Execute a multiple linear regression (MLR) for BME680 gas readings of a single sensor

Read the CSV file created by the CCU Historian, ensure that field separator is ';' and decimal separator is '.', if necessary edit CSV file before reading it by the provided script 'csv_convert_historian.bsh'
The provided script 'get_new_history.bsh' is searching for the CCU Historian's CSV in the directory '${HOME}/Downloads'. The conversion script 'csv_convert_historian.bsh' is invoked as part of 'csv_convert_historian.bsh'

Important note: The below calculated multlinear regression coefficients do not fit for the sensor 'HB-UNI-Sensor1-AQ-BME680'! The sensor 'HB-UNI-Sensor1-AQ-BME680' is requiring regression parameters for temperature and absolute humidity aH, while this regression is for temperature and relative humidity rH.

In [1]:

```
import warnings
warnings.simplefilter(action='ignore', category=FutureWarning)

import pandas as pd
from datetime import datetime

import numpy as np


dateparse = lambda x: pd.datetime.strptime(x, '%d.%m.%Y %H:%M:%S,%f')

df0 = pd.read_csv("historian.csv", sep=';', thousands=".", decimal=",", skiprows = [0

df0.head(9)
#df['Datum']
#type(df['sensor 1'][0])
```

Out[1]:

	Datum	Mode	raw_gas_resistance	relative_humidity	temperature
0	2021-01-15 19:00:00.000	2	177160	28.9	24.6
1	2021-01-15 19:00:56.674	2	177160	28.9	24.6
2	2021-01-15 19:00:56.683	2	177160	29.6	24.6
3	2021-01-15 19:00:56.688	2	174900	29.6	24.6
4	2021-01-15 19:05:29.488	2	174900	29.6	24.6
5	2021-01-15 19:05:29.498	2	174900	30.1	24.6
6	2021-01-15 19:05:29.504	2	175280	30.1	24.6
7	2021-01-15 19:10:02.302	2	175280	30.1	24.6
8	2021-01-15 19:10:02.306	2	175280	29.7	24.6

In [2]:
```
# keep every 3rd row (CCU historian is tracking every change of a datapoint separatel
# each three consecutive entries in history.csv are identical; therefore we take ever
df = df0[(df0.index % 3 == 0)]

df.head(9)
```

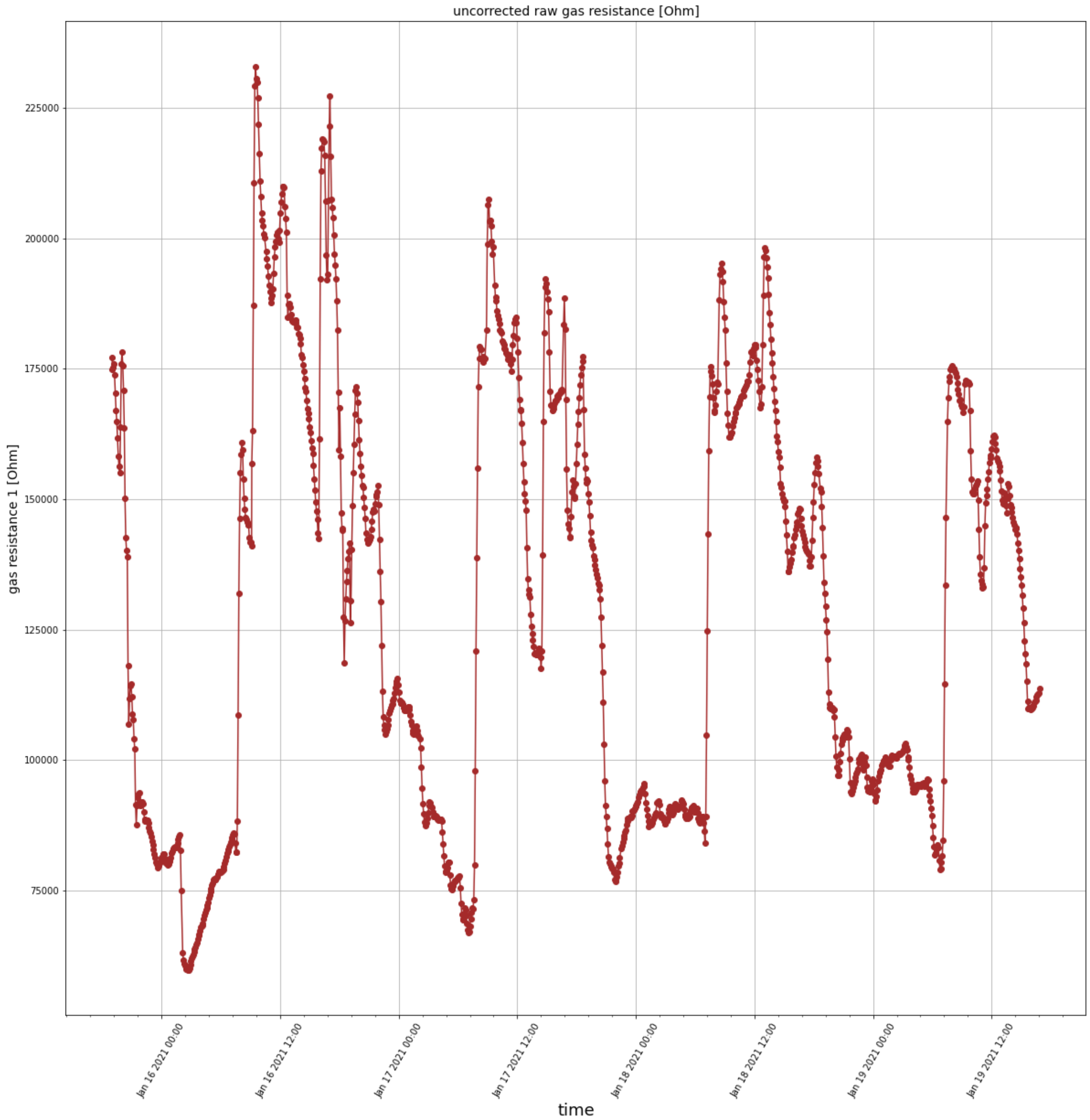
Out[2]:

	Datum	Mode	raw_gas_resistance	relative_humidity	temperature
0	2021-01-15 19:00:00.000	2	177160	28.9	24.6
3	2021-01-15 19:00:56.688	2	174900	29.6	24.6
6	2021-01-15 19:05:29.504	2	175280	30.1	24.6
9	2021-01-15 19:10:02.312	2	175860	29.7	24.6
12	2021-01-15 19:14:35.120	2	173780	29.9	24.6
15	2021-01-15 19:19:07.932	2	170320	30.3	24.6
18	2021-01-15 19:23:40.751	2	167060	30.7	24.6
21	2021-01-15 19:28:13.551	2	164920	30.9	24.6
24	2021-01-15 19:32:46.361	2	161640	31.2	24.7

Time series diagram of the measured raw gas resistance

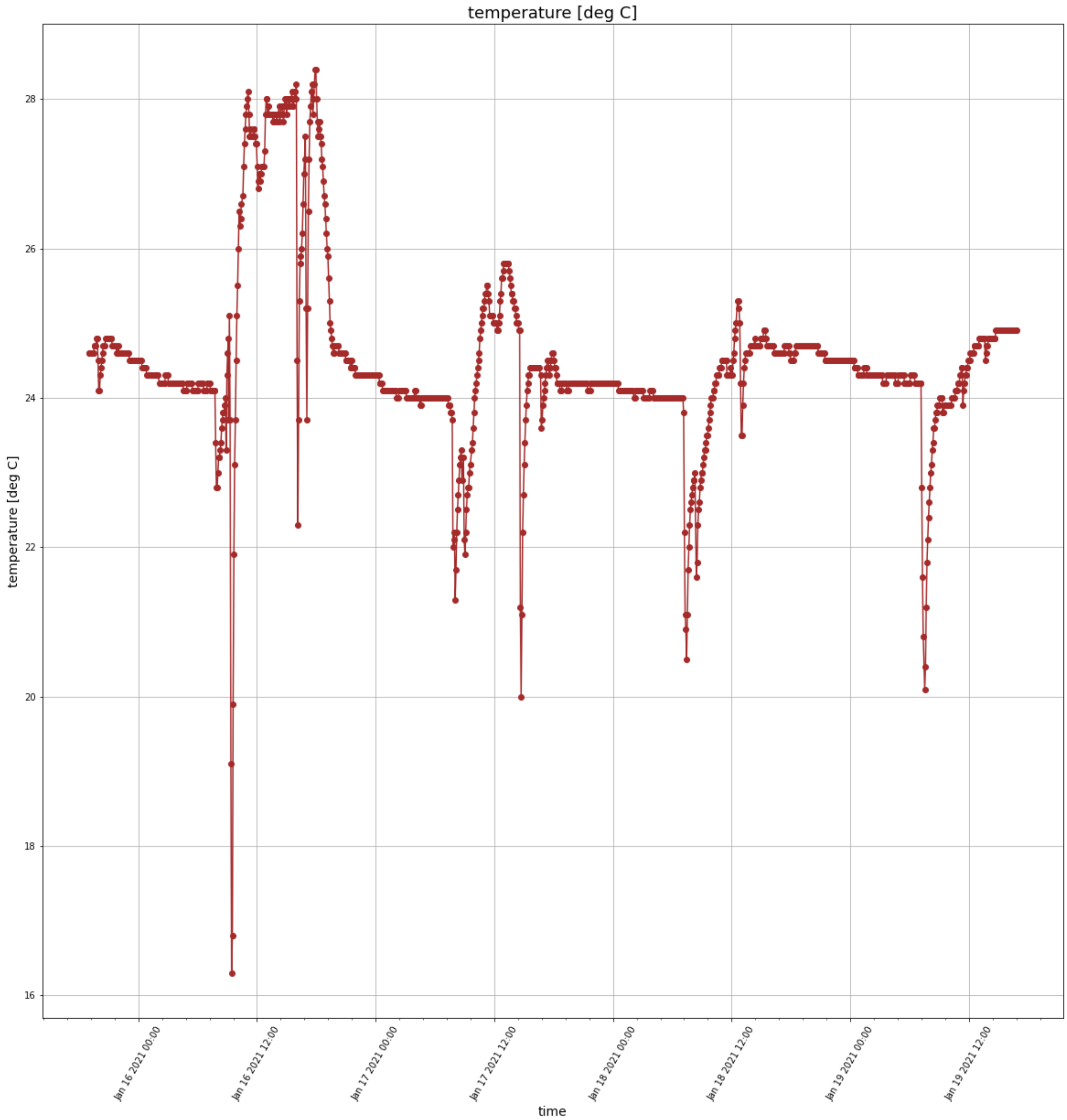
In [3]:

```
import matplotlib.pyplot as plt
import matplotlib.dates as mdates
from matplotlib.dates import DateFormatter
from matplotlib.ticker import (MultipleLocator, FormatStrFormatter,
                               AutoMinorLocator)

fig, ax = plt.subplots(figsize=(20, 20))
plt.xticks(rotation=60)
ax.xaxis.set_major_formatter(DateFormatter('%b %d %Y %H:%M'))

ax.xaxis.set_minor_locator(AutoMinorLocator())

ax.plot_date(df['Datum'], df['raw_gas_resistance'], linestyle='solid', color='brown')
plt.title('uncorrected raw gas resistance [Ohm]', fontsize=14)
plt.xlabel('time', fontsize=18)
plt.ylabel('gas resistance 1 [Ohm]', fontsize=14)
plt.grid(True)
plt.show()
```



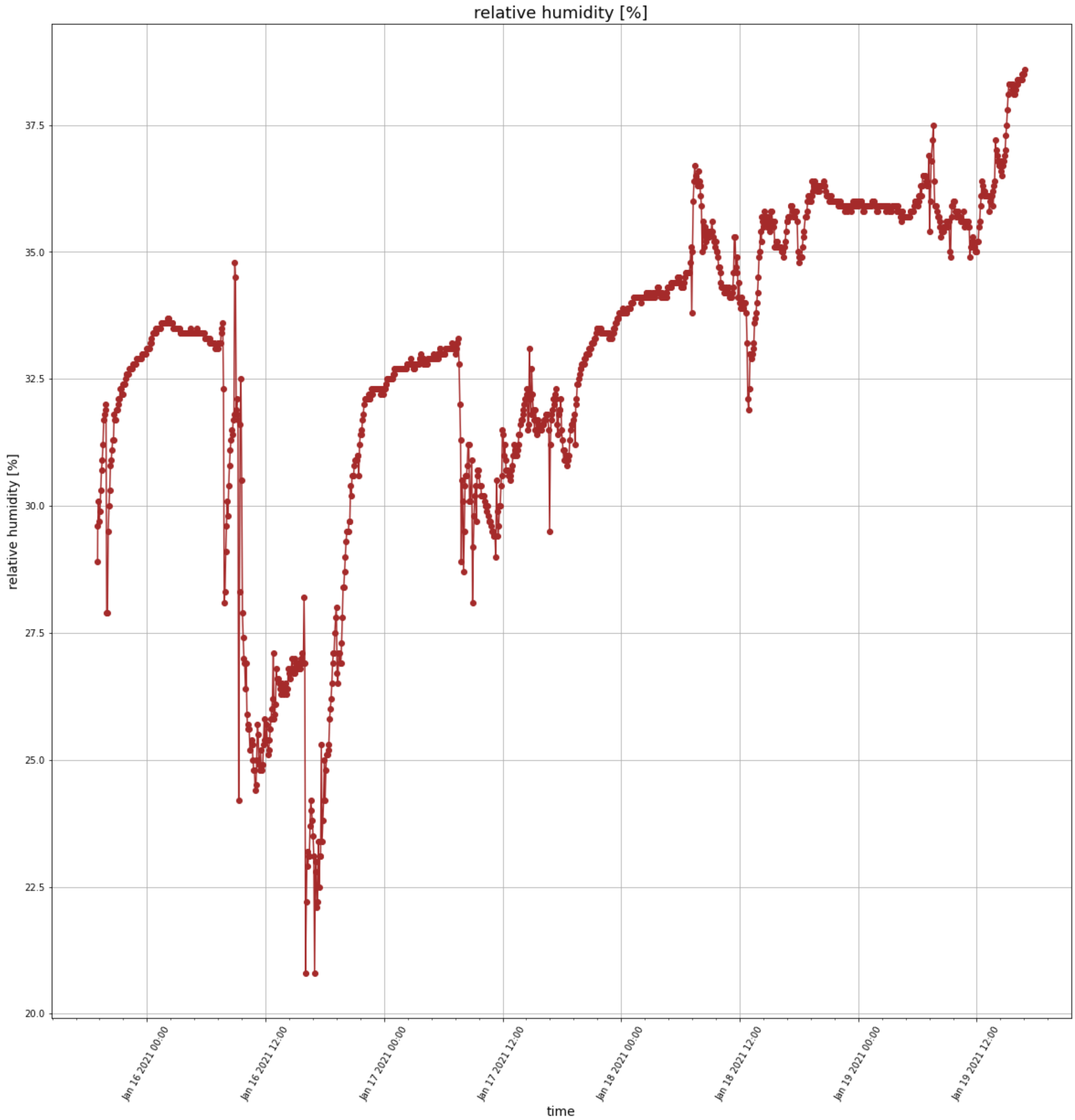
Time series diagram of the measured temperature

In [4]:
```
import matplotlib.pyplot as plt
import matplotlib.dates as mdates
from matplotlib.dates import DateFormatter
from matplotlib.ticker import (MultipleLocator, FormatStrFormatter,
                               AutoMinorLocator)

fig, ax = plt.subplots(figsize=(20, 20))
plt.xticks(rotation=60)
ax.xaxis.set_major_formatter(DateFormatter('%b %d %Y %H:%M'))

ax.xaxis.set_minor_locator(AutoMinorLocator())

ax.plot_date(df['Datum'], df['temperature'], linestyle='solid', color='brown')
plt.title('temperature [deg C]', fontsize=18)
plt.xlabel('time', fontsize=14)
plt.ylabel('temperature [deg C]', fontsize=14)
plt.grid(True)
plt.show()
```



Time series diagram of the measured relative humidity

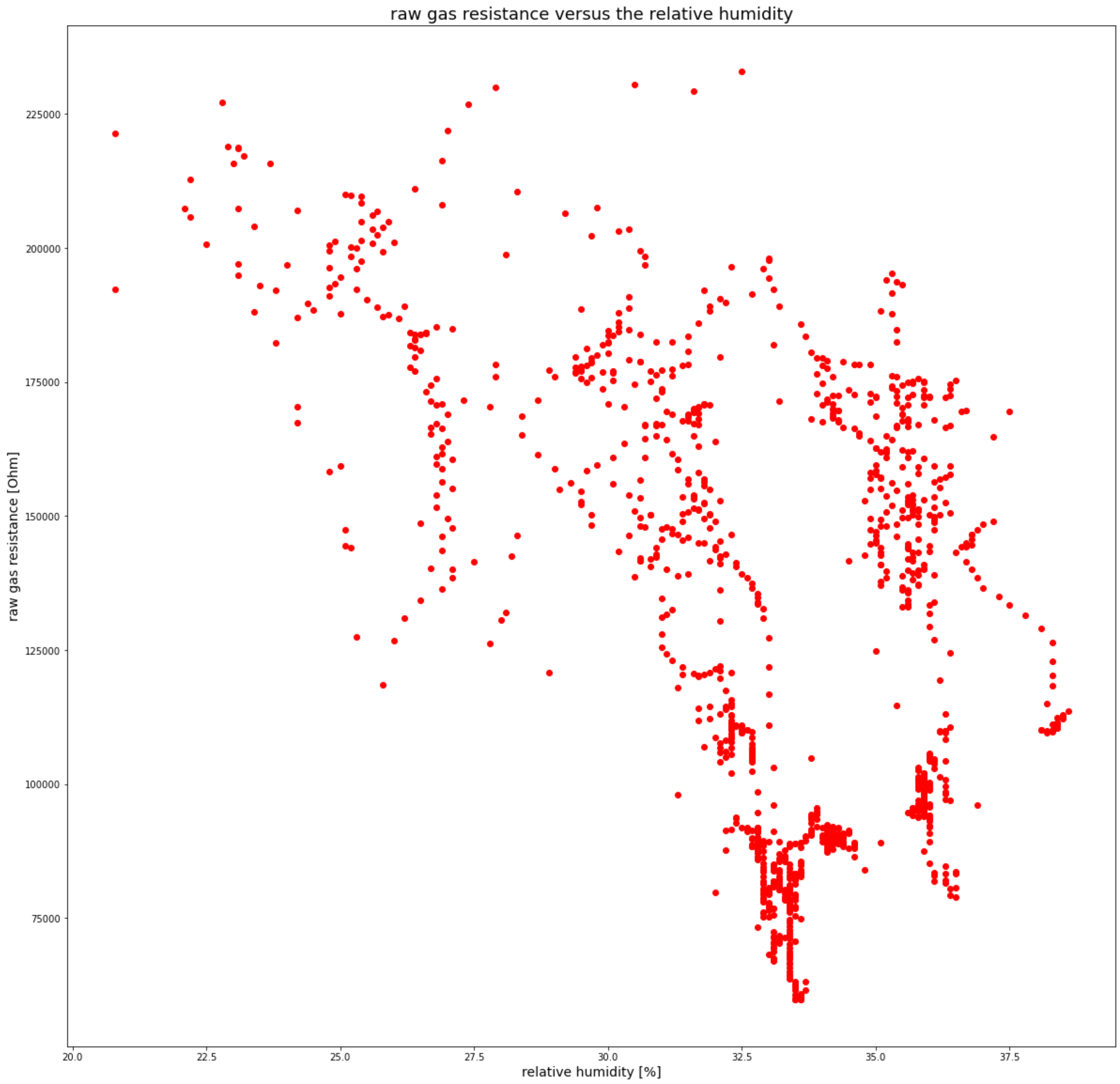
In [5]:
```python
import matplotlib.pyplot as plt
import matplotlib.dates as mdates
from matplotlib.dates import DateFormatter
from matplotlib.ticker import (MultipleLocator, FormatStrFormatter,
                               AutoMinorLocator)

fig, ax = plt.subplots(figsize=(20, 20))
plt.xticks(rotation=60)
ax.xaxis.set_major_formatter(DateFormatter('%b %d %Y %H:%M'))

ax.xaxis.set_minor_locator(AutoMinorLocator())

ax.plot_date(df['Datum'], df['relative_humidity'], linestyle='solid', color='brown')
plt.title('relative humidity [%]', fontsize=18)
plt.xlabel('time', fontsize=14)
plt.ylabel('relative humidity [%]', fontsize=14)
plt.grid(True)
plt.show()
```



Scatter plot of raw gas resistance versus the relative humidity, is the dependency somehow linear (should be for a multilinear regression)?

In [6]:

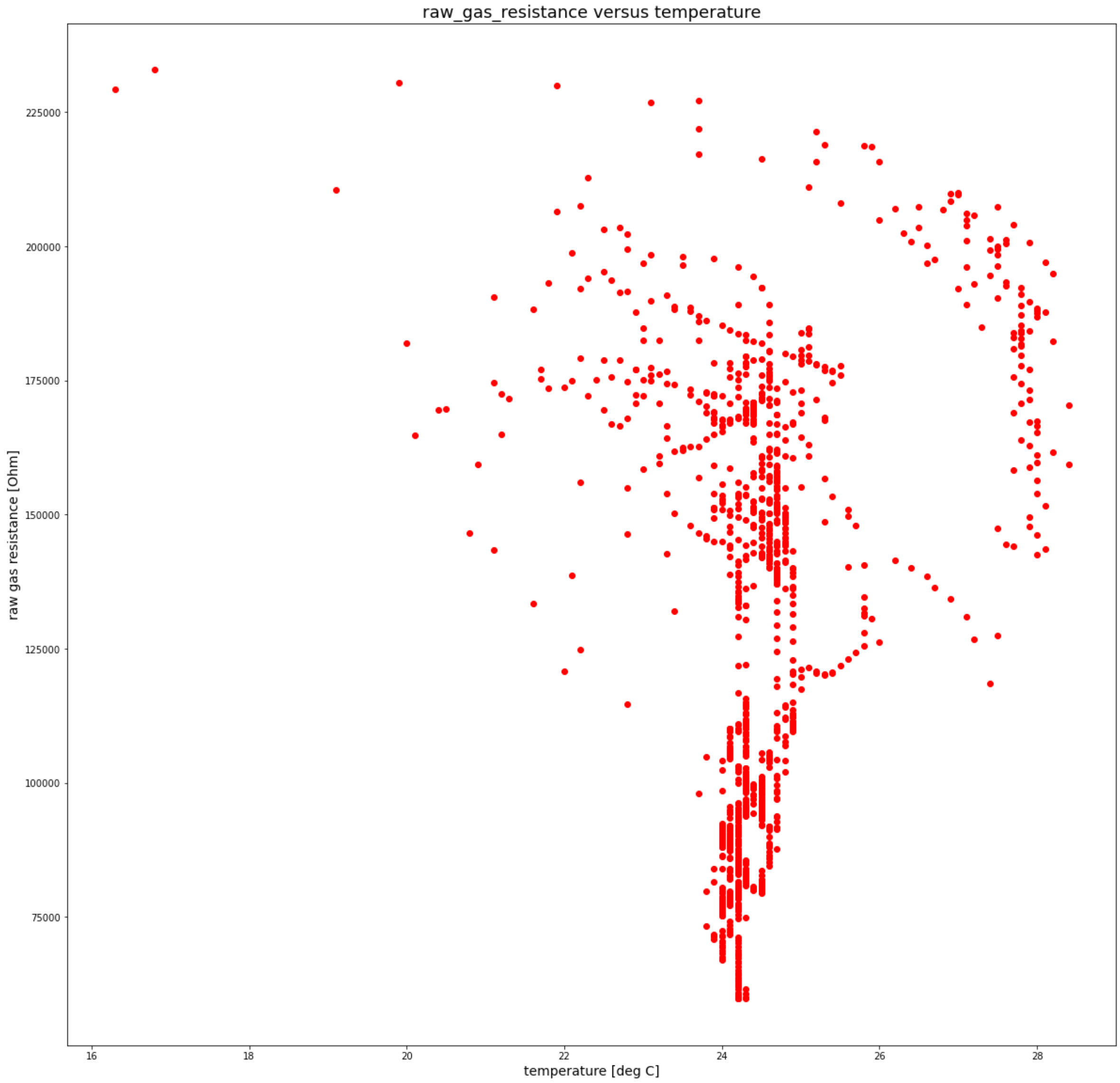
```
import pandas as pd
import matplotlib.pyplot as plt
import numpy as np


plt.figure(figsize=(20,20))

plt.scatter(df['relative_humidity'], df['raw_gas_resistance'], color='red')
plt.title('raw gas resistance versus the relative humidity', fontsize=18)
plt.xlabel('relative humidity [%]', fontsize=14)
plt.ylabel('raw gas resistance [Ohm]', fontsize=14)
plt.show()
```



Scatter plot of raw gas resistance versus the temperature, is the dependency somehow linear (should be for a multilinear regression)?

In [7]:

```
import pandas as pd
import matplotlib.pyplot as plt
import numpy as np


plt.figure(figsize=(20,20))
plt.scatter(df['temperature'], df['raw_gas_resistance'], color='red')
plt.title('raw_gas_resistance versus temperature', fontsize=18)
plt.xlabel('temperature [deg C]', fontsize=14)
plt.ylabel('raw gas resistance [Ohm]', fontsize=14)
plt.grid(False)
plt.show()
```



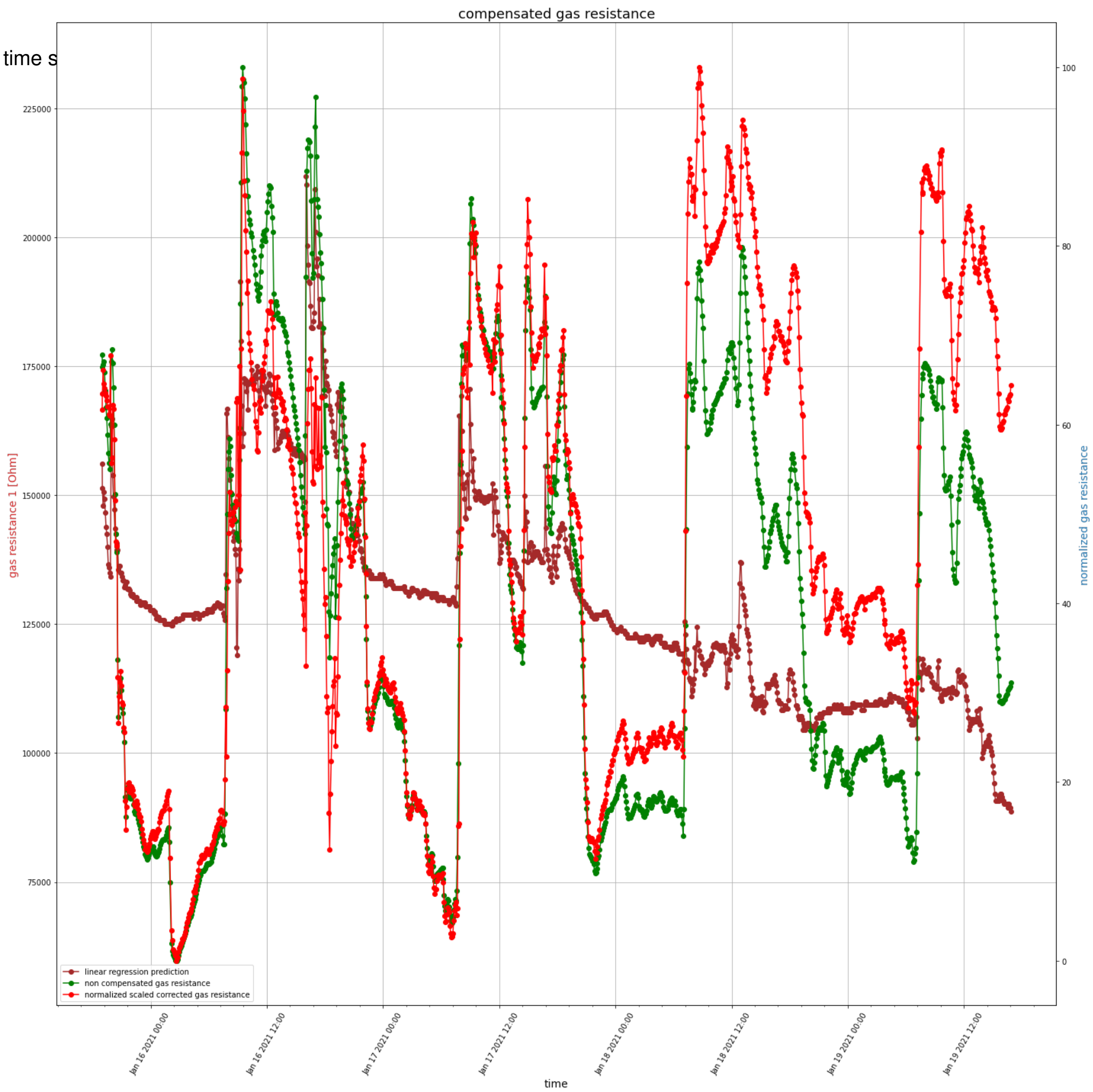
Execute a multiple linear regression of raw gas resistance oin dependency of the relative humidity and the temperature
use the prediction 'predictions1' of the mutiple linear regression to create a corrected gas resistance 'residuals' with eliminated influence of the relative humidity and the temperature
create a normalized scaled corrected gas resistance 'normalized_residuals'

In [8]:

```
import pandas as pd
from sklearn import linear_model
import statsmodels.api as sm
import matplotlib.pyplot as plt
import matplotlib.dates as mdates
from matplotlib.dates import DateFormatter
from matplotlib.ticker import (MultipleLocator, FormatStrFormatter,
                               AutoMinorLocator)


X = df[['temperature','relative_humidity']] # here we have 2 variables for multiple r
Y = df['raw_gas_resistance']

# with sklearn
regr = linear_model.LinearRegression()
regr.fit(X, Y)

print('Intercept: \n', regr.intercept_)
print('Coefficients: \n', regr.coef_)

X = sm.add_constant(X)
model = sm.OLS(Y, X).fit()
predictions = model.predict(X)

print_model = model.summary()
print(print_model)
print(model.rsquared)

print(len(X))

residuals=df['raw_gas_resistance']-predictions
min_res=min(residuals)
max_res=max(residuals)

#clip min of residual to epsilon in order to avoid a log(0) trap
epsilon=0.0001

normalized_residuals=((residuals-min_res)/(max_res-min_res)).clip(epsilon,None)*100


fig, ax1 = plt.subplots(figsize=(20, 20))
plt.xticks(rotation=60)
ax1.xaxis.set_major_formatter(DateFormatter('%b %d %Y %H:%M'))

ax1.xaxis.set_minor_locator(AutoMinorLocator())

lns1=ax1.plot_date(df['Datum'], predictions, linestyle='solid', color='brown', label=
lns2=ax1.plot_date(df['Datum'], df['raw_gas_resistance'], linestyle='solid', color='g
color = 'tab:red'
ax1.set_xlabel('time', fontsize=14)
ax1.set_ylabel('gas resistance 1 [Ohm]', color=color, fontsize=14)

ax2 = ax1.twinx()  # instantiate a second axes that shares the same x-axis
ax2.xaxis.set_major_formatter(DateFormatter('%b %d %Y %H:%M'))

ax2.xaxis.set_minor_locator(AutoMinorLocator())

color = 'tab:blue'
ax2.set_ylabel('normalized gas resistance', color=color, fontsize=14)  # we already h
lns3=ax2.plot_date(df['Datum'], normalized_residuals, linestyle='solid', color='red',

plt.title('compensated gas resistance', fontsize=18)

ax1.grid(True)
lns = lns1+lns2+lns3
labs = [l.get_label() for l in lns]
ax1.legend(lns, labs, loc="lower left")

fig.tight_layout()  # otherwise the right y-label is slightly clipped
plt.show()

```

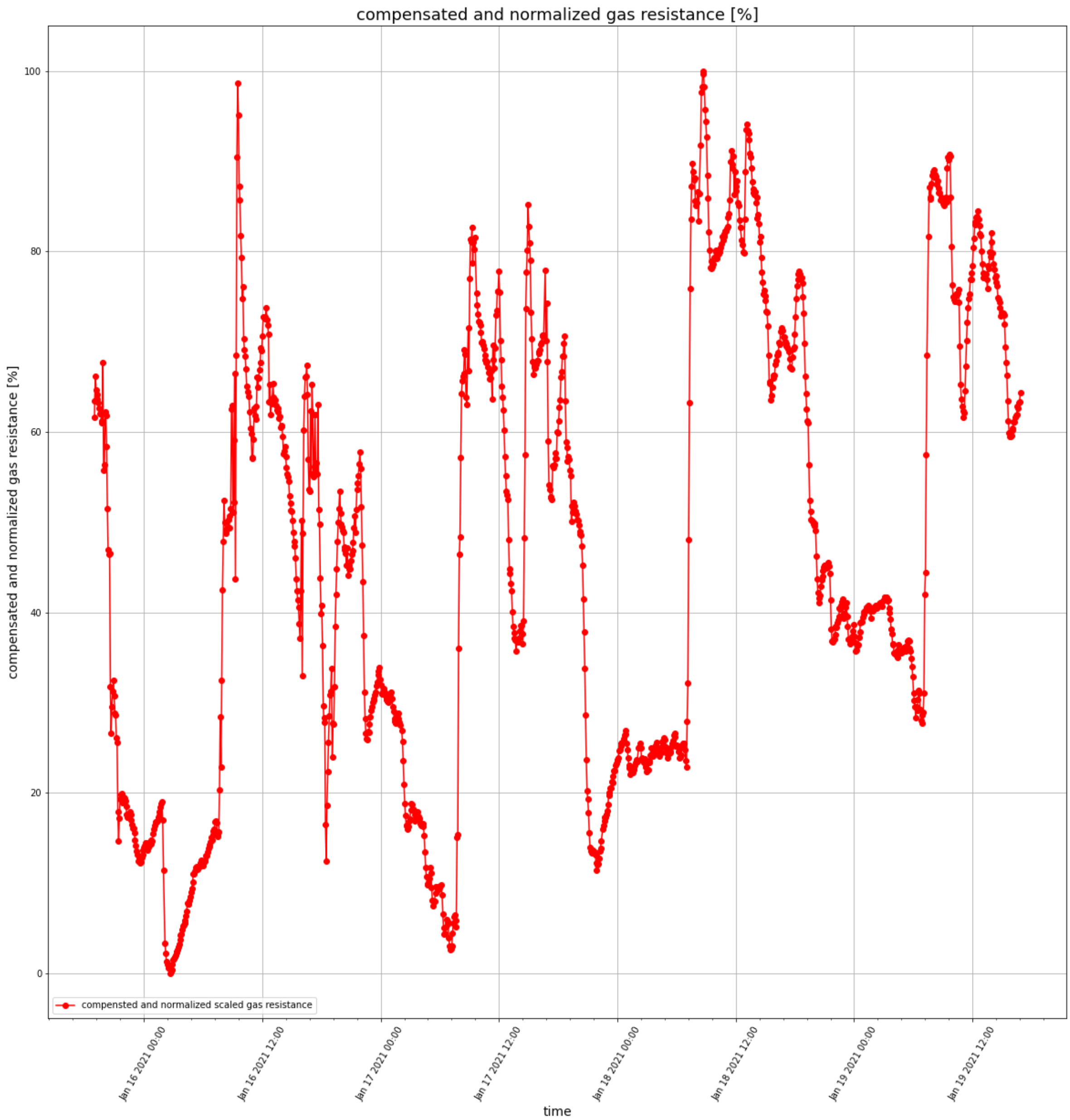
```
Intercept: 
 441752.56271364645
Coefficients: 
```

```
 [-3580.07022682 -6835.83257652]
                            OLS Regression Results
==============================================================================
Dep. Variable:     raw_gas_resistance   R-squared:                       0.240
Model:                            OLS   Adj. R-squared:                  0.238
Method:                 Least Squares   F-statistic:                     192.7
Date:                Sat, 03 Jun 2023   Prob (F-statistic):           1.82e-73
Time:                        14:45:11   Log-Likelihood:                -14600.
No. Observations:                1226   AIC:                         2.921e+04
Df Residuals:                    1223   BIC:                         2.922e+04
Df Model:                           2
Covariance Type:            nonrobust
=====================================================================================
                        coef    std err          t      P>|t|      [0.025      0.975]
-------------------------------------------------------------------------------------
const              4.418e+05   3.31e+04     13.348      0.000    3.77e+05    5.07e+05
temperature       -3580.0702   1010.716     -3.542      0.000   -5563.000   -1597.140
relative_humidity -6835.8326    375.767    -18.192      0.000   -7573.053   -6098.612
==============================================================================
Omnibus:                      856.831   Durbin-Watson:                   0.013
Prob(Omnibus):                  0.000   Jarque-Bera (JB):               72.785
Skew:                           0.048   Prob(JB):                     1.57e-16
Kurtosis:                       1.810   Cond. No.                     1.32e+03
==============================================================================

Notes:
[1] Standard Errors assume that the covariance matrix of the errors is correctly specif
ied.
[2] The condition number is large, 1.32e+03. This might indicate that there are
strong multicollinearity or other numerical problems.
0.23958989174335643
1226
```


time s
compensated gas resistance
gas resistance 1 [Ohm]
normalized gas resistance
time
225000
200000
175000
150000
125000
100000
75000
100
80
60
40
20
0
Jan 16 2021 00:00
Jan 16 2021 12:00
Jan 17 2021 00:00
Jan 17 2021 12:00
Jan 18 2021 00:00
Jan 18 2021 12:00
Jan 19 2021 00:00
Jan 19 2021 12:00
linear regression prediction
non compensated gas resistance
normalized scaled corrected gas resistance

In [9]:

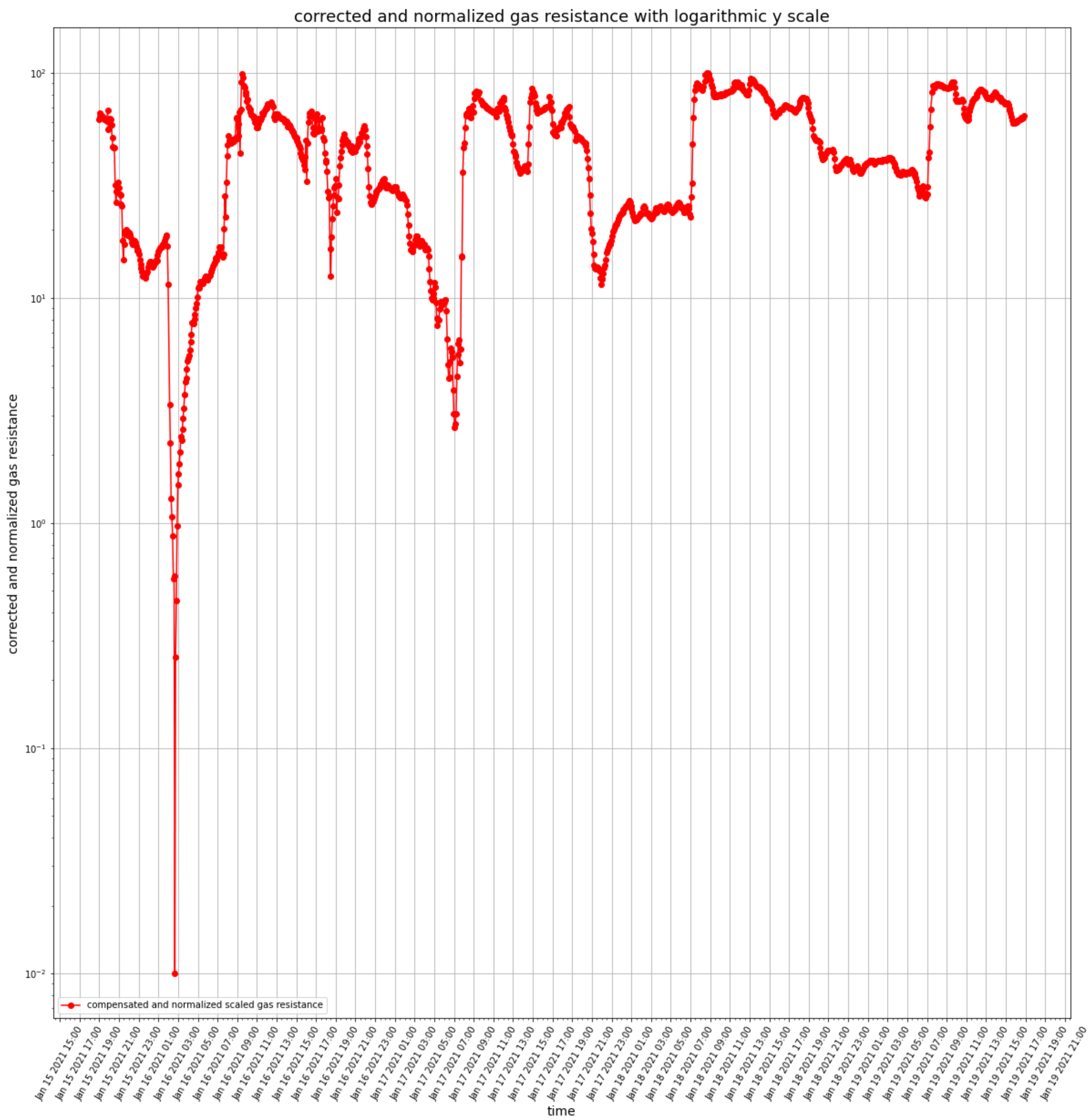
```
import pandas as pd
from sklearn import linear_model
import statsmodels.api as sm
import matplotlib.pyplot as plt
from datetime import datetime
from matplotlib.dates import DateFormatter
from matplotlib.ticker import (MultipleLocator, FormatStrFormatter,
                               AutoMinorLocator)


fig, ax = plt.subplots(figsize=(20, 20))
plt.xticks(rotation=60)
ax.xaxis.set_major_formatter(DateFormatter('%b %d %Y %H:%M'))

ax.xaxis.set_minor_locator(AutoMinorLocator())

plt.plot_date(df['Datum'], normalized_residuals, linestyle='solid', color='red', labe

plt.title('compensated and normalized gas resistance [%]', fontsize=18)
plt.xlabel('time', fontsize=14)
plt.ylabel('compensated and normalized gas resistance [%]', fontsize=14)
plt.grid(True)
plt.legend(loc ="lower left")
plt.show()
```



time series diagrams of compensated and normalized scaled gas resistance with logarithmic y scale 0.01 .. 100

In [10]:

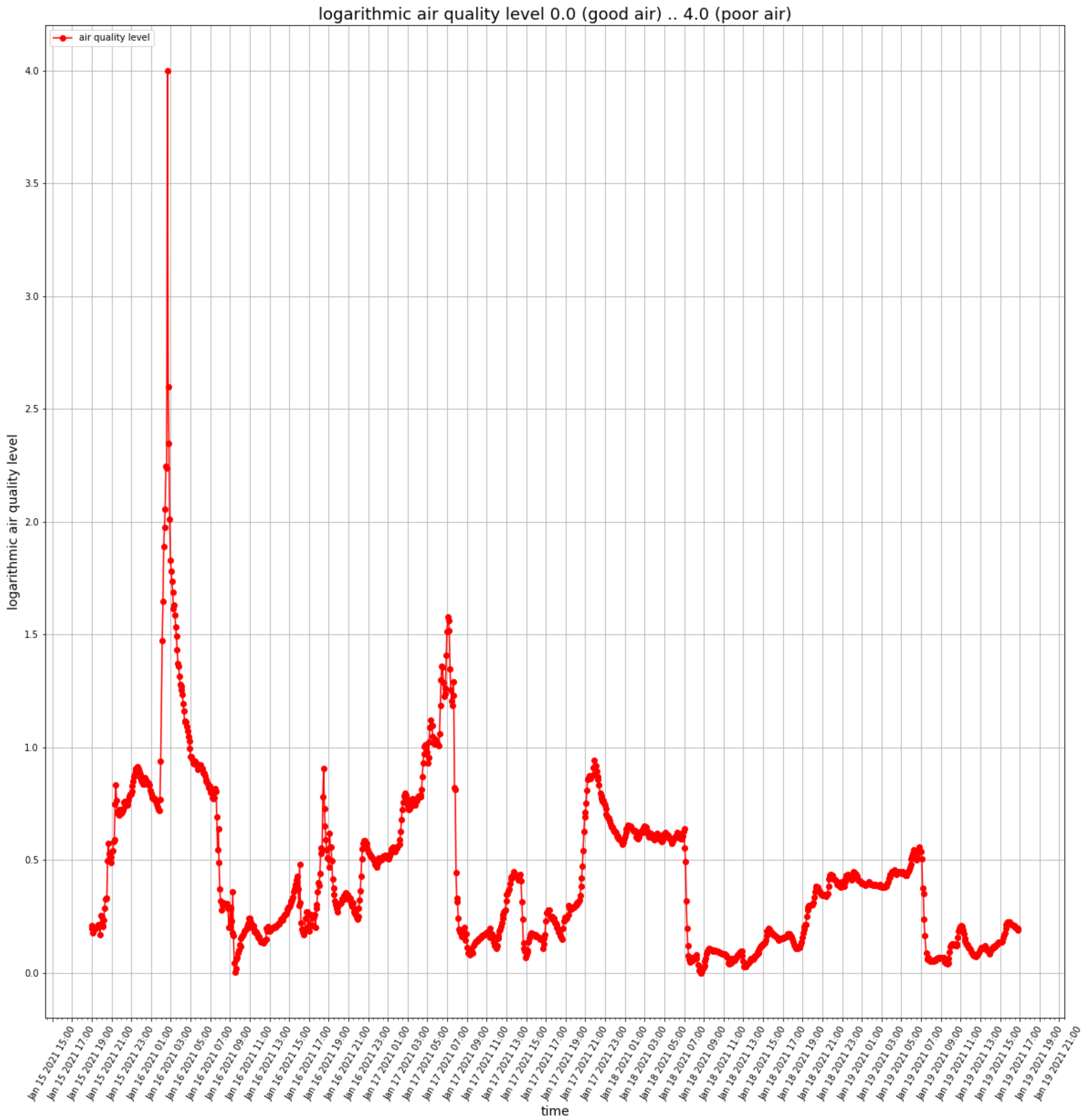
```
import pandas as pd
from sklearn import linear_model
import statsmodels.api as sm
import matplotlib.pyplot as plt
from datetime import datetime
from matplotlib.dates import DateFormatter
from matplotlib.ticker import (MultipleLocator, FormatStrFormatter,
                               AutoMinorLocator)


fig, ax = plt.subplots(figsize=(20, 20))
plt.yscale('log')
plt.xticks(rotation=60)
ax.xaxis.set_major_formatter(DateFormatter('%b %d %Y %H:%M'))
hours = mdates.HourLocator(interval = 2)
ax.xaxis.set_major_locator(hours)
ax.xaxis.set_minor_locator(AutoMinorLocator())


plt.xticks(rotation=60)
plt.plot_date(df['Datum'], normalized_residuals, linestyle='solid', color='red', labe

plt.title('corrected and normalized gas resistance with logarithmic y scale', fontsiz
plt.xlabel('time', fontsize=14)
plt.ylabel('corrected and normalized gas resistance', fontsize=14)
plt.grid(True)
plt.legend(loc ="lower left")
plt.show()
```



time series diagrams of the logarithmic air quality level the air quality level can vary between 0.0 (fresh air) and 4.0 (very poor air quality)

In [11]:

```
import pandas as pd
from sklearn import linear_model
import statsmodels.api as sm
import matplotlib.pyplot as plt
from datetime import datetime
from matplotlib.dates import DateFormatter
from matplotlib.ticker import (MultipleLocator, FormatStrFormatter,
                               AutoMinorLocator)

log_normalized_residuals = -(np.log10(normalized_residuals)-2)


fig, ax = plt.subplots(figsize=(20, 20))
plt.xticks(rotation=60)
ax.xaxis.set_major_formatter(DateFormatter('%b %d %Y %H:%M'))
hours = mdates.HourLocator(interval = 2)
ax.xaxis.set_major_locator(hours)
ax.xaxis.set_minor_locator(AutoMinorLocator())


plt.xticks(rotation=60)
plt.plot_date(df['Datum'], log_normalized_residuals, linestyle='solid', color='red',

plt.title('logarithmic air quality level 0.0 (good air) .. 4.0 (poor air)', fontsize=
plt.xlabel('time', fontsize=14)
plt.ylabel('logarithmic air quality level', fontsize=14)
plt.grid(True)
plt.legend(loc ="upper left")
plt.show()
```



Please check whether the R-squared (uncentered) of the multiple linear regression above is sufficiently good (should be > 0.7): R-squared (also called coefficient of determination) is the portion of variance in the dependent variables that can be explained by the independent variables. Hence, as a rule of thumb for interpreting the strength of a relationship based on its R-squared value is:

- if R-squared value < 0.3 this value is generally considered as None or very weak effect size
- if R-squared value 0.3 < r < 0.5 this value is generally considered as weak or low effect size
- if R-squared value 0.5 < r < 0.7 this value is generally considered as moderate effect size
- if R-squared value 0.7 < r < 1.0 this value is generally considered as strong effect size

If R-squared value is < 0.3, the collected history may be too short. Please try to collect datapoints for a longer timeframe!

In [12]:

```
print("\n\nR-squared (uncentered) of the multiple linear regression      = %11.2lf\r
```

```
R-squared (uncentered) of the multiple linear regression      =        0.24
```

Important note: Please do not use the calculated coefficients for the sensor ''HB-UNI-Sensor1-AQ-BME680' since the won't fit, see remark at the top.

Please enter the following parameters of the multilinear regression into the Homematic/RaspberryMatic WebUI page 'Startseite > Einstellungen > Geräte > Geräte-/ Kanalparameter einstellen' of your concerning BME680 AQ sensor device
which was the source of the history.csv file above

In [13]:

```
print("\nNumber of captured data points used for the MLR                    = %11d"

print("\nPlease enter the WebUI device parameter 'WEATHER|mlr_alpha'         = %11.3l
print("Please enter the WebUI device parameter 'WEATHER|mlr_beta'          = %11.3lf'
print("Please enter the WebUI device parameter 'WEATHER|mlr_delta'         = %11.3lf'

import datetime
now = datetime.datetime.now()
print("\n\nPlease check whether current date and time are correct: ")
print(str(now))

```

```
Number of captured data points used for the MLR                  =        1226

Please enter the WebUI device parameter 'WEATHER|mlr_alpha'         =   -3580.070
Please enter the WebUI device parameter 'WEATHER|mlr_beta'          =   -6835.833
Please enter the WebUI device parameter 'WEATHER|mlr_delta'         =  441752.563


Please check whether current date and time are correct: 
2023-06-03 14:45:14.456795
```

Congratulations, you are done!

Please repeat the multilinear regression update of the WebUI device parameters on a regular basis every month or similar as appropriate ..