Visualization

January 26, 2025

1 Data analyzis of the MGZ mission

This Jupiter Notebook makes basic analyzis and refinement on the measured datas of our CanSat when our data sources are updated and our notebook is restarted. Dou to the fact that our mission is a one time flight, this technique is a bit overcomplicated and unnescessarily robust. However, this method of data analyzis makes reusability a possibility and testing less time consuming. Our scripts are designed to be easily readable and usable on other windows computers as well. This makes collaboration accessible and less problematic. These are crucial aspects on an offical mission, which we aim to replicate to the best of our ability.

For more information, read the README.md document.

1.1 Setup and sorting

Before we start the analyzis we have to include the necessary modules and libraries. We will try to make sure that our code is bulletproof aganist all types of errors and easily fixable by using error handling. Let's organize our measurements using OOP. In addition, we are able set test_data_mode = True which generates test values for the notebook. If an organized database is avalible, we are able to set only_analizys_mode = True. This drastically reduces execution time.

[81]:
```
__author__ = "KarmaDemon"

# Select the modes of the program
TEST_DATA_MODE = True
ONLY_ANALYZIS_MODE = False
INTO_PDF = True

# Txt and database names
TXT_NAME = "raw_data.txt"
DATABASE_NAME = "datas/raw_data.db"

# CanSat attributes and conditions
DRAG_COEFFICIENT = 0.5 # drag coefficient
AIR_DENSITY = 1.225  # kg/m^3 (standard atmospheric model)
SURFACE_AREA = 0.1  # m^2 (assumed cross-sectional area)
MASS = 1.0  # kg (assumed mass)

# Import the necessary modules
import os
```

```python
import sys
import subprocess
import math

try:
    import program_files.cansattools as cansattools
except ImportError:
    print("The execution failed. The cansattools module can't be imported.")
    sys.exit(1)
try:
    logger = cansattools.logger_creator("jupyter_notebook")
except ImportError:
    logger = None
    print("Error importing cansattools module. Logging is disabled.")

try:
    #from mpl_toolkits import mplot3d
    import numpy as np
    import matplotlib.pyplot as plt
    import matplotlib.cm as cm
    import plotly.express as px
    import pandas as pd
    from mpl_toolkits.mplot3d import Axes3D
    %matplotlib inline
    import program_files.classes as classes
    import sqlite3
    from sqlite3 import Error
except ImportError as e:
    logger.error(f"Error importing modules: {e}")

# Store the data in classes
bmp280: list[classes.BMP280] = []
dht11: list[classes.DHT11] = []
gpses: list[classes.GPS] = []

if not ONLY_ANALYZIS_MODE:
    #create or replace database
    cansattools.create_db(DATABASE_NAME, replace_mode=True)
    if TEST_DATA_MODE:
        bmp_current = classes.BMP280(0, 30.0, 4000.0, 100.0, 0.0, 0.0)
        dht_current = classes.DHT11(0, 50.0, 30.0)
        for i in range(0, 2000):
            bmp280.append(bmp_current)
            dht11.append(dht_current)

            bmp_current.time = cansattools.test_data_generator(bmp_current.
↪time, 3000000, 0, 20, True)
```

```
            bmp_current.temperature = cansattools.
↪test_data_generator(bmp_current.temperature, 100, -100, 5)
            bmp_current.pressure = cansattools.test_data_generator(bmp_current.
↪pressure, 100000, 0, 20)
            bmp_current.height = cansattools.test_data_generator(bmp_current.
↪height, 1000, 20, 20)
            if i > 0:
                bmp_current.calculate_speed(bmp280[-2])
                bmp_current.calculate_acceleration(bmp280[-2])
            bmp_current = classes.BMP280(bmp_current.time, bmp_current.
↪temperature, bmp_current.pressure, bmp_current.height, bmp_current.speed,␣
↪bmp_current.acceleration)

            dht_current.time = cansattools.test_data_generator(dht_current.
↪time, 3000000, 0, 5, True)
            dht_current.humidity = cansattools.test_data_generator(dht_current.
↪humidity, 100, 0, 5)
            dht_current.temperature = cansattools.
↪test_data_generator(dht_current.temperature, 100, -100, 5)
            dht_current = classes.DHT11(dht_current.time, dht_current.humidity,␣
↪dht_current.temperature)

        gps_current = classes.GPS(0, 0.0, 0.0, 0.0)
        for i in range(0, 80):
            gpses.append(gps_current)
            gps_current.time = cansattools.test_data_generator(gps_current.
↪time, 3000000, 0, 400, True)
            gps_current.latitude = cansattools.test_data_generator(gps_current.
↪latitude, 90, -90, 20)
            gps_current.longitude = cansattools.test_data_generator(gps_current.
↪longitude, 180, -180, 20)
            gps_current.altitude = cansattools.test_data_generator(gps_current.
↪altitude, 1000, 20, 20)
            gps_current = classes.GPS(gps_current.time, gps_current.latitude,␣
↪gps_current.longitude, gps_current.altitude)
    else:
        # Open the txt file and read the data
        try:
            with open(f"datas/{TXT_NAME}", "r") as file:
                data = file.readlines()
        except FileNotFoundError:
            try:
                with open(f"{TXT_NAME}", "r") as file:
                    data = file.readlines()
            except FileNotFoundError:
                logger.error(f"File {TXT_NAME} not found")
```

```python
        for line in data:
            try:
                if "BMP280" in line:
                    bmp280.append(classes.BMP280(line.split()[1:]))
                elif "DHT11" in line:
                    dht11.append(classes.DHT11(line.split()[1:]))
                elif "GPS" in line:
                    gpses.append(classes.GPS(line.split()[1:]))
            except Exception as e:
                logger.error(f"Error inserting data into the classes: {e}", exc_info=True)

        # Insert the data into the SQLite database
        cansattools.txt_to_db(data, DATABASE_NAME)

        # Clear the data
        data = None
else:
    try:
        conn = sqlite3.connect(DATABASE_NAME)
        c = conn.cursor()
    except Error as e:
        logger.error(f"Error connecting to the database: {e}", exc_info=True)
    try:
        # Get length of the table
        c.execute("SELECT COUNT(*) FROM BMP280")
        conn.commit()
        bmp280_length = c.fetchone()[0]
        c.execute("SELECT COUNT(*) FROM DHT11")
        conn.commit()
        dht11_length = c.fetchone()[0]
        c.execute("SELECT COUNT(*) FROM GPS")
        conn.commit()
        gps_length = c.fetchone()[0]
        # Get the data from the table
        for i in range(1, bmp280_length):
            bmp_current = classes.BMP280(0, 0.0, 0.0, 0.0, 0.0, 0.0)
            bmp_current.read_from_db(table_name="BMP280", index=i, conn=conn, c=c)
            bmp280.append(bmp_current)
        for i in range(1, dht11_length):
            dht_current = classes.DHT11(0, 0.0, 0.0)
            dht_current.read_from_db(table_name="DHT11", index=i, conn=conn, c=c)
            dht11.append(dht_current)
        for i in range(1, gps_length):
```

```
            gps_current = classes.GPS(0, 0.0, 0.0, 0.0)
            gps_current.read_from_db(table_name="GPS", index=i, conn=conn, c=c)
            gpses.append(gps_current)
    except Error as e:
        logger.error(f"Error inserting data into the objects: {e}",␣
↪exc_info=True)
    try:
        conn.close()
    except Error as e:
        logger.error(f"Error closing the database connection: {e}",␣
↪exc_info=True)
```

```
WARNING:test_data_generator:Failed to generate a value within bounds after 100
attempts for the current data: -89.31412946533749
NoneType: None
NoneType: None

WARNING:test_data_generator:Failed to generate a value within bounds after 100
attempts for the current data: -98
NoneType: None
NoneType: None

WARNING:test_data_generator:Failed to generate a value within bounds after 100
attempts for the current data: -105
NoneType: None
NoneType: None

WARNING:test_data_generator:Failed to generate a value within bounds after 100
attempts for the current data: -14.379996570229455
NoneType: None
NoneType: None

WARNING:test_data_generator:Failed to generate a value within bounds after 100
attempts for the current data: -66
NoneType: None
NoneType: None

WARNING:test_data_generator:Failed to generate a value within bounds after 100
attempts for the current data: -17
NoneType: None
NoneType: None

WARNING:test_data_generator:Failed to generate a value within bounds after 100
attempts for the current data: -27
NoneType: None
NoneType: None

WARNING:test_data_generator:Failed to generate a value within bounds after 100
```

```
attempts for the current data: -36
NoneType: None
NoneType: None

WARNING:test_data_generator:Failed to generate a value within bounds after 100
attempts for the current data: -123
NoneType: None
NoneType: None

WARNING:test_data_generator:Failed to generate a value within bounds after 100
attempts for the current data: -178
NoneType: None
NoneType: None

WARNING:test_data_generator:Failed to generate a value within bounds after 100
attempts for the current data: -122
NoneType: None
NoneType: None

WARNING:test_data_generator:Failed to generate a value within bounds after 100
attempts for the current data: -104
NoneType: None
NoneType: None

WARNING:test_data_generator:Failed to generate a value within bounds after 100
attempts for the current data: -181
NoneType: None
NoneType: None

WARNING:test_data_generator:Failed to generate a value within bounds after 100
attempts for the current data: 130
NoneType: None
NoneType: None

WARNING:test_data_generator:Failed to generate a value within bounds after 100
attempts for the current data: -126.95024117578076
NoneType: None
NoneType: None
```

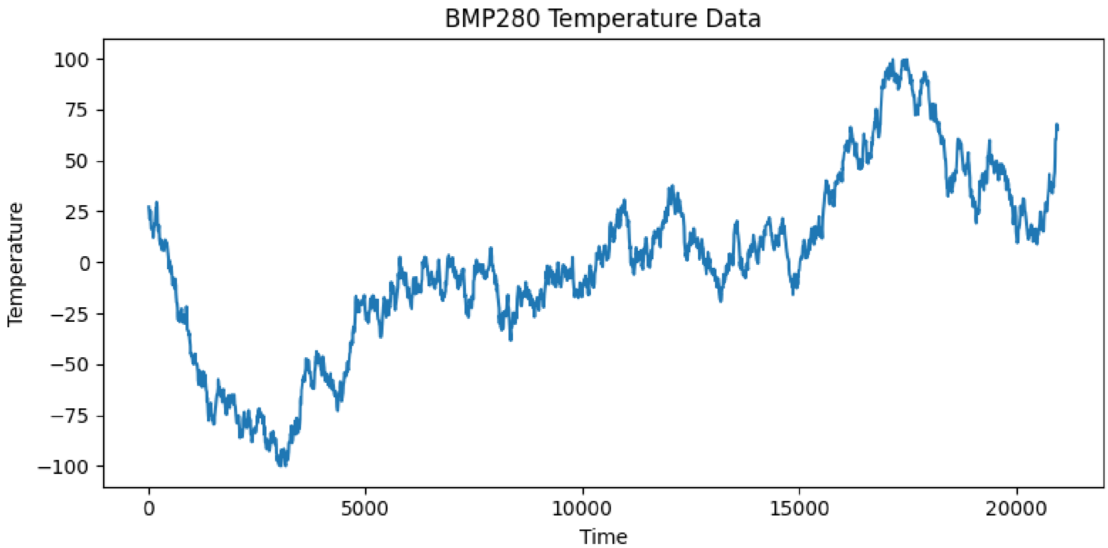
1.2 Raw data visualization

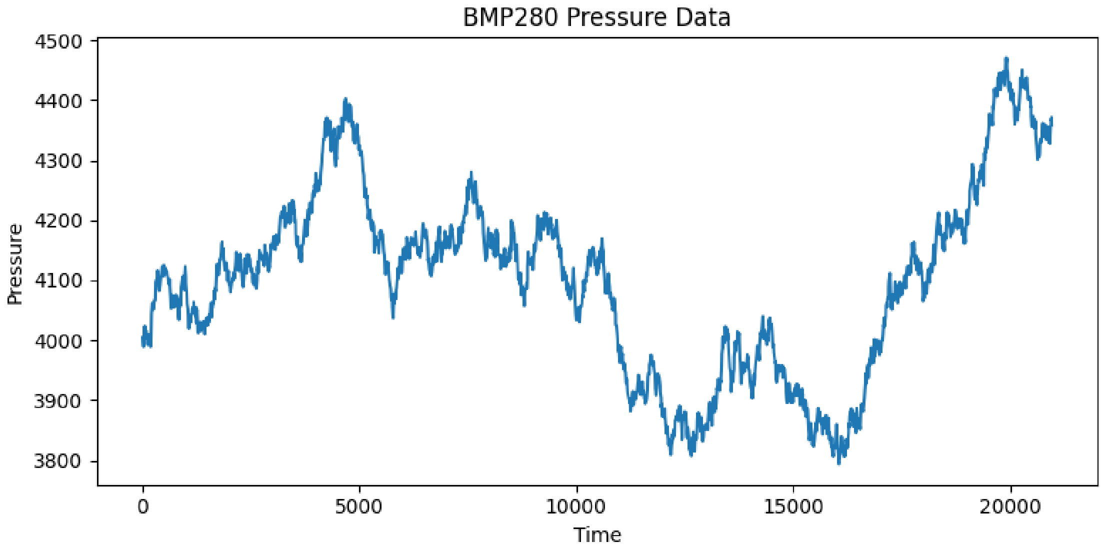
First of all, let's have a look at our measured datas by each sensor on graphs. Due to the sensors' inaccuracies there may be outliers.

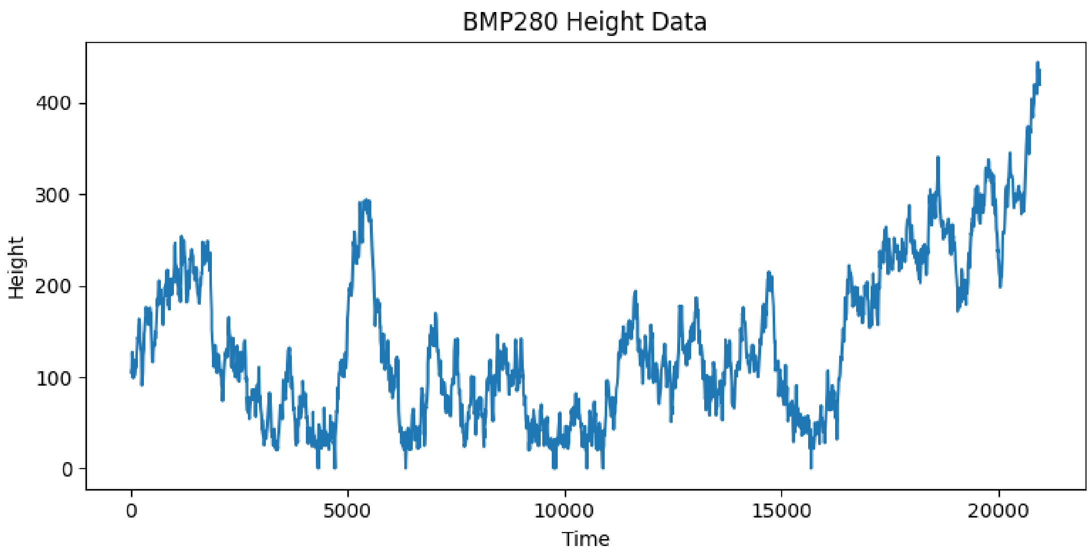
1.2.1 BMP280

[82]:
```
try:
    if len(bmp280) > 0:
        print("Fortunately, the BMP280 measurements are available. Therefore,␣
↪we can plot the data.")
        print("The amount of data provided by the BMP280 sensor is: ",␣
↪len(bmp280))
        fig: plt.Figure
        axs: plt.Axes
        fig, axs= plt.subplots(3, figsize=(8, 12))

        axs[0].plot([bmp.time for bmp in bmp280], [bmp.temperature for bmp in␣
↪bmp280], '-')
        axs[0].set_xlabel('Time')
        axs[0].set_ylabel('Temperature')
        axs[0].set_title('BMP280 Temperature Data')

        axs[1].plot([bmp.time for bmp in bmp280], [bmp.pressure for bmp in␣
↪bmp280], '-')
        axs[1].set_xlabel('Time')
        axs[1].set_ylabel('Pressure')
        axs[1].set_title('BMP280 Pressure Data')

        axs[2].plot([bmp.time for bmp in bmp280], [bmp.height for bmp in␣
↪bmp280], '-')
        axs[2].set_xlabel('Time')
        axs[2].set_ylabel('Height')
        axs[2].set_title('BMP280 Height Data')

        plt.tight_layout()
        cansattools.save_graph(fig, "BMP_raw")
        plt.show()
    else:
        print("Unfortunately, the BMP280 measurements are not available.␣
↪Therefore, we cannot plot the data as expected.")
except Exception as e:
    logger.error(f"Error visualizing data: {e}", exc_info=True)
```

```
Fortunately, the BMP280 measurements are available. Therefore, we can plot the
data.
The amount of data provided by the BMP280 sensor is:  2000
```


BMP280 Temperature Data
Temperature
Time
100
75
50
25
0
−25
−50
−75
−100
0
5000
10000
15000
20000

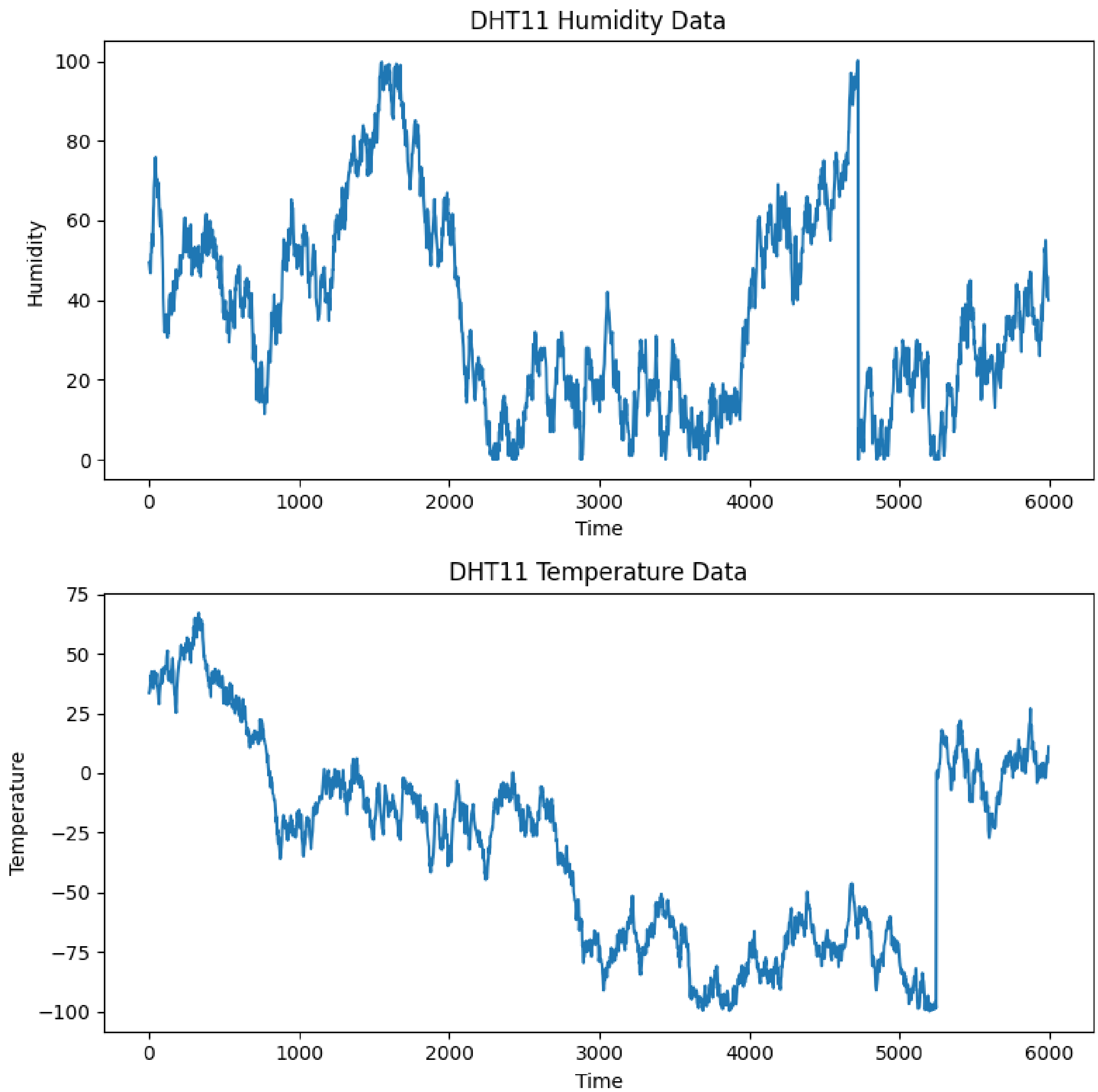

BMP280 Pressure Data
Pressure
Time
4500
4400
4300
4200
4100
4000
3900
3800
0
5000
10000
15000
20000


BMP280 Height Data
Height
Time
400
300
200
100
0
0
5000
10000
15000
20000

1.2.2 DHT11

[83]:
```
try:
    if len(dht11) > 0:
        print("Fortunately, the DHT11 measurements are available. Therefore, we␣
↪can plot the data.")
        print("The amount of data provided by the DHT11 sensor is: ",␣
↪len(dht11))
        fig: plt.Figure
        axs: plt.Axes
        fig, axs= plt.subplots(2, figsize=(8, 8))
        axs[0].plot([dht.time for dht in dht11], [dht.humidity for dht in␣
↪dht11], '-')
        axs[0].set_xlabel('Time')
        axs[0].set_ylabel('Humidity')
        axs[0].set_title('DHT11 Humidity Data')

        axs[1].plot([dht.time for dht in dht11], [dht.temperature for dht in␣
↪dht11], '-')
        axs[1].set_xlabel('Time')
        axs[1].set_ylabel('Temperature')
        axs[1].set_title('DHT11 Temperature Data')

        plt.tight_layout()
        cansattools.save_graph(fig, "DHT_raw")
        plt.show()
    else:
        print("Unfortunately, the DHT11 measurements are not available.␣
↪Therefore, we cannot plot the data as expected.")
except Exception as e:
    logger.error(f"Error visualizing data: {e}", exc_info=True)
```

```
Fortunately, the DHT11 measurements are available. Therefore, we can plot the
data.
The amount of data provided by the DHT11 sensor is:  2000
```



1.2.3 GPS

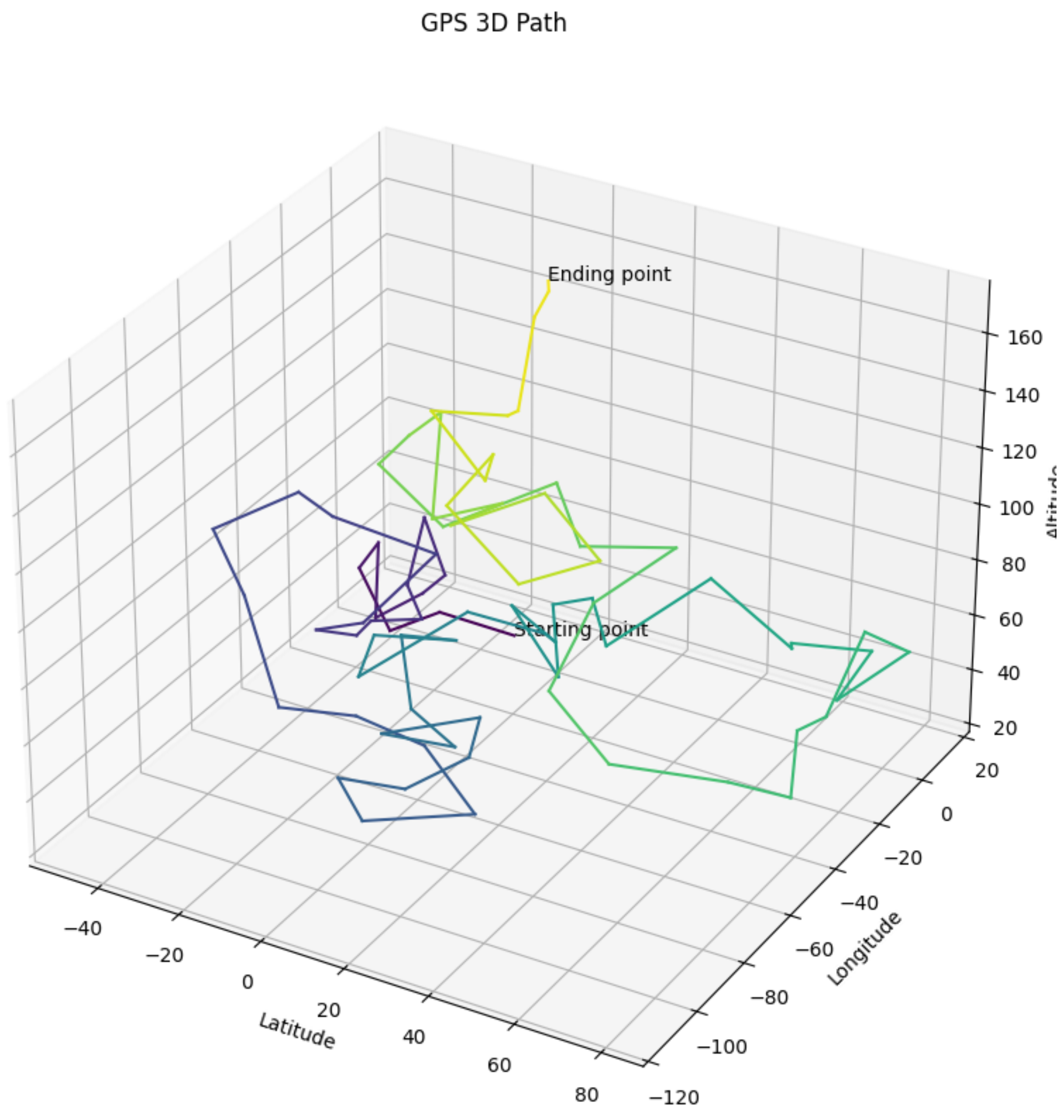
We can create a 3 dimentional map of the gps measurements. Unfortunetly, the altitude data cannot always be measured due to communicational problems. This can cause inaccuracies in the illustration. The passage of time is indicated with changing colors.

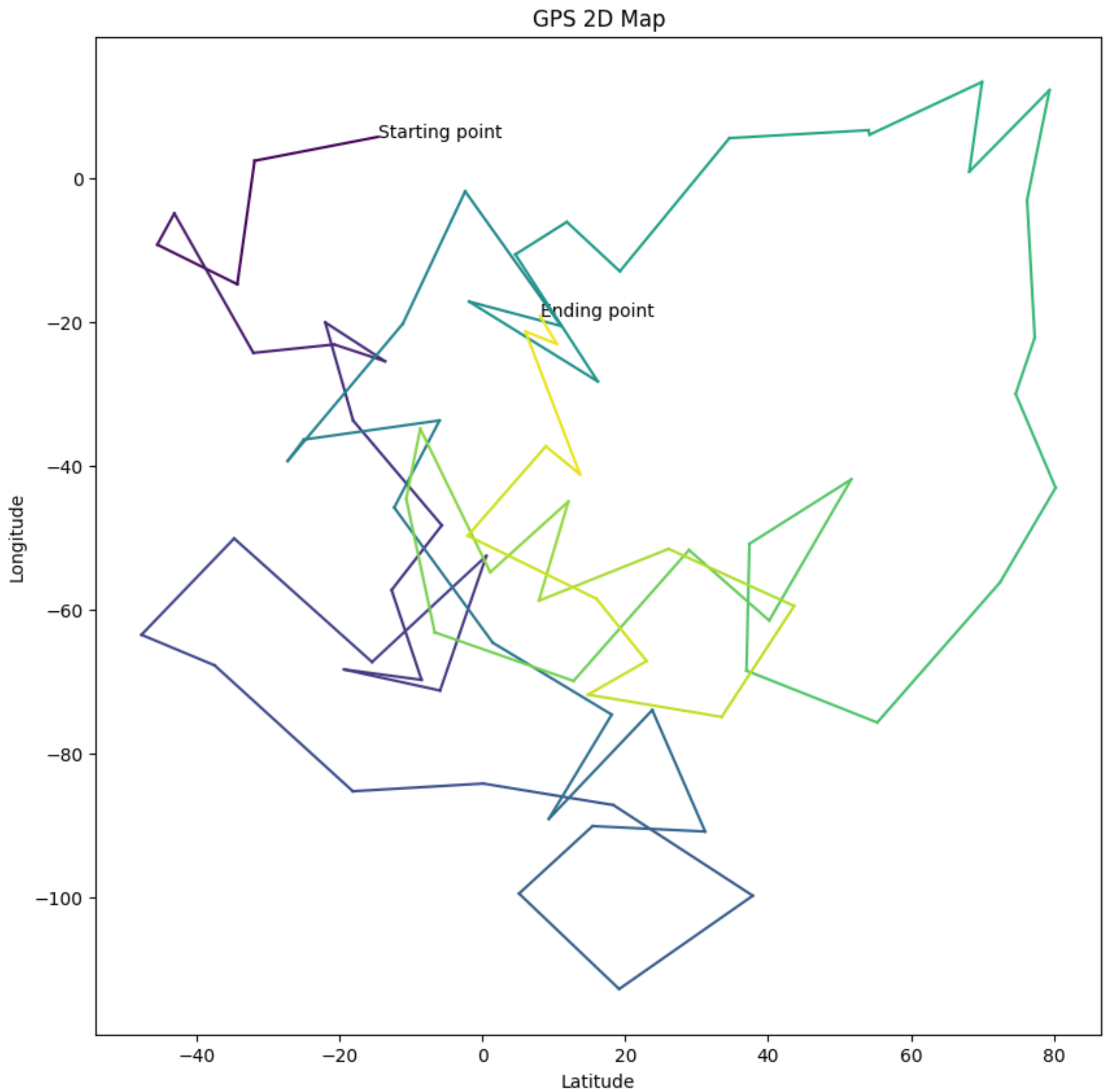
[84]:
```
try:
    if len(gpses) > 0:
        print("Fortunately, the GPS measurements are available. Therefore, we␣
↪can plot the data.")
        print("The amount of data provided by the GPS sensor is: ", len(gpses))

        cmap = plt.get_cmap('viridis')
```

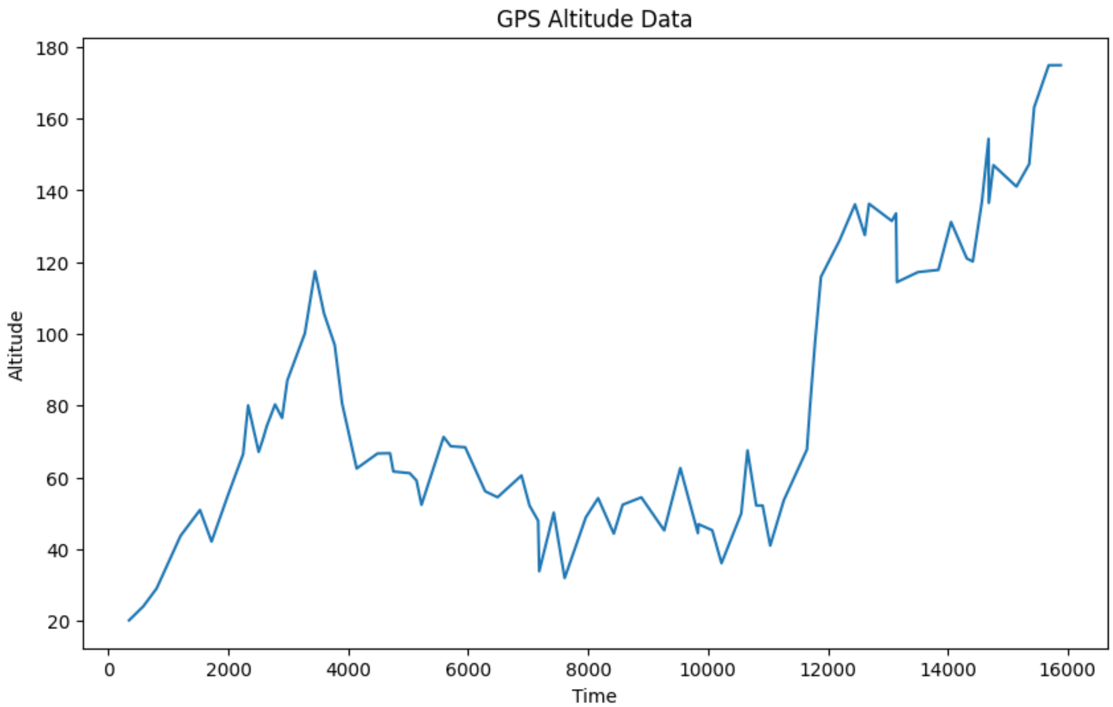
```
    times = np.array([gps.time for gps in gpses])
    normalized_times = (times - times.min()) / (times.max() - times.min())
    colors = cmap(normalized_times)

    # Plot the GPS data
    fig = plt.figure(figsize=(10, 14))

    # 3D path map
    ax = plt.axes(projection='3d')
    for i in range(len(gpses) - 1):
        ax.plot3D([gpses[i].latitude, gpses[i+1].latitude],
                  [gpses[i].longitude, gpses[i+1].longitude],
                  [gpses[i].altitude, gpses[i+1].altitude],
                  color=colors[i])
    ax.text(gpses[0].latitude, gpses[0].longitude, gpses[0].altitude,␣
↪'Starting point', size=10, zorder=1, color='k')
    ax.text(gpses[-1].latitude, gpses[-1].longitude, gpses[-1].altitude,␣
↪'Ending point', size=10, zorder=1, color='k')
    ax.set_xlabel('Latitude')
    ax.set_ylabel('Longitude')
    ax.set_zlabel('Altitude')
    ax.set_title('GPS 3D Path')
    cansattools.save_graph(fig, "GPS_3D_raw")
    plt.show()

    # 2D map
    fig = plt.figure(figsize=(10, 10))
    ax = fig.add_subplot(111)
    for i in range(len(gpses) - 1):
        ax.plot([gpses[i].latitude, gpses[i+1].latitude], [gpses[i].
↪longitude, gpses[i+1].longitude], '-', color=colors[i])
    ax.text(gpses[0].latitude, gpses[0].longitude, 'Starting point',␣
↪size=10, zorder=1, color='k')
    ax.text(gpses[-1].latitude, gpses[-1].longitude, 'Ending point',␣
↪size=10, zorder=1, color='k')
    ax.set_xlabel('Latitude')
    ax.set_ylabel('Longitude')
    ax.set_title('GPS 2D Map')
    cansattools.save_graph(fig, "GPS_2D_raw")
    plt.show()

    # 2D altitude-time graph
    fig = plt.figure(figsize=(10, 6))
    ax = fig.add_subplot(111)
    ax.plot([gps.time for gps in gpses], [gps.altitude for gps in gpses],␣
↪'-')
```

```
        ax.set_xlabel('Time')
        ax.set_ylabel('Altitude')
        ax.set_title('GPS Altitude Data')
        cansattools.save_graph(fig, "GPS_altitude-time_raw")
        plt.show()
    else:
        print("Unfortunately, the GPS measurements are not available.␣
↪Therefore, we cannot plot the data as expected.")
except Exception as e:
    logger.error(f"Error visualizing GPS datas: {e}", exc_info=True)
```

```
Fortunately, the GPS measurements are available. Therefore, we can plot the
data.
The amount of data provided by the GPS sensor is:  80
```




GPS 2D Map
Starting point
Ending point
Longitude
Latitude
0
−20
−40
−60
−80
−100
−40
−20
0
20
40
60
80



1.3 Refining datas

For proper analyzis we should refine the measured datas. This includes the detection of lacking data provision and outliers. The refined values will be stored in a database.

[85]:
```
if not ONLY_ANALYZIS_MODE:
    # Fill objects with test data and insert them into the database
    try:
        conn = sqlite3.connect(DATABASE_NAME)
        c = conn.cursor()
    except Error as e:
        logger.error(f"Error connecting to the database: {e}", exc_info=True)

    #calculate maximum altitude and index
    max_altitude = max(bmp.height for bmp in bmp280)
    max_altitude_index = bmp280.index([bmp for bmp in bmp280 if bmp.height ==␣
↪max_altitude][0])

    #We should set different values for the launch and for the descent
    try:
        for i, bmp in enumerate(bmp280[1:max_altitude_index-1], start=1):
            previous_bmp = bmp280[i-1]
            next_bmp = bmp280[i+1]
```

```
            bmp.refine(previous_bmp, next_bmp, outlier_threshold=19, lacking_data_threshold=19)
            bmp.insert_into_db("BMP280", c)
        for i, bmp in enumerate(bmp280[max_altitude_index:-2], start=max_altitude_index+1): #suspected error
            previous_bmp = bmp280[i-1]
            next_bmp = bmp280[i+1]
            bmp.refine(previous_bmp, next_bmp, outlier_threshold=19, lacking_data_threshold=19)
            bmp.insert_into_db("BMP280", c)
    except Error as e:
        logger.error(f"Error inserting BMP280 data into the database: {e}", exc_info=True)
    except Exception as e:
        logger.error(f"Error refining BMP280 data: {e}", exc_info=True)

    try:
        for i, dht in enumerate(dht11[1:-1], start=1):
            previous_dht = dht11[i-1]
            next_dht = dht11[i+1]
            dht.refine(previous_dht, next_dht, outlier_threshold=5, lacking_data_threshold=5)
            dht.insert_into_db("DHT11", c)
    except Error as e:
        logger.error(f"Error inserting DHT11 data into the database: {e}", exc_info=True)
    except Exception as e:
        logger.error(f"Error refining DHT11 data: {e}", exc_info=True)

    try:
        for i, gps in enumerate(gpses[1:-1], start=1):
            previous_gps = gpses[i-1]
            next_gps = gpses[i+1]
            gps.refine(previous_gps, next_gps, outlier_threshold=18, lacking_data_threshold=350)
            gps.insert_into_db("GPS", c)
    except Error as e:
        logger.error(f"Error inserting GPS data into the database: {e}", exc_info=True)
    except Exception as e:
        logger.error(f"Error refining GPS data: {e}", exc_info=True)

    try:
        conn.commit()
        conn.close()
    except Error as e:
```

```
        logger.error(f"Error committing changes to the database: {e}",␣
↪exc_info=True)
```

1.3.1 Visualization of refined datas

Let's visualize the refined datas for comparition aganist the raw datas.

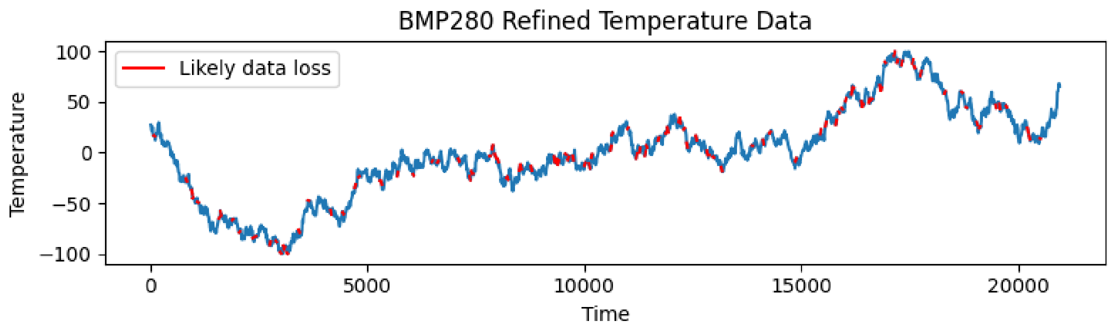
[86]:
```
try:
    first_time_missing_data = True
    first_time_outlier = True
    if len(bmp280) > 0:
        print("Number of missing data points: ", sum(1 for bmp in bmp280 if bmp.
↪missing_data))
        print("Number of temperature outliers: ", sum(1 for bmp in bmp280 if␣
↪bmp.is_temperature_outlier))
        print("Number of pressure outliers: ", sum(1 for bmp in bmp280 if bmp.
↪is_pressure_outlier))
        print("Number of height outliers: ", sum(1 for bmp in bmp280 if bmp.
↪is_height_outlier))
        print("Number of speed outliers: ", sum(1 for bmp in bmp280 if bmp.
↪is_speed_outlier))
        print("Number of acceleration outliers: ", sum(1 for bmp in bmp280 if␣
↪bmp.is_acceleration_outlier))
        fig: plt.Figure
        axs: plt.Axes
        fig, axs= plt.subplots(5, figsize=(8, 12))

        axs[0].plot([bmp.time for bmp in bmp280 if not bmp.
↪is_temperature_outlier], [bmp.temperature for bmp in bmp280 if not bmp.
↪is_temperature_outlier], '-')
        axs[0].set_xlabel('Time')
        axs[0].set_ylabel('Temperature')
        axs[0].set_title('BMP280 Refined Temperature Data')
        for i, bmp in enumerate(bmp280[1:], start=1):
            if bmp.missing_data:
                axs[0].plot([bmp280[i-1].time, bmp.time], [bmp280[i-1].
↪temperature, bmp.temperature], '-', color='red', label='Likely data loss' if␣
↪first_time_missing_data else '')
                first_time_missing_data = False
            if bmp.is_temperature_outlier:
                axs[0].plot([bmp.time], [bmp.temperature], 'o', color='green',␣
↪label='Outlier' if first_time_outlier else '')
                first_time_outlier = False
        axs[0].legend()
        first_time_missing_data = True
        first_time_outlier = True
```

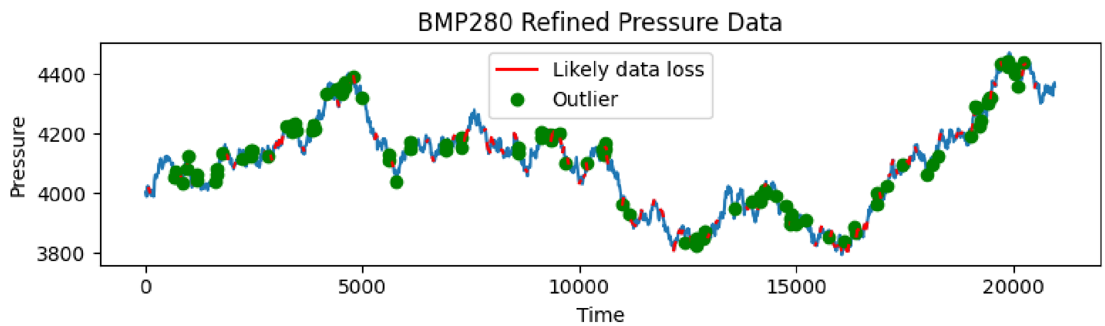
```python
        axs[1].plot([bmp.time for bmp in bmp280 if not bmp.is_pressure_outlier], [bmp.pressure for bmp in bmp280 if not bmp.is_pressure_outlier], '-')
        axs[1].set_xlabel('Time')
        axs[1].set_ylabel('Pressure')
        axs[1].set_title('BMP280 Refined Pressure Data')
        for i, bmp in enumerate(bmp280[1:], start=1):
            if bmp.missing_data:
                axs[1].plot([bmp280[i-1].time, bmp.time], [bmp280[i-1].pressure, bmp.pressure], '-', color='red', label='Likely data loss' if first_time_missing_data else '')
                first_time_missing_data = False
            if bmp.is_pressure_outlier:
                axs[1].plot([bmp.time], [bmp.pressure], 'o', color='green', label='Outlier' if first_time_outlier else '')
                first_time_outlier = False
        axs[1].legend()
        first_time_missing_data = True
        first_time_outlier = True

        axs[2].plot([bmp.time for bmp in bmp280 if not bmp.is_height_outlier], [bmp.height for bmp in bmp280 if not bmp.is_height_outlier], '-', label='BMP280')
        axs[2].plot([gps.time for gps in gpses if not gps.is_altitude_outlier], [gps.altitude for gps in gpses if not gps.is_altitude_outlier], '-', color='black', label='GPS')
        axs[2].set_xlabel('Time')
        axs[2].set_ylabel('Height')
        axs[2].set_title('BMP280 and GPS Height Data in Comparison')
        for i, bmp in enumerate(bmp280[1:], start=1):
            if bmp.missing_data:
                axs[2].plot([bmp280[i-1].time, bmp.time], [bmp280[i-1].height, bmp.height], '-', color='red', label='Likely data loss' if first_time_missing_data else '')
                first_time_missing_data = False
            if bmp.is_height_outlier:
                axs[2].plot([bmp.time], [bmp.height], 'o', color='green', label='Outlier' if first_time_outlier else '')
                first_time_outlier = False
        for i, gps in enumerate(gpses[1:], start=1):
            if gps.missing_data:
                axs[2].plot([gpses[i-1].time, gps.time], [gpses[i-1].altitude, gps.altitude], '-', color='red')
            if gps.is_altitude_outlier:
                axs[2].plot([gps.time], [gps.altitude], 'o', color='green')
        axs[2].legend()
```

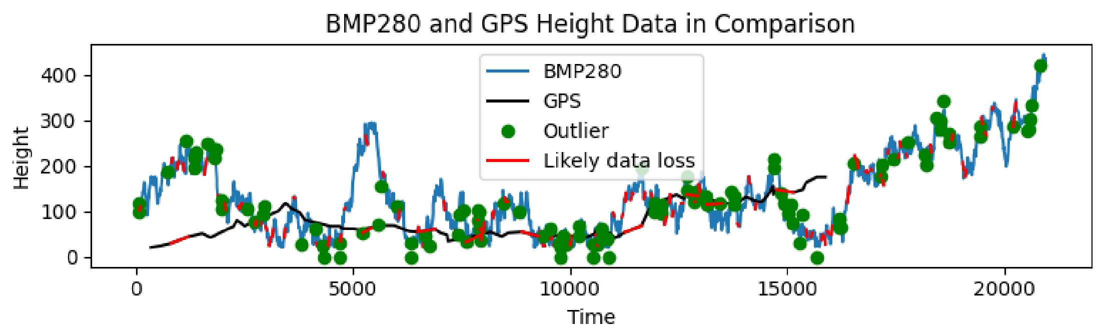
```
        first_time_missing_data = True
        first_time_outlier = True

        axs[3].plot([bmp.time for bmp in bmp280 if not bmp.is_speed_outlier],␣
↪[bmp.speed for bmp in bmp280 if not bmp.is_speed_outlier], '-')
        axs[3].set_xlabel('Time')
        axs[3].set_ylabel('Speed')
        axs[3].set_title('BMP280 Refined Vertical Speed Data')
        for i, bmp in enumerate(bmp280[1:], start=1):
            if bmp.missing_data:
                axs[3].plot([bmp280[i-1].time, bmp.time], [bmp280[i-1].speed,␣
↪bmp.speed], '-', color='red', label='Likely data loss' if␣
↪first_time_missing_data else '')
                first_time_missing_data = False
            if bmp.is_speed_outlier:
                axs[3].plot([bmp.time], [bmp.speed], 'o', color='green',␣
↪label='Outlier' if first_time_outlier else '')
                first_time_outlier = False
        axs[3].legend()
        first_time_missing_data = True
        first_time_outlier = True

        axs[4].plot([bmp.time for bmp in bmp280 if not bmp.
↪is_acceleration_outlier], [bmp.acceleration for bmp in bmp280 if not bmp.
↪is_acceleration_outlier], '-')
        axs[4].set_xlabel('Time')
        axs[4].set_ylabel('Acceleration')
        axs[4].set_title('BMP280 Refined Vertical Acceleration Data')
        for i, bmp in enumerate(bmp280[1:], start=1):
            if bmp.missing_data:
                axs[4].plot([bmp280[i-1].time, bmp.time], [bmp280[i-1].
↪acceleration, bmp.acceleration], '-', color='red', label='Likely data loss'␣
↪if first_time_missing_data else '')
                first_time_missing_data = False
            if bmp.is_acceleration_outlier:
                axs[4].plot([bmp.time], [bmp.acceleration], 'o', color='green',␣
↪label='Outlier' if first_time_outlier else '')
                first_time_outlier = False
        axs[4].legend()
        first_time_missing_data = True
        first_time_outlier = True

        plt.tight_layout()
        cansattools.save_graph(fig, "BMP_refined")
        plt.show()
    else:
```

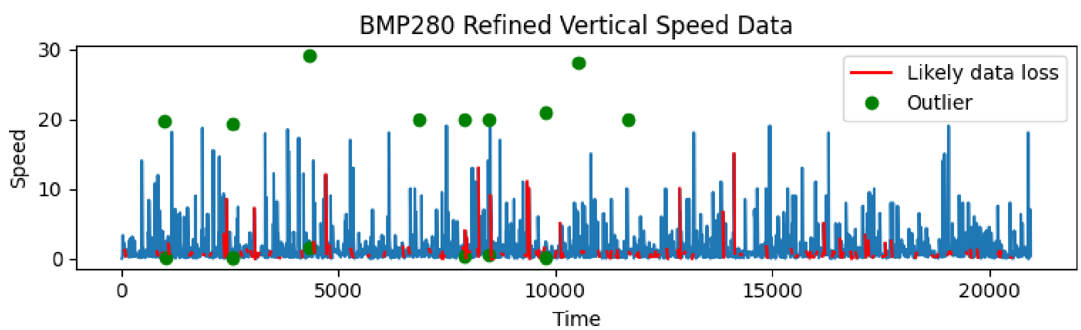
```
        print("Unfortunately, the BMP280 measurements are not available.␣
 ↪Therefore, we cannot plot the data as expected.")
except Exception as e:
    logger.error(f"Error visualizing data: {e}", exc_info=True)
```

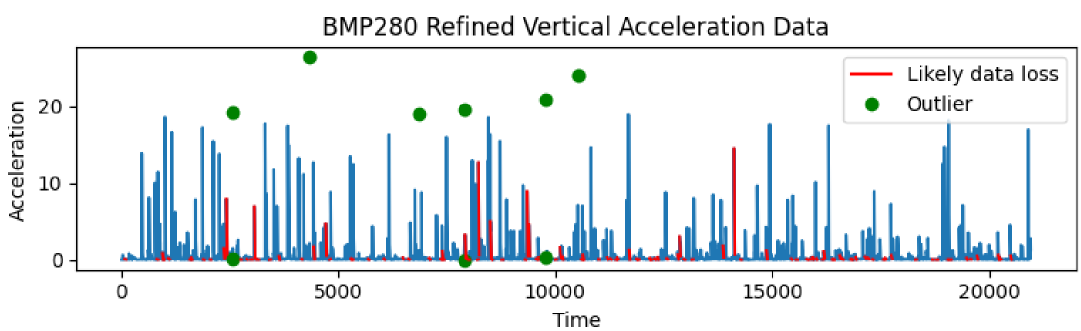
```
Number of missing data points:  107
Number of temperature outliers:  0
Number of pressure outliers:  103
Number of height outliers:  99
Number of speed outliers:  16
Number of acceleration outliers:  9
```


BMP280 Refined Temperature Data
Likely data loss
Temperature
Time


BMP280 Refined Pressure Data
Likely data loss
Outlier
Pressure
Time


BMP280 and GPS Height Data in Comparison
BMP280
GPS
Outlier
Likely data loss
Height
Time


BMP280 Refined Vertical Speed Data
Likely data loss
Outlier
Speed
Time


BMP280 Refined Vertical Acceleration Data
Likely data loss
Outlier
Acceleration
Time

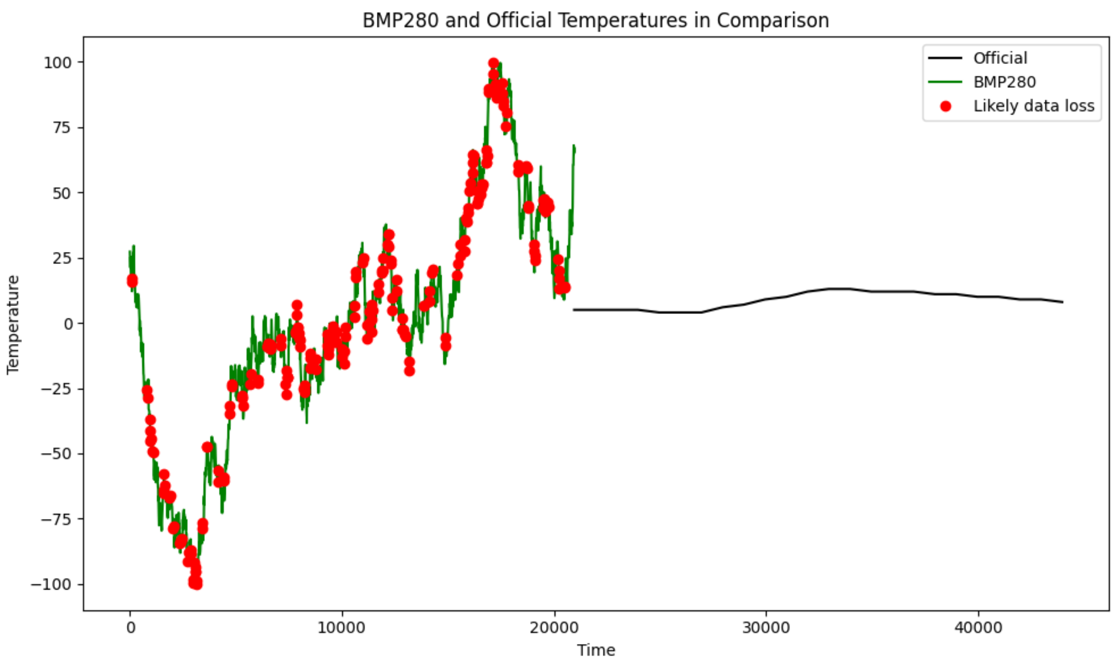
1.4 Calculating windspeed and comparition

1.4.1 Comparing temperature data with official sources

If we would like to compare our temperature measurements as well with official weather forecast values, we have to webscrape the datas from a proper website. We will use https://koponyeg.hu/elorejelzes/Tat%C3%A1rszentgy%C3%B6rgy for this purpose.

[87]:
```
try:
    if len(bmp280) > 0:
        official_datas = cansattools.get_official_data()
        # Temperaturee example: 17° we need them like this 17
        official_temperatures = [float(temp[:len(temp)-1]) for temp in␣
↪official_datas["temperatures"]]
        official_times = official_datas["times"]
        # Adjusting, compressing timestamps
        official_times[0] = bmp280[len(bmp280)-1].time
        for i in range(1, len(official_times)):
            official_times[i] = official_times[i-1] + 1000

        # Visualize bmp280 and official temperatures
        fig = plt.figure(figsize=(10, 6))
        ax = fig.add_subplot(111)
        ax.plot(official_times, official_temperatures, '-', color='black',␣
↪label='Official')
        ax.plot([bmp.time for bmp in bmp280 if not bmp.is_temperature_outlier],␣
↪[bmp.temperature for bmp in bmp280 if not bmp.is_temperature_outlier], '-',␣
↪color='green', label='BMP280')
        ax.set_xlabel('Time')
        ax.set_ylabel('Temperature')
        ax.set_title('BMP280 and Official Temperatures in Comparison')
        first_time_missing_data = True
        for i, bmp in enumerate(bmp280[1:], start=1):
            if bmp.missing_data:
                ax.plot([bmp280[i-1].time, bmp.time], [bmp280[i-1].temperature,␣
↪bmp.temperature], '-', color='red', label='Likely data loss' if␣
↪first_time_missing_data else '')
                first_time_missing_data = False
        ax.legend()
        plt.tight_layout()
        cansattools.save_graph(fig, "BMP_official")
        plt.show()
        # Difference between the last BMP280 and first official data
        difference: float = abs(bmp280[-1].temperature -␣
↪official_temperatures[0])
```

```
        print("The difference between the last BMP280 and first official data␣
↪is: ", difference)
        if difference > 3.0:
            print("We have a big difference between the last BMP280 and first␣
↪official data. This means that the forecast datas are not accurate and our␣
↪measurements were not good as well.")
        else:
            print("It seems that we only have a slight difference. This means␣
↪that the forecast datas are pretty accurate and our measurements were good␣
↪as well.")
    else:
        print("Unfortunately, the BMP280 measurements are not available.␣
↪Therefore, we cannot compare the data as expected.")
except Exception as e:
    logger.error(f"Error comparing the BMP280 and official temperatures: {e}",␣
↪exc_info=True)
```




```
The difference between the last BMP280 and first official data is:
60.57393512145178
We have a big difference between the last BMP280 and first official data. This
means that the forecast datas are not accurate and our measurements were not
good as well.
```

Note that the official datas are greatly compressed for proper illustration. They store the forecasts for one day.

1.4.2 Calculating wind speed

We can try to calculate windspeed from our GPS coordinates using the attached timestamps. However, we will use plenty of simplification in order to make our goal more accomplishable.

[88]:
```python
timestamps = np.array([gps.time for gps in gpses if not gps.is_latitude_outlier␣
↪and not gps.is_longitude_outlier])
x = np.array([gps.latitude for gps in gpses if not gps.is_latitude_outlier and␣
↪not gps.is_longitude_outlier])
y = np.array([gps.longitude for gps in gpses if not gps.is_latitude_outlier and␣
↪not gps.is_longitude_outlier])
positions = np.column_stack((x, y))

velocities = np.diff(positions, axis=0) / np.diff(timestamps)[:, np.newaxis]

# Assume simplified drag model
drag_forces = 0.5 * AIR_DENSITY * np.linalg.norm(velocities, axis=1)[:, np.
↪newaxis]**2 * DRAG_COEFFICIENT * SURFACE_AREA

# Calculate the acceleration due to drag
acceleration_due_to_drag = drag_forces / MASS

# Calculate the wind velocity (assuming the wind is the difference between the␣
↪actual velocity and the velocity without wind)
wind_velocities = velocities - acceleration_due_to_drag

# Calculate the wind speed (magnitude of the wind velocity)
wind_speeds = np.linalg.norm(wind_velocities, axis=1)

# Calculate the wind direction (in radians)
wind_directions = np.arctan2(wind_velocities[:, 1], wind_velocities[:, 0])

# Calculate the average wind speed and direction
average_wind_speed: float = np.mean(wind_speeds)
average_wind_direction: float = np.mean(wind_directions)

# Convert the average wind direction from radians to degrees
average_wind_direction_degrees = np.degrees(average_wind_direction)

print("Average Wind Speed:", round(average_wind_speed, 3), "m/s")
print("Average Wind Direction (degrees):",␣
↪round(average_wind_direction_degrees, 3))

# Comparing the wind speed with the official data (example 10 km/h)
official_wind_speed = float(official_datas["wind_speed"][0][:-4])/3.6
print("Official Wind Speed:", official_wind_speed, "m/s")
difference = average_wind_speed - official_wind_speed
```

```
if 0 <= difference and difference < 3:
    print("Our measured wind speed is slightly higher than the official data.")
elif 0 > difference and difference > -3 :
    print("Our measured wind speed is slightly lower than the official data.")
elif difference >= 3:
    print("Our measured wind speed is significantly higher than the official␣
 ↪data.")
elif difference <= -3:
    print("Our measured wind speed is significantly lower than the official␣
 ↪data.")

# Remove unnescessary variables
del timestamps, x, y, positions, velocities, drag_forces,␣
 ↪acceleration_due_to_drag, wind_velocities, wind_speeds, difference
```

```
Average Wind Speed: 0.132 m/s
Average Wind Direction (degrees): 7.635
Official Wind Speed: 4.722222222222222 m/s
Our measured wind speed is significantly lower than the official data.
```

1.5 CanSat path 3D illustration

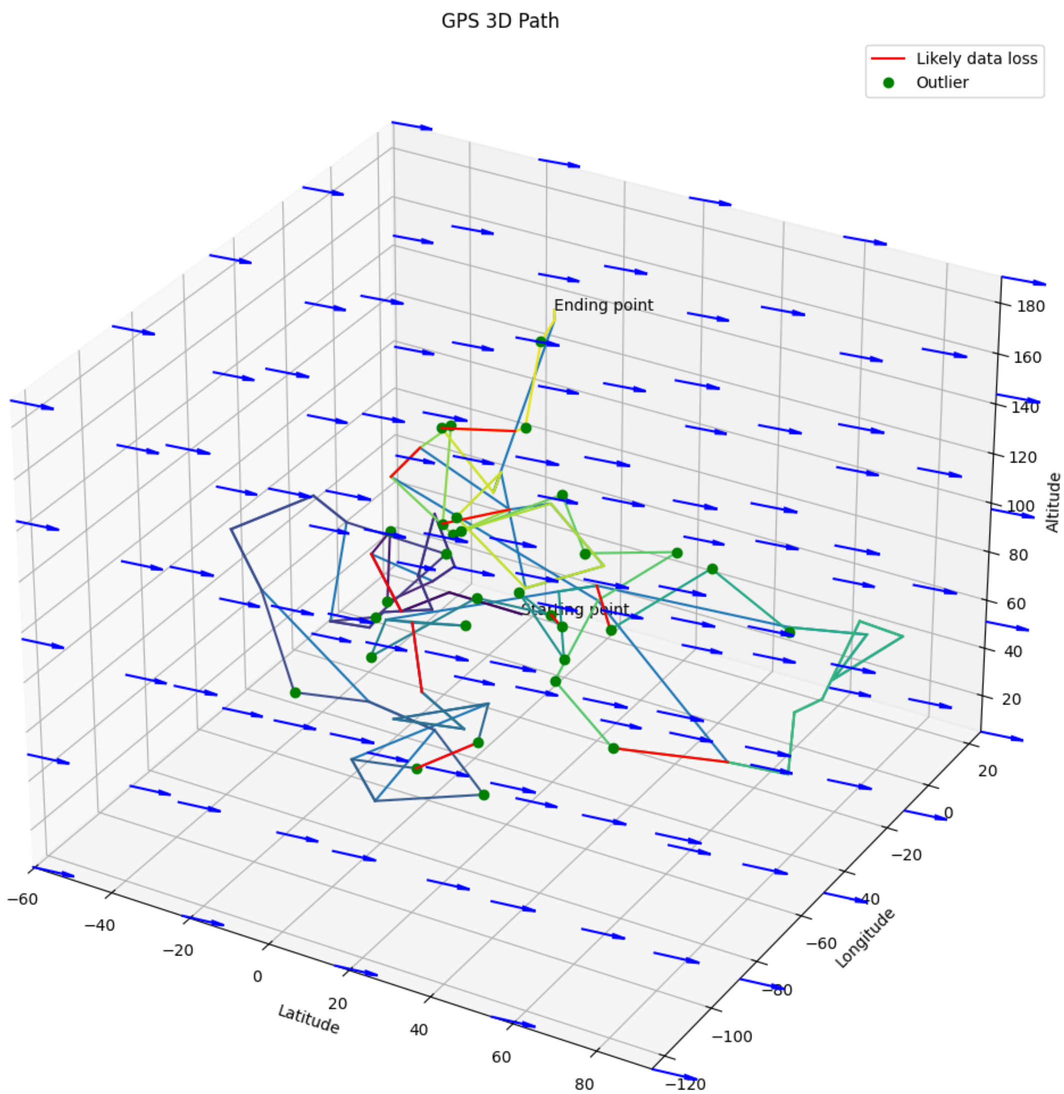
Now that we refined the datas, let's illustrate the path of our Cansat with the additional pieces of information.

[89]:
```
if TEST_DATA_MODE:
    average_wind_speed = 10
try:
    first_time_missing_data = True
    first_time_outlier = True
    if len(gpses) > 0:
        print("Number of missing data points: ", sum(1 for gps in gpses if gps.
 ↪missing_data))
        print("Number of latitude outliers: ", sum(1 for gps in gpses if gps.
 ↪is_latitude_outlier))
        print("Number of longitude outliers: ", sum(1 for gps in gpses if gps.
 ↪is_longitude_outlier))
        print("Number of altitude outliers: ", sum(1 for gps in gpses if gps.
 ↪is_altitude_outlier))

        # Calculate the bounds of the cube
        min_lat, max_lat = min([gps.latitude for gps in gpses]), max([gps.
 ↪latitude for gps in gpses])
        min_lon, max_lon = min([gps.longitude for gps in gpses]), max([gps.
 ↪longitude for gps in gpses])
        min_alt, max_alt = min([gps.altitude for gps in gpses]), max([gps.
 ↪altitude for gps in gpses])
```

```
    # Create a 3D grid of points within the cube
    grid_size = 5
    lat_grid = np.linspace(min_lat - 0.1 * (max_lat - min_lat), max_lat + 0.
↪1 * (max_lat - min_lat), grid_size)
    lon_grid = np.linspace(min_lon - 0.1 * (max_lon - min_lon), max_lon + 0.
↪1 * (max_lon - min_lon), grid_size)
    alt_grid = np.linspace(min_alt - 0.1 * (max_alt - min_alt), max_alt + 0.
↪1 * (max_alt - min_alt), grid_size)
    lat_grid, lon_grid, alt_grid = np.meshgrid(lat_grid, lon_grid, alt_grid)

    # Calculate the wind vectors at each point in the grid
    wind_vectors = np.zeros((grid_size, grid_size, grid_size, 3))
    for i in range(grid_size):
        for j in range(grid_size):
            for k in range(grid_size):
                wind_vectors[i, j, k, :] = average_wind_speed * np.
↪array([np.cos(average_wind_direction), np.sin(average_wind_direction), 0])

    # 3D path map
    fig = plt.figure(figsize=(10, 14))
    ax = plt.axes(projection='3d')
    ax.quiver(lat_grid, lon_grid, alt_grid, wind_vectors[:, :, :, 0],␣
↪wind_vectors[:, :, :, 1], wind_vectors[:, :, :, 2], color='blue')
    # Plot the GPS data
    ax.plot3D([gps.latitude for gps in gpses if not gps.is_latitude_outlier␣
↪and not gps.is_longitude_outlier and not gps.is_altitude_outlier], [gps.
↪longitude for gps in gpses if not gps.is_latitude_outlier and not gps.
↪is_longitude_outlier and not gps.is_altitude_outlier], [gps.altitude for gps␣
↪in gpses if not gps.is_latitude_outlier and not gps.is_longitude_outlier and␣
↪not gps.is_altitude_outlier], '-')

    for i in range(len(gpses) - 1):
        ax.plot3D([gpses[i].latitude, gpses[i+1].latitude],
                    [gpses[i].longitude, gpses[i+1].longitude],
                    [gpses[i].altitude, gpses[i+1].altitude],
                    color=colors[i])
    ax.text(gpses[0].latitude, gpses[0].longitude, gpses[0].altitude,␣
↪'Starting point', size=10, zorder=1, color='k')
    ax.text(gpses[-1].latitude, gpses[-1].longitude, gpses[-1].altitude,␣
↪'Ending point', size=10, zorder=1, color='k')
    ax.set_xlim(min_lat - 0.1 * (max_lat - min_lat), max_lat + 0.1 *␣
↪(max_lat - min_lat))
    ax.set_ylim(min_lon - 0.1 * (max_lon - min_lon), max_lon + 0.1 *␣
↪(max_lon - min_lon))
```

```
        ax.set_zlim(min_alt - 0.1 * (max_alt - min_alt), max_alt + 0.1 *␣
↪(max_alt - min_alt))
        ax.set_xlabel('Latitude')
        ax.set_ylabel('Longitude')
        ax.set_zlabel('Altitude')
        ax.set_title('GPS 3D Path')

        for i, gps in enumerate(gpses[1:], start=1):
            if gps.missing_data:
                ax.plot([gpses[i-1].latitude, gps.latitude], [gpses[i-1].
↪longitude, gps.longitude], [gpses[i-1].altitude, gps.altitude], '-',␣
↪color='red', label='Likely data loss' if first_time_missing_data else '')
                first_time_missing_data = False
            if gps.is_latitude_outlier or gps.is_longitude_outlier or gps.
↪is_altitude_outlier:
                ax.plot([gps.latitude], [gps.longitude], [gps.altitude], 'o',␣
↪color='green', label='Outlier' if first_time_outlier else '')
                first_time_outlier = False
        plt.legend()
        plt.tight_layout()
        cansattools.save_graph(fig, "GPS_3D_refined")
        plt.show()
except Exception as e:
    logger.error(f"Error visualizing data: {e}", exc_info=True)
```

```
Number of missing data points:  9
Number of latitude outliers:  8
Number of longitude outliers:  17
Number of altitude outliers:  9
```

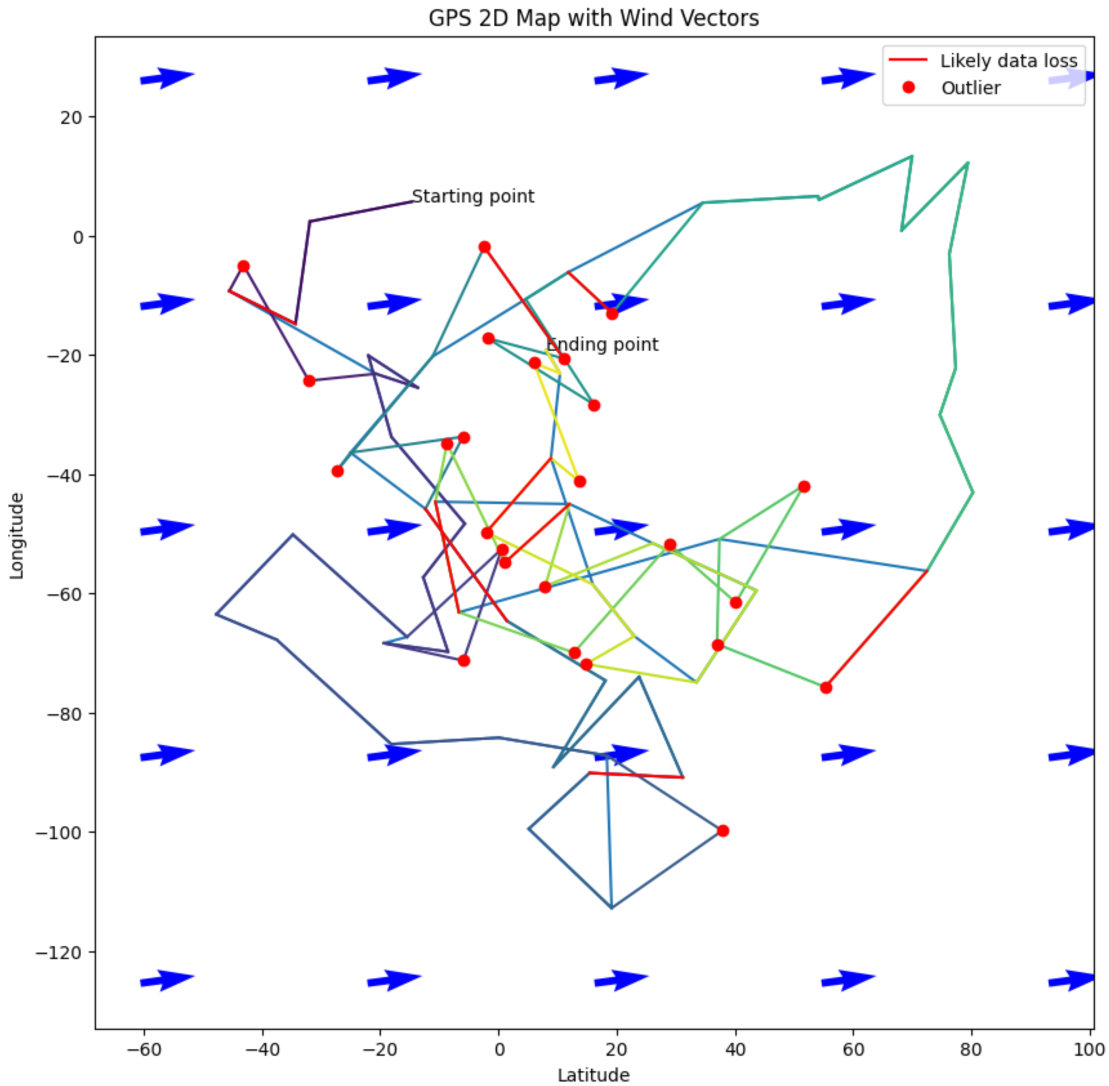


We can have a look at a 2D map to see the impact of the wind more clearly.

[90]:
```
#2D map with wind vectors outliers and missing data
try:
    first_time_missing_data = True
    first_time_outlier = True
    if len(gpses) > 0:
        print("Number of missing data points: ", sum(1 for gps in gpses if gps.
↪missing_data))
        print("Number of latitude outliers: ", sum(1 for gps in gpses if gps.
↪is_latitude_outlier))
```

```
        print("Number of longitude outliers: ", sum(1 for gps in gpses if gps.
 ↪is_longitude_outlier))
        fig = plt.figure(figsize=(10, 10))
        ax = fig.add_subplot(111)
        ax.quiver(lat_grid[:, :, 0], lon_grid[:, :, 0], wind_vectors[:, :, 0,␣
 ↪0], wind_vectors[:, :, 0, 1], color='blue')
        # Plot the GPS data
        ax.plot([gps.latitude for gps in gpses if not gps.is_latitude_outlier␣
 ↪and not gps.is_longitude_outlier], [gps.longitude for gps in gpses if not␣
 ↪gps.is_latitude_outlier and not gps.is_longitude_outlier], '-')
        for i in range(len(gpses) - 1):
            ax.plot([gpses[i].latitude, gpses[i+1].latitude], [gpses[i].
 ↪longitude, gpses[i+1].longitude], '-', color=colors[i])
        ax.text(gpses[0].latitude, gpses[0].longitude, 'Starting point',␣
 ↪size=10, zorder=1, color='k')
        ax.text(gpses[-1].latitude, gpses[-1].longitude, 'Ending point',␣
 ↪size=10, zorder=1, color='k')
        ax.set_xlabel('Latitude')
        ax.set_ylabel('Longitude')
        ax.set_title('GPS 2D Map with Wind Vectors')
        for i, gps in enumerate(gpses[1:], start=1):
            if gps.missing_data:
                ax.plot([gpses[i-1].latitude, gps.latitude], [gpses[i-1].
 ↪longitude, gps.longitude], '-', color='red', label='Likely data loss' if␣
 ↪first_time_missing_data else '')
                first_time_missing_data = False
            if gps.is_latitude_outlier or gps.is_longitude_outlier:
                ax.plot([gps.latitude], [gps.longitude], 'o', color='green',␣
 ↪label='Outlier' if first_time_outlier else '')
                first_time_outlier = False
        plt.legend()
        cansattools.save_graph(fig, 'GPS_2D_refined')
        plt.show()
except Exception as e:
    logger.error(f"Error visualizing data: {e}", exc_info=True)

# Remove unnescessary variables
del lat_grid, lon_grid, alt_grid, wind_vectors, min_lat, max_lat, min_lon,␣
 ↪max_lon, min_alt, max_alt
```

```
Number of missing data points:  9
Number of latitude outliers:  8
Number of longitude outliers:  17
```



1.6 Location of coordinates

The following

[91]:
```
try:
    filtered_gpses = [gps for gps in gpses if not gps.is_latitude_outlier and␣
 ↪not gps.is_longitude_outlier]

    df = pd.DataFrame({
        "Lat": [gps.latitude for gps in filtered_gpses if not gps.
 ↪is_latitude_outlier],
        "Long": [gps.longitude for gps in filtered_gpses if not gps.
 ↪is_longitude_outlier],
```

```
        "Address": [f"Latitude: {gps.latitude}, Longitude: {gps.longitude}" for␣
↪gps in filtered_gpses if not gps.is_latitude_outlier and not gps.
↪is_longitude_outlier],
        "Listed": [1 for gps in filtered_gpses if not gps.is_latitude_outlier␣
↪and not gps.is_longitude_outlier]
    })

    color_scale = [(0, 'orange'), (1,'red')]

    fig = px.scatter_mapbox(df,
                            lat="Lat",
                            lon="Long",
                            hover_name="Address",
                            hover_data=["Address", "Listed"],
                            color="Listed",
                            color_continuous_scale=color_scale,
                            size="Listed",
                            zoom=8,
                            height=800,
                            width=800)

    fig.update_layout(mapbox_style="open-street-map")
    fig.update_layout(margin={"r":0,"t":0,"l":0,"b":0})
    fig.show()
    # Remove unnescessary variables
    del filtered_gpses, df, color_scale
except Exception as e:
    logger.error(f"Error visualizing data: {e}", exc_info=True)
```

1.7 Final conclusions

Now that we used or datas in a variety of ways we can say a few words about how the mission went based on the measurements.

[92]:
```
# Overall conclusions, predictions, and assumptions
try:
    # Calculate the percentage of missing data points for each sensor
    missing_bmp280 = sum(1 for bmp in bmp280 if bmp.missing_data) / len(bmp280)␣
↪* 100
    missing_dht11 = sum(1 for dht in dht11 if dht.missing_data) / len(dht11) *␣
↪100
    missing_gps = sum(1 for gps in gpses if gps.missing_data) / len(gpses) * 100

    # Calculate the percentage of outliers for each sensor
    outliers_bmp280 = sum(1 for bmp in bmp280 if bmp.is_temperature_outlier) /␣
↪len(bmp280) * 100 #outlier problems
```

```
    outliers_dht11 = sum(1 for dht in dht11 if dht.is_humidity_outlier) /␣
↪len(dht11) * 100
    outliers_gps = sum(1 for gps in gpses if gps.is_altitude_outlier) /␣
↪len(gpses) * 100

    # Print overall conclusions
    print("Overall Conclusions:")
    print(f"BMP280 Sensor: {missing_bmp280:.2f}% missing data, {outliers_bmp280:
↪.2f}% outliers")
    print(f"DHT11 Sensor: {missing_dht11:.2f}% missing data, {outliers_dht11:.
↪2f}% outliers")
    print(f"GPS Sensor: {missing_gps:.2f}% missing data, {outliers_gps:.2f}%␣
↪outliers")

    # Determine the weather conditions based on the data
    avg_temperature = np.mean([bmp.temperature for bmp in bmp280 if not bmp.
↪is_temperature_outlier])
    avg_humidity = np.mean([dht.humidity for dht in dht11 if not dht.
↪is_humidity_outlier])
    avg_pressure = np.mean([bmp.pressure for bmp in bmp280 if not bmp.
↪is_height_outlier])

    print("\nWeather Conditions:")
    if avg_temperature < 0:
        print("It is likely very cold.")
    elif avg_temperature < 10:
        print("It is likely cold.")
    elif avg_temperature < 20:
        print("It is likely mild.")
    else:
        print("It is likely warm.")

    if avg_humidity > 80:
        print("It is likely humid.")
    elif avg_humidity < 30:
        print("It is likely dry.")
    else:
        print("Humidity is moderate.")

    if average_wind_speed > 5:
        print("It is likely windy.")
    else:
        print("It is likely calm.")

    # Determine the season based on the temperature and humidity
    print("\nSeason Prediction:")
```

```
    if avg_temperature < 0:
        print("It is likely winter.")
    elif avg_temperature < 15 and avg_humidity > 60:
        print("It is likely autumn.")
    elif avg_temperature < 15 and avg_humidity < 60:
        print("It is likely spring.")
    else:
        print("It is likely summer.")

    # Additional conclusions
    print("\nAdditional Conclusions:")
    if missing_bmp280 > 10 or missing_dht11 > 10 or missing_gps > 10:
        print("There were too many instances of missing data. Sensor␣
↪reliability may be an issue.")
    else:
        print("The sensors worked well with minimal missing data.")

    if outliers_bmp280 > 5 or outliers_dht11 > 5 or outliers_gps > 5:
        print("There were a significant number of outliers. Sensor accuracy may␣
↪be an issue.")
    else:
        print("The sensors provided accurate data with minimal outliers.")

except Exception as e:
    logger.error(f"Error generating conclusions: {e}", exc_info=True)
```

```
Overall Conclusions:
BMP280 Sensor: 5.35% missing data, 0.00% outliers
DHT11 Sensor: 0.00% missing data, 0.10% outliers
GPS Sensor: 11.25% missing data, 11.25% outliers

Weather Conditions:
It is likely very cold.
Humidity is moderate.
It is likely windy.

Season Prediction:
It is likely winter.

Additional Conclusions:
There were too many instances of missing data. Sensor reliability may be an
issue.
There were a significant number of outliers. Sensor accuracy may be an issue.
```

1.8 Convert Notebook into a pdf

For people who cannot open the Notebook due to the lack of environment setup we should convert our analyzis into a PDF file. This code tries to create Visualization.pdf which contains the whole analyzis with the scripts. This process takes approximately 3 minutes to complete. If you would like to skip the conversion, set INTO_PDF constant to false.

[93]:
```
if INTO_PDF:
    try:
        subprocess.run(f"python -m jupyter nbconvert --to pdf --output␣
 ↪Visualization.pdf Visualization.ipynb", shell=True, check=True, timeout=600)
        print("Exporting to PDF...")
    except Exception as e:
        logger.error(f"Error exporting the notebook into pdf format: {e}",␣
 ↪exc_info=True)
    if os.path.exists("Visualization.pdf"):
        print("PDF exported successfully.")
    else:
        print("PDF export failed.")
        logger.error("PDF export failed.", exc_info=True)
else:
    print("PDF export skipped.")
```

```
PDF export skipped.
```