

# Dark-Fiber Charakterisierung

## für entanglement polarisierter QKD

Analyse des Einflusses meteorologischer Faktoren auf Messdaten

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**Datensatz:** Nordhausen - Sundhausen

### 1 Vorbereitung der Datenanalyse

#### 1.1 Ressourcen und Literatur

- Messdaten
- Messgerät
- Open-Meteo: [Wetterdaten](#) & [Dokumentation](#)
- Sonnenauf- und untergang

#### 1.2 Verwendete Libraries / Softwaretools

```
[2]: import requests
import pandas as pd
import matplotlib.pyplot as plt
import matplotlib.dates as mdates
import numpy as np
import io
import datetime
```

#### 1.3 Eigene Hilfsfunktionen

```
[3]: def lowpass(data, box = 100):
    box = box
    LP_filter = np.full(int(box), 1/box)
    lps = np.convolve(ydata, LP_filter)
    lps = lps[ int((box-1) / 2) :len(lps) - int((box - 1) / 2)]
```

```

    return lps

def highpass(data, box = 100):
    lps = lowpass(data, box)
    hps = data - lps[:-1]
    return hps

```

```
[4]: def butter_filter(data, cutoff, fs=18, order=4, btype='low'):
    nyq = 0.5 * fs
    normal_cutoff = cutoff / nyq
    b, a = butter(order, normal_cutoff, btype=btype, analog=False)
    y = filtfilt(b, a, data)
    return y
```

## 2 Aufbereitung der Wetterdaten

```
[5]: # Nordhausen - Breitengrad: 51.5 & Längengrad: 10.8
```

```

url = (
    "https://archive-api.open-meteo.com/v1/archive?"
    "latitude=51.5&longitude=10.8&"
    "start_date=2024-11-29&end_date=2024-12-03&"
    "hourly=temperature_2m,relative_humidity_2m,cloud_cover,wind_speed_10m,wind_direction_10m,rain"
    "timezone=Europe/Berlin"
)

response = requests.get(url)

if response.status_code == 200:
    data = response.json()
    weather = pd.DataFrame(data["hourly"])
    print(weather.head())
else:
    print("Fehler beim Abrufen:", response.status_code)
    print(response.text)
```

	time	temperature_2m	relative_humidity_2m	cloud_cover	\
0	2024-11-29T00:00	4.3	86	100	
1	2024-11-29T01:00	4.0	88	99	
2	2024-11-29T02:00	3.9	88	99	
3	2024-11-29T03:00	3.4	92	50	
4	2024-11-29T04:00	2.6	95	77	

	wind_speed_10m	wind_direction_10m	rain
0	12.6	287	0.0
1	12.3	280	0.0

```

2          12.6          275   0.0
3          10.3          277   0.0
4          9.4          275   0.0

```

```
[6]: units = data['hourly_units']
weather_columns = []
for key, value in units.items():
    weather_columns.append(f'{key} [{value}]')

weather.columns = weather_columns
weather.head()
```

```
[6]:      time [iso8601]  temperature_2m [°C]  relative_humidity_2m [%]  \
0  2024-11-29T00:00          4.3            86
1  2024-11-29T01:00          4.0            88
2  2024-11-29T02:00          3.9            88
3  2024-11-29T03:00          3.4            92
4  2024-11-29T04:00          2.6            95
```

	cloud_cover [%]	wind_speed_10m [km/h]	wind_direction_10m [°]	rain [mm]
0	100	12.6	287	0.0
1	99	12.3	280	0.0
2	99	12.6	275	0.0
3	50	10.3	277	0.0
4	77	9.4	275	0.0

```
[7]: weather.to_csv("open-meteo_nordhausen.csv", index=False)
```

```
[8]: w_data = [
    {"header": "temperature_2m [°C]", "color": "tab:red", "unit": "°C", "label": "Temperature"},  

    {"header": "relative_humidity_2m [%]", "color": "tab:purple", "unit": "%", "label": "Humidity"},  

    {"header": "cloud_cover [%]", "color": "tab:gray", "unit": "%", "label": "Cloud Cover"},  

    {"header": "wind_speed_10m [km/h]", "color": "tab:green", "unit": "km/h", "label": "Windspeed"},  

    {"header": "wind_direction_10m [°]", "color": "tab:orange", "unit": "°", "label": "Winddirection"},  

    {"header": "rain [mm]", "color": "tab:cyan", "unit": "mm", "label": "Rain"}]  
  

for i in range(len(w_data)):  

    print(f'{i}: {w_data[i]["label"]}')
```

```

0: Temperature
1: Humidity
2: Cloud Cover

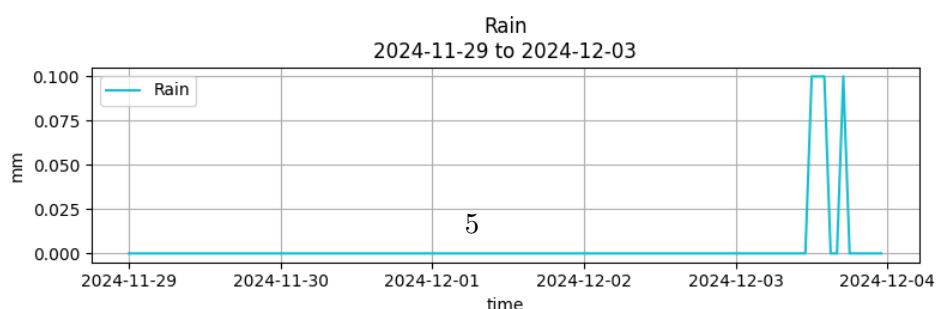
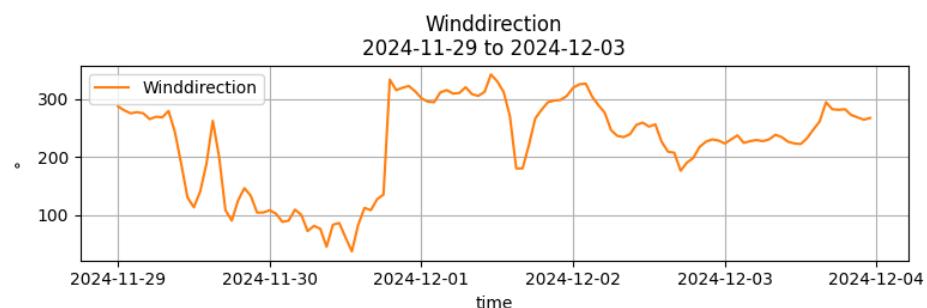
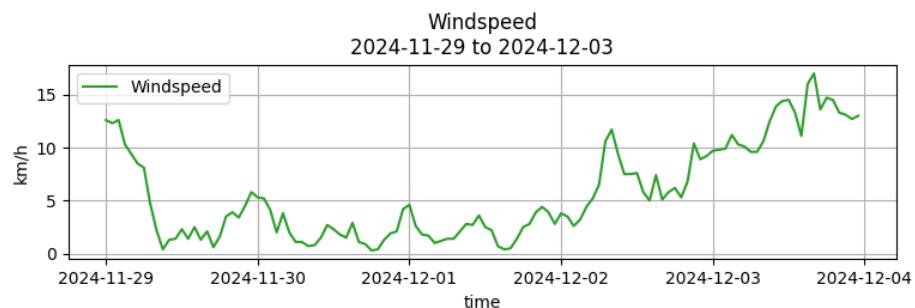
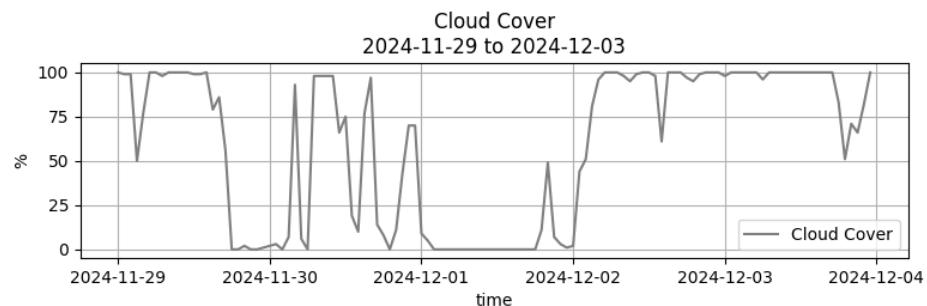
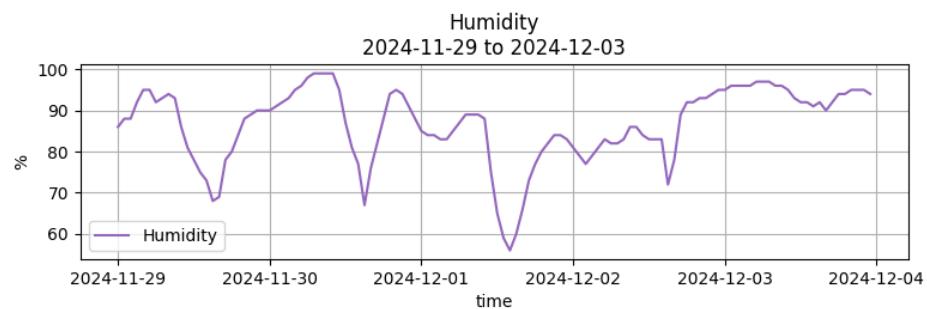
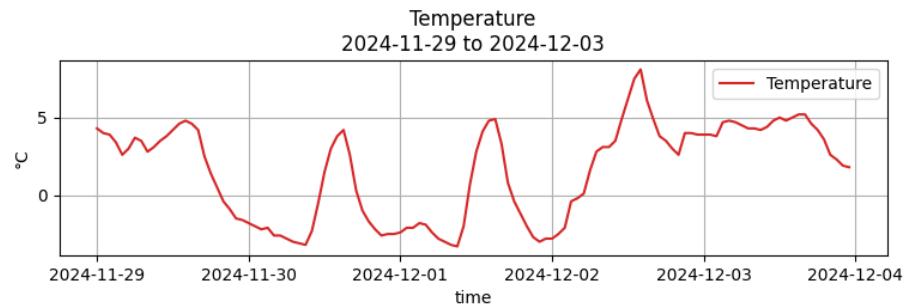
```

```
3: Windspeed  
4: Winddirection  
5: Rain
```

```
[9]: sunrise = [  
    datetime.datetime.strptime('2024-11-29 07:57:00', '%Y-%m-%d %H:%M:%S'),  
    datetime.datetime.strptime('2024-11-30 07:59:00', '%Y-%m-%d %H:%M:%S'),  
    datetime.datetime.strptime('2024-12-01 08:00:00', '%Y-%m-%d %H:%M:%S'),  
    datetime.datetime.strptime('2024-12-02 08:02:00', '%Y-%m-%d %H:%M:%S'),  
    datetime.datetime.strptime('2024-12-03 08:03:00', '%Y-%m-%d %H:%M:%S')  
]  
sunset = [  
    datetime.datetime.strptime('2024-11-29 16:12:00', '%Y-%m-%d %H:%M:%S'),  
    datetime.datetime.strptime('2024-11-30 16:11:00', '%Y-%m-%d %H:%M:%S'),  
    datetime.datetime.strptime('2024-12-01 16:11:00', '%Y-%m-%d %H:%M:%S'),  
    datetime.datetime.strptime('2024-12-02 16:10:00', '%Y-%m-%d %H:%M:%S'),  
    datetime.datetime.strptime('2024-12-03 16:09:00', '%Y-%m-%d %H:%M:%S')  
]
```

```
[10]: weather[weather_columns[0]] = pd.to_datetime(weather[weather_columns[0]])  
weather.set_index(weather_columns[0], inplace=True)
```

```
[11]: fig, axs = plt.subplots(len(w_data), 1, figsize=(8, 16), sharex=False)  
  
for i in range(len(w_data)):  
    ax = axs[i] if len(weather_columns) > 1 else axs  
    ax.plot(weather.index, weather[w_data[i]["header"]], label=w_data[i]["label"], color=w_data[i]["color"])  
  
    ax.grid()  
    ax.legend(loc='best')  
    ax.set_title(f'{w_data[i]["label"]}\n{weather.index[0].strftime("%Y-%m-%d")}\n{weather.index[-1].strftime("%Y-%m-%d")}')  
    ax.set_xlabel("time")  
    ax.set_ylabel(w_data[i]["unit"])  
  
plt.tight_layout()  
plt.show()
```



### 3 Aufbereitung der Messdaten

```
[12]: filename = '29.11.2024_10d.csv'
skip = 8
sep = ";"
```

```
columns = ['Time[date hh:mm:ss] ', ' Elapsed Time [hh:mm:ss:ms]', ' Normalized
↳ s 1 ', ' Normalized s 2 ', ' Normalized s 3 ', ' S 0 [mW]', ' S 1 [mW]', ' S
↳ 2 [mW]', ' S 3 [mW]', ' Azimuth[°] ', ' Ellipticity[°] ', ' DOP[%] ', ' ↳
↳ DOCP[%] ', ' DOLP[%] ', ' Power[mW] ', ' Pol Power[mW] ', ' Unpol Power[mW]
↳ ', ' Power[dBm] ', ' Pol Power[dBm] ', ' Unpol Power[dBm] ', ' ↳
↳ Power-Split-Ratio ', ' Phase Difference[°] ', ' Warning']
```

```
for c in range(len(columns)):
    print(c, ': ', columns[c])
```

```
0 : Time[date hh:mm:ss]
1 : Elapsed Time [hh:mm:ss:ms]
2 : Normalized s 1
3 : Normalized s 2
4 : Normalized s 3
5 : S 0 [mW]
6 : S 1 [mW]
7 : S 2 [mW]
8 : S 3 [mW]
9 : Azimuth[°]
10 : Ellipticity[°]
11 : DOP[%]
12 : DOCP[%]
13 : DOLP[%]
14 : Power[mW]
15 : Pol Power[mW]
16 : Unpol Power[mW]
17 : Power[dBm]
18 : Pol Power[dBm]
19 : Unpol Power[dBm]
20 : Power-Split-Ratio
21 : Phase Difference[°]
22 : Warning
```

## 4 Zusammenhang zwischen Messdaten und Wetterdaten

### 4.1 Polarisationsgrad (DOP[%])

```
[13]: degree = pd.read_csv(filename, skiprows=skip, sep=sep, usecols=[columns[0],  
    ↪columns[11]])
```

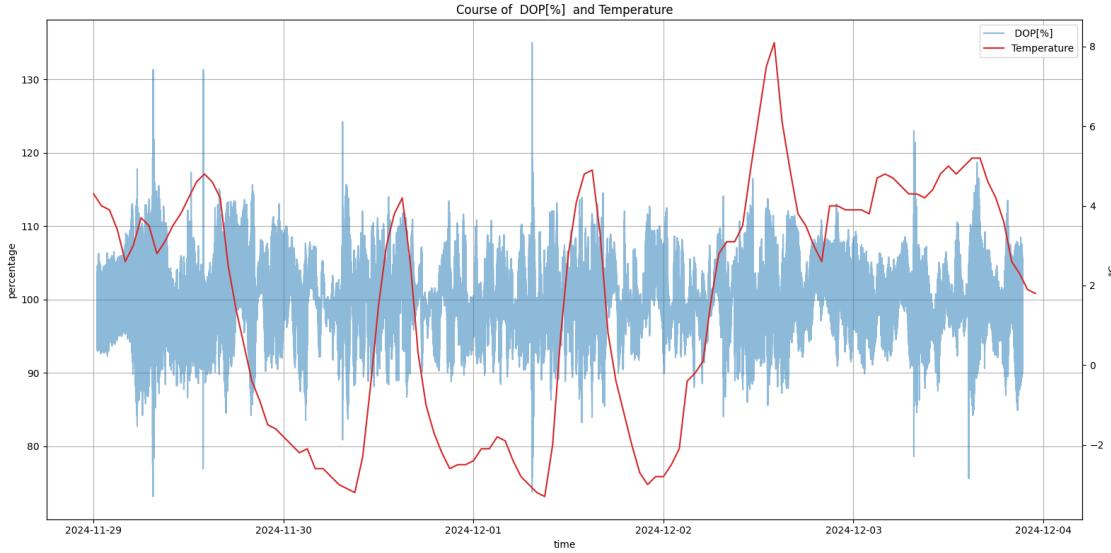
```
[14]: degree[columns[0]] = pd.to_datetime(degree[columns[0]])  
degree.set_index(columns[0], inplace=True)
```

```
[15]: degree = degree[columns[11]]  
degree = degree.drop(degree[(degree > 140) | (degree < 0)].index)  
  
degree_daily = degree.groupby(degree.index.date)  
degree_daily_list = list(degree_daily)
```

```
[16]: weather_daily = weather.groupby(weather.index.date)  
weather_daily_list = list(weather_daily)
```

#### 4.1.1 Originaldaten

```
[17]: current = 0 #Temperature  
  
fig, ax1 = plt.subplots(figsize=(16, 8))  
  
ax1.plot(degree.index, degree, label=columns[11], color="tab:blue", alpha = 0.5  
    ↪)  
ax1.set_xlabel('time')  
ax1.set_ylabel('percentage')  
h1, l1 = ax1.get_legend_handles_labels()  
  
ax2 = ax1.twinx()  
  
ax2.plot(weather.index, weather[w_data[current]["header"]],  
    ↪label=w_data[current]["label"], color = w_data[current]["color"])  
ax2.set_ylabel(w_data[current]["unit"])  
h2, l2 = ax2.get_legend_handles_labels()  
  
ax1.grid()  
ax1.legend(h1+h2, l1+l2, loc="best")  
ax1.set_title(f'Course of {columns[11]} and {w_data[current]["label"]}')  
  
plt.tight_layout()  
plt.show()
```



```
[18]: current = 0 # Temperature

fig, axs = plt.subplots(len(degree_daily_list), 1, figsize=(8, 16), sharex=False)

for i in range(len(degree_daily_list)):
    ax1 = axs[i] if len(degree_daily_list) > 1 else axs
    df_day = degree_daily_list[i][1]

    ax1.plot(df_day.index, df_day, label=columns[11], alpha=0.5)
    ax1.set_xlabel('time')
    ax1.set_ylabel('percentage')
    h1, l1 = ax1.get_legend_handles_labels()

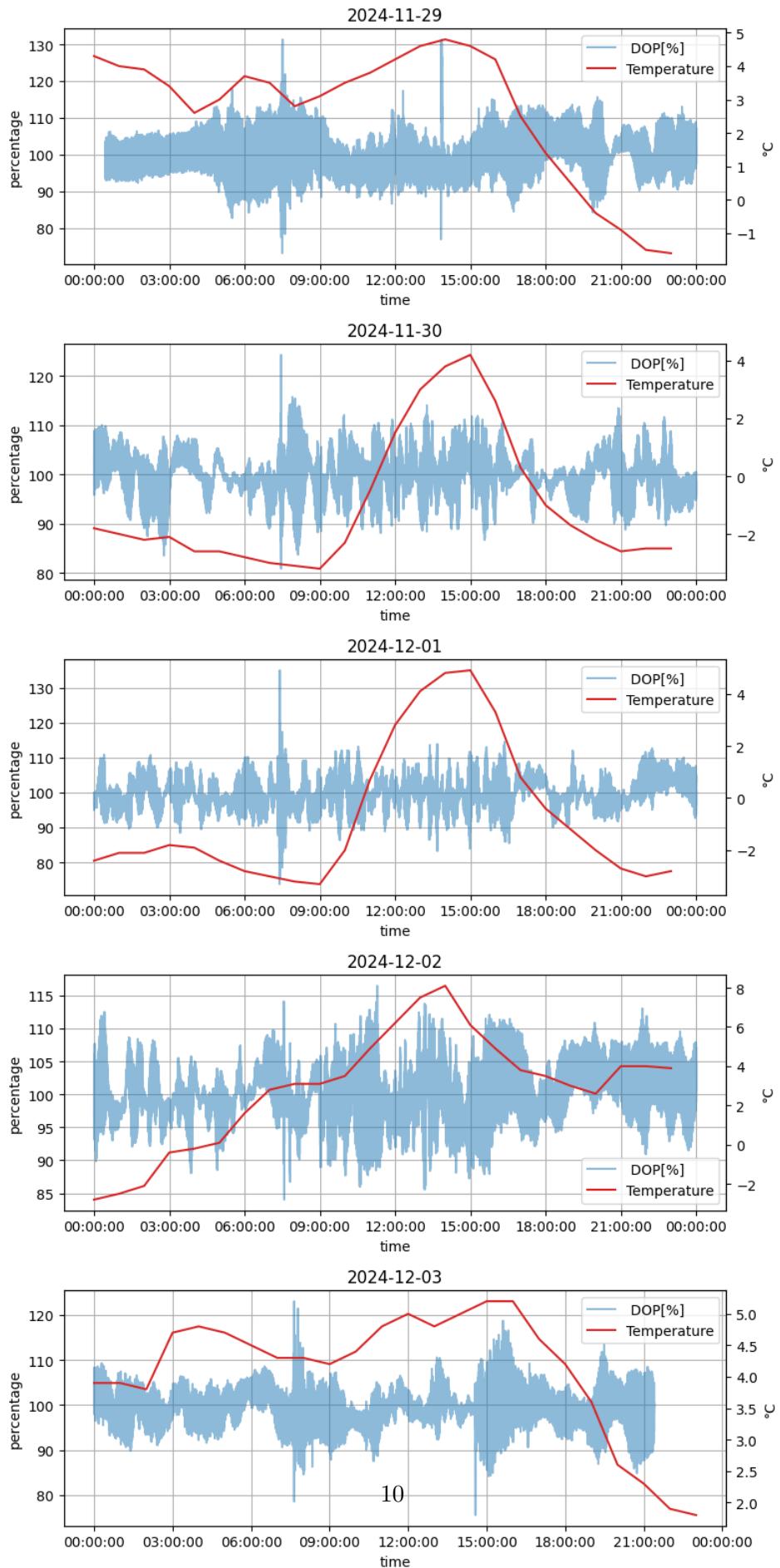
    ax2 = ax1.twinx()

    ax2.plot(weather_daily_list[i][1].index, weather_daily_list[i][1][w_data[current]["header"]], label=w_data[current]["label"], color = w_data[current]["color"])
    ax2.set_ylabel(w_data[current]["unit"])
    h2, l2 = ax2.get_legend_handles_labels()

    ax1.grid()
    ax1.legend(h1+h2, l1+l2, loc="best")
    ax1.set_title(degree_daily_list[i][0])
    ax1.xaxis.set_major_formatter(mdates.DateFormatter('%H:%M:%S'))

plt.tight_layout()
```

```
plt.show()
```



```
[19]: for current in range(len(w_data)):
    fig, ax1 = plt.subplots(figsize=(16, 8))

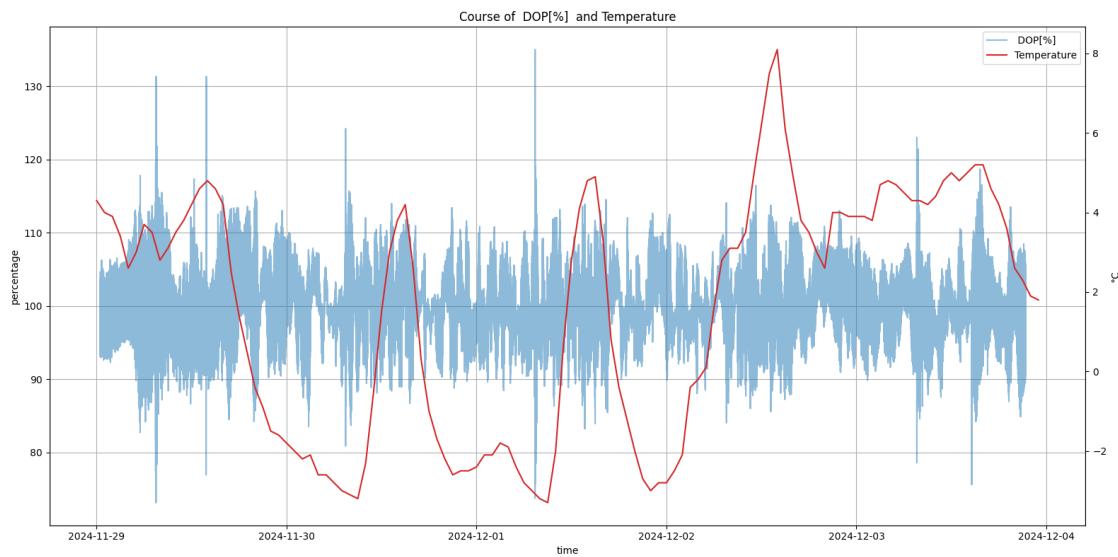
    ax1.plot(degree.index, degree, label=columns[11], color="tab:blue", alpha = 0.5)
    ax1.set_xlabel('time')
    ax1.set_ylabel('percentage')
    h1, l1 = ax1.get_legend_handles_labels()

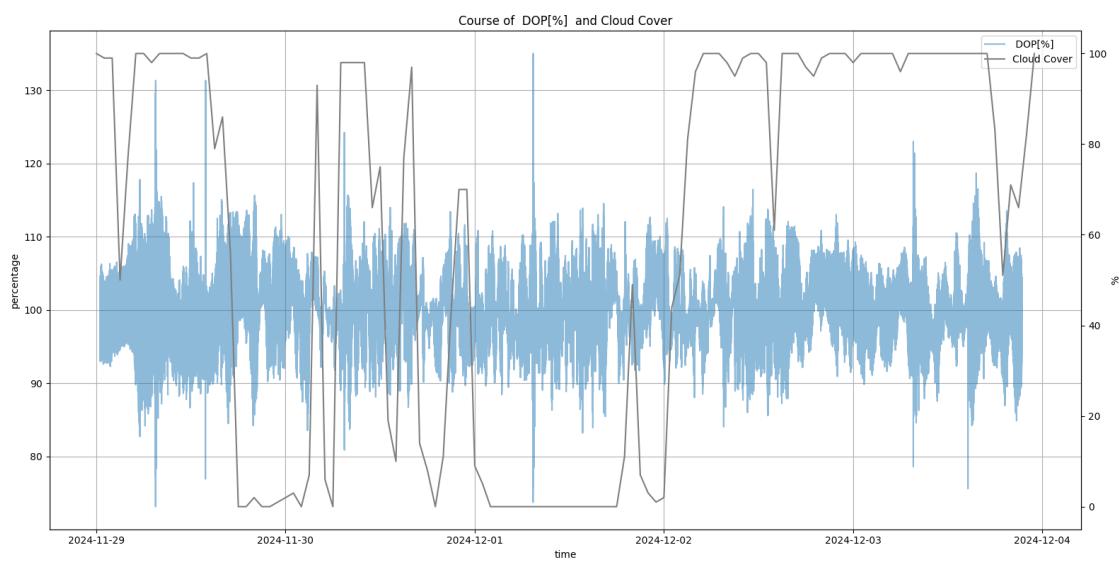
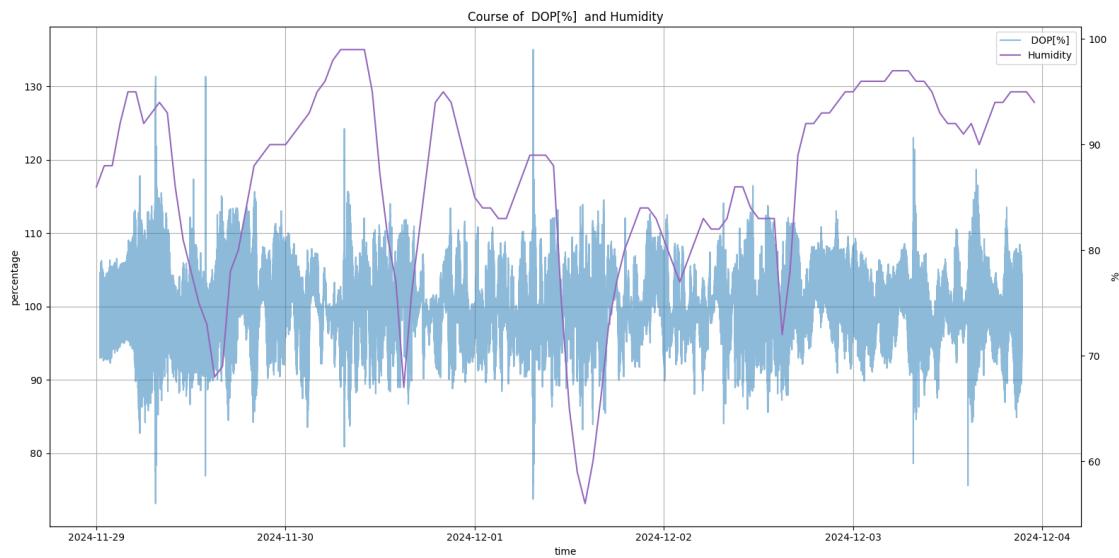
    ax2 = ax1.twinx()

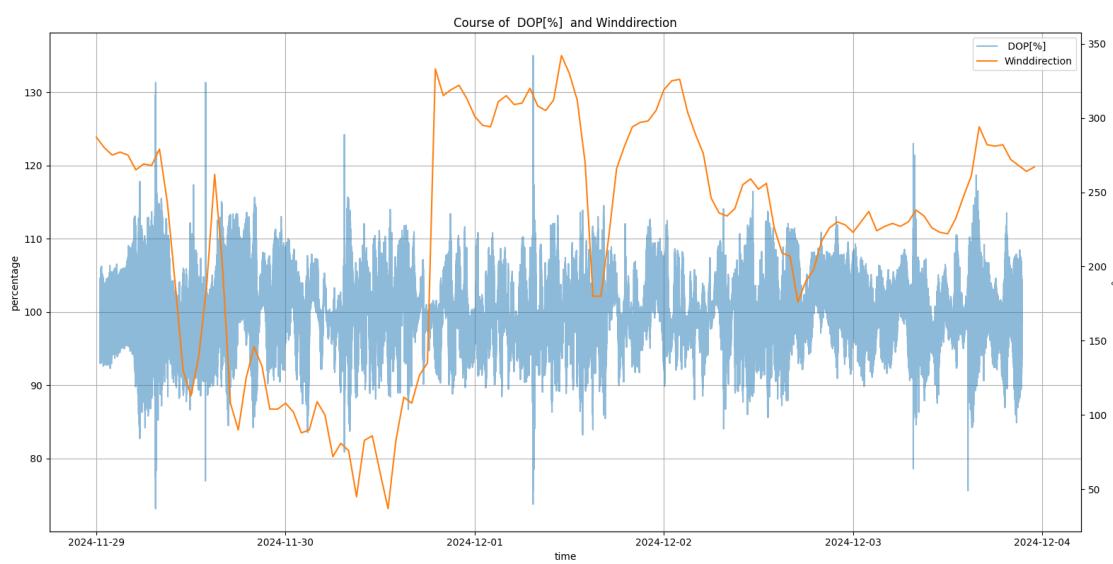
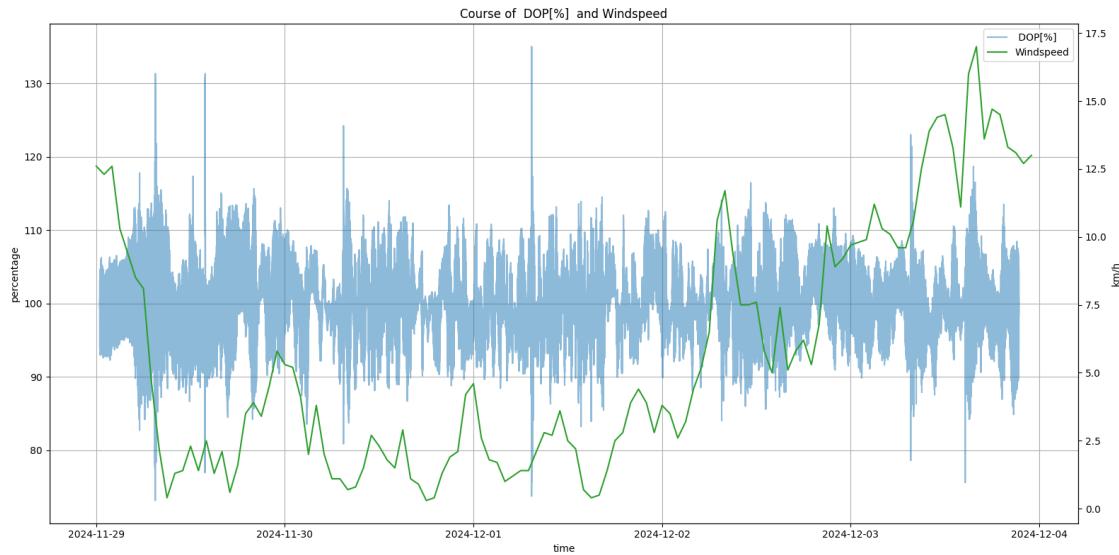
    ax2.plot(weather.index, weather[w_data[current]["header"]], label=w_data[current]["label"], color = w_data[current]["color"])
    ax2.set_ylabel(w_data[current]["unit"])
    h2, l2 = ax2.get_legend_handles_labels()

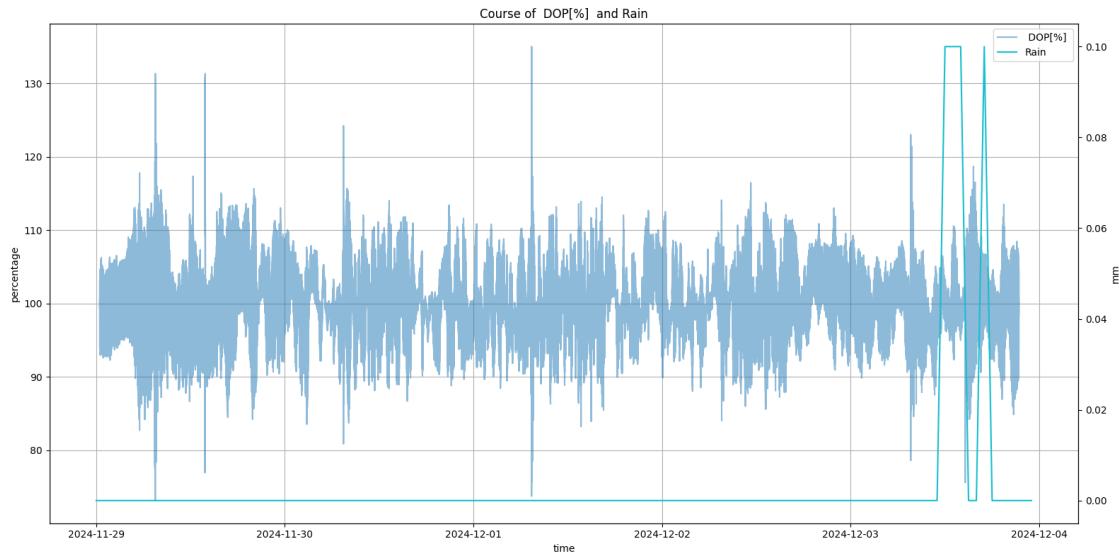
    ax1.grid()
    ax1.legend(h1+h2, l1+l2, loc="best")
    ax1.set_title(f'Course of {columns[11]} and {w_data[current]["label"]}')

    plt.tight_layout()
    plt.show()
```



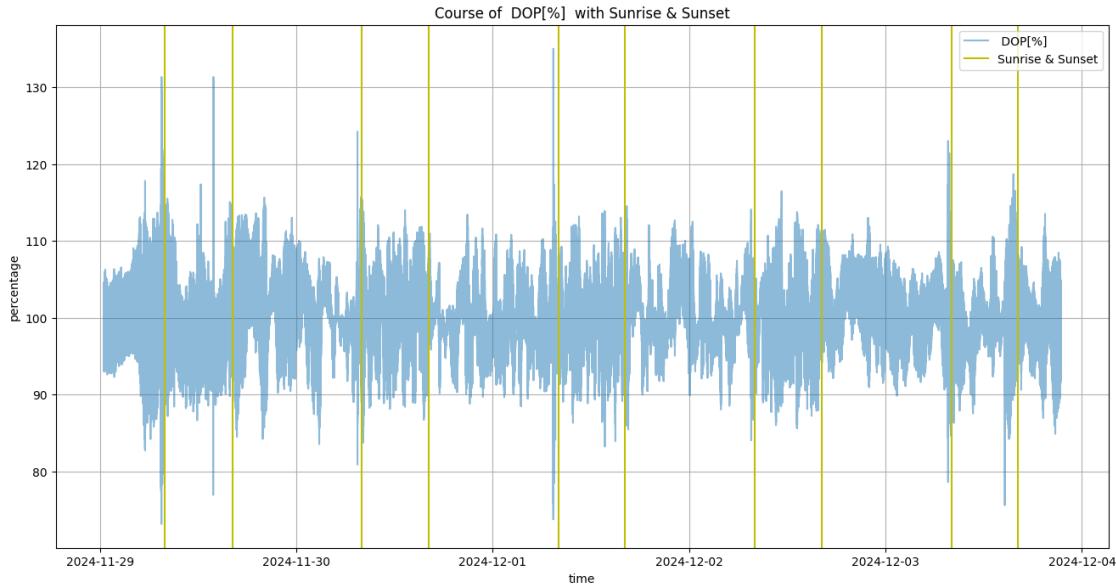






[20]: # Sunlight (day-night context)

```
plt.figure(figsize = (16,8))
plt.plot(degree.index, degree, label=columns[11], alpha = 0.5)
for i in range(len(sunrise)):
    plt.axvline(x = sunrise[i], color = 'y')
    if i == 0: plt.axvline(x = sunset[i], color = 'y',label = 'Sunrise & Sunset')
    else: plt.axvline(x = sunset[i], color = 'y')
plt.grid()
plt.legend(loc = 'best')
plt.title(f'Course of {columns[11]} with Sunrise & Sunset')
plt.xlabel('time')
plt.ylabel('percentage')
plt.show()
```



#### 4.1.2 Anwendung von Tief- und Hochpassfiltern

```
[21]: for current in range(len(w_data)):
    fig, ax1 = plt.subplots(figsize=(16, 8))

    ydata = np.array(degree)
    lps = lowpass(ydata, 1000)

    ax1.plot(degree.index, lps[:-1] , label=columns[11], color="tab:blue", alpha = 0.5 )
    ax1.set_xlabel('time')
    ax1.set_ylabel('percentage')
    h1, l1 = ax1.get_legend_handles_labels()

    ax2 = ax1.twinx()

    ax2.plot(weather.index, weather[w_data[current]["header"]], label=w_data[current]["label"], color = w_data[current]["color"])
    ax2.set_ylabel(w_data[current]["unit"])
    h2, l2 = ax2.get_legend_handles_labels()

    ax1.grid()
    ax1.legend(h1+h2, l1+l2, loc="best")
    ax1.set_title(f'Applied Low Pass Filter')

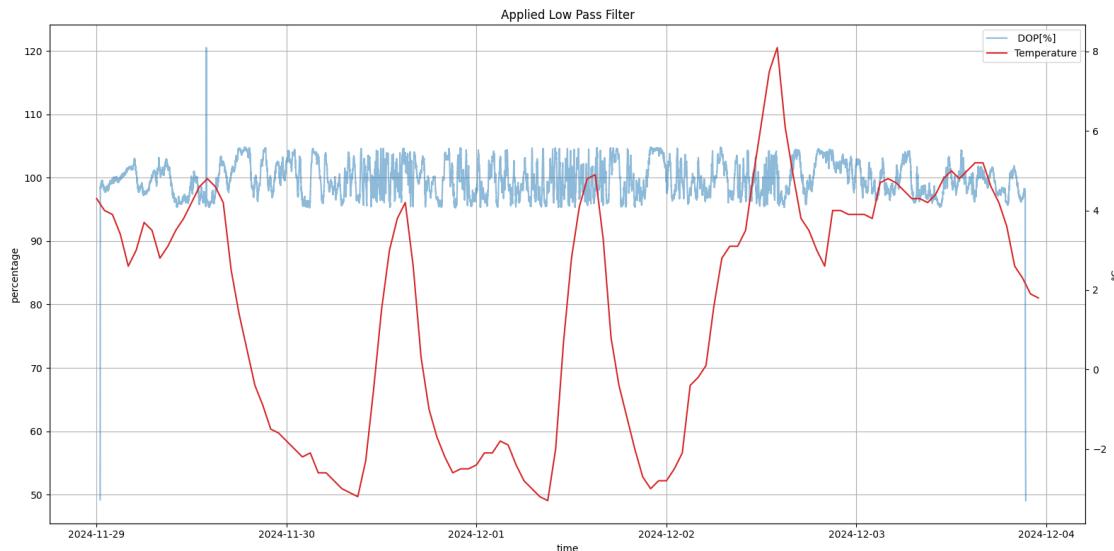
    plt.tight_layout()
    plt.show()
```

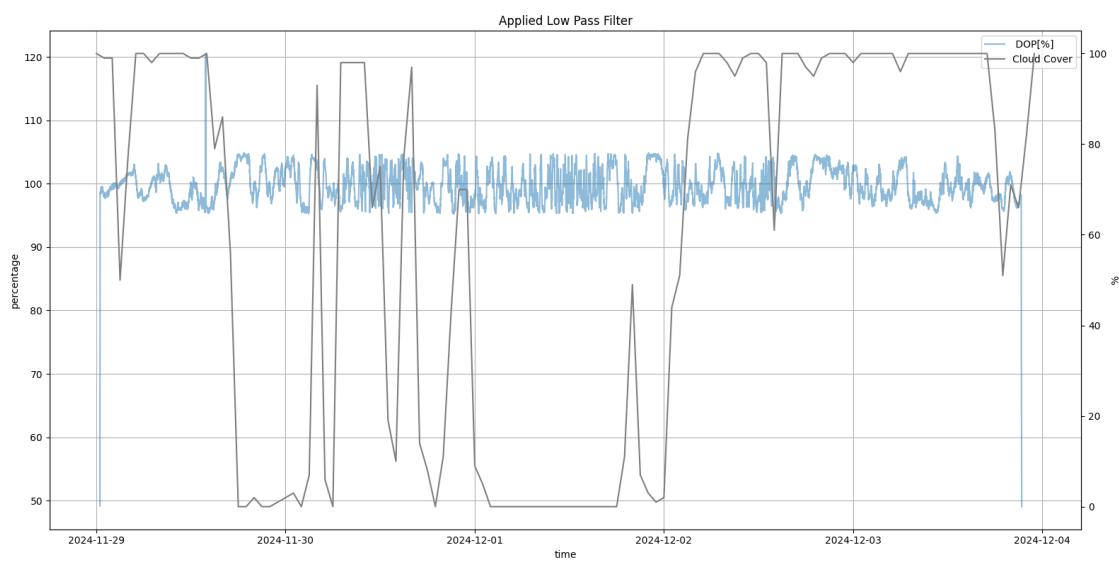
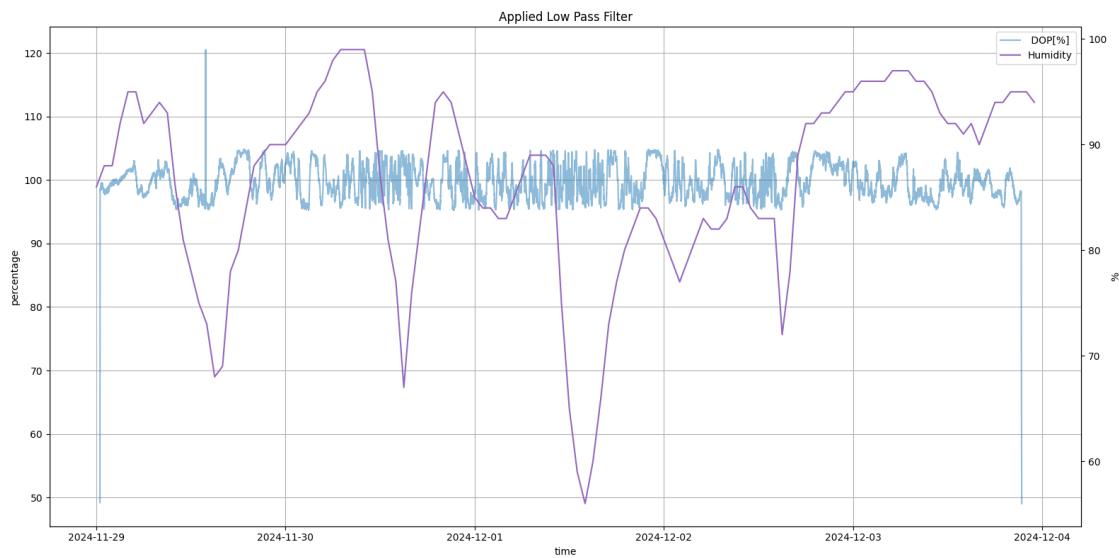
```

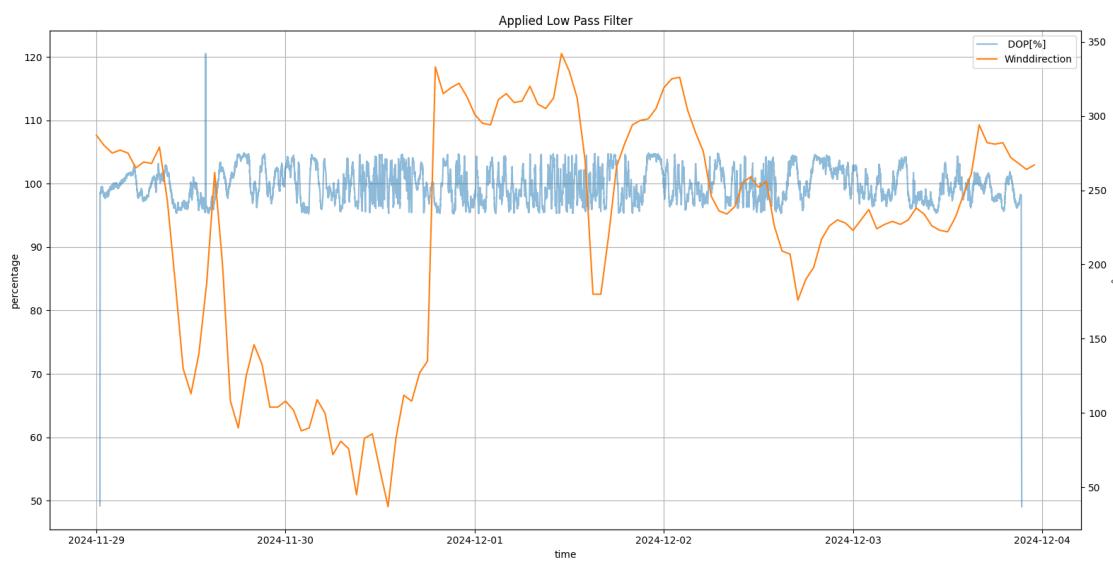
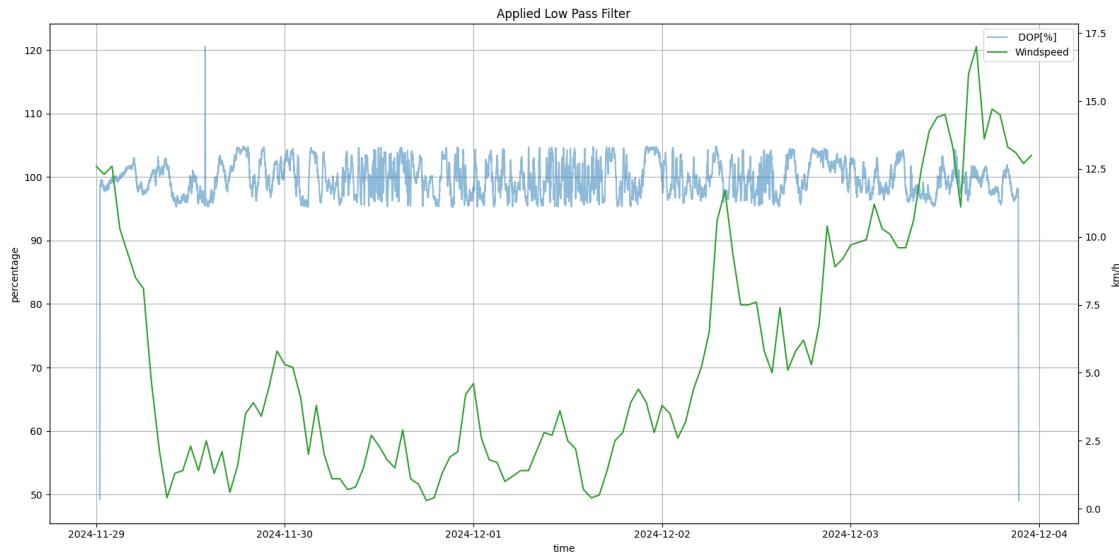
# Sunlight (day-night context)

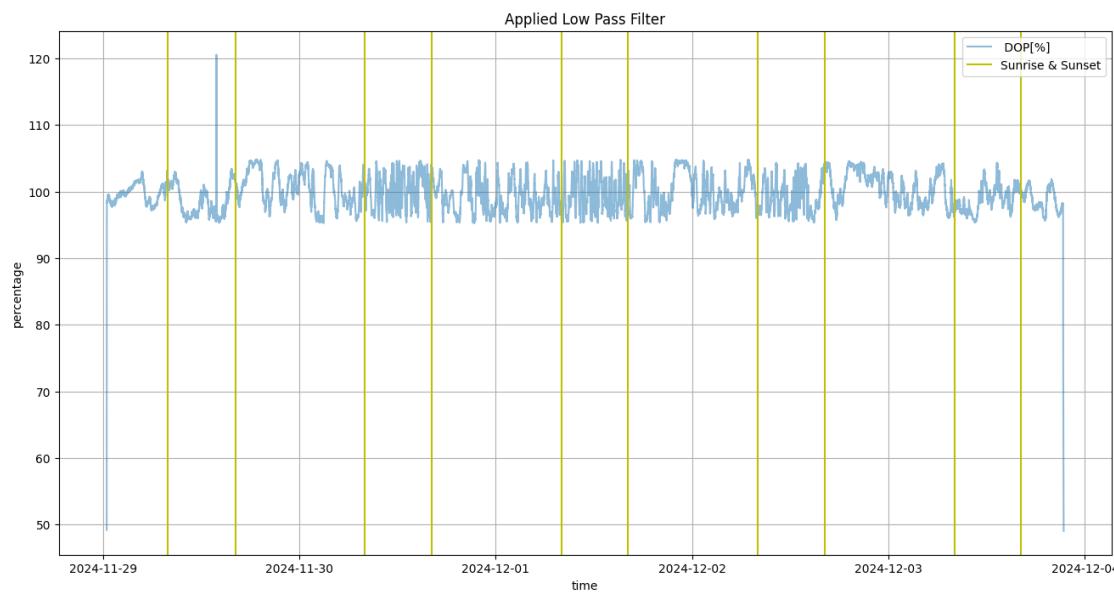
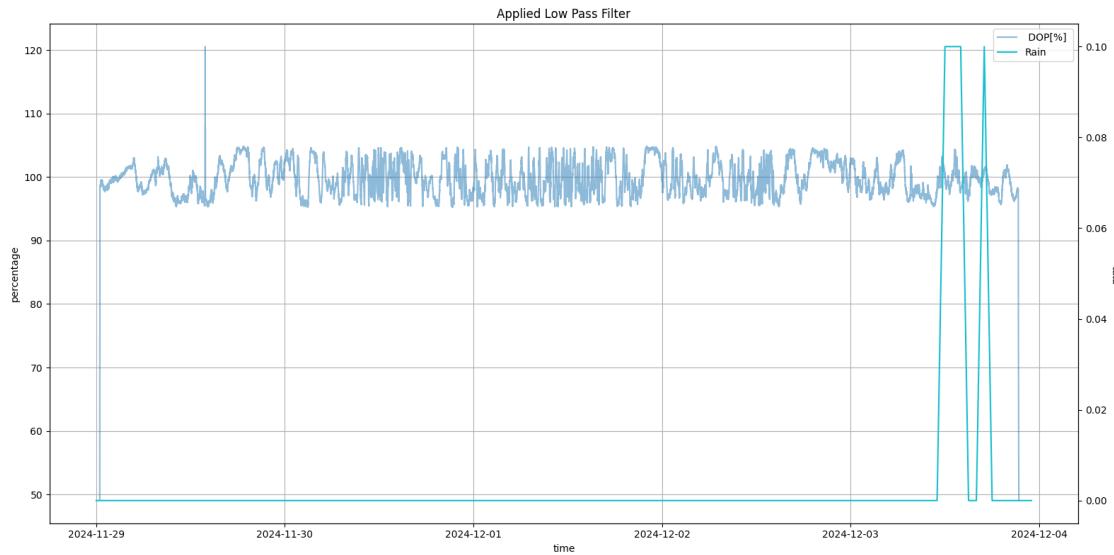
plt.figure(figsize = (16,8))
ydata = np.array(degree)
lps = lowpass(ydata, 1000)
plt.plot(degree.index, lps[:-1], label=columns[11], alpha = 0.5)
for i in range(len(sunrise)):
    plt.axvline(x = sunrise[i], color = 'y')
    if i == 0: plt.axvline(x = sunset[i], color = 'y',label = 'Sunrise & Sunset')
    else: plt.axvline(x = sunset[i], color = 'y')
plt.grid()
plt.legend(loc = 'best')
plt.title(f'Applied Low Pass Filter')
plt.xlabel('time')
plt.ylabel('percentage')
plt.show()

```









```
[22]: for current in range(len(w_data)):
    fig, ax1 = plt.subplots(figsize=(16, 8))

    ydata = np.array(degree)
    hps = highpass(ydata, 1000)

    ax1.plot(degree.index, hps, label=columns[11], color="tab:blue", alpha = 0.5)
    ax1.set_xlabel('time')
```

```

ax1.set_ylabel('percentage')
h1, l1 = ax1.get_legend_handles_labels()

ax2 = ax1.twinx()

ax2.plot(weather.index, weather[w_data[current]["header"]],  

        label=w_data[current]["label"], color = w_data[current]["color"])
ax2.set_ylabel(w_data[current]["unit"])

h2, l2 = ax2.get_legend_handles_labels()

ax1.grid()
ax1.legend(h1+h2, l1+l2, loc="best")
ax1.set_title(f'Applied High Pass Filter')

plt.tight_layout()
plt.show()

```

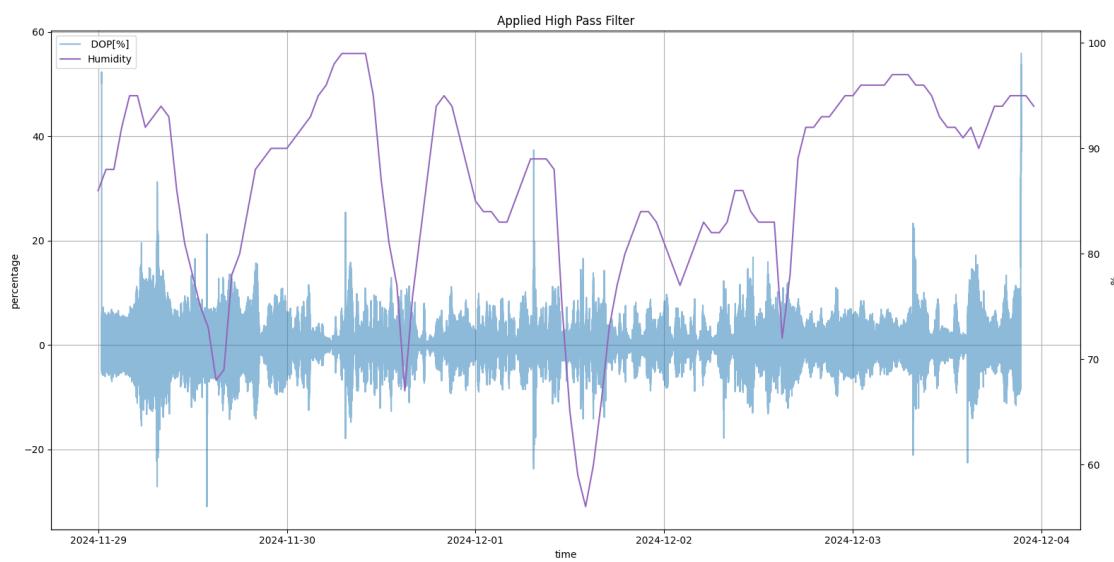
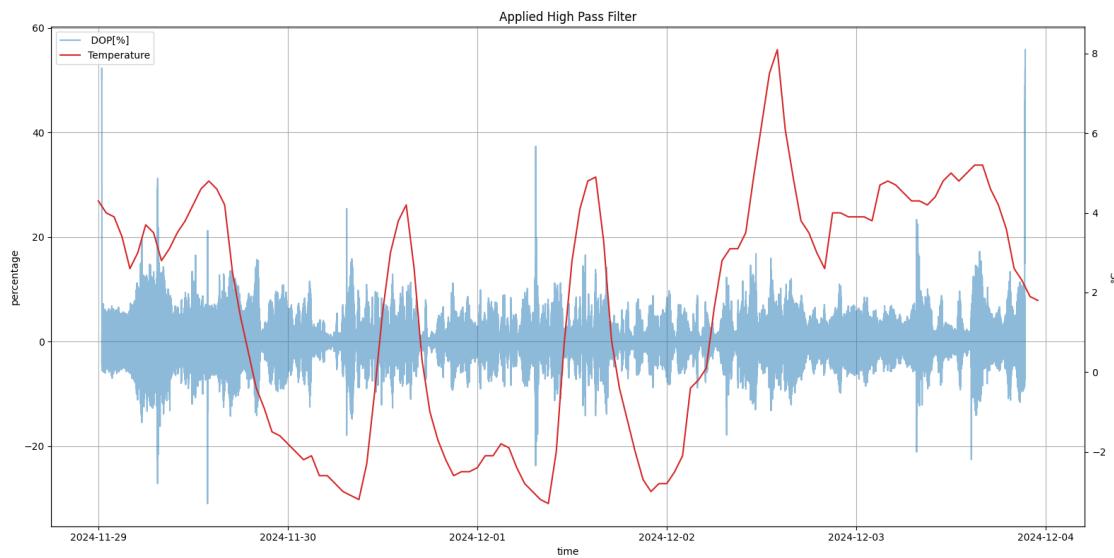
*# Sunlight (day-night context)*

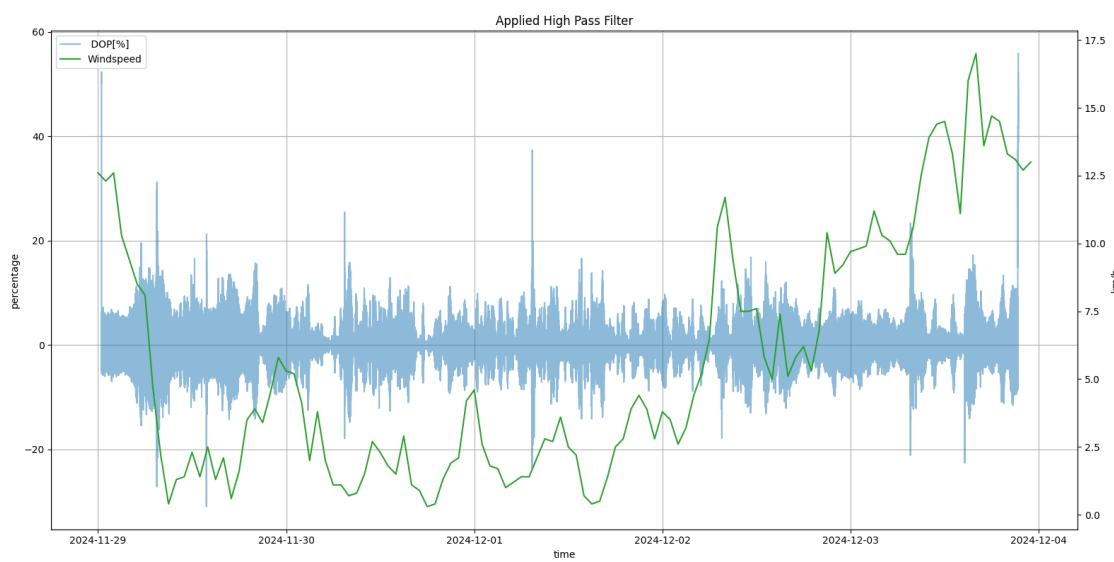
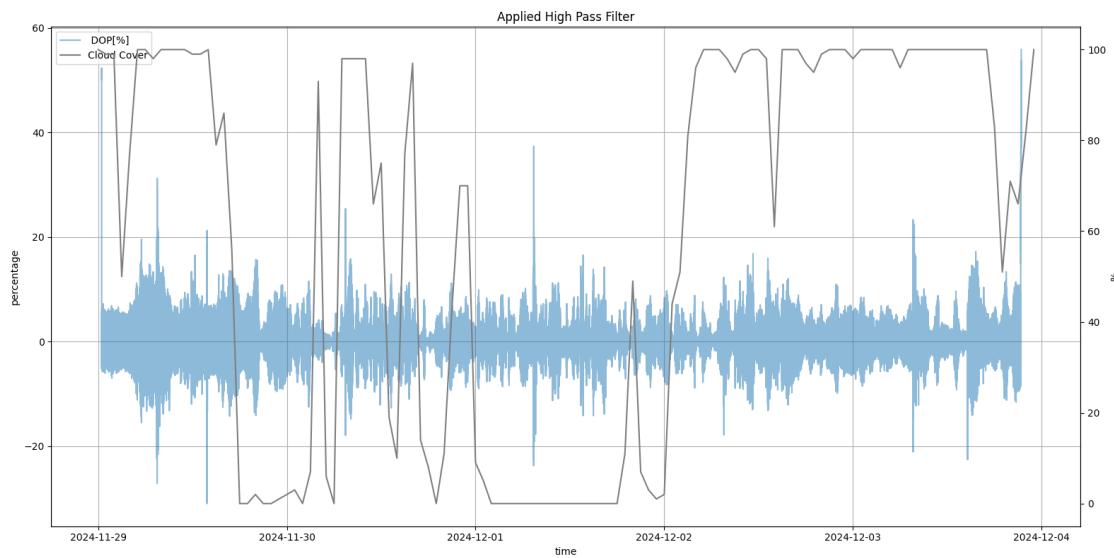
```

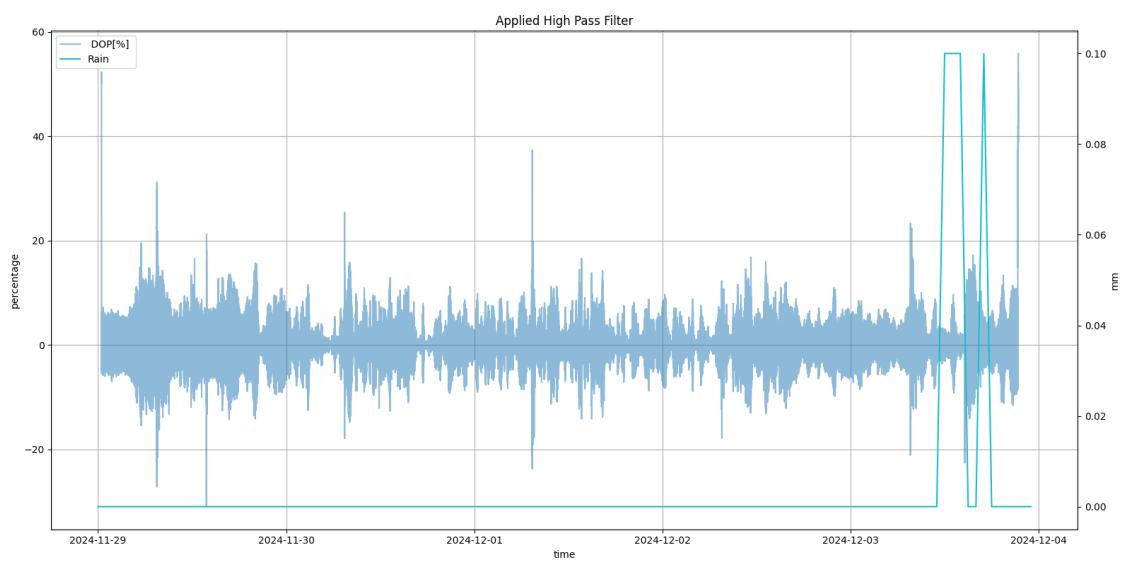
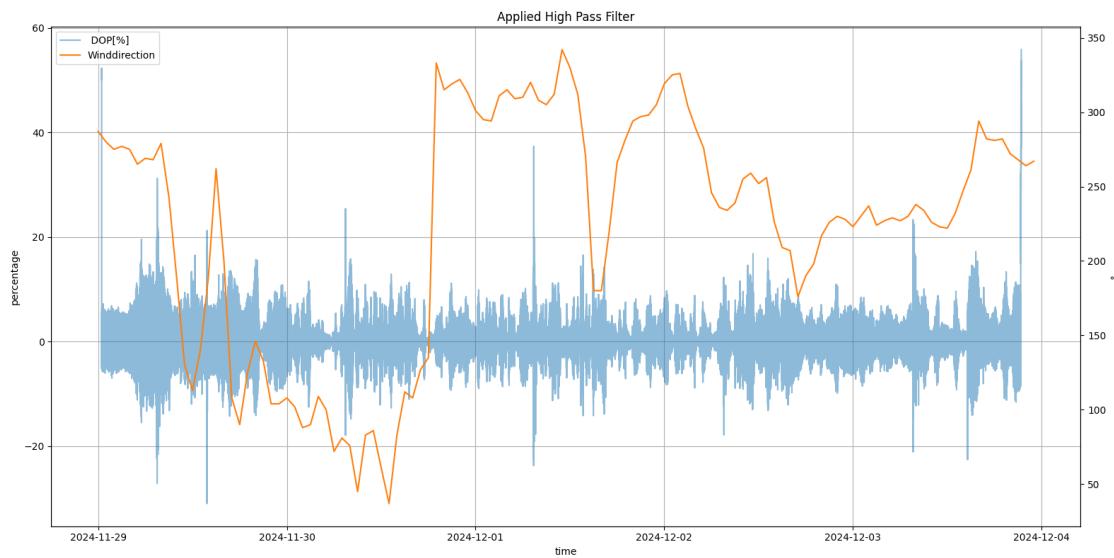
plt.figure(figsize = (16,8))
ydata = np.array(degree)
hps = highpass(ydata, 1000)
plt.plot(degree.index, hps, label=columns[11], alpha = 0.5)
for i in range(len(sunrise)):
    plt.axvline(x = sunrise[i], color = 'y')
    if i == 0: plt.axvline(x = sunset[i], color = 'y', label = 'Sunrise &  

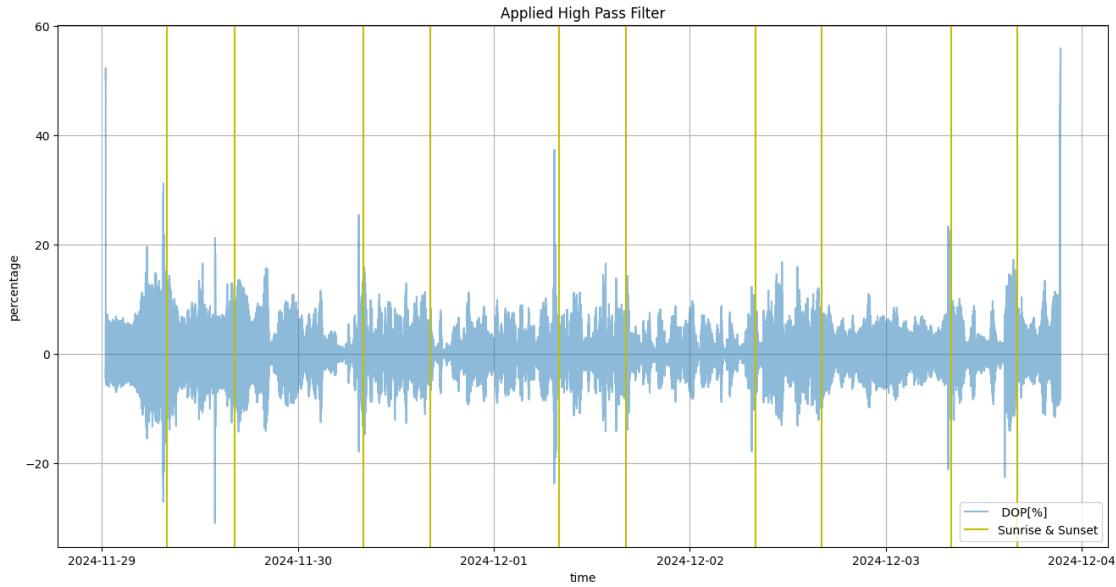
                           Sunset')
    else: plt.axvline(x = sunset[i], color = 'y')
plt.grid()
plt.legend(loc = 'best')
plt.title(f'Applied High Pass Filter')
plt.xlabel('time')
plt.ylabel('percentage')
plt.show()

```









## 4.2 Winkelparameter (Azimuth [°], Ellipticity[°])

```
[23]: angle = pd.read_csv(filename, skiprows=skip, sep=sep, usecols=[columns[0], columns[9], columns[10]])
```

```
[24]: angle[columns[0]] = pd.to_datetime(angle[columns[0]])
angle.set_index(columns[0], inplace=True)
```

```
[25]: angle_daily = angle.groupby(angle.index.date)
angle_daily_list = list(angle_daily)

angle_daily = angle.groupby(angle.index.date)
angle_daily_list = list(angle_daily)
```

### 4.2.1 Originaldaten

```
[26]: for current in range(len(w_data)):
    fig, ax1 = plt.subplots(figsize=(16, 8))

    ax1.plot(angle.index, angle[columns[9]], label=columns[9], color="tab:blue", alpha=0.5)
    ax1.plot(angle[columns[10]], label=columns[10], color="tab:pink", alpha=0.5)
    ax1.set_xlabel('time')
    ax1.set_ylabel('degree')
    h1, l1 = ax1.get_legend_handles_labels()
```

```

ax2 = ax1.twinx()

ax2.plot(weather.index, weather[w_data[current]["header"]],  

        label=w_data[current]["label"], color = w_data[current]["color"],  

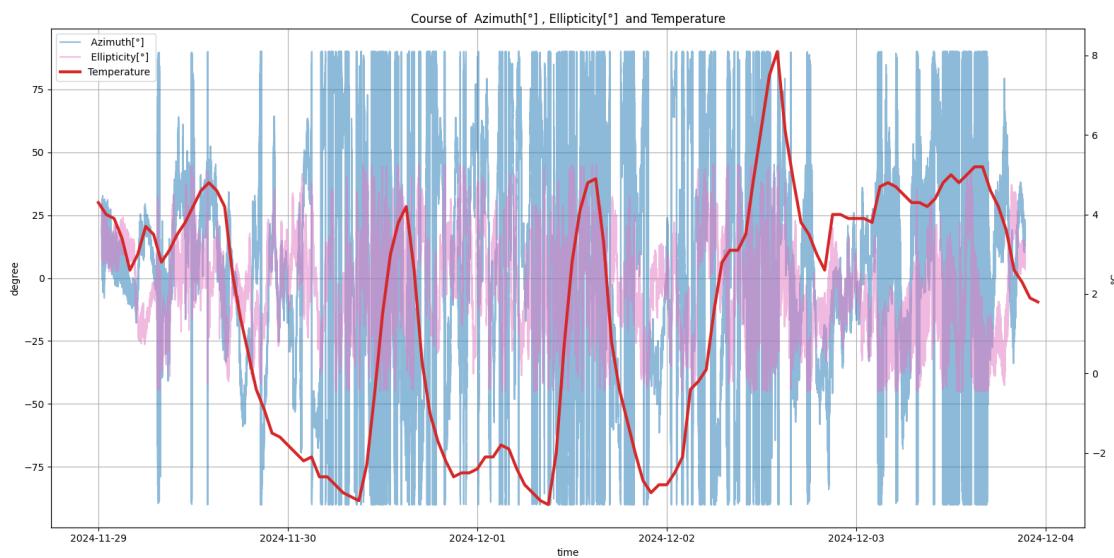
        linewidth=3)
ax2.set_ylabel(w_data[current]["unit"])
h2, l2 = ax2.get_legend_handles_labels()

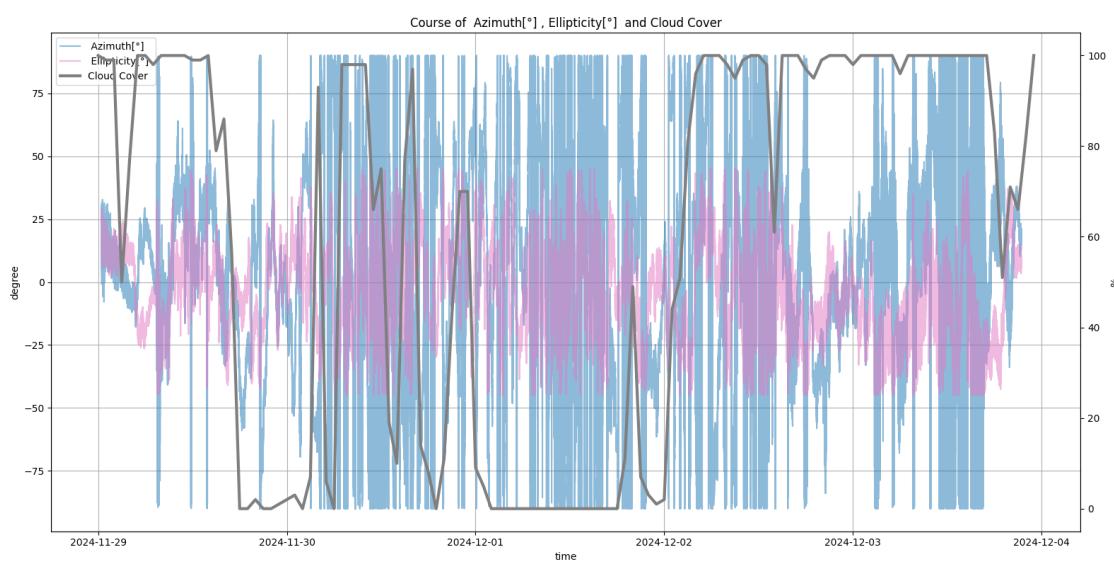
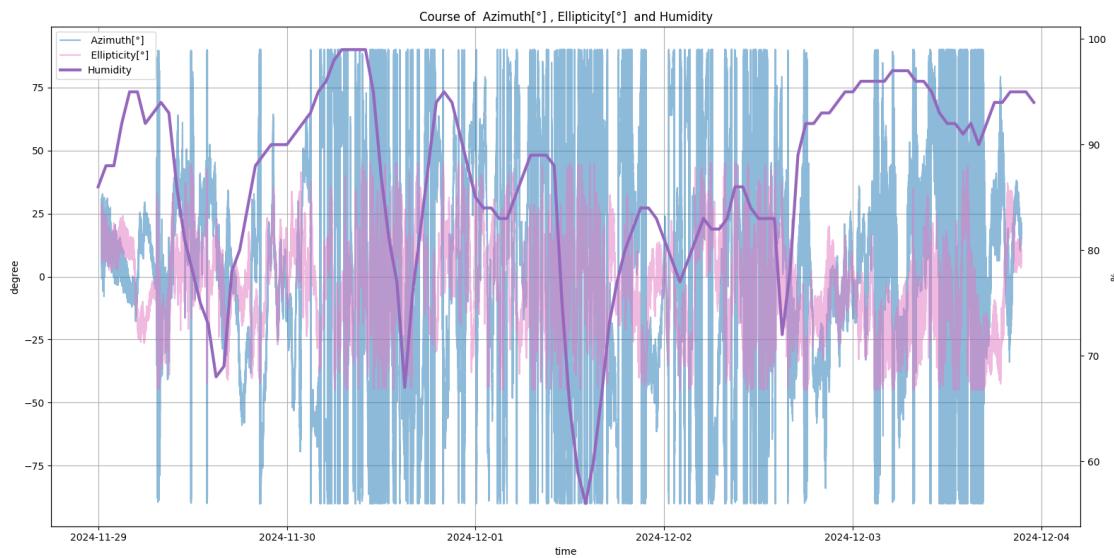
ax1.grid()
ax1.legend(h1+h2, l1+l2, loc="best")
ax1.set_title(f'Course of {columns[9]},{columns[10]} and  

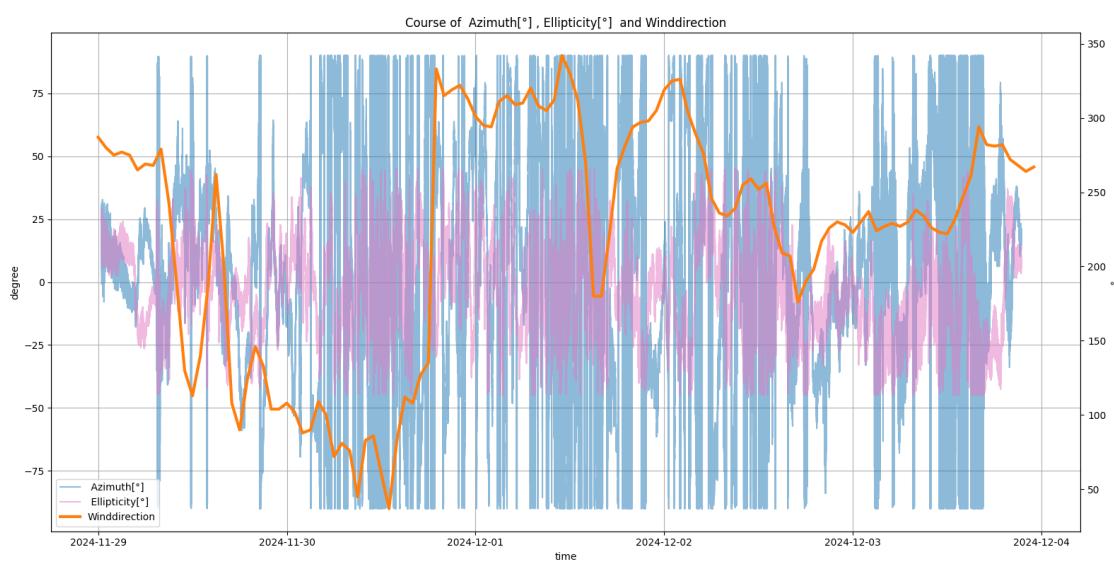
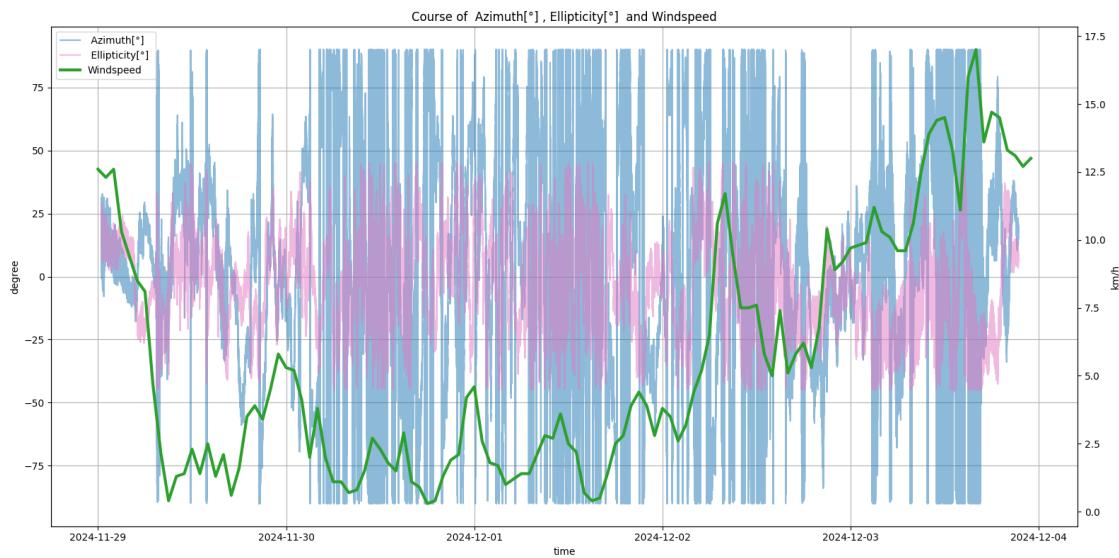
w_data[current]["label"]}')

plt.tight_layout()
plt.show()

```







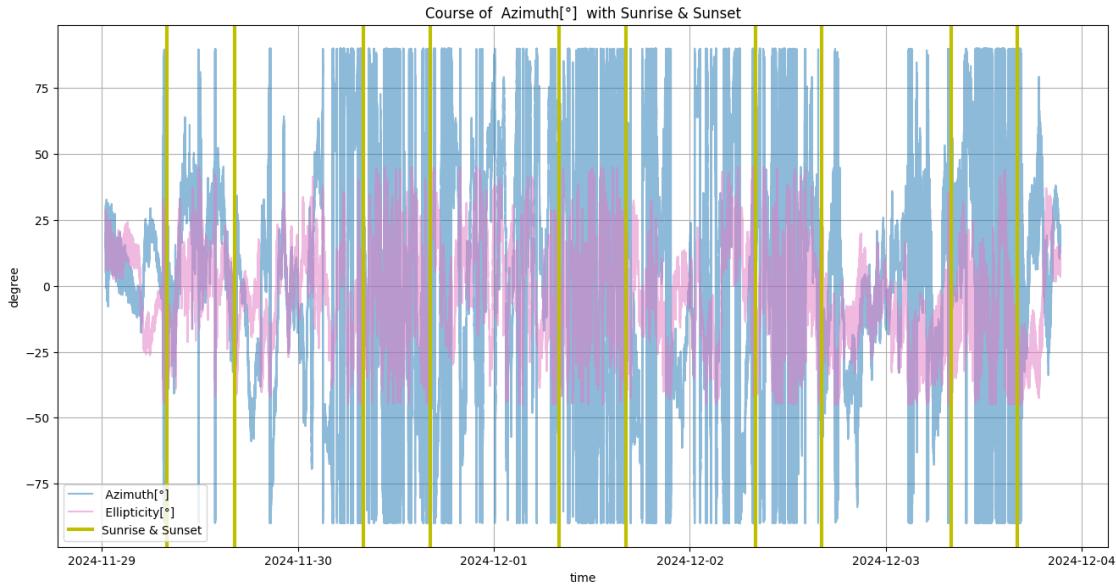


[27]: # Sunlight (day-night context)

```

plt.figure(figsize = (16,8))
plt.plot(angle.index, angle[columns[9]], label=columns[9], color= "tab:blue", alpha= 0.5)
plt.plot(angle.index, angle[columns[10]], label=columns[10], color= "tab:pink", alpha= 0.5)
for i in range(len(sunrise)):
    plt.axvline(x = sunrise[i], color = 'y', linewidth=3)
    if i == 0: plt.axvline(x = sunset[i], color = 'y',label = 'Sunrise & Sunset', linewidth=3)
    else: plt.axvline(x = sunset[i], color = 'y', linewidth=3)
plt.grid()
plt.legend(loc = 'best')
plt.title(f'Course of {columns[9]} with Sunrise & Sunset')
plt.xlabel('time')
plt.ylabel('degree')
plt.show()

```



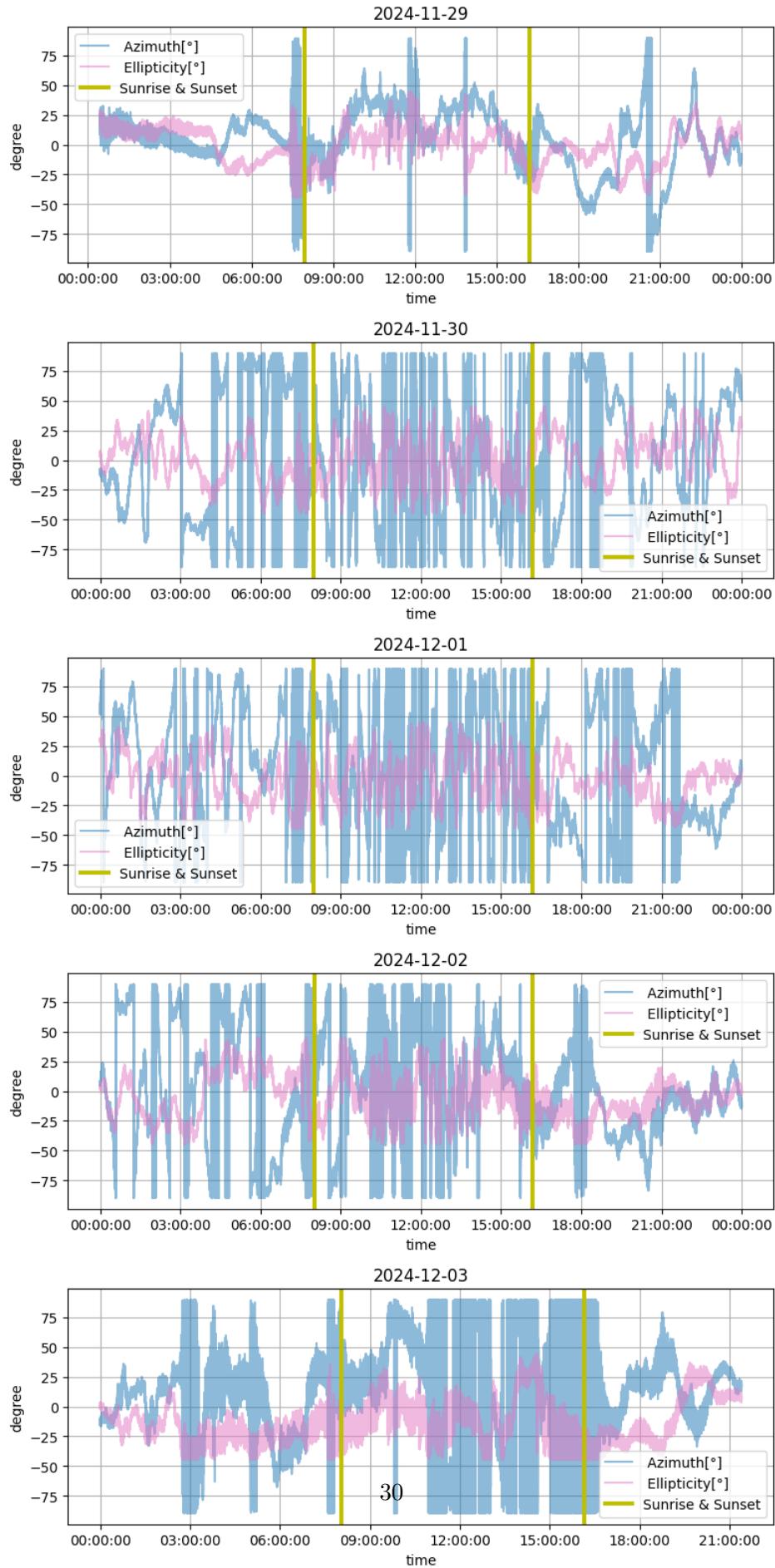
```
[28]: fig, axs = plt.subplots(len(angle_daily_list), 1, figsize=(8, 16), sharex=False)

for i in range(len(angle_daily_list)):
    ax1 = axs[i] if len(angle_daily_list) > 1 else axs
    az = angle_daily_list[i][1][columns[9]]
    el = angle_daily_list[i][1][columns[10]]

    ax1.plot(angle_daily_list[i][1].index, az, label=columns[9], color="tab:blue", alpha=0.5)
    ax1.plot(el, label=columns[10], color="tab:pink", alpha=0.5)
    ax1.axvline(x=sunrise[i], color='y', linewidth=3)
    ax1.axvline(x=sunset[i], color='y', label='Sunrise & Sunset', linewidth=3)
    ax1.set_xlabel('time')
    ax1.set_ylabel('degree')
    h1, l1 = ax1.get_legend_handles_labels()

    ax1.grid()
    ax1.legend(loc="best")
    ax1.set_title(degree_daily_list[i][0])
    ax1.xaxis.set_major_formatter(mdates.DateFormatter('%H:%M:%S'))

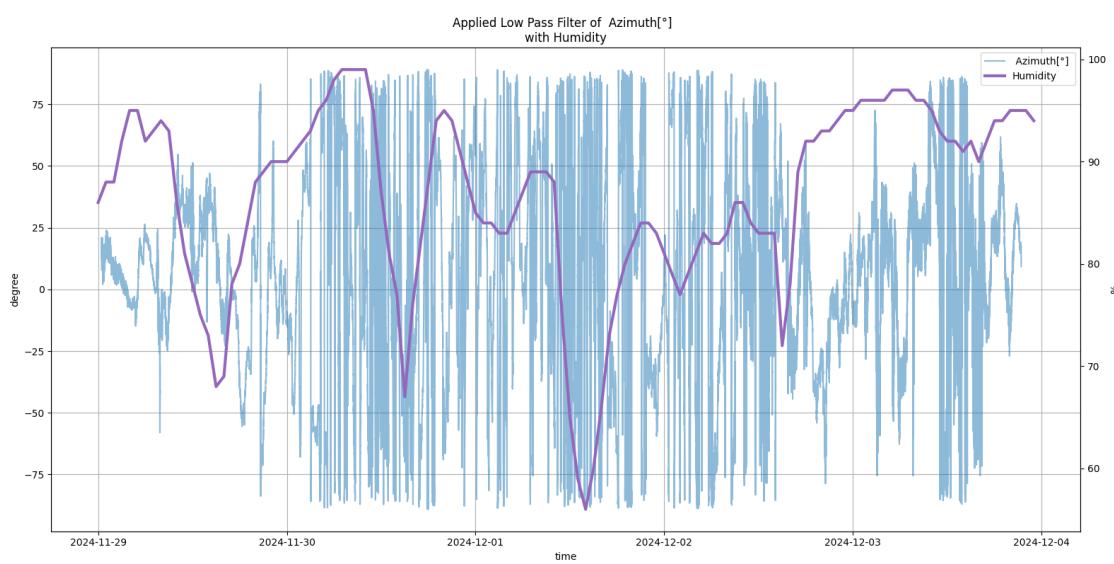
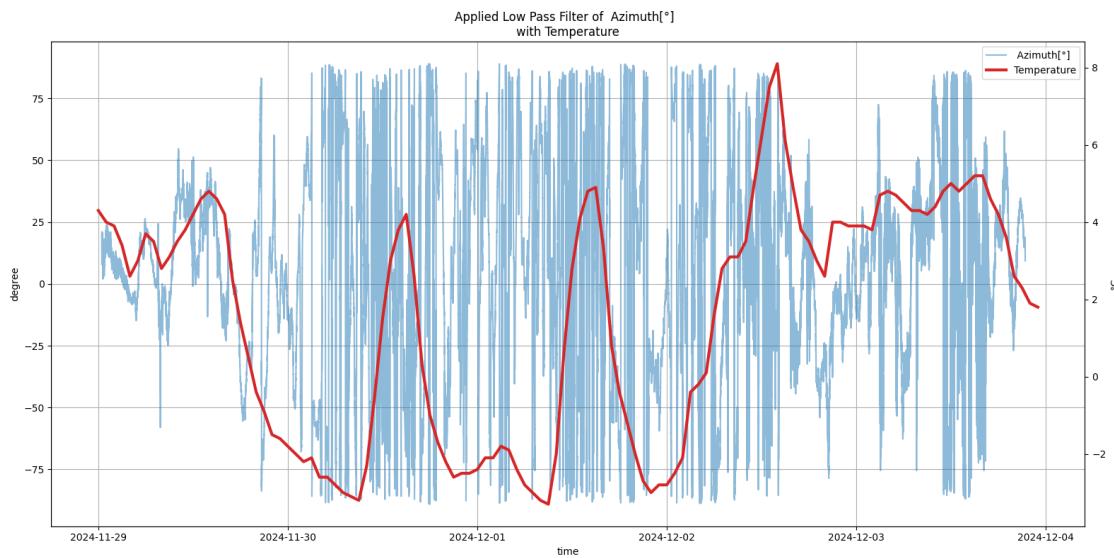
plt.tight_layout()
plt.show()
```

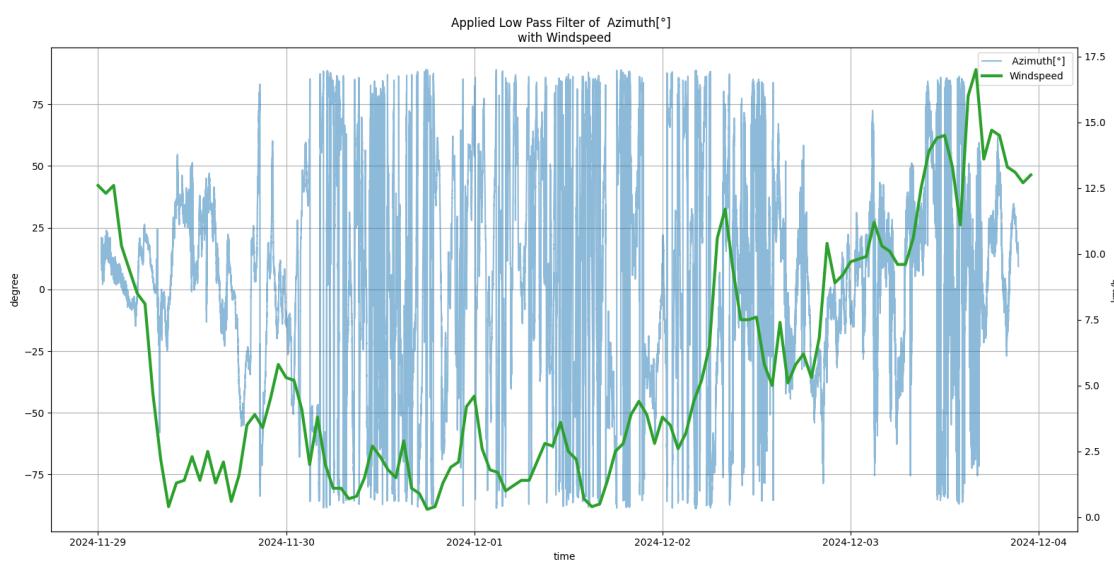
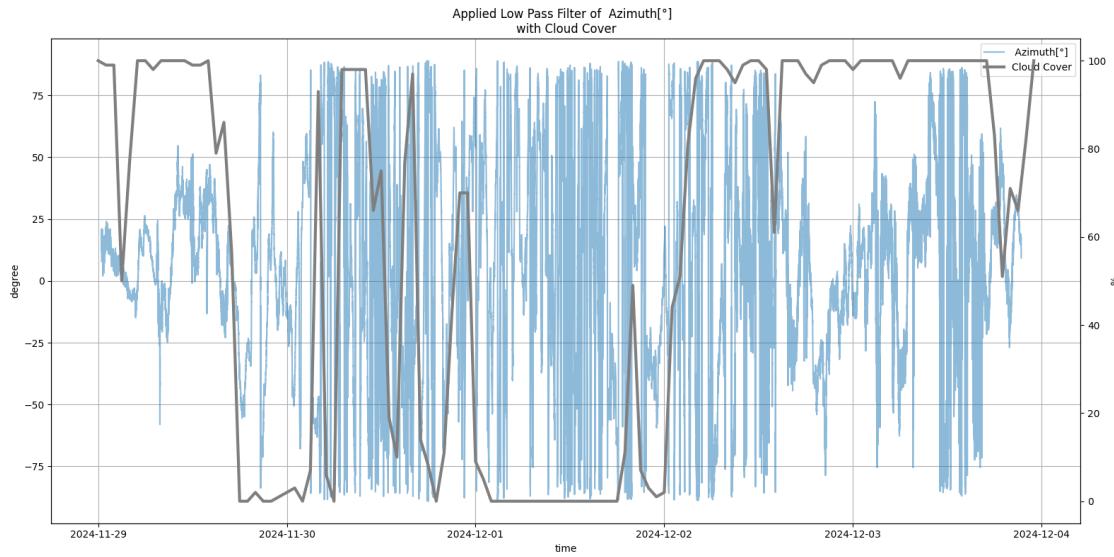


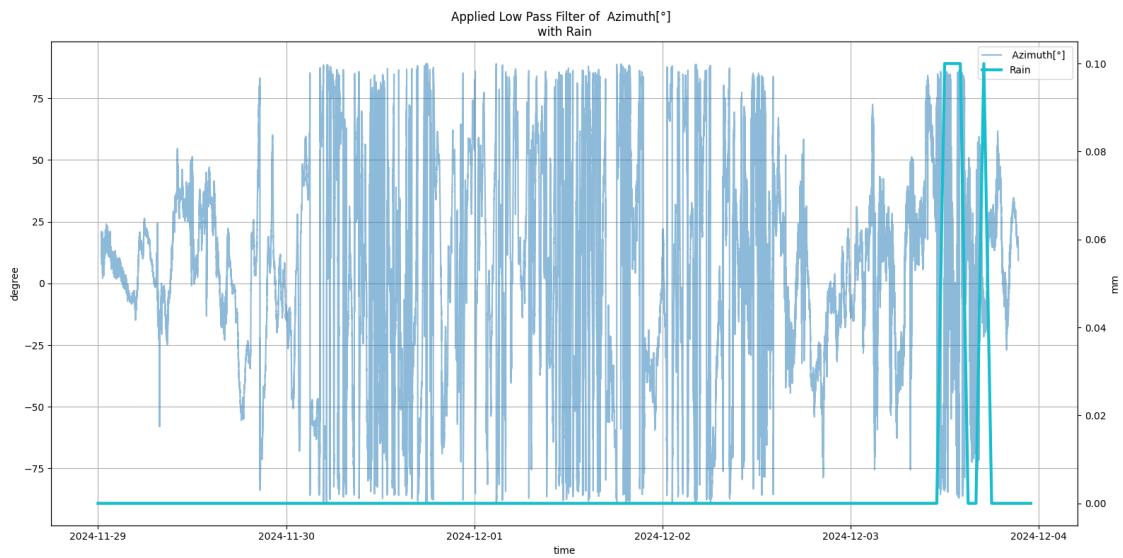
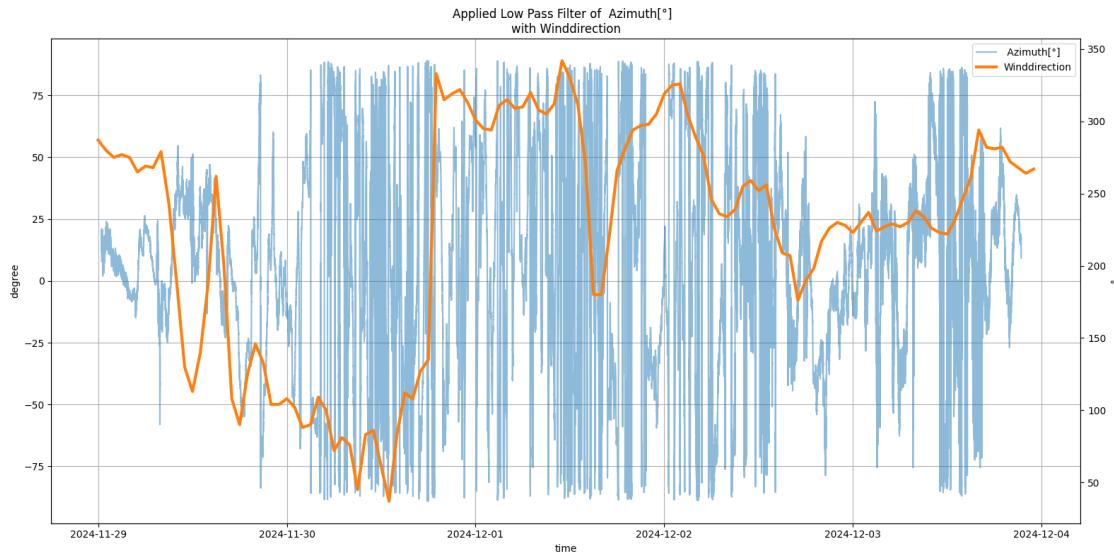
#### 4.2.2 Anwendung des Tiefpassfilters

##### Azimuth

```
[29]: for current in range(len(w_data)):  
    fig, ax1 = plt.subplots(figsize=(16, 8))  
  
    ydata = np.array(angle[columns[9]])  
    lps = lowpass(ydata, 100)  
  
    ax1.plot(angle.index, lps[:-1], label=columns[9], color= "tab:blue", alpha=0.5)  
  
    ax1.set_xlabel('time')  
    ax1.set_ylabel('degree')  
    h1, l1 = ax1.get_legend_handles_labels()  
  
    ax2 = ax1.twinx()  
  
    ax2.plot(weather.index, weather[w_data[current]["header"]],  
            label=w_data[current]["label"], color = w_data[current]["color"],  
            linewidth=3)  
    ax2.set_ylabel(w_data[current]["unit"])  
    h2, l2 = ax2.get_legend_handles_labels()  
  
    ax1.grid()  
    ax1.legend(h1+h2, l1+l2, loc="best")  
    ax1.set_title(f'Applied Low Pass Filter of {columns[9]} \nwith  
{w_data[current]["label"]}')  
  
    plt.tight_layout()  
    plt.show()
```







```
[30]: # Sunlight (day-night context)

plt.figure(figsize = (16,8))

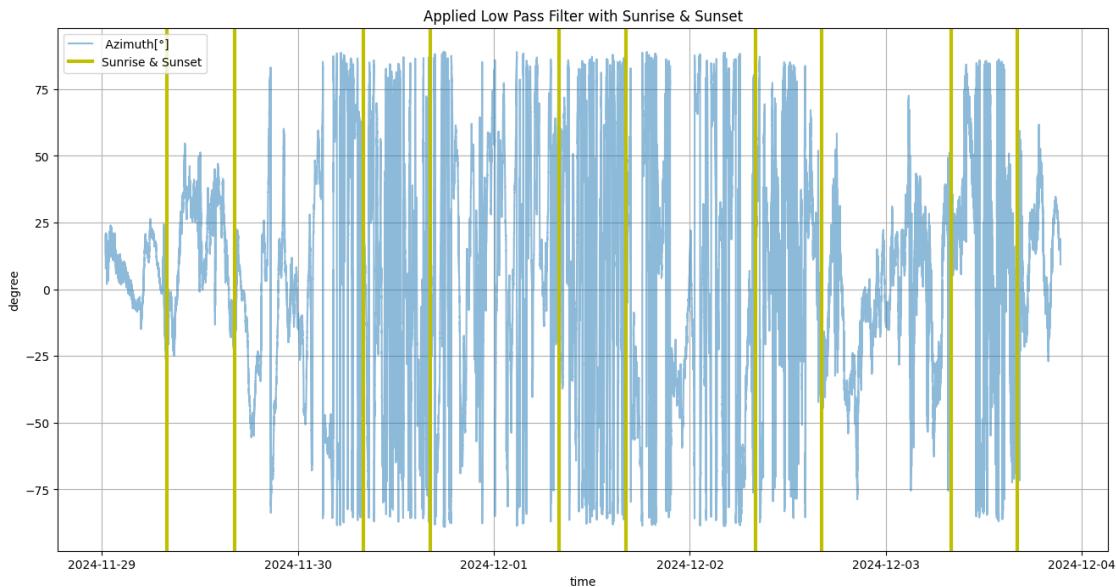
ydata = np.array(angle[columns[9]])
lps = lowpass(ydata, 100)

plt.plot(angle.index, lps[:-1], label=columns[9], color= "tab:blue", alpha= 0.5)
for i in range(len(sunrise)):
    plt.axvline(x = sunrise[i], color = 'y', linewidth=3)
```

```

if i == 0: plt.axvline(x = sunset[i], color = 'y', label = 'Sunrise & Sunset', linewidth=3)
else: plt.axvline(x = sunset[i], color = 'y', linewidth=3)
plt.grid()
plt.legend(loc = 'best')
plt.title(f'Applied Low Pass Filter with Sunrise & Sunset')
plt.xlabel('time')
plt.ylabel('degree')
plt.show()

```



## Ellipticity

```

[31]: for current in range(len(w_data)):
    fig, ax1 = plt.subplots(figsize=(16, 8))

    ydata = np.array(angle[columns[10]])
    lps = lowpass(ydata, 100)

    ax1.plot(angle.index, lps[:-1], label=columns[10], color= "tab:blue", alpha= 0.5)

    ax1.set_xlabel('time')
    ax1.set_ylabel('degree')
    h1, l1 = ax1.get_legend_handles_labels()

    ax2 = ax1.twinx()

```

```

    ax2.plot(weather.index, weather[w_data[current]["header"]], □
    ↵label=w_data[current]["label"], color = w_data[current]["color"], □
    ↵linewidth=3)
    ax2.set_ylabel(w_data[current]["unit"])
    h2, l2 = ax2.get_legend_handles_labels()

    ax1.grid()
    ax1.legend(h1+h2, l1+l2, loc="best")
    ax1.set_title(f'Applied Low Pass Filter of {columns[10]} \nwith □
    ↵{w_data[current]["label"]}')

    plt.tight_layout()
    plt.show()

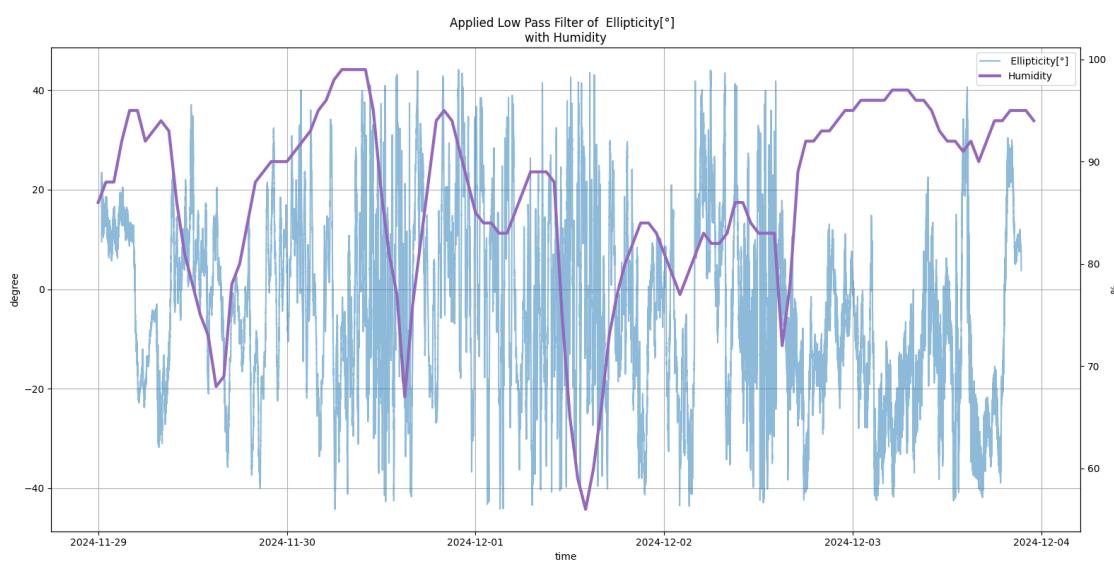
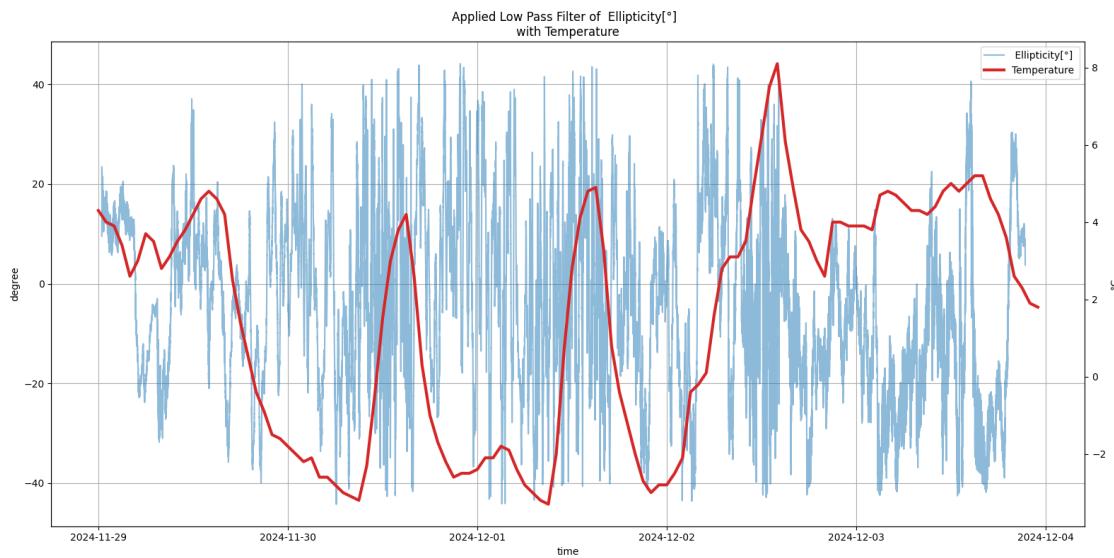
# Sunlight (day-night context)

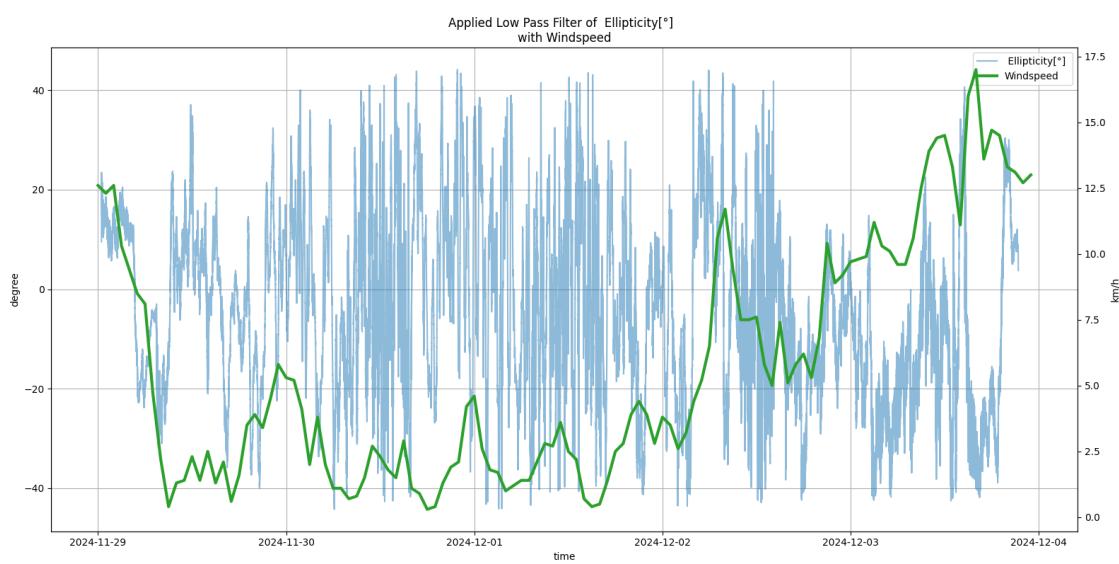
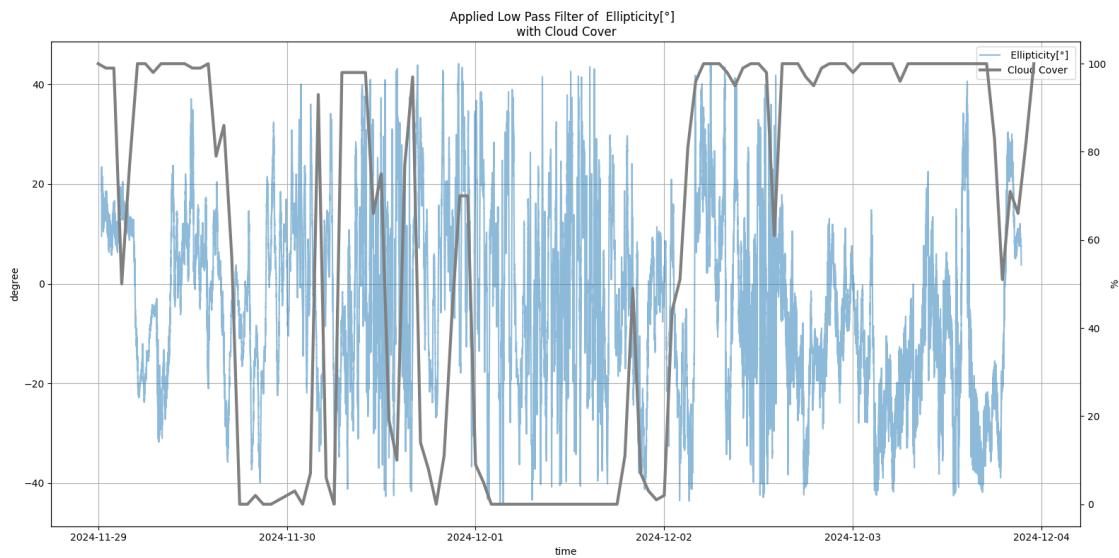
plt.figure(figsize = (16,8))

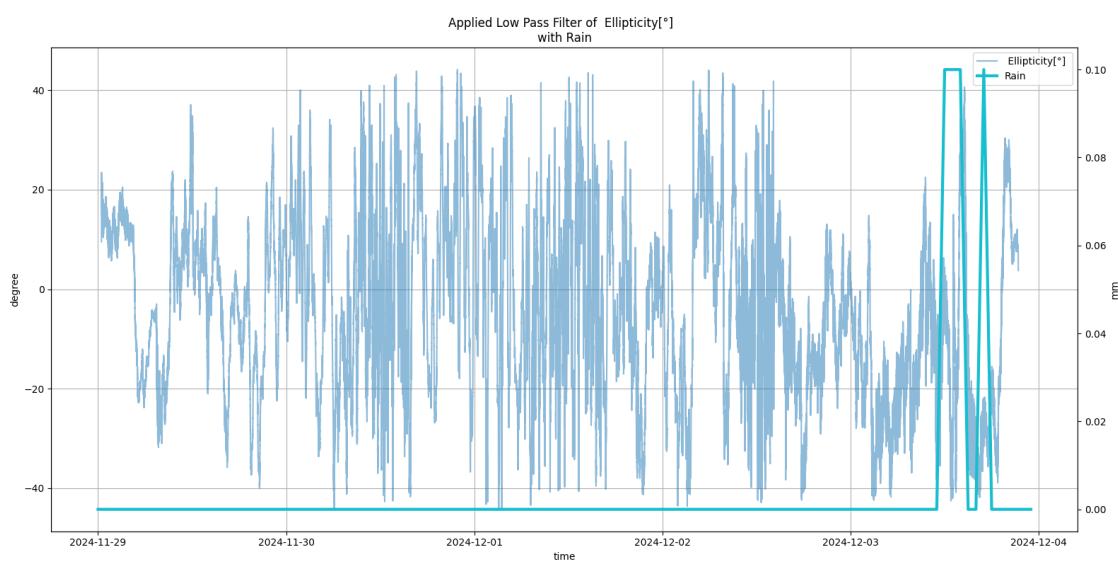
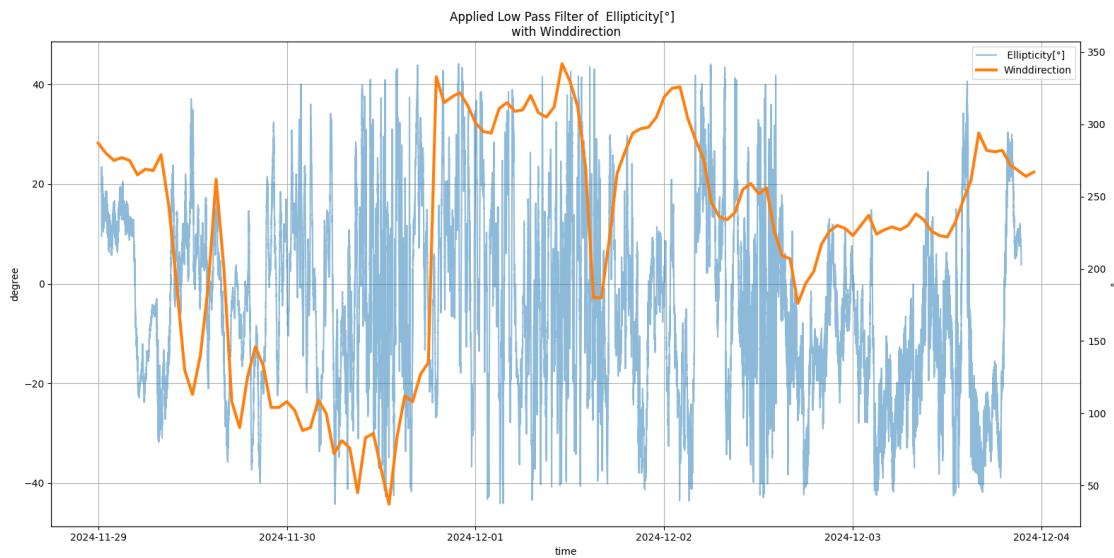
ydata = np.array(angle[columns[10]])
lps = lowpass(ydata, 100)

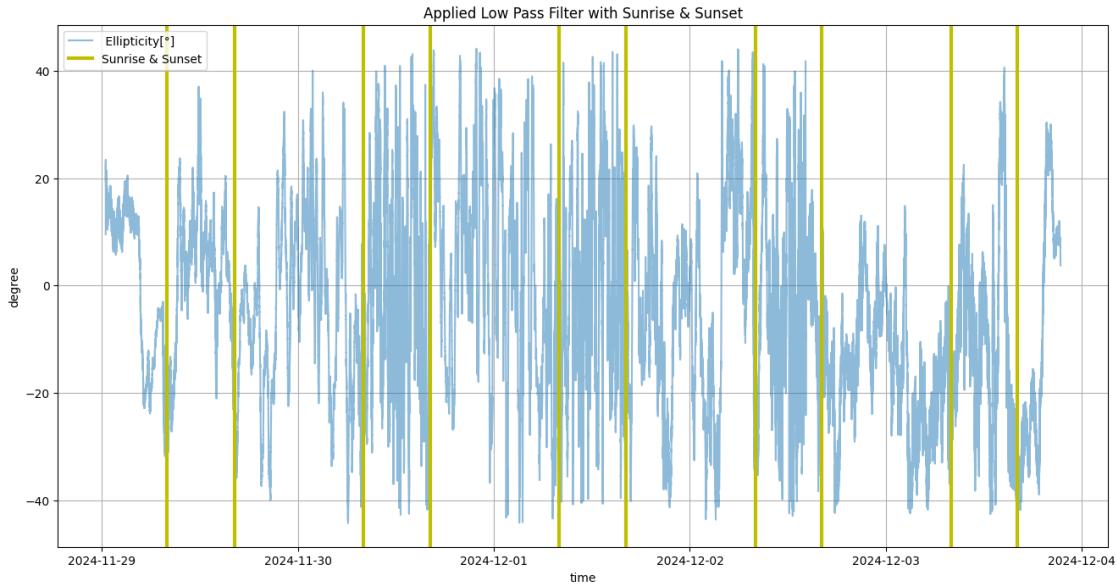
plt.plot(angle.index, lps[:-1], label=columns[10], color= "tab:blue", alpha= 0.
    ↵5)
for i in range(len(sunrise)):
    plt.axvline(x = sunrise[i], color = 'y', linewidth=3)
    if i == 0: plt.axvline(x = sunset[i], color = 'y', label = 'Sunrise & □
    ↵Sunset', linewidth=3)
    else: plt.axvline(x = sunset[i], color = 'y', linewidth=3)
plt.grid()
plt.legend(loc = 'best')
plt.title(f'Applied Low Pass Filter with Sunrise & Sunset')
plt.xlabel('time')
plt.ylabel('degree')
plt.show()

```









#### 4.2.3 Anwendung des Hochpassfilters

##### Azimuth

```
[32]: for current in range(len(w_data)):
    fig, ax1 = plt.subplots(figsize=(16, 8))

    ydata = np.array(angle[columns[9]])
    hps = highpass(ydata, 100)

    ax1.plot(angle.index, hps, label=columns[9], color= "tab:blue", alpha= 0.5)

    ax1.set_xlabel('time')
    ax1.set_ylabel('degree')
    h1, l1 = ax1.get_legend_handles_labels()

    ax2 = ax1.twinx()

    ax2.plot(weather.index, weather[w_data[current]]["header"], label=w_data[current]["label"], color = w_data[current]["color"], linewidth=3)
    ax2.set_ylabel(w_data[current]["unit"])
    h2, l2 = ax2.get_legend_handles_labels()

    ax1.grid()
    ax1.legend(h1+h2, l1+l2, loc="best")
    ax1.set_title(f'Applied High Pass Filter of {columns[9]} \nwith {w_data[current]["label"]}' )
```

```

plt.tight_layout()
plt.show()

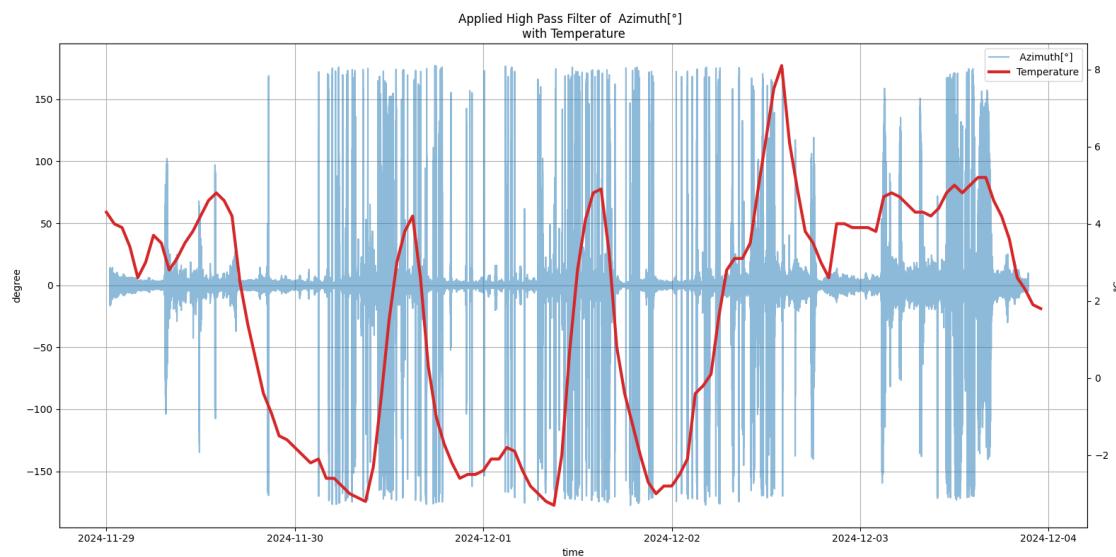
# Sunlight (day-night context)

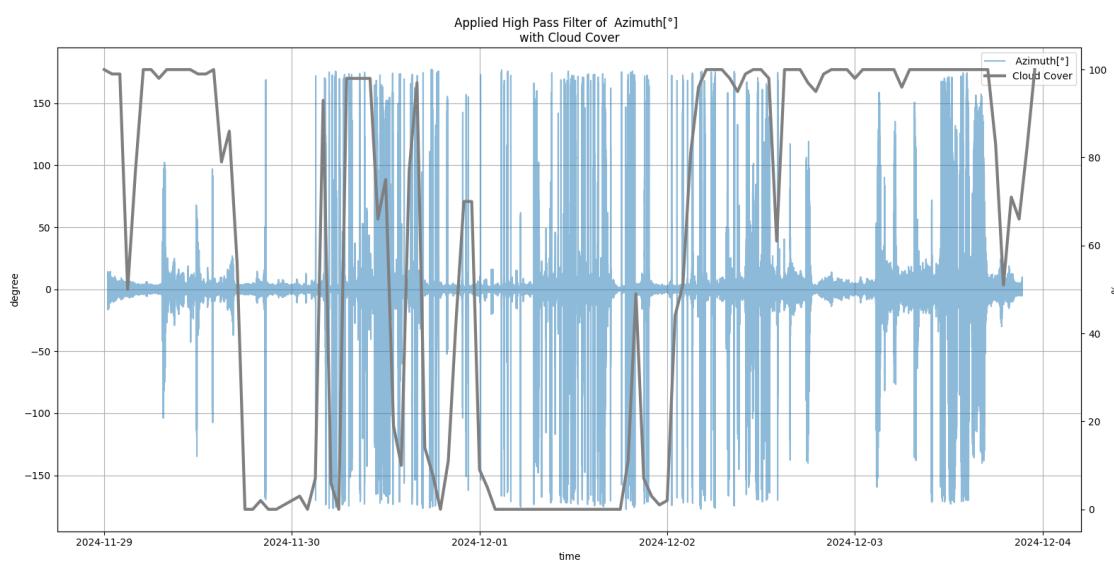
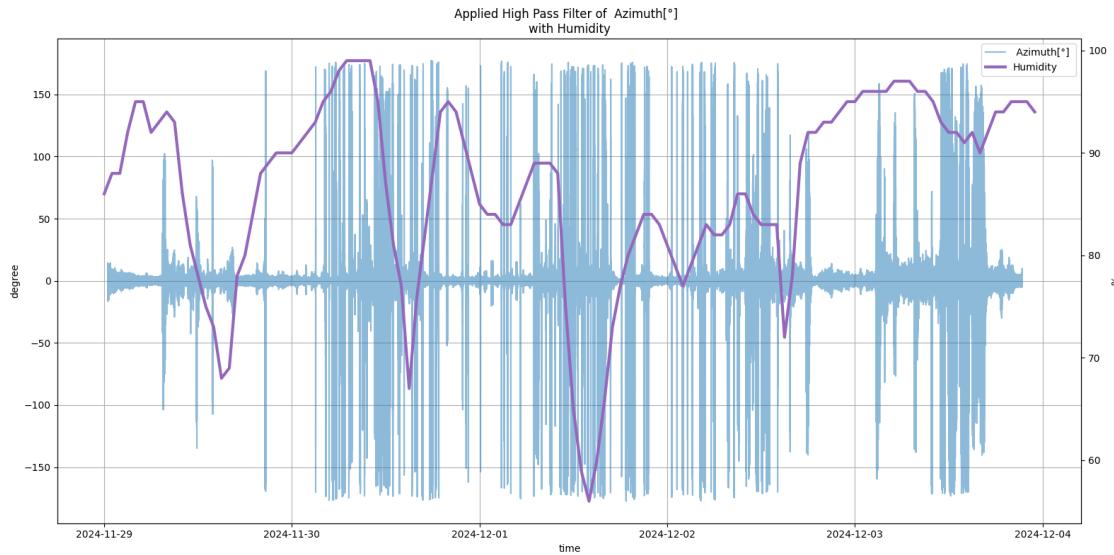
plt.figure(figsize = (16,8))

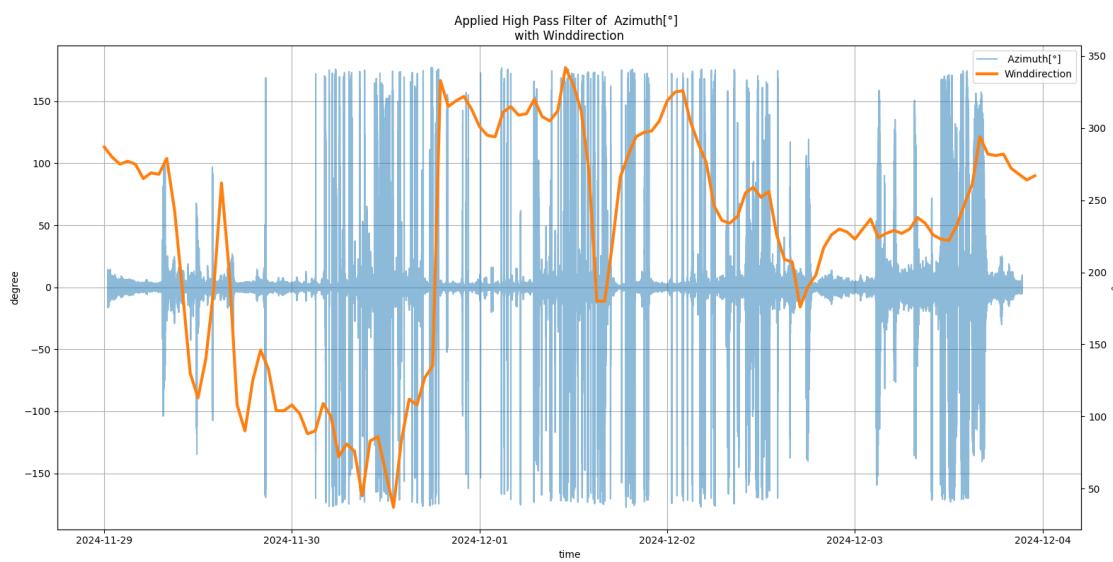
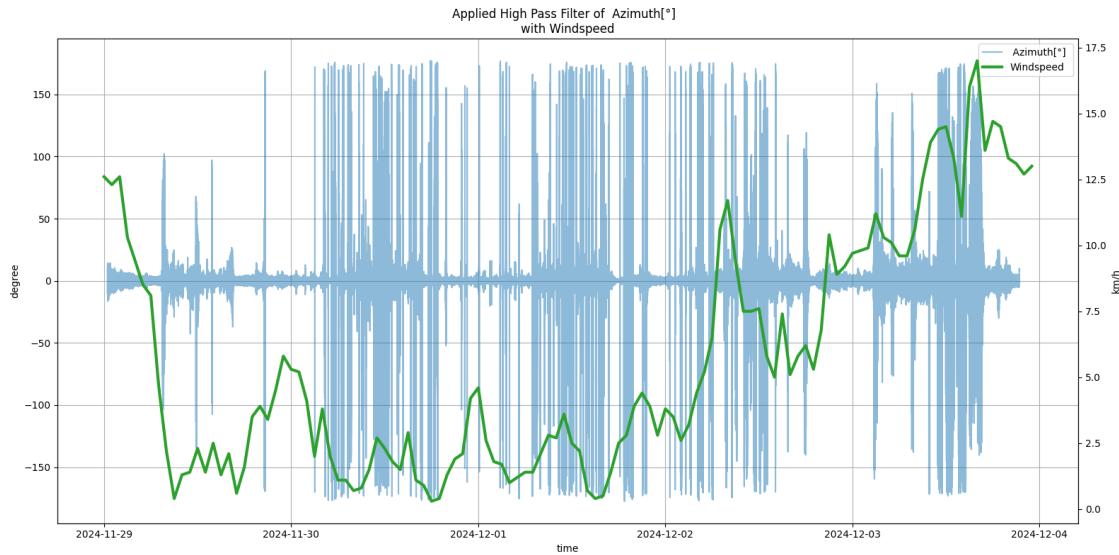
ydata = np.array(angle[columns[9]])
hps = highpass(ydata, 100)

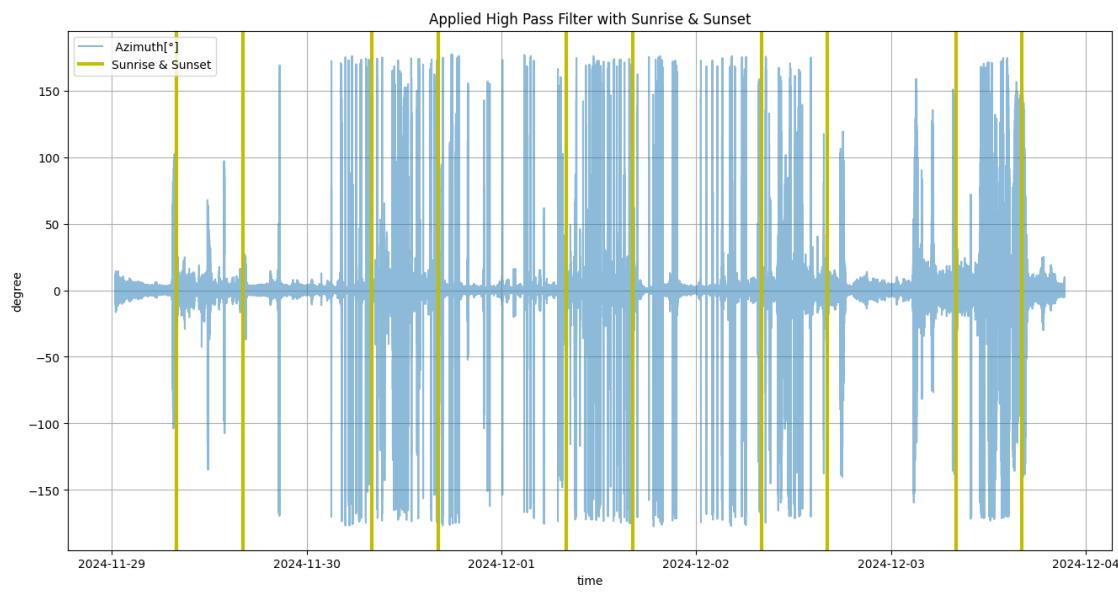
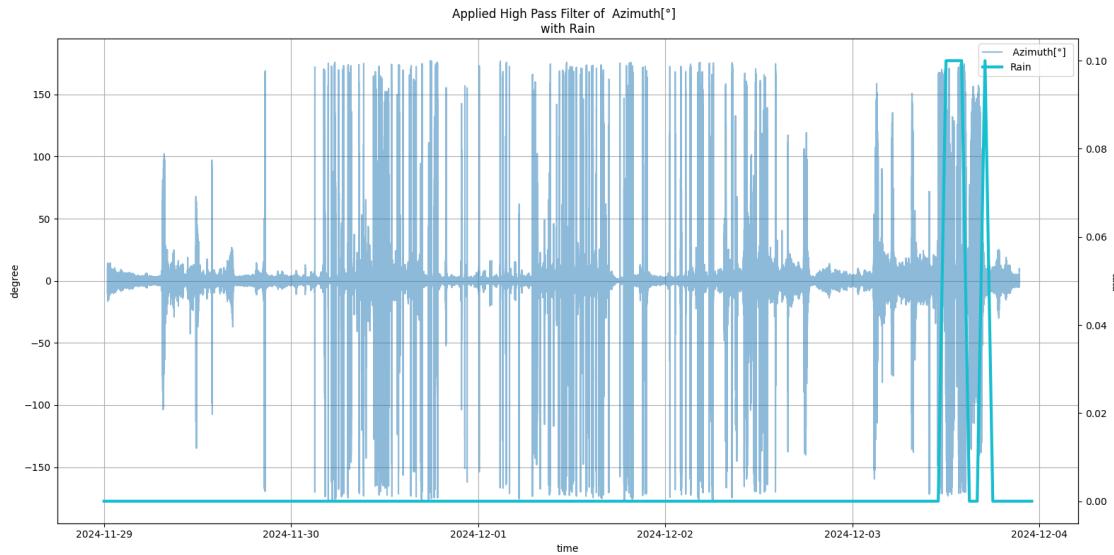
plt.plot(angle.index, hps, label=columns[9], color= "tab:blue", alpha= 0.5)
for i in range(len(sunrise)):
    plt.axvline(x = sunrise[i], color = 'y', linewidth=3)
    if i == 0: plt.axvline(x = sunset[i], color = 'y',label = 'Sunrise & Sunset', linewidth=3)
    else: plt.axvline(x = sunset[i], color = 'y', linewidth=3)
plt.grid()
plt.legend(loc = 'best')
plt.title(f'Applied High Pass Filter with Sunrise & Sunset')
plt.xlabel('time')
plt.ylabel('degree')
plt.show()

```









## Ellipticity

```
[33]: for current in range(len(w_data)):
    fig, ax1 = plt.subplots(figsize=(16, 8))

    ydata = np.array(angle[columns[10]])
    hps = highpass(ydata, 100)

    ax1.plot(angle.index, hps, label=columns[10], color= "tab:blue", alpha= 0.5)
```

```

ax1.set_xlabel('time')
ax1.set_ylabel('degree')
h1, l1 = ax1.get_legend_handles_labels()

ax2 = ax1.twinx()

ax2.plot(weather.index, weather[w_data[current]["header"]],  

         label=w_data[current]["label"], color = w_data[current]["color"],  

         linewidth=3)
ax2.set_ylabel(w_data[current]["unit"])
h2, l2 = ax2.get_legend_handles_labels()

ax1.grid()
ax1.legend(h1+h2, l1+l2, loc="best")
ax1.set_title(f'Applied High Pass Filter of {columns[10]} \nwith  

{w_data[current]["label"]}')

plt.tight_layout()
plt.show()

# Sunlight (day-night context)

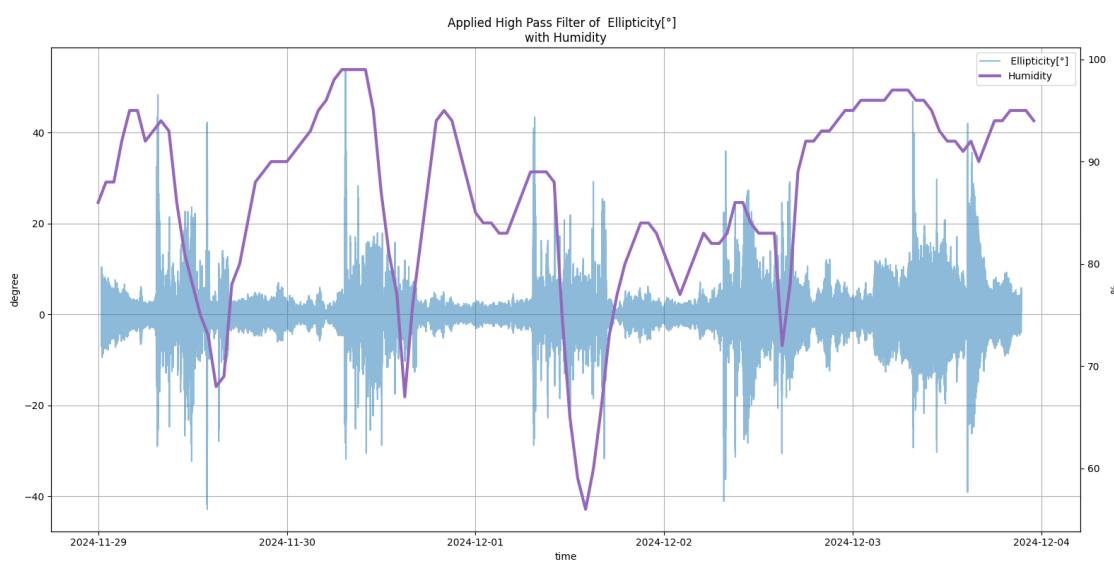
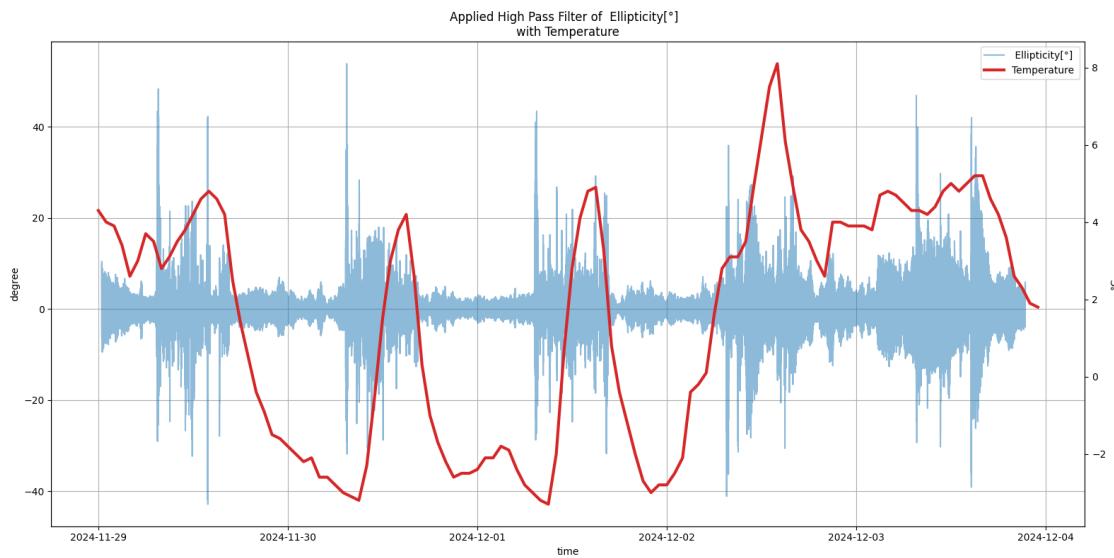
plt.figure(figsize = (16,8))

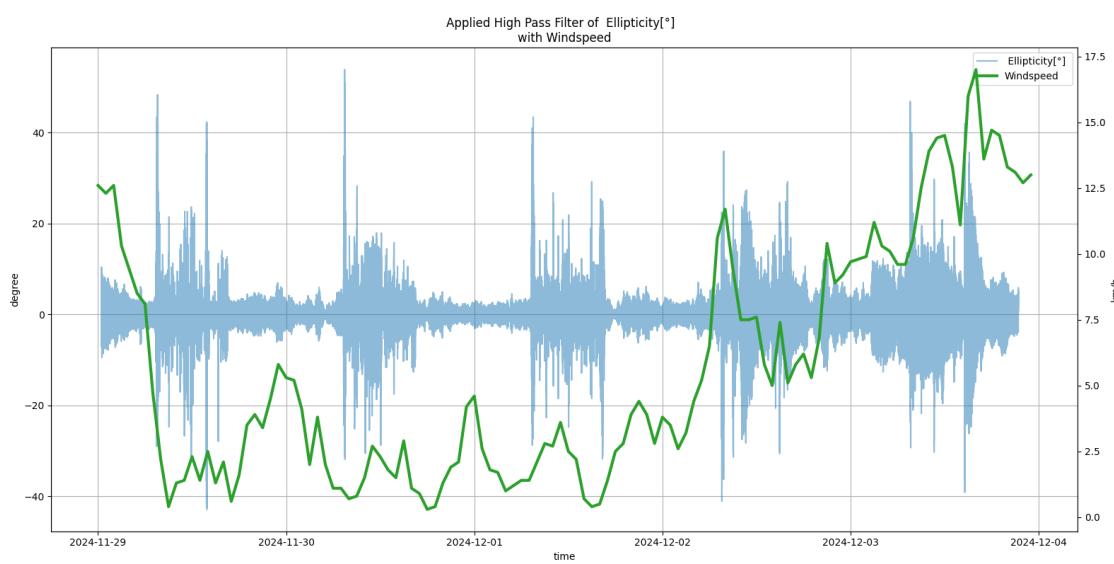
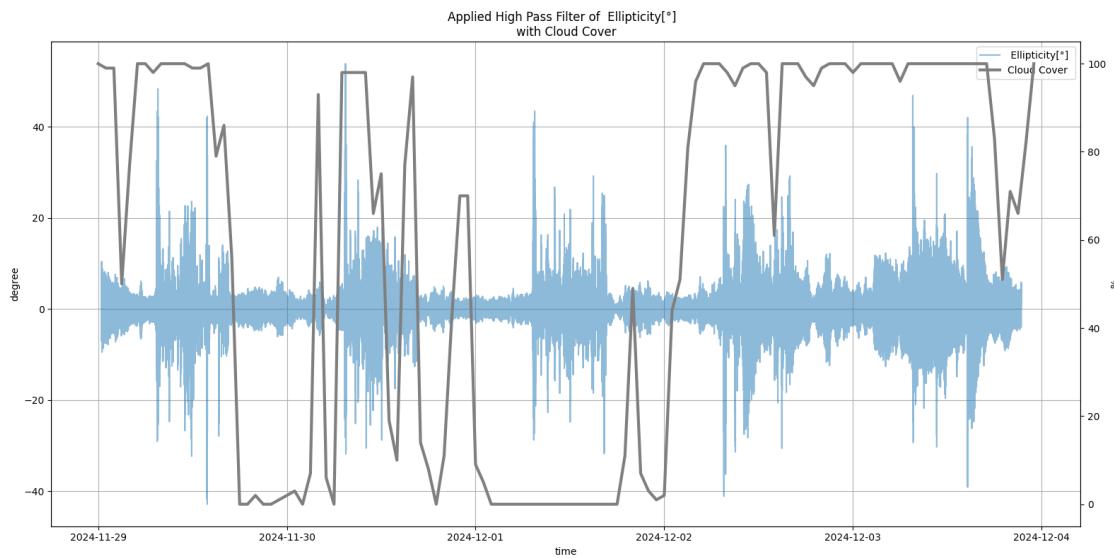
ydata = np.array(angle[columns[10]])
hps = highpass(ydata, 1000)
plt.plot(angle.index, hps, label=columns[10], alpha= 0.5)

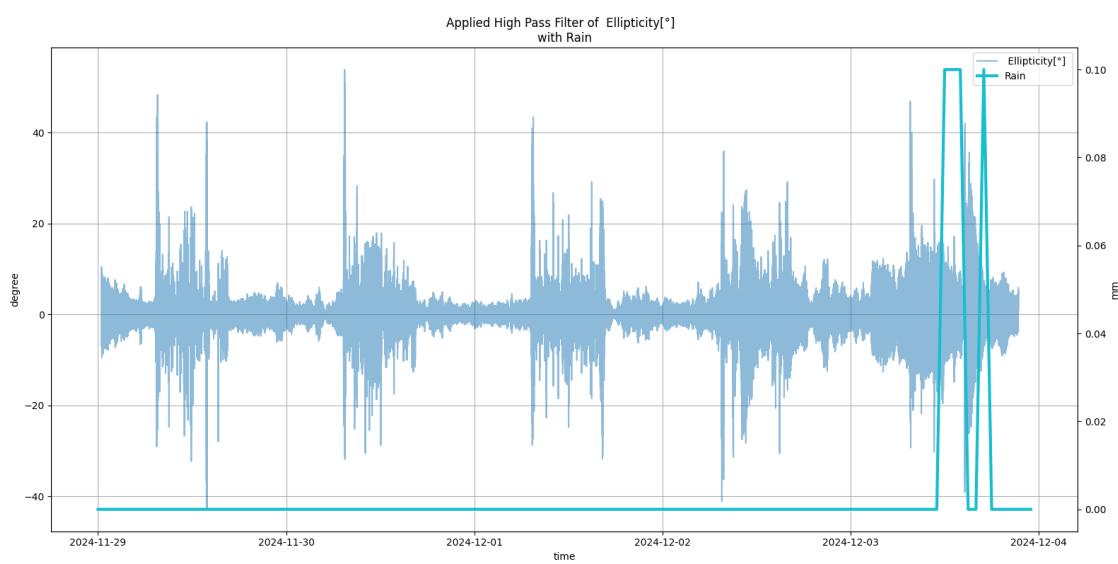
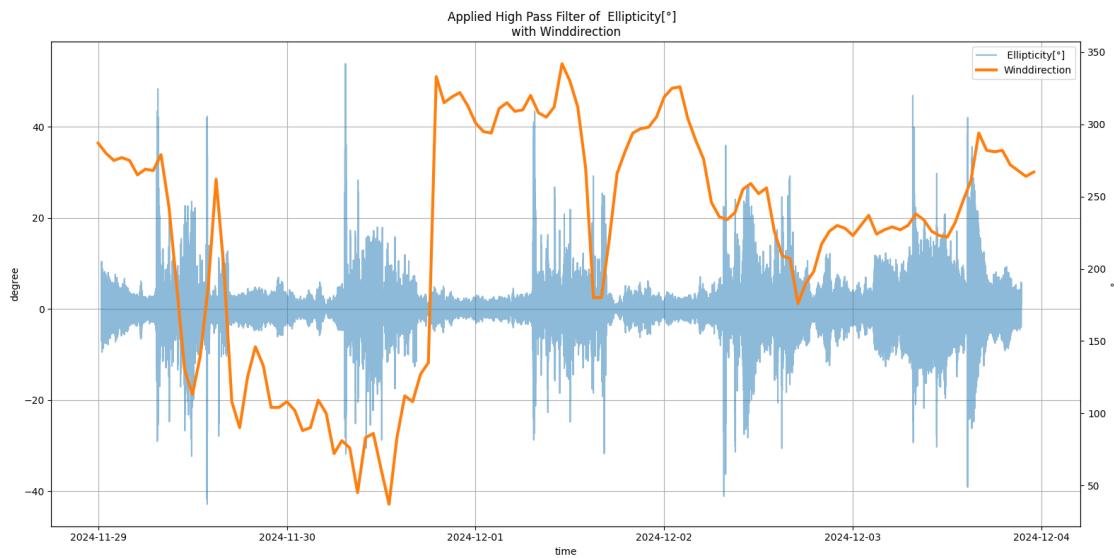
for i in range(len(sunrise)):
    plt.axvline(x = sunrise[i], color = 'y', linewidth=3)
    if i == 0: plt.axvline(x = sunset[i], color = 'y', label = 'Sunrise &  

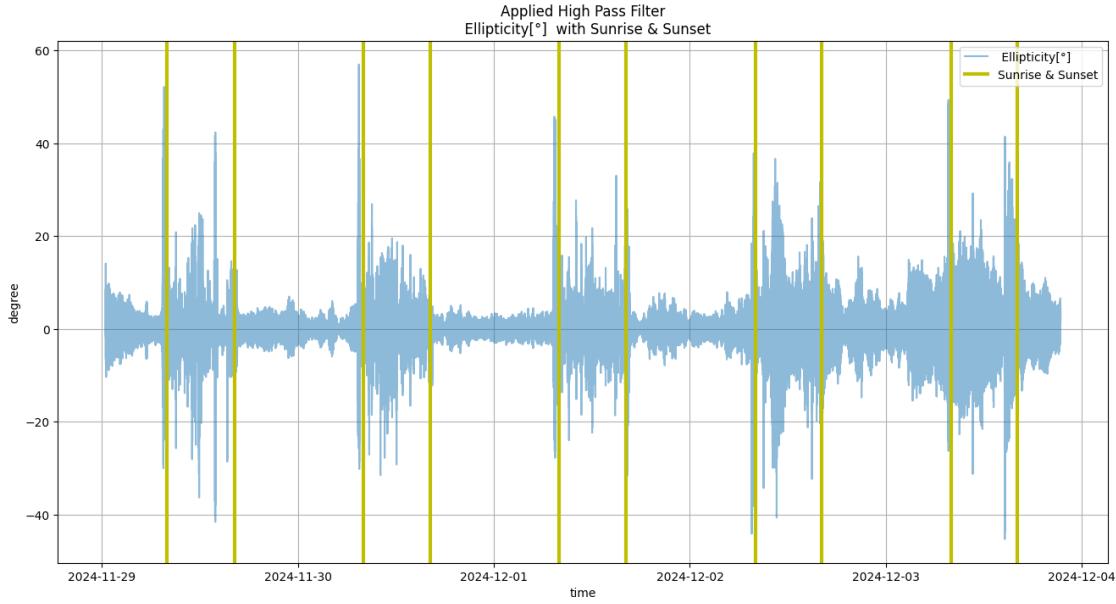
Sunset', linewidth=3)
    else: plt.axvline(x = sunset[i], color = 'y', linewidth=3)
plt.grid()
plt.legend(loc = 'best')
plt.title(f'Applied High Pass Filter\n {columns[10]} with Sunrise & Sunset')
plt.xlabel('time')
plt.ylabel('degree')
plt.show()

```









#### 4.2.4 Untersuchung von Zusammenhängen zwischen Ellipticity und Wetter

```
[34]: current = 0 #Temperature

fig, ax1 = plt.subplots(figsize=(16, 8))

ydata = np.array(angle[columns[10]])
hps = highpass(ydata, 1000)
ax1.plot(angle.index, hps, label=columns[10], alpha= 0.5)

for i in range(len(sunrise)):
    ax1.axvline(x = sunrise[i], color = 'y', linewidth=3)
    if i == 0: ax1.axvline(x = sunset[i], color = 'y', label = 'Sunrise & Sunset', linewidth=3)
    else: ax1.axvline(x = sunset[i], color = 'y', linewidth=3)

ax1.set_xlabel('time')
ax1.set_ylabel('degree')
h1, l1 = ax1.get_legend_handles_labels()

ax2 = ax1.twinx()

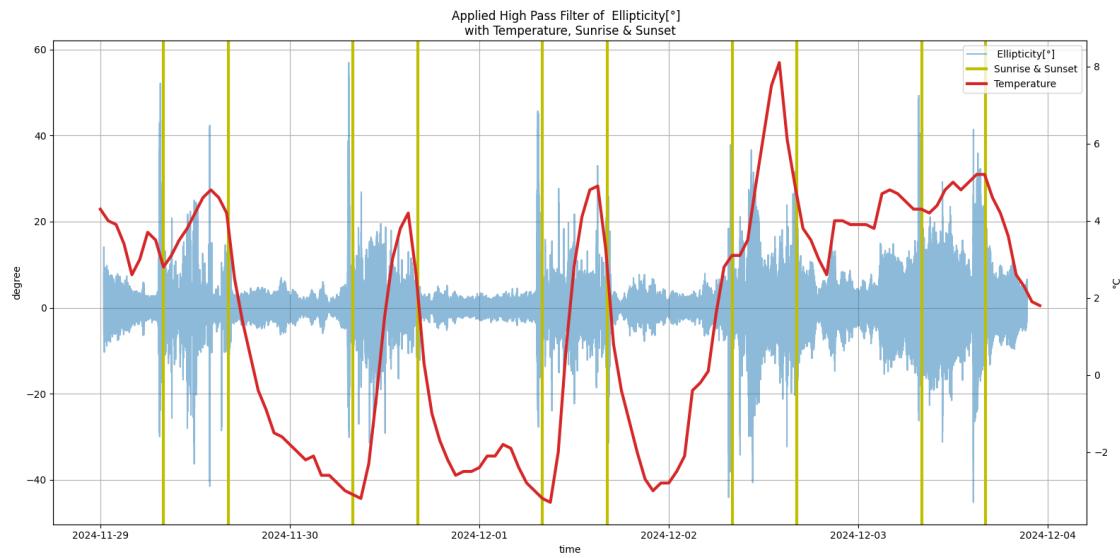
ax2.plot(weather.index, weather[w_data[current]["header"]], label=w_data[current]["label"], color = w_data[current]["color"], linewidth=3)
ax2.set_ylabel(w_data[current]["unit"])
h2, l2 = ax2.get_legend_handles_labels()
```

```

ax1.grid()
ax1.legend(h1+h2, l1+l2, loc="best")
ax1.set_title(f'Applied High Pass Filter of {columns[10]} \nwith\n ↵{w_data[current]["label"]}, Sunrise & Sunset')

plt.tight_layout()
plt.show()

```



```

[35]: current = 2 #Cloud Cover

fig, ax1 = plt.subplots(figsize=(16, 8))

ydata = np.array(angle[columns[10]])
hps = highpass(ydata, 1000)
ax1.plot(angle.index, hps, label=columns[10], alpha= 0.5)

for i in range(len(sunrise)):
    ax1.axvline(x = sunrise[i], color = 'y', linewidth=3)
    if i == 0: ax1.axvline(x = sunset[i], color = 'y', label = 'Sunrise &\nSunset', linewidth=3)
    else: ax1.axvline(x = sunset[i], color = 'y', linewidth=3)

ax1.set_xlabel('time')
ax1.set_ylabel('degree')
h1, l1 = ax1.get_legend_handles_labels()

ax2 = ax1.twinx()

```

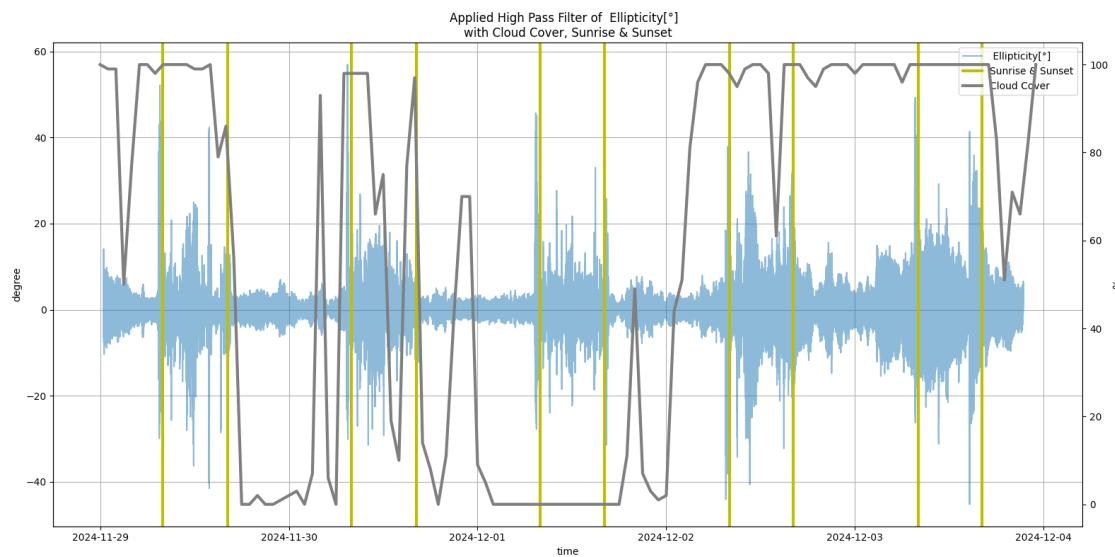
```

ax2.plot(weather.index, weather[w_data[current]["header"]], ▾
    ↪label=w_data[current]["label"], color = w_data[current]["color"], ▾
    ↪linewidth=3)
ax2.set_ylabel(w_data[current]["unit"])
h2, l2 = ax2.get_legend_handles_labels()

ax1.grid()
ax1.legend(h1+h2, l1+l2, loc="best")
ax1.set_title(f'Applied High Pass Filter of {columns[10]} \nwith ▾
    ↪{w_data[current]["label"]}, Sunrise & Sunset')

plt.tight_layout()
plt.show()

```



```

[36]: current = 3 #Windspeed

fig, ax1 = plt.subplots(figsize=(16, 8))

ydata = np.array(angle[columns[10]])
hps = highpass(ydata, 1000)
ax1.plot(angle.index, hps, label=columns[10], alpha= 0.5)

for i in range(len(sunrise)):
    ax1.axvline(x = sunrise[i], color = 'y', linewidth=3)
    if i == 0: ax1.axvline(x = sunset[i], color = 'y', label = 'Sunrise & ▾
        ↪Sunset', linewidth=3)
    else: ax1.axvline(x = sunset[i], color = 'y', linewidth=3)

```

```

ax1.set_xlabel('time')
ax1.set_ylabel('degree')
h1, l1 = ax1.get_legend_handles_labels()

ax2 = ax1.twinx()

ax2.plot(weather.index, weather[w_data[current]["header"]], □
    ↪label=w_data[current]["label"], color = w_data[current]["color"], □
    ↪linewidth=3)
ax2.set_ylabel(w_data[current]["unit"])
h2, l2 = ax2.get_legend_handles_labels()

ax1.grid()
ax1.legend(h1+h2, l1+l2, loc="best")
ax1.set_title(f'Applied High Pass Filter of {columns[10]} \nwith □
    ↪{w_data[current]["label"]}, Sunrise & Sunset')

plt.tight_layout()
plt.show()

```

