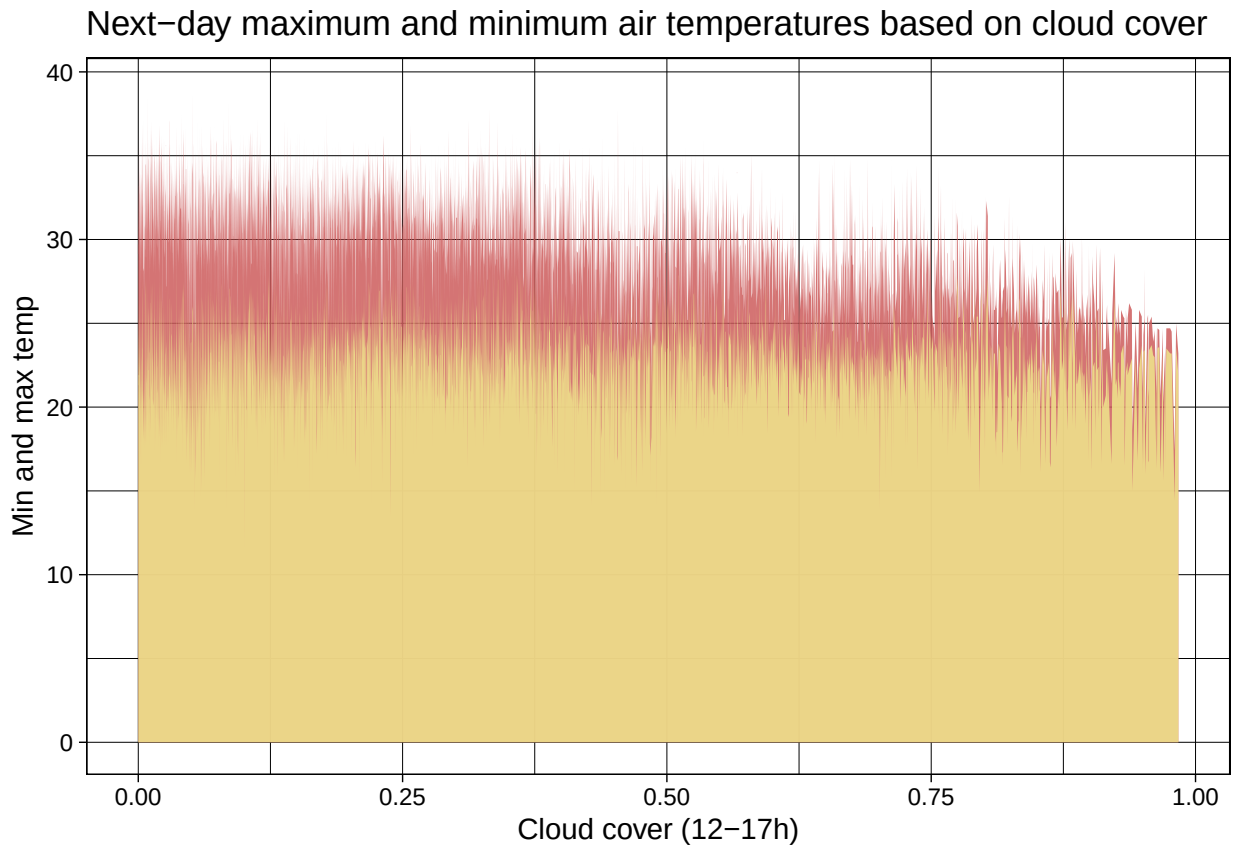
```
par(mfrow = c(1,4), mar = c(4,4,2,1), bty = "l")
ggplot(data) +
  geom_area(aes(x = data$CC1, y = data$Next_Tmax),
            fill = 'indianred', alpha = 0.85)+
  geom_area(aes(x = data$CC1, y = data$Next_Tmin),
            fill = 'khaki', alpha = 0.85)+
  labs(
    title = "Next-day maximum and minimum air temperatures based on cloud cover",
    x="Cloud cover (0-5h)",
    y="Min and max temp"
  )+
  theme_linedraw()
```



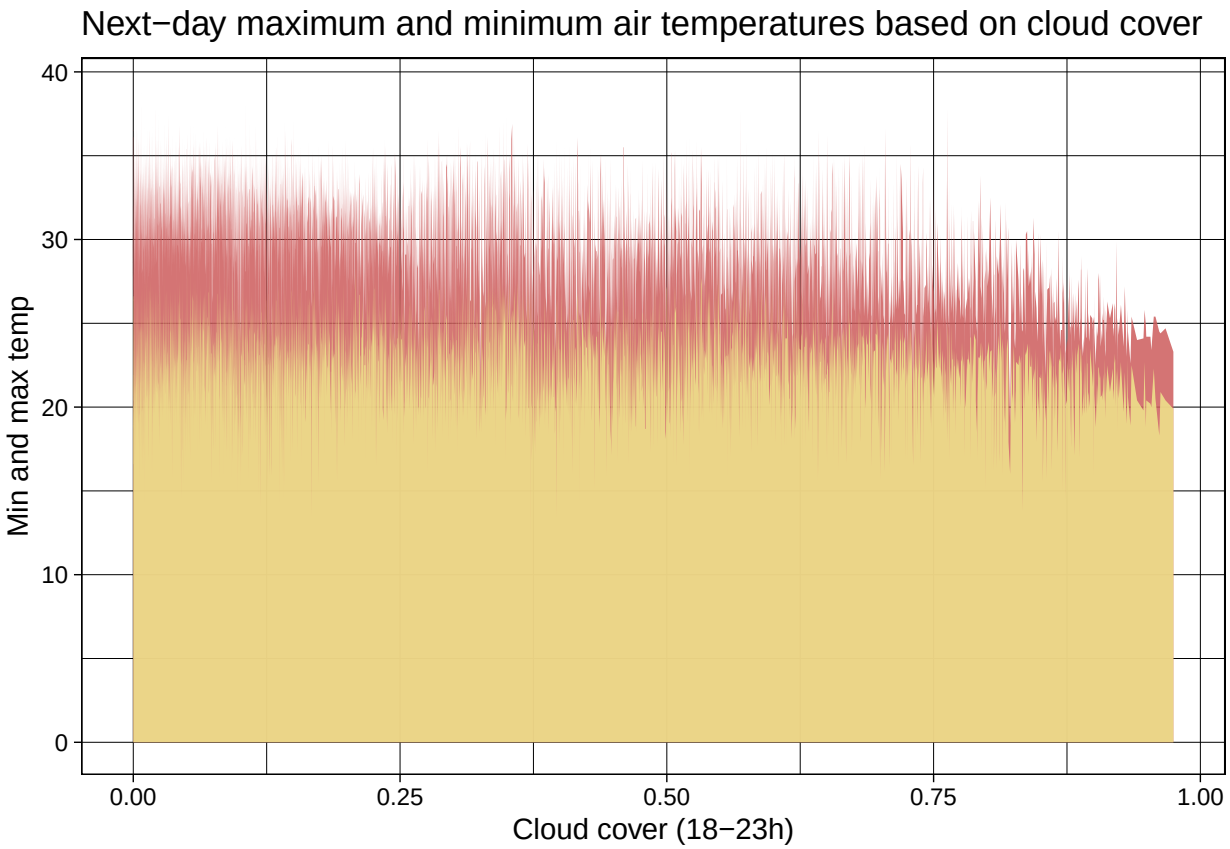

```
ggplot(data) +
  geom_area(aes(x = data$CC2, y = data$Next_Tmax),
            fill = 'indianred', alpha = 0.85)+
  geom_area(aes(x = data$CC1, y = data$Next_Tmin),
            fill = 'khaki', alpha = 0.85)+
  labs(
    title = "Next-day maximum and minimum air temperatures based on cloud cover",
    x="Cloud cover (6-11h)",
    y="Min and max temp"
  )+
  theme_linedraw()
```




```
ggplot(data) +
  geom_area(aes(x = data$CC3, y = data$Next_Tmax),
            fill = 'indianred', alpha = 0.85)+
  geom_area(aes(x = data$CC3, y = data$Next_Tmin),
            fill = 'khaki', alpha = 0.85)+
  labs(
    title = "Next-day maximum and minimum air temperatures based on cloud cover",
    x="Cloud cover (12-17h)",
    y="Min and max temp"
  )+
  theme_linedraw()
```



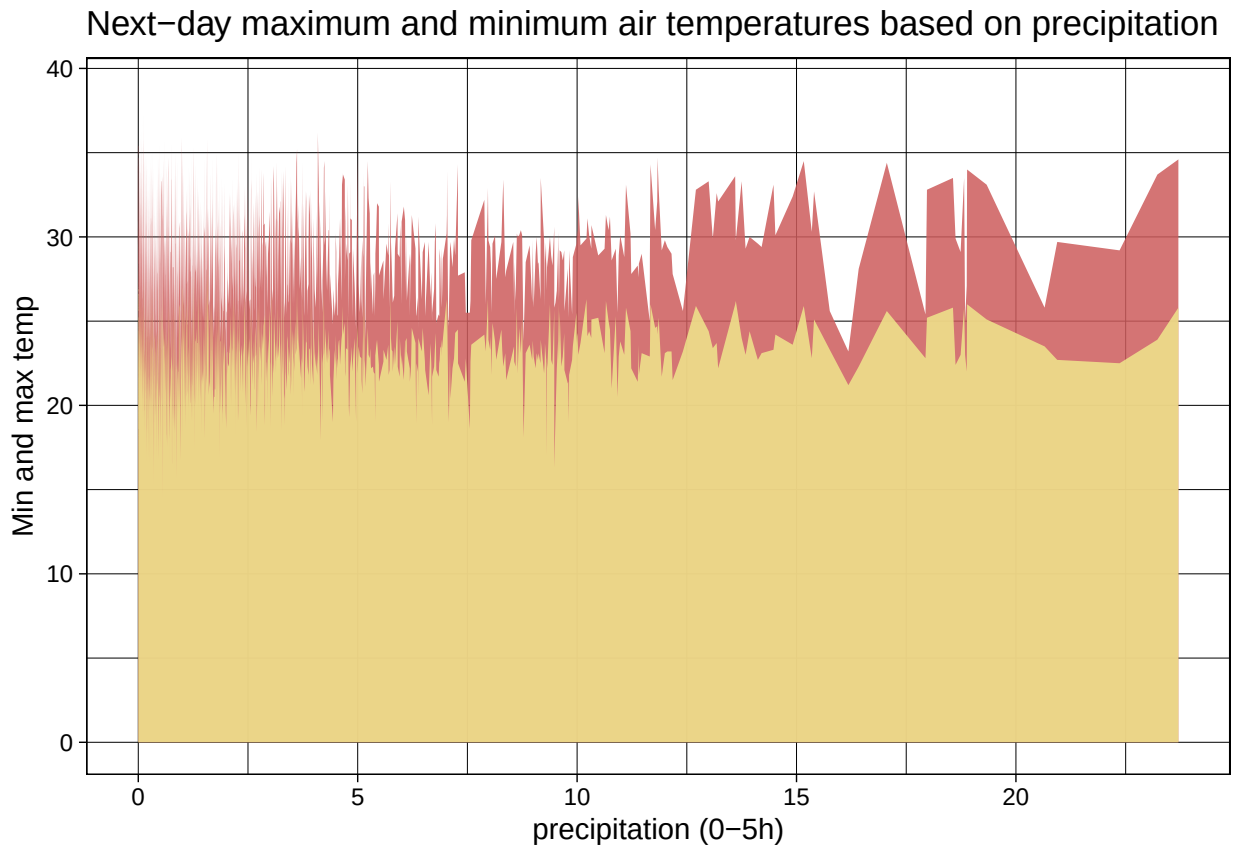

```
ggplot(data) +
  geom_area(aes(x = data$CC4, y = data$Next_Tmax),
            fill = 'indianred', alpha = 0.85)+
  geom_area(aes(x = data$CC4, y = data$Next_Tmin),
            fill = 'khaki', alpha = 0.85)+
  labs(
    title = "Next-day maximum and minimum air temperatures based on cloud cover",
    x="Cloud cover (18-23h)",
    y="Min and max temp"
  )+
  theme_linedraw()
```



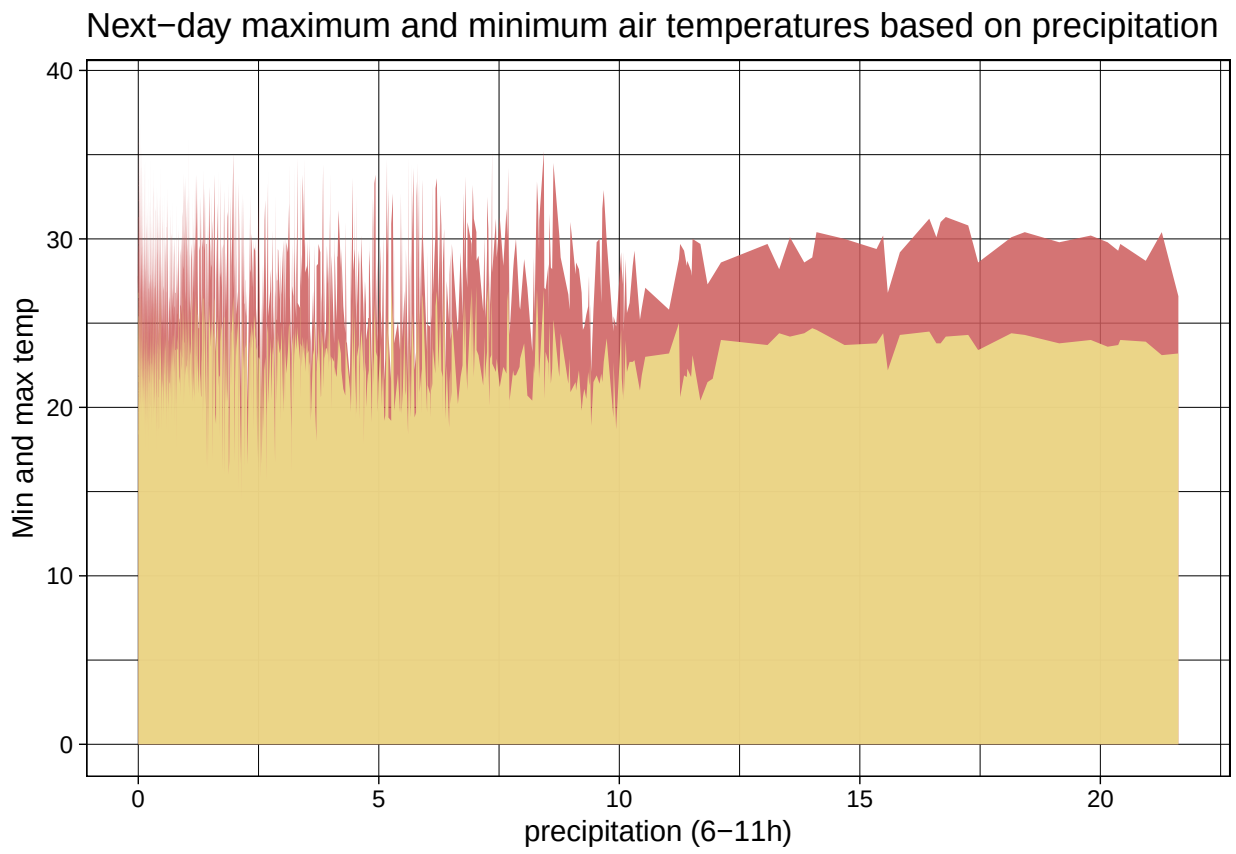
We can observe a slight negative correlation, in particular between the next-day maximum temperature forecast and the next-day forecast of the level of cloud cover.

The following plots show the relation between temperature forecasts and the model forecasts of next-day average precipitations (in %):

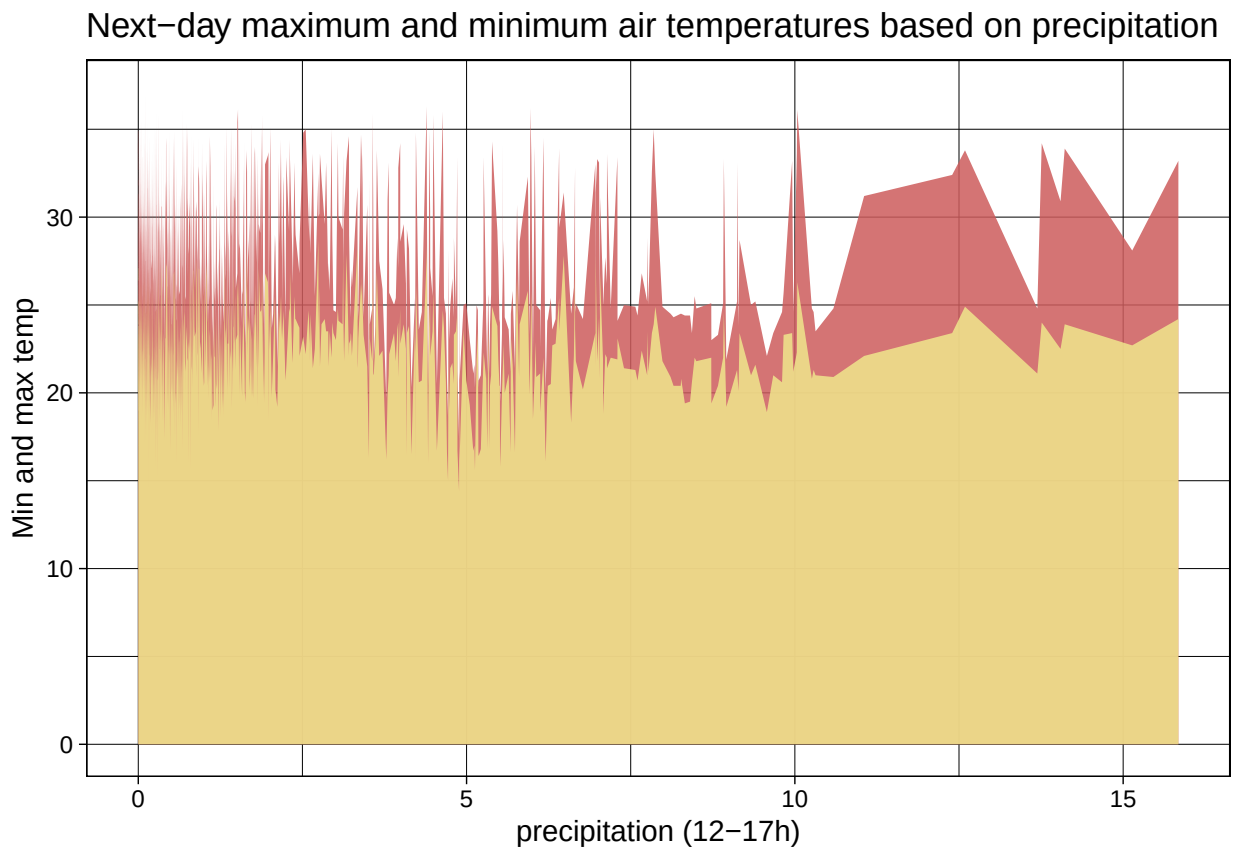
```
par(mfrow = c(1,4), mar = c(4,4,2,1), bty = "l")
ggplot(data) +
  geom_area(aes(x = data$PPT1, y = data$Next_Tmax),
            fill = 'indianred', alpha = 0.85)+
  geom_area(aes(x = data$PPT1, y = data$Next_Tmin),
            fill = 'khaki', alpha = 0.85)+
  labs(
    title = "Next-day maximum and minimum air temperatures based on precipitation",
    x="precipitation (0-5h)",
    y="Min and max temp"
  )+
  theme_linedraw()
```



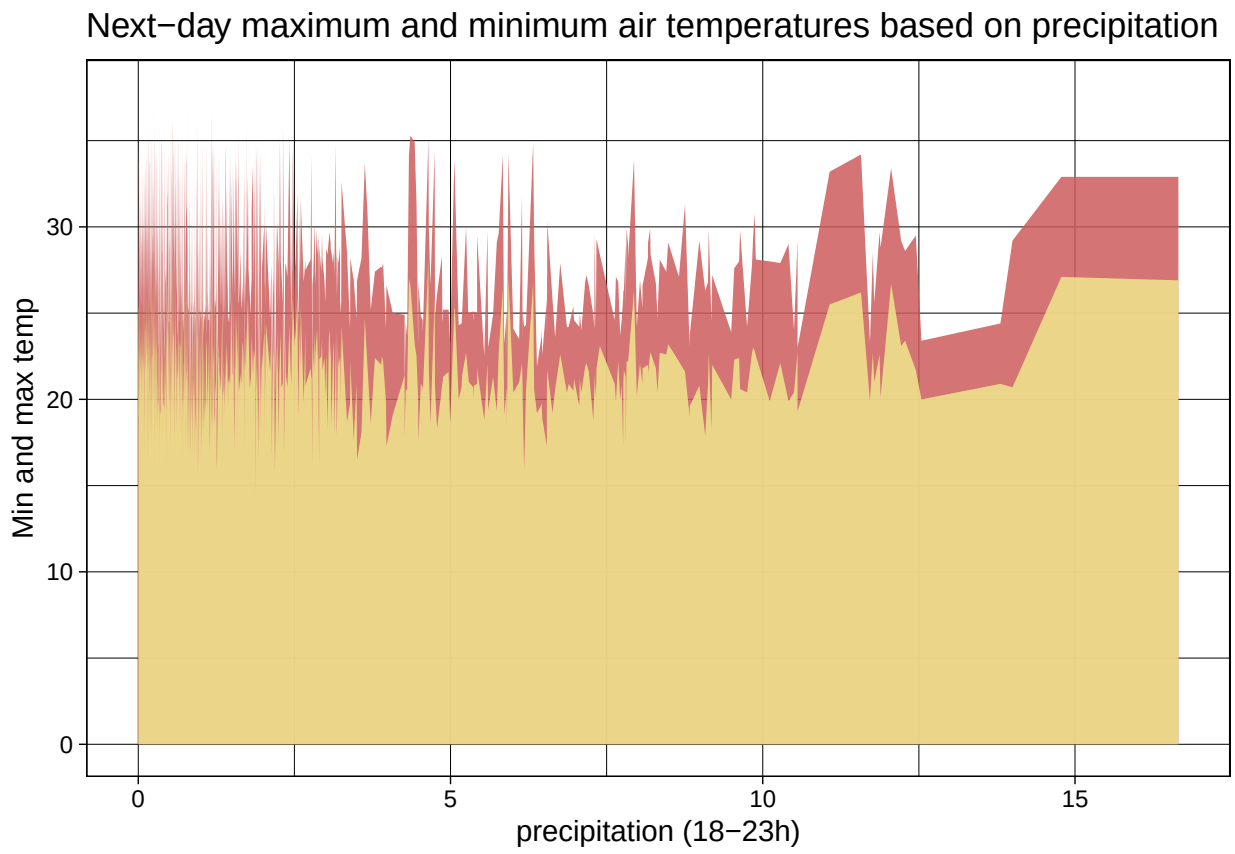

```
ggplot(data) +
  geom_area(aes(x = data$PPT2, y = data$Next_Tmax),
            fill = 'indianred', alpha = 0.85)+
  geom_area(aes(x = data$PPT2, y = data$Next_Tmin),
            fill = 'khaki', alpha = 0.85)+
  labs(
    title = "Next-day maximum and minimum air temperatures based on precipitation",
    x="precipitation (6-11h)",
    y="Min and max temp"
  )+
  theme_linedraw()
```




```
ggplot(data) +
  geom_area(aes(x = data$PPT3, y = data$Next_Tmax),
            fill = 'indianred', alpha = 0.85)+
  geom_area(aes(x = data$PPT3, y = data$Next_Tmin),
            fill = 'khaki', alpha = 0.85)+
  labs(
    title = "Next-day maximum and minimum air temperatures based on precipitation",
    x="precipitation (12-17h)",
    y="Min and max temp"
  )+
  theme_linedraw()
```



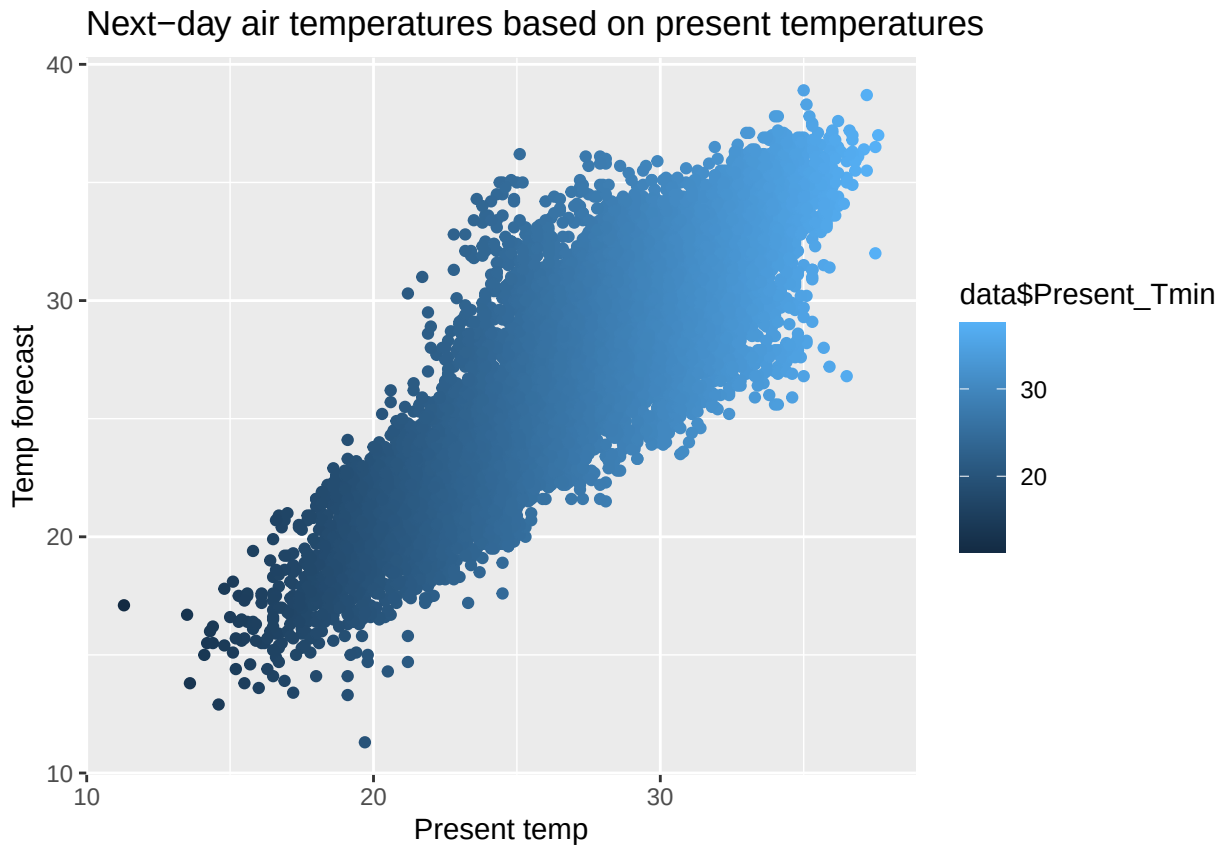

```
ggplot(data) +
  geom_area(aes(x = data$PPT4, y = data$Next_Tmax),
            fill = 'indianred', alpha = 0.85)+
  geom_area(aes(x = data$PPT4, y = data$Next_Tmin),
            fill = 'khaki', alpha = 0.85)+
  labs(
    title = "Next-day maximum and minimum air temperatures based on precipitation",
    x="precipitation (18-23h)",
    y="Min and max temp"
  )+
  theme_linedraw()
```



the results show a positive correlation between air temperature and precipitation. As the level of precipitation increases, the variability of the temperature forecasts also decreases.

The following plot shows the relation between the present minimum and maximum air temperature and the next-day max and min temperatures:

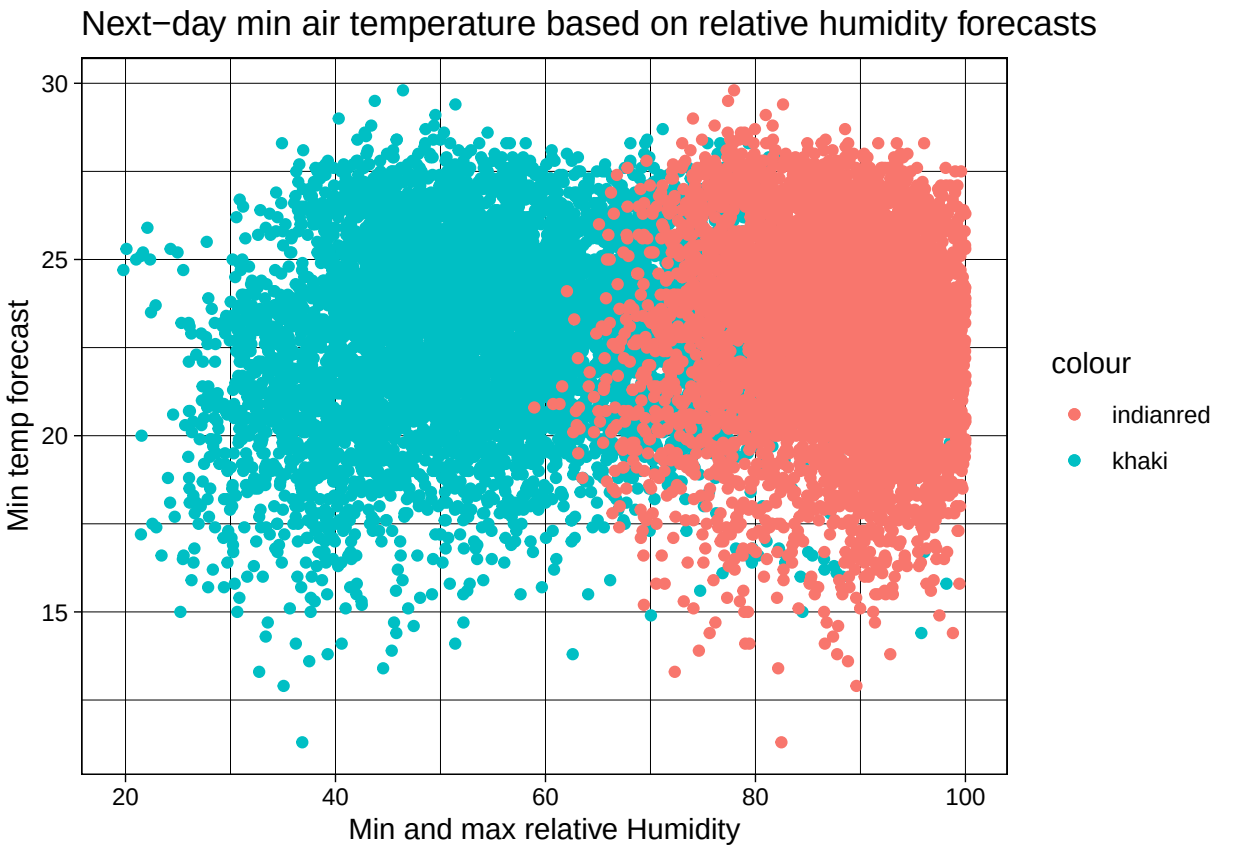
```
ggplot(data) +
  geom_point(aes(x = data$Present_Tmin, y = data$Next_Tmin, color=data$Present_Tmin))+
  geom_point(aes(x = data$Present_Tmax, y = data$Next_Tmax, color= data$Present_Tmax))+
  labs(
    title = "Next-day air temperatures based on present temperatures",
    x="Present temp",
    y="Temp forecast"
  )
```



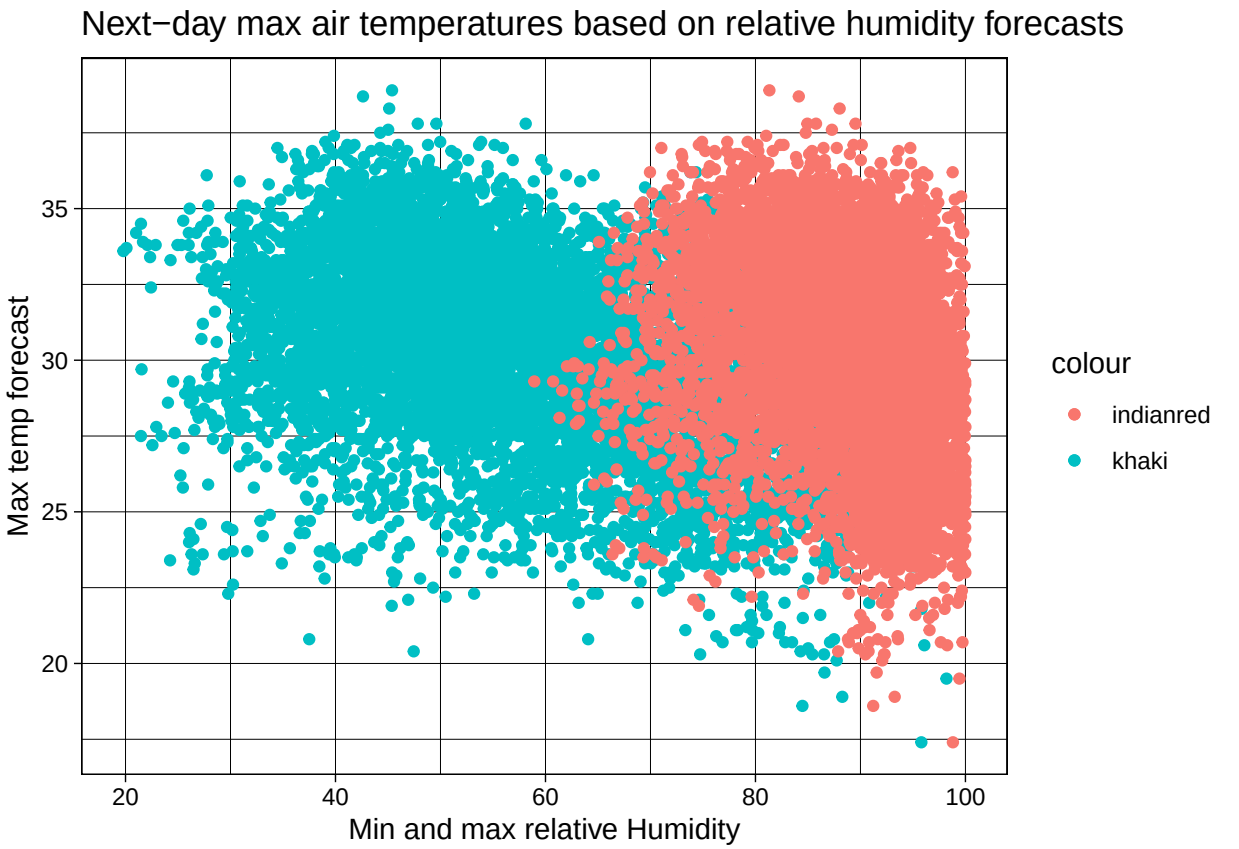
There is a clear positive correlation between present and future temperatures.

The following plot shows the relation between the model forecast of next-day minimum and maximum relative humidity and the next-day max and min temperatures:

```
par(mfrow = c(1,2), mar = c(4,4,2,1), bty = "l")
ggplot(data) +
  geom_point(aes(x = data$RHmin, y = data$Next_Tmin, color="khaki"))+
  geom_point(aes(x = data$RHmax, y = data$Next_Tmin, color= "indianred"))+
  labs(
    title = "Next-day min air temperature based on relative humidity forecasts",
    x="Min and max relative Humidity",
    y="Min temp forecast"
  )+
  theme_linedraw()
```



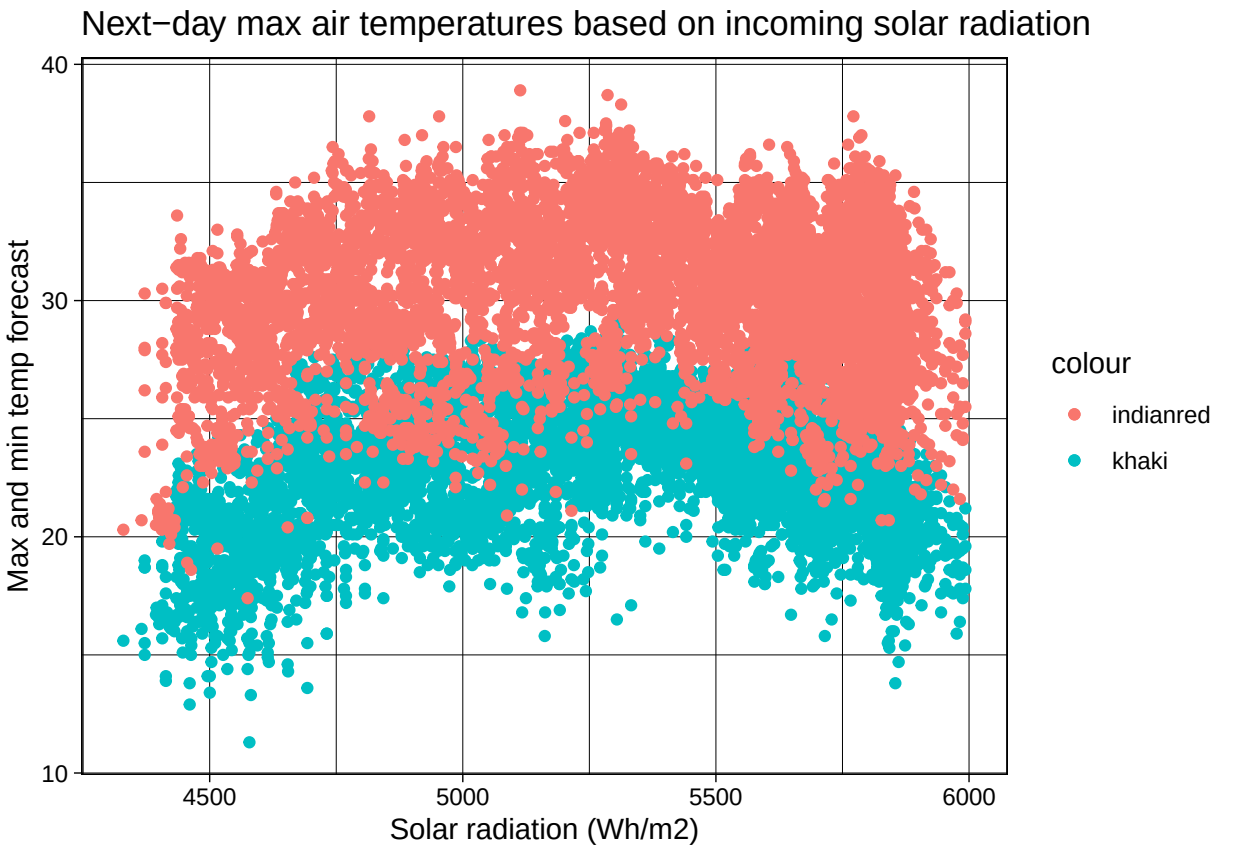

```
ggplot(data) +
  geom_point(aes(x = data$RHmin, y = data$Next_Tmax, color="khaki"))+
  geom_point(aes(x = data$RHmax, y = data$Next_Tmax, color= "indianred"))+
  labs(
    title = "Next-day max air temperatures based on relative humidity forecasts",
    x="Min and max relative Humidity",
    y="Max temp forecast"
  )+
  theme_linedraw()
```



The correlation seems weak, but the plot between relative humidity and max temperature forecast appears to be negative.

Next, we can observe how incoming solar radiation (h/m2) affects the next day temperature forecasts:

```
ggplot(data) +
  geom_point(aes(x = data$Solar.radiation, y = data$Next_Tmin, color="khaki"))+
  geom_point(aes(x = data$Solar.radiation, y = data$Next_Tmax, color= "indianred"))+
  labs(
    title = "Next-day max air temperatures based on incoming solar radiation",
    x="Solar radiation (Wh/m2)",
    y="Max and min temp forecast"
  )+
  theme_linedraw()
```



The relation between the two variables seems to be non-linear: temperature and solar radiation are positively correlated until a solar radiation between 5000 and 5500 Wh/m2, but then the data starts to show a negative correlation.

1.4 Issues of validity, reliability and sample selection

The main issue of this data set is the number of missing data, which can affect the overall quality of the analysis. Other than this, the sampling has been done over a long period of time and in different locations, so to avoid bias selection.