Thunder Prediction

Bad weather classification

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CivEng 290-002

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Outline

1. Motivation
2. Data Preparation
3. Exploratory Data Analysis
4. Classification Methods
5. Future Improvements
6. Challenges

Motivation

Predict bad weathers to prepare for flight planning / trajectory optimization

Data Preparation

Raw Data

FEDERAL CLIMATE COMPLEX
DATA DOCUMENTATION
FOR
INTEGRATED SURFACE DATA
(ISD)

January 12, 2018

NOAA - National Centers for Environmental Information
US Air Force - 14th Weather Squadron
151 Patton Avenue
Asheville, NC 28801-5001 USA

Time Range: 1901 - 2022
Granularity: Hourly
24*365 = 8760 observations / station / year
Variables: 79 Features, Sparse

Global Hourly Data

	STATION	DATE	SOURCE	LATITUDE	LONGITUDE	ELEVATION	NAME	REPORT_TYPE	CALL_SIGN	QUALITY_CONTROL	...	MW2	MW3	MW4	MW5
0	72243012960	2000-01-01T00:00:00	3	29.98	-95.36	29.0	HOUSTON INTERCONTINENTAL AIRPORT, TX US	SY-MT	IAH	V020	...	NaN	NaN	NaN	NaN
1	72243012960	2000-01-01T00:53:00	C	29.98	-95.36	29.0	HOUSTON INTERCONTINENTAL AIRPORT, TX US	FM-15	IAH	V020	...	NaN	NaN	NaN	NaN

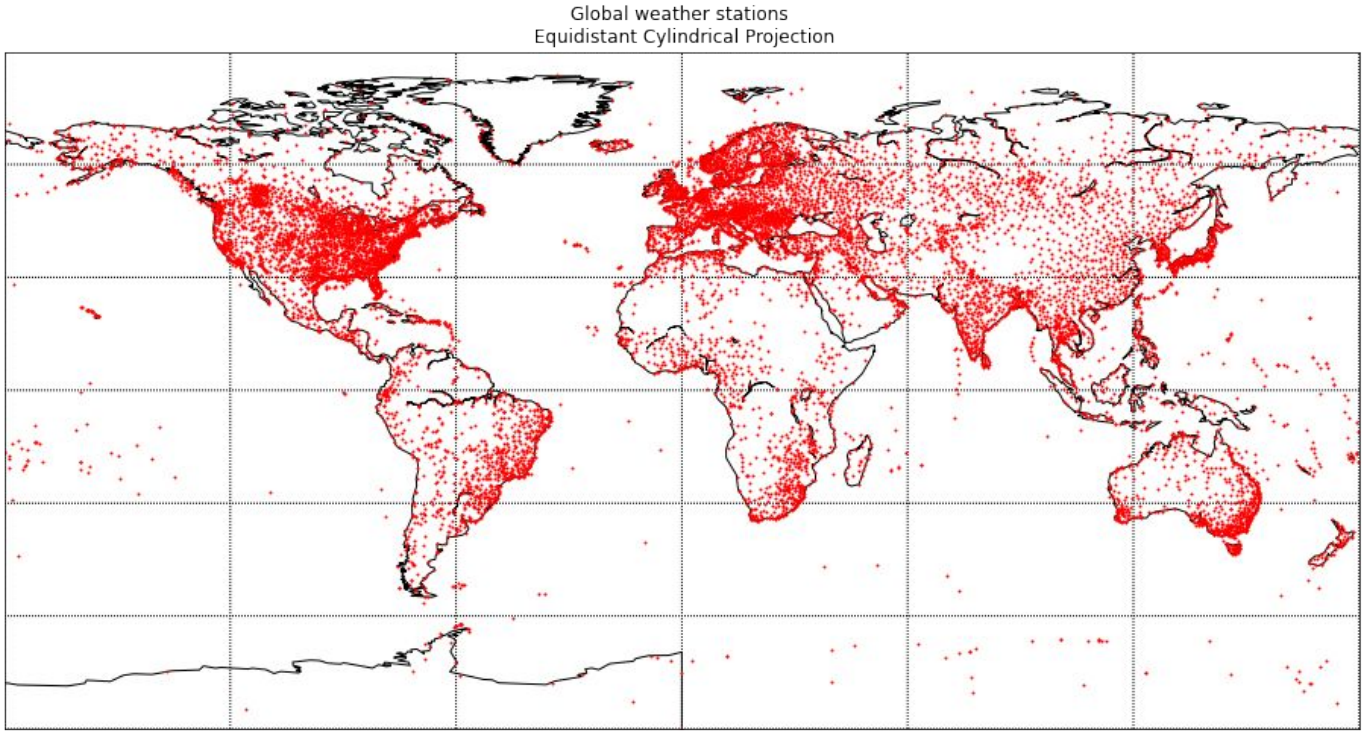
Data Cleaning

1. Select and Parse columns
   ['DATE','WND','CIG','VIS','TMP','DEW''AT1','AT2','AT3']
   Single column contain multiple information
   Examples:
      'WND': 999,9,C,0000,5
      'AT1': MW,01,FG ,5
2. Replace "999" as NaN
3. Fill NaN forward & backward
4. Get binary values of AT (daily weather observation)
5. Generalize weather observation to 1 day (Assumption!)

Loop for selected stations over selected time,
Concatenate Data Frames

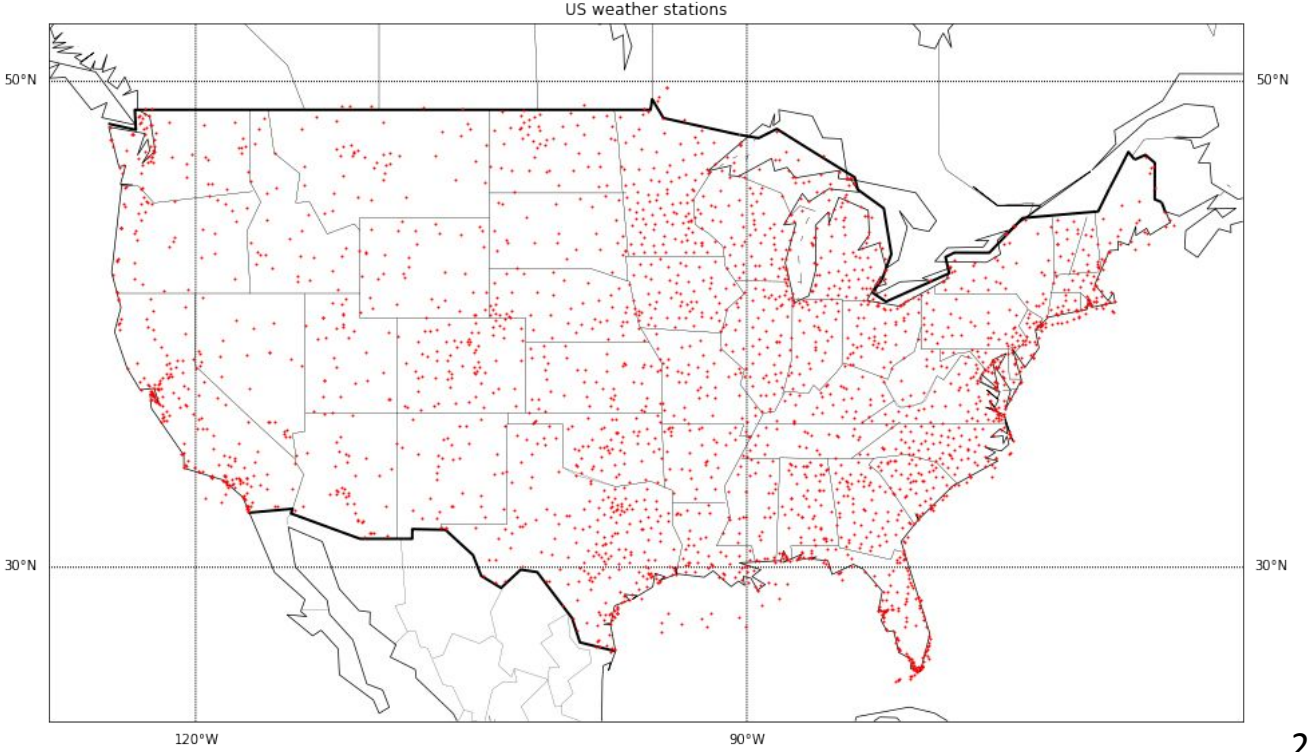
Exploratory Data Analysis

Stations Overview - World



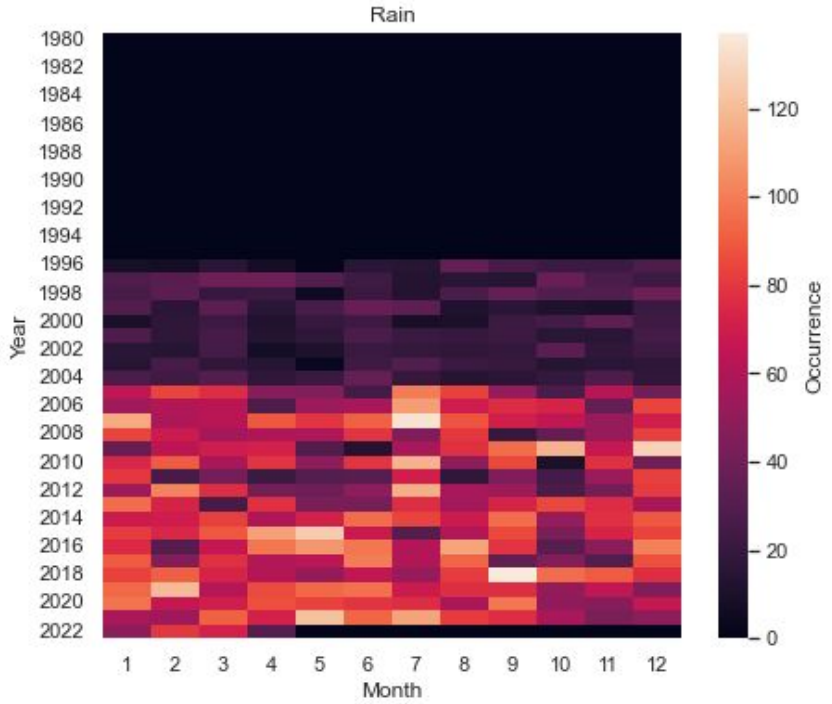
NOAA - Global Hourly
12981 Stations Worldwide

Stations Overview - US



2824 Stations in US
173 Stations in California
217 Stations in Texas

Monthly Overview - Raw Data Heat Map



- Houston, TX area (~ 4.8 million samples)
- Missing Data until ~1995
- Less Data between 1995 ~ 2003

- Cleaned irrelevant and faulty data
- Removed repeating samples
- Data transformation
- Rebuild the data set for analysis

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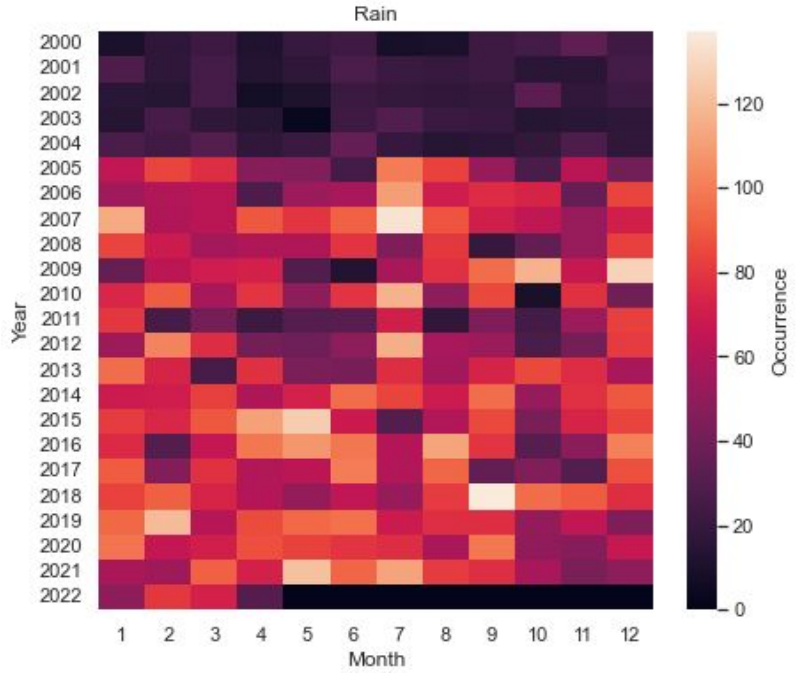
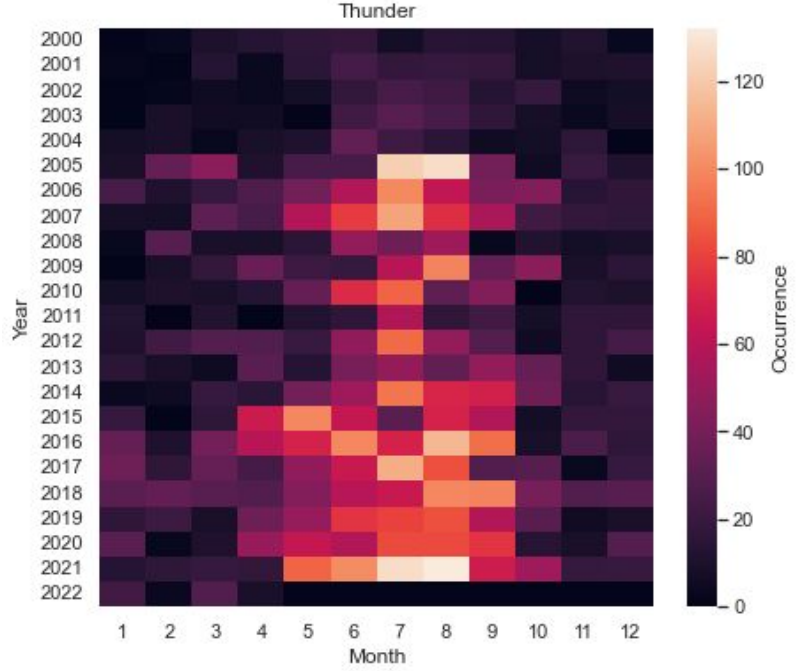
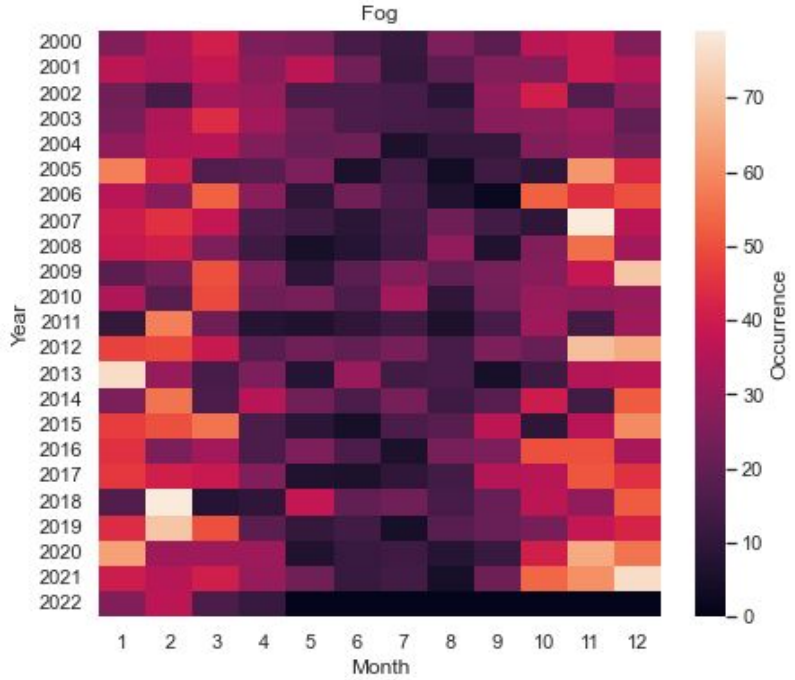
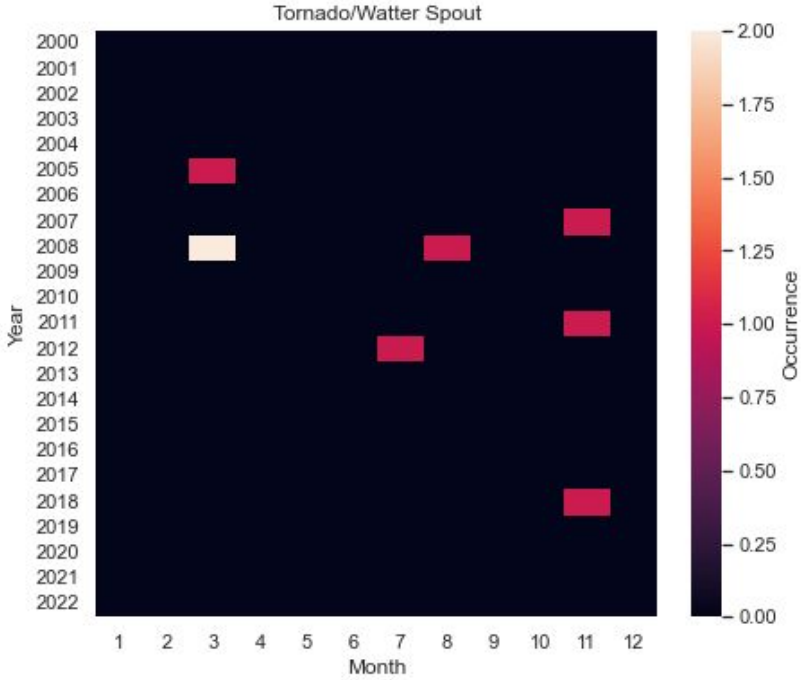
Monthly Overview - RAIN / THUNDER





Monthly Overview - FOG / TORNADO





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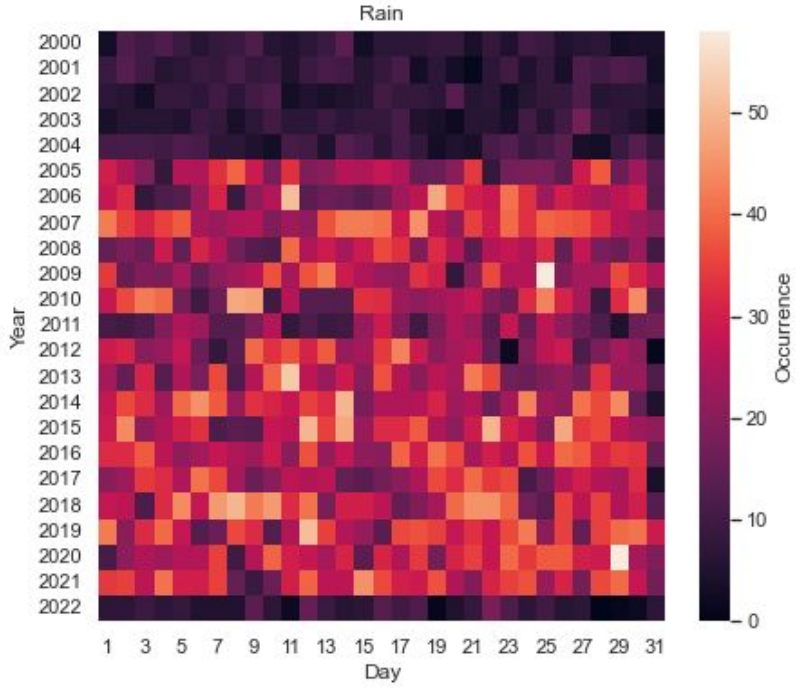
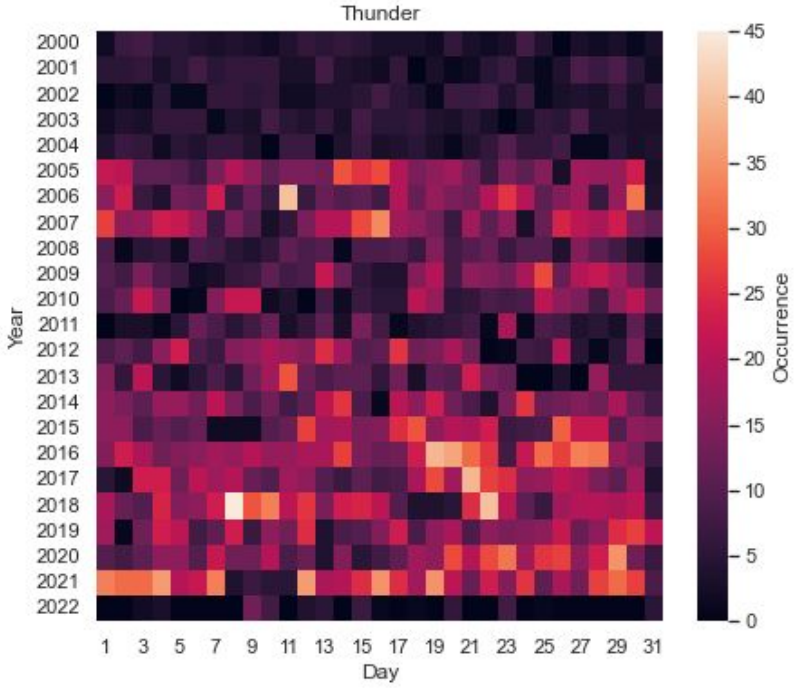
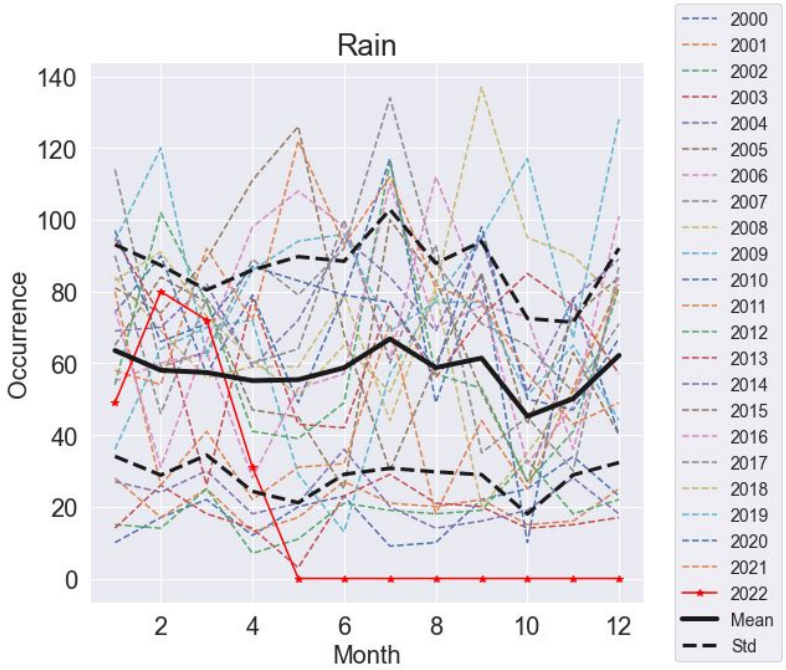
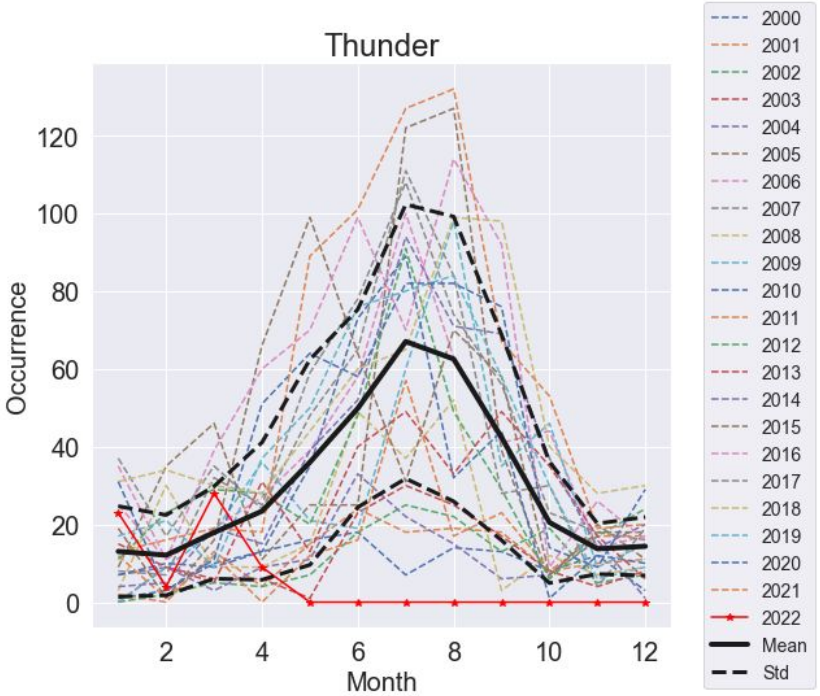
Daily Overview - RAIN / THUNDER



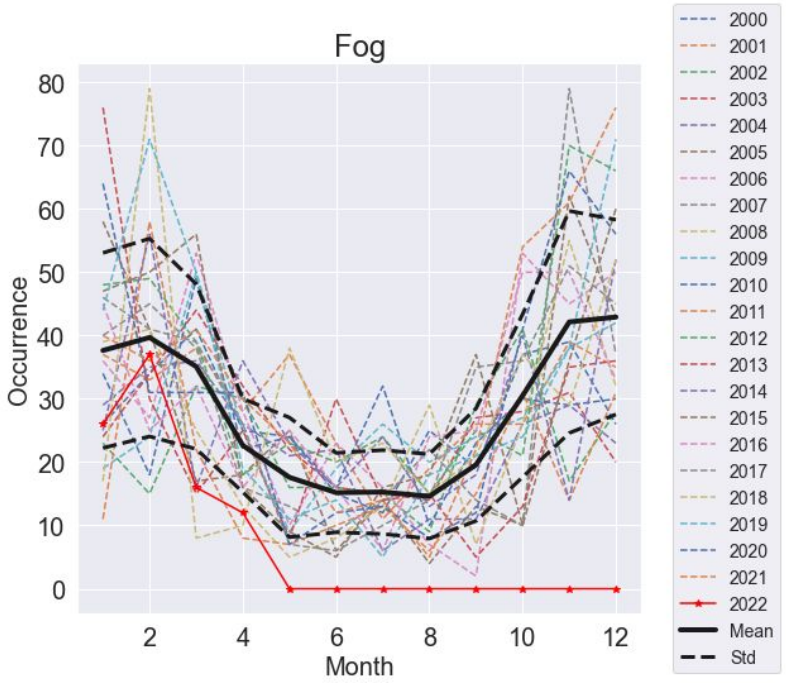


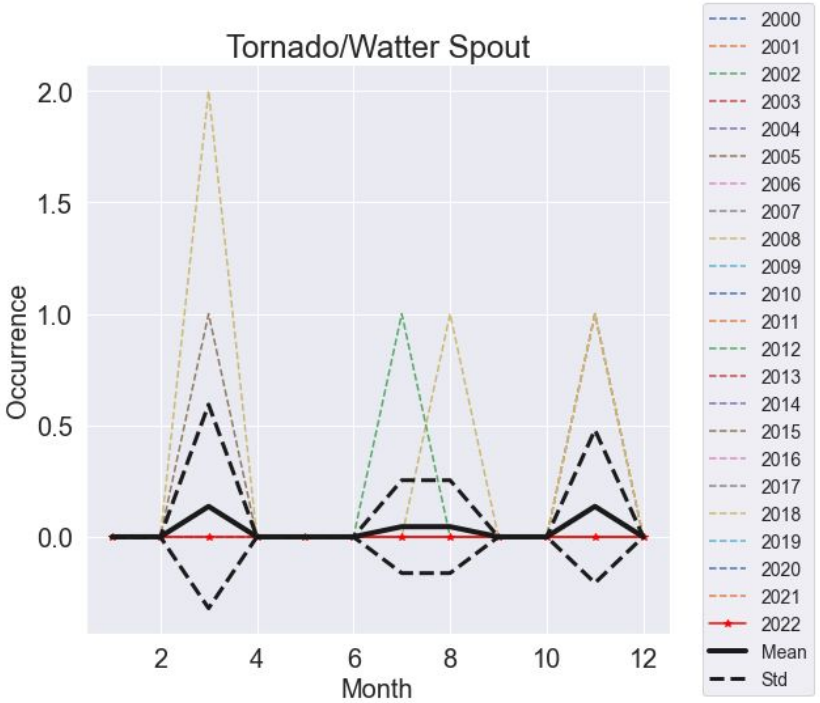
Statistics over Yearly & Monthly Date





Statistics over Yearly & Monthly Date





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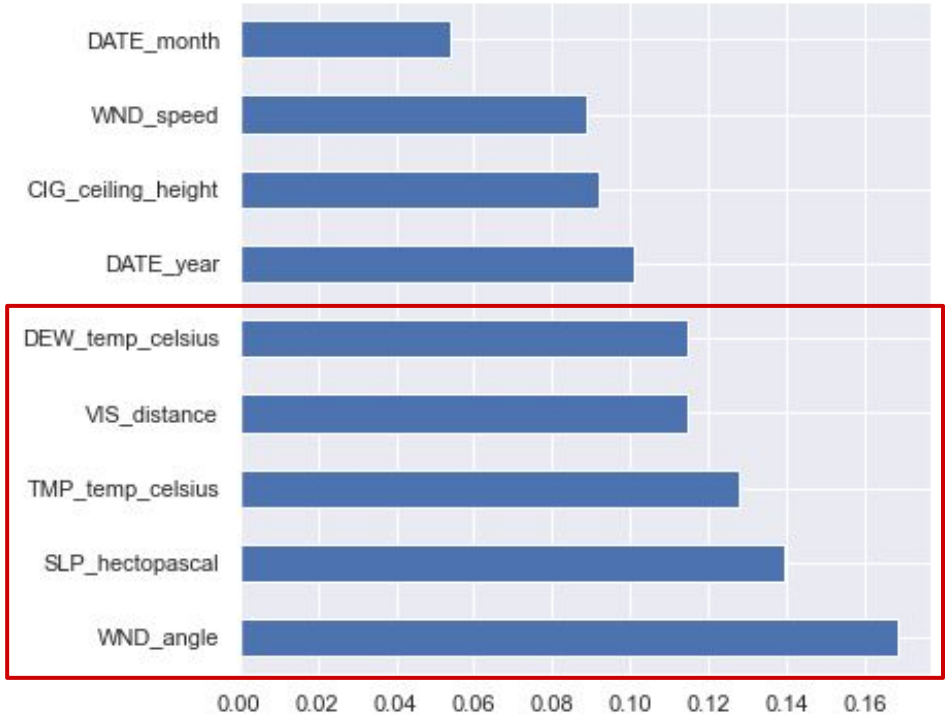
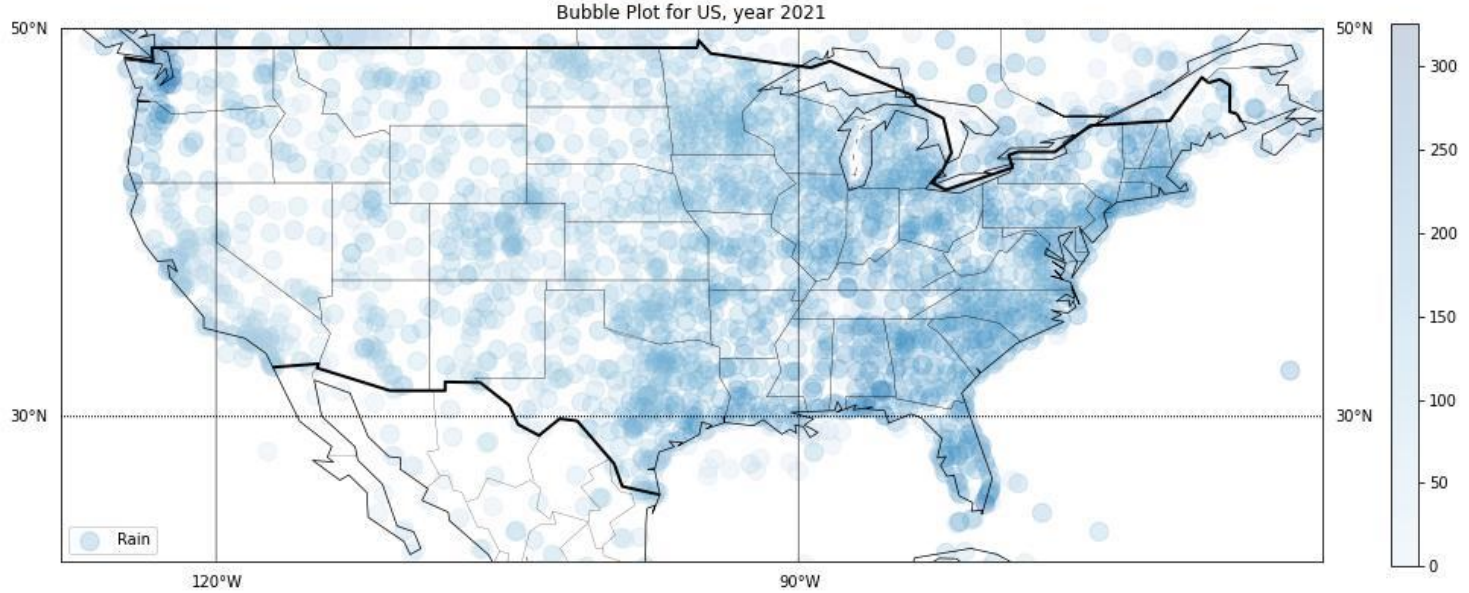
Feature Importance in Bad Weather Report



- SLP: Sea Level Pressure
- TMP: Temperature
- VIS: Visible Distance
- CIG: Ceiling Height

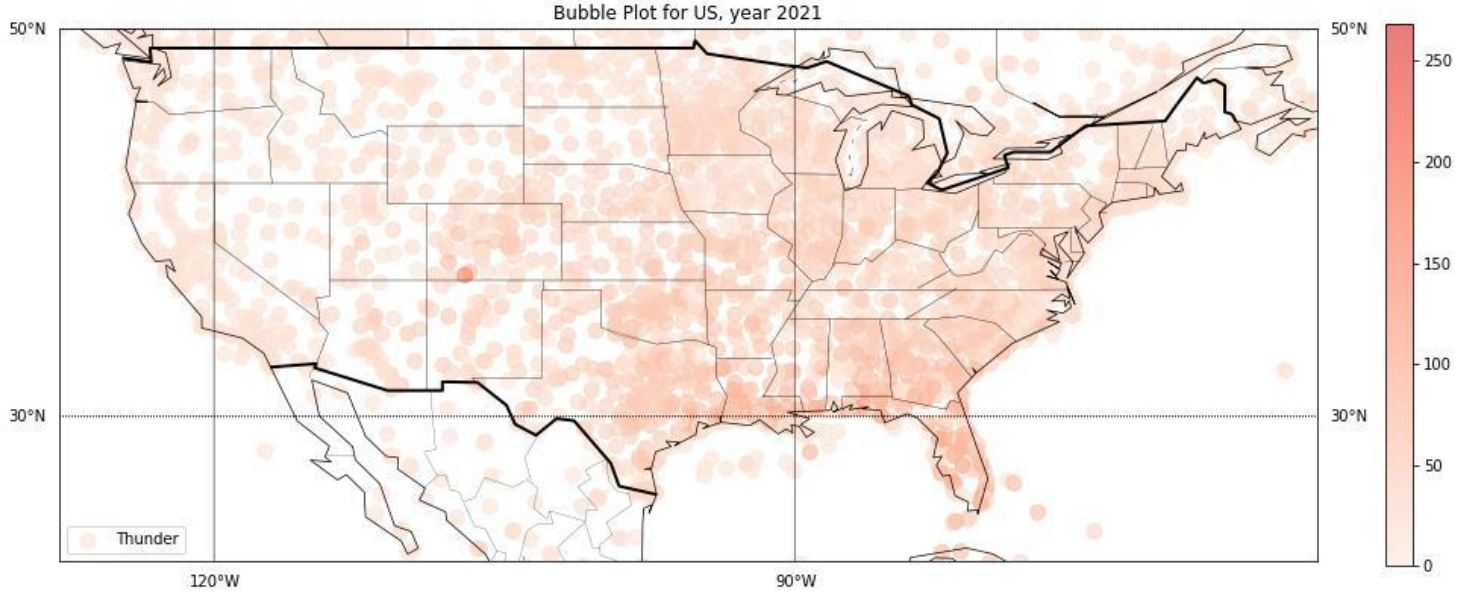
Bubble Map of Weathers (RAIN) - US



Color Gradient ~ Number of weathers occured

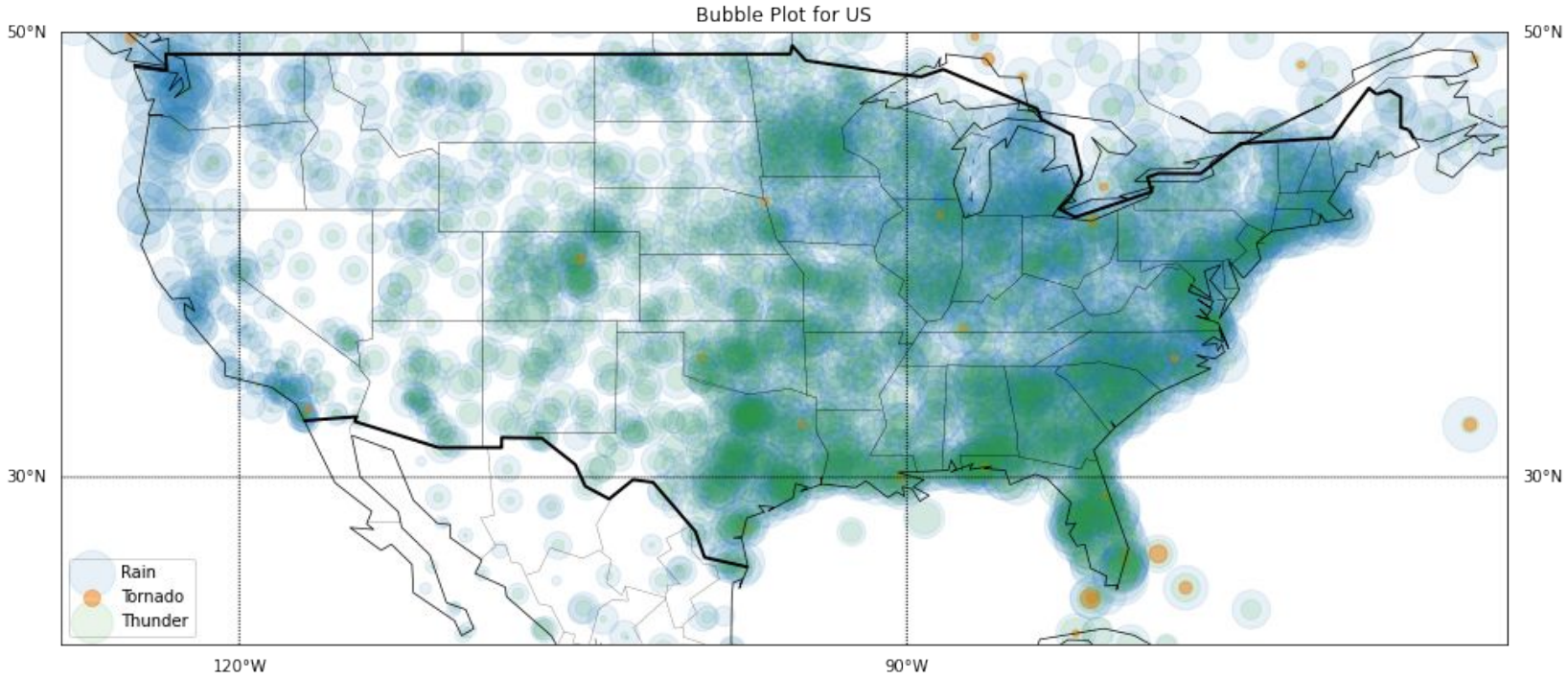
Bubble Map of Weathers (THUNDER) - US

TORNADO?



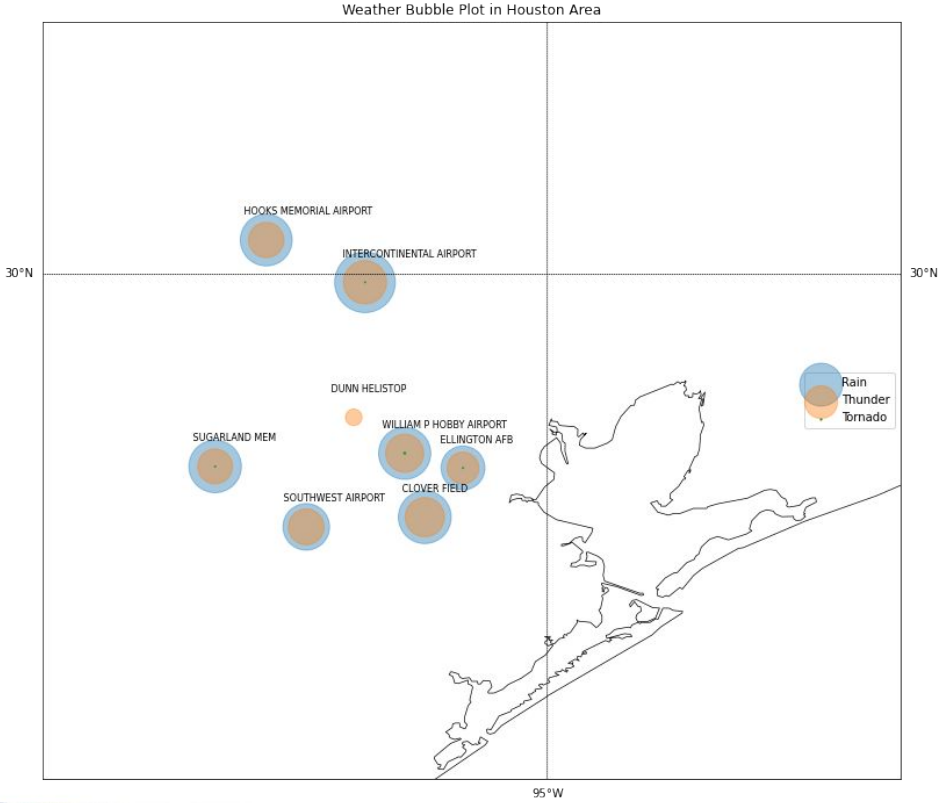
Color Gradient ~ Number of weathers occured

Bubble Map of Weathers - US



Marker Size ~ Number of weathers occured

Bubble Map of Weathers - Houston Area



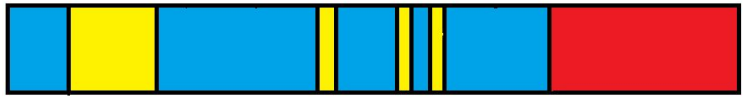
Marker Size ~ Number of weathers occured

Classification Methods

Data

We select one station: Houston Airport
Time range: Year 2000 - 2022
Dataset shape: 309,428 observations

Train-Validation-Test Split: 70-15-15
- Train+Val & Test Splits according to time (non-shuffle)
- Train & Val split with shuffle



Supervised Learning

Baseline: Majority rule
- 18% thunders -> Predict all data as non-thunder
- Baseline accuracy for test set is 0.798

Training data shape:
X: (215670, 13)
Y: (215670, 1)

X:
DATE: year,month,day,hour
Latitude, Longitude
Wind angle
Wind speed
Ceiling height
Visibility
Temperature
Dew point temperature
Sea level pressure

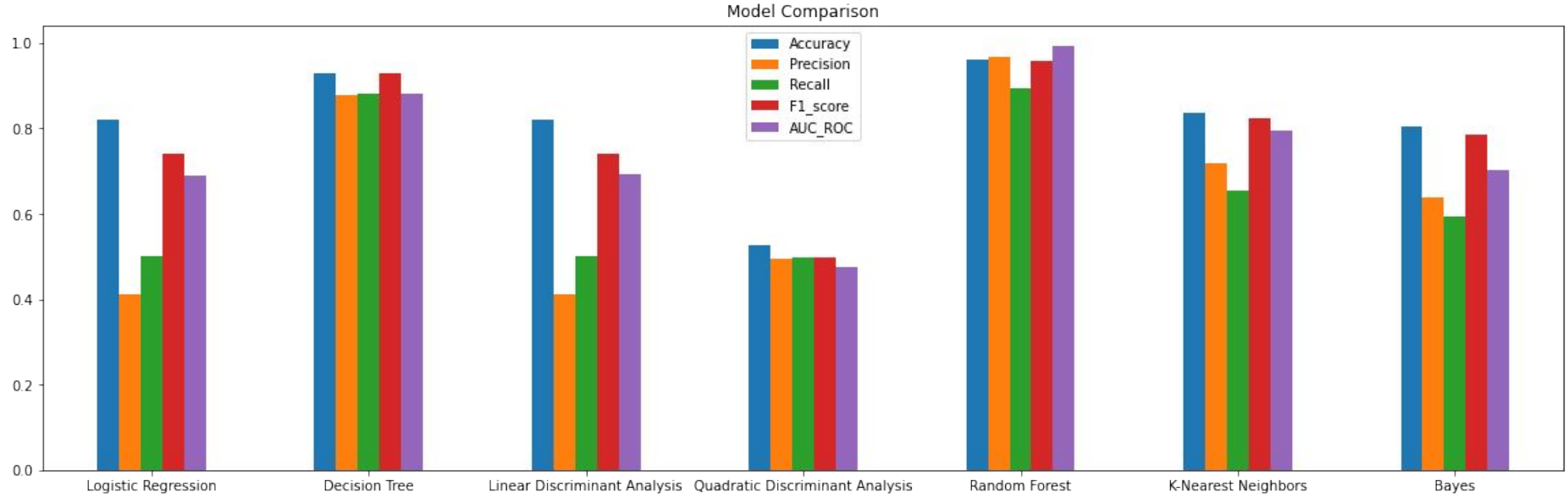
Y:
Thunder_binary

DATE_year	DATE_month	DATE_day	DATE_hour	LATITUDE	LONGITUDE	WND_angle	WND_speed	CIG_ceiling_height	VIS_distance	TMP_temp_celsius	DEW_temp_celsius	SLP_hectopascal
2005	7	27	14	29.98	-95.36	230.0	3.1	7620.0	16093.0	28.9	23.3	1016.6
2004	8	28	5	29.98	-95.36	190.0	1.5	22000.0	16093.0	26.0	24.0	1015.5
2006	10	18	23	29.98	-95.36	50.0	4.1	671.0	2414.0	25.0	23.0	1006.5

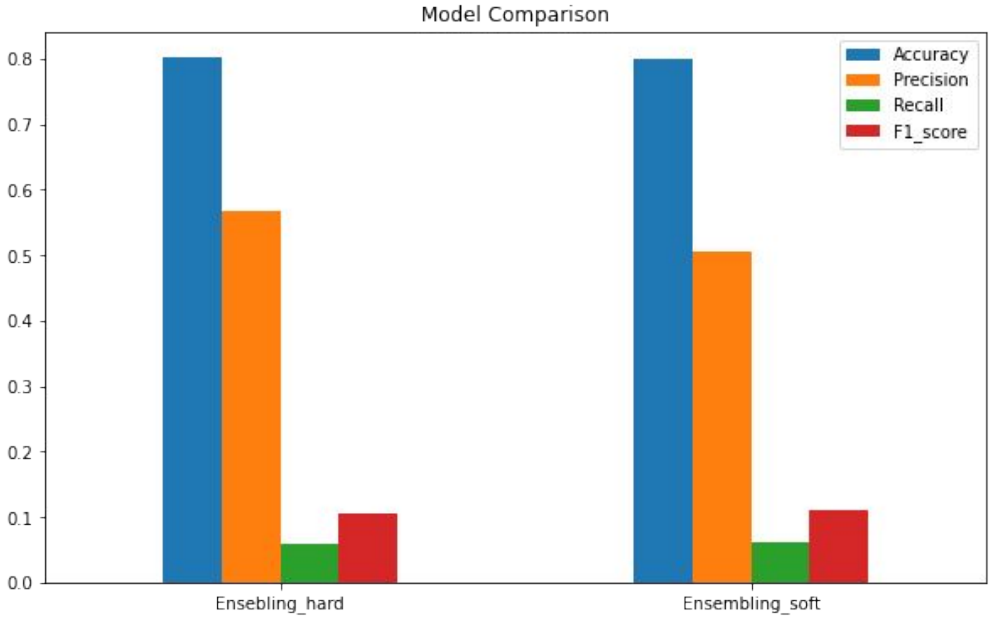
Model Comparison

	Model	Fitting time	Scoring time	Accuracy	Precision	Recall	F1_score	AUC_ROC
4	Random Forest	23.583221	0.611752	0.959531	0.966304	0.894381	0.957838	0.992388
1	Decision Tree	1.281843	0.026187	0.929693	0.879450	0.881624	0.929790	0.881624
5	K-Nearest Neighbors	0.408562	3.324306	0.836866	0.719312	0.655562	0.823084	0.795989
0	Logistic Regression	1.314030	0.020501	0.821422	0.410711	0.500000	0.740887	0.688961
2	Linear Discriminant Analysis	0.433447	0.031723	0.821422	0.410711	0.500000	0.740887	0.692926
6	Bayes	0.101537	0.028895	0.804331	0.638136	0.593777	0.785782	0.700893
3	Quadratic Discriminant Analysis	0.189265	0.034565	0.525873	0.493154	0.496627	0.497315	0.476229

Model Comparison - Training Set

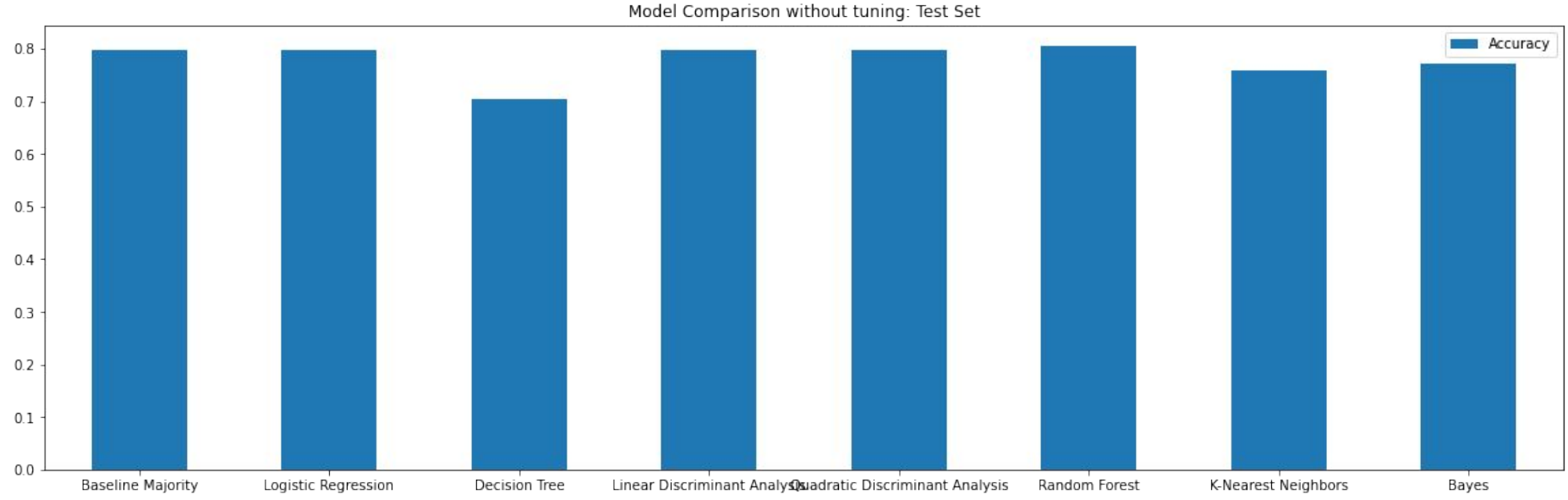


Ensemble Method - Training Set



	Model	Accuracy	Precision	Recall	F1_score	AUC_ROC
0	Ensebling_hard	0.80125	0.567992	0.058044	0.105324	not applicable
1	Ensembling_soft	0.79875	0.506173	0.061358	0.109448	0.686952

Model Comparison - Without tuning



	Model	Accuracy
5	Random Forest	0.804481
0	Baseline Majority	0.798449
1	Logistic Regression	0.798449
3	Linear Discriminant Analysis	0.798449
4	Quadratic Discriminant Analysis	0.798039
7	Bayes	0.771453
6	K-Nearest Neighbors	0.758268
2	Decision Tree	0.703889

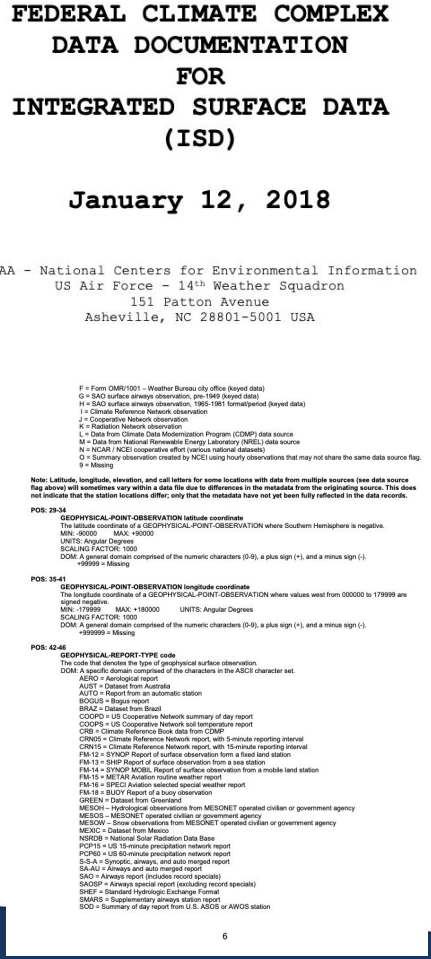
Future improvements

- Fine tunings according to validation set
  - Features selection
  - Parameters selection
- Detailed analysis
  - Confusion matrix visualize
- Other models
  - NN
  - Time series
- Multiclass- MultiOutput classifiers
- Oversampling
  - Imbalanced data
- Model using more stations
  - Sampling, PCA
  - Computing power ?
- Various weather prediction/classification
  - Improve model to predict more various types of bad weather
- Different data source/format
  - Using global daily summary dataset

Challenges & Lessons learned

- Large file size when bulk downloading
- Data formats are messy, missing, sparse
  - Parse & extract according to documentation
- Data preprocessing eating up RAM
  - Preprocess each .csv then combine
- Data storing taking up enormous disk space
- SVM & NN takes long time to train
- Feasibility of the classification models

2013.tar.gz	2021-02-05 13:50	4.2G
2014.tar.gz	2021-02-04 19:30	4.4G
2015.tar.gz	2021-02-04 19:13	4.5G
2016.tar.gz	2021-02-04 19:51	4.5G
2017.tar.gz	2020-12-07 00:21	4.6G
2018.tar.gz	2020-12-06 08:51	4.6G
2019.tar.gz	2020-10-24 01:16	4.7G
2020.tar.gz	2021-02-28 07:25	4.6G
2021.tar.gz	2022-02-09 00:35	4.6G



FEDERAL CLIMATE COMPLEX
DATA DOCUMENTATION
FOR
INTEGRATED SURFACE DATA
(ISD)

January 12, 2018

NOAA - National Centers for Environmental Information
US Air Force - 14th Weather Squadron
151 Patton Avenue
Asheville, NC 28801-5001 USA

F = Form OMR/1001 – Weather Bureau city office (keyed data)
G = SAO surface airways observation, pre-1949 (keyed data)
H = SAO surface airways observation, 1965-1981 format/period (keyed data)
I = Climate Reference Network observation
J = Cooperative Network observation
K = Radiation Network observation
L = Data from Climate Data Modernization Program (CDMP) data source
M = Data from National Renewable Energy Laboratory (NREL) data source
N = NCAR / NCEI cooperative effort (various national datasets)
O = Summary observation created by NCEI using hourly observations that may not share the same data source flag.
9 = Missing

Note: Latitude, longitude, elevation, and call letters for some locations with data from multiple sources (see data source flag above) will sometimes vary within a data file due to differences in the metadata from the originating source. This does not indicate that the station locations differ; only that the metadata have not yet been fully reflected in the data records.

POS: 29-34
GEOPHYSICAL-POINT-OBSERVATION latitude coordinate
The latitude coordinate of a GEOPHYSICAL-POINT-OBSERVATION where Southern Hemisphere is negative.
MIN: -90000 MAX: +90000
UNITS: Angular Degrees
SCALING FACTOR: 1000
DOM: A general domain comprised of the numeric characters (0-9), a plus sign (+), and a minus sign (-).
+99999 = Missing

POS: 35-41
GEOPHYSICAL-POINT-OBSERVATION longitude coordinate
The longitude coordinate of a GEOPHYSICAL-POINT-OBSERVATION where values west from 000000 to 179999 are signed negative.
MIN: -179999 MAX: +180000 UNITS: Angular Degrees
SCALING FACTOR: 1000
DOM: A general domain comprised of the numeric characters (0-9), a plus sign (+), and a minus sign (-).
+999999 = Missing

POS: 42-46
GEOPHYSICAL-REPORT-TYPE code
The code that denotes the type of geophysical surface observation.
DOM: A specific domain comprised of the characters in the ASCII character set.
AERO = Aerological report
AUST = Dataset from Australia
AUTO = Report from an automatic station
BOGUS = Bogus report
BRAZ = Dataset from Brazil
COOPD = US Cooperative Network summary of day report
COOPS = US Cooperative Network soil temperature report
CRB = Climate Reference Book data from CDMP
CRN05 = Climate Reference Network report, with 5-minute reporting interval
CRN15 = Climate Reference Network report, with 15-minute reporting interval
FM-12 = SYNOP Report of surface observation form a fixed land station
FM-13 = SHIP Report of surface observation from a sea station
FM-14 = SYNOP MOBIL Report of surface observation from a mobile land station
FM-15 = METAR Aviation routine weather report
FM-16 = SPECI Aviation selected special weather report
FM-18 = BUOY Report of a buoy observation
GREEN = Dataset from Greenland
MESOH = Hydrological observations from MESONET operated civilian or government agency
MESOS = MESONET operated civilian or government agency
MESOW = Snow observations from MESONET operated civilian or government agency
MEXIC = Dataset from Mexico
NSRDB = National Solar Radiation Data Base
PCP15 = US 15-minute precipitation network report
PCP60 = US 60-minute precipitation network report
S-S-A = Synoptic, airways, and auto merged report
SA-AU = Airways and auto merged report
SAO = Airways report (includes record specials)
SAOSP = Airways special report (excluding record specials)
SHEF = Standard Hydrologic Exchange Format
SMARS = Supplementary airways station report
SOD = Summary of day report from U.S. ASOS or AWOS station

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Thank you!

Any Questions?