

# Rain in Australia. Classification Prediction Model

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**Abstract** An abstract of less than 150 words.

## Introduction

## Background

## Objective

## Data Analysis

The data set we are going to use for our research contains daily weather observations from numerous Australian weather stations from 2007 till 2017. There are over 142000 records. It has been sourced from [Kaggle](#)

## Data Dictionary

We exclude the variable Risk-MM when training your binary classification model. If we don't exclude it, you will leak the answers to our model and reduce its predictability

Column Name	Column Description
Date	Date of observation
Location	Common name of the location of the weather station
MinTemp	Minimum temperature in degrees Celsius
MaxTemp	Maximum temperature in degrees Celsius
Rainfall	Amount of rainfall recorded for the day in mm
Evaporation	So-called Class A pan evaporation (mm) in the 24 hours to 9am
Sunshine	Number of hours of bright sunshine in the day
WindGustDir	Direction of the strongest wind gust in the 24 hours to midnight
WindGustSpeed	Speed (km/h) of the strongest wind gust in the 24 hours to midnight
WindDir9amDirection	Of the wind at 9am
WindDir3pmDirection	Of the wind at 3pm
WindSpeed9amWind	Wind speed (km/hr) averaged over 10 minutes prior to 9am
WindSpeed3pmWind	Wind Speed (km/hr) averaged over 10 minutes prior to 3pm
Humidity9amHumidity	Humidity (percent) at 9am
Humidity3pmHumidity	Humidity (percent) at 3pm
Pressure9amAtmospheric	Pressure (hpa) reduced to mean sea level at 9am
Pressure3pmAtmospheric	Pressure (hpa) reduced to mean sea level at 3pm
Cloud9amFraction	Area of sky obscured by cloud at 9am. This is measured in "oktas", which are a unit of eighths. It records how many eighths of the sky are obscured by cloud. A 0 measure indicates completely clear sky whilst an 8 indicates that it is completely overcast
Cloud3pmFraction	Area of sky obscured by cloud (in "oktas": eighths) at 3pm. See Cloud9am for a description of the values

Column Name	Column Description
Temp9amTemperature	Temperature (degrees C) at 9am
Temp3pmTemperature	Temperature (degrees C) at 3pm
RainTodayBoolean	Rainy today. 1 if precipitation (mm) in the 24 hours to 9am exceeds 1mm, otherwise 0
RISK_MM	Amount of rain. A kind of measure of the "risk". This column is redundant and will be dropped
RainTomorrowThe	<b>Target variable. Will it rain tomorrow?</b>

## Data Exploration

Let's take a close look at the data set. We start with loading weather observations from the file into a data frame. We remove RISK\_MM as explained and convert Date column to *date* format

```
weatherData = read.csv("../data/weatherAUS.csv", header = TRUE, na.strings = c("NA", "", "#NA"), sep = ",")
weatherData = subset(weatherData, select = -RISK_MM)
weatherData$Date = as.Date(as.character(weatherData$Date), "%Y-%m-%d")
```

Now let's load coordinates of the weather stations and have a bird-eye view of the weather station locations

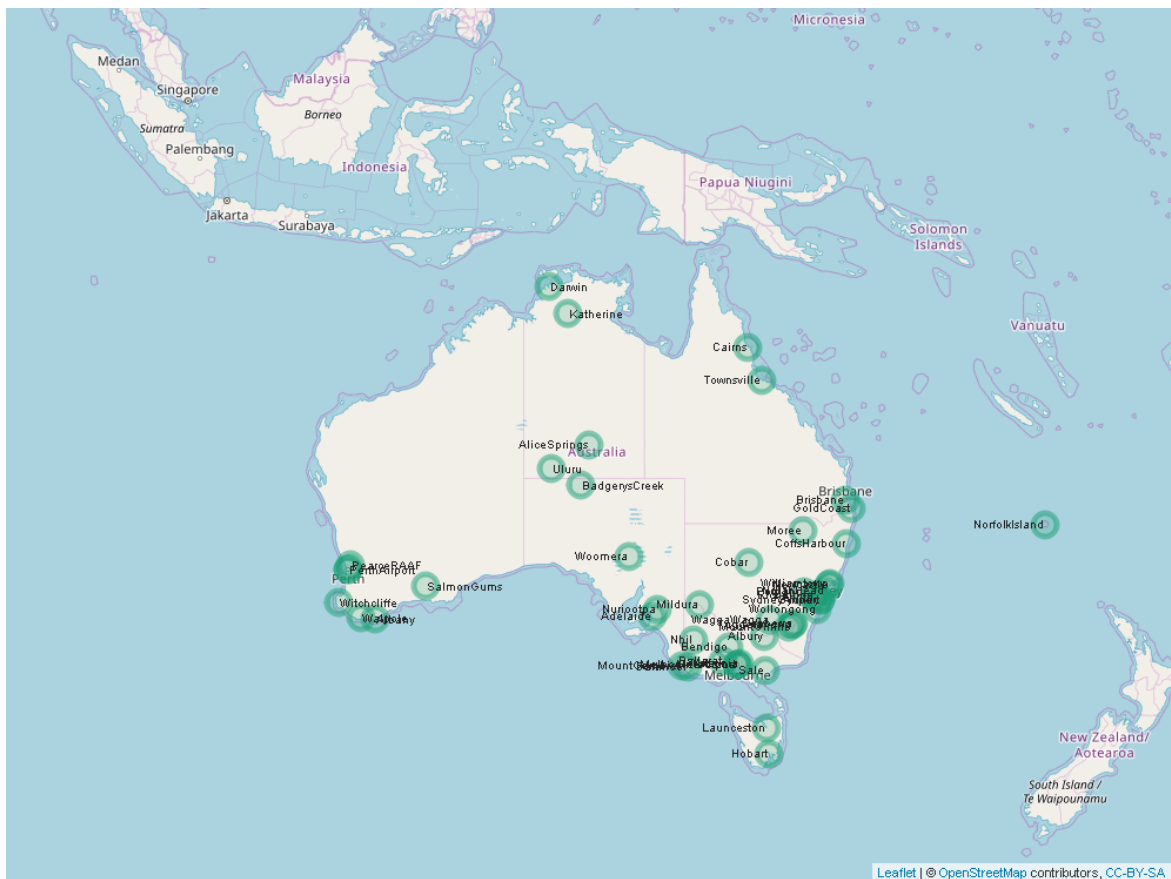


Figure 1: Australian Weather Stations

Let's review data summary

```
summary(weatherData)
```

```
#>      Date      Location      MinTemp      MaxTemp
#> Min.   :2007-11-01 Canberra: 3418 Min.    :-4.50 Min.    :-4.80
#> 1st Qu.:2011-01-06 Sydney   : 3337 1st Qu.: 7.60 1st Qu.:17.90
#> Median :2013-05-27 Perth    : 3193 Median :12.00 Median :22.60
```

```

#> Mean :2013-04-01 Darwin : 3192 Mean :12.19 Mean :23.23
#> 3rd Qu.:2015-06-12 Hobart : 3188 3rd Qu.:16.80 3rd Qu.:28.20
#> Max. :2017-06-25 Brisbane: 3161 Max. :33.90 Max. :48.10
#> (Other) :122704 NA's :637 NA's :322
#> Rainfall Evaporation Sunshine WindGustDir
#> Min. : 0.00 Min. : 0.00 Min. : 0.00 W : 9780
#> 1st Qu.: 0.00 1st Qu.: 2.60 1st Qu.: 4.90 SE : 9309
#> Median : 0.00 Median : 4.80 Median : 8.50 E : 9071
#> Mean : 2.35 Mean : 5.47 Mean : 7.62 N : 9033
#> 3rd Qu.: 0.80 3rd Qu.: 7.40 3rd Qu.:10.60 SSE : 8993
#> Max. :371.00 Max. :145.00 Max. :14.50 (Other):86677
#> NA's :1406 NA's :60843 NA's :67816 NA's :9330
#> WindGustSpeed WindDir9am WindDir3pm WindSpeed9am
#> Min. : 6.00 N :11393 SE :10663 Min. : 0
#> 1st Qu.: 31.00 SE : 9162 W : 9911 1st Qu.: 7
#> Median : 39.00 E : 9024 S : 9598 Median : 13
#> Mean : 39.98 SSE : 8966 WSW : 9329 Mean : 14
#> 3rd Qu.: 48.00 NW : 8552 SW : 9182 3rd Qu.: 19
#> Max. :135.00 (Other):85083 (Other):89732 Max. :130
#> NA's :9270 NA's :10013 NA's : 3778 NA's :1348
#> WindSpeed3pm Humidity9am Humidity3pm Pressure9am
#> Min. : 0.00 Min. : 0.00 Min. : 0.00 Min. : 980.5
#> 1st Qu.:13.00 1st Qu.: 57.00 1st Qu.: 37.00 1st Qu.:1012.9
#> Median :19.00 Median : 70.00 Median : 52.00 Median :1017.6
#> Mean :18.64 Mean : 68.84 Mean : 51.48 Mean :1017.7
#> 3rd Qu.:24.00 3rd Qu.: 83.00 3rd Qu.: 66.00 3rd Qu.:1022.4
#> Max. :87.00 Max. :100.00 Max. :100.00 Max. :1041.0
#> NA's :2630 NA's :1774 NA's :3610 NA's :14014
#> Pressure3pm Cloud9am Cloud3pm Temp9am
#> Min. : 977.1 Min. :0.00 Min. :0.0 Min. : -7.20
#> 1st Qu.:1010.4 1st Qu.:1.00 1st Qu.:2.0 1st Qu.:12.30
#> Median :1015.2 Median :5.00 Median :5.0 Median :16.70
#> Mean :1015.3 Mean :4.44 Mean :4.5 Mean :16.99
#> 3rd Qu.:1020.0 3rd Qu.:7.00 3rd Qu.:7.0 3rd Qu.:21.60
#> Max. :1039.6 Max. :9.00 Max. :9.0 Max. :40.20
#> NA's :13981 NA's :53657 NA's :57094 NA's :904
#> Temp3pm RainToday RainTomorrow
#> Min. : -5.40 No :109332 No :110316
#> 1st Qu.:16.60 Yes : 31455 Yes: 31877
#> Median :21.10 NA's: 1406
#> Mean :21.69
#> 3rd Qu.:26.40
#> Max. :46.70
#> NA's :2726

```

Next set of plots renders distribution of a few selected features.

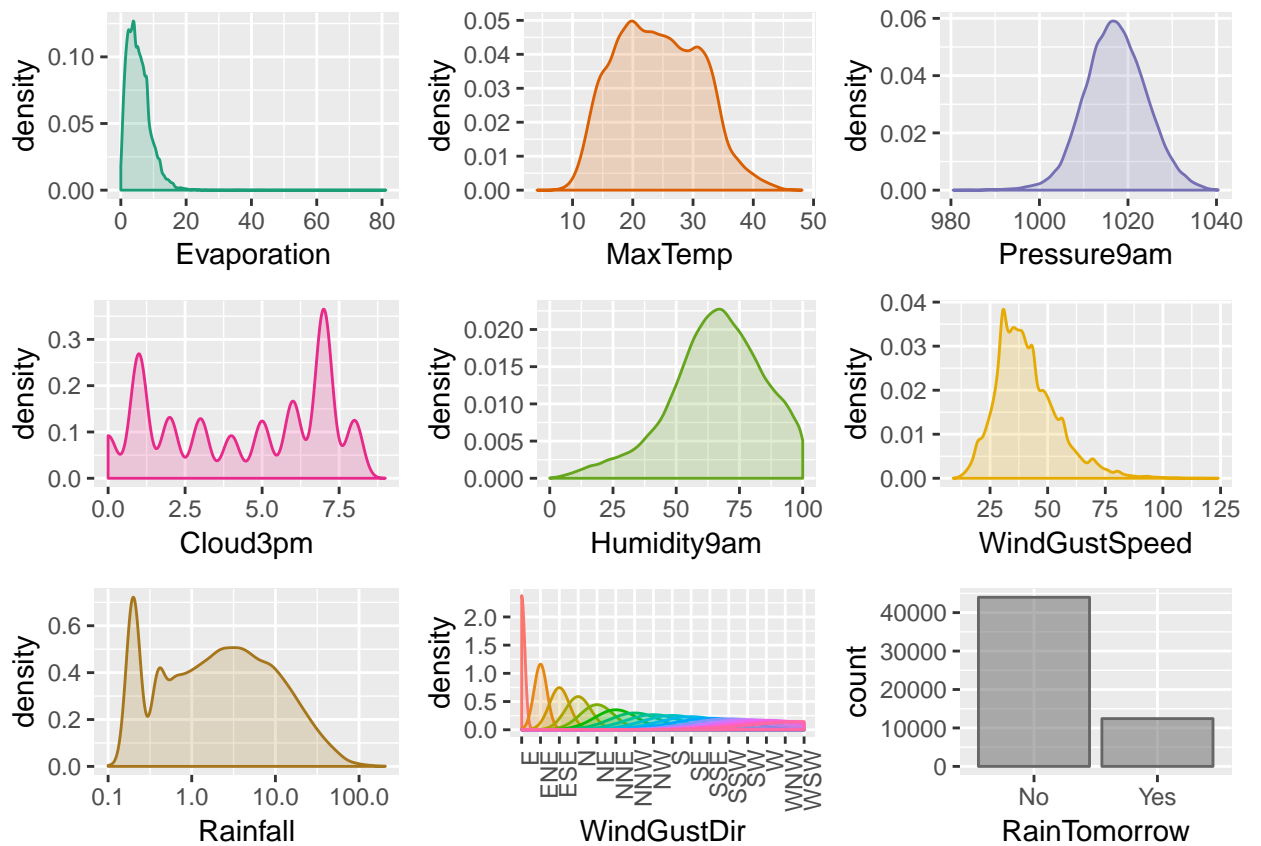


Figure 2: Observations Distribution

### Missing Data

Further analysis of data shows that many features are missing. Some data losses are very significant. We are going to identify what data is missing and if it is feasible to recover the data.

```
print(sort(colSums(is.na(weatherData)), decreasing = T))
```

```
#>      Sunshine      Evaporation      Cloud3pm      Cloud9am      Pressure9am
#>      67816         60843         57094         53657         14014
#>      Pressure3pm      WindDir9am      WindGustDir      WindGustSpeed      WindDir3pm
#>      13981         10013         9330         9270         3778
#>      Humidity3pm      Temp3pm      WindSpeed3pm      Humidity9am      Rainfall
#>      3610          2726         2630         1774         1406
#>      RainToday      WindSpeed9am      Temp9am      MinTemp      MaxTemp
#>      1406          1348         904         637         322
#>      Date      Location      RainTomorrow
#>      0          0          0
```

To speed up data processing and plot rendering we are going to use a data sample. For population of 142K observations, 20K sample size would be sufficient for 99% confidence level with the confidence interval 1.

```
weatherSample = sample_n(weatherData, 20000)
aggr(weatherSample, numbers = F, prop = T, col = mainPalette, sortVars = T, bars = F, varheight = T)
```

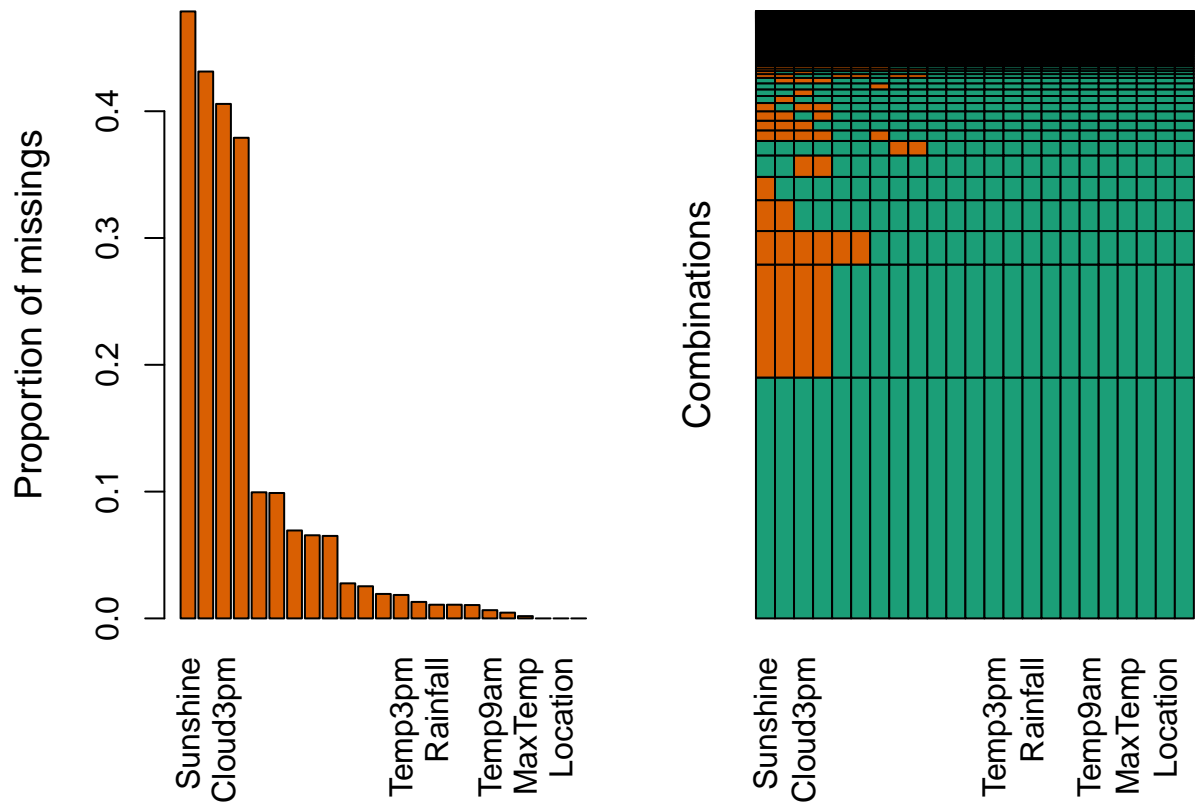


Figure 3: Missing Data Summary

```
#>
#> Variables sorted by number of missings:
#>   Variable   Count
#>   Sunshine 0.47870
#>   Evaporation 0.43130
#>   Cloud3pm 0.40575
#>   Cloud9am 0.37905
#>   Pressure9am 0.09945
#>   Pressure3pm 0.09890
#>   WindDir9am 0.06935
#>   WindGustDir 0.06555
#>   WindGustSpeed 0.06505
#>   WindDir3pm 0.02765
#>   Humidity3pm 0.02535
#>   WindSpeed3pm 0.01930
#>   Temp3pm 0.01850
#>   Humidity9am 0.01300
#>   Rainfall 0.01080
#>   RainToday 0.01080
#>   WindSpeed9am 0.01055
#>   Temp9am 0.00650
#>   MinTemp 0.00455
#>   MaxTemp 0.00180
#>   Date 0.00000
#>   Location 0.00000
#>   RainTomorrow 0.00000
```

As demonstrated in Figure 3 *Sunshine*, *Evaporation* and *Clouds* columns suffer the loss of data between 48% and 38%. This is significant! Since we are dealing with the weather patterns we should be observing cyclical data patterns. Let's review data distribution of features that damaged the most.

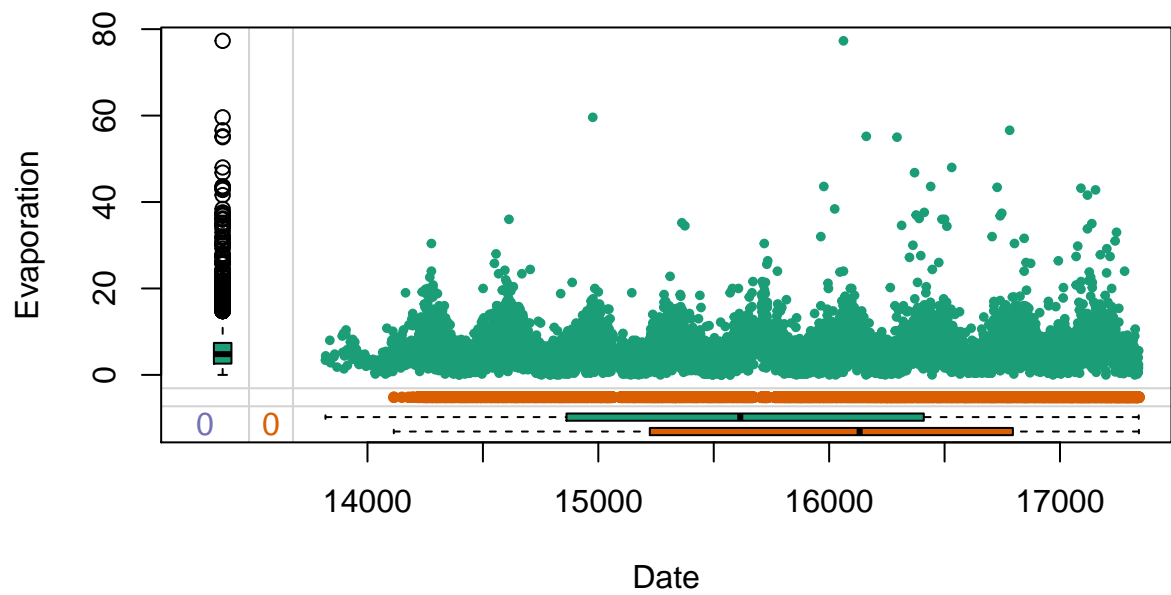


Figure 4: Date/Evaporation Margin Plot

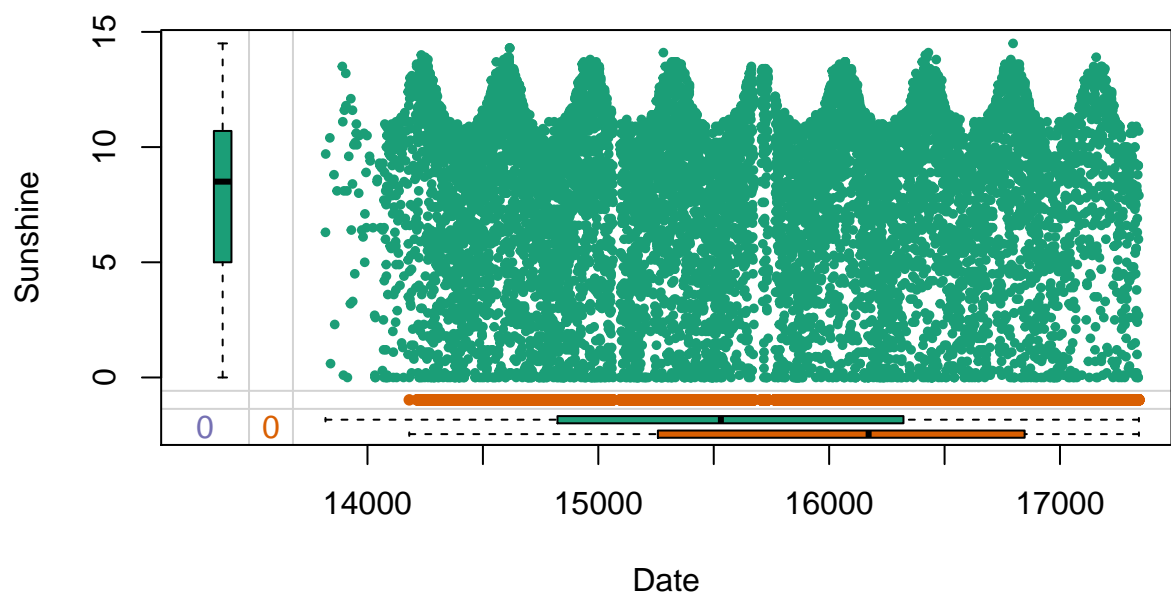
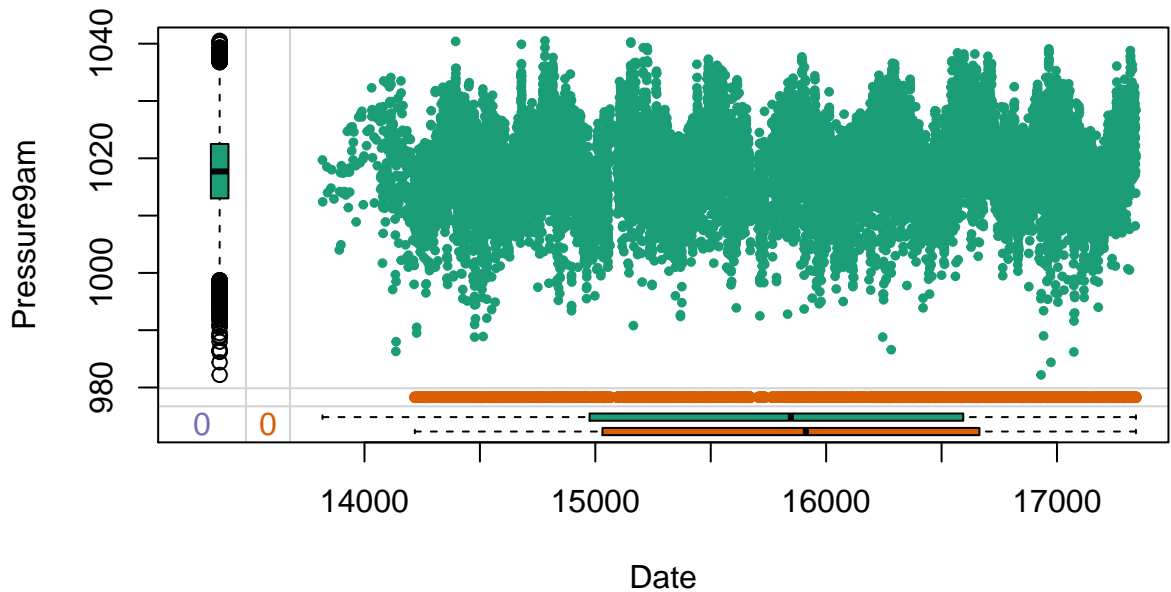


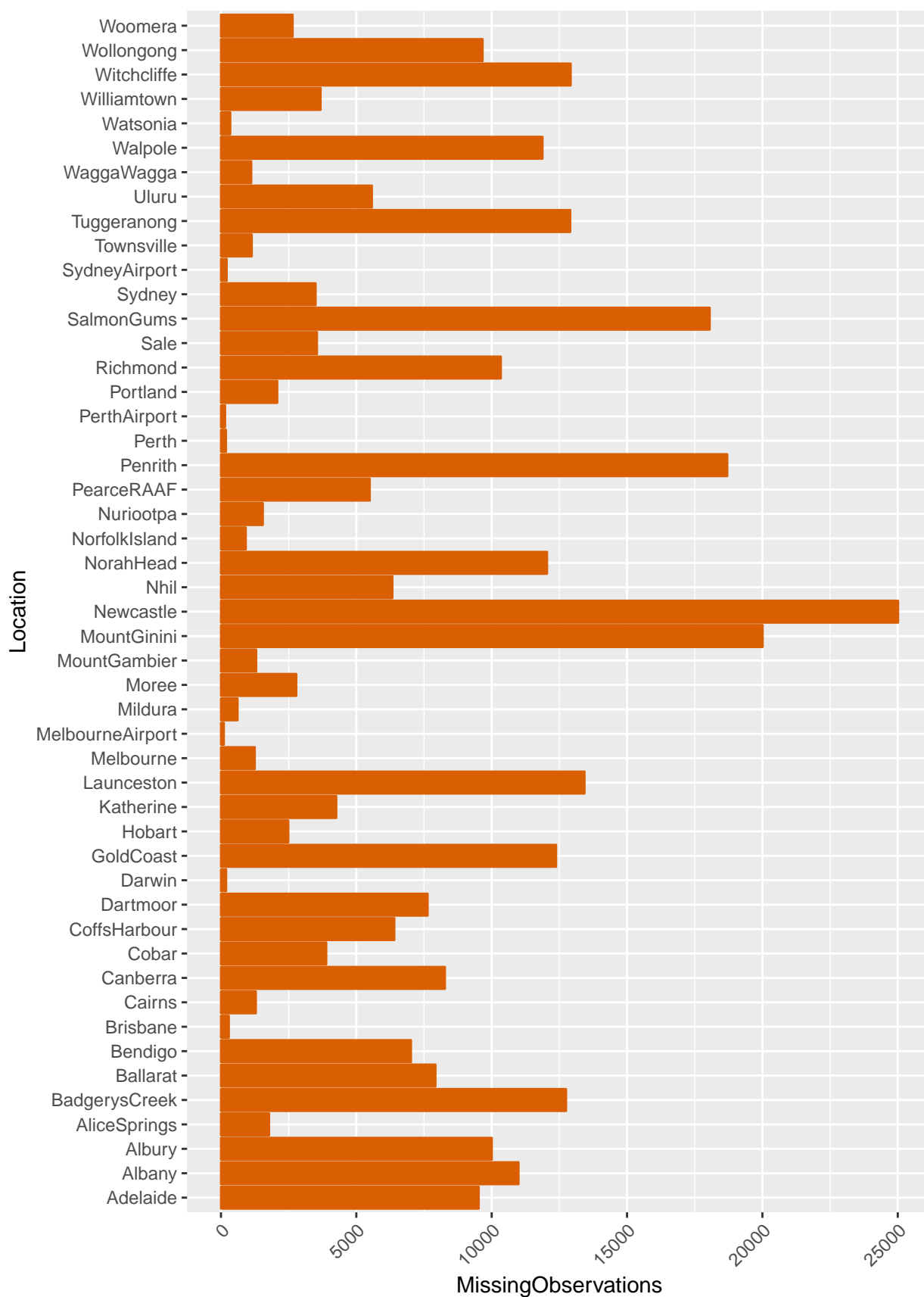
Figure 5: Date/ Sunshine Margin Plot



**Figure 6:** Date/ Pressure3pm Margin Plot

So what do the margin plots tell us? First of all let's take a look at *Date* axis. The *Date* has been converted to number to ensure continuous flow of the data. All features we picked exhibit cyclical pattern as expected. Along the vertical axis we observe the box plot of the respective feature. *Evaporation* data is quite remarkable (Figure ??); it has very narrow distribution and a lot of so-called outliers. Though forces of nature follow seasonal patterns they often exhibit wide range of seasonal anomalies, which the plots highlight. The distribution of the missing data of a given feature is depicted along the horizontal axis. In all three cases the missing data is randomly distributed along observed date range. Along the horizontal axis we may see box plots of the date and a given feature. *Pressure9am* (Figure ??) distributed evenly across the observed date frame. *Evaporation* and *Sunshine* exhibit more data losses towards the end of the observed period

Let's examine one more dimension of the missing data, namely features vs feature vs location



**Figure 7:** Missing Data By Location

Remarkably Figure 7 shows that 6460 observations are missing on average per location. Though if we take a second look at the weather station map 1 we would see that Mount Gini (the station that



miss the most data), Bendigo and Ballarat are close to Melbourne, where the staff has kept observing data on regular basis. Newcastle to Sydney and so on...

### Data correlation and other observations

Let's examine how the features are correlated to each other. Knowing weather we can make an accurate prediction that the temperature features should be highly correlated, as well as pressure, wind speed, clouds and humidity groups

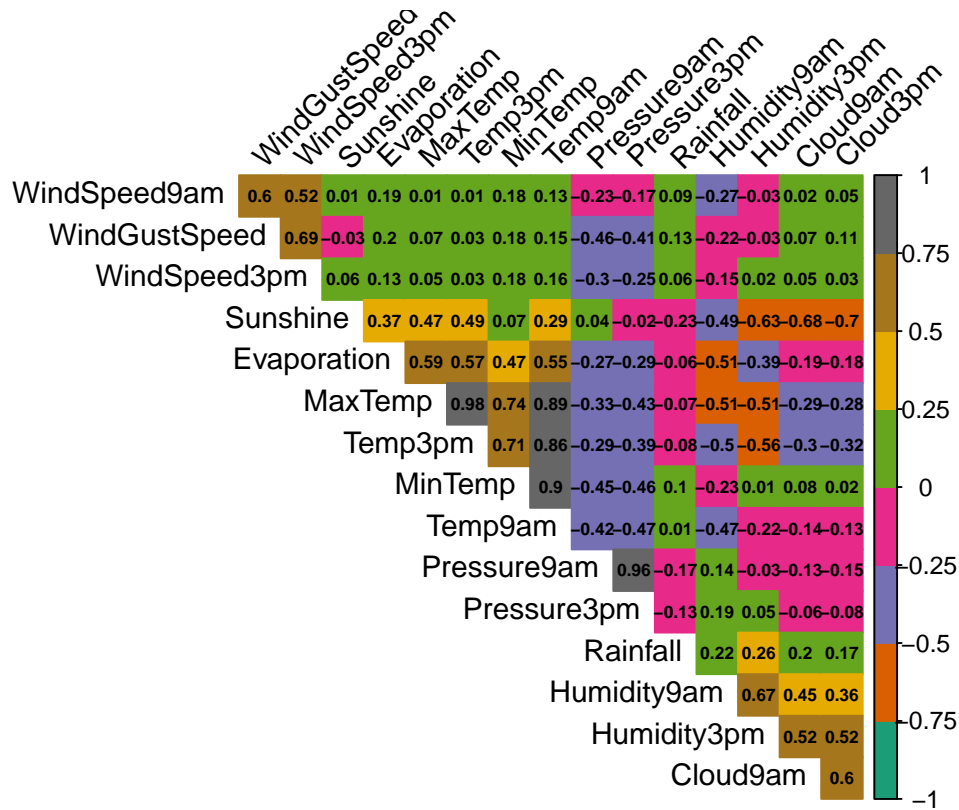


Figure 8: Data Correlation

Figure 8 confirms our initial guess. This observation will help us to eliminate redundant features later when we get to the point of selecting useful predictors for our model

### Takeaways from Data Exploration Exercise

- The data we are dealing with suffers major observation losses (Figure 3)
- The least represented features are
  - *Sunshine* 48%
  - *Evaporation* 43%
  - *Cloud* group (40% and 38% respectively)
- The rest of the features exhibit medium to minor data losses, where *Pressure* group leads the way with 10%
- The missing data is distributed randomly over the observed time frame (Figures 4, 5, 6)
- We also witnessed that some weather stations recorded less data and some were almost perfect at record keeping (Figure 7). Luckily many majority weather stations situate relatively close to each other (see figure 1). Thus if a station has data gaps the neighboring station data could be used to approximate the missing data with plausible accuracy
- We have also noticed that many features are either positively or negatively correlated (Figure 8), where
  - *MaxTemp*, *Temp3pm* and *Temp9am* exhibits correlation of 0.86 to 0.98
  - *Pressure9am* and *Pressure3pm* have correlation coefficient of 0.96
  - *Sunshine* and *Cloud* group correlated negatively with coefficient of -0.7
  - *Rainfall* feature is of particular interest since this is what we are trying to predict. Unfortunately it does not demonstrate any strong correlations with any other feature

- Doing the data analysis we have also seen seasonal patterns and data that fall outside of the normal distribution range by far (outliers). Those are anomalies of nature.
- The last but not least the target feature (the value we are trying to predict) is unbalanced. so we are dealing with unbalanced data set. See Figure 2 *RainTomorrow* plot

## Data Preparation

Data exploration confirmed that despite of significant data loss we should be able to impute data with high degree of plausibility

## Datas Imputing

Before we start dealing with missing observations let's do some feature engineering, which will + improve imputation processing speed + improve model training performance and hopefully accuracy

First of all let's get rid of *Date* column. Outside of the presentation it does not carry too much information. What would be useful indeed is a feature that captures seasonal observation fluctuations. That would be *month* and *day* combined, giving us year-round (365) days of observations

Secondly we convert categorical features to numbers. But before we do so we would like to ponder about *Location*. We have couple options here. Either we convert the locations to the numbers or we can replace them with the real geographical coordinates. After some deliberation we can conclude that the coordinates will not add too much knowledge in the context of the model training. But they will certainly break this categorical feature (coordinates have 4,6 decimal places, which effectively make them continuous). So we stick with categories

This is our original set:

```
str(weatherData)

#> 'data.frame':   142193 obs. of  23 variables:
#> $ Date          : Date, format: "2008-12-01" "2008-12-02" ...
#> $ Location       : Factor w/ 49 levels "Adelaide","Albany",...: 3 3 3 3 3 3 3 3 3 3 ...
#> $ MinTemp        : num  13.4 7.4 12.9 9.2 17.5 14.6 14.3 7.7 9.7 13.1 ...
#> $ MaxTemp        : num  22.9 25.1 25.7 28 32.3 29.7 25 26.7 31.9 30.1 ...
#> $ Rainfall       : num  0.6 0 0 0 1 0.2 0 0 0 1.4 ...
#> $ Evaporation    : num  NA NA NA NA NA NA NA NA NA NA ...
#> $ Sunshine       : num  NA NA NA NA NA NA NA NA NA NA ...
#> $ WindGustDir    : Factor w/ 16 levels "E","ENE","ESE",...: 14 15 16 5 14 15 14 14 7 14 ...
#> $ WindGustSpeed  : int  44 44 46 24 41 56 50 35 80 28 ...
#> $ WindDir9am     : Factor w/ 16 levels "E","ENE","ESE",...: 14 7 14 10 2 14 13 11 10 9 ...
#> $ WindDir3pm     : Factor w/ 16 levels "E","ENE","ESE",...: 15 16 16 1 8 14 14 14 8 11 ...
#> $ WindSpeed9am   : int  20 4 19 11 7 19 20 6 7 15 ...
#> $ WindSpeed3pm   : int  24 22 26 9 20 24 24 17 28 11 ...
#> $ Humidity9am    : int  71 44 38 45 82 55 49 48 42 58 ...
#> $ Humidity3pm    : int  22 25 30 16 33 23 19 19 9 27 ...
#> $ Pressure9am    : num  1008 1011 1008 1018 1011 ...
#> $ Pressure3pm    : num  1007 1008 1009 1013 1006 ...
#> $ Cloud9am       : int  8 NA NA NA 7 NA 1 NA NA NA ...
#> $ Cloud3pm       : int  NA NA 2 NA 8 NA NA NA NA NA ...
#> $ Temp9am        : num  16.9 17.2 21 18.1 17.8 20.6 18.1 16.3 18.3 20.1 ...
#> $ Temp3pm        : num  21.8 24.3 23.2 26.5 29.7 28.9 24.6 25.5 30.2 28.2 ...
#> $ RainToday      : Factor w/ 2 levels "No","Yes": 1 1 1 1 1 1 1 1 1 2 ...
#> $ RainTomorrow   : Factor w/ 2 levels "No","Yes": 1 1 1 1 1 1 1 1 2 1 ...
```

Transformation

```
data = mutate(weatherData, MMDD = as.numeric( format(Date, "%m%d")), Location = unclass(Location),
              WindGustDir = unclass(WindGustDir),
              WindDir9am = unclass(WindDir9am), WindDir3pm = unclass(WindDir3pm),
              RainToday = unclass(RainToday)-1, RainTomorrow = unclass(RainTomorrow)-1)
data = subset(data, select = -Date)
```

Resulting data frame structure:

```
str(data)
```

```
#> 'data.frame': 142193 obs. of 23 variables:
#> $ Location : int 3 3 3 3 3 3 3 3 3 ...
#> $ MinTemp : num 13.4 7.4 12.9 9.2 17.5 14.6 14.3 7.7 9.7 13.1 ...
#> $ MaxTemp : num 22.9 25.1 25.7 28 32.3 29.7 25 26.7 31.9 30.1 ...
#> $ Rainfall : num 0.6 0 0 0 1 0.2 0 0 0 1.4 ...
#> $ Evaporation : num NA NA NA NA NA NA NA NA NA NA ...
#> $ Sunshine : num NA NA NA NA NA NA NA NA NA NA ...
#> $ WindGustDir : int 14 15 16 5 14 15 14 14 7 14 ...
#> $ WindGustSpeed: int 44 44 46 24 41 56 50 35 80 28 ...
#> $ WindDir9am : int 14 7 14 10 2 14 13 11 10 9 ...
#> $ WindDir3pm : int 15 16 16 1 8 14 14 14 8 11 ...
#> $ WindSpeed9am : int 20 4 19 11 7 19 20 6 7 15 ...
#> $ WindSpeed3pm : int 24 22 26 9 20 24 24 17 28 11 ...
#> $ Humidity9am : int 71 44 38 45 82 55 49 48 42 58 ...
#> $ Humidity3pm : int 22 25 30 16 33 23 19 19 9 27 ...
#> $ Pressure9am : num 1008 1011 1008 1018 1011 ...
#> $ Pressure3pm : num 1007 1008 1009 1013 1006 ...
#> $ Cloud9am : int 8 NA NA NA 7 NA 1 NA NA NA ...
#> $ Cloud3pm : int NA NA 2 NA 8 NA NA NA NA NA ...
#> $ Temp9am : num 16.9 17.2 21 18.1 17.8 20.6 18.1 16.3 18.3 20.1 ...
#> $ Temp3pm : num 21.8 24.3 23.2 26.5 29.7 28.9 24.6 25.5 30.2 28.2 ...
#> $ RainToday : num 0 0 0 0 0 0 0 0 1 ...
#> $ RainTomorrow : num 0 0 0 0 0 0 0 1 0 ...
#> $ MMDD : num 1201 1202 1203 1204 1205 ...
```

To impute the missing data we employ **MICE** package. Our imputation strategy is to employ **Predictive mean matching** model which is a robust, fast imputation algorithm that works with numeric values ( this is why we have converted all data to the numeric values) Lets do a dry run first to see what predictors and methods for each feature to cure *MICE* software chooses. As before we will be working with a 20K data sample. Imputation process on the whole set take about 3 hours and 20 minutes to complete! In addition we let *MICE* to choose predictors for us running **quickpred()** method

```
meta = mice(data, maxit = 0, print = FALSE)
weatherSample = sample_n(data, 20000)
methods = meta$method
predictors = quickpred(data)
```

Let's review the methods chosen by the software making sure that they meet our requirements highlighted prior in the imputation strategy paragraph

```
print(methods)
```

```
#>      Location      MinTemp      MaxTemp      Rainfall      Evaporation
#>      " "      "pmm"      "pmm"      "pmm"      "pmm"
#>      Sunshine WindGustDir WindGustSpeed WindDir9am WindDir3pm
#>      "pmm"      "pmm"      "pmm"      "pmm"      "pmm"
#>      WindSpeed9am WindSpeed3pm Humidity9am Humidity3pm Pressure9am
#>      "pmm"      "pmm"      "pmm"      "pmm"      "pmm"
#>      Pressure3pm Cloud9am Cloud3pm Temp9am Temp3pm
#>      "pmm"      "pmm"      "pmm"      "pmm"      "pmm"
#>      RainToday RainTomorrow MMDD
#>      "pmm"      " "      " "
```

The code output above shows that 1 the features without missing data will not be imputed 2 The imputation targets will all be treated with *Predictive mean matching* algorithm ("pmm")

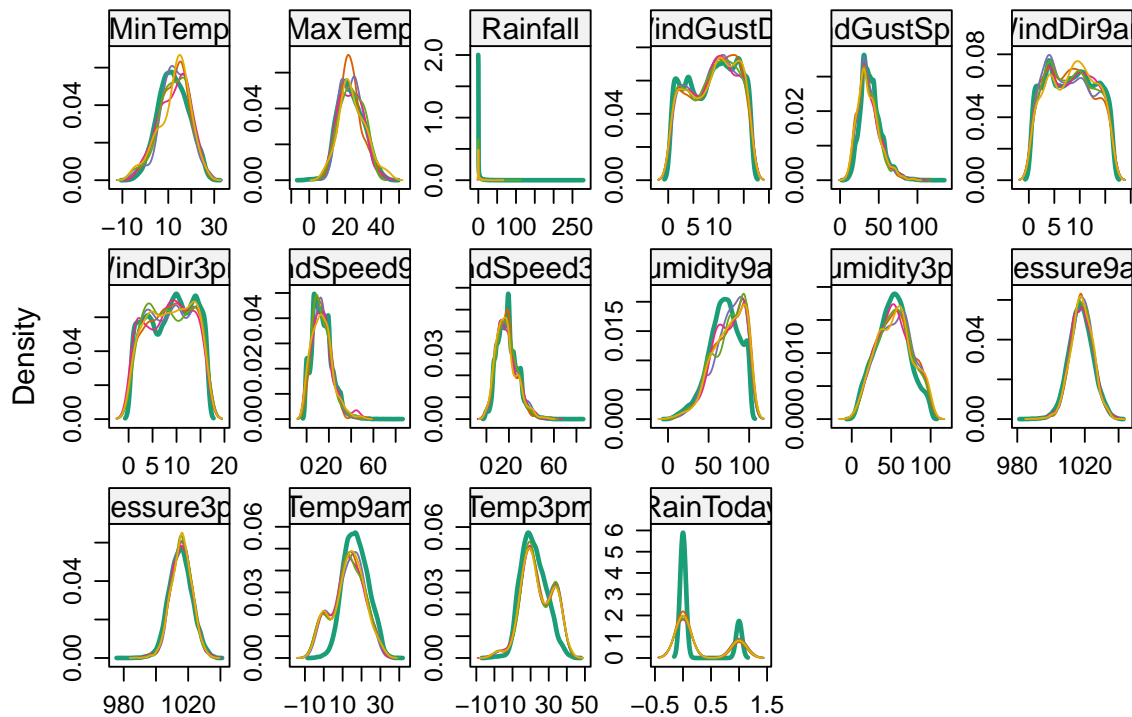
This is exactly what we need. Now let's review the predictors (*The command output is not included into report to save space*)

The matrix of predictors has the predictors in the columns and the features to be imputed in the rows. If the cell value equals has **1** the predictor will be employed in calculations for the respective imputation target. Surprisingly **MMDD** is not used widely to predict the missing data, nether do the **Location**.

Now we are going to start the imputation process. **Note: it might take about 4 - 5 minutes even for a smaple** We have disabled that output of the function as we do not want to pollute the report with rubbish messages

```
imputed = mice(weatherSample, pred = predictors, meth = methods, seed = 38019,
               nnet.MaxNWts = 2000, printFlag = F)
```

Now it is time to analyze the imputed values. In general, a good imputed value is a value that could have been observed had it not been missing. The MAR assumption can never be tested from the observed data. To check whether the imputations created by MICE algorithm are plausible we employ density charts and compare the distribution of the imputed values vs real observations. Let's do this (*again the plots take time, patience...*).



**Figure 9:** Imputed Values Distribution vs Real Observations

Figure 9 illustrates imputed value distribution for each imputed feature vs observed data. The fat green line renders the real data distribution and the thin lines of the other colors the distribution of imputed values after each imputation cycle (*there are five of them by default*). Where the last one is yellow. The yellow line should be shadowing the contour of the green one as close as possible, which give us an indication that the result of the imputation is plausible. Looking at the charts we can conclude that the imputation has been successful! Let's apply imputed values to our sample set and verify if there are any NAs left

```
weatherSample = complete(imputed)
print(colSums(is.na(weatherSample)))
```

```
#>      Location      MinTemp      MaxTemp      Rainfall      Evaporation
#>      0              0          0          0              0
#>      Sunshine  WindGustDir WindGustSpeed  WindDir9am  WindDir3pm
#>      0              0          0          0              0
#>      WindSpeed9am WindSpeed3pm Humidity9am Humidity3pm Pressure9am
#>      0              0          0          0              0
#>      Pressure3pm  Cloud9am    Cloud3pm    Temp9am    Temp3pm
#>      0              0          0          0              0
#>      RainToday   RainTomorrow MMDD
#>      0              0          0
```

Outstanding! There are no missing values. Now we move on to the next part - model training

```
# clean the memory
rm(methods, meta, imputed, predictors)
```

## **Modeling and Evalutation**

**Feature Selection**

**Decision Tree Model**

**Naive Bayes Model**

**Random Forest Model**

**Logistic Regression Model**

**Model Comparison**

**Model Deployment**

**Conclusion**

**Bibliography**

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