Traverse City

Traverse City is a Lake Michigan coastal city that get a lot of Lake-Effect snow.

We attempt to verify that cloud sequences are contiguous

```
import os
import pandas as pd
import numpy as np
import pickle
import ast

# Plotting libraries
import matplotlib.pyplot as plt
import matplotlib.cm as cm
import seaborn as sns
%matplotlib inline
```

I think this is just winter months:

```
les = pd.read_csv(r'D:\user\docs\NU\
_info6106\2006Fall_2017Spring_GOES_meteo_combined.csv')
les.head()
```

```
     Date_UTC Time_UTC    Date_CST Time_CST  \
0  2006-10-01    00:00  2006-09-30    00:00
1  2006-10-01    01:00  2006-09-30    01:00
2  2006-10-01    02:00  2006-09-30    02:00
3  2006-10-01    03:00  2006-09-30    03:00
4  2006-10-01    04:00  2006-09-30    04:00

                        File_name_for_1D_lake  \
0  goes11.2006.10.01.0000.v01.nc-var1-t0.csv
1  goes11.2006.10.01.0100.v01.nc-var1-t0.csv
2  goes11.2006.10.01.0200.v01.nc-var1-t0.csv
3  goes11.2006.10.01.0300.v01.nc-var1-t0.csv
4  goes11.2006.10.01.0400.v01.nc-var1-t0.csv

                               File_name_for_2D_lake  \
0  T_goes11.2006.10.01.0000.v01.nc-var1-t0.csv.csv
1  T_goes11.2006.10.01.0100.v01.nc-var1-t0.csv.csv
2  T_goes11.2006.10.01.0200.v01.nc-var1-t0.csv.csv
3  T_goes11.2006.10.01.0300.v01.nc-var1-t0.csv.csv
4  T_goes11.2006.10.01.0400.v01.nc-var1-t0.csv.csv

                                           Lake_data_1D  \
0  [0.0075, 0.0025, 0.0, 0.005, 0.0, 0.005, nan, ...
```

```
1  [0.0025, nan, 0.0025, 0.0025, nan, 0.0, nan, 0...
2  [0.0, nan, 0.0075, nan, nan, 0.0025, nan, nan,...
3  [0.0025, nan, 0.0025, 0.0, 0.0075, nan, 0.005,...
4  [0.0025, nan, 0.0, nan, 0.0075, 0.0, nan, nan,...

                                        Lake_data_2D Temp (F) RH
(%)  ...  \
0  [array([   nan,    nan,    nan,    nan,    nan...       48
86  ...
1  [array([   nan,    nan,    nan,    nan,    nan...       48
86  ...
2  [array([nan, nan, nan, nan, nan, nan, nan, nan...       48
86  ...
3  [array([nan, nan, nan, nan, nan, nan, nan, nan...       48
86  ...
4  [array([   nan,    nan,    nan,    nan,    nan...       48
89  ...

  Low Cloud Ht (ft) Med Cloud Ht (ft) High Cloud Ht (ft) Visibility
(mi)  \
0              4100              4800               7000
10
1              6000                 m                  m
10
2              5500             11000                  m
10
3              6000                 m                  m
10
4              2200              3500                  m
8

  Atm Press (hPa) Sea Lev Press (hPa) Altimeter (hPa) Precip (in)  \
0           984.0             1007.00         1006.80        0.00
1           983.7             1006.50         1006.40        0.00
2           982.7             1005.70         1005.40        0.00
3           982.0             1005.10         1004.70        0.00
4           982.0             1004.90         1004.70        0.02

  Wind Chill (F) Heat Index (F)
0             45             NC
1             44             NC
2             45             NC
3             44             NC
4             46             NC

[5 rows x 24 columns]
```

EDA

```
column_names = les.columns.tolist()
print(column_names)
```

```
['Date_UTC', 'Time_UTC', 'Date_CST', 'Time_CST',
'File_name_for_1D_lake', 'File_name_for_2D_lake', 'Lake_data_1D',
'Lake_data_2D', 'Temp (F)', 'RH (%)', 'Dewpt (F)', 'Wind Spd (mph)',
'Wind Direction (deg)', 'Peak Wind Gust(mph)', 'Low Cloud Ht (ft)',
'Med Cloud Ht (ft)', 'High Cloud Ht (ft)', 'Visibility (mi)', 'Atm
Press (hPa)', 'Sea Lev Press (hPa)', 'Altimeter (hPa)', 'Precip (in)',
'Wind Chill (F)', 'Heat Index (F)']
```

```
# Renaming
les.rename(columns={ "Temp (F)": "Temp_F", "RH (%)": "RH_pct",
                    "Dewpt (F)" : "Dewpt_F", "Wind Spd (mph)" :
"Wind_Spd_mph",
                    "Wind Direction (deg)" : "Wind_Direction_deg",
"Peak Wind Gust(mph)" : "Peak_Wind_Gust_mph",
                    "Low Cloud Ht (ft)" : "Low_Cloud_Ht_ft", "Med Cloud
Ht (ft)" : "Med_Cloud_Ht_ft",
                    "High Cloud Ht (ft)" : "High_Cloud_Ht_ft",
"Visibility (mi)" : "Visibility_mi",
                    "Atm Press (hPa)" : "Atm_Press_hPa", "Sea Lev Press
(hPa)" : "Sea_Lev_Press_hPa",
                    "Altimeter (hPa)" : "Altimeter_hPa", "Precip
(in)" : "Precip_in",
                    "Wind Chill (F)" : "Wind_Chill_F", "Heat Index (F)"
: "Heat_Index_F",
                    } , inplace = True)

les.head()
```

```
     Date_UTC Time_UTC    Date_CST Time_CST  \
0  2006-10-01    00:00  2006-09-30    00:00
1  2006-10-01    01:00  2006-09-30    01:00
2  2006-10-01    02:00  2006-09-30    02:00
3  2006-10-01    03:00  2006-09-30    03:00
4  2006-10-01    04:00  2006-09-30    04:00

                       File_name_for_1D_lake  \
0  goes11.2006.10.01.0000.v01.nc-var1-t0.csv
1  goes11.2006.10.01.0100.v01.nc-var1-t0.csv
2  goes11.2006.10.01.0200.v01.nc-var1-t0.csv
3  goes11.2006.10.01.0300.v01.nc-var1-t0.csv
4  goes11.2006.10.01.0400.v01.nc-var1-t0.csv

                                File_name_for_2D_lake  \
0  T_goes11.2006.10.01.0000.v01.nc-var1-t0.csv.csv
1  T_goes11.2006.10.01.0100.v01.nc-var1-t0.csv.csv
```

```
2  T_goes11.2006.10.01.0200.v01.nc-var1-t0.csv.csv
3  T_goes11.2006.10.01.0300.v01.nc-var1-t0.csv.csv
4  T_goes11.2006.10.01.0400.v01.nc-var1-t0.csv.csv

                                          Lake_data_1D  \
0  [0.0075, 0.0025, 0.0, 0.005, 0.0, 0.005, nan, ...
1  [0.0025, nan, 0.0025, 0.0025, nan, 0.0, nan, 0...
2  [0.0, nan, 0.0075, nan, nan, 0.0025, nan, nan,...
3  [0.0025, nan, 0.0025, 0.0, 0.0075, nan, 0.005,...
4  [0.0025, nan, 0.0, nan, 0.0075, 0.0, nan, nan,...

                                          Lake_data_2D Temp_F
RH_pct  ...  \
0  [array([   nan,    nan,    nan,    nan,    nan...     48
86  ...
1  [array([   nan,    nan,    nan,    nan,    nan...     48
86  ...
2  [array([nan, nan, nan, nan, nan, nan, nan, nan...     48
86  ...
3  [array([nan, nan, nan, nan, nan, nan, nan, nan...     48
86  ...
4  [array([   nan,    nan,    nan,    nan,    nan...     48
89  ...

  Low_Cloud_Ht_ft Med_Cloud_Ht_ft High_Cloud_Ht_ft Visibility_mi  \
0            4100            4800             7000            10
1            6000               m                m            10
2            5500           11000                m            10
3            6000               m                m            10
4            2200            3500                m             8

  Atm_Press_hPa Sea_Lev_Press_hPa Altimeter_hPa Precip_in Wind_Chill_F
\
0         984.0           1007.00       1006.80      0.00           45

1         983.7           1006.50       1006.40      0.00           44

2         982.7           1005.70       1005.40      0.00           45

3         982.0           1005.10       1004.70      0.00           44

4         982.0           1004.90       1004.70      0.02           46


  Heat_Index_F
0           NC
1           NC
2           NC
3           NC
4           NC
```

```
[5 rows x 24 columns]
```

Missing value handling in dataframe

- As per the abbr in the table:
  - `m` or `M`: Data is missing
  - `NC`: Wind Chill/Heat Index do not meet the required thresholds to be calculated

Replace the missing values with 0.

```
# Replace with 0
les = les.replace(['m', 'M'], '0')
```

Drop **Wind_Chill_F** and **Heat_Index_F** due to a large number of NC values

```
les = les.drop(['Wind_Chill_F', 'Heat_Index_F'], axis=1)
les = les.reset_index(drop=True)

def missing_values(df):
    total_null = df.isna().sum()
    percent_null = total_null / df.count() # Total count of null
values / Total count of values
    missing_data = pd.concat([total_null, percent_null], axis = 1,
keys = ['Total Null', 'Percentage Null'])
    return missing_data

missing_values(les)
```

```
                        Total Null  Percentage Null
Date_UTC                         0         0.000000
Time_UTC                         0         0.000000
Date_CST                         0         0.000000
Time_CST                         0         0.000000
File_name_for_1D_lake            0         0.000000
File_name_for_2D_lake            0         0.000000
Lake_data_1D                     0         0.000000
Lake_data_2D                     0         0.000000
Temp_F                         239         0.004991
RH_pct                         239         0.004991
Dewpt_F                        239         0.004991
Wind_Spd_mph                   239         0.004991
Wind_Direction_deg             239         0.004991
Peak_Wind_Gust_mph             239         0.004991
Low_Cloud_Ht_ft                239         0.004991
Med_Cloud_Ht_ft                239         0.004991
High_Cloud_Ht_ft               239         0.004991
Visibility_mi                  239         0.004991
Atm_Press_hPa                  239         0.004991
Sea_Lev_Press_hPa              239         0.004991
```

```
Altimeter_hPa                239          0.004991
Precip_in                    239          0.004991
```

Dropping null values:

```
les = les.dropna()
print('Total observation count after missing value treatment: ',
len(les))

Total observation count after missing value treatment:  47882
```

> **Note to self**: Next run, replace NA with 0 because we may actually have erased too many records by dropping NAs...

Changing Datatype

```
les.info()

<class 'pandas.core.frame.DataFrame'>
Int64Index: 47882 entries, 0 to 48120
Data columns (total 22 columns):
 #   Column                 Non-Null Count  Dtype
---  ------                 --------------  -----
 0   Date_UTC               47882 non-null  object
 1   Time_UTC               47882 non-null  object
 2   Date_CST               47882 non-null  object
 3   Time_CST               47882 non-null  object
 4   File_name_for_1D_lake  47882 non-null  object
 5   File_name_for_2D_lake  47882 non-null  object
 6   Lake_data_1D           47882 non-null  object
 7   Lake_data_2D           47882 non-null  object
 8   Temp_F                 47882 non-null  object
 9   RH_pct                 47882 non-null  object
 10  Dewpt_F                47882 non-null  object
 11  Wind_Spd_mph           47882 non-null  object
 12  Wind_Direction_deg     47882 non-null  object
 13  Peak_Wind_Gust_mph     47882 non-null  object
 14  Low_Cloud_Ht_ft        47882 non-null  object
 15  Med_Cloud_Ht_ft        47882 non-null  object
 16  High_Cloud_Ht_ft       47882 non-null  object
 17  Visibility_mi          47882 non-null  object
 18  Atm_Press_hPa          47882 non-null  object
 19  Sea_Lev_Press_hPa      47882 non-null  object
 20  Altimeter_hPa          47882 non-null  object
 21  Precip_in              47882 non-null  object
dtypes: object(22)
memory usage: 8.4+ MB

# Using apply method
columns = les.columns
```

```
les[columns[8:]] = les[columns[8:]].apply(pd.to_numeric,
errors='coerce')

les.info()
```

```
<class 'pandas.core.frame.DataFrame'>
Int64Index: 47882 entries, 0 to 48120
Data columns (total 22 columns):
 #   Column                 Non-Null Count  Dtype
---  ------                 --------------  -----
 0   Date_UTC               47882 non-null  object
 1   Time_UTC               47882 non-null  object
 2   Date_CST               47882 non-null  object
 3   Time_CST               47882 non-null  object
 4   File_name_for_1D_lake  47882 non-null  object
 5   File_name_for_2D_lake  47882 non-null  object
 6   Lake_data_1D           47882 non-null  object
 7   Lake_data_2D           47882 non-null  object
 8   Temp_F                 47882 non-null  float64
 9   RH_pct                 47882 non-null  float64
 10  Dewpt_F                47882 non-null  float64
 11  Wind_Spd_mph           47882 non-null  int64
 12  Wind_Direction_deg     47882 non-null  int64
 13  Peak_Wind_Gust_mph     47882 non-null  int64
 14  Low_Cloud_Ht_ft        47882 non-null  int64
 15  Med_Cloud_Ht_ft        47882 non-null  int64
 16  High_Cloud_Ht_ft       47882 non-null  int64
 17  Visibility_mi          47882 non-null  int64
 18  Atm_Press_hPa          47882 non-null  float64
 19  Sea_Lev_Press_hPa      47882 non-null  float64
 20  Altimeter_hPa          47882 non-null  float64
 21  Precip_in              47882 non-null  float64
dtypes: float64(7), int64(7), object(8)
memory usage: 8.4+ MB
```

Dropping data for the night-time

We focus on data from **14:00 UTC to 21:00 UTC**, when there is enough sunlight to generate reflections and capture useful information. This time window provides valid data for the experiment and can be used to extract important insights from Lake Michigan and its surrounding areas.

`14:00 UTC is 10:00am EST and 21:00 UTC is 5:00pm EST.`

```
filtered_les = les.loc[(les['Time_UTC'] >= '14:00')
                       & (les['Time_UTC'] <= '21:00')]
filtered_les
```

```
         Date_UTC Time_UTC    Date_CST Time_CST  \
14     2006-10-01    14:00  2006-10-01    14:00
```

```
15     2006-10-01    15:00  2006-10-01    15:00
16     2006-10-01    16:00  2006-10-01    16:00
17     2006-10-01    17:00  2006-10-01    17:00
18     2006-10-01    18:00  2006-10-01    18:00
...           ...      ...         ...      ...
48114  2015-03-31    17:00  2015-03-31    17:00
48115  2015-03-31    18:00  2015-03-31    18:00
48116  2015-03-31    19:00  2015-03-31    19:00
48117  2015-03-31    20:00  2015-03-31    20:00
48118  2015-03-31    21:00  2015-03-31    21:00

                            File_name_for_1D_lake  \
14     goes11.2006.10.01.1400.v01.nc-var1-t0.csv
15     goes11.2006.10.01.1500.v01.nc-var1-t0.csv
16     goes11.2006.10.01.1600.v01.nc-var1-t0.csv
17     goes11.2006.10.01.1700.v01.nc-var1-t0.csv
18     goes11.2006.10.01.1800.v01.nc-var1-t0.csv
...                                          ...
48114  goes15.2015.03.31.1700.v01.nc-var1-t0.csv
48115  goes15.2015.03.31.1800.v01.nc-var1-t0.csv
48116  goes15.2015.03.31.1900.v01.nc-var1-t0.csv
48117  goes15.2015.03.31.2000.v01.nc-var1-t0.csv
48118  goes15.2015.03.31.2100.v01.nc-var1-t0.csv

                                  File_name_for_2D_lake  \
14     T_goes11.2006.10.01.1400.v01.nc-var1-t0.csv.csv
15     T_goes11.2006.10.01.1500.v01.nc-var1-t0.csv.csv
16     T_goes11.2006.10.01.1600.v01.nc-var1-t0.csv.csv
17     T_goes11.2006.10.01.1700.v01.nc-var1-t0.csv.csv
18     T_goes11.2006.10.01.1800.v01.nc-var1-t0.csv.csv
...                                                ...
48114  T_goes15.2015.03.31.1700.v01.nc-var1-t0.csv.csv
48115  T_goes15.2015.03.31.1800.v01.nc-var1-t0.csv.csv
48116  T_goes15.2015.03.31.1900.v01.nc-var1-t0.csv.csv
48117  T_goes15.2015.03.31.2000.v01.nc-var1-t0.csv.csv
48118  T_goes15.2015.03.31.2100.v01.nc-var1-t0.csv.csv

                                             Lake_data_1D  \
14     [0.067499995, 0.07, 0.0625, 0.06, 0.0725, 0.06...
15     [0.067499995, 0.067499995, 0.06, 0.06, 0.05749...
16     [0.0725, 0.067499995, 0.07, 0.07, 0.067499995,...
17     [0.067499995, 0.067499995, 0.067499995, 0.07, ...
18     [0.085, 0.085, 0.0875, 0.0725, 0.0775, 0.0775,...
...                                                  ...
48114  [0.225, 0.22749999, 0.48, 0.3075, 0.1925, 0.24...
48115  [0.2075, 0.1925, 0.18249999, 0.1625, 0.1725, 0...
48116  [0.22, 0.1925, 0.1775, 0.16749999, 0.16499999,...
48117  [0.2575, 0.22, 0.21249999, 0.17999999, 0.185, ...
48118  [0.2225, 0.18249999, 0.19, 0.17999999, 0.1725,...
```

```
                                                Lake_data_2D  Temp_F
RH_pct  ...  \
14     [array([       nan,        nan,        nan,   ...    60.0
49.0  ...
15     [array([       nan,        nan,        nan,   ...    60.0
47.0  ...
16     [array([   nan,    nan,    nan,    nan,    nan...    59.0
55.0  ...
17     [array([ nan,  nan,  nan,  nan,  nan,  nan,  n...    55.0
71.0  ...
18     [array([   nan,    nan,    nan,    nan,    nan...    50.0
82.0  ...
...                                                  ...     ...     .
..  ...
48114  [array([   nan,    nan,    nan,    nan,    nan...    39.0
54.0  ...
48115  [array([   nan,    nan,    nan,    nan,    nan...    37.0
61.0  ...
48116  [array([       nan,        nan,        nan,   ...    37.0
66.0  ...
48117  [array([   nan,    nan,    nan,    nan,    nan...    36.0
85.0  ...
48118  [array([ nan,  nan,  nan,  nan,  nan,  nan,  n...    36.0
85.0  ...

       Wind_Direction_deg  Peak_Wind_Gust_mph  Low_Cloud_Ht_ft  \
14                    270                   0             3600
15                      0                   0                0
16                     40                   0                0
17                      0                   0                0
18                      0                   0             8000
...                   ...                 ...              ...
48114                  20                   0             7000
48115                 330                   0             5500
48116                 310                  18             3500
48117                   0                   0             2100
48118                   0                   0             4600

       Med_Cloud_Ht_ft  High_Cloud_Ht_ft  Visibility_mi  Atm_Press_hPa
\
14                   0                 0             10          994.7

15                   0                 0             10          994.7

16                   0                 0             10          994.7

17                   0                 0             10          994.7

18                   0                 0             10          994.7
```

```
...                 ...                 ...             ...             ...

48114             10000                   0              10           989.0

48115              7000                   0              10           989.3

48116              5500                   0              10           990.7

48117              2900                5000              10           991.0

48118                 0                   0              10           991.7


       Sea_Lev_Press_hPa  Altimeter_hPa  Precip_in
14                1017.8         1017.6        0.0
15                1017.7         1017.6        0.0
16                1017.8         1017.6        0.0
17                1017.8         1017.6        0.0
18                1017.9         1017.6        0.0
...                  ...            ...        ...
48114             1012.6         1011.9        0.0
48115             1012.8         1012.2        0.0
48116             1014.1         1013.5        0.0
48117             1014.6         1013.9        0.0
48118             1015.0         1014.6        0.0

[15959 rows x 22 columns]
```

```
filtered_les = filtered_les.reset_index(drop=True)
filtered_les.head()
```

```
     Date_UTC Time_UTC    Date_CST Time_CST  \
0  2006-10-01    14:00  2006-10-01    14:00
1  2006-10-01    15:00  2006-10-01    15:00
2  2006-10-01    16:00  2006-10-01    16:00
3  2006-10-01    17:00  2006-10-01    17:00
4  2006-10-01    18:00  2006-10-01    18:00

                       File_name_for_1D_lake  \
0  goes11.2006.10.01.1400.v01.nc-var1-t0.csv
1  goes11.2006.10.01.1500.v01.nc-var1-t0.csv
2  goes11.2006.10.01.1600.v01.nc-var1-t0.csv
3  goes11.2006.10.01.1700.v01.nc-var1-t0.csv
4  goes11.2006.10.01.1800.v01.nc-var1-t0.csv

                              File_name_for_2D_lake  \
0  T_goes11.2006.10.01.1400.v01.nc-var1-t0.csv.csv
1  T_goes11.2006.10.01.1500.v01.nc-var1-t0.csv.csv
2  T_goes11.2006.10.01.1600.v01.nc-var1-t0.csv.csv
3  T_goes11.2006.10.01.1700.v01.nc-var1-t0.csv.csv
4  T_goes11.2006.10.01.1800.v01.nc-var1-t0.csv.csv
```

```
                                          Lake_data_1D  \
0  [0.067499995, 0.07, 0.0625, 0.06, 0.0725, 0.06...
1  [0.067499995, 0.067499995, 0.06, 0.06, 0.05749...
2  [0.0725, 0.067499995, 0.07, 0.07, 0.067499995,...
3  [0.067499995, 0.067499995, 0.067499995, 0.07, ...
4  [0.085, 0.085, 0.0875, 0.0725, 0.0775, 0.0775,...

                                          Lake_data_2D  Temp_F
RH_pct  ...  \
0  [array([       nan,        nan,        nan,   ...    60.0
49.0  ...
1  [array([       nan,        nan,        nan,   ...    60.0
47.0  ...
2  [array([   nan,    nan,    nan,    nan,    nan...    59.0
55.0  ...
3  [array([ nan,  nan,  nan,  nan,  nan,  nan,  n...    55.0
71.0  ...
4  [array([   nan,    nan,    nan,    nan,    nan...    50.0
82.0  ...

   Wind_Direction_deg  Peak_Wind_Gust_mph  Low_Cloud_Ht_ft
Med_Cloud_Ht_ft  \
0                 270                   0             3600
0
1                   0                   0                0
0
2                  40                   0                0
0
3                   0                   0                0
0
4                   0                   0             8000
0

   High_Cloud_Ht_ft  Visibility_mi  Atm_Press_hPa
Sea_Lev_Press_hPa  \
0                 0             10          994.7              1017.8

1                 0             10          994.7              1017.7

2                 0             10          994.7              1017.8

3                 0             10          994.7              1017.8

4                 0             10          994.7              1017.9


   Altimeter_hPa  Precip_in
0         1017.6        0.0
1         1017.6        0.0
```

```
2          1017.6         0.0
3          1017.6         0.0
4          1017.6         0.0

[5 rows x 22 columns]
```

```
# Summary
filtered_les.describe()
```

```
              Temp_F        RH_pct       Dewpt_F  Wind_Spd_mph  \
count  15959.000000  15959.000000  15959.000000  15959.000000
mean      34.931261     68.740335     25.234351      7.137039
std       14.344283     14.927241     13.538403      5.093937
min      -15.000000      0.000000    -20.000000      0.000000
25%       25.000000     59.000000     16.000000      3.000000
50%       34.000000     70.000000     25.000000      7.000000
75%       44.000000     80.000000     34.000000     10.000000
max       88.000000    100.000000     66.000000     34.000000

       Wind_Direction_deg  Peak_Wind_Gust_mph  Low_Cloud_Ht_ft  \
count        15959.000000        15959.000000     15959.000000
mean           158.714832            4.500971      4563.800363
std            128.081797            9.510925      5747.505620
min              0.000000            0.000000         0.000000
25%              0.000000            0.000000      1500.000000
50%            190.000000            0.000000      2700.000000
75%            270.000000            0.000000      4500.000000
max            360.000000           52.000000     28000.000000

       Med_Cloud_Ht_ft  High_Cloud_Ht_ft  Visibility_mi  Atm_Press_hPa
\
count     15959.000000      15959.000000   15959.000000   15959.000000

mean       3457.098816       1033.362993       8.174698     990.931687

std        6318.061684       3981.234855       3.033164      41.719389

min           0.000000          0.000000       0.000000       0.000000

25%           0.000000          0.000000       7.000000     987.000000

50%           0.000000          0.000000      10.000000     993.300000

75%        4000.000000          0.000000      10.000000     999.000000

max       25000.000000      26000.000000      10.000000    1018.900000


       Sea_Lev_Press_hPa  Altimeter_hPa     Precip_in
count       15959.000000   15959.000000  15959.000000
mean          960.019663    1014.892355      0.002377
```

```
std           232.924553      26.926521      0.016545
min             0.000000       0.000000      0.000000
25%          1009.500000    1009.800000      0.000000
50%          1016.400000    1016.300000      0.000000
75%          1022.500000    1022.000000      0.000000
max          1043.600000    1042.300000      0.860000
```

```
print('Total observations: ', filtered_les.shape[0])
print('Total number of features: ', filtered_les.shape[1])
```

```
Total observations:  15959
Total number of features:  22
```

```
data_sample = les['Lake_data_1D'][16]
data_sample
```

```
'[0.0725, 0.067499995, 0.07, 0.07, 0.067499995, 0.067499995, 0.065,
0.067499995, 0.07, 0.0625, 0.0625, 0.06, 0.0625, 0.055, 0.067499995,
0.055, 0.065, 0.07, 0.065, 0.0725, 0.0775, 0.0625, 0.067499995,
0.0625, 0.065, 0.067499995, 0.0625, 0.0625, 0.06, 0.0625, 0.0625,
0.065, 0.06, 0.06, 0.0625, 0.0625, 0.067499995, 0.067499995,
0.067499995, 0.067499995, 0.0775, 0.074999996, 0.067499995, 0.065,
0.049999997, 0.049999997, 0.067499995, 0.067499995, 0.055, 0.055,
0.0725, 0.067499995, 0.065, 0.0625, 0.065, 0.0625, 0.065, 0.057499997,
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0.067499995, 0.057499997, 0.065, 0.0625, 0.0625, 0.06, 0.067499995,
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0.095, 0.099999994, 0.107499994, 0.1175, 0.12, 0.122499995,
0.18249999, 0.22749999, 0.21499999]'
```

Cloud Imagery

```
def arrays_2_png(lat, lon, val, fig_name):
    status_code = -1
    # Here it starts
    if len(lat) == len(lon) == len(val):
        plt.figure(figsize=(10, 10))
        plt.scatter(lon, lat, c=val, cmap=cm.gray, marker='s')
        plt.colorbar(orientation='vertical')
        plt.savefig('D:/user/docs/NU/_Noctis/lake-michigan-images/' +
fig_name + '.png')
        status_code = 0
    else:
        status_code = 255

    return status_code

df_lat_lon = df_lat_lon = pd.read_csv(
    r'D:\user\docs\NU\_Noctis\data\
lat_long_1D_labels_for_plotting.csv')
df_lat_lon.head(5)
```

```
   latitude  longitude
0     41.78     -87.54
1     41.78     -87.50
2     41.78     -87.46
3     41.78     -87.42
4     41.78     -87.38
```

```
df_lat_lon.shape
```

```
(3599, 2)
```

```
lat_lst = df_lat_lon['latitude'].to_list()
lon_lst = df_lat_lon['longitude'].to_list()

data_sample = filtered_les['Lake_data_1D'][16]
data_sample
```

```
'[0.1575, 0.1375, 0.13, 0.1325, 0.1325, 0.1275, 0.13, 0.1275,
0.13499999, 0.1275, 0.1525, 0.22, 0.19749999, 0.155, 0.1375, 0.1525,
0.1425, 0.1475, 0.16, 0.13499999, 0.1325, 0.125, 0.114999995, 0.1275,
0.125, 0.145, 0.1425, 0.1325, 0.16499999, 0.1925, 0.19749999, 0.17,
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0.1475, 0.14, 0.1275, 0.114999995, 0.114999995, 0.122499995, 0.1325,
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0.225, 0.235, 0.16749999, 0.1525, 0.16499999, 0.16, 0.1475, 0.155,
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0.19749999, 0.19749999, 0.1875, 0.1875, 0.17999999, 0.1425, 0.1275,
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0.19749999, 0.21499999, 0.26999998, 0.255, 0.21499999, 0.185, 0.1875,
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0.24249999, 0.255, 0.22999999, 0.1775, 0.16499999, 0.16, 0.1575,
0.19999999, 0.19749999, 0.1475, 0.1425, 0.145, 0.1725, 0.225, 0.22,
0.1875, 0.2025, 0.225, 0.225, 0.21499999, 0.1925, 0.185, 0.1925,
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0.22999999, 0.22749999, 0.19749999, 0.19749999, 0.17999999, 0.175,
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0.155, 0.17, 0.1525, 0.14, 0.1525, 0.145, 0.1425, 0.1525, 0.1525,
0.1575, 0.1525, 0.16499999, 0.1425, 0.2225, 0.21499999, 0.22, 0.2075,
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0.1475, 0.1375, 0.14, 0.1325, 0.145, 0.145, 0.1625, 0.1525, 0.145,
0.17, 0.1475, 0.1375, 0.1475, 0.2075, 0.1725, 0.16499999, 0.16,
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0.30249998, 0.29999998, 0.295, 0.29999998, 0.285, 0.2525, 0.21499999,
0.175, 0.175, 0.185, 0.1625, 0.1575, 0.1525, 0.1475, 0.1475, 0.1475,
0.1525, 0.1525, 0.1375, 0.1425, 0.16, 0.1475, 0.14999999, 0.14999999,
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0.275, 0.28, 0.26749998, 0.24, 0.2075, 0.18249999, 0.2325, 0.2375,
0.25, 0.1875, 0.21249999, 0.1925, 0.2725, 0.2875, 0.29, 0.29, 0.2875,
0.18249999, 0.1725, 0.17, 0.185, 0.2325, 0.24249999, 0.24, 0.22,
0.19999999, 0.24749999, 0.2775, 0.21499999, 0.19999999, 0.2575, 0.175,
0.17999999, 0.265, 0.285, 0.30249998, 0.2925, 0.275, 0.22, 0.225,
0.2725, 0.2575, 0.26749998, 0.285, 0.26999998, 0.265, 0.22999999,
0.25, 0.295, 0.3125, 0.31, 0.1925, 0.265, 0.26749998, 0.2825,
0.26749998, 0.28, 0.275, 0.235, 0.1875, 0.16499999, 0.16, 0.155,
0.16499999, 0.19999999, 0.29999998, 0.30249998, 0.30249998, 0.295,
0.285, 0.2825, 0.3075, 0.30249998, 0.295, 0.2925, 0.2825, 0.255, 0.22,
0.19999999, 0.2775, 0.29]'
```

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data_sample2
```

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nan,  nan,  nan,  nan,  nan,  nan,  nan,  nan,  nan,\n        nan,
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nan,        nan,        nan,\n              nan,        nan,
nan,        nan,        nan,\n              nan,        nan,
nan,        nan,        nan,\n              nan,        nan,
nan,        nan,        nan,\n              nan,        nan,
nan,        nan,        nan,\n       0.29      , 0.29749998,
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, 0.415     , 0.39999998,\n             nan,        nan,        nan,
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nan,        nan,        nan,        nan,\n             nan,
nan,        nan,        nan,        nan,\n             nan,
nan,        nan,        nan,        nan,\n             nan,
nan,        nan,        nan,        nan,\n             nan,
nan,        nan,        nan,        nan,\n             nan,
nan,        nan,        nan,        nan,\n             nan,
nan,        nan,        nan,        nan,\n             nan,
nan,        nan,        nan,        nan,\n             nan,
nan,        nan,        nan,        nan,\n             nan,
nan,        nan,        nan,        nan,\n             nan,
nan,        nan,        nan,        nan,\n             nan,
nan,        nan,        nan,        nan,\n             nan,
nan,        nan,        nan,        nan,\n             nan,
nan,        nan, 0.17999999, 0.1725    ,\n       0.19749999, 0.1925
, 0.24249999, 0.21249999, 0.1625    ,\n       0.1525    , 0.1475    ,
0.145     , 0.1375    , 0.145     ,\n       0.1475    , 0.155     ,
0.2325    , 0.2575    , 0.30249998]), array([       nan,        nan,
nan,        nan,        nan,\n             nan,        nan,
nan,        nan,        nan,\n             nan,        nan,
nan,        nan,        nan,\n             nan,        nan,
nan,        nan,        nan,\n             nan,        nan,
nan,        nan,        nan,\n             nan,        nan,
nan,        nan,        nan,\n             nan,        nan,
nan,        nan,        nan,\n             nan,        nan,
nan,        nan,        nan,\n             nan,        nan,
nan,        nan,        nan,\n             nan,        nan,
nan,        nan,        nan,\n             nan,        nan,
nan,        nan,        nan,\n             nan,        nan,
nan,        nan,        nan,\n             nan,        nan,
nan,        nan,        nan,\n             nan,        nan,
nan,        nan,        nan,\n             nan,        nan,
nan,        nan,        nan,\n             nan,        nan,
nan,        nan,        nan,\n             nan,        nan,
nan,        nan,        nan,\n             nan,        nan,
nan, 0.2025    , 0.19999999,\n       0.155     , 0.17      ,
0.24749999, 0.24      , 0.1625    ,\n       0.1575    , 0.1425    ,
0.1625    , 0.1425    , 0.1425    ,\n       0.145     , 0.16499999,
0.2375    , 0.26749998, 0.295     ]), array([       nan,        nan,
nan,        nan,        nan,\n             nan,        nan,
nan,        nan,        nan,\n             nan,        nan,
nan,        nan,        nan,\n             nan,        nan,
nan,        nan,        nan,\n             nan,        nan,
nan,        nan,        nan,\n             nan,        nan,
nan,        nan,        nan,\n             nan,        nan,
nan,        nan,        nan,\n             nan,        nan,
nan,        nan,        nan,\n             nan,        nan,
```

```
nan,        nan,        nan,\n             nan,        nan,
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nan,        nan,        nan,\n             nan,        nan,
nan,        nan,        nan,\n             nan,        nan,
nan,        nan,        nan,\n             nan,        nan,
nan,        nan, 0.22999999,\n       0.16499999, 0.155     ,
0.24249999, 0.285     , 0.17      ,\n       0.1525    , 0.1475    ,
0.1525    , 0.16      , 0.16499999,\n       0.1525    , 0.1725    ,
0.25      , 0.285     , 0.2925    ]), array([       nan,        nan,
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nan,        nan,        nan,\n             nan,        nan,
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nan,        nan,        nan,\n             nan,        nan,
nan,        nan,        nan,\n             nan,        nan,
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0.19999999, 0.225     , 0.16749999,\n       0.16499999, 0.1525    ,
0.145     , 0.1475    , 0.1625    ,\n       0.1475    , 0.17999999,
0.1875    , 0.26999998, 0.2825    ]), array([       nan,        nan,
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nan,        nan,        nan,\n             nan,        nan,
nan,        nan,        nan,\n             nan,        nan,
nan,        nan,        nan,\n             nan,        nan,
nan,        nan,        nan,\n             nan,        nan,
nan,        nan,        nan,\n             nan,        nan,
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nan,        nan,        nan,\n             nan,        nan,
nan,        nan,        nan,\n             nan,        nan,
nan,        nan,        nan,\n             nan,        nan,
```

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nan,        nan,        nan,\n              nan,        nan,
nan,        nan,        nan,\n       0.16499999, 0.17       ,
0.21249999, 0.2175    , 0.155     ,\n       0.1425    , 0.1375    ,
0.17      , 0.14999999, 0.16      ,\n       0.17      , 0.19749999,
0.21249999, 0.265     , 0.255     ]), array([       nan,        nan,
nan,        nan,        nan,\n              nan,        nan,
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nan,        nan,        nan,\n              nan,        nan,
nan,        nan,        nan,\n              nan,        nan,
nan,        nan,        nan,\n              nan,        nan,
nan,        nan,        nan,\n              nan,        nan,
nan,        nan,        nan,\n              nan,        nan,
nan,        nan,        nan,\n              nan,        nan,
nan,        nan,        nan,\n              nan,        nan,
nan,        nan,        nan,\n              nan,        nan,
nan,        nan,        nan,\n              nan,        nan,
nan,        nan,        nan,\n              nan,        nan,
nan,        nan,        nan,\n              nan,        nan,
nan,        nan,        nan,\n              nan,        nan,
nan,        nan,        nan,\n       0.17      , 0.1925    ,
nan,        nan,        nan,\n              nan, 0.14      , 0.1475
, 0.14999999, 0.14999999,\n       0.17      , 0.175     , 0.1925    ,
0.22999999, 0.22      ]), array([       nan,        nan,        nan,
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nan,        nan,\n              nan,        nan,        nan,
nan,        nan,\n              nan,        nan,        nan,
nan,        nan,\n              nan,        nan,        nan,
nan,        nan,\n              nan,        nan,        nan,
nan,        nan,\n              nan,        nan,        nan,
nan,        nan,\n              nan,        nan,        nan,
nan,        nan,\n              nan,        nan,        nan,
nan,        nan,\n              nan,        nan,        nan,
nan,        nan,\n              nan,        nan,        nan,
nan,        nan,\n              nan,        nan,        nan,
nan,        nan,\n              nan,        nan,        nan,
nan,        nan,\n       0.185     ,        nan,        nan,
nan,        nan,\n              nan, 0.14999999, 0.1375    , 0.16
,        nan,\n       0.17999999, 0.24499999, 0.2725    , 0.25      ,
0.19999999]), array([   nan,    nan,    nan,    nan,    nan,    nan,
nan,    nan,\n          nan,    nan,    nan,    nan,    nan,    nan,
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nan,    nan,\n          nan,    nan,    nan,    nan,    nan,    nan,
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nan,    nan,\n          nan,    nan,    nan,    nan,    nan,    nan,
nan,    nan,\n          nan,    nan,    nan,    nan,    nan,    nan,
nan,    nan,\n          nan,    nan,    nan,    nan,    nan,    nan,
nan,    nan,\n          nan,    nan,    nan,    nan,    nan,    nan,
nan,    nan,\n          nan,    nan,    nan,    nan,    nan,    nan,
nan,    nan,\n          nan,    nan,    nan,    nan,    nan,    nan,
nan,    nan,\n          nan,    nan,    nan,    nan,    nan,    nan,
nan,    nan,\n          nan,    nan, 0.22  ,    nan,    nan,    nan,
nan,    nan,\n          nan, 0.1475, 0.1425,    nan, 0.1775, 0.265 ,
0.2875, 0.295 ,\n       0.2775]), array([   nan,    nan,    nan,
nan,    nan,    nan,    nan,    nan,\n          nan,    nan,    nan,
nan,    nan,    nan,    nan,    nan,\n          nan,    nan,    nan,
nan,    nan,    nan,    nan,    nan,\n          nan,    nan,    nan,
nan,    nan,    nan,    nan,    nan,\n          nan,    nan,    nan,
nan,    nan,    nan,    nan,    nan,\n          nan,    nan,    nan,
nan,    nan,    nan,    nan,    nan,\n          nan,    nan,    nan,
nan,    nan,    nan,    nan,    nan,\n          nan,    nan,    nan,
nan,    nan,    nan,    nan,    nan,\n          nan,    nan,    nan,
nan,    nan,    nan,    nan,    nan,\n          nan,    nan,    nan,
nan,    nan,    nan,    nan,    nan,\n          nan,    nan,    nan,
nan,    nan,    nan,    nan,    nan,\n          nan,    nan, 0.1925,
nan,    nan,    nan,    nan,    nan,\n          nan,    nan, 0.1475,
nan, 0.1775, 0.2575, 0.29  , 0.3125,\n       0.29  ]),
array([       nan,        nan,        nan,        nan,        nan,\n
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nan,        nan,        nan,        nan,        nan,\n
nan,        nan,        nan,        nan,        nan,\n
nan,        nan,        nan,        nan,        nan,\n
nan,        nan,        nan,        nan,        nan,\n
nan,        nan,        nan,        nan,        nan,\n
nan,        nan,        nan,        nan,        nan,\n
nan,        nan,        nan,        nan,        nan,\n
nan,        nan,        nan,        nan,        nan,\n
nan,        nan,        nan,        nan,        nan,\n
nan,        nan,        nan,        nan,        nan,\n
nan,        nan,        nan,        nan,        nan,\n
nan,        nan,        nan,        nan,        nan,\n
nan,        nan,        nan,        nan,        nan,\n
nan,        nan,        nan,        nan,        nan,\n
nan,        nan,        nan,        nan,        nan,\n
0.22999999,        nan,        nan,        nan,        nan,\n
nan,        nan,        nan,        nan,        nan,\n       0.19
, 0.2175    , 0.29      , 0.31      ,        nan]), array([   nan,
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nan,    nan,    nan,    nan,    nan,    nan,    nan,\n          nan,
nan,    nan,    nan,    nan,    nan,    nan,    nan,\n          nan,
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nan,    nan,    nan,    nan,    nan,    nan,    nan,\n          nan,
nan,    nan,    nan,    nan,    nan,    nan,    nan,\n          nan,
nan,    nan,    nan,    nan,    nan,    nan,    nan,\n          nan,
nan,    nan,    nan,    nan,    nan,    nan,    nan,\n          nan,
nan,    nan,    nan,    nan,    nan,    nan,    nan,\n          nan,
nan,    nan,    nan,    nan,    nan,    nan,    nan,\n          nan,
nan,    nan,    nan,    nan,    nan,    nan,    nan,\n          nan,
nan,    nan,    nan,    nan,    nan,    nan,    nan,\n          nan,
nan,    nan,    nan,    nan,    nan,    nan,    nan,\n          nan,
nan,    nan,    nan, 0.17  , 0.155 , 0.2875,    nan,\n          nan]),
array([       nan,        nan,        nan,        nan,        nan,\n
nan,        nan,        nan,        nan,        nan,\n
nan,        nan,        nan,        nan,        nan,\n
nan,        nan,        nan,        nan,        nan,\n
nan,        nan,        nan,        nan,        nan,\n
nan,        nan,        nan,        nan,        nan,\n
nan,        nan,        nan,        nan,        nan,\n
nan,        nan,        nan,        nan,        nan,\n
nan,        nan,        nan,        nan,        nan,\n
nan,        nan,        nan,        nan,        nan,\n
nan,        nan,        nan,        nan,        nan,\n
nan,        nan,        nan,        nan,        nan,\n
nan,        nan,        nan,        nan,        nan,\n
nan,        nan,        nan,        nan,        nan,\n
nan,        nan,        nan,        nan,        nan,\n
nan,        nan,        nan,        nan,        nan,\n
nan,        nan,        nan,        nan,        nan,\n
nan,        nan,        nan,        nan,        nan,\n
nan,        nan,        nan,        nan,        nan,\n
nan,        nan,        nan,        nan,        nan,\n       0.1775
, 0.16499999,        nan,        nan,        nan]), array([       nan,
nan,        nan,        nan,        nan,\n              nan,
nan,        nan,        nan,        nan,\n              nan,
nan,        nan,        nan,        nan,\n              nan,
nan,        nan,        nan,        nan,\n              nan,
nan,        nan,        nan,        nan,\n              nan,
nan,        nan,        nan,        nan,\n              nan,
nan,        nan,        nan,        nan,\n              nan,
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nan,        nan,        nan,        nan,\n              nan,
nan,        nan,        nan,        nan,\n              nan,
nan,        nan,        nan,        nan,\n              nan,
nan,        nan,        nan,        nan,\n              nan,
nan,        nan,        nan,        nan,\n              nan,
nan,        nan,        nan,        nan,\n              nan,
nan,        nan,        nan,        nan,\n              nan,
nan,        nan,        nan,        nan,\n              nan,
nan,        nan,        nan,        nan,\n              nan,
nan,        nan,        nan,        nan,\n              nan,
nan,        nan,        nan,        nan,\n              nan,
```

```
nan,        nan,        nan,        nan,\n       0.1575    ,
0.16499999,        nan,        nan,        nan]), array([   nan,
nan,    nan,    nan,    nan,    nan,    nan,    nan,\n           nan,
nan,    nan,    nan,    nan,    nan,    nan,    nan,\n           nan,
nan,    nan,    nan,    nan,    nan,    nan,    nan,\n           nan,
nan,    nan,    nan,    nan,    nan,    nan,    nan,\n           nan,
nan,    nan,    nan,    nan,    nan,    nan,    nan,\n           nan,
nan,    nan,    nan,    nan,    nan,    nan,    nan,\n           nan,
nan,    nan,    nan,    nan,    nan,    nan,    nan,\n           nan,
nan,    nan,    nan,    nan,    nan,    nan,    nan,\n           nan,
nan,    nan,    nan,    nan,    nan,    nan,    nan,\n           nan,
nan,    nan,    nan,    nan,    nan,    nan,    nan,\n           nan,
nan,    nan,    nan,    nan,    nan,    nan,    nan,\n           nan,
nan,    nan,    nan,    nan,    nan,    nan,    nan,\n           nan,
nan,    nan,    nan, 0.1625,    nan,    nan,    nan,\n
nan])]'
```

1D data conversion

```
import ast

data_sample_lst = ast.literal_eval(data_sample)
data_sample_lst[0:10]
```

```
[0.1575,
 0.1375,
 0.13,
 0.1325,
 0.1325,
 0.1275,
 0.13,
 0.1275,
 0.13499999,
 0.1275]
```

```
ldata_sample = data_sample.strip('][').split(', ')
ldata_sample[0:10]
```

```
['0.1575',
 '0.1375',
 '0.13',
 '0.1325',
 '0.1325',
 '0.1275',
 '0.13',
 '0.1275',
 '0.13499999',
 '0.1275']
```

```
data_sample_lst2 = [float(el) for el in ldata_sample]
data_sample_lst2[0:10]
```

```
[0.1575,
 0.1375,
 0.13,
 0.1325,
 0.1325,
 0.1275,
 0.13,
 0.1275,
 0.13499999,
 0.1275]
```

```
data_sample_lst2 = [float(el) for el in filtered_les['Lake_data_1D']
[16].strip('][').split(', ')]
data_sample_lst2[0:10]
```

```
[0.1575,
 0.1375,
 0.13,
 0.1325,
 0.1325,
 0.1275,
 0.13,
 0.1275,
 0.13499999,
 0.1275]
```

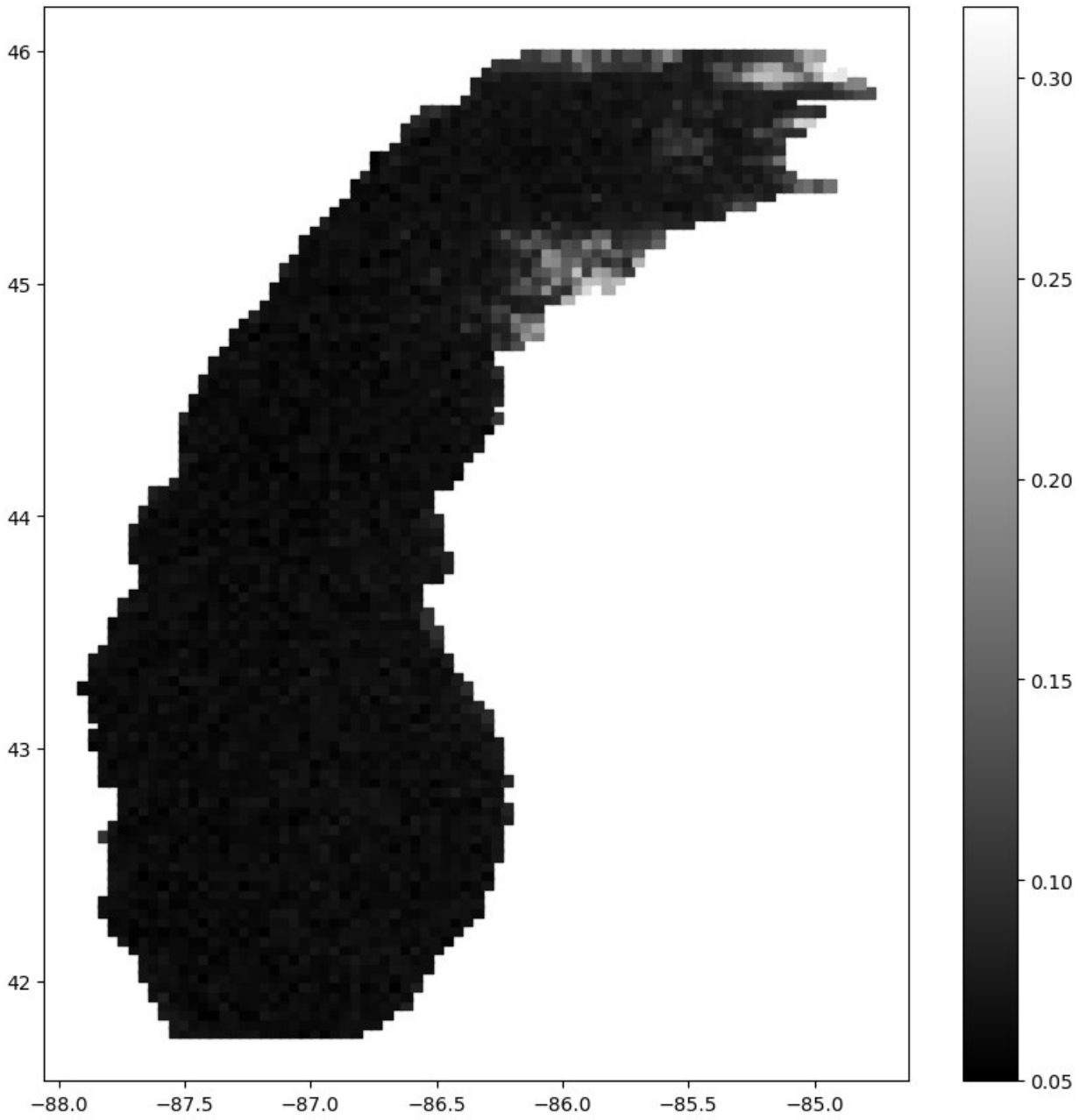
```
data_sample_lst == data_sample_lst2
```

```
True
```

Plotting 1D data

```
arrays_2_png(lat_lst, lon_lst, data_sample_lst, 'sample')
```

```
0
```



goes11.2008.11.03.1600

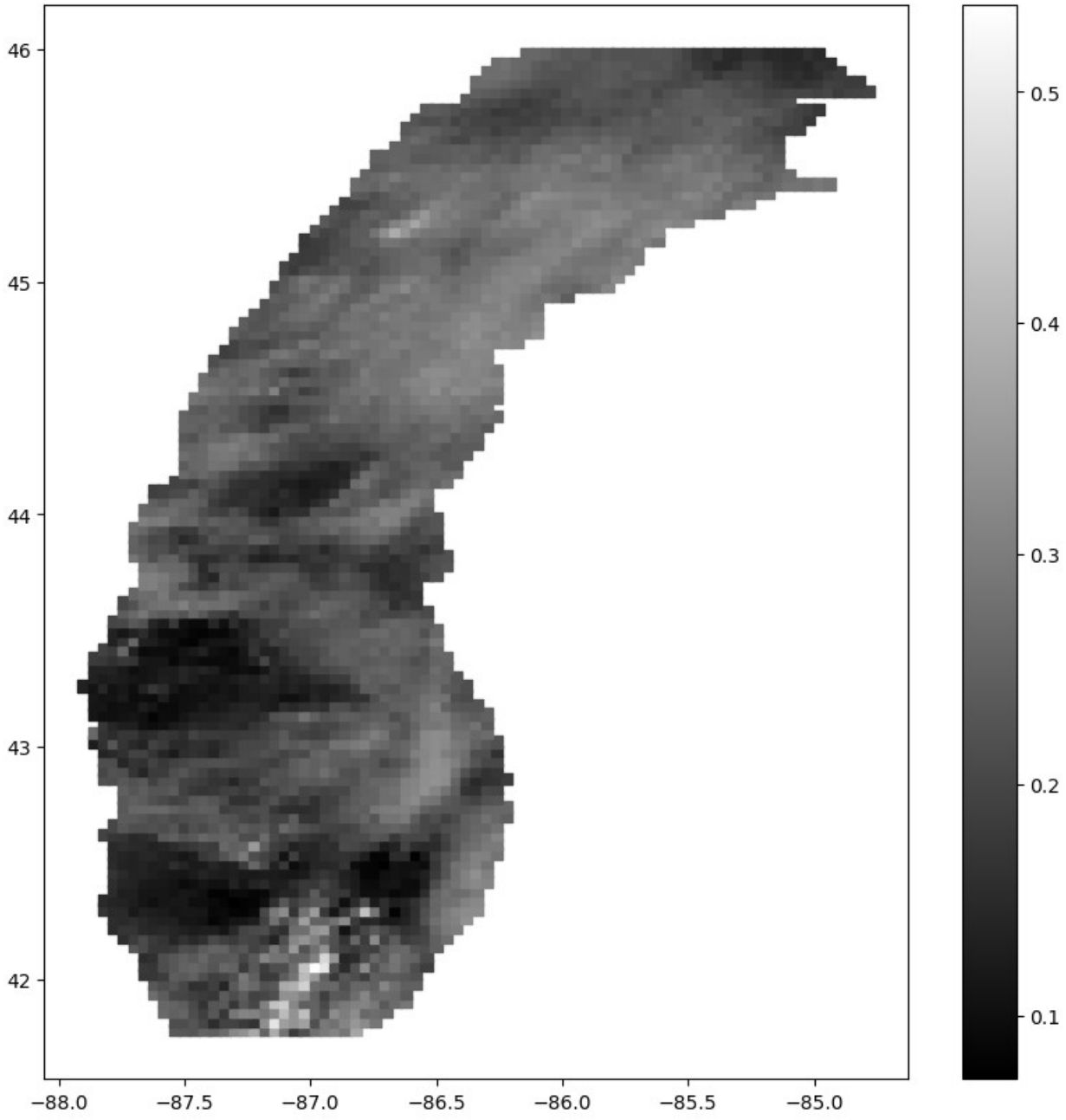
```
filtered_les.loc[5177]

Date_UTC                                                    2008-
01-10
Time_UTC
16:00
Date_CST                                                    2008-
01-10
```

```
Time_CST
16:00
File_name_for_1D_lake            goes11.2008.01.10.1600.v01.nc-var1-
t0.csv
File_name_for_2D_lake      T_goes11.2008.01.10.1600.v01.nc-var1-
t0.csv.csv
Lake_data_1D             [0.2375, 0.2325, 0.22749999, 0.255,
0.24749999...
Lake_data_2D             [array([       nan,        nan,        nan,
...
Temp_F
36.0
RH_pct
58.0
Dewpt_F
23.0
Wind_Spd_mph
8
Wind_Direction_deg
80
Peak_Wind_Gust_mph
0
Low_Cloud_Ht_ft
10000
Med_Cloud_Ht_ft
0
High_Cloud_Ht_ft
0
Visibility_mi
10
Atm_Press_hPa
986.0
Sea_Lev_Press_hPa
1009.6
Altimeter_hPa
1008.8
Precip_in
0.0
Name: 5177, dtype: object
```

```
arrays_2_png(lat_lst, lon_lst,
ast.literal_eval(filtered_les['Lake_data_1D'][5177]), 'sample')
```

```
0
```




```
les['Lake_data_1D'][5177].strip('][').split(', ')
```

```
['0.1025',
 '0.095',
 '0.095',
 '0.089999996',
 '0.082499996',
 '0.095',
 '0.0875',
 '0.082499996',
 '0.082499996',
```

```
'0.095',
'0.082499996',
'0.085',
'0.082499996',
'0.089999996',
'0.082499996',
'0.089999996',
'0.095',
'0.095',
'0.1025',
'0.1025',
'0.085',
'0.0875',
'0.089999996',
'0.0775',
'0.0925',
'0.085',
'0.082499996',
'0.089999996',
'0.082499996',
'0.0775',
'0.0875',
'0.089999996',
'0.0775',
'0.0775',
'0.085',
'0.0725',
'0.089999996',
'0.0875',
'0.1025',
'0.0875',
'0.0975',
'0.0925',
'0.0875',
'0.089999996',
'0.089999996',
'0.089999996',
'0.082499996',
'0.082499996',
'0.0925',
'0.0875',
'0.085',
'0.0925',
'0.082499996',
'0.0875',
'0.085',
'0.0875',
'0.0875',
'0.082499996',
```

```
'0.089999996',
'0.089999996',
'0.085',
'0.089999996',
'0.095',
'0.105',
'0.0925',
'0.082499996',
'0.089999996',
'0.089999996',
'0.089999996',
'0.08',
'0.085',
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'0.0875',
'0.08',
'0.082499996',
'0.074999996',
'0.067499995',
'0.0775',
'0.082499996',
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'0.0975',
'0.082499996',
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'0.085',
'0.089999996',
'0.089999996',
'0.074999996',
'0.082499996',
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'0.0775',
'0.085',
'0.082499996',
'0.0875',
'0.082499996',
'0.089999996',
'0.095',
'0.0875',
'0.089999996',
```

```
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'0.099999994',
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'0.1025',
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'0.1125',
'0.0925',
'0.095',
'0.082499996',
'0.085',
'0.085',
'0.0775',
'0.074999996',
'0.082499996',
'0.08',
'0.082499996',
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'0.085',
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'0.0875',
'0.089999996',
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'0.105',
'0.0875',
'0.1025',
'0.1275',
'0.14',
'0.11',
'0.0875',
'0.089999996',
'0.0875',
'0.085',
'0.085',
'0.082499996',
'0.095',
'0.08',
'0.082499996',
'0.085',
'0.0875',
'0.085',
'0.0875',
'0.08',
```

```
'0.085',
'0.082499996',
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'0.08',
'0.074999996',
'0.089999996',
'0.0875',
'0.0875',
'0.095',
'0.095',
'0.0975',
'0.095',
'0.1025',
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'0.085',
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```

```
def rectify(crap_string):
    return [0.0 if el == 'nan' else float(el) for el in
crap_string.strip('][').split(', ')]

arrays_2_png(lat_lst, lon_lst,
             [0.0 if el == 'nan' else float(el) for el in
filtered_les['Lake_data_1D'][5177].strip('][').split(', ')],
             'sample')
```

```
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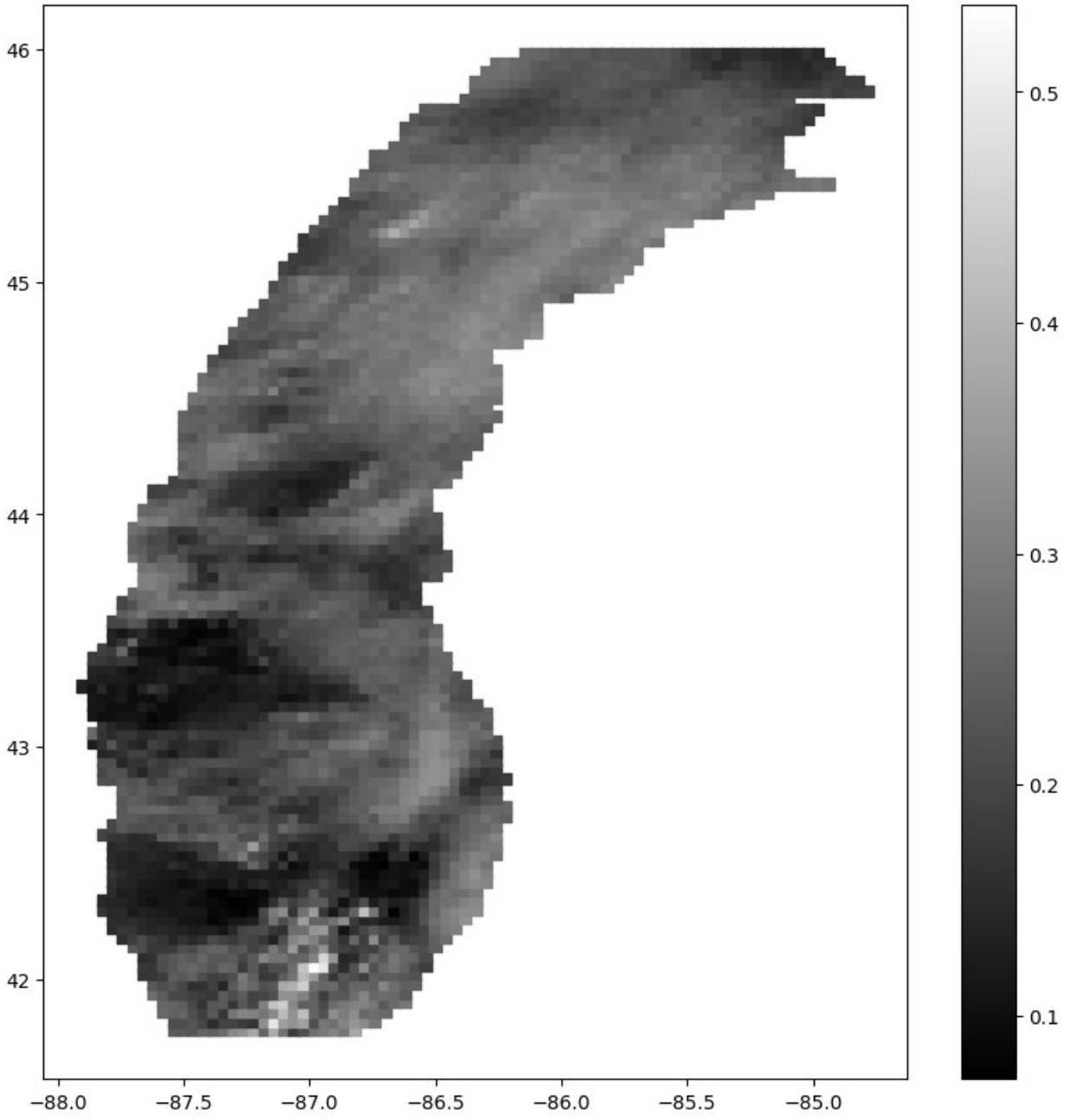
```




```
arrays_2_png(lat_lst, lon_lst,
             rectify(filtered_les['Lake_data_1D'][5177]),
             'sample')
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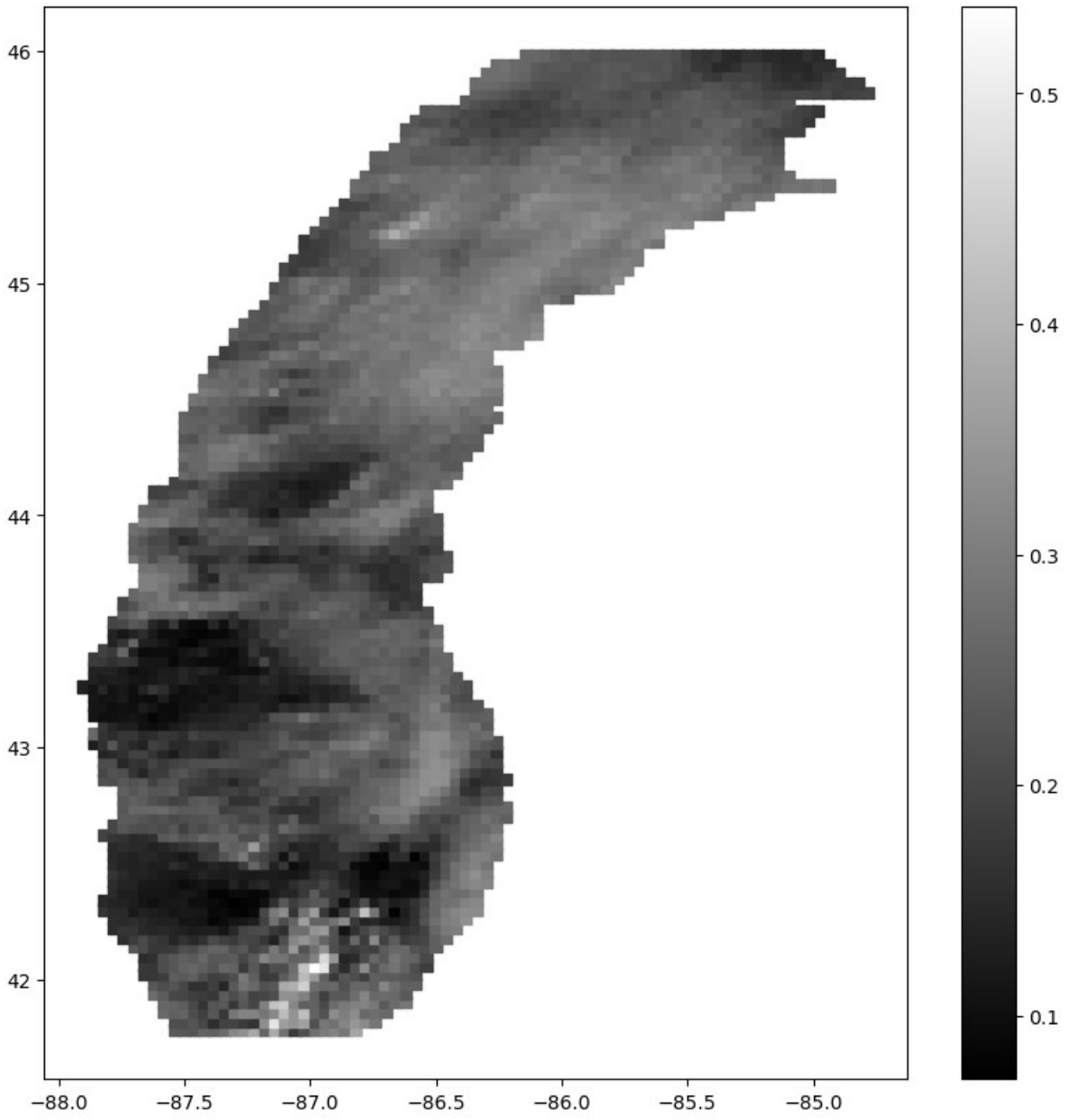
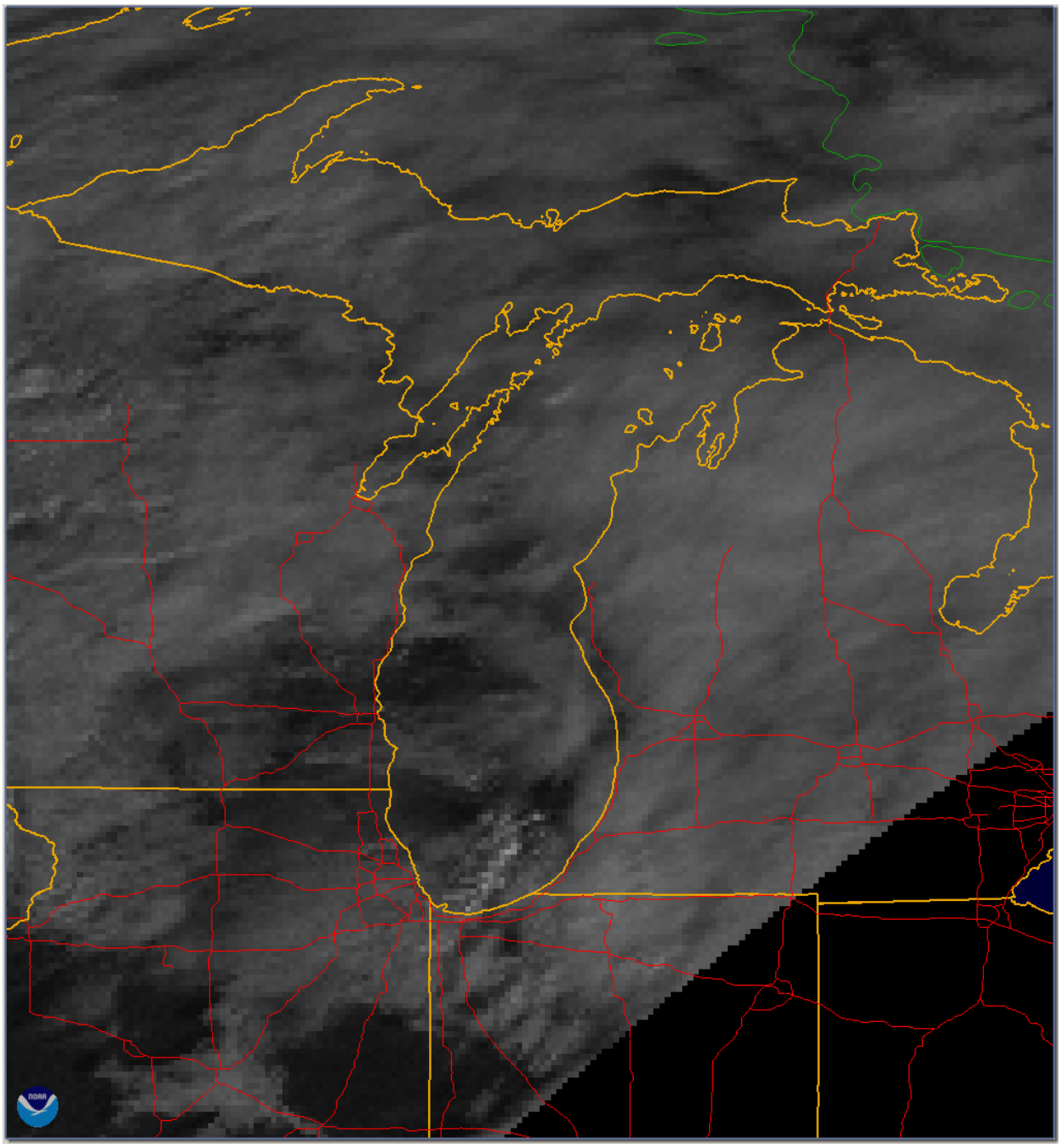



```
from IPython.display import Image
Image("D:/user/docs/NU/_Noctis/original-images/goes11.2008.01.10.1600.v01.nc.png")
```



Ok, this looks good.

Image generation

We will generate 64 × 64 images for each daytime Cloud frame.

The images are pretty large and take up a lot of memory and processing time for the network, so we resize them into 64 x 64 pixels. Then, we convert the images into grayscale and save them for training.

The function below removes the colormap and axis, so that clean images can be stored to train the models:

```
# Remove the colormap and axis to clean images
def arrays_2_png_data(lat, lon, val, fig_name):
    status_code = -1

    if len(lat) == len(lon) == len(val):
        plt.figure(figsize=(10, 10))
        plt.scatter(lon, lat, c=val, cmap=cm.gray, marker='s')
        plt.axis('off')
        plt.savefig(f'D:/user/docs/NU/_Noctis/lake-michigan-images/' +
fig_name +'.png')
        plt.close()
        status_code = 0
    else:
        status_code = 255

    return status_code
```

A small test first:

```
for i, row in les.iterrows():
    if i == 10:
        arr = [0.0 if el == 'nan' else float(el) for el in
row.Lake_data_1D.strip('][').split(', ')]
        print(arr)
        arrays_2_png_data(lat_lst, lon_lst, arr, str(i))
        break
```

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0.012499999, 0.0075, 0.0075, 0.0075, 0.01, 0.0075, 0.0175, 0.0075,
0.012499999, 0.015]
```

OK, this works. Let's read in the 1D column and serialize lake Michigan clouds:

```
from tqdm import tqdm
for i, row in tqdm(les.iterrows()):
    if i == 100:
        break

100it [00:00, 4545.83it/s]

from tqdm import tqdm
for i, row in tqdm(filtered_les.iterrows()):

    try:
        #arr = np.array(eval(row.Lake_data_1D))
        arr = [0.0 if el == 'nan' else float(el) for el in
row.Lake_data_1D.strip('][').split(', ')]
        arrays_2_png_data(lat_lst, lon_lst, arr, str(i))
    except: # If no data is available (fill with zeros)
        #txt = row.Lake_data_1D
        #txt = txt.replace('nan', '0')
        #arr = np.array(eval(txt))
        print("oopsie at row:", i)
```

```
15959it [42:03,  6.32it/s]
```

Interesting... Looking at the folder, images around image #12921 are very incomplete. Memory issue? Let stry regenerating that image:

```
for i, row in tqdm(les.iterrows()):
    try:
        if 12921 == i:
            #arr = np.array(eval(row.Lake_data_1D))
            arr = [0.0 if el == 'nan' else float(el) for el in
row.Lake_data_1D.strip('][').split(', ')]
            arrays_2_png_data(lat_lst, lon_lst, arr, 'sample')
    except: # If no data is available (fill with zeros)
        #txt = row.Lake_data_1D
        #txt = txt.replace('nan', '0')
        #arr = np.array(eval(txt))
        print("oopsie at row", str(i))
```

```
47882it [00:02, 16684.09it/s]
```

Yes, that worked! So, it is *likely* a this notebook's memory issue!

Looking at the containing folder, it looks like images from image #10127 to image #13046 are corrupt!

Let's regenerate these in a separate folder:

```
def arrays_2_png_data_regen(lat, lon, val, fig_name, folder_name):
    status_code = -1

    if len(lat) == len(lon) == len(val):
        plt.figure(figsize=(10, 10))
        plt.scatter(lon, lat, c=val, cmap=cm.gray, marker='s')
        plt.axis('off')
        plt.savefig(folder_name + '/' + fig_name +'.png')
        plt.close()
        status_code = 0
    else:
        status_code = 255

    return status_code

for i, row in tqdm(les.iterrows()):
    try:
        if 10127 <= i <= 13046:
            #arr = np.array(eval(row.Lake_data_1D))
            arr = [0.0 if el == 'nan' else float(el) for el in
row.Lake_data_1D.strip('][').split(', ')]
            arrays_2_png_data_regen(lat_lst, lon_lst, arr, str(i),
"D:/user/docs/NU/_Noctis/lake-michigan-images-regen")
```

```
    except: # If no data is available (fill with zeros)
        #txt = row.Lake_data_1D
        #txt = txt.replace('nan', '0')
        #arr = np.array(eval(txt))
        print("oopsie at row", str(i))
```

```
47882it [07:59, 99.77it/s]
```

Examining the regeneration folder, most of the images look suspiciously like brown noise. For example, image #12969. Let's regenerate that one to verify:

```
for i, row in tqdm(les.iterrows()):
    try:
        if i == 12969:
            #arr = np.array(eval(row.Lake_data_1D))
            arr = [0.0 if el == 'nan' else float(el) for el in
row.Lake_data_1D.strip('][').split(', ')]
            arrays_2_png_data_regen(lat_lst, lon_lst, arr, 'sample',
"D:/user/docs/NU/_Noctis/lake-michigan-images-regen")
    except: # If no data is available (fill with zeros)
        #txt = row.Lake_data_1D
        #txt = txt.replace('nan', '0')
        #arr = np.array(eval(txt))
        print("oopsie at row", str(i))
```

```
47882it [00:01, 35208.51it/s]
```

Yup, `sample` looks exactly lime image #12969 in the regenerating folder.

Note the missing filename and missing data:

```
filtered_les.loc[12969]
```

```
Date_UTC                                                    2012-
03-22
Time_UTC
16:00
Date_CST                                                    2012-
03-22
Time_CST
16:00
File_name_for_1D_lake
None
File_name_for_2D_lake
None
Lake_data_1D              [nan, nan, nan, nan, nan, nan, nan, nan, nan,
...
Lake_data_2D
[nan]
Temp_F
```

```
75.0
RH_pct
51.0
Dewpt_F
56.0
Wind_Spd_mph
10
Wind_Direction_deg
100
Peak_Wind_Gust_mph
0
Low_Cloud_Ht_ft
7500
Med_Cloud_Ht_ft
15000
High_Cloud_Ht_ft
20000
Visibility_mi
10
Atm_Press_hPa
995.3
Sea_Lev_Press_hPa
1018.3
Altimeter_hPa
1018.3
Precip_in
0.0
Name: 12969, dtype: object
```

```
filtered_les['Lake_data_1D'][12969]
```

```
'[nan, nan, nan, nan, nan, nan, nan, nan, nan, nan, nan, nan, nan,
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```

So, appears to be a missing data issue?

When `File_name_for_1D_lake == None`, that means there is no image data, but we keep the meteo data.

So let's use this band of missing data as the separation between the training set and the validation set!

Note to myself: IN order to always ensure that data is not corrupt:

- For *each meteo city*, produce a combined csv just like Traverse City.
- Then, run logic that goes over *every row* and verifies that the image filename is not null *and* that the 1D data is not made out of a majority of nans.
- Then, randomly select 100 rows over the entire dataset and produce a 100-row 2-column image collection that plots lake Michigan cloud cover on the right and the original satellite image on the right.

We need to be able to scan all 100 images and verify that the cloud covers match.

I copy contents of folder `D:\user\docs\NU\_Noctis\lake-michigan-images-regen` into folder `D:\user\docs\NU\_Noctis\lake-michigan-images`.

Removing the 255-level padding around Lake Michigan

We need to do this *before* we resize the images to 64 × 64, otherwise we will get artificial aliasing around the lake MIchigan coastline, which will look like spurious Cloud intensity around the coastline!

We know that image #39 is corrupt: all black. It should give us the shape of Lake Michigan!

```
from PIL import Image, ImageOps

img =
Image.open('D:/user/docs/NU/_Noctis/lake-michigan-images/39.png')
img
```

Let's create a mask that is all ones *over* lake Michigan, and all zeros over land:

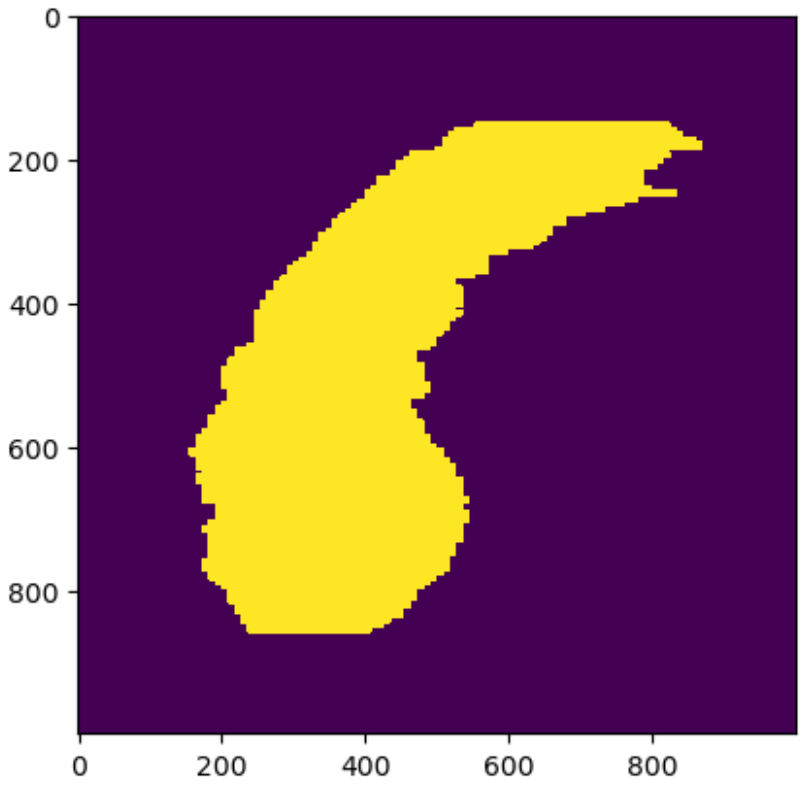
```
#full = np.full(img.size, 255)
img = ImageOps.grayscale(img)
#mask = (full - img).astype(np.uint8)
#mask = (0 < mask).astype(int)
img = np.asarray(img)
mask = (255 != img).astype(int)
np.nonzero(mask)
```

```
(array([150, 150, 150, ..., 860, 860, 860], dtype=int64),
 array([553, 554, 555, ..., 406, 407, 408], dtype=int64))
```

```
(mask * 255)[150, 553], (mask * 255)[860, 408]
```

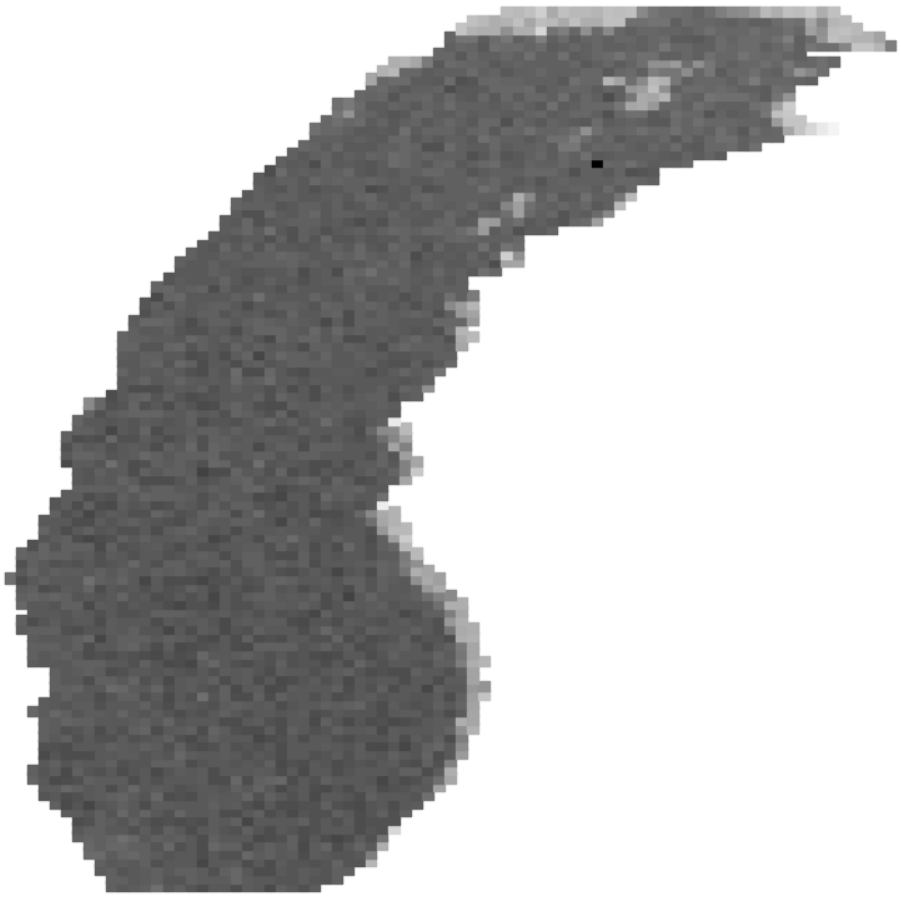
```
(255, 255)
```

```
plt.imshow(mask * 255, interpolation='none')
plt.show()
```

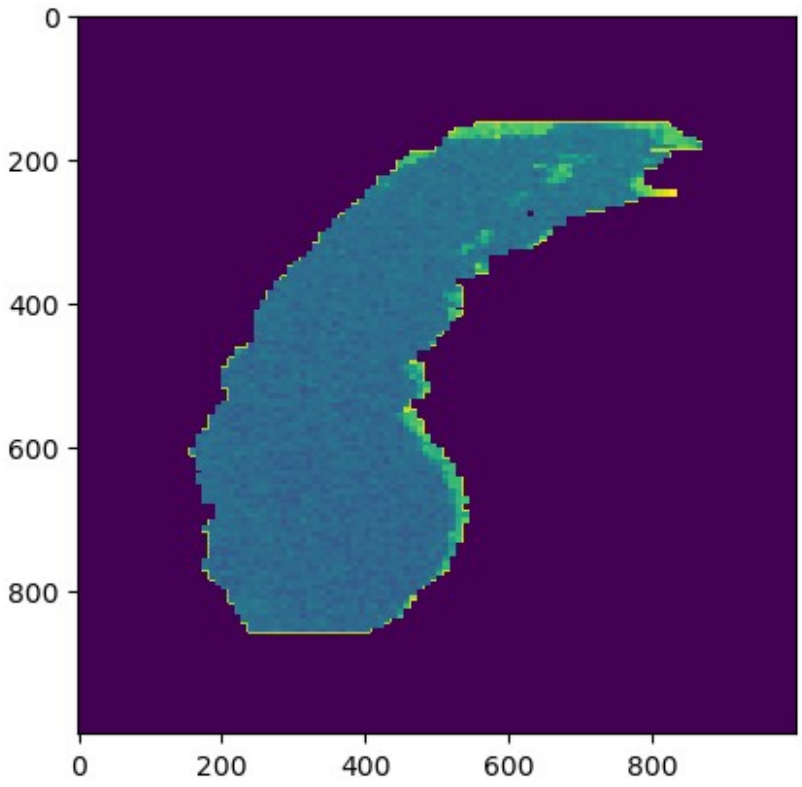


Now let's see what Image #6 should really look like, without the spurious full-intensity over land:

```
img = Image.open('D:/user/docs/NU/_Noctis/lake-michigan-images/6.png')
img = ImageOps.grayscale(img)
img
```



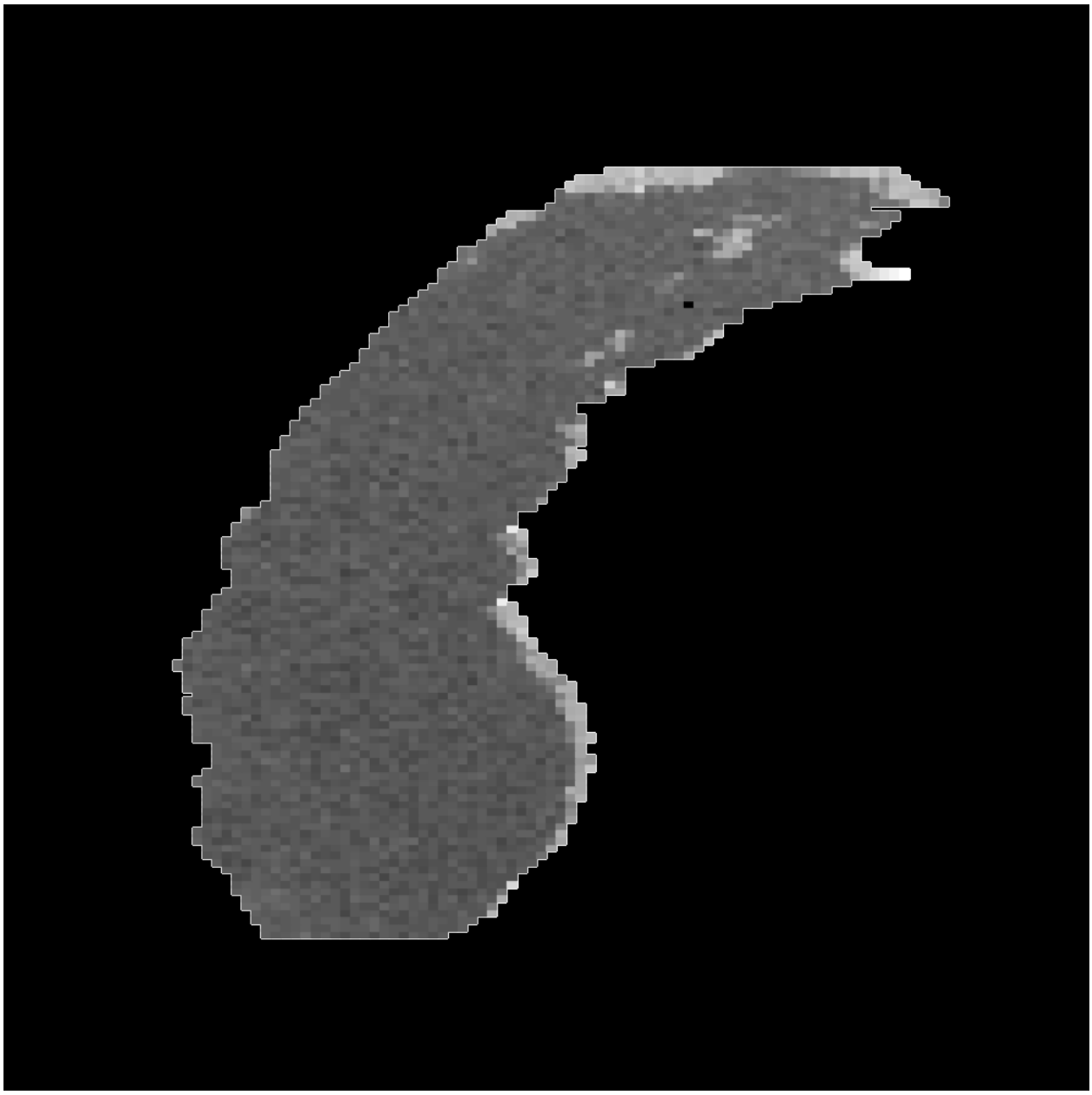
```
newimg = np.asarray(img) * mask # mask with the lake michigan mask to
zero out outside region
plt.imshow(newimg, interpolation='none')
plt.show()
```




```
(newimg)[150, 553], (newimg)[860, 408]
```

```
(245, 231)
```

```
ImageOps.grayscale(Image.fromarray(newimg))
```



And this is how we save the image above:

```
ImageOps.grayscale(Image.fromarray(newimg)).save('D:/user/docs/NU/
_Noctis/lake-michigan-images/sample.png')
```

To combine all ops:

```
f_img = 'D:/user/docs/NU/_Noctis/lake-michigan-images/6.png'
g_img = 'D:/user/docs/NU/_Noctis/lake-michigan-images/sample.png'
img = Image.open(f_img)
img = ImageOps.grayscale(img)
newimg = np.asarray(img) * mask # mask with the lake michigan mask to
```

```
zero out land region
newimg64 = ImageOps.grayscale(Image.fromarray(newimg)).resize((64,64))
newimg64.save(g_img)
```

So now let's repeat these operations *prior* to compressing to 64 × 64:

Shrinking to 64 × 64

We now resize images to 64 × 64 in order to reduce network training memory requirements, with zero intensities on land and avoiding aliasing around the lake border:

```
from PIL import Image, ImageOps
f = 'D:/user/docs/NU/_Noctis/lake-michigan-images'
g = 'D:/user/docs/NU/_Noctis/lake-michigan-images-64'
for file in tqdm(os.listdir(f)):
    f_img = f + "/" + file
    g_img = g + "/" + file
    img = Image.open(f_img)
    img = ImageOps.grayscale(img)
    newimg = np.asarray(img) * mask # mask with the lake michigan mask
to zero out land region
    newimg64 =
ImageOps.grayscale(Image.fromarray(newimg)).resize((64,64),
Image.ANTIALIAS)
    newimg64.save(g_img)
```

```
  0%|          | 0/15960 [00:00<?, ?it/s]C:\Users\Dino\AppData\Local\
Temp\ipykernel_6780\778164306.py:10: DeprecationWarning: ANTIALIAS is
deprecated and will be removed in Pillow 10 (2023-07-01). Use LANCZOS
or Resampling.LANCZOS instead.
  newimg64 =
ImageOps.grayscale(Image.fromarray(newimg)).resize((64,64),
Image.ANTIALIAS)
100%|██████████| 15959/15960 [03:32<00:00, 75.08it/s]

---------------------------------------------------------------------
-----
ValueError                                Traceback (most recent call
last)
Cell In[224], line 9
      7 img = Image.open(f_img)
      8 img = ImageOps.grayscale(img)
----> 9 newimg = np.asarray(img) * mask # mask with the lake michigan
mask to zero out land region
     10 newimg64 =
ImageOps.grayscale(Image.fromarray(newimg)).resize((64,64),
Image.ANTIALIAS)
     11 newimg64.save(g_img)
```

```
ValueError: operands could not be broadcast together with shapes
(64,64) (1000,1000)
```

I think there's still aliasing on the coastline compared to the original images, but I think this is about the best we can get.

Optional: Limiting

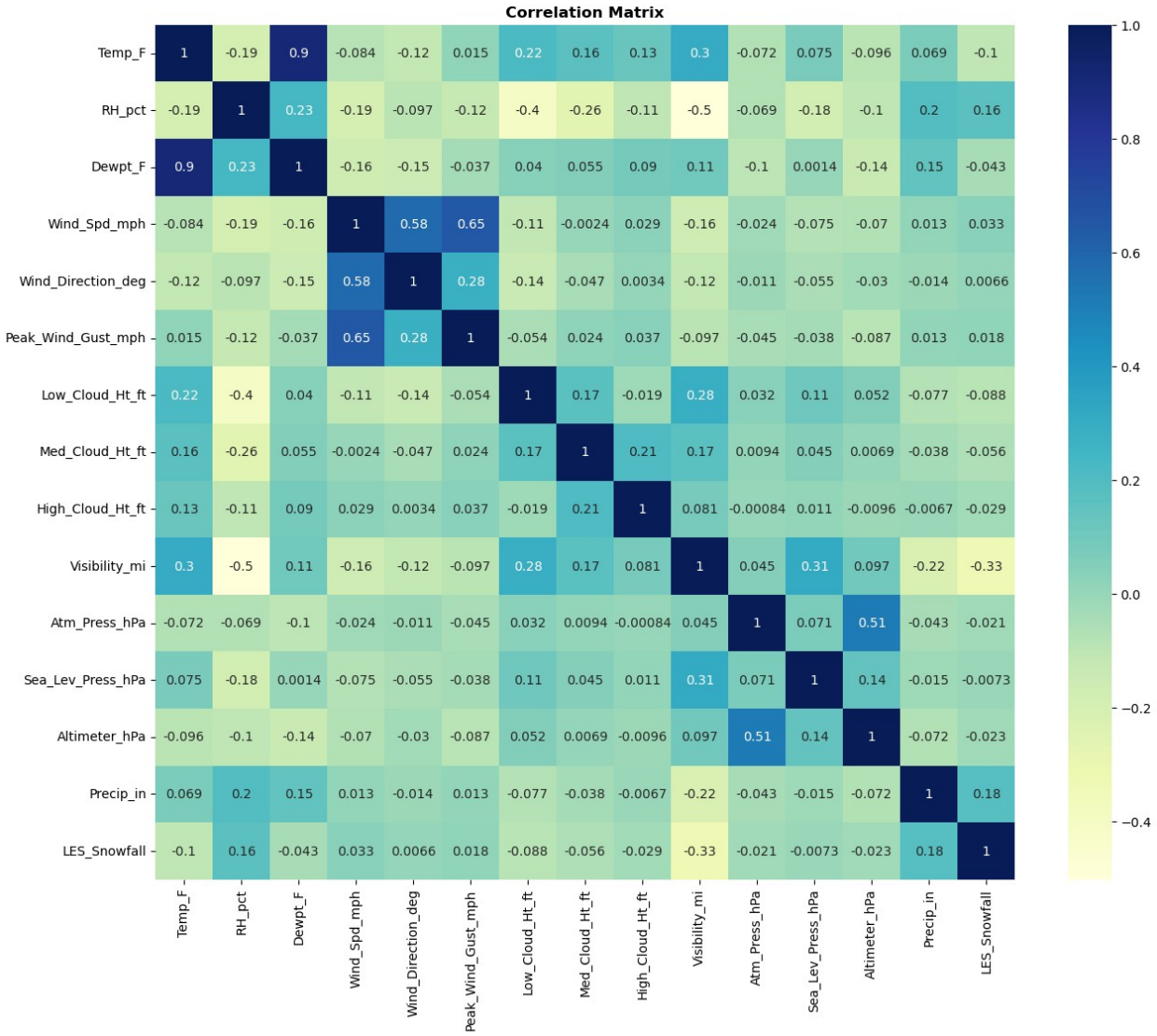
Correlations

Plotting the pearson correlation plot to visualise the correlation between various features

```
# Correlation
correlation_matrix = filtered_les.corr(method = 'pearson')
plt.subplots(figsize=(15,12))

# Heatmap
sns.heatmap(correlation_matrix, annot = True, cmap = "YlGnBu")
plt.title("Correlation Matrix", size = 12, weight = 'bold')
```

```
Text(0.5, 1.0, 'Correlation Matrix')
```



Observations from the above correlation plots:

- Few features are very heavily correated with each other
- We remove the ones that have shown `positive correlation` greater than 0.6
  - **Temp_F** is highly correlated with **Dewpt_F**
  - **Wind_Spd_mph** is highly correlated with **Peak_Wind_Gust_mph**
- We also note some strong `negative correlation`, but all of them are greater than -0.6, hence we do not drop those features

We can drop the above columns since they imply to the same information, and keeping them as features will increase the model size.

```
filtered_les = filtered_les.drop(['Dewpt_F', 'Peak_Wind_Gust_mph'],
axis=1)
filtered_les = filtered_les.reset_index(drop=True)
```

```
# Information about dataset shape
print('Total observations: ', filtered_les.shape[0])
print('Total number of features: ', filtered_les.shape[1])
filtered_les.head()
```

```
Total observations:  15959
Total number of features:  17
```

	File_name_for_1D_lake	File_name_for_2D_lake	Lake_data_1D	Lake_data_2D	Temp_F	RH_pct	Wind_Spd_mph	Wind_Direction_deg	Low_Cloud_Ht_ft	Med_Cloud_Ht_ft
0	goes11.2006.10.01.1400.v01.nc-var1-t0.csv	T_goes11.2006.10.01.1400.v01.nc-var1-t0.csv.csv	[0.067499995, 0.07, 0.0625, 0.06, 0.0725, 0.06...	[array([nan, nan, nan, ...	60.0	49.0	10	270	3600	0
1	goes11.2006.10.01.1500.v01.nc-var1-t0.csv	T_goes11.2006.10.01.1500.v01.nc-var1-t0.csv.csv	[0.067499995, 0.067499995, 0.06, 0.06, 0.05749...	[array([nan, nan, nan, ...	60.0	47.0	3	0	0	0
2	goes11.2006.10.01.1600.v01.nc-var1-t0.csv	T_goes11.2006.10.01.1600.v01.nc-var1-t0.csv.csv	[0.0725, 0.067499995, 0.07, 0.07, 0.067499995,...	[array([nan, nan, nan, nan, nan...	59.0	55.0	6	40	0	0
3	goes11.2006.10.01.1700.v01.nc-var1-t0.csv	T_goes11.2006.10.01.1700.v01.nc-var1-t0.csv.csv	[0.067499995, 0.067499995, 0.067499995, 0.07, ...	[array([nan, nan, nan, nan, nan, nan, n...	55.0	71.0	0	0	0	0
4	goes11.2006.10.01.1800.v01.nc-var1-t0.csv	T_goes11.2006.10.01.1800.v01.nc-var1-t0.csv.csv	[0.085, 0.085, 0.0875, 0.0725, 0.0775, 0.0775,...	[array([nan, nan, nan, nan, nan...	50.0	82.0				

```
4              0                    0              8000                   0


   High_Cloud_Ht_ft  Visibility_mi  Atm_Press_hPa
Sea_Lev_Press_hPa  \
0                 0             10          994.7               1017.8

1                 0             10          994.7               1017.7

2                 0             10          994.7               1017.8

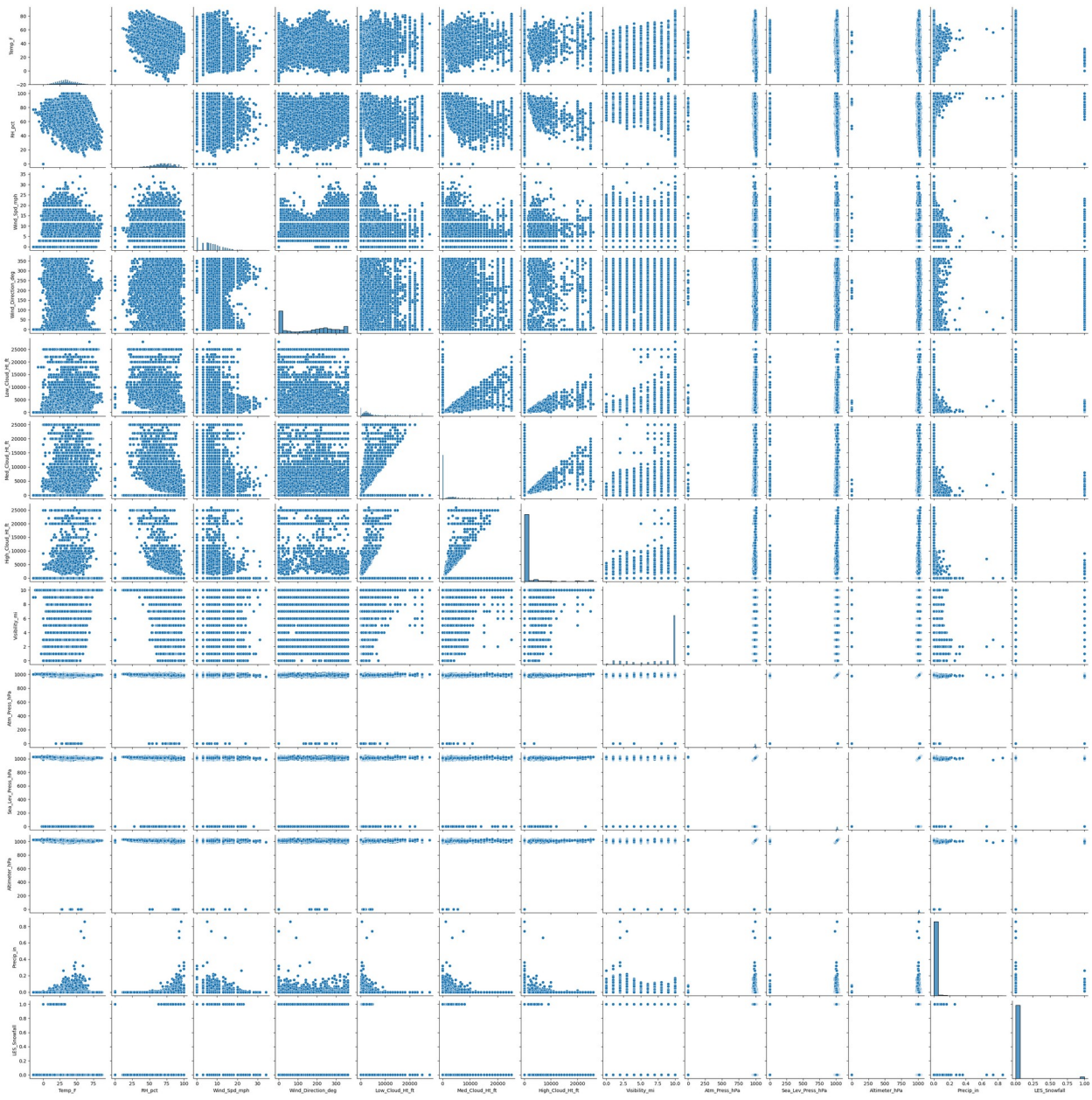
3                 0             10          994.7               1017.8

4                 0             10          994.7               1017.9


   Altimeter_hPa  Precip_in  LES_Snowfall
0         1017.6        0.0           0.0
1         1017.6        0.0           0.0
2         1017.6        0.0           0.0
3         1017.6        0.0           0.0
4         1017.6        0.0           0.0
```

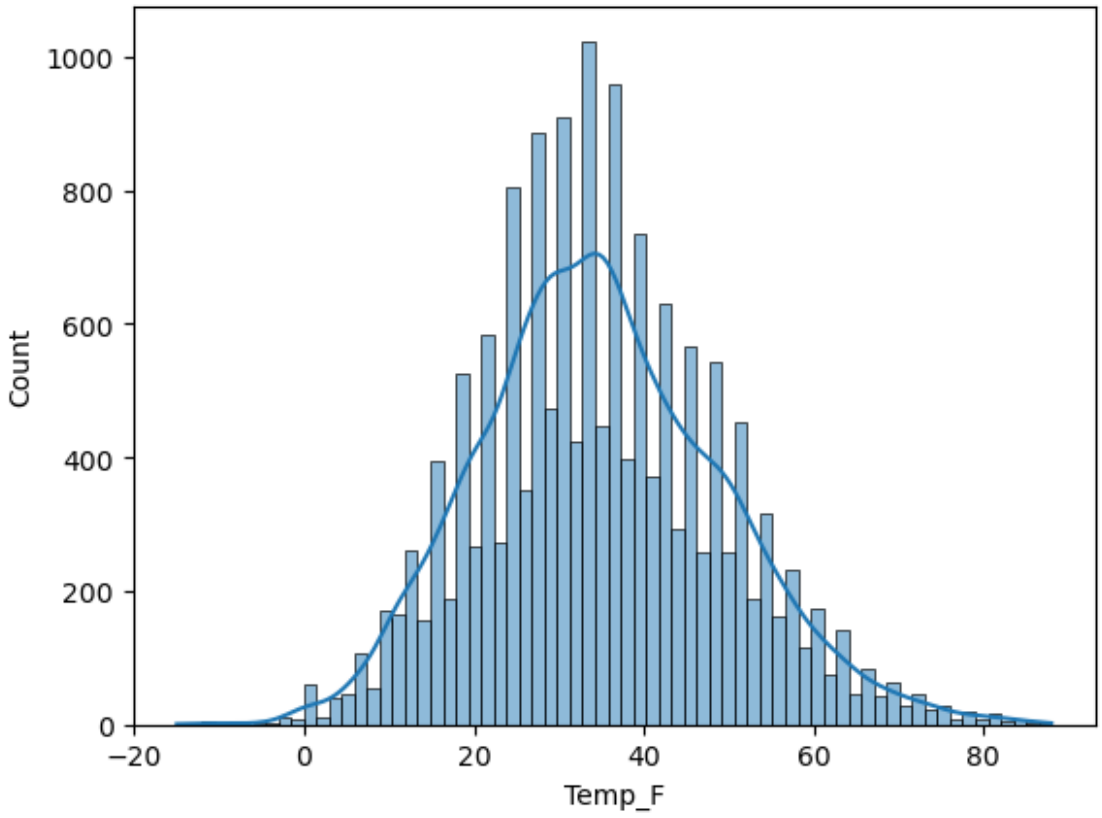
```
sns.pairplot(filtered_les)
```

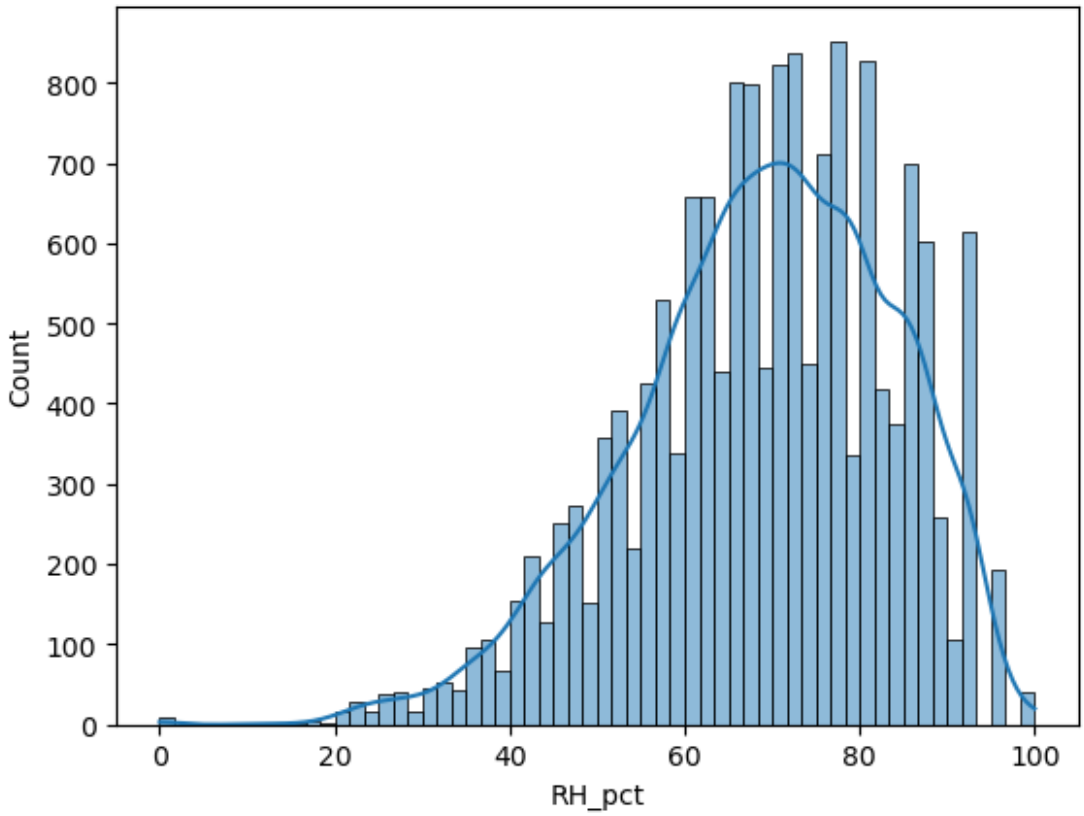
```
<seaborn.axisgrid.PairGrid at 0x224c34d1e50>
```

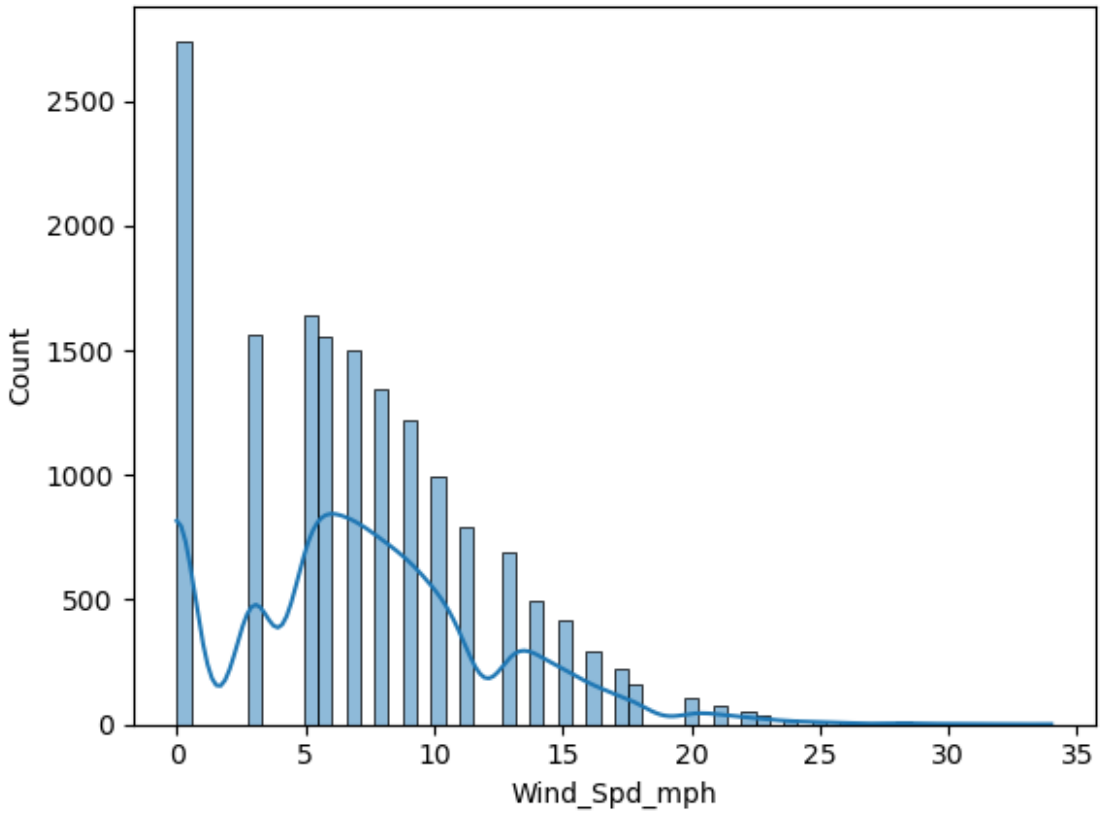


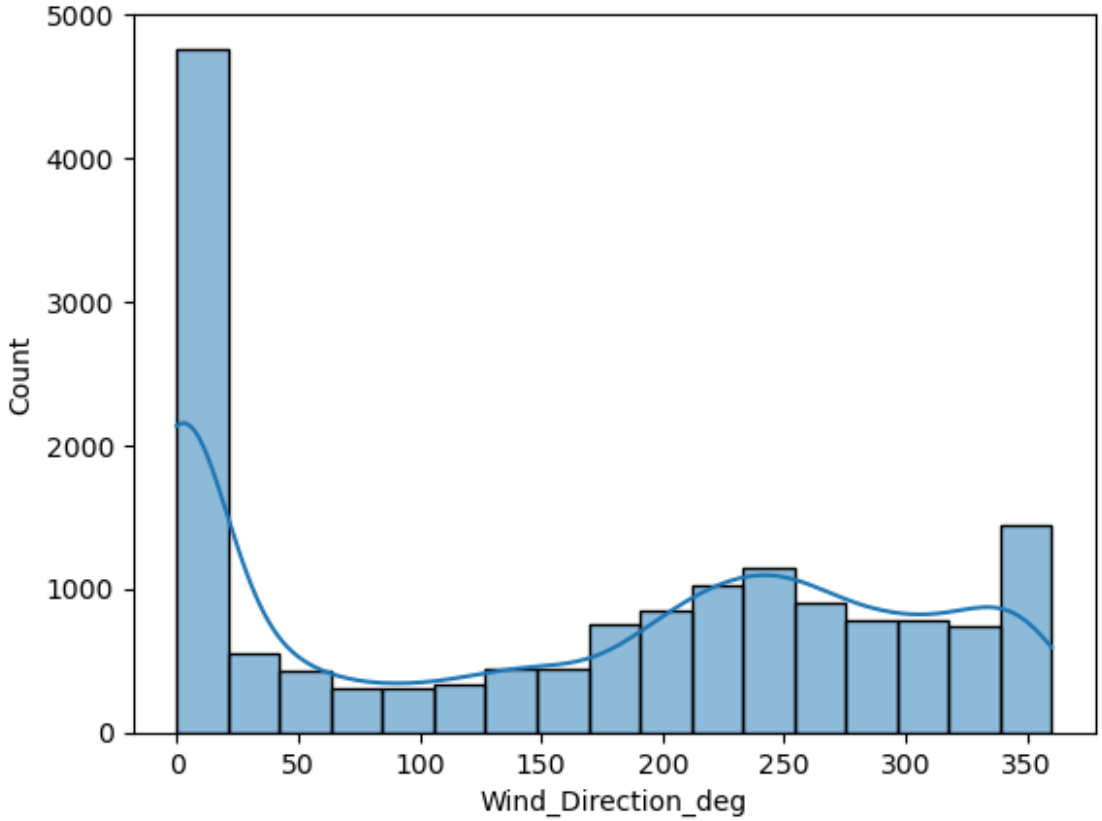

```
def distPlot(data):
    cols = data.columns[4:]
    for col in cols:
        sns.histplot(data[col], kde=True)
        plt.show()

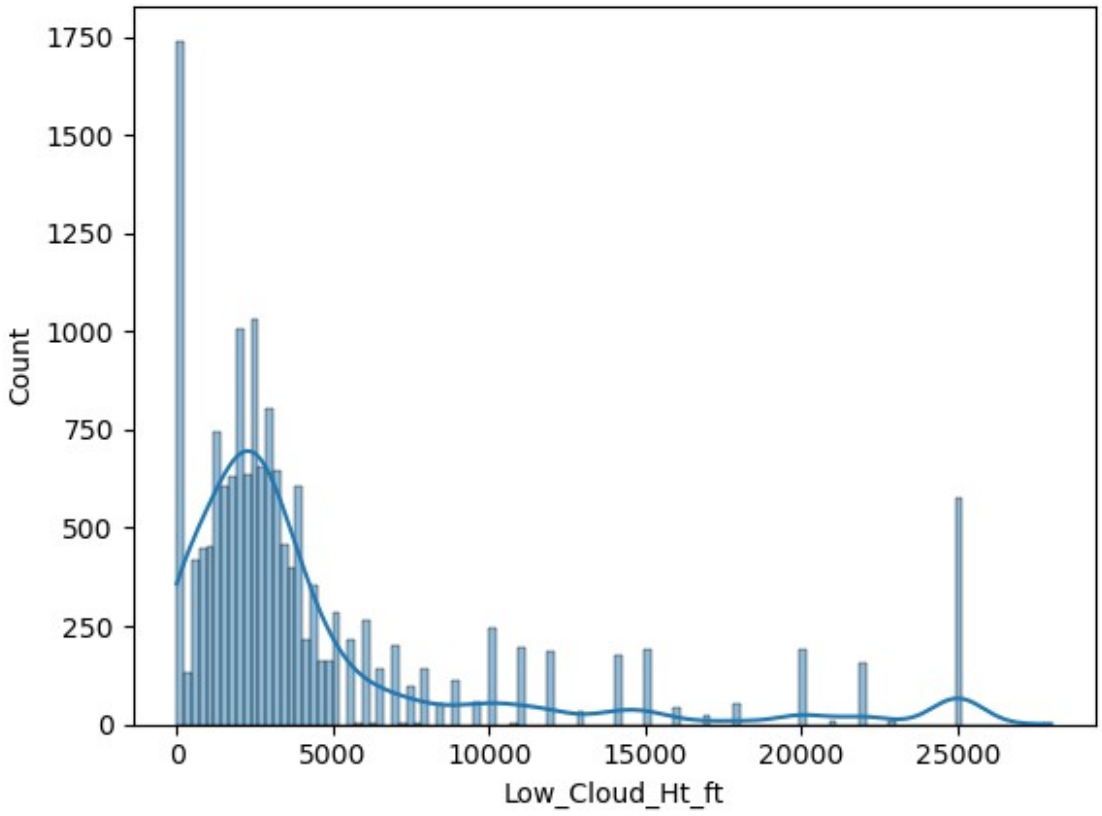
distPlot(filtered_les)
```

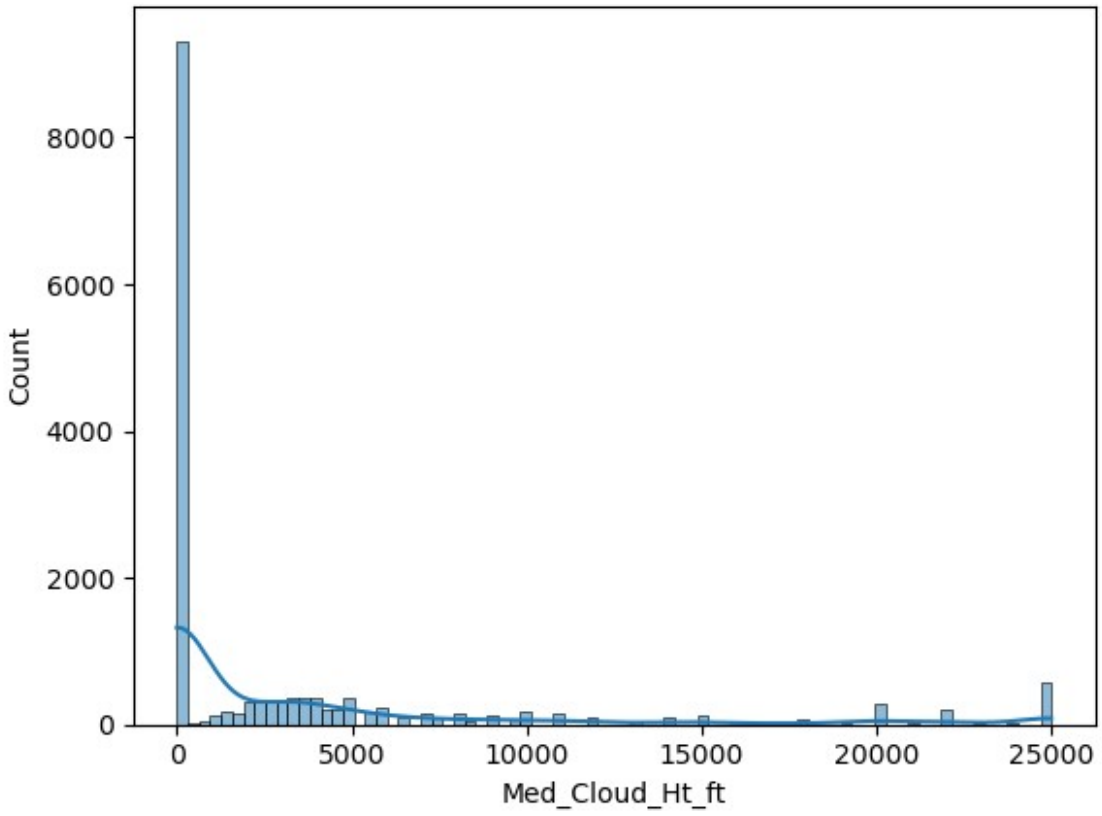

Count
1000
800
600
400
200
0
−20
0
20
40
60
80
Temp_F

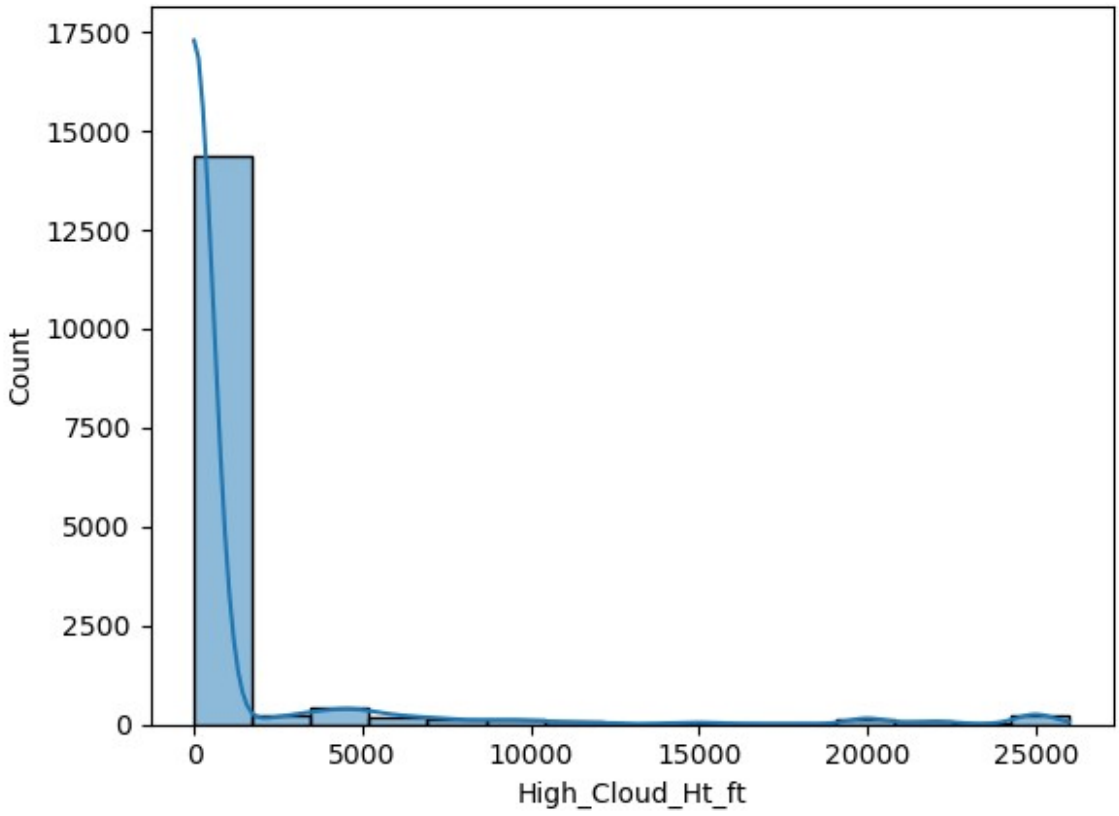

Count
800
700
600
500
400
300
200
100
0
0
20
40
60
80
100
RH_pct

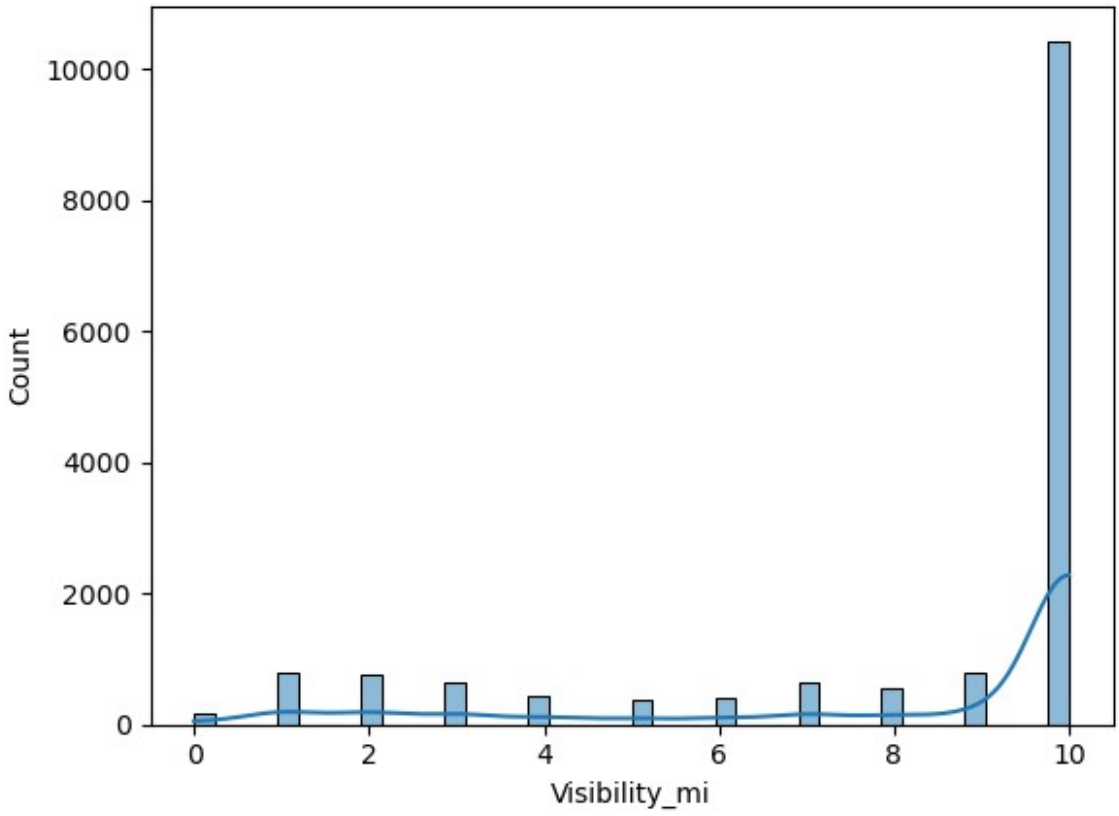

Count
2500
2000
1500
1000
500
0
0
5
10
15
20
25
30
35
Wind_Spd_mph

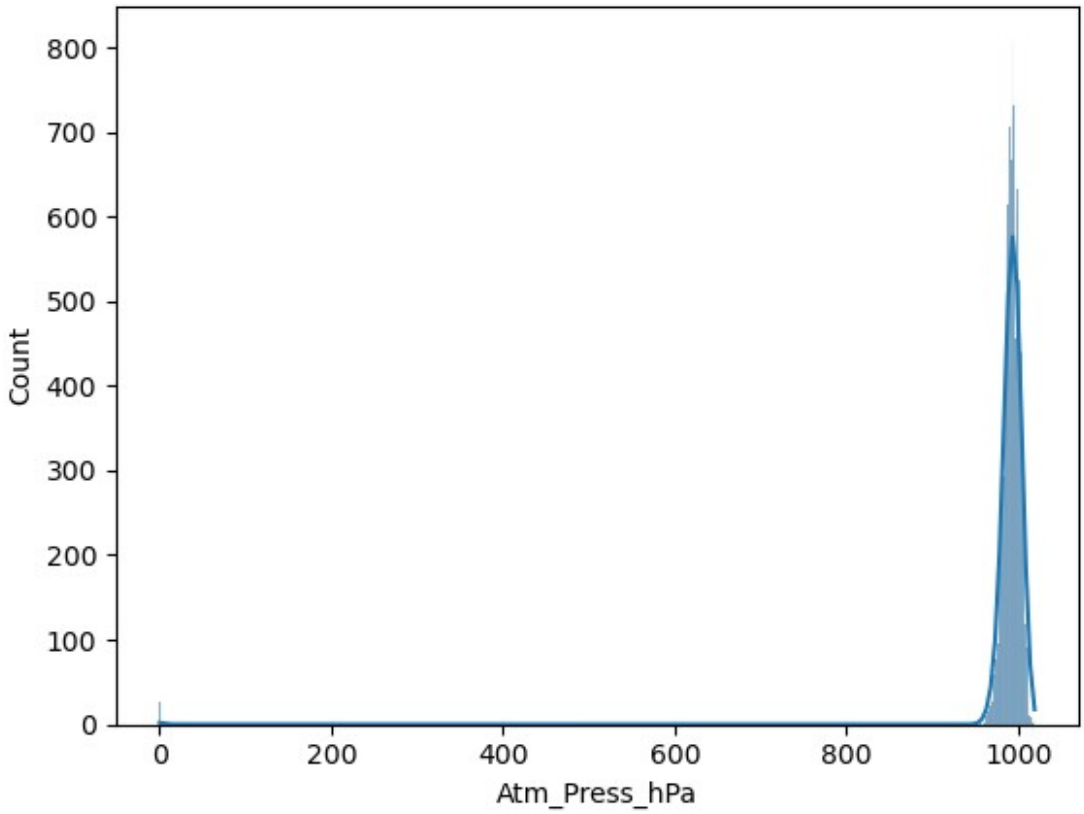

Count
5000
4000
3000
2000
1000
0
0
50
100
150
200
250
300
350
Wind_Direction_deg

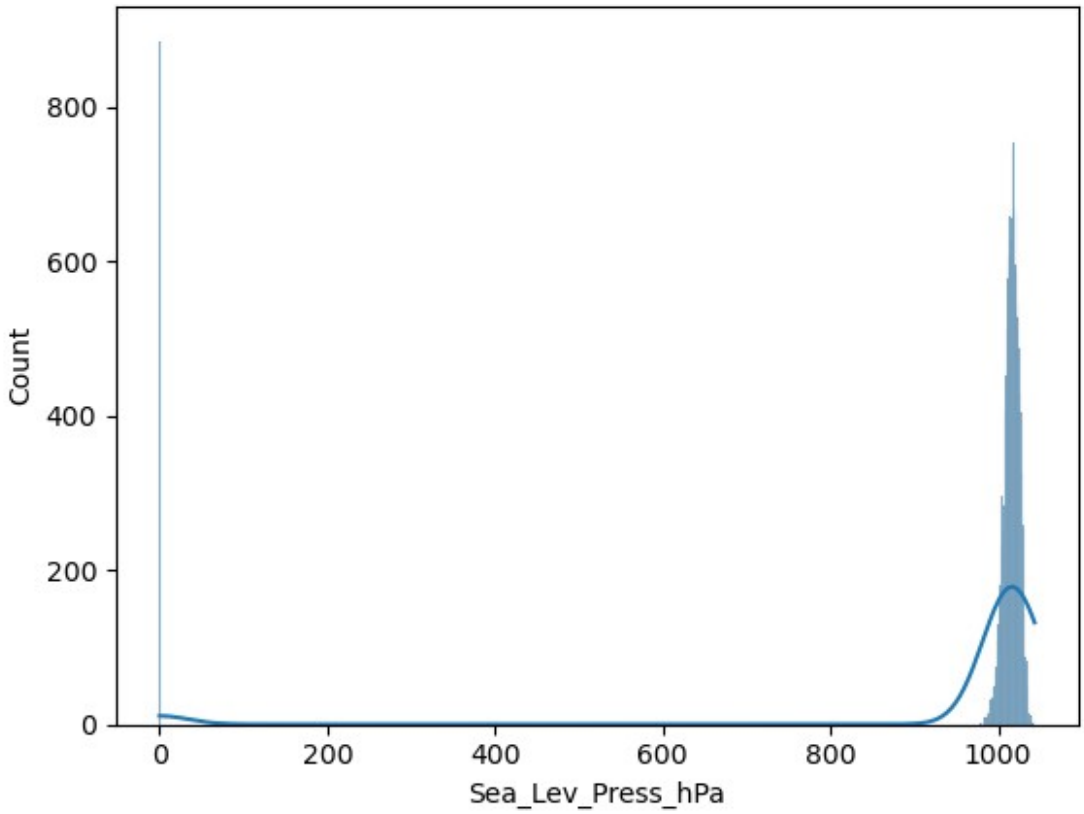

1750
1500
1250
1000
750
500
250
0
Count
0
5000
10000
15000
20000
25000
Low_Cloud_Ht_ft

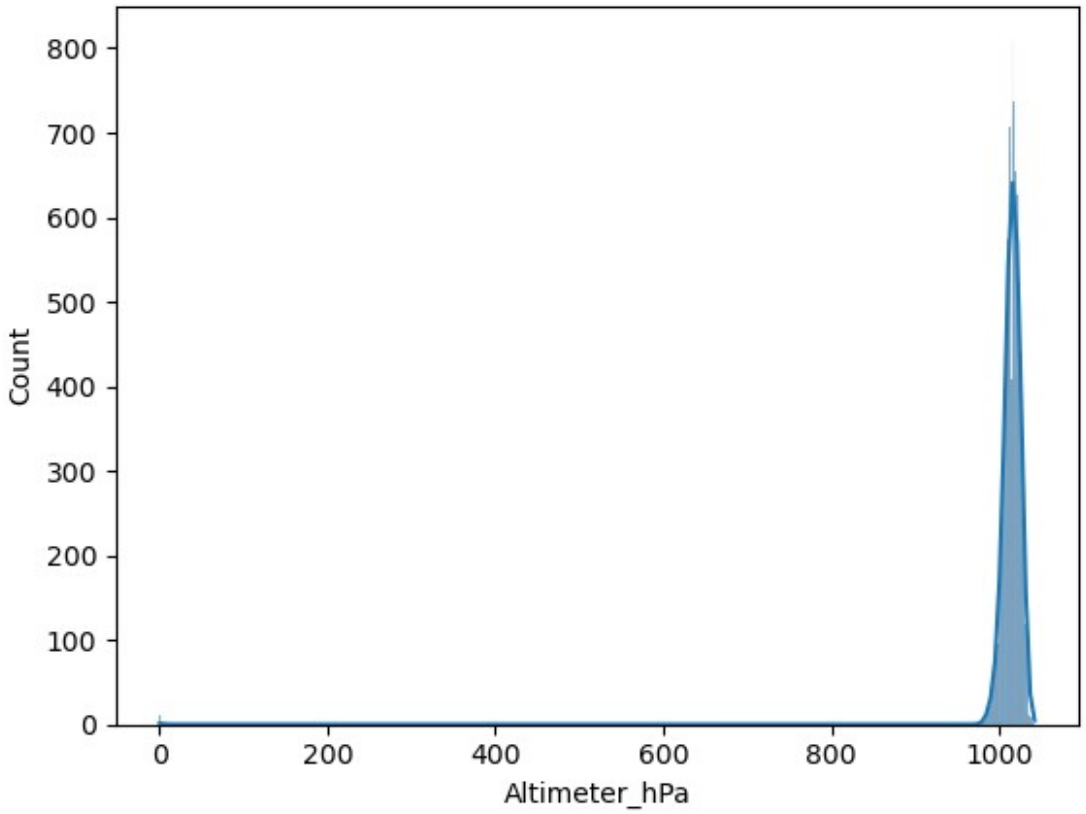

8000
6000
4000
2000
0
Count
0
5000
10000
15000
20000
25000
Med_Cloud_Ht_ft

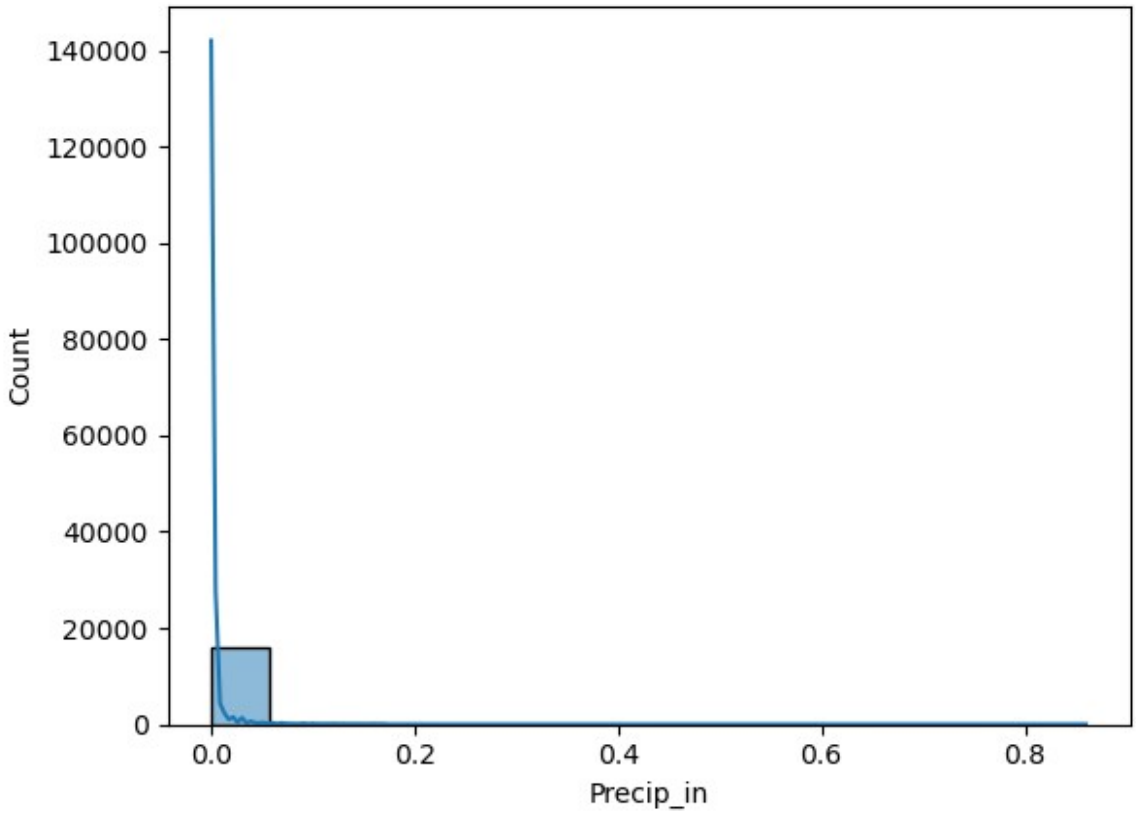

17500
15000
12500
10000
7500
5000
2500
0
Count
0
5000
10000
15000
20000
25000
High_Cloud_Ht_ft

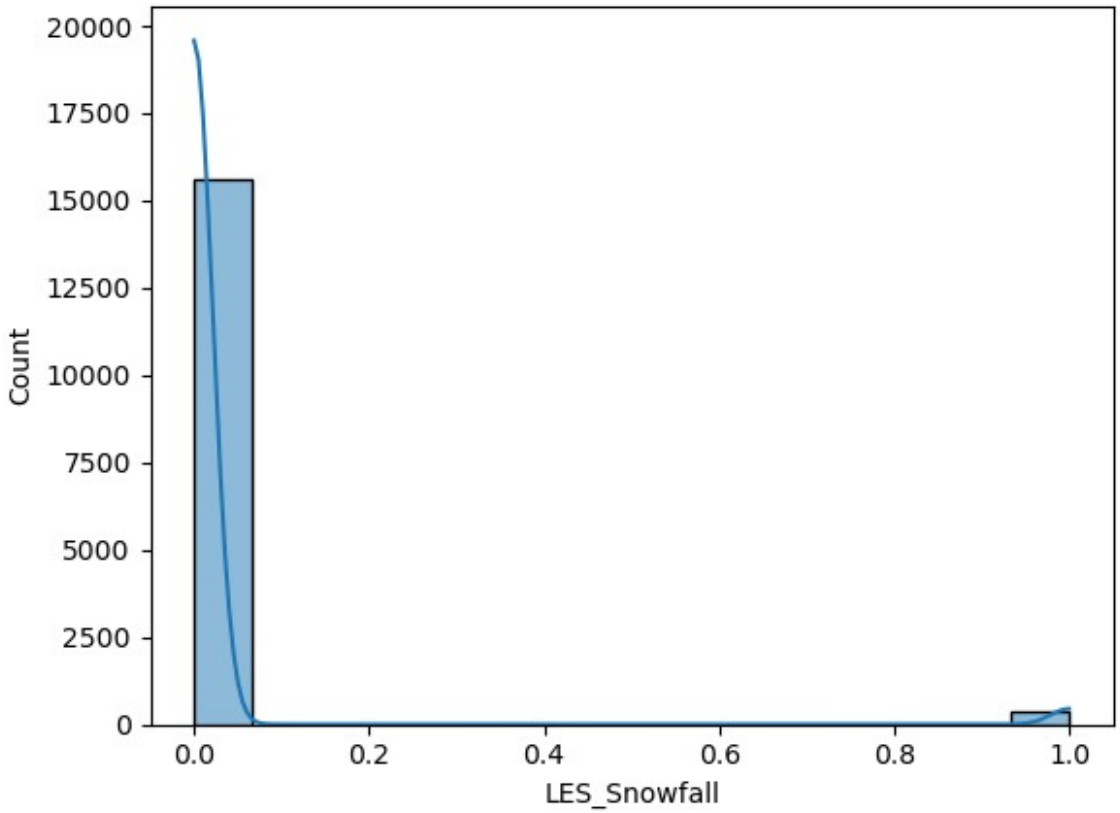

10000
8000
6000
4000
2000
0
Count
0
2
4
6
8
10
Visibility_mi


800
700
600
500
400
300
200
100
0
Count
0
200
400
600
800
1000
Atm_Press_hPa


800
600
400
200
0
Count
0
200
400
600
800
1000
Sea_Lev_Press_hPa


800
700
600
500
400
300
200
100
0
Count
0
200
400
600
800
1000
Altimeter_hPa


140000
120000
100000
80000
60000
40000
20000
0
Count
0.0
0.2
0.4
0.6
0.8
Precip_in

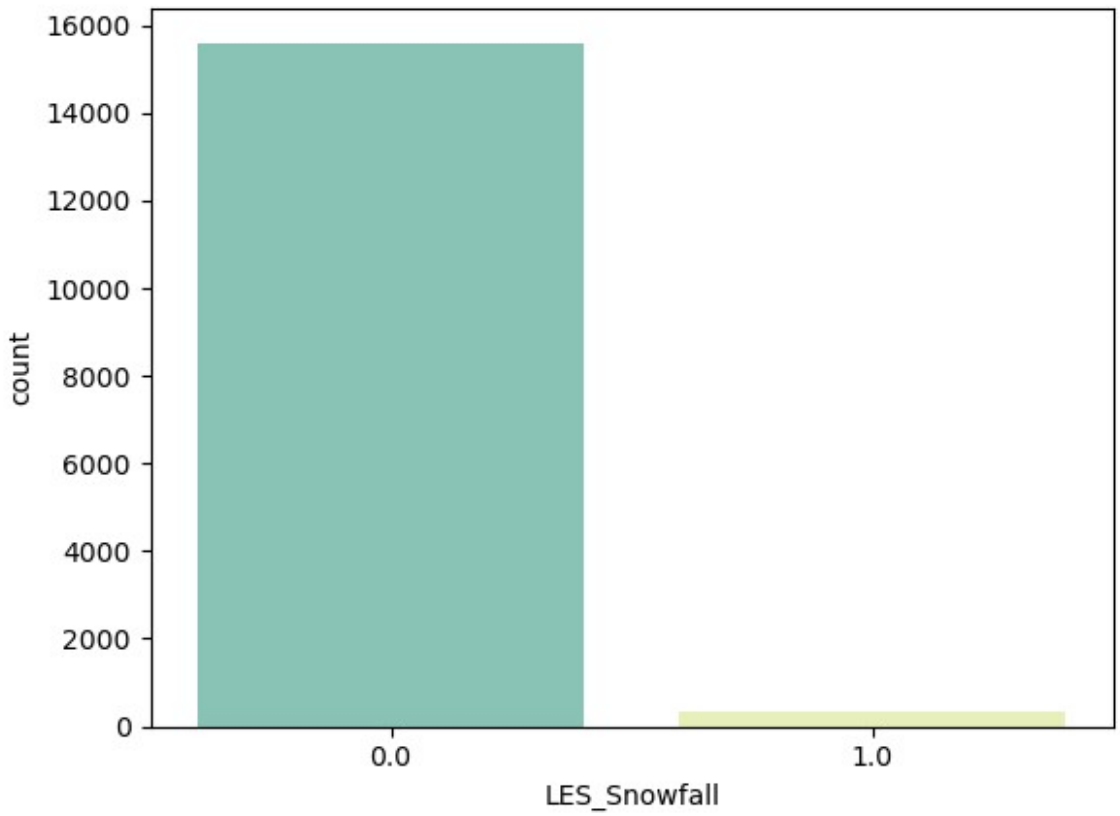



```
filtered_les['LES_Snowfall'].value_counts()
```

```
0.0    15607
1.0      352
Name: LES_Snowfall, dtype: int64
```

```
sns.countplot(x = filtered_les['LES_Snowfall'], palette=["#7fcdbb",
"#edf8b1"])
```

```
<AxesSubplot:xlabel='LES_Snowfall', ylabel='count'>
```



Feature engineering: Precipitation

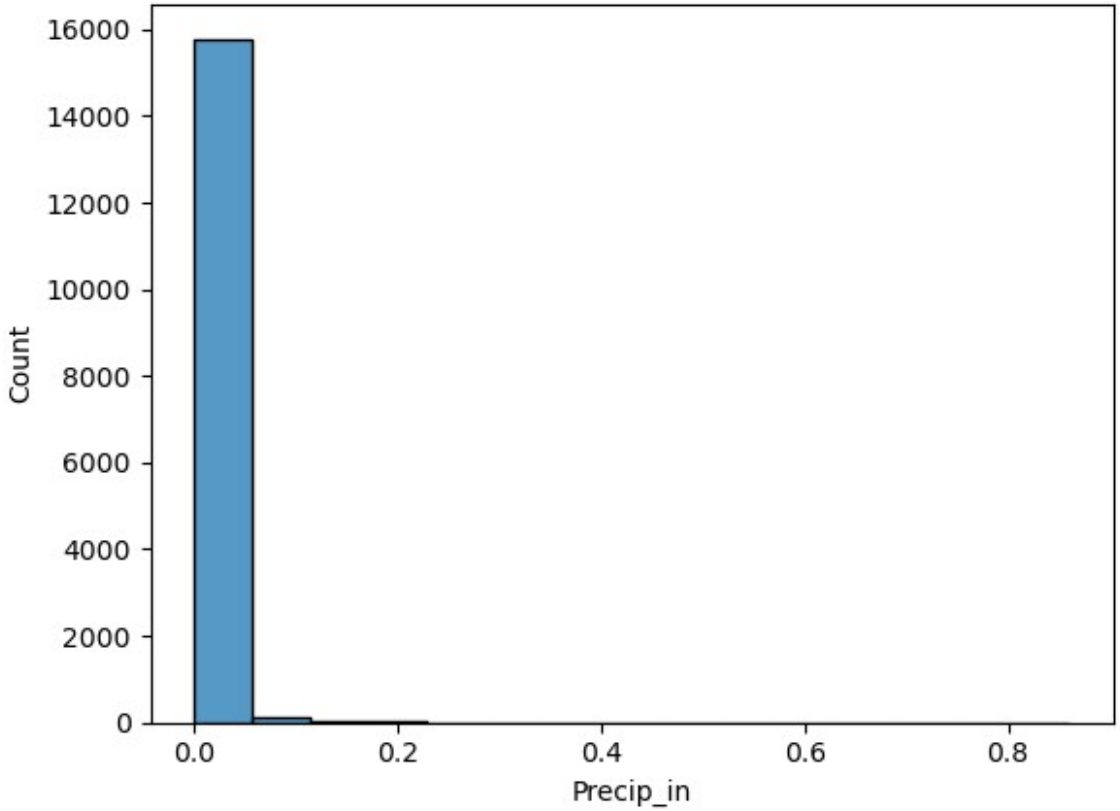
```
filtered_les["Precip_in"].value_counts()
```

```
0.00    14827
0.01      509
0.02      195
0.03      142
0.04       69
0.05       48
0.06       31
0.07       31
0.09       19
0.08       16
0.10       14
0.12       10
0.15        6
0.16        6
0.13        6
0.14        6
0.11        5
0.17        3
0.32        2
```

```
0.19        2
0.18        2
0.20        2
0.26        1
0.28        1
0.36        1
0.86        1
0.66        1
0.74        1
0.22        1
0.21        1
Name: Precip_in, dtype: int64
```

```
sns.histplot(filtered_les["Precip_in"])
```

```
<AxesSubplot:xlabel='Precip_in', ylabel='Count'>
```



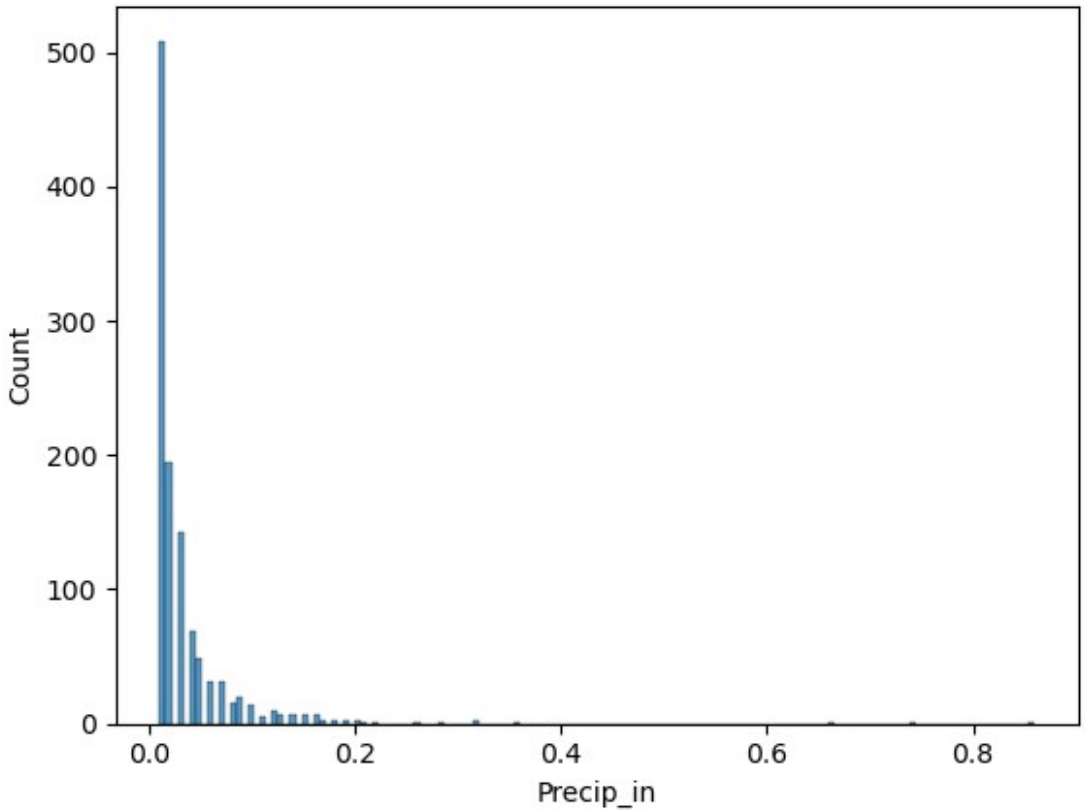

```
filtered_les["Precip_in"][filtered_les["Precip_in"] > 0]
```

```
78       0.01
79       0.01
80       0.03
81       0.02
83       0.03
```

```
        ...
15935    0.04
15936    0.01
15938    0.01
15939    0.01
15940    0.02
Name: Precip_in, Length: 1132, dtype: float64
```

```
sns.histplot(filtered_les["Precip_in"][filtered_les["Precip_in"] > 0])
```

```
<AxesSubplot:xlabel='Precip_in', ylabel='Count'>
```



Adding a new column for precipitation:

```
filtered_les.loc[filtered_les['Precip_in'] > 0, 'LES_Precipitation'] =
1
filtered_les.loc[filtered_les['Precip_in'] <= 0, 'LES_Precipitation']
= 0
filtered_les
```

```
                          File_name_for_1D_lake  \
0      goes11.2006.10.01.1400.v01.nc-var1-t0.csv
1      goes11.2006.10.01.1500.v01.nc-var1-t0.csv
2      goes11.2006.10.01.1600.v01.nc-var1-t0.csv
```

```
3      goes11.2006.10.01.1700.v01.nc-var1-t0.csv
4      goes11.2006.10.01.1800.v01.nc-var1-t0.csv
...                                          ...
15954  goes15.2015.03.31.1700.v01.nc-var1-t0.csv
15955  goes15.2015.03.31.1800.v01.nc-var1-t0.csv
15956  goes15.2015.03.31.1900.v01.nc-var1-t0.csv
15957  goes15.2015.03.31.2000.v01.nc-var1-t0.csv
15958  goes15.2015.03.31.2100.v01.nc-var1-t0.csv

                                  File_name_for_2D_lake  \
0      T_goes11.2006.10.01.1400.v01.nc-var1-t0.csv.csv
1      T_goes11.2006.10.01.1500.v01.nc-var1-t0.csv.csv
2      T_goes11.2006.10.01.1600.v01.nc-var1-t0.csv.csv
3      T_goes11.2006.10.01.1700.v01.nc-var1-t0.csv.csv
4      T_goes11.2006.10.01.1800.v01.nc-var1-t0.csv.csv
...                                                ...
15954  T_goes15.2015.03.31.1700.v01.nc-var1-t0.csv.csv
15955  T_goes15.2015.03.31.1800.v01.nc-var1-t0.csv.csv
15956  T_goes15.2015.03.31.1900.v01.nc-var1-t0.csv.csv
15957  T_goes15.2015.03.31.2000.v01.nc-var1-t0.csv.csv
15958  T_goes15.2015.03.31.2100.v01.nc-var1-t0.csv.csv

                                             Lake_data_1D  \
0      [0.067499995, 0.07, 0.0625, 0.06, 0.0725, 0.06...
1      [0.067499995, 0.067499995, 0.06, 0.06, 0.05749...
2      [0.0725, 0.067499995, 0.07, 0.07, 0.067499995,...
3      [0.067499995, 0.067499995, 0.067499995, 0.07, ...
4      [0.085, 0.085, 0.0875, 0.0725, 0.0775, 0.0775,...
...                                                  ...
15954  [0.225, 0.22749999, 0.48, 0.3075, 0.1925, 0.24...
15955  [0.2075, 0.1925, 0.18249999, 0.1625, 0.1725, 0...
15956  [0.22, 0.1925, 0.1775, 0.16749999, 0.16499999,...
15957  [0.2575, 0.22, 0.21249999, 0.17999999, 0.185, ...
15958  [0.2225, 0.18249999, 0.19, 0.17999999, 0.1725,...

                                             Lake_data_2D  Temp_F
RH_pct  \
0      [array([       nan,        nan,        nan,   ...    60.0
49.0
1      [array([       nan,        nan,        nan,   ...    60.0
47.0
2      [array([   nan,    nan,    nan,    nan,    nan...    59.0
55.0
3      [array([ nan,  nan,  nan,  nan,  nan,  nan,  n...    55.0
71.0
4      [array([   nan,    nan,    nan,    nan,    nan...    50.0
82.0
...                                                  ...     ...     .
..
15954  [array([   nan,    nan,    nan,    nan,    nan...    39.0
```

```
54.0
15955  [array([   nan,    nan,    nan,    nan,    nan...    37.0
61.0
15956  [array([       nan,        nan,        nan,   ...    37.0
66.0
15957  [array([   nan,    nan,    nan,    nan,    nan...    36.0
85.0
15958  [array([ nan,  nan,  nan,  nan,  nan,  nan,  n...    36.0
85.0

       Wind_Spd_mph  Wind_Direction_deg  Low_Cloud_Ht_ft
Med_Cloud_Ht_ft  \
0                10                 270             3600
0
1                 3                   0                0
0
2                 6                  40                0
0
3                 0                   0                0
0
4                 0                   0             8000
0
...             ...                 ...              ...
...
15954             5                  20             7000
10000
15955             3                 330             5500
7000
15956            11                 310             3500
5500
15957             0                   0             2100
2900
15958             0                   0             4600
0

       High_Cloud_Ht_ft  Visibility_mi  Atm_Press_hPa
Sea_Lev_Press_hPa  \
0                     0             10          994.7
1017.8
1                     0             10          994.7
1017.7
2                     0             10          994.7
1017.8
3                     0             10          994.7
1017.8
4                     0             10          994.7
1017.9
...                 ...            ...            ...                .
..
```

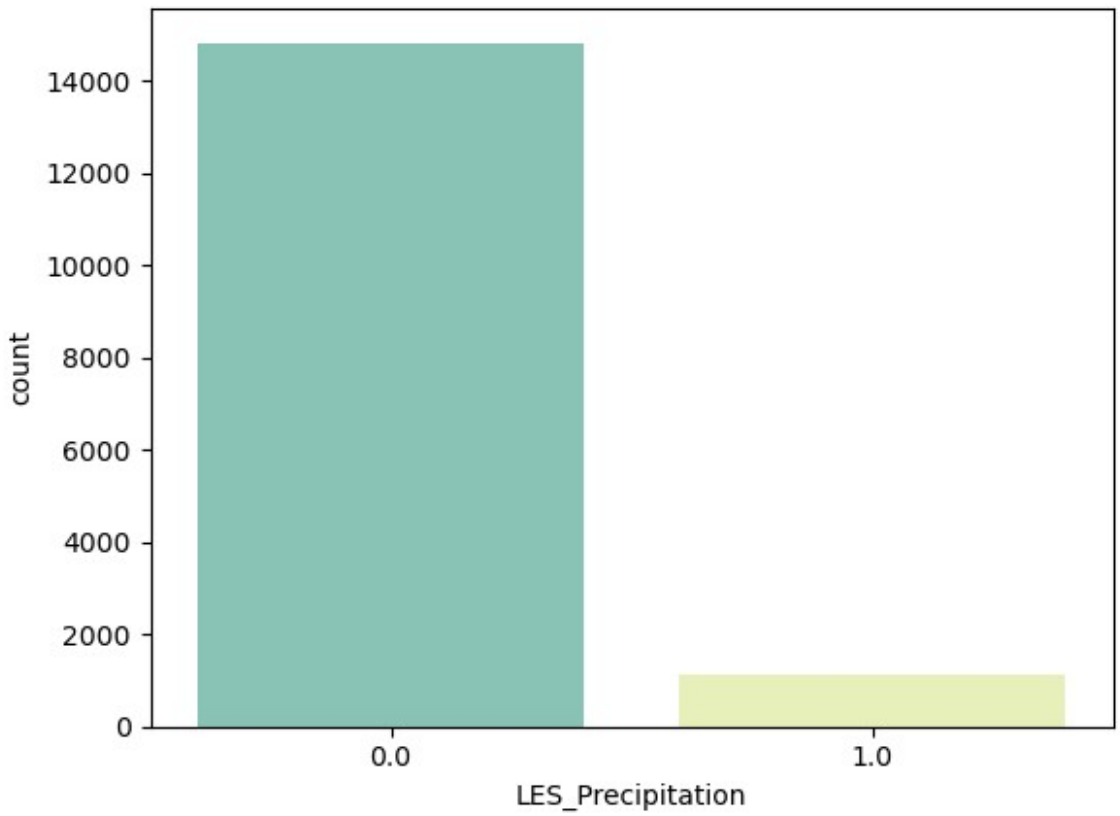
```
15954                   0              10           989.0
1012.6
15955                   0              10           989.3
1012.8
15956                   0              10           990.7
1014.1
15957                5000              10           991.0
1014.6
15958                   0              10           991.7
1015.0
```

	Altimeter_hPa	Precip_in	LES_Snowfall	LES_Precipitation
0	1017.6	0.0	0.0	0.0
1	1017.6	0.0	0.0	0.0
2	1017.6	0.0	0.0	0.0
3	1017.6	0.0	0.0	0.0
4	1017.6	0.0	0.0	0.0
...	...	...	...	...
15954	1011.9	0.0	0.0	0.0
15955	1012.2	0.0	0.0	0.0
15956	1013.5	0.0	0.0	0.0
15957	1013.9	0.0	0.0	0.0
15958	1014.6	0.0	0.0	0.0

```
[15959 rows x 18 columns]
```

```
sns.countplot(x = filtered_les['LES_Precipitation'],
palette=["#7fcdbb", "#edf8b1"])
```

```
<AxesSubplot:xlabel='LES_Precipitation', ylabel='count'>
```



Predicting Cloud patterns

This means we are going to live with the nighttime discontinuity in imagery.

First, load all 64 × 64 images, with cropping of an 8-pixel border all around the lake:

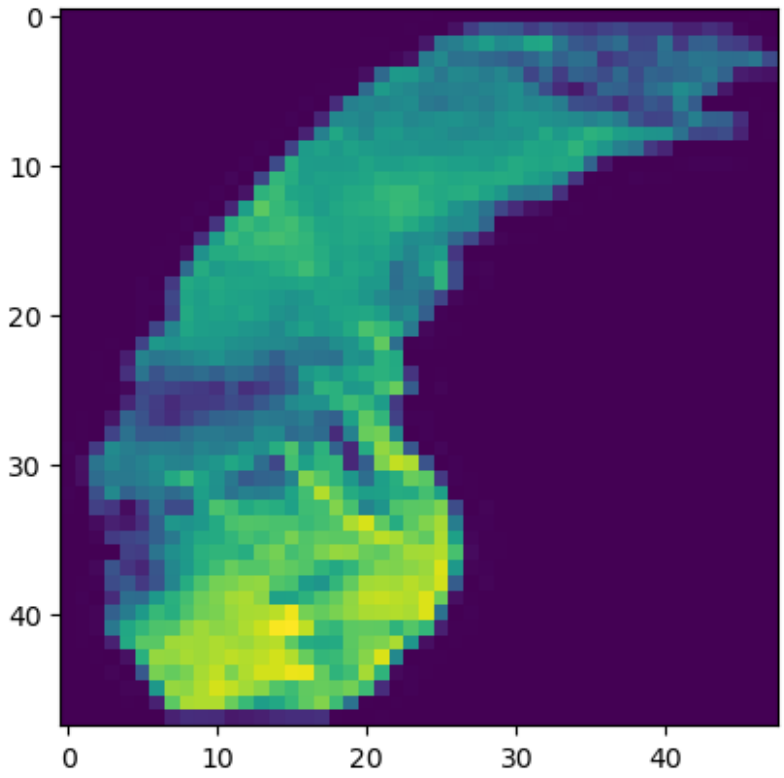
```
from tqdm import tqdm
import cv2

images = []
for idx in tqdm(range(15959)):
    # im shape -> (64, 64)
    im = cv2.imread('D:/user/docs/NU/_Noctis/lake-michigan-images-64/'
+ str(idx) + '.png')
    # Storing 1 channel, since the images are grayscale, and cropping
    images.append(im[8:-8,8:-8,0])
    # images shape -> (35, 64, 64)

100%|██████████| 15959/15959 [00:32<00:00, 492.98it/s]

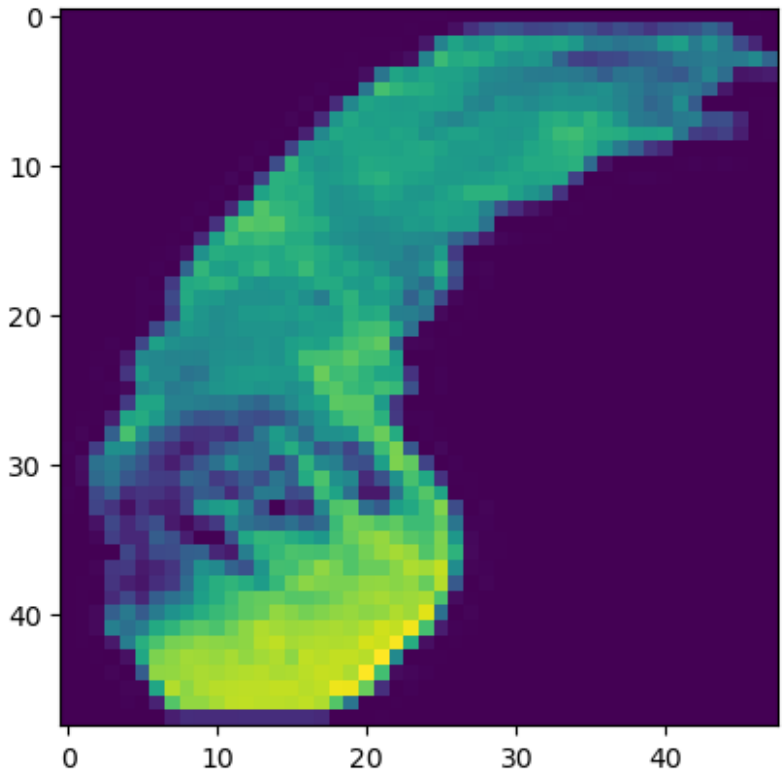
plt.imshow(images[146])

<matplotlib.image.AxesImage at 0x2124eac9730>
```




```
plt.imshow(images[147])
```

```
<matplotlib.image.AxesImage at 0x2124eaffb50>
```




```
from PIL import Image, ImageOps
Image.open('D:/user/docs/NU/_Noctis/lake-michigan-images-64/147.png')
```

```
full = np.full(im.shape, 255)
mask = (full - img).astype(np.uint8)
mask = (0 < mask).astype(int)
mask
```

```
array([[0, 0, 0, ..., 0, 0, 0],
       [0, 0, 0, ..., 0, 0, 0],
       [0, 0, 0, ..., 0, 0, 0],
       ...,
       [0, 0, 0, ..., 0, 0, 0],
       [0, 0, 0, ..., 0, 0, 0],
       [0, 0, 0, ..., 0, 0, 0]])
```

Cloud Sequence Visualization

Our data consists of sequences of frames, each of which are used to predict the upcoming frame. Let's take a look at some of these sequential frames.

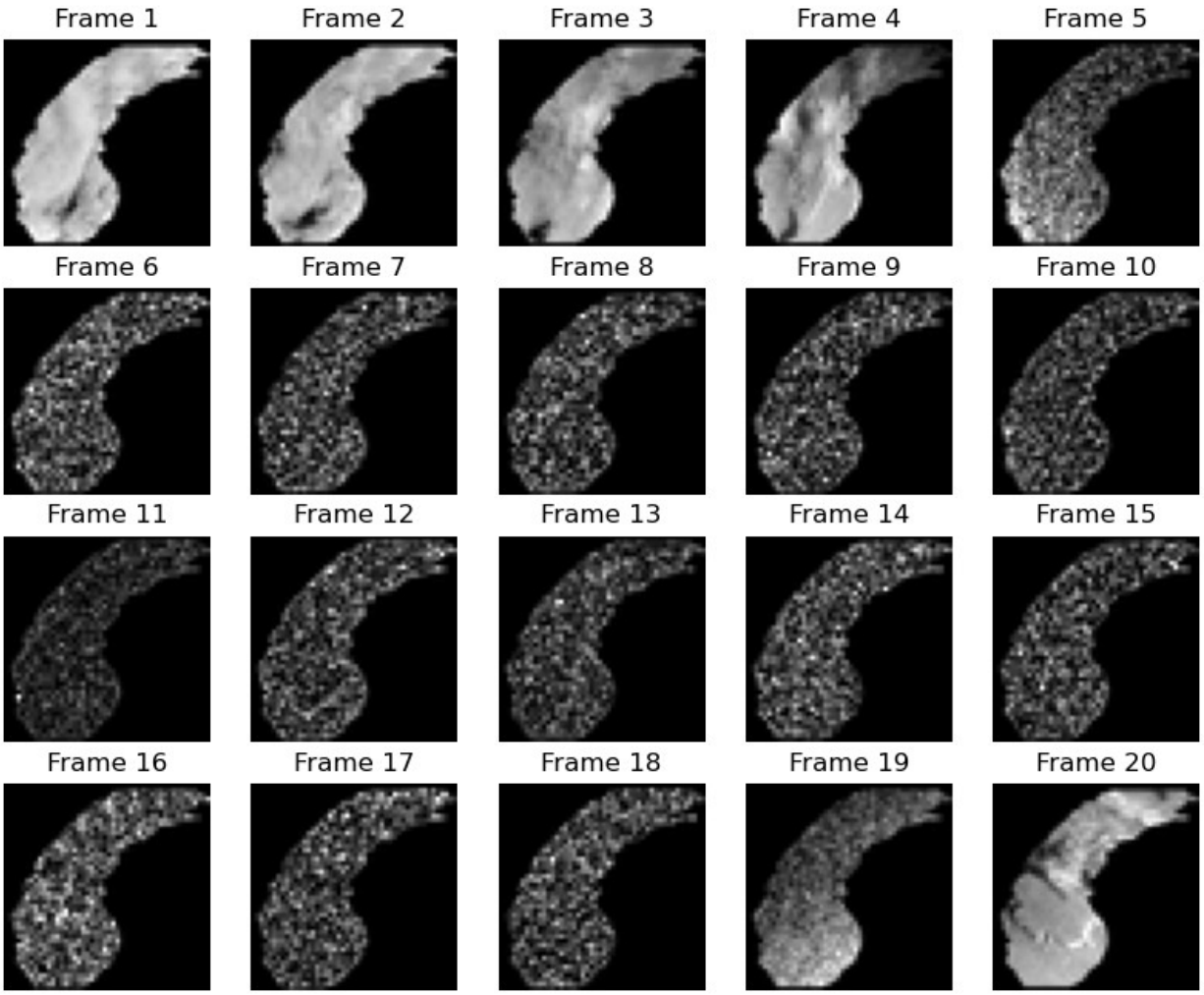
> **Note**: Do not run the next cell because it shows an example that includes corrupt images (ones with just nans):

```
# Construct a figure on which we will visualize the images.
fig, axes = plt.subplots(4, 5, figsize=(10, 8))

# Plot each of the sequential images for one random data example.
data_choice = np.random.choice(range(len(images)), size=1)[0]
for idx, ax in enumerate(axes.flat):
    ax.imshow(images[data_choice + idx], cmap="gray")
    ax.set_title(f"Frame {idx + 1}")
    ax.axis("off")

# Print information and display the figure.
print(f"Displaying next frames starting at image {data_choice}.")
plt.show()
```

```
Displaying next frames starting at image 11491.
```



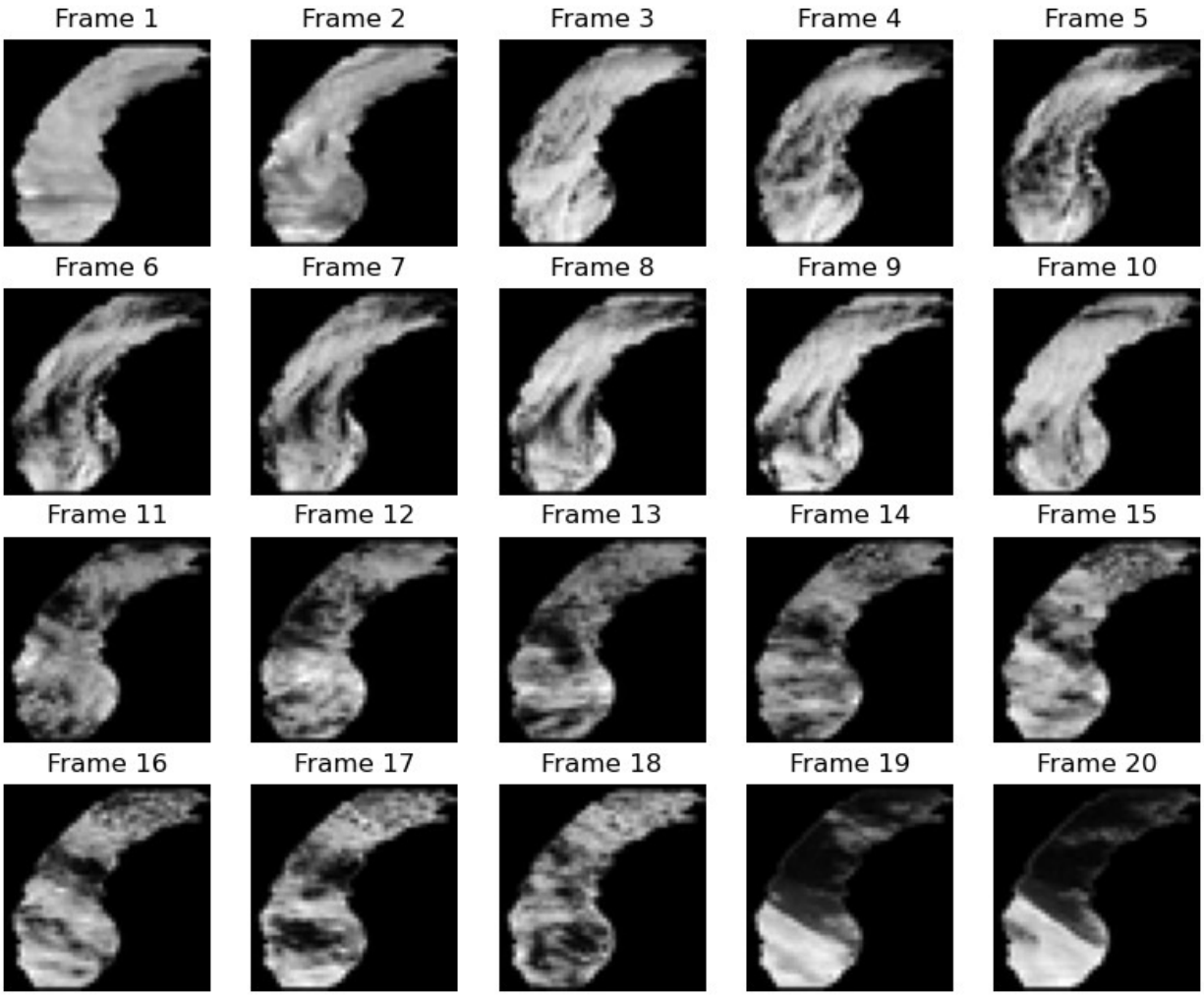
Run this one instead, whcih displays a valid sequence of images:

```
# Construct a figure on which we will visualize the images.
fig, axes = plt.subplots(4, 5, figsize=(10, 8))

# Plot each of the sequential images for one random data example.
data_choice = np.random.choice(range(len(images)), size=1)[0]
for idx, ax in enumerate(axes.flat):
    ax.imshow(images[data_choice + idx], cmap="gray")
    ax.set_title(f"Frame {idx + 1}")
    ax.axis("off")

# Print information and display the figure.
print(f"Displaying next frames starting at image {data_choice}.")
plt.show()
```

```
Displaying next frames starting at image 4446.
```



Since daytime only consists of 7 hours, this image sequence of length 20 obligatorily includes nighttimes. In other words, there is an image above that jumps over nighttime and thus is more discontinuous in cloud cover.

20 images is about 3 days (3×7).

As an exercise, let's see if based on 6 hours of cloud cover, we can predict the 7th hour.

We are going to use 6 sequential images as the input, and the next (shifted by 1) 6 images as output.