Exercise 2.1: algorithm runtimes.

The dataset stored in runtimes.csv contains information on the runtime of two algorithms (a serial version and a distributed version) on test problems of di erent size (measured in pixels), and for various numbers of worker threads (for the distributed version).

1. Create a chart that examines how fast runtime increases with problem size, for the single and distributed versions, and for different numbers of threads for the latter.

In [184]:
```
# importing necessary libraries

import pandas as pd
import numpy as np
import seaborn as sns
import matplotlib.pyplot as plt
import csv
import random
from scipy.interpolate import griddata
```

In [185]:
```
#loading the dataset

df = pd.read_csv('runtimes.csv', comment = "#")

print(df.head())
```

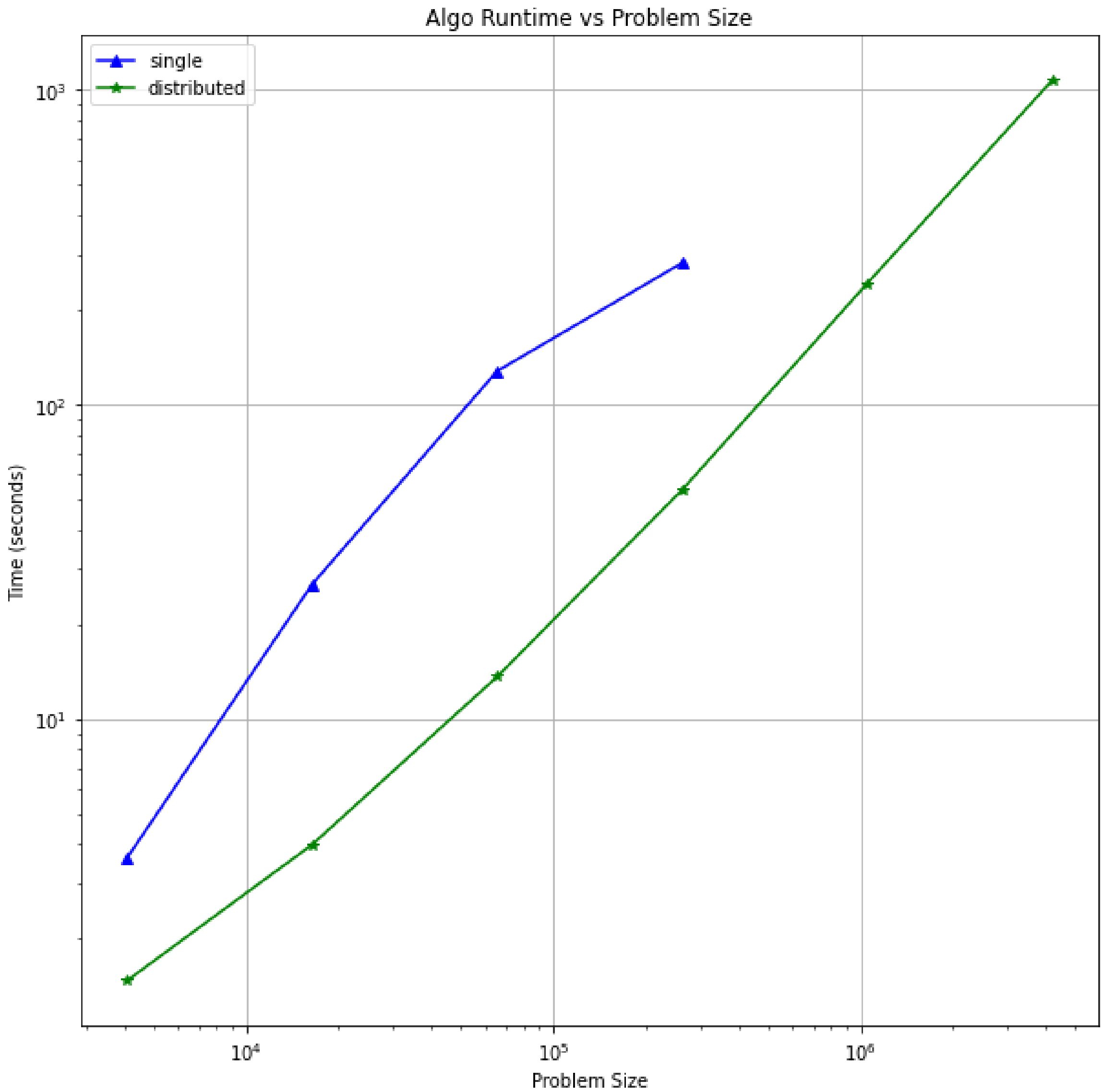
```
   size  workers      time         algo
0  4096        1  3.736606  distributed
1  4096        2  2.133074  distributed
2  4096        3  1.673441  distributed
3  4096        4  1.515788  distributed
4  4096        5  1.475265  distributed
```

In [186]:
```
#checking for null values
df.isnull().sum()
```

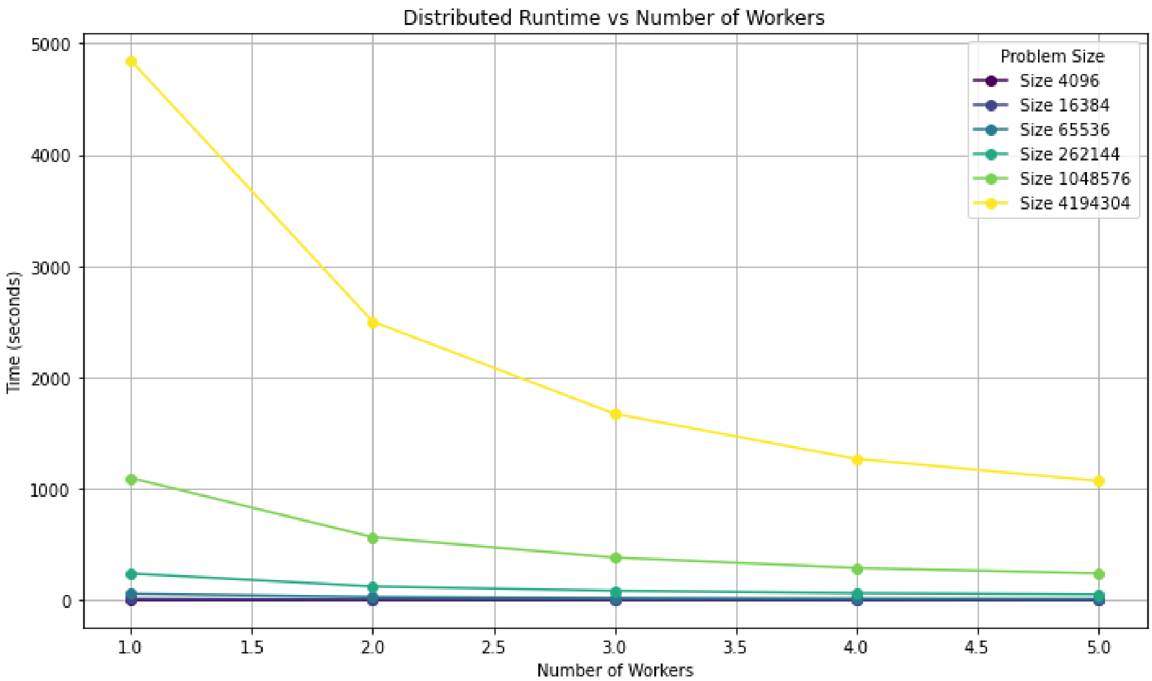
Out[186]:
```
size       0
workers    0
time       0
algo       0
dtype: int64
```

In [187]:
```
#filter data for single and distributed algorithm

df_single = df[df['algo'] == 'single']
df_distributed = df[df['algo'] == 'distributed']
```

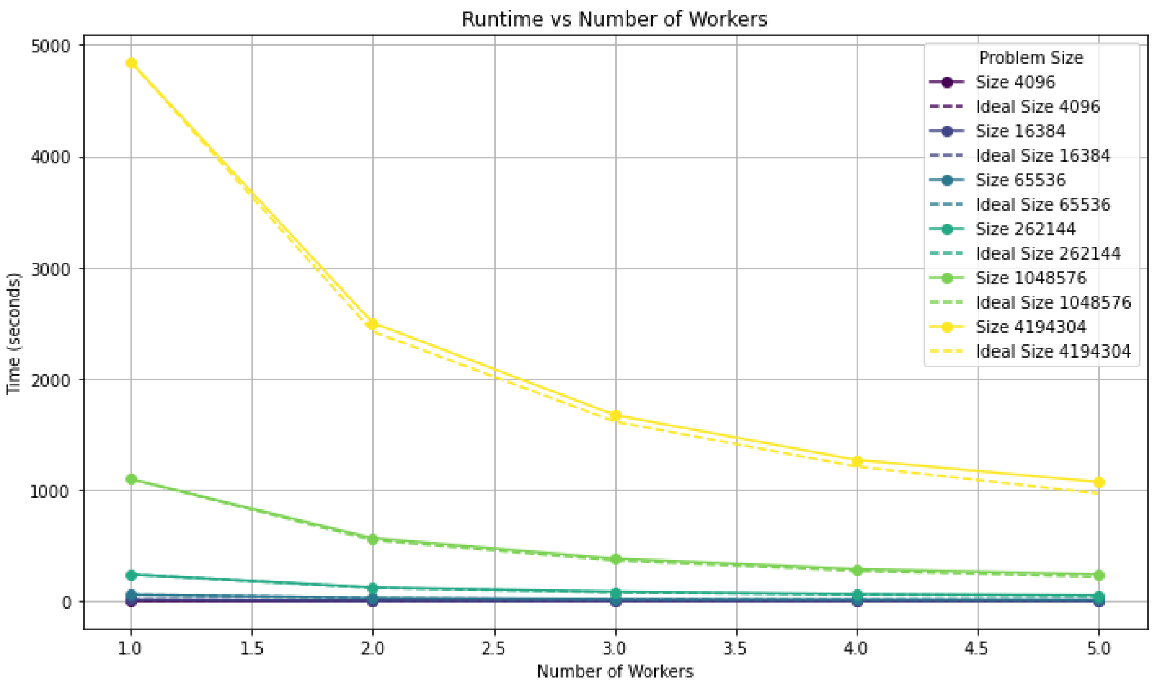
In [188]:
```
#Create a chart that examines how fast runtime increases with problem
fig, ax1 = plt.subplots(figsize=(10, 10))

colors = ['blue', 'green']
markers = ['^','*']

# Plot for Single-threaded runtime vs Problem Size
for algo_type, color, marker in zip(['single', 'distributed'], colors,
    subset = df[df['algo'] == algo_type]

    # Use minimum runtime for each size if multiple entries per size a
    subset = subset.groupby(['size', 'algo'])['time'].min().reset_inde
    ax1.plot(subset['size'], subset['time'], marker=marker, linestyle=

ax1.set_title('Algo Runtime vs Problem Size')
ax1.set_xlabel('Problem Size')
ax1.set_ylabel('Time (seconds)')
ax1.set_xscale('log')
ax1.set_yscale('log')
ax1.legend()
ax1.grid(True)
```



In [189]:
```
fig, ax2 = plt.subplots(figsize=(10, 6))

#Different colors for each problem size using a colormap
problem_sizes = df_distributed['size'].unique()
colors = plt.cm.viridis(np.linspace(0, 1, len(problem_sizes)))


# Plot distributed runtime by number of workers for each problem size
for size, color in zip(sorted(problem_sizes), colors):
    subset = df_distributed[df_distributed['size'] == size]
    ax2.plot(subset['workers'], subset['time'], 'o-', label=f'Size {si

ax2.set_title('Distributed Runtime vs Number of Workers')
ax2.set_xlabel('Number of Workers')
ax2.set_ylabel('Time (seconds)')
ax2.legend(title='Problem Size')
ax2.grid(True)

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



In [190]:
```
import matplotlib.pyplot as plt
import pandas as pd

# Create a plot
fig, ax = plt.subplots(figsize=(10, 6))

# Get unique problem sizes
problem_sizes = df_distributed['size'].unique()
colors = plt.cm.viridis(np.linspace(0, 1, len(problem_sizes)))  # Colo

for size, color in zip(sorted(problem_sizes), colors):
    subset = df_distributed[df_distributed['size'] == size]
    # Plot actual data
    ax.plot(subset['workers'], subset['time'], 'o-', label=f'Size {siz

     # Calculate and plot ideal scalability
    t1 = subset[subset['workers'] == 1]['time'].values[0]
    ideal_time = [t1 / n for n in subset['workers']]
    ax.plot(subset['workers'], ideal_time, '--', color=color, label=f'


ax.set_title('Runtime vs Number of Workers')
ax.set_xlabel('Number of Workers')
ax.set_ylabel('Time (seconds)')
ax.legend(title = "Problem Size")
ax.grid(True)

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



Exercise 2.2: precipitation data.

In this exercise we process precipitation data of the Deutscher Wetterdienst (DWD). The original data is available at [https://www.dwd.de/DE/leistungen/cdc/cdc_ueberblick-klimadate (https://www.dwd.de/DE/leistungen/cdc/cdc_ueberblick-klimadate)](https://www.dwd.de/DE/leistungen/cdc/cdc_ueberblick-klimadate) n.html, but all data required for the exercise is already provided in the zip file of the problem sheet.

1. The file zehn_min_rr_Beschreibung_Stationen.txt (as available on the DWD website) contains basic information about the weather measurement stations. Its format should be self-explanatory. Convert it into reasonable CSV format. As a warmup, create a scatter plot of the geographical position of all weather stations and their elevation.

In [191]:

```python
# Open the text file and read its contents
with open('zehn_min_rr_Beschreibung_Stationen.txt', 'r', encoding = 'l
    lines = file.readlines()
    print(lines[:10])
```

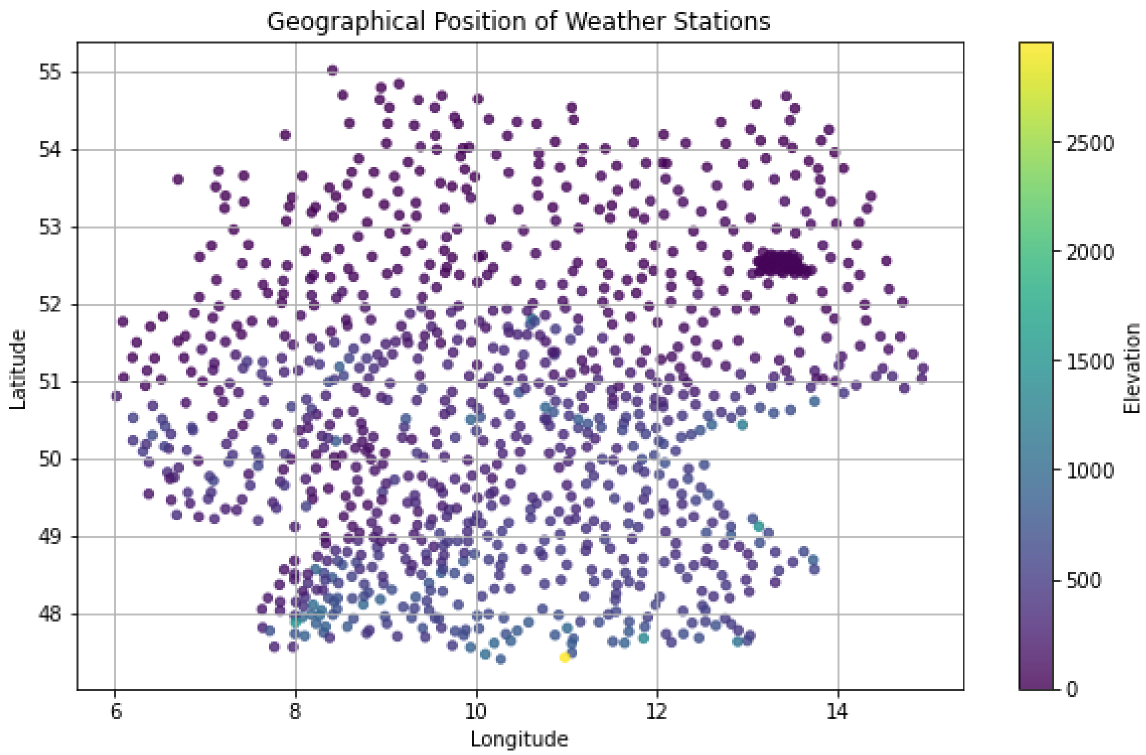
```
['Stations_id von_datum bis_datum Stationshoehe geoBreite geoLaenge
Stationsname Bundesland\n', '----------- --------- --------- -------
------ --------- --------- -----------------------------------------
----------\n', '00020 20040812 20240422            432     48.9219
9.9129 Abtsgmünd-Untergröningen
Baden-Württemberg
\n', '00044 20070208 20240422           44      52.9336    8.2370 G
roßenkneten
Niedersachsen
\n', '00053 20050831 20240422           60      52.5850   13.5634 A
hrensfelde
Brandenburg
\n', '00073 20070213 20240422          374      48.6183   13.0620 A
ldersbach-Kramersepp
Bayern
\n', '00078 20041010 20240422           64      52.4853    7.9125 A
lfhausen
Niedersachsen
\n', '00087 20041019 20240422          158      51.0950   11.0479 A
lperstedt
Thüringen
\n', '00091 20020819 20240422          304      50.7446    9.3450 A
lsfeld-Eifa
Hessen
\n', '00096 20190409 20240422           50      52.9437   12.8518 N
euruppin-Alt Ruppin
Brandenburg
\n']
```

In [192]:
```
# Extracting column headers from the first line
headers = lines[0].split()


data = []
for line in lines[2:]:
    parts = line.split(maxsplit = len(headers)-1)

    data.append(parts)

# Writing the extracted data into a CSV file
with open('zehn_min_rr_Beschreibung_Stationen.csv', 'w', newline='') a
    writer = csv.writer(csvfile)
    writer.writerow(headers)
    writer.writerows(data)
```

In [193]:
```
#reading csv_file
df = pd.read_csv('zehn_min_rr_Beschreibung_Stationen.csv')
print(df.head())
print("\nNo. of rows in the dataset:", df.shape[0])
```

```
   Stations_id  von_datum  bis_datum  Stationshoehe  geoBreite  geoL
aenge  \
0           20   20040812   20240422            432    48.9219
9.9129
1           44   20070208   20240422             44    52.9336
8.2370
2           53   20050831   20240422             60    52.5850    1
3.5634
3           73   20070213   20240422            374    48.6183    1
3.0620
4           78   20041010   20240422             64    52.4853
7.9125

               Stationsname
Bundesland
0  Abtsgmünd-Untergröningen  Baden-Württemberg
...
1               Großenkneten  Niedersachsen
...
2                Ahrensfelde  Brandenburg
...
3      Aldersbach-Kramersepp  Bayern
...
4                 Alfhausen  Niedersachsen
...

No. of rows in the dataset: 1068
```

In [194]:
```
# Scatter plot
plt.figure(figsize=(10, 6))
plt.scatter(df['geoLaenge'], df['geoBreite'], c = df['Stationshoehe'],
plt.colorbar(label = 'Elevation')
plt.xlabel('Longitude')
plt.ylabel('Latitude')
plt.title('Geographical Position of Weather Stations')
plt.grid(True)
plt.show()
```



2. The file 10min_processed.csv contains condensed precipitation data for the day 2024- 04-20 in intervals of 10 minutes for (a subset of) the weather stations listed above. The column stationid corresponds to the column Stations_id in the other table. The column date indicates the beginning of the 10 minute interval in the format YYYYMMDDHHMM. The column rain encodes precipitation in this interval in millimeters, missing values are encoded as -999.

In [195]:
```
#loading 10min_processed.csv file

min_Processed = pd.read_csv('10min_processed.csv')
min_Processed.rename(columns={'stationid': 'Stations_id'}, inplace=Tru
```

In [196]:
```
#convert the date column to datetime format
min_Processed['date'] = pd.to_datetime(min_Processed['date'], format='

# Extract the hour part of the 'date' column
min_Processed['hour'] = df_min_Processed['date'].dt.hour
```

In [197]:
```
# replace missing values encoded as '-999' to zero
min_Processed['rain'] = df_min_Processed['rain'].apply(lambda x: max(x
```

In [198]:
```
min_Processed_grouped = min_Processed.groupby(['Stations_id', 'hour'])
```

In [199]:
```
# Sum the rain values within each hour
hourly_precipitation = min_Processed_grouped['rain'].sum().reset_index
```

In [200]:
```
# merge the two data frames to get the locations of each station from
df_min_Processed_merged = hourly_precipitation.merge(df[['Stations_id'
```

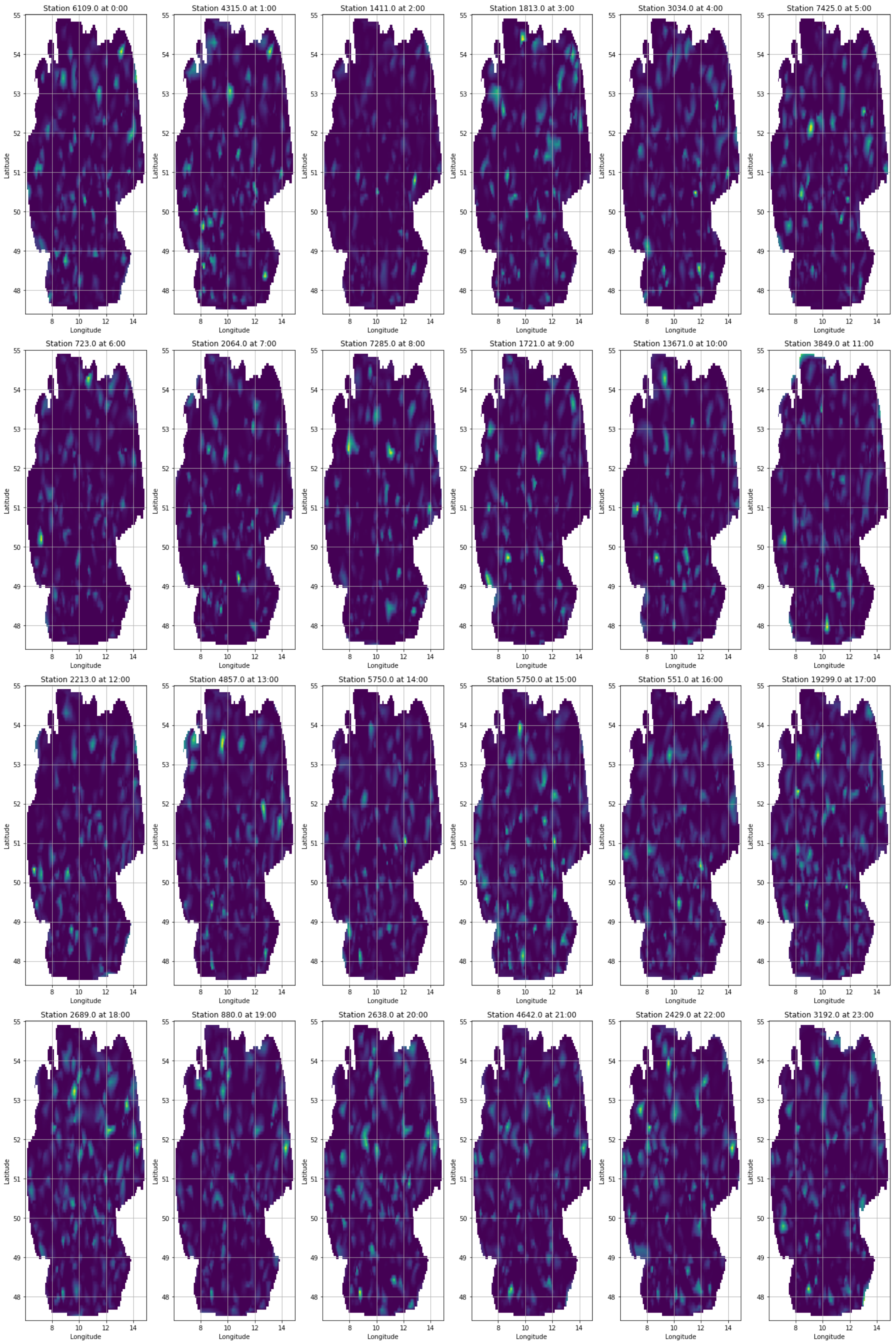
In [201]:
```
# Set up a larger figure to accommodate multiple subplots
fig, axs = plt.subplots(4, 6, figsize=(20, 30))

# Create a subplot for each selected hour
for hour in range(24):
    hour_data = df_min_Processed_merged[df_min_Processed_merged['hour'

    ax = axs.flatten()[hour]

    # Create a subplot (2 rows, 2 columns)
    scatter = ax.scatter(hour_data['geoLaenge'], hour_data['geoBreite'
    ax.set_title(f'At {hour}:00')
    ax.set_xlabel('Longitude')
    ax.set_ylabel('Latitude')
    ax.grid(True)



# Show the plots
plt.tight_layout()  # Adjust subplots to fit into the figure area.
plt.show()
```

3. The file griddata.npz contains the arrays geolat, geolong and ind. The two former arrays contain latitude and longitude positions of a regular rectangular Cartesian grid covering the measurement area, the third

array contains an approximate binary indicator of the region covered by the measurements (with True indicating coverage). Interpolate the above precipitation data from the weather stations to this grid (only to the region indicated by ind) and display the data as an image. This gives a smoother visual impression of the geographical distribution of precipitation. Do this for all hours of the day as a small multiple.

In [202]:
```
# load grid data

with np.load('griddata.npz') as df:
    geolat = df['geolat']
    geolong = df['geolong']
    ind = df['ind']
```

In [203]:
```
# Set up a larger figure to accommodate multiple subplots
fig, axs = plt.subplots(4, 6, figsize=(20, 30))

# Create a subplot for each selected hour
for hour in range(24):
    ax = axs.flatten()[hour]

    hour_data = df_min_Processed_merged[df_min_Processed_merged['hour'
    max_rain_station = hour_data.loc[hour_data['rain'].idxmax()]

    # Interpolate precipitation data to the grid
    interpolated_rain = griddata((hour_data['geoLaenge'], hour_data['g

    # Mask out regions where 'ind' is False as it is not part of the m
    interpolated_rain = np.ma.masked_where(~ind, interpolated_rain)

    im = ax.imshow(interpolated_rain, extent=(geolong.min(), geolong.m
    ax.set_title(f'Station {max_rain_station["Stations_id"]} at {hour}
    #ax.set_title(f'At {hour}:00')
    ax.set_xlabel('Longitude')
    ax.set_ylabel('Latitude')
    ax.grid(True)



# Show the plots
plt.tight_layout()  # Adjust subplots to fit into the figure area.
plt.show()
```


Station 6109.0 at 0:00
Station 4315.0 at 1:00
Station 1411.0 at 2:00
Station 1813.0 at 3:00
Station 3034.0 at 4:00
Station 7425.0 at 5:00
Station 723.0 at 6:00
Station 2064.0 at 7:00
Station 7285.0 at 8:00
Station 1721.0 at 9:00
Station 13671.0 at 10:00
Station 3849.0 at 11:00
Station 2213.0 at 12:00
Station 4857.0 at 13:00
Station 5750.0 at 14:00
Station 5750.0 at 15:00
Station 551.0 at 16:00
Station 19299.0 at 17:00
Station 2689.0 at 18:00
Station 880.0 at 19:00
Station 2638.0 at 20:00
Station 4642.0 at 21:00
Station 2429.0 at 22:00
Station 3192.0 at 23:00
Latitude
Longitude

In [ ]: