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# Dark-Fiber Charakterisierung für entanglement polarisierter QKD

Verhalten der Winkelparameter: Schwerpunkt Ellipticity [°]

**Autor:** Laura Komma

**Datensatz:** Nordhausen - Sundhausen

## 1 Aufbereitung der Messdaten

### 1.1 Ressourcen und Literatur

- Messdaten
- Messgerät
- Open-Meteo: [Wetterdaten](#) & [Dokumentation](#)
- Sonnenauf- und untergang
- Plotting Tool für Poincaré-Kugel

### 1.2 Verwendete Libraries / Softwaretools

```
[1]: import matplotlib.pyplot as plt
import matplotlib.dates as mdates
import numpy as np
import pandas as pd

import io
import datetime
import requests
from mpl_toolkits.mplot3d import Axes3D
from scipy.stats import norm
from scipy.signal import butter, filtfilt

from py_pol.jones_vector import Jones_vector, degrees
from py_pol.stokes import Stokes
```

### 1.3 Eigene Hilfsfunktionen

```
[2]: def format_time(x, pos):
    h = int(x) // 3600
    m = (int(x) % 3600) // 60
    return f"{h:02d}:{m:02d}"

[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

[5]: def convert_angel(az, el):
    az = np.array(az) * degrees
    el = np.array(el) * degrees

    x = np.cos(2*el) * np.cos(2*az)
    y = np.cos(2*el) * np.sin(2*az)
    z = np.sin(2*el)
    return x, y, z

[6]: def calculate_freq(x, y, z):
    bins = 50
    coords = np.vstack((x, y, z)).T
    hist, edges = np.histogramdd(coords, bins=bins)

    # Indices for each coordinate pair (with clipping)
    bin_indices = [
        np.clip(np.digitize(x, edges[0]) - 1, 0, bins - 1),
        np.clip(np.digitize(y, edges[1]) - 1, 0, bins - 1),
        np.clip(np.digitize(z, edges[2]) - 1, 0, bins - 1)
    ]
    freq = hist[bin_indices[0], bin_indices[1], bin_indices[2]]
```

```

    return freq

[7]: def plot_poincare(x, y, z, freq, elev=15, azim=45, title="Not given"):
    fig = plt.figure(figsize=(6, 6))
    ax = fig.add_subplot(111, projection='3d')

    # Poincaré-Sphere
    u = np.linspace(0, 2 * np.pi, 50)
    v = np.linspace(0, np.pi, 50)
    X = np.outer(np.cos(u), np.sin(v))
    Y = np.outer(np.sin(u), np.sin(v))
    Z = np.outer(np.ones(np.size(u)), np.cos(v))

    ax.plot_surface(X, Y, Z, color='lightgray', alpha=0.1, edgecolor='k', ↴
    linewidth=0.5)

    # Axes
    ax.plot([0, 1.6], [0, 0], [0, 0], color='red')      # +S1
    ax.plot([0, -1.6], [0, 0], [0, 0], color='red')     # -S1
    ax.plot([0, 0], [0, 1.6], [0, 0], color='green')    # +S2
    ax.plot([0, 0], [0, -1.6], [0, 0], color='green')   # -S2
    ax.plot([0, 0], [0, 0], [0, 1.4], color='blue')     # +S3
    ax.plot([0, 0], [0, 0], [0, -1.4], color='blue')    # -S3

    # Labeling Axes
    ax.text( 2.0, 0, 0, 'S1', color='red', fontsize=10)
    ax.text(-1.8, 0, 0, '-S1', color='red', fontsize=10)
    ax.text( 0, 1.8, 0, 'S2', color='green', fontsize=10)
    ax.text( 0, -2.0, 0, '-S2', color='green', fontsize=10)
    ax.text( 0, 0, 1.6, 'S3', color='blue', fontsize=10)
    ax.text( 0, 0, -1.6, '-S3', color='blue', fontsize=10)

    # Measurement
    sc = ax.scatter(x, y, z, c=freq, cmap='hot', s=15)
    plt.colorbar(sc, label='density')

    # Scaling
    ax.set_box_aspect([1, 1, 1])
    ax.set_xticks([]); ax.set_yticks([]); ax.set_zticks([])

    # Aligning Poincaré-Sphere
    ax.view_init(elev=elev, azim=azim)

    ax.set_title(title)

plt.show()

```

## 1.4 Aufbereitung der Messdaten

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

```
[9]: 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])  
  
colors = ["tab:blue", "tab:orange", "tab:green", "tab:red", "tab:purple"]
```

```
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
```

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

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

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

## 1.5 Aufbereitung der Wetterdaten

```
[13]: # Nordhausen - Latitude: 51.5 & Longitude: 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,r
        "timezone=Europe/Berlin"
)

response = requests.get(url)

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

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

weather.columns = weather_columns
weather.to_csv("open-meteo_nordhausen.csv", index=False)
```

```
[15]: 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')
]
```

```
[16]: 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

```
[17]: weather[weather_columns[0]] = pd.to_datetime(weather[weather_columns[0]])  

weather.set_index(weather_columns[0], inplace=True)
```

## 2 Analyse der Mess- und Wetterdaten

### 2.1 Tägliche Aufteilung der Messdaten

```
[18]: plt.figure(figsize = (16,9))  

for date, df_day in angle_daily_list:  

    values = df_day[columns[10]]  

    plt.plot(values, label=str(date), alpha=0.5)  

plt.grid()  

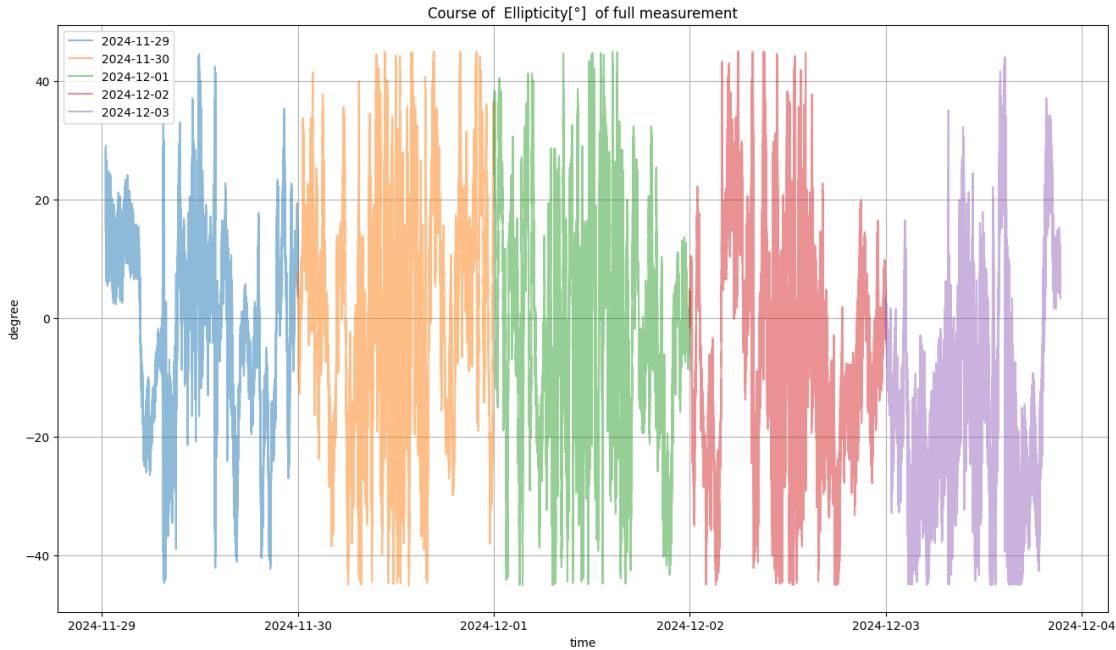
plt.legend(loc = 'best')  

plt.title(f'Course of {columns[10]} of full measurement')  

plt.xlabel('time')  

plt.ylabel('degree')  

plt.show()
```



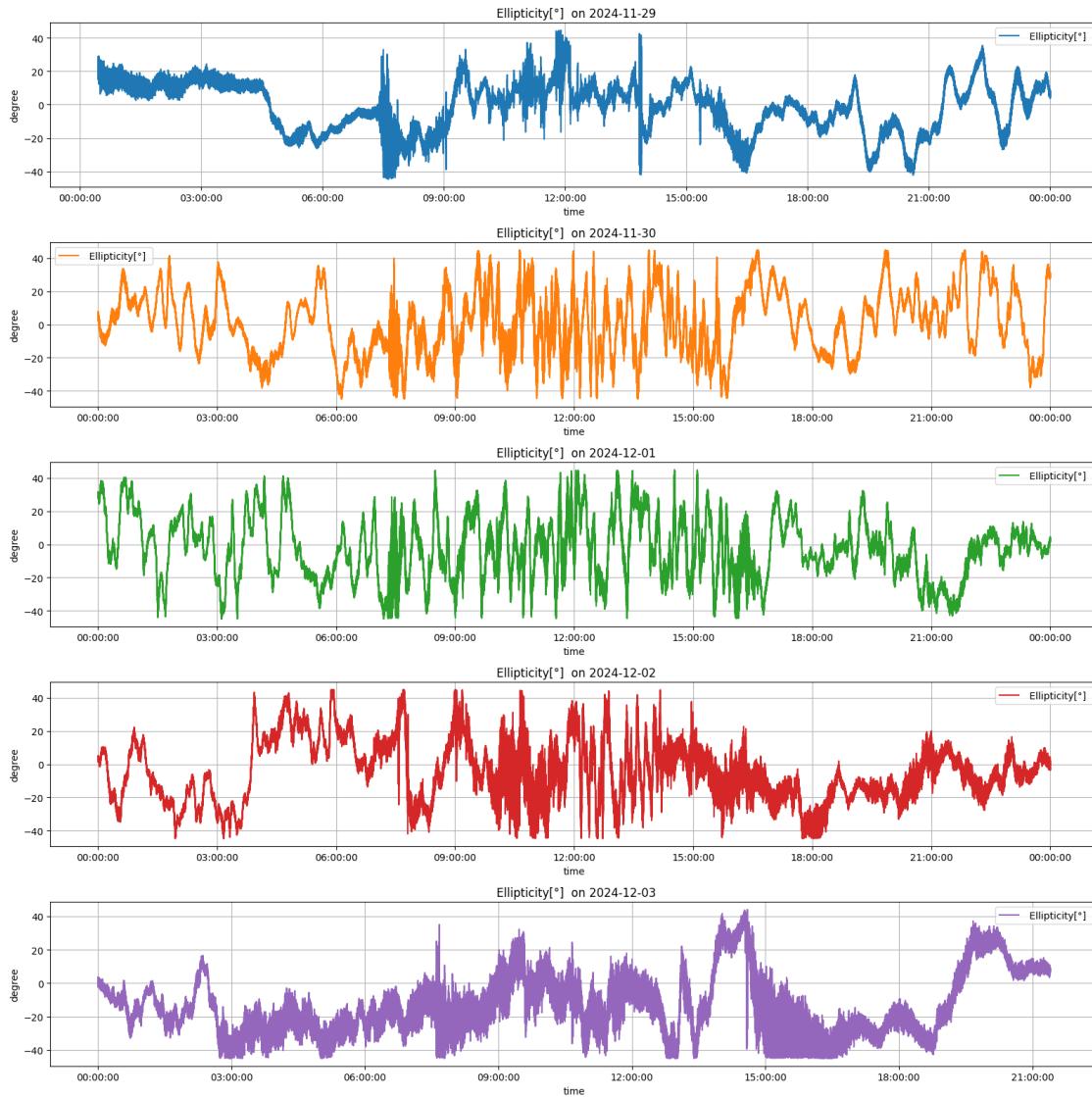
```
[19]: fig, axs = plt.subplots(len(angle_daily_list), 1, figsize=(16, 16), sharex=False)

for i in range(len(angle_daily_list)):
    ax = axs[i] if len(angle_daily_list) > 1 else axs
    df_day = angle_daily_list[i][1][columns[10]]

    ax.plot(df_day.index, df_day, label=columns[10], color=colors[i])
    ax.grid()
    ax.legend(loc='best')
    ax.set_title(f'{columns[10]} on {angle_daily_list[i][0]}')
    ax.set_xlabel('time')
    ax.set_ylabel('degree')

    ax.xaxis.set_major_formatter(mdates.DateFormatter('%H:%M:%S'))

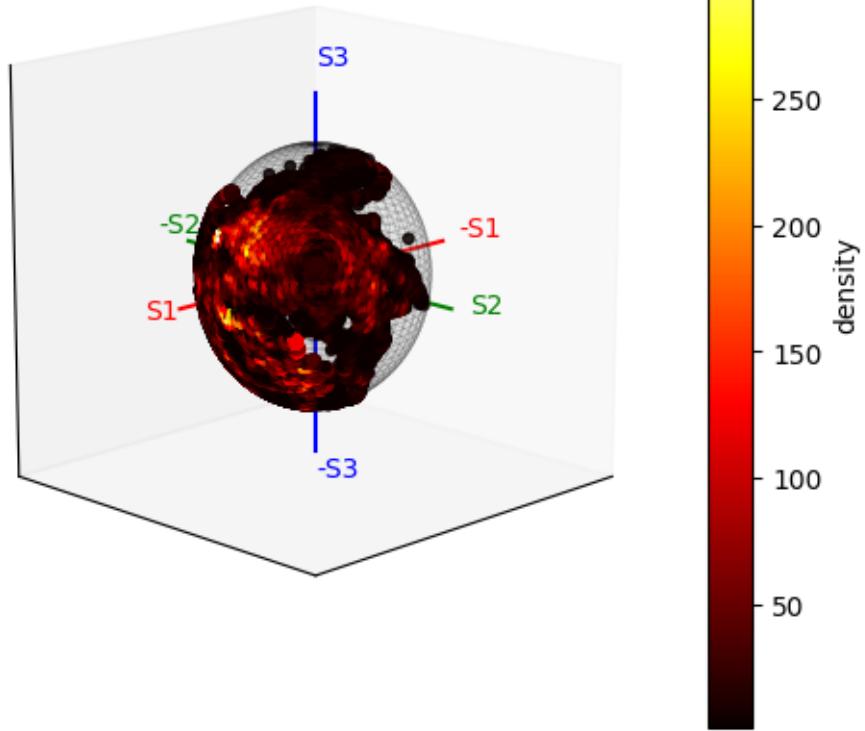
plt.tight_layout()
plt.show()
```



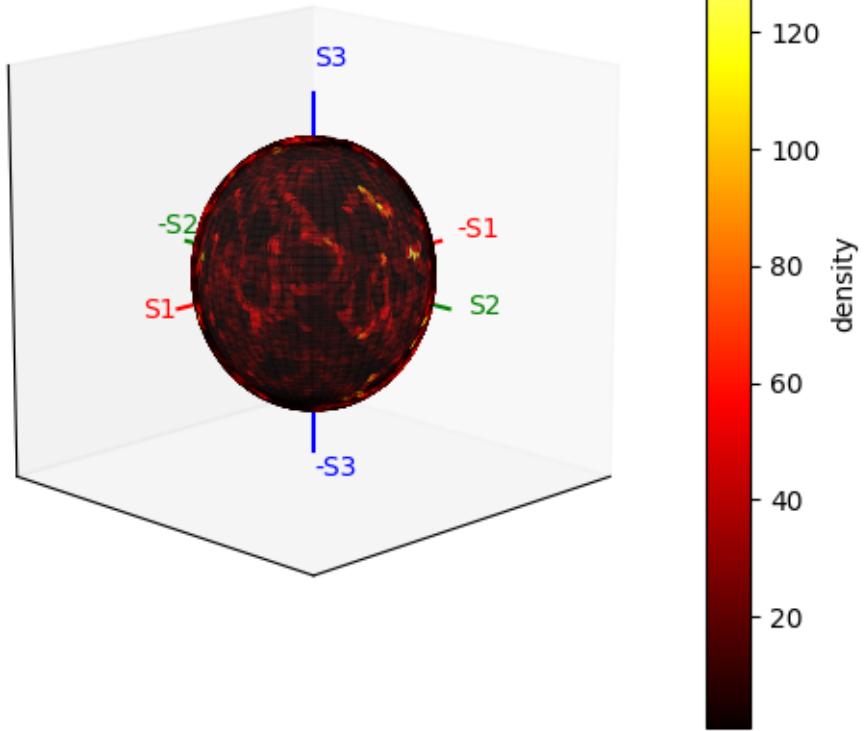
```
[20]: for i in range(len(angle_daily_list)):
    df_day = angle_daily_list[i][1]
    resample = df_day.resample('S').mean().ffill()
    title = f'Resampled measurement of {angle_daily_list[i][0]}\n(samples={len(resample)}:,{})'

    x,y,z = convert_angel(resample[columns[9]], resample[columns[10]])
    freq = calculate_freq(x, y, z)
    plot_poincare(x, y, z, freq, title=title)
```

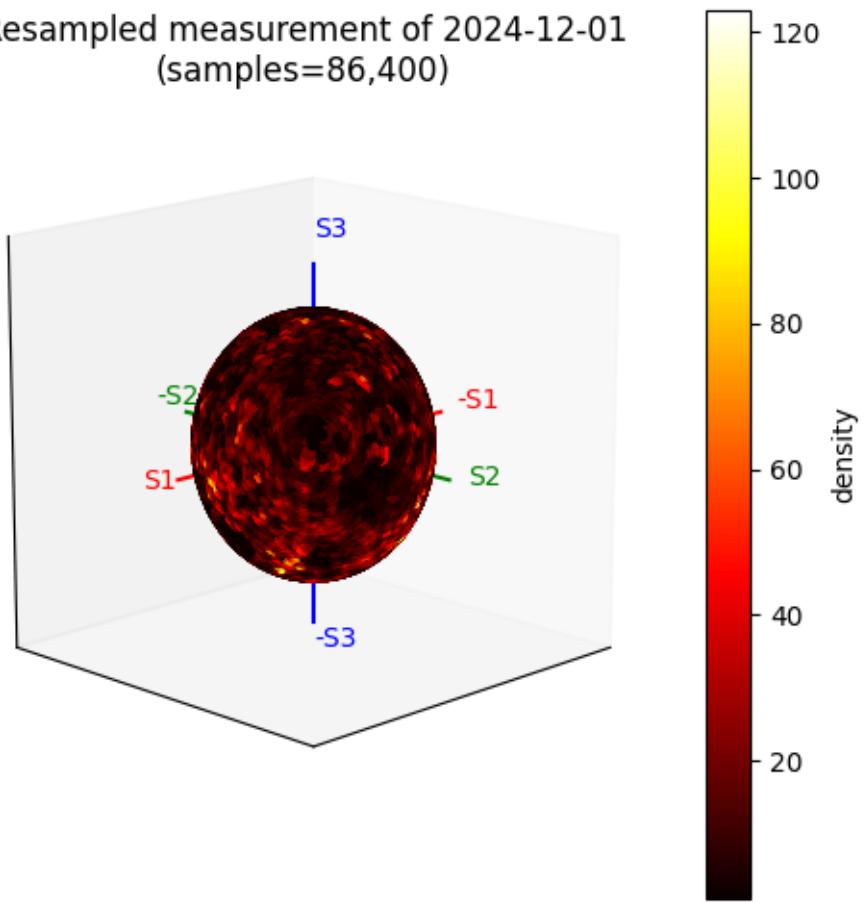
Resampled measurement of 2024-11-29  
(samples=84,796)



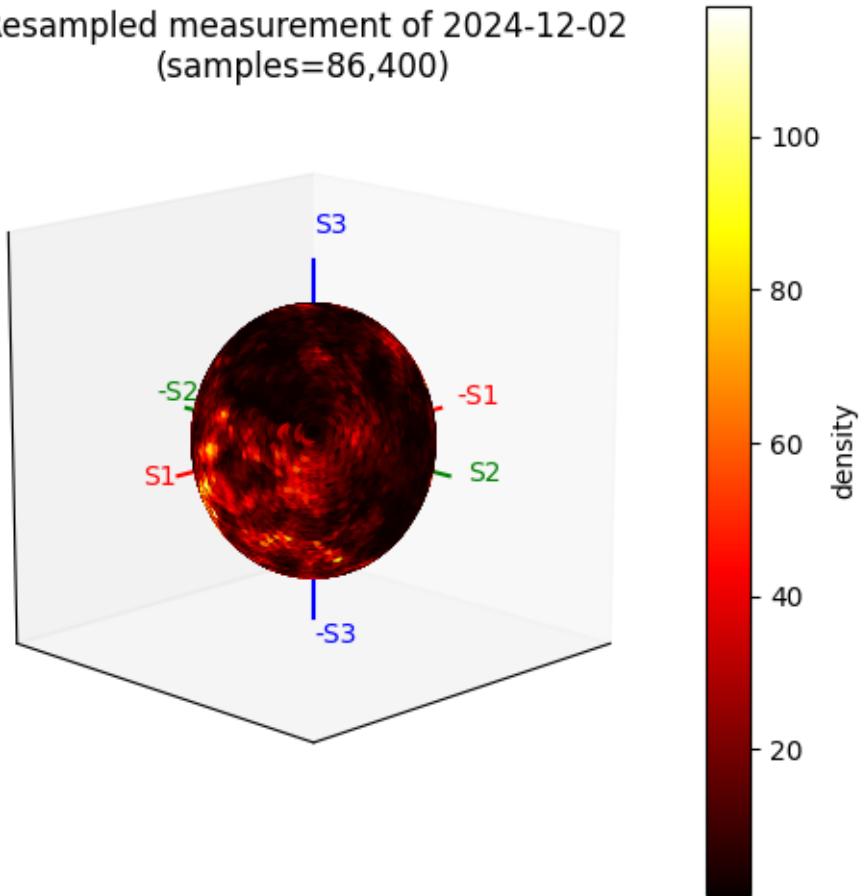
Resampled measurement of 2024-11-30  
(samples=86,400)



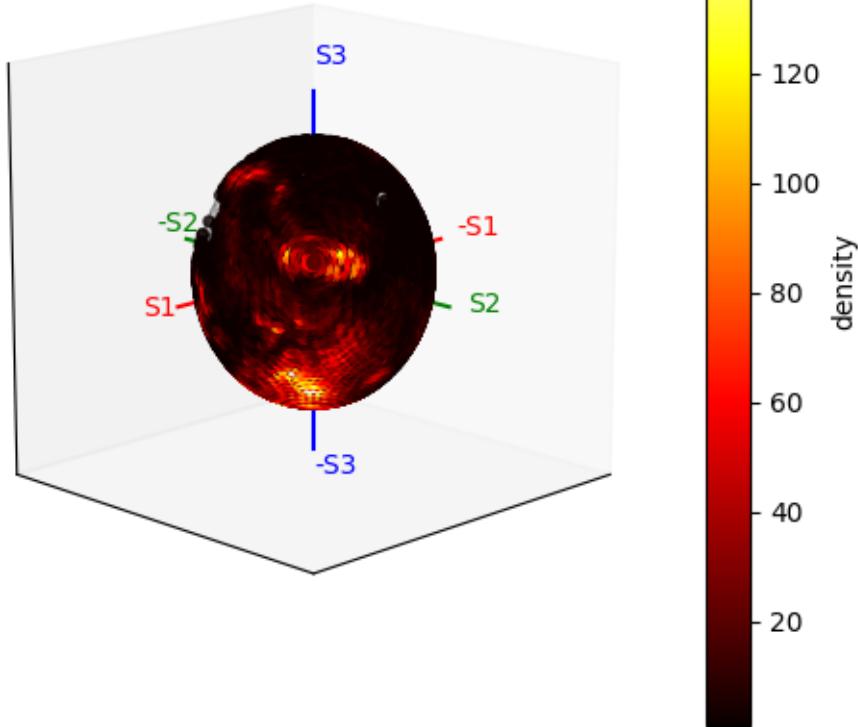
Resampled measurement of 2024-12-01  
(samples=86,400)



Resampled measurement of 2024-12-02  
(samples=86,400)



Resampled measurement of 2024-12-03  
(samples=77,044)

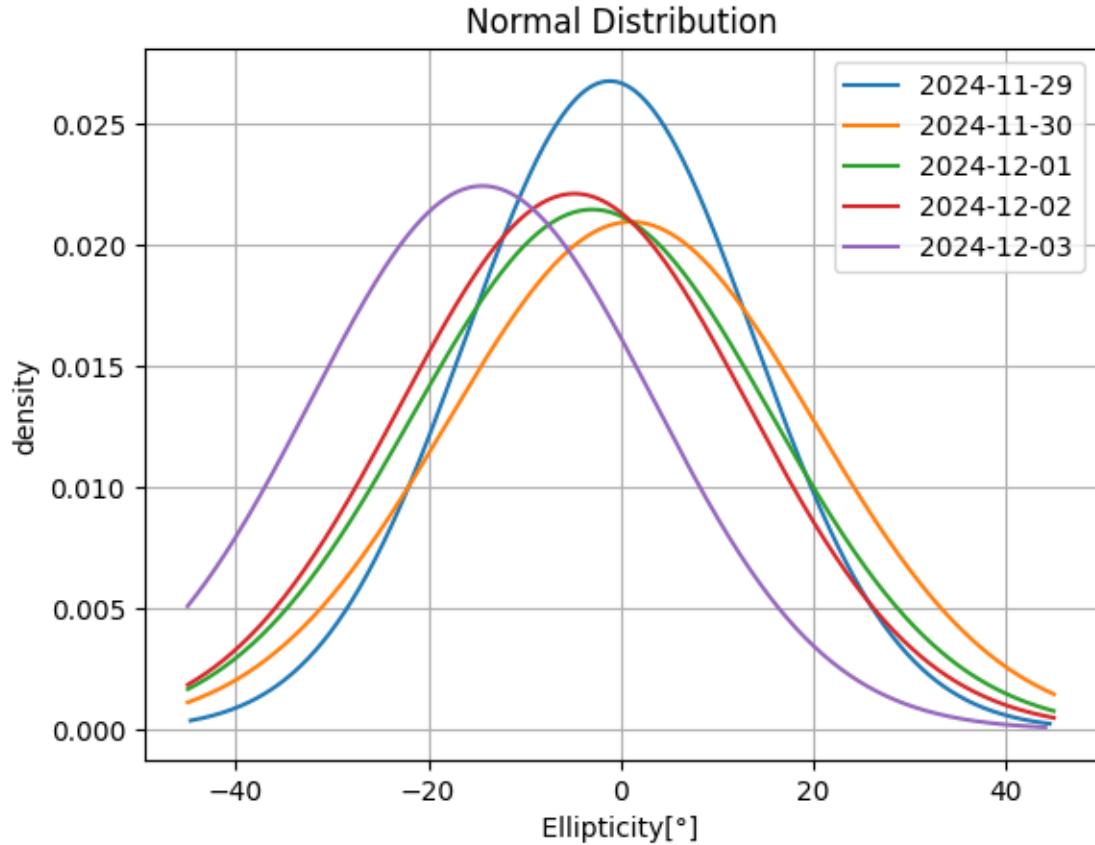


## 2.2 Normalverteilung

```
[21]: for i in range(len(angle_daily_list)):
    ydata1 = np.array(angle_daily_list[i][1][columns[10]])
    mu1 = np.mean(ydata1)
    sigma1 = np.std(ydata1)
    x1 = np.linspace(ydata1.min(),ydata1.max(),len(ydata1))
    y1 = norm.pdf(x1, mu1, sigma1)

    plt.plot(x1, y1, label = angle_daily_list[i][0])

plt.title(f'Normal Distribution')
plt.legend(loc = 'best')
plt.xlabel(columns[10])
plt.ylabel('density')
plt.grid()
plt.show()
```



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

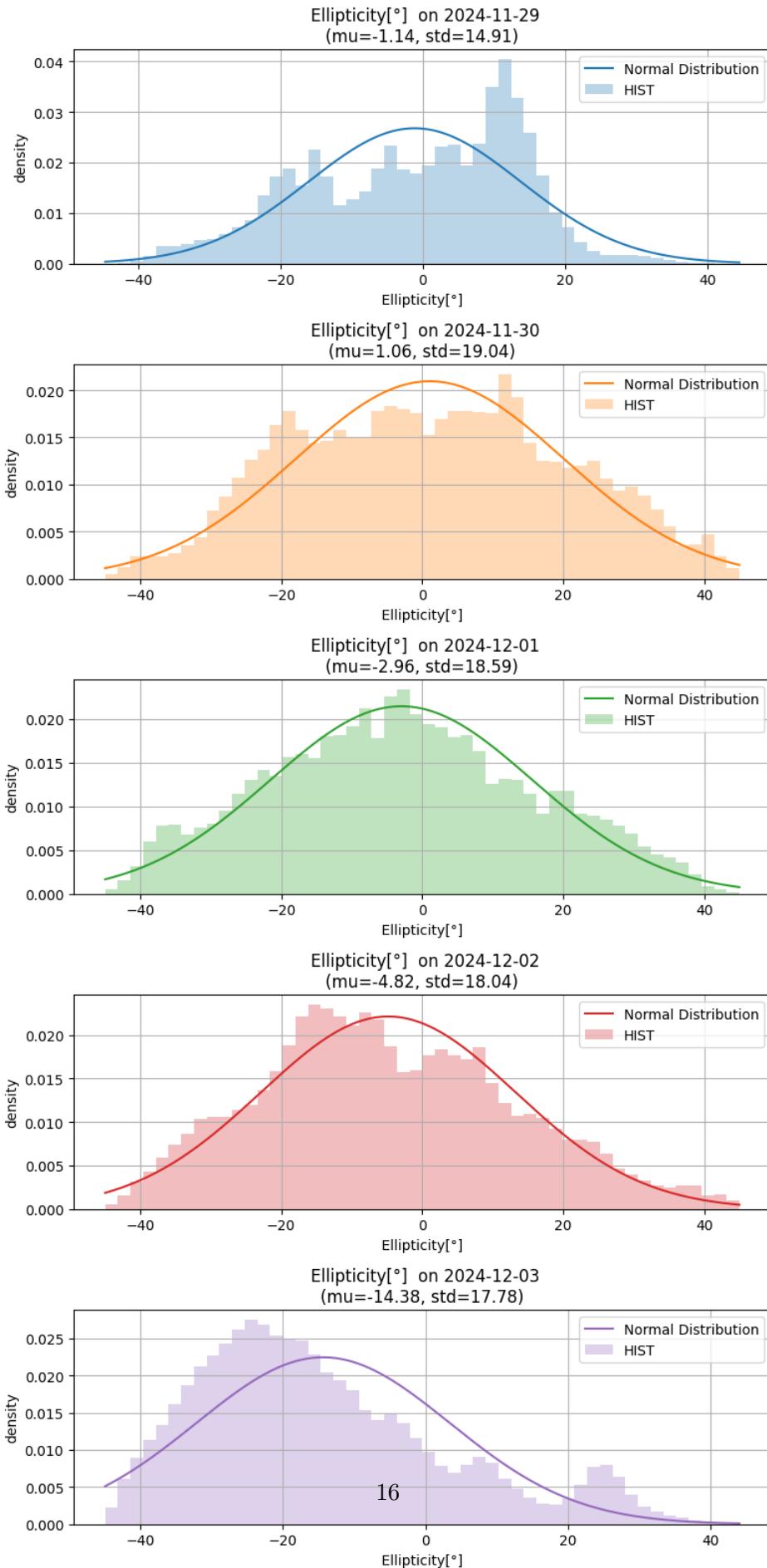
for i in range(len(angle_daily_list)):
    ax = axs[i] if len(angle_daily_list) > 1 else axs
    ydata1 = np.array(angle_daily_list[i][1][columns[10]])
    mu1 = np.mean(ydata1)
    sigma1 = np.std(ydata1)
    x1 = np.linspace(ydata1.min(), ydata1.max(), len(ydata1))
    y1 = norm.pdf(x1, mu1, sigma1)

    ax.plot(x1, y1, label = 'Normal Distribution', color=colors[i])
    ax.hist(ydata1, bins = 50, density = True, color=colors[i], alpha = 0.3, label = "HIST")

    ax.grid()
    ax.legend(loc='best')
    ax.set_title(f'{columns[10]} on {angle_daily_list[i][0]}\n(mu={mu1:.2f},\nstd={sigma1:.2f})')
    ax.set_xlabel(columns[10])
```

```
ax.set_ylabel('density')

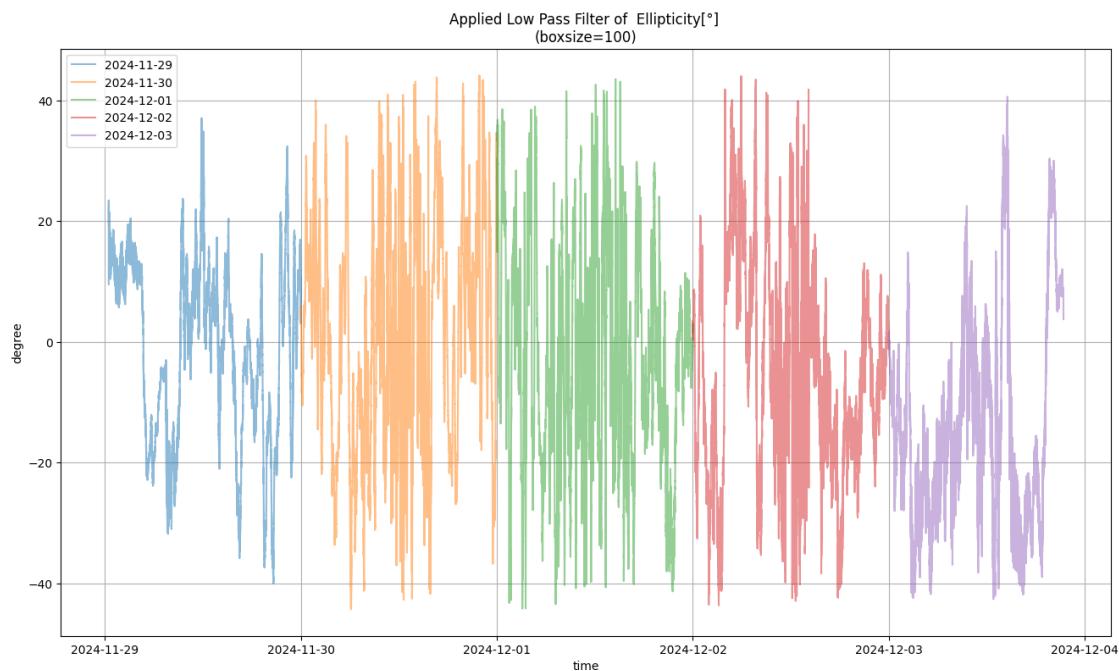
plt.tight_layout()
plt.show()
```



## 2.3 Filterung mittels Tief- und Hochpass

```
[23]: box = 100

plt.figure(figsize = (16,9))
for date, df_day in angle_daily_list:
    ydata = np.array(df_day[columnns[10]])
    lps = lowpass(ydata, box)
    plt.plot(df_day.index, lps[:-1], label=str(date) , alpha=0.5)
plt.grid()
plt.legend(loc = 'best')
plt.title(f'Applied Low Pass Filter of {columnns[10]}\n(boxsize={box})')
plt.xlabel('time')
plt.ylabel('degree')
plt.show()
```



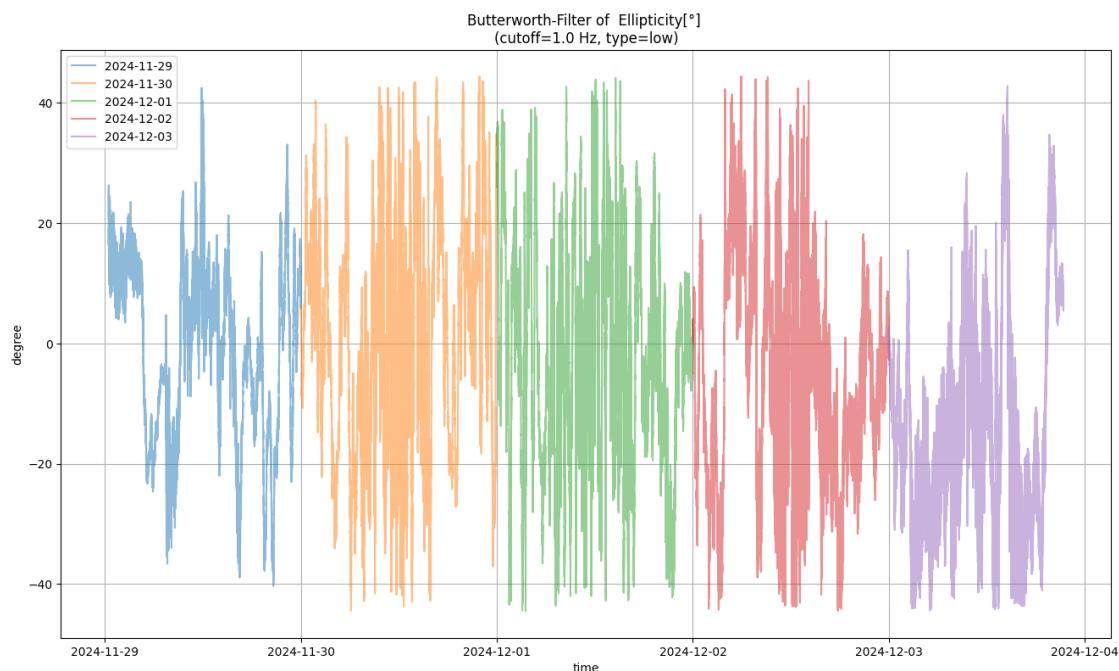
```
[24]: cutoff = 1.0
pass_type = 'low'

plt.figure(figsize = (16,9))
for date, df_day in angle_daily_list:
    ydata = np.array(df_day[columnns[10]])
```

```

lps = butter_filter(ydata, cutoff=cutoff, btype=pass_type)
plt.plot(df_day.index, lps, label=str(date), alpha=0.5)
plt.grid()
plt.legend(loc='best')
plt.title(f'Butterworth-Filter of {columns[10]}\n(cutoff={cutoff} Hz, type={pass_type})')
plt.xlabel('time')
plt.ylabel('degree')
plt.show()

```



```

[25]: box = 100

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

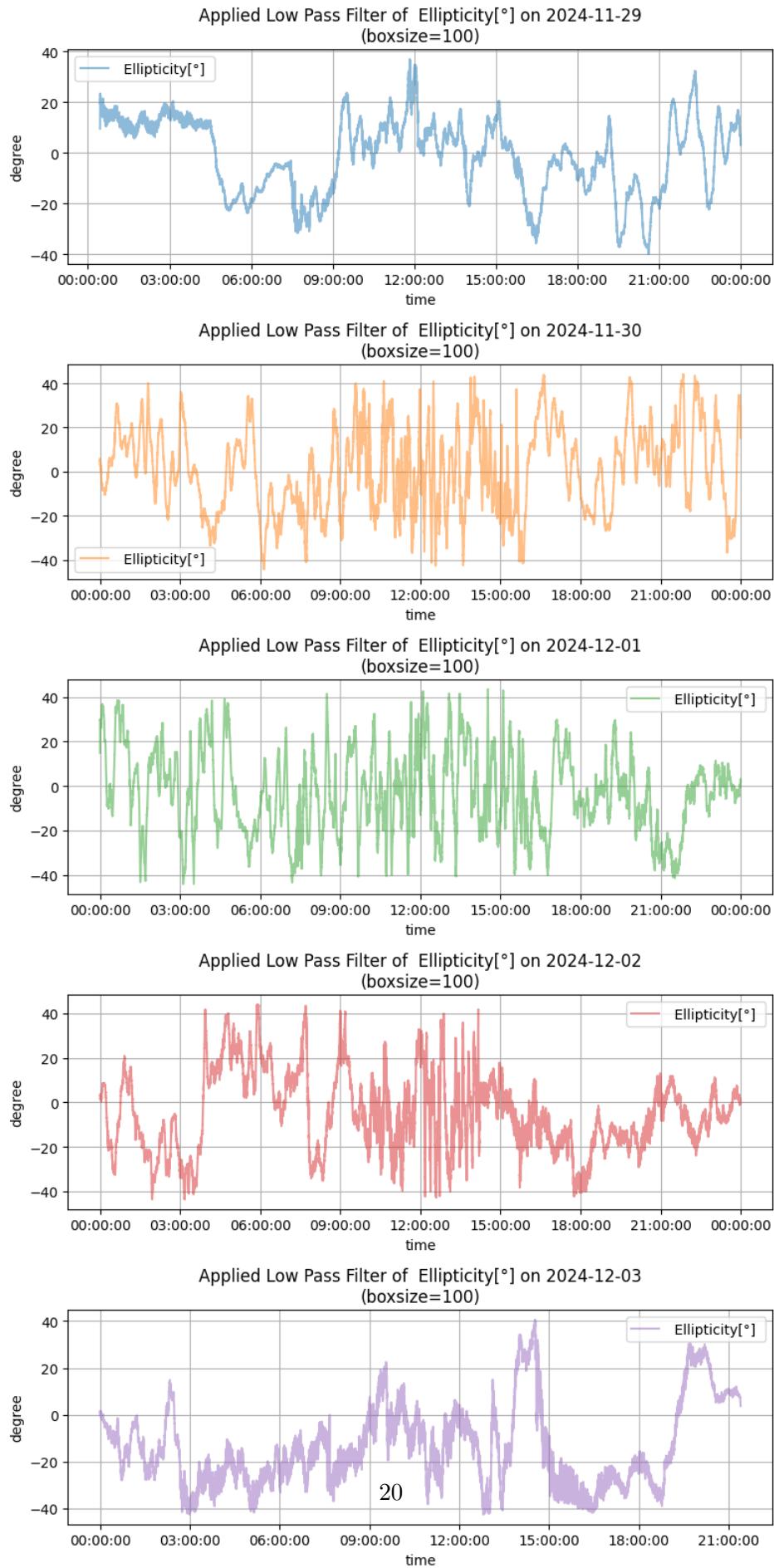
for i in range(len(angle_daily_list)):
    ax = axs[i] if len(angle_daily_list) > 1 else axs
    df_day = angle_daily_list[i][1][columns[10]]
    ydata = np.array(df_day)
    lps = lowpass(ydata, box)

    ax.plot(df_day.index, lps[:-1], label=columns[10], color=colors[i], alpha=0.5)

    ax.grid()
    ax.legend(loc='best')

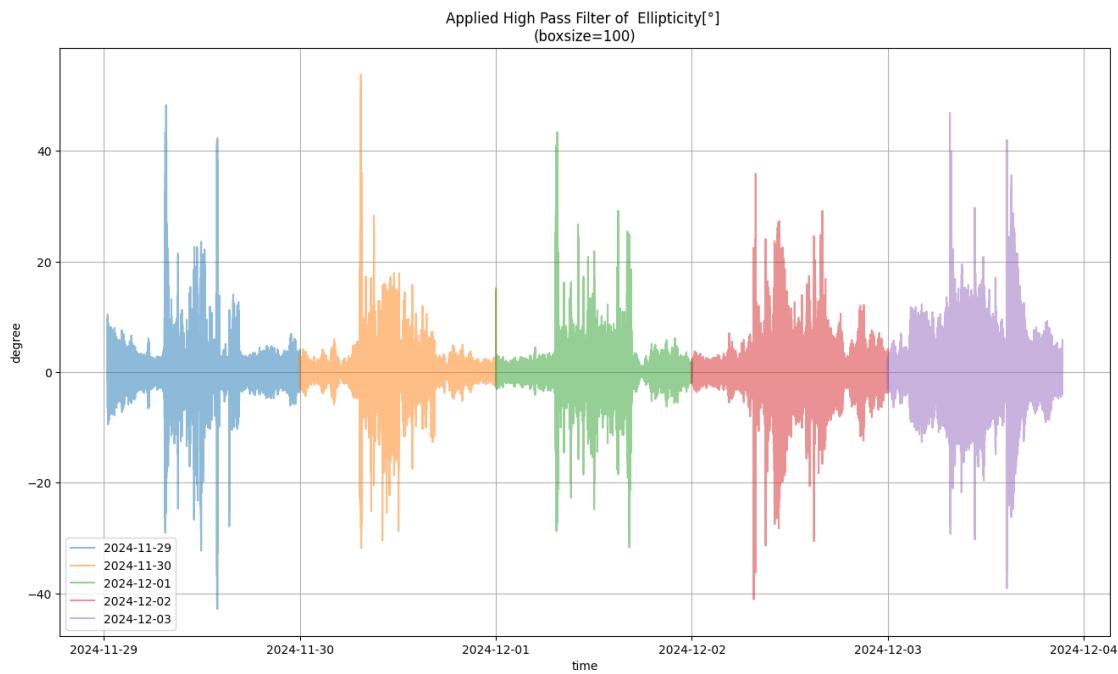
```

```
    ax.set_title(f'Applied Low Pass Filter of {columns[10]} on\n' +\n    f'{angle_daily_list[i][0]}\n(boxesize={box})')\n\n    ax.set_xlabel('time')\n    ax.set_ylabel('degree')\n\n    ax.xaxis.set_major_formatter(mdates.DateFormatter('%H:%M:%S'))\n\nplt.tight_layout()\nplt.show()
```



```
[26]: box = 100

plt.figure(figsize = (16,9))
for date, df_day in angle_daily_list:
    ydata = np.array(df_day[columnns[10]])
    hps = highpass(ydata, box)
    plt.plot(df_day.index, hps, label=str(date) , alpha=0.5)
plt.grid()
plt.legend(loc = 'best')
plt.title(f'Applied High Pass Filter of {columnns[10]}\n(boxsize={box})')
plt.xlabel('time')
plt.ylabel('degree')
plt.show()
```



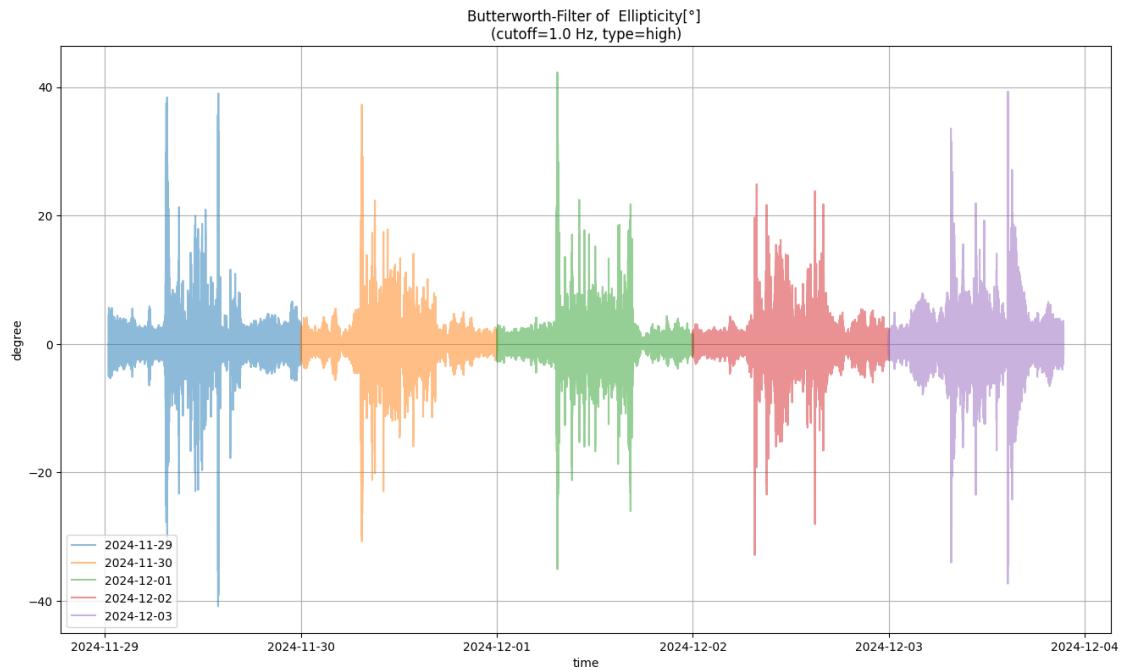
```
[27]: cutoff = 1.0
pass_type = 'high'

plt.figure(figsize = (16,9))
for date, df_day in angle_daily_list:
    ydata = np.array(df_day[columnns[10]])
    lps = butter_filter(ydata, cutoff=cutoff, btype=pass_type)
    plt.plot(df_day.index, lps, label=str(date) , alpha=0.5)
```

```

plt.grid()
plt.legend(loc = 'best')
plt.title(f'Butterworth-Filter of {columns[10]}\n(cutoff={cutoff} Hz, type={pass_type})')
plt.xlabel('time')
plt.ylabel('degree')
plt.show()

```



[28]:

```

box = 100

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

for i in range(len(angle_daily_list)):
    ax = axs[i] if len(angle_daily_list) > 1 else axs
    df_day = angle_daily_list[i][1][columns[10]]
    ydata = np.array(df_day)
    hps = highpass(ydata, box)

    ax.plot(df_day.index, hps, label=columns[10], color=colors[i], alpha=0.5)

    ax.grid()
    ax.legend(loc='best')
    ax.set_title(f'Applied High Pass Filter of {columns[10]} on {angle_daily_list[i][0]}\n(boxesize={box})')
    ax.set_xlabel('time')

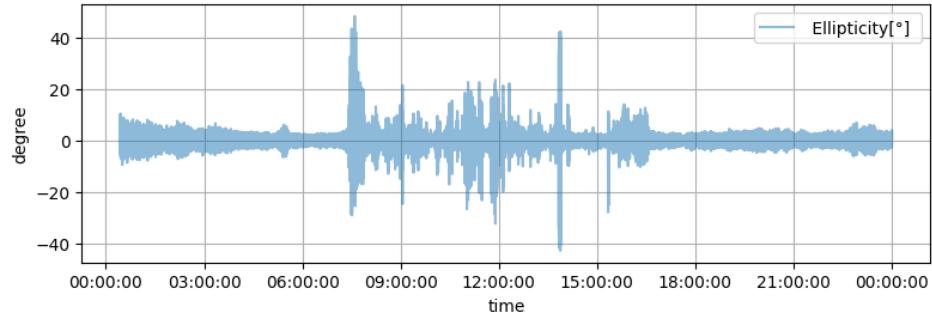
```

```
ax.set_ylabel('degree')

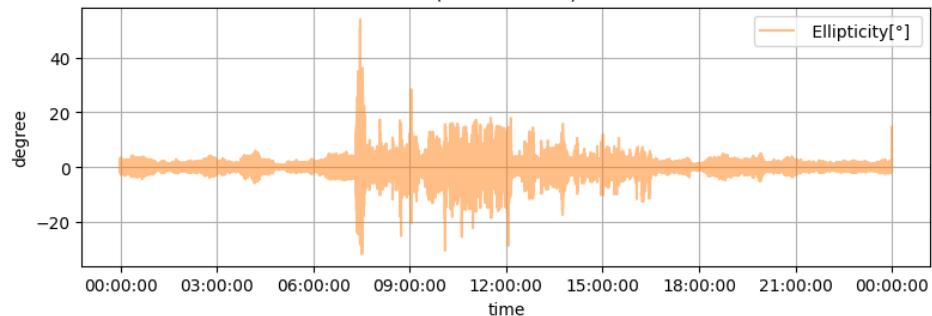
ax.xaxis.set_major_formatter(mdates.DateFormatter('%H:%M:%S'))

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

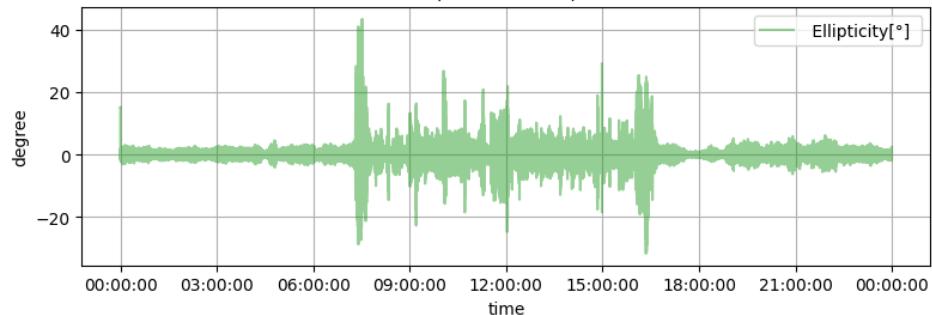
Applied High Pass Filter of Ellipticity[°] on 2024-11-29  
(boxsize=100)



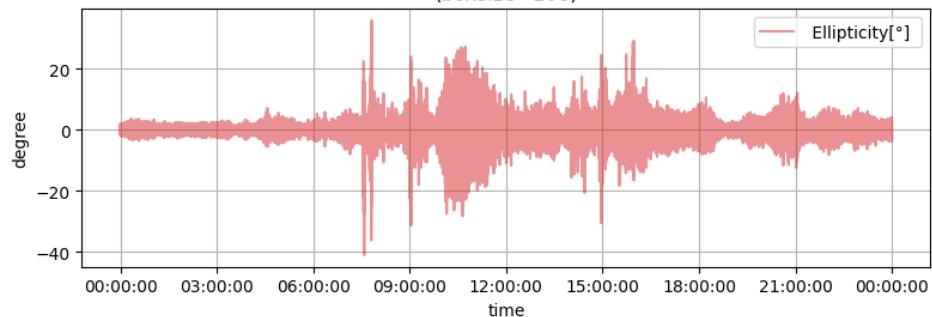
Applied High Pass Filter of Ellipticity[°] on 2024-11-30  
(boxsize=100)



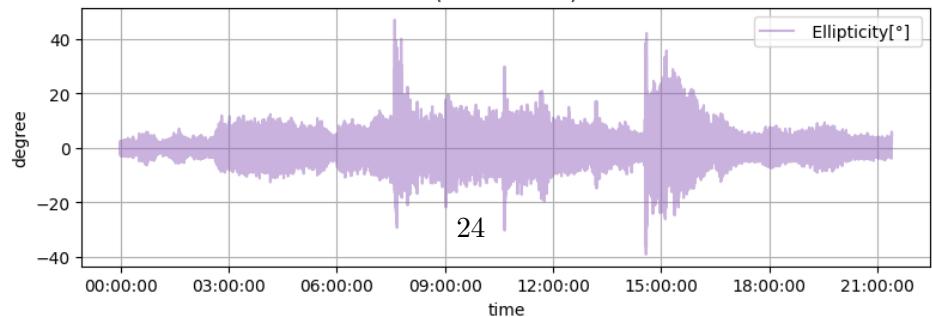
Applied High Pass Filter of Ellipticity[°] on 2024-12-01  
(boxsize=100)



Applied High Pass Filter of Ellipticity[°] on 2024-12-02  
(boxsize=100)



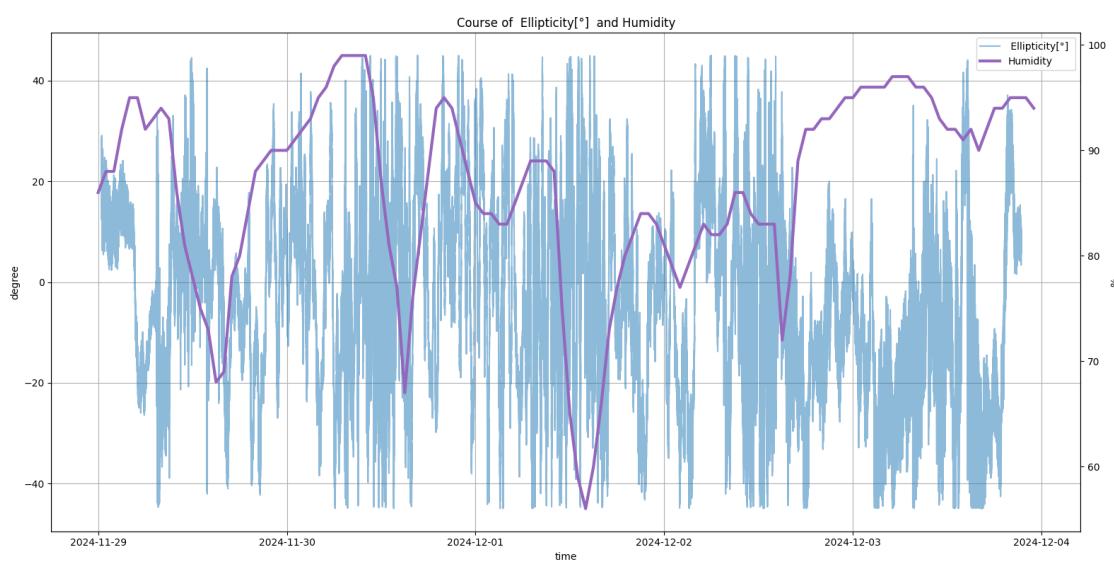
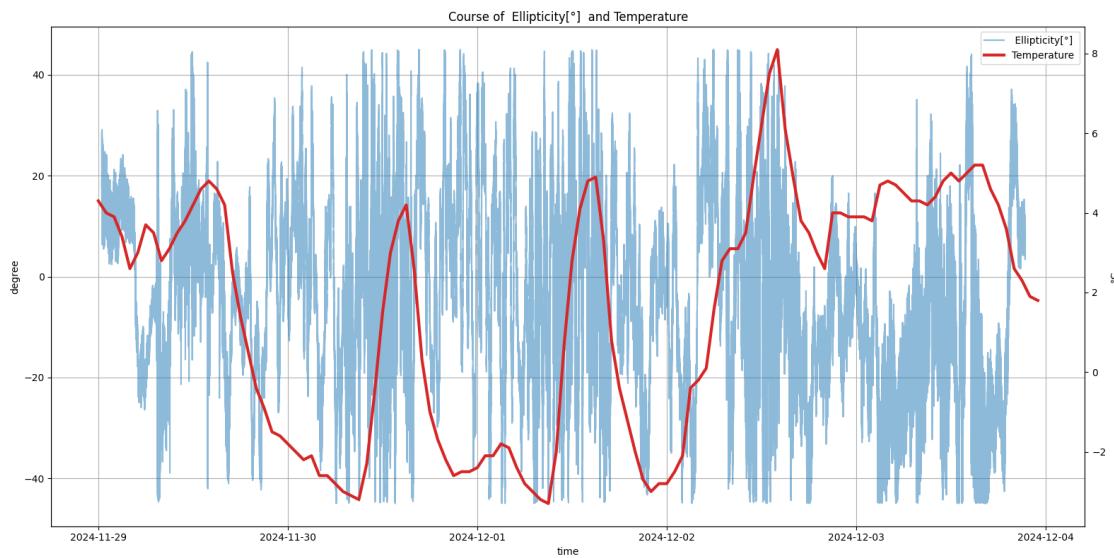
Applied High Pass Filter of Ellipticity[°] on 2024-12-03  
(boxsize=100)

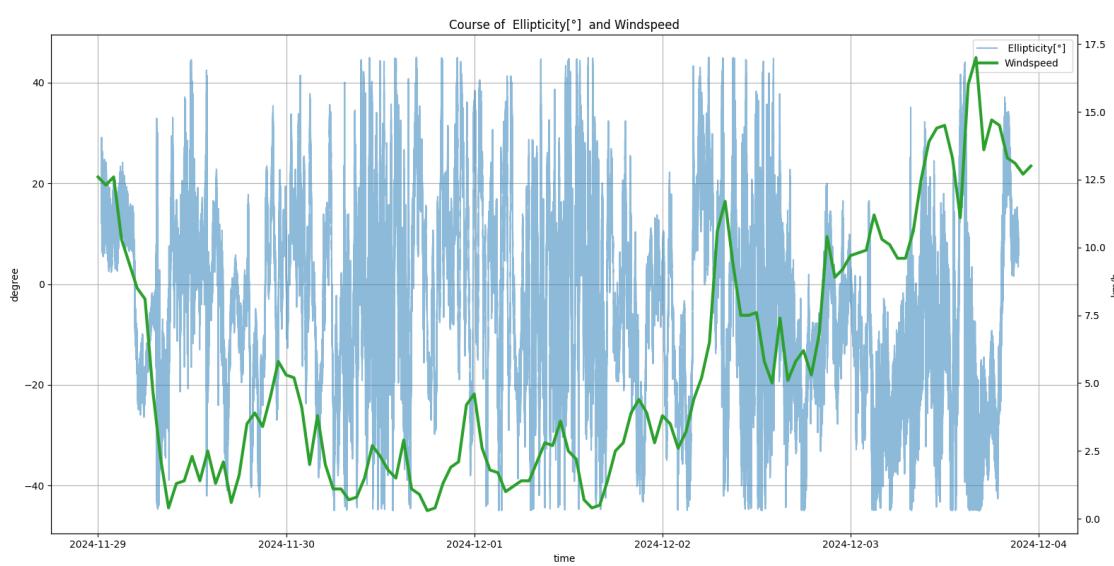
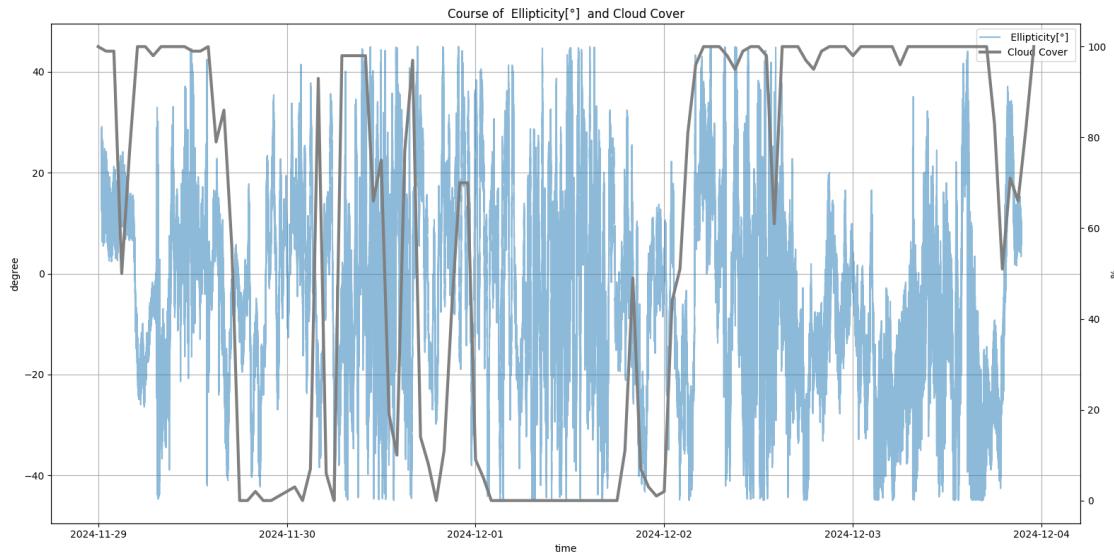


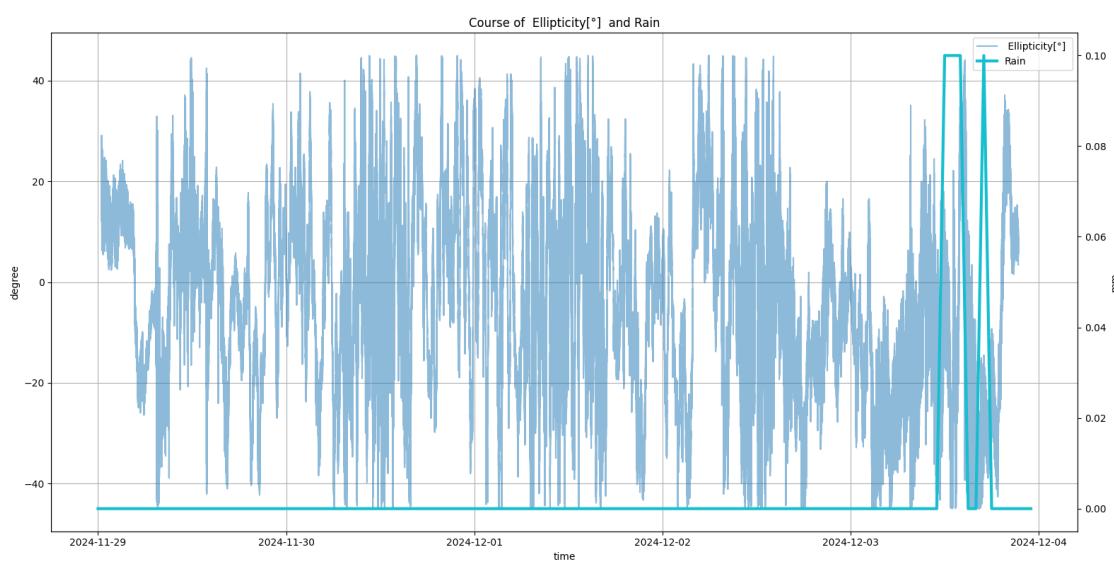
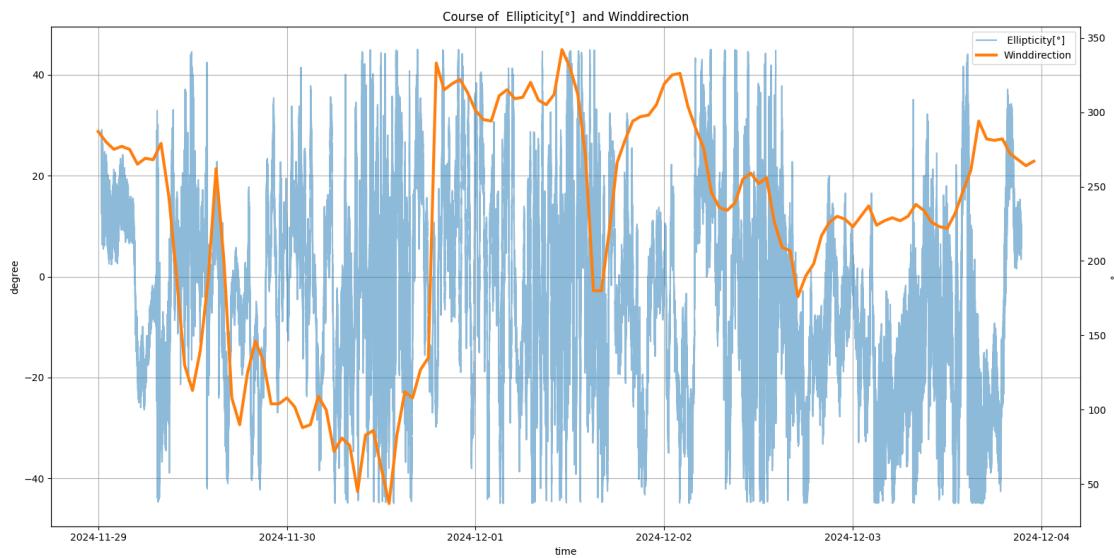
## 2.4 Analyse potenzieller Zusammenhänge

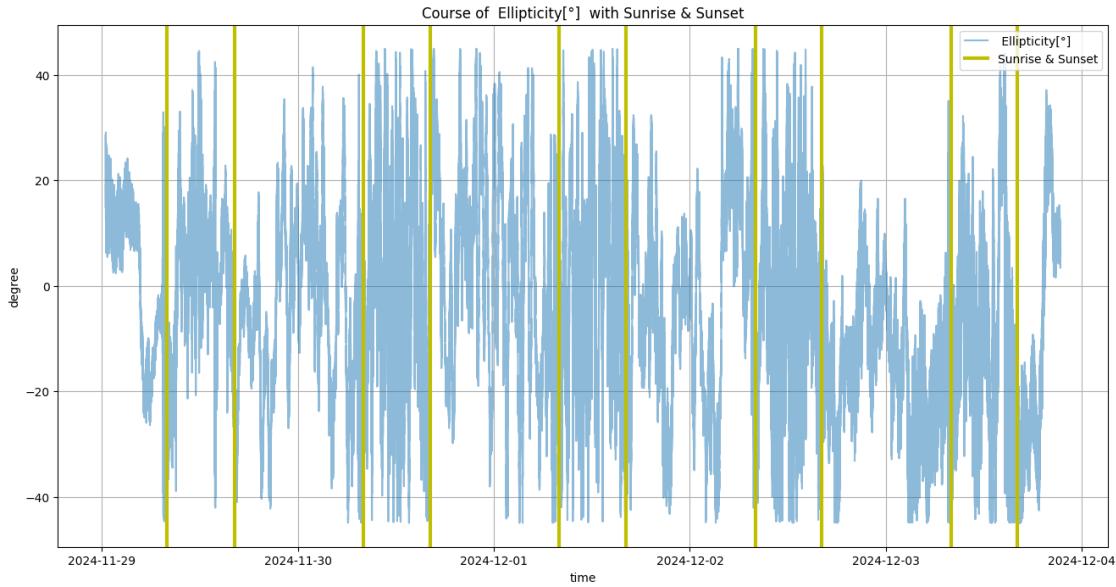
### 2.4.1 Originaldaten und Wetterparameter

```
[29]: for current in range(len(w_data)):  
    fig, ax1 = plt.subplots(figsize=(16, 8))  
  
    ax1.plot(angle[columns[10]], label=columns[10], 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[10]} and {w_data[current]["label"]}')  
  
    plt.tight_layout()  
    plt.show()  
  
# Sunlight (day-night context)  
  
plt.figure(figsize = (16,8))  
plt.plot(angle.index, angle[columns[10]], 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'Course of {columns[10]} with Sunrise & Sunset')  
plt.xlabel('time')  
plt.ylabel('degree')  
plt.show()
```









## 2.4.2 Tiefpass-gefilterte Daten und Wetterparameter

```
[31]: box = 100

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

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

    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]} with\u
    ↵{w_data[current]["label"]}\n(boxsize={box})')

    plt.tight_layout()
    plt.show()

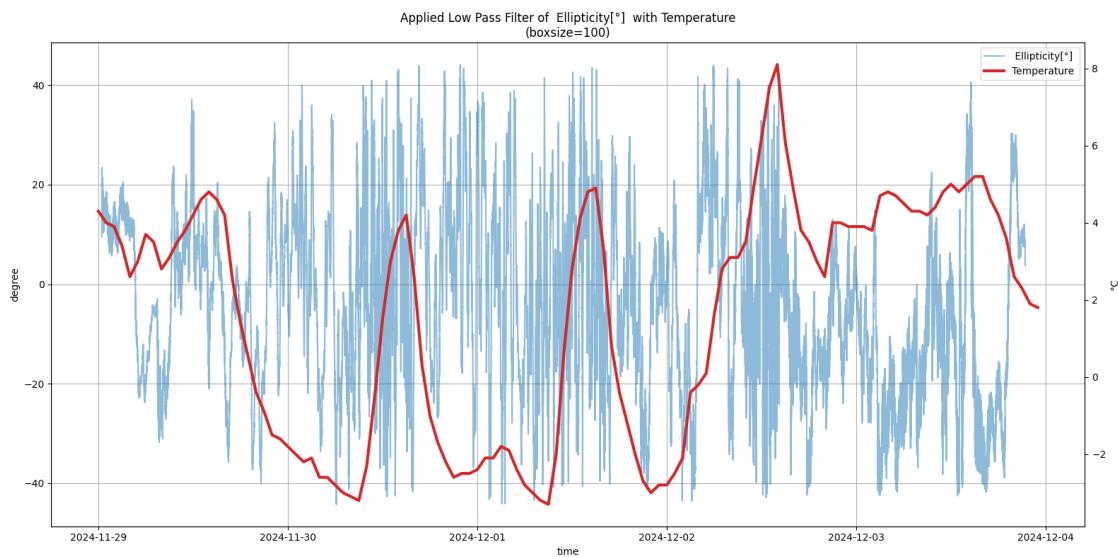
# Sunlight (day-night context)

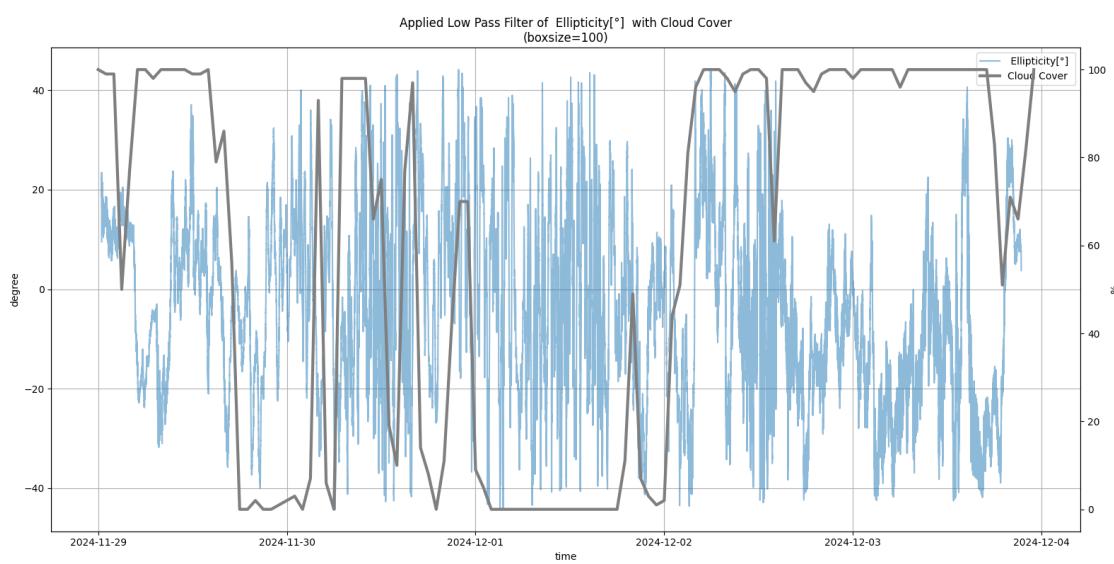
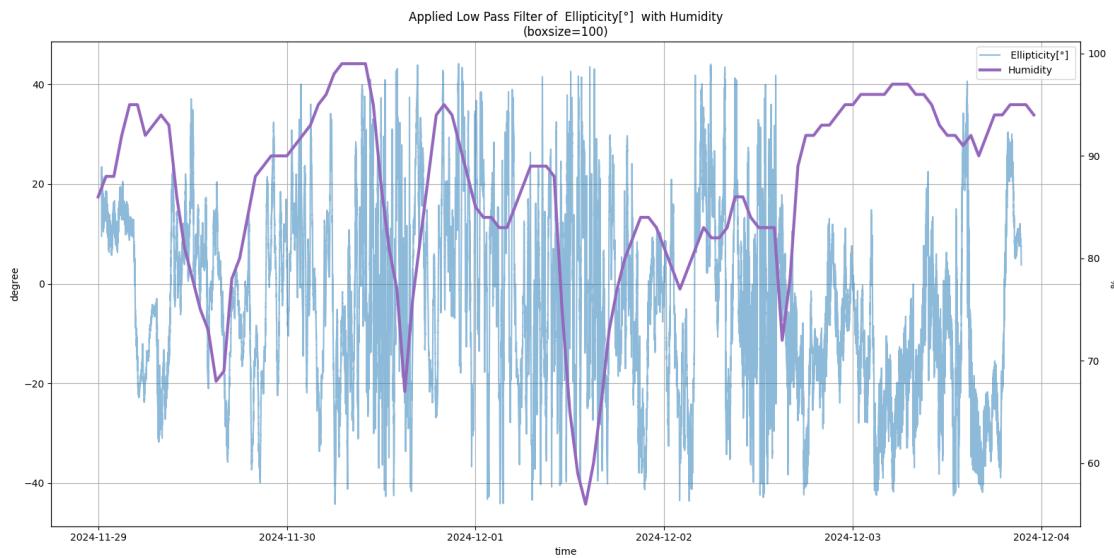
plt.figure(figsize = (16,8))

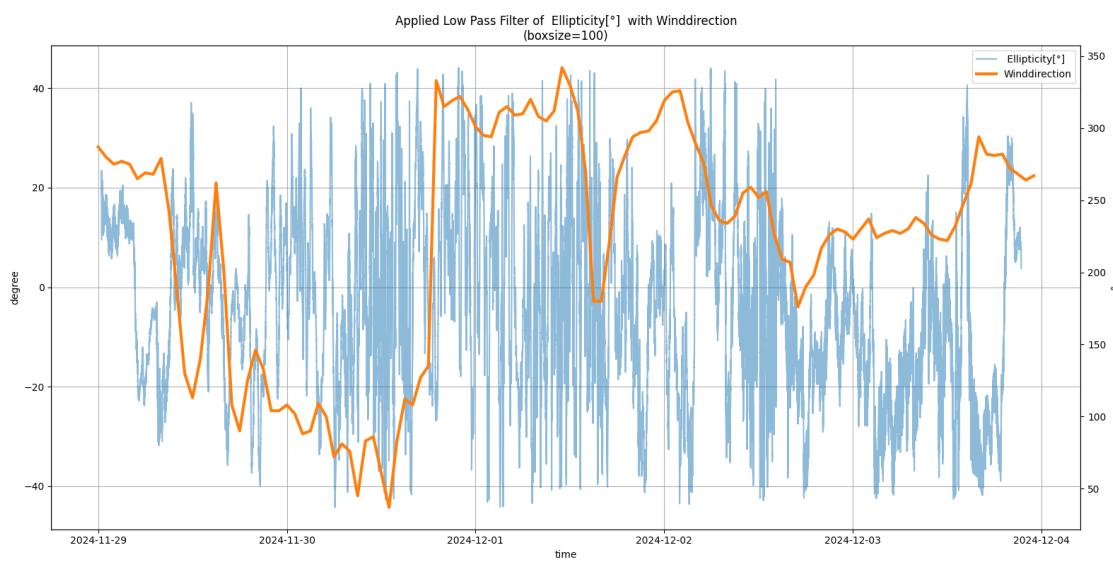
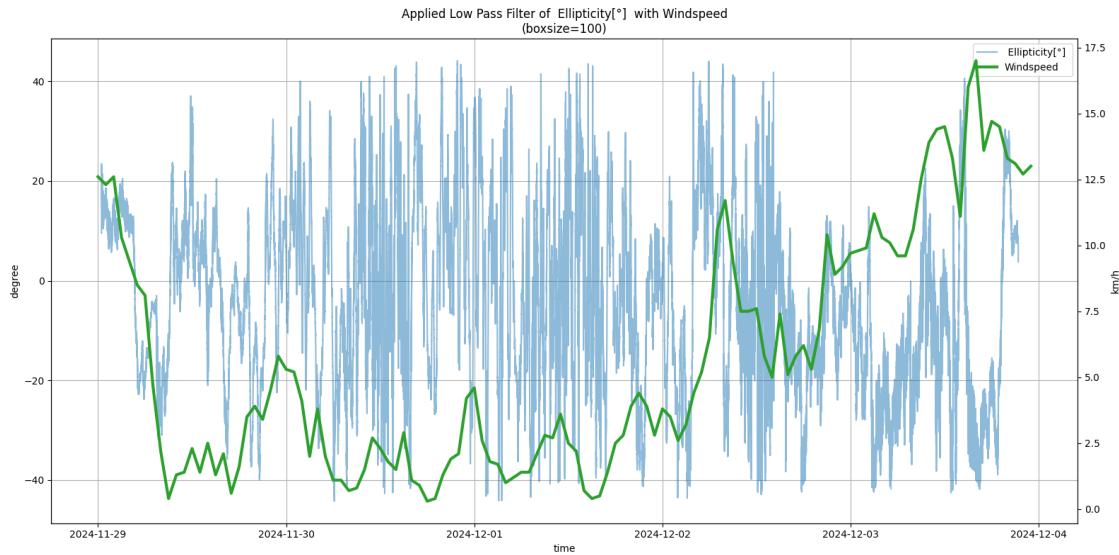
ydata = np.array(angle[columns[9]])
lps = lowpass(ydata, box)

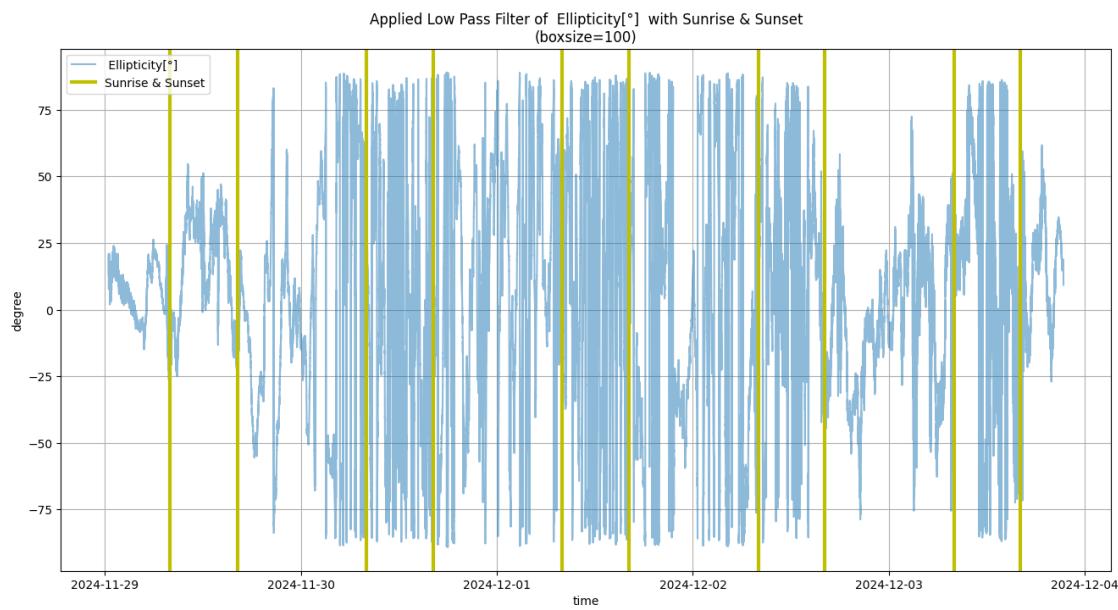
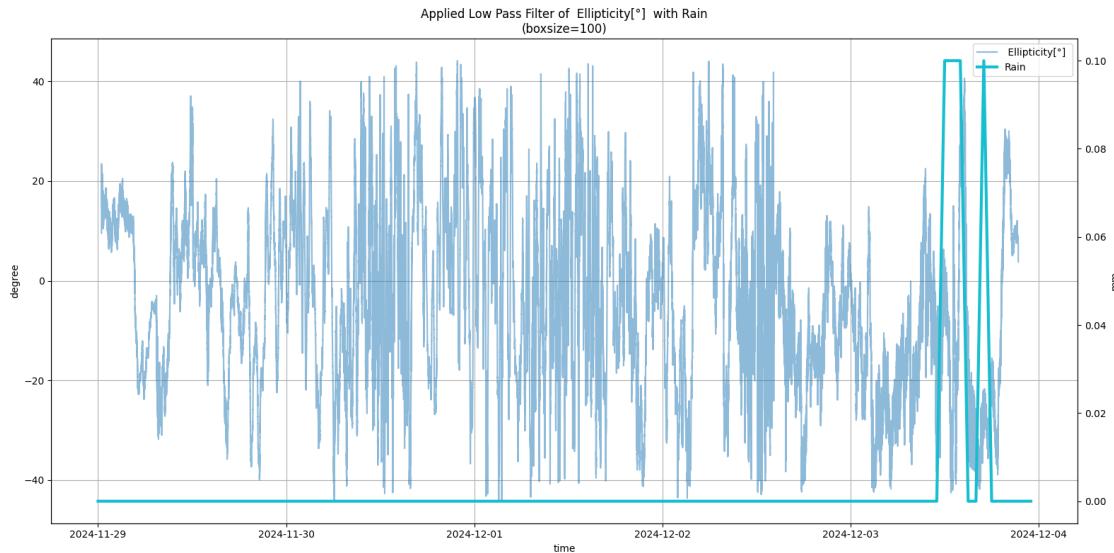
plt.plot(angle.index, lps[:-1], label=columns[10], color= "tab:blue", alpha= 0.
    ↵5)
for i in range(len(sunrise)):
    plt.axvline(x = sunrise[i], color = 'y', linewidth=3)
    if i == 0: plt.axvline(x = sunset[i], color = 'y', label = 'Sunrise &\u
    ↵Sunset', linewidth=3)
    else: plt.axvline(x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

```









#### 2.4.3 Hochpass-gefilterte Daten und Wetterparameter

```
[32]: box = 100

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

    ydata = np.array(angle[columns[10]])
```

```

hps = highpass(ydata, box)

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]} with  

{w_data[current]["label"]}\n(boxsize={box})')

plt.tight_layout()
plt.show()

# Sunlight (day-night context)

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

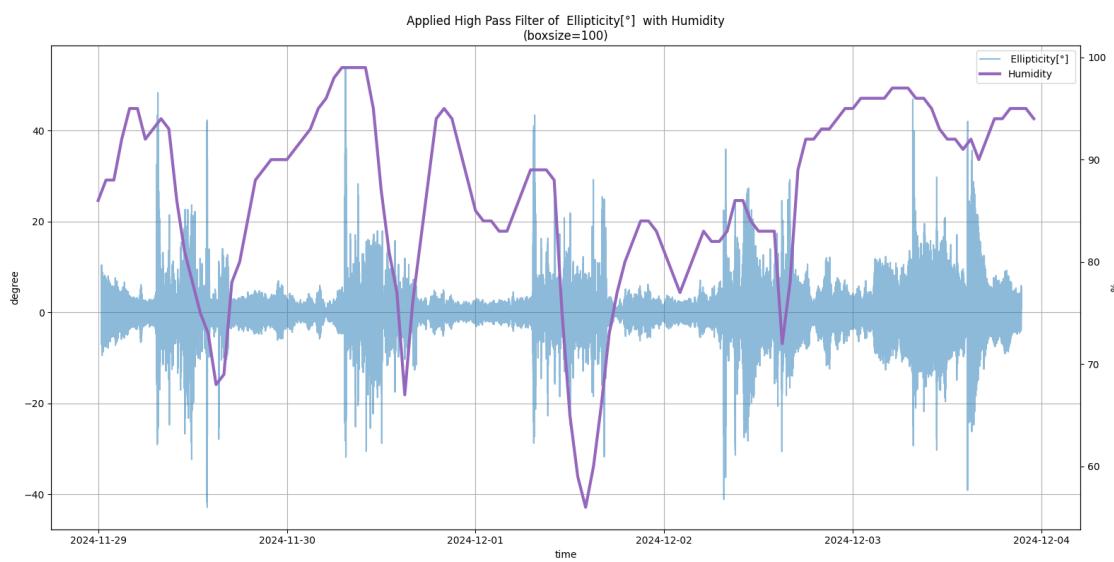
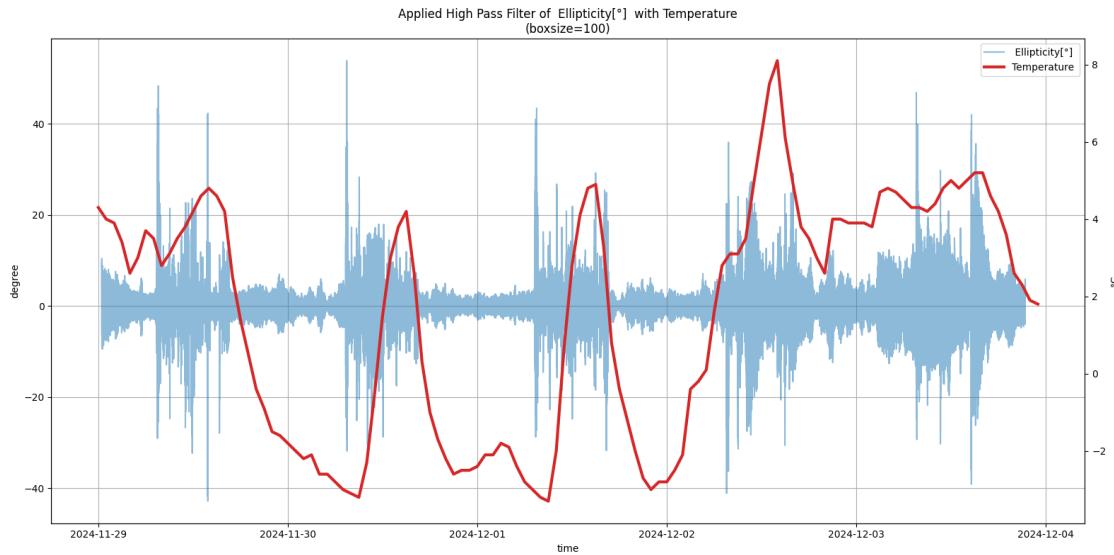
ydata = np.array(angle[columns[9]])
hps = highpass(ydata, box)

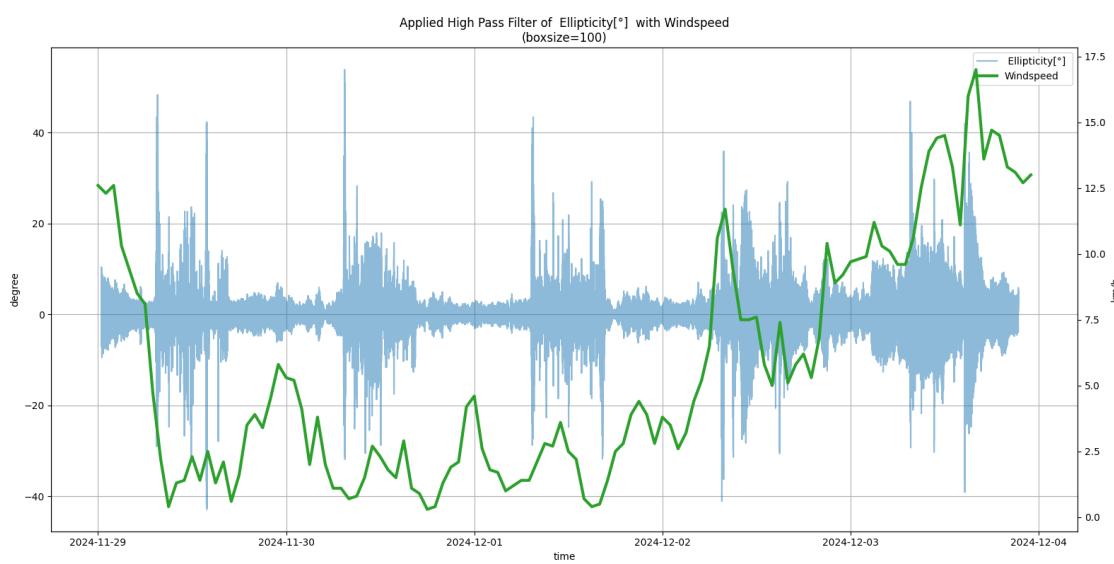
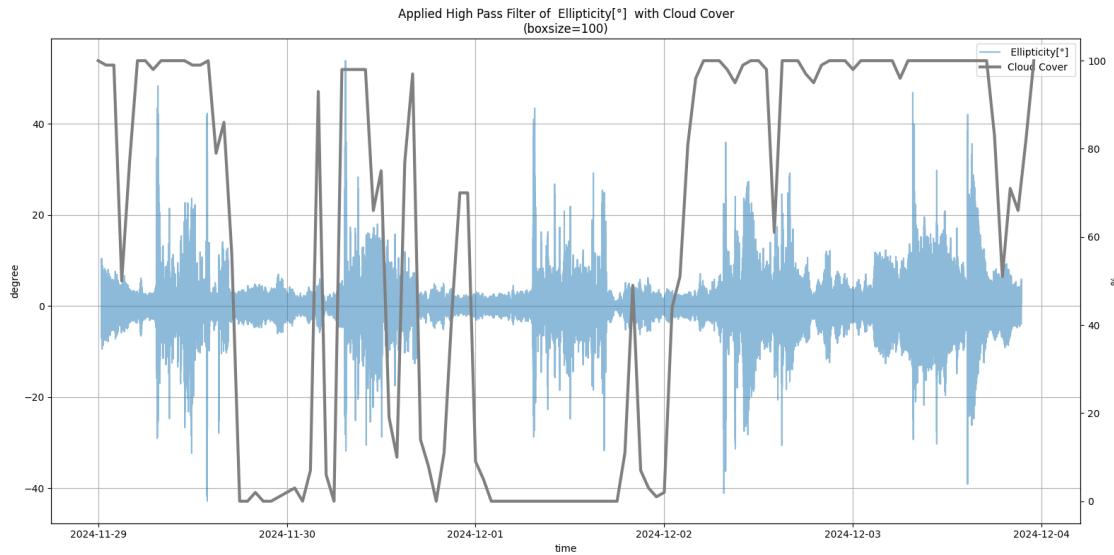
plt.plot(angle.index, hps, label=columns[10], color= "tab:blue", alpha= 0.5)
for i in range(len(sunrise)):
    plt.axvline(x = sunrise[i], color = 'y', linewidth=3)
    if i == 0: plt.axvline(x = sunset[i], color = 'y', label = 'Sunrise &  

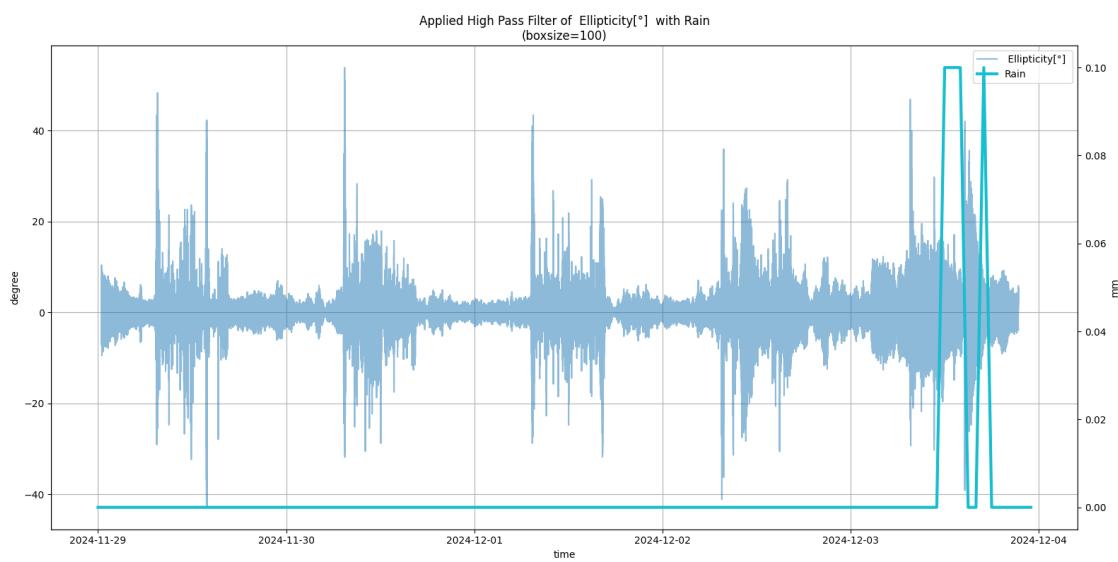
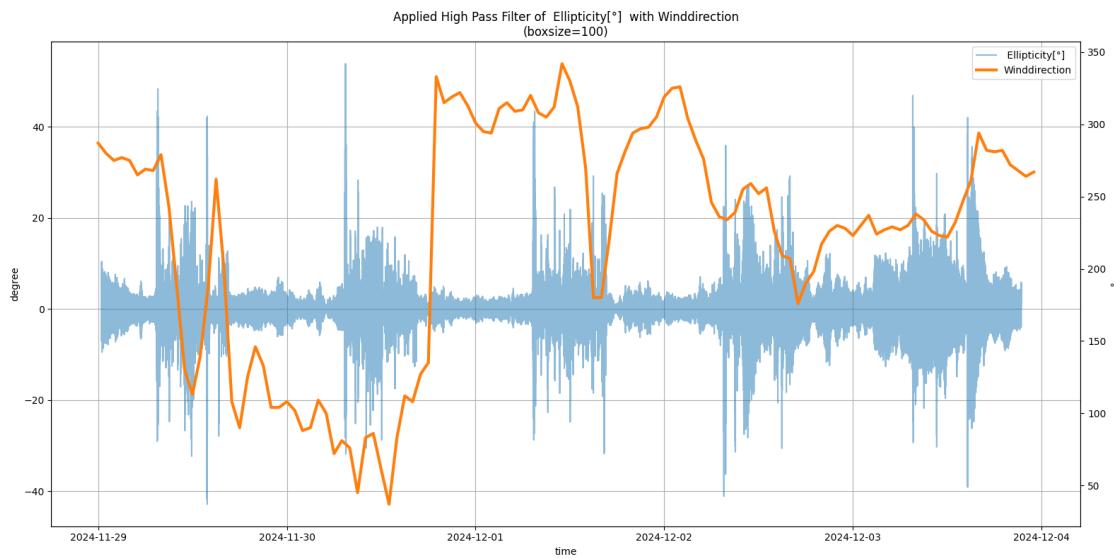
    Sunset', linewidth=3)
    else: plt.axvline(x = sunset[i], color = 'y', linewidth=3)
plt.grid()
plt.legend(loc = 'best')
plt.title(f'Applied High Pass Filter of {columns[10]} with Sunrise &  

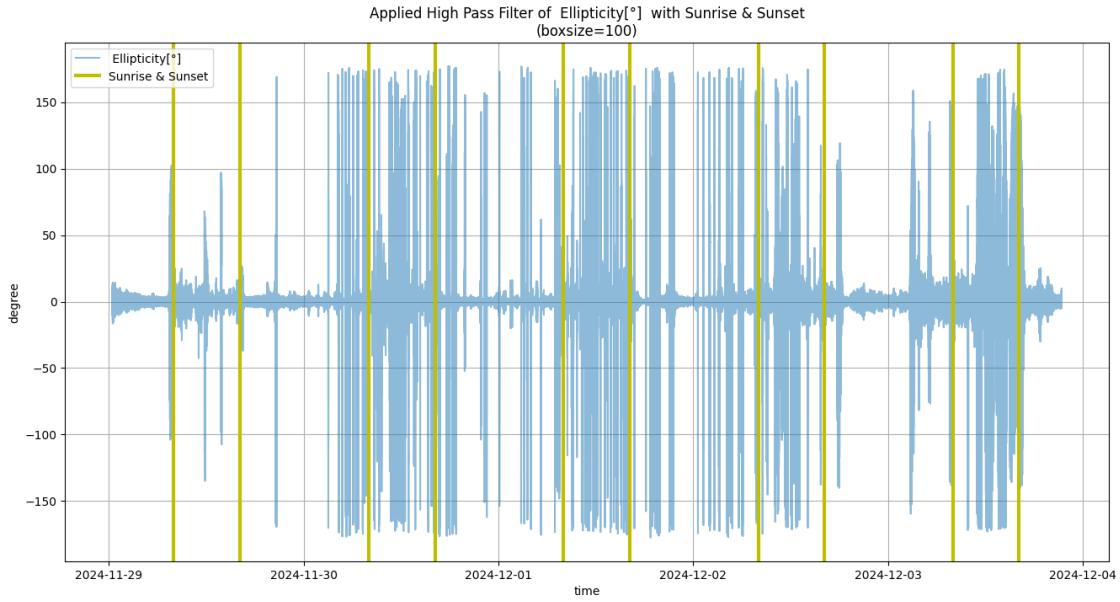
Sunset\n(boxsize={box})')
plt.xlabel('time')
plt.ylabel('degree')
plt.show()

```









#### 2.4.4 Spezielle Auffälligkeiten

```
[33]: box = 1000

for current in [0,2,3]:
    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"])

    plt.show()
```

```

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]} with_{w_data[current]["label"]}, Sunrise & Sunset\n(boxesize={box})')

plt.tight_layout()
plt.show()

```

