

Configuration Manual

MSc Research Project Data Analytics

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Configuration Manual

Edmond Connolly 16126556

1 Introduction

The following document will provide an illustration of the steps taken in order to model a time series forecast of Irelands Electricity consumption.

2 System Information

2.1 System Hardware

The implementation of this project was conducted in windows 10 home. The processor was an intel i7 and the environment operated with 16gb of ram. For a full system specification please refer to *figure 1*.

Item	Value
OS Name	Microsoft Windows 10 Home
Version	10.0.19041 Build 19041
Other OS Description	Not Available
OS Manufacturer	Microsoft Corporation
System Name	DESKTOP-OC5C7O2
System Manufacturer	System manufacturer
System Model	System Product Name
System Type	x64-based PC
System SKU	ASUS_MB_CNL
Processor	Intel(R) Core(TM) i7-9700K CPU @ 3.60GHz, 3600 Mhz, 8 Core(s), 8 Logical Pr
BIOS Version/Date	American Megatrends Inc. 1302, 02/09/2019
SMBIOS Version	3.2
Embedded Controller Version	255.255
BIOS Mode	UEFI
BaseBoard Manufacturer	ASUSTEK COMPUTER INC.
BaseBoard Product	PRIME Z390-A
BaseBoard Version	Rev 1.xx
Platform Role	Desktop
Secure Boot State	Off
PCR7 Configuration	Binding Not Possible
Windows Directory	C:\Windows
System Directory	C:\Windows\system32
Boot Device	\Device\HarddiskVolume1
Locale	United Kingdom
Hardware Abstraction Layer	Version = "10.0.19041.1151"
Username	DESKTOP-OC5C7O2\edoco
Time Zone	GMT Summer Time
Installed Physical Memory (RAM)	16.0 GB
Total Physical Memory	15.9 GB
Available Physical Memory	6.84 GB
Total Virtual Memory	32.9 GB
Available Virtual Memory	16.9 GB
Page File Space	17.0 GB

Figure 1	:	System	Information	
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2.2 System Software

An Annaconda environment was created to install all the necessary Python 3 Packages for conducting the research. The preprocessing of data took place in exclusively in Jupyter notebooks and Microsoft Excel. Jupyter Notebooks was used for preliminary data exploration and to impute missing values and encode the days of the week. Output csvs' were aggregated and further processed in Excel. The Spyder programming editor was used for the implementation of the Sarimax and LSTM models. The Sarimax model was developed with pythons statsmodels package. The output was visualised with matplotlib. The LSTM was developed with the Keras library.

The figures below refer to the packages employed at each stage of the project. *figure* 2 refers to the packages used in the preprocessing stage. This stage often included outputting data to csvs' for further preprocessing in Excel. *Figure 24* is a list of the packages employed in the implementation and Evaluation of the Sarimax model. *Figure* 4 are the packages from which the LSTM was developed.

```
import csv
import os
import pandas as pd
import numpy as np
import sklearn
from pandas import read_csv
from numpy import isnan
from sklearn.impute import KNNImputer
pd.set_option("display.max_columns", None)
pd.set_option("display.max_rows", None)
```

Figure 2: Preprocessing Packages

```
1 import pandas as pd
2 import numpy as np
3 import matplotlib.pyplot as plt
4 import statsmodels.graphics.tsaplots as sgt
5 import statsmodels.tsa.stattools as sts
6 from statsmodels.tsa.seasonal import STL
7 from statsmodels.tsa.statespace.sarimax import SARIMAX
8 from sklearn.metrics import r2_score, mean_absolute_error
9 import seaborn as sns
10 sns.set()
```



```
1 import numpy as np
2 import tensorflow as tf
3 from tensorflow import keras
4 import pandas as pd
5 import seaborn as sns
6 from pylab import rcParams
7 import matplotlib.pyplot as plt
8 from matplotlib import rc
9 from sklearn.model_selection import train_test_split
10 from sklearn.metrics import mean_squared_error, r2_score, mean_absolute_error
11 from pandas.plotting import register_matplotlib_converters
12
```

Figure 4: LSTM Packages

3 Data Preparation

Data from three sources was used to model eletricity consumption in the Republic of Ireland. The first of these sources was Eirgrid. It is Eirgrid that are responsible for operating and maintaining the Electrical grid in Ireland. The raw dataset from Eirgrid contains date from 2014 through 2020 (*figure 5*) and is provided in 15 minute intervals. The only feature required form this dataset was the electricity consumption for the Republic of Ireland.

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3	01/01/2014 00:15	0	625.68	855.46	345.94	352.82	2733.59	2868.97	1021 59	995.07	45.0%											
4	01/01/2014 00:30	0	614 72	840	333.22	339.6	2686 17	2826.42	972.06	932 71	43.8%											
5	01/01/2014 00:45	0	588.73	824.25	307.44	313.66	2657.56	2786.94	985.81	959.06	44.5%											
6	01/01/2014 01:00	0	593.06	818.84	306.87	315.17	2584.65	2723.94	958.63	920.82	44.3%											
7	01/01/2014 01:15	0	586.7	831.37	302.89	311.27	2566.28	2686.41	965.56	930.65	44.8%											
8	01/01/2014 01:30	0	599.73	826.4	312.69	322.63	2532.75	2596.84	918.1	882.18	44.1%											
9	01/01/2014 01:45	0	561.82	805.79	280.63	286.5	2496.42	2543.19	954.3	922.9	45.0%											
10	01/01/2014 02:00	0	543.61	784.76	267.7	277.92	2435.1	2483.39	940.28	919.49	45.7%											
11	01/01/2014 02:15	0	535.37	768.59	258.76	272.14	2424.75	2437.31	971.81	943.66	46.9%											
12	01/01/2014 02:30	0	531.9	748.3	257.93	268.9	2362.4	2391.76	972.32	944.46	47.7%											
13	01/01/2014 02:45	0	531.39	737.54	249.49	265.39	2373.1	2340.71	967.37	946.64	46.6%											
14	01/01/2014 03:00	0	512.07	716.34	235.45	244.03	2359.04	2303.49	932.08	899.44	44.6%											
15	01/01/2014 03:15	0	521.65	709.01	252.27	259.75	2313.24	2272.87	959.38	928.87	46.5%											
16	01/01/2014 03:30	0	522.08	702.94	244.94	254.36	2259.29	2227.45	932	894.58	46.0%											
17	01/01/2014 03:45	0	523.22	688.7	244.47	254.75	2291.68	2202.69	950.3	921.93	45.2%											
18	01/01/2014 04:00	0	493.18	677.57	206.54	222.4	2352.01	2170.37	940.74	908.63	42.1%											
19	01/01/2014 04:15	0	491.15	6/4.//	201.51	213.82	2377.82	2146.61	927.81	893.6	40.0%											
20	01/01/2014 04:30	0	501.85	667.9	197.41	213.38	2332.01	2118.14	944.83	905.95	40.9%											
21	01/01/2014 04:45	0	508.18	663.22	210.34	220.26	2370.26	2093.52	1005.34	950.89	40.7%											
22	01/01/2014 05:00	0	5 15.0	003.10	224.00	229.10	23/9.53	2090.45	1001.02	953.30	40.4%									<u> </u>		
23	01/01/2014 05:15	0	405.02	666.66	222.04	221.32	2231.40	2070.00	1020.04	900.10	43.170											
25	01/01/2014 05:45	0	613.61	656.01	204.03	232.69	2185.66	2070.55	1133.28	885.35	43.270											
26	01/01/2014 06:00	0	535.65	662.88	236.92	245.99	2293.4	2030.33	11/0.06	9/12 18	43.3%											
27	01/01/2014 06:15	0	545.95	671.51	252.08	259.64	2375.01	2098.08	1187.63	1045 74	43.7%											
28	01/01/2014 06:30	0	493.41	674 77	222 74	227 11	2352 71	2093.03	1178 86	1041.33	44.9%											
29	01/01/2014 06:45	0	448.64	672.2	215.18	182.92	2268.65	2092.46	1165.09	961.16	45.0%											
30	01/01/2014 07:00	0	444.86	688.48	225.2	175.69	2303.52	2106.31	1183.17	966.35	44.4%											
31	01/01/2014 07:15	0	444.99	695.29	231.82	183.76	2257.75	2124.49	1168.59	962.56	46.4%											
32	01/01/2014 07:30	0	445.13	710.26	226.07	179.35	2271.31	2124.89	1189.93	955.03	45.9%											
33	01/01/2014 07:45	0	425.99	713.7	237.95	162.35	2219.45	2133.43	1173.05	898.53	45.9%											
34	01/01/2014 08:00	0	401.84	725.33	213.92	146.3	2166.14	2116.2	1107.61	852.97	44.9%											
35	01/01/2014 08:15	0	414.06	736.09	208.84	119.76	2069.55	2098.79	1094.21	788.44	44.8%											
36	01/01/2014 08:30	0	393.38	733.58	213.3	108.75	2035.93	2118.55	1082.54	770.08	45.7%											
37	01/01/2014 08:45	0	381.43	743.29	215.47	103.53	2064.91	2127.45	1030.74	747.96	44.6%											
38	01/01/2014 09:00	0	375.91	759.91	190.31	92.78	2061.07	2172.41	968.15	669.25	41.8%											
39	01/01/2014 09:15	0	455.91	787.04	197.29	90.8	2077.13	2236.76	919.48	629.06	38.1%											
40	01/01/2014 09:30	0	516.51	810.33	241.74	123.09	2068.92	2290.1	884.49	687.67	40.6%											
41	01/01/2014 09:45	0	591.04	827.13	218.32	110.79	2046.74	2350.48	820.45	643.86	38.5%											

Figure 5: Electricity Consumption 2014 -2020

Meteorological data was collected from a number of weather stations throughout Ireland to provide features for the LSTM and Sarimax independent variables. An example of this data is illustrated in *figure 6* and *figure 7*.

The final source of data was from the National Oceanic and Atmospheric Administration. This is a sub-department of the U.S. Department of Commerce. This dataset contains daily information of sun-rise and sunset times and the length of daylight for each day. It also contains data relating to the aspect of the sun to geographic co-ordinates (*figure 8*). It contains climate data indicative of seasonal changes.

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27 01-Jan-42		0 9.	7	0 0	5.8	0 4	.7	2	0 102	0.3	17.2	1		1		1		0	0		1.1	1 1	.4	-	_			
28 02-Jan-42	0	0 9.	9	0 1	7.9	0 6	.7	0	0.1 101	6.2	15.2	1		1		1		0	0		0.3	7 0	.9					
29 03-Jan-42	0	0 11.	2	0 8	8.9	0 7	.2	0	1.5 100	6.8	14	1		1		1	0.	1	0		0.5	5 0	.6					
30 04-Jan-42	0	9.	2	0 3	2.7	0 3	.4	0	3.5 100	1.5	17	1		1		1	0.	6	0		0.0	5 0	.7					
31 05-Jan-42	0	0 3.	5	1 -(0.8	0	0	0	0.6 101	3.4	13	1		1		1	3.	4	0		0.0	5 0	.7					
32 06-Jan-42	0	0 5.	1 1	0 0	0.7	1 -3	.7	2	0 102	1.1	9.7	1		1		1	0.	1	0		0.4	4 0	.5					
33 07-Jan-42	0	0 7.	1	0 0	0.5	1 .	-1	3	0 102	1.7	10.3	1		1		1		4	0		0.2	2 0	.2					
34 08-Jan-42	0	0 7.	1	0 1	1.4	0 0	.2	3	0 101	6.8	9.3	1		1		1	3.	7	0		0.3	2 0	.2					
35 09-Jan-42	C	0 4.	5	0 (0.7	0 0	.9	0	0.2 1	012	11.8	1		1		1	0.	6	0		0.5	5 0	.7					
36 10-Jan-42	0	0 5.	3	1 -4	2.8	1 -4	.1	3	0 101	5.9	4	1		1		1		5	0		(0 0	.1					
37 11-Jan-42	0	0	4	1 -3	2.6	1 -9	.5	0	1.1 101	4.6	2.8	1		1		1	1.	.6	0		0.2	2 0	.3					
38 12-Jan-42	0	0 5.	1	0 0	0.1	1 -1	.1	0	2.5 99	9.5	8.6	1		1		1		0	0		0.3	3 0	.5					
39 13-Jan-42	0	0 4.	8	1 -1	1.4	1 .	-2	0	0.2	987	7.5	1		1		1	6.	1	0		(0	0					
40 14-Jan-42	0	0 4.	7	1 -3	3.1	1 .	-8	0	0.1 99	6.9	3.8	1		1		1	3.	8	0		0.1	1 0	.2					
41 15-Jan-42	0	0 4.	5	0 (0.2	1 -7	.8	0	2.1 99	7.2	26.3	1		1		1		0	0		0.4	\$ 0	.7					
42 16-Jan-42	0	0 4.	4		3	0 2	.2	0	9.6 99	6.9	18	1		1		1		0	0		0.4	• 0	.6					

Figure 6: Meteorological Data - Variables

16840	31-May-15	0	12.5	0	5.5	0	7.2	oi	11	993.9	19	0	28	0	260	0	42	7.8	0	2149	12.25	2.1	4.2	23.6	23.6	20.4	
6841	01-lun-15	0	12.3	0	5.1	0	4.4	ő	3.1	989.4	17.9	0	34	0	190	0	51	0.5	0	869	9.925	1.5	2.5	21.6	21.6	18.6	
16942	02-Jun-15	0	14.9	0	6.7	0	5.0	0	1.6	001.2	16.6	0	22	0	250	0	45	6.9	0	2109	11.075	2.0	4.7	22.2	22.2	19.5	
16042	02-Jun-15	0	15.0	0	6.5	0	5.0	0	0.2	1006.2	0.0	0	19	0	250	0	24	5	0	1500	12.25	2.0	2.6	24	22.2	21.6	
16944	04-Jun-15	0	16.4	0	7.2	0	4.2	0	0.2	1009.9	0.5	0	10	0	140	0	24		0	1969	14.025	2.0	4.2	26.2	26.2	24.1	
N60AS	05-Jun-15	0	15.9	0	0.2	0	9.2	0	2.6	1002.2	12.5	0	22	0	220	0	27	79	0	2112	14.025	2.5	4.2	26.3	20.3	24.1	
10040	05-Jun-15	0	15.5	0	7.3		6.2		2.0	1011.2	10.5	0	20	0	230	0	30	10	0	2113	13.05	3.2		20.1	20.1	24.5	
10040	00-Jun-15	0	16.3	0	7.5	0	0.5	0	0.4	1011.5	10.3	0	20	0	230	0	35	10	0	2121	12.03	3.2	3.4	20.2	20.2	20.0	
10047	07-Jun-15	0	10.5	0	4.5	0	4	2	0	1022.5	0.4	0	13	0	270	0	19		0	2421	14.2	3.3	4.7	30.0	30.0	25.4	
:0040	08-101-15	0	15.4		2.5		1.5	3	0	1027.4	7.5	0	12	0	50	0	15	2.1		2000	14.575	2.5	5.0	52.4	52.4	51.4	
:0849	09-Jun-15	0	15.6	0	0.7	1	-3.2	3	0	1026.1	5.9	0	9	0	/0	0	10	15.2	0	2985	15.675	3.3	5	34.8	34.8	34	
:0850	10-Jun-15	0	16.3	0	2.6	1	-0.5	3	0	1020.5	/	0	11	0	60	0	19	15.7	0	2997	17.125	3.4	5.2	37.1	37.1	30.0	
16851	11-Jun-15	0	15.2	0		0	4.4	0	0	1010.9	7.9	0	12	0	80	0	10	9.2	0	2378	16.9	3	4.5	39.1	39.1	38.8	
:0852	12-Jun-15	0	16.1	0	9.7	0	8	2	0	1003	7.8	0	12	0	40	0	18	2	0	1313	16.45	2.5	3.4	40.7	40.7	40.6	
26853	13-Jun-15	0	18	0	6.5	0	9.5	2	0	1001.9	8.9	0	13	0	330	0	19	5.8	0	2161	17.1	3.4	4.8	42.8	42.8	42.9	
26854	14-Jun-15	0	15.6	0	5.2	0	2.9	0	0	1007.2	7.1	0	13	0	320	0	19	9	0	2051	16.625	2.9	4.2	44.6	44.6	44.8	
26855	15-Jun-15	0	17.9	0	4.7	1	-0.7	2	0	1011.6	6.4	0	13	0	130	0	21	6	0	2280	17.775	3	4.4	46.4	46.4	46.8	
26856	16-Jun-15	0	21.2	0	12	0	11.8	2	0	1013	9.1	0	15	0	250	0	20	4.4	0	1895	19.15	3.3	4.7	48.3	48.3	48.9	
26857	17-Jun-15	0	18.7	0	8.1	0	15.9	0	0.6	1011.8	14	0	22	0	260	0	30	1.3	0	1343	18.6	2	3.3	48.8	48.8	49.5	
16858	18-Jun-15	0	18.6	0	7.3	0	6	0	0	1013.4	10.3	0	17	0	280	0	25	9.9	0	2361	17.05	3.6	5.4	50.8	50.8	51.7	
16859	19-Jun-15	0	17.5	0	9.5	0	6.6	0	0.6	1013.2	12.1	0	17	0	260	0	23	2.7	0	1601	17.05	2.3	3.7	51.5	51.5	52.5	
16860	20-Jun-15	0	20.7	0	11.3	0	14.5	0	0.1	1009.5	14.4	0	21	0	260	0	27	6.7	0	2023	18.425	3.6	5.4	53.3	53.3	54.5	
16861	21-Jun-15	0	17.1	0	9.3	0	9.9	2	0	1005.1	15.5	0	22	0	260	0	29	5.5	0	1885	17.225	3.2	5	55	55	56.3	
16862	22-Jun-15	0	18.1	0	6	0	7.2	2	0	1004.3	10.3	0	17	0	310	0	25	6.4	0	2117	16.625	3.1	4.7	56.5	56.5	57.9	
16863	23-Jun-15	0	19	0	3.6	1	-1.2	3	0	1007.7	7.2	0	12	0	120	0	18	12.5	0	2878	18	3.6	5.4	58.3	58.3	59.8	
16864	24-Jun-15	0	19.7	0	11.3	0	10	2	0	1007.7	9.2	0	15	0	240	0	18	2.8	0	1578	18.875	3	4.2	59.7	59.7	61.4	
16865	25-Jun-15	0	20.2	0	13.9	0	12.3	0	0.5	1005.8	8.6	0	16	0	210	0	22	0.1	0	791	17.975	2.3	3	60.3	60.3	62	
16866	26-Jun-15	0	21	0	11.8	0	12.2	0	1.2	1003.1	11.5	0	19	0	260	0	24	7.9	0	2265	18.425	3.8	5.6	60.8	60.8	62.6	
16867	27-Jun-15	0	19.4	0	10.9	0	8.5	0	2.5	1005	11.3	0	17	0	200	0	24	4.8	0	1433	17.7	2.8	4	59.6	59.6	61.5	
16868	28-Jun-15	0	19.6	0	12.9	0	12.8	0	0.7	1004.2	14.2	0	20	0	260	0	31	6.6	0	1839	17.775	3.5	5.1	60.5	60.5	62.5	
16869	29-Jun-15	0	21.2	0	12.5	0	11.7	2	0	1007.7	9.2	0	15	0	220	0	21	3.6	0	1920	18.5	3.5	4.9	62.1	62.1	64.1	
16870	30-Jun-15	0	24.7	0	14.9	0	14.8	0	0	1003.8	9.8	0	20	0	110	0	25	12.8	0	2813	21.85	5	6.9	64.2	64.2	66.4	
16871	01-Jul-15	0	23.4	0	12.9	0	11.2	2	0	999.3	5.8	0	15	0	130	0	21	3.7	0	1440	21.6	2.8	3.7	65.4	65.4	67.6	
16872	02-Jul-15	0	20.2	0	13.2	0	13.1	0	0	1006.3	8.7	0	15	0	260	0	20	8.3	0	1928	20.45	3.5	4.8	66.8	66.8	69.1	
16873	03-Jul-15	0	19.6	0	8.2	0	3.8	0	0.1	1008	10	0	19	0	140	0	26	11.1	0	2578	20.125	3.5	5.3	68.1	68.1	70.4	
16874	04-Jul-15	0	20.9	0	10.6	0	13	0	0.3	1003	12.4	0	22	0	240	0	30	6.2	0	2133	19.75	3.4	5.2	69.1	69.1	71.5	
16875	05-Jul-15	0	18.6	0	9.5	0	5	0	4.5	1004	7.3	0	13	0	270	0	21	4.2	0	1416	18.3	2.5	3.4	65.5	65.5	67.9	
16876	06-Jul-15	0	20.1	0	9.2	0	5.7	0	4.7	999.4	10.7	0	24	0	140	0	33	0.5	0	759	16.025	1.8	2.5	61.5	61.5	64	
16877	07-Jul-15	0	17.7	0	11.9	0	12.5	0	5.9	993.5	14.6	0	23	0	240	0	30	3.7	0	1696	16	2.7	4.3	56.8	56.8	59.3	
16878	08-Jul-15	0	17.6	0	6.6	0	11.7	0	0.5	1003.1	14.2	0	22	0	290	0	32	5.6	0	1905	15.6	2.6	4.2	57.6	57.6	60.1	
16879	09-Jul-15	0	17.3	0	4.3	0	0.8	2	0	1011.8	7.2	0	16	0	130	0	23	8.8	0	2395	16.125	2.9	4.3	58.9	58.9	61.6	
16880	10-Jul-15	0	20.9	0	14.3	0	13.7	0	0.3	1005.3	9.1	0	19	0	220	0	26	5.4	0	1749	18.925	3.3	4.6	60.2	60.2	62.9	
16881	11-Jul-15	0	17.8	0	11.1	0	10.1	0	0.4	1002.5	13.9	0	21	0	200	0	29	1.9	0	1046	17	2.1	3.1	60.7	60.7	63.5	
16882	12-Jul-15	0	18.1	0	11.6	0	12.1	2	0	1002.8	10.3	0	22	0	260	0	29	2.5	0	1343	17.125	2.4	3.5	61.8	61.8	64.6	
		-		-		-		-	-			-		-		-			-								

Figure 7: Meteorological Data

	0.033AC (2	023						,					- Score											Curror	in Controlly	e.		
Fil	e Horr	ie Inser	t Page	e Layout	Formulas	Data	Review	View	Kutools	™ Kuto	ools Plus	Help														ß	Share	Commer
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1	Date	Time (hrs	Julian Day	ululian Cent	tury	Geom Me	Geom Me	Eccent Far	Sup Eq.of	Sun True	Sup True A	Sun Rad V	Sun Ann I	Mean Ohl	Oblig Corr	Sun Rt Asr	Sun Declir	varv	Fa of Time	HA Sunris	Solar Noo	Suprise Time (LST)	sunset Tir	Sunlight D	True Solar	Hour Angl	Solar Zeni	i Solar Elev
5	01-Jan-14	12:00:00	2456659	0.140014		281.0671	5397.889	0.016703	-0.07201	280,9951	5397.817	0.98331	280,9921	23 43747	23 43535	-78.047	-22.9805	0.04302	-3.55243	56 96885	0.519803	08:40:38	16:16:24	455 7508	691 4836	-7.12911	76.65833	13.34167
-	02-Jan-14	12:00:00	2456660	0.140041		282.0527	5398.875	0.016703	-0.03839	282.0143	5398,836	0.983302	282.0113	23.43747	23,43535	-76.9443	-22,8927	0.04302	-4.01954	57,1339	0.520127	08:40:27	16:17:31	457.0712	691.0165	-7.24588	76.57906	13.42094
4	03-Jan-14	12:00:00	2456661	0.140068		283.0384	5399.86	0.016703	-0.00477	283.0336	5399.855	0.983298	283.0306	23,43747	23,43535	-75.8432	-22,7973	0.04302	-4,48087	57.31265	0.520448	08:40:12	16:18:42	458,5012	690,5551	-7.36122	76,49226	13,50774
5	04-Jan-14	12:00:00	2456662	0.140096		284.024	5400.846	0.016703	0.028853	284.0529	5400.875	0.9833	284.0498	23,43747	23.43535	-74,7436	-22,6944	0.04302	-4.93595	57,50487	0.520764	08:39:53	16:19:55	460.039	690.1	-7,47499	76.39797	13.60203
5	05-Jan-14	12:00:00	2456663	0.140123		285.0097	5401.831	0.016703	0.062469	285.0721	5401.894	0.983307	285.0691	23.43747	23.43535	-73.6457	-22.584	0.04302	-5.3843	57.71034	0.521075	08:39:30	16:21:11	461.6827	689.6517	-7.58707	76.29623	13.70377
7	06-Jan-14	12:00:00	2456664	0.140151		285.9953	5402.817	0.016703	0.096064	286.0914	5402.913	0.983319	286.0883	23.43747	23.43535	-72.5497	-22.4662	0.04302	-5.82544	57.92878	0.521382	08:39:04	16:22:30	463.4303	689.2106	-7.69736	76.18708	13.81292
8	07-Jan-14	12:00:00	2456665	0.140178		286.9809	5403.803	0.016703	0.12963	287.1106	5403.932	0.983336	287.1076	23.43747	23.43534	-71.4556	-22.3409	0.04302	-6.25892	58.15996	0.521683	08:38:35	16:23:52	465.2797	688.7771	-7.80573	76.07056	13.92944
э	08-Jan-14	12:00:00	2456666	0.140205		287.9666	5404.788	0.016703	0.163154	288.1298	5404.951	0.983359	288.1267	23.43747	23.43534	-70.3636	-22.2083	0.04302	-6.6843	58.40358	0.521978	08:38:02	16:25:16	467.2286	688.3517	-7.91208	75.94672	14.05328
.0	09-Jan-14	12:00:00	2456667	0.140233		288.9522	5405.774	0.016703	0.196627	289.1489	5405.97	0.983386	289.1458	23.43747	23.43534	-69.2738	-22.0685	0.04302	-7.10116	58.65938	0.522267	08:37:26	16:26:42	469.275	687.9348	-8.01629	75.81561	14.18439
.1	10-Jan-14	12:00:00	2456668	0.14026		289.9379	5406.759	0.016703	0.230039	290.1679	5406.989	0.983418	290.1649	23.43747	23.43534	-68.1863	-21.9215	0.04302	-7.50907	58.92705	0.522551	08:36:46	16:28:11	471.4164	687.5269	-8.11827	75.67729	14.32271
.2	11-Jan-14	12:00:00	2456669	0.140287		290.9235	5407.745	0.016703	0.263377	291.1869	5408.008	0.983456	291.1839	23.43747	23.43534	-67.1011	-21.7673	0.04302	-7.90763	59.20631	0.522828	08:36:03	16:29:42	473.6505	687.1284	-8.21791	75.53181	14.46819
.3	12-Jan-14	12:00:00	2456670	0.140315		291.9092	5408.731	0.016703	0.296633	292.2058	5409.027	0.983498	292.2028	23.43747	23.43534	-66.0184	-21.6061	0.04302	-8.29647	59.49685	0.523098	08:35:16	16:31:15	475.9748	686.7395	-8.31512	75.37924	14.62076
.4	13-Jan-14	12:00:00	2456671	0.140342		292.8948	5409.716	0.016703	0.329796	293.2246	5410.046	0.983546	293.2216	23.43747	23.43533	-64.9382	-21.438	0.04302	-8.67522	59.79836	0.523361	08:34:27	16:32:50	478.3869	686.3608	-8.4098	75.21964	14.78036
.5	14-Jan-14	12:00:00	2456672	0.14037		293.8805	5410.702	0.016703	0.362854	294.2433	5411.065	0.983599	294.2403	23.43747	23.43533	-63.8607	-21.2629	0.04302	-9.04352	60.11054	0.523616	08:33:34	16:34:27	480.8843	685.9925	-8.50188	75.05307	14.94693
.6	15-Jan-14	12:00:00	2456673	0.140397		294.8661	5411.687	0.016703	0.395798	295.2619	5412.083	0.983656	295.2589	23.43747	23.43533	-62.786	-21.081	0.04302	-9.40103	60.43306	0.523865	08:32:38	16:36:06	483.4645	685.635	-8.59126	74.8796	15.1204
.7	16-Jan-14	12:00:00	2456674	0.140424		295.8518	5412.673	0.016703	0.428618	296.2804	5413.102	0.983719	296.2773	23.43747	23.43533	-61.714	-20.8924	0.04302	-9.74744	60.76562	0.524105	08:31:39	16:37:46	486.125	685.2886	-8.67786	74.69931	15.30069
.8	17-Jan-14	12:00:00	2456675	0.140452		296.8374	5413.659	0.016703	0.461303	297.2987	5414.12	0.983787	297.2957	23.43746	23.43533	-60.6449	-20.6972	0.04302	-10.0825	61.10789	0.524338	08:30:37	16:39:29	488.8631	684.9535	-8.76161	74.51227	15.48773
.9	18-Jan-14	12:00:00	2456676	0.140479		297.8231	5414.644	0.016703	0.493843	298.3169	5415.138	0.983859	298.3139	23.43746	23.43533	-59.5788	-20.4954	0.04302	-10.4058	61.45957	0.524562	08:29:32	16:41:12	491.6765	684.6302	-8.84245	74.31855	15.68145
10	19-Jan-14	12:00:00	2456677	0.140507		298.8087	5415.63	0.016703	0.526228	299.3349	5416.156	0.983937	299.3319	23.43746	23.43532	-58.5157	-20.2872	0.04302	-10.7172	61.82032	0.524779	08:28:24	16:42:58	494.5626	684.3188	-8.92029	74.11823	15.88177
11	20-Jan-14	12:00:00	2456678	0.140534		299.7944	5416.615	0.016703	0.558447	300.3528	5417.174	0.984019	300.3497	23.43746	23.43532	-57.4556	-20.0726	0.04302	-11.0163	62.18985	0.524986	08:27:13	16:44:44	497.5188	684.0197	-8.99508	73.9114	16.0886
2	21-Jan-14	12:00:00	2456679	0.140561		300.78	5417.601	0.016703	0.590491	301.3705	5418.191	0.984106	301.3674	23.43746	23.43532	-56.3987	-19.8517	0.04302	-11.3031	62.56783	0.525185	08:26:00	16:46:32	500.5427	683.7329	-9.06677	73.69814	16.30186
:3	22-Jan-14	12:00:00	2456680	0.140589		301.7657	5418.587	0.016703	0.622349	302.388	5419.209	0.984198	302.3849	23.43746	23.43532	-55.3449	-19.6246	0.04302	-11.5772	62.95396	0.525376	08:24:44	16:48:21	503.6317	683.4588	-9.1353	73.47854	16.52146
54	23-Jan-14	12:00:00	2456681	0.140616		302.7513	5419.572	0.016703	0.654012	303.4053	5420.226	0.984295	303.4022	23.43746	23.43532	-54.2944	-19.3915	0.04302	-11.8385	63.34793	0.525557	08:23:25	16:50:12	506.7835	683.1975	-9.20063	73.25267	16.74733
!5	24-Jan-14	12:00:00	2456682	0.140643		303.737	5420.558	0.016703	0.685469	304.4224	5421.243	0.984397	304.4193	23.43746	23.43532	-53.2471	-19.1525	0.04302	-12.0868	63.74945	0.52573	08:22:03	16:52:03	509.9956	682.9492	-9.2627	73.02065	16.97935
!6	25-Jan-14	12:00:00	2456683	0.140671		304.7226	5421.543	0.016703	0.716712	305.4393	5422.26	0.984504	305.4362	23.43746	23.43531	-52.2031	-18.9075	0.04302	-12.3219	64.1582	0.525893	08:20:39	16:53:55	513.2656	682.7141	-9.32148	72.78255	17.21745
27	26-Jan-14	12:00:00	2456684	0.140698		305.7082	5422.529	0.016703	0.747729	306.456	5423.277	0.984615	306.4529	23.43746	23.43531	-51.1624	-18.6568	0.04302	-12.5438	64.57391	0.526047	08:19:13	16:55:48	516.5913	682.4922	-9.37695	72.53847	17.46153
18	27-Jan-14	12:00:00	2456685	0.140726		306.6939	5423.515	0.016703	0.778512	307.4724	5424.293	0.984731	307.4693	23.43746	23.43531	-50.125	-18.4005	0.043019	-12.7522	64.99628	0.526192	08:17:44	16:57:42	519.9703	682.2838	-9.42906	72.28851	17.71149
9	28-Jan-14	12:00:00	2456686	0.140753		307.6795	5424.5	0.016703	0.809051	308.4886	5425.309	0.984851	308.4855	23.43746	23.43531	-49.0911	-18.1386	0.043019	-12.9472	65.42504	0.526327	08:16:13	16:59:37	523.4004	682.0888	-9.4778	72.03276	17.96724
0	29-Jan-14	12:00:00	2456687	0.14078		308.6652	5425.486	0.016703	0.839337	309.5045	5426.325	0.984976	309.5014	23.43746	23.43531	-48.0605	-17.8713	0.043019	-13.1285	65.85992	0.526453	08:14:39	17:01:32	526.8793	681.9075	-9.52314	71.77132	18.22868
1	30-Jan-14	12:00:00	2456688	0.140808		309.6508	5426.471	0.016703	0.86936	310.5202	5427.341	0.985106	310.5171	23.43746	23.43531	-47.0333	-17.5986	0.043019	-13.2963	66.30063	0.52657	08:13:03	17:03:28	530.405	681.7397	-9.56507	71.50431	18.49569
2	31-Jan-14	12:00:00	2456689	0.140835		310.6365	5427.457	0.016703	0.899111	311.5356	5428.356	0.98524	311.5325	23.43746	23.4353	-46.0094	-17.3207	0.043019	-13.4503	66.74693	0.526677	08:11:26	17:05:24	533.9754	681.5857	-9.60358	71.23181	. 18.76819
3	01-Feb-14	12:00:00	2456690	0.140862		311.6221	5428.443	0.016703	0.92858	312.5507	5429.371	0.985379	312.5476	23.43746	23.4353	-44.989	-17.0377	0.043019	-13.5906	67.19855	0.526774	08:09:46	17:07:21	537.5884	681.4454	-9.63866	70.95393	19.04607
4	02-Feb-14	12:00:00	2456691	0.14089		312.6078	5429.428	0.016703	0.957759	313.5655	5430.386	0.985522	313.5624	23.43746	23.4353	-43.972	-16.7498	0.043019	-13.7172	67.65526	0.526862	08:08:04	17:09:18	541.2421	681.3188	-9.67031	70.67078	19.32922
5	03-Feb-14	12:00:00	2456692	0.140917		313.5934	5430.414	0.016703	0.986639	314.5801	5431.4	0.98567	314.5769	23.43746	23.4353	-42.9584	-16.4569	0.043019	-13.8302	68.11681	0.52694	08:06:20	17:11:16	544.9345	681.2058	-9.69854	70.38247	19.61753
6	04-Feb-14	12:00:00	2456693	0.140945		314.5791	5431.399	0.016703	1.015211	315.5943	5432.415	0.985822	315.5912	23.43746	23.4353	-41.9482	-16.1593	0.043019	-13.9294	68.58297	0.527009	08:04:34	17:13:14	548.6638	681.1066	-9.72334	70.0891	19.9109
17	05-Feb-14	12:00:00	2456694	0.140972		315.5647	5432.385	0.016703	1.043466	316.6082	5433.428	0.985978	316.6051	23.43746	23.4353	-40.9414	-15.8571	0.043019	-14.015	69.05351	0.527069	08:02:46	17:15:12	552.4281	681.021	-9.74474	69.79079	20.20921
:8	06-Feb-14	12:00:00	2456695	0.140999		316.5504	5433.371	0.016703	1.071396	317.6218	5434.442	0.986138	317.6186	23.43746	23.43529	-39.9379	-15.5503	0.043019	-14.087	69.52822	0.527119	08:00:56	17:17:10	556.2258	680.949	-9.76275	69.48763	20.51237
19	07-Feb-14	12:00:00	2456696	0.141027		317.536	5434.356	0.016703	1.098991	318.635	5435.455	0.986303	318.6319	23.43746	23.43529	-38.9378	-15.239	0.043019	-14.1455	70.00689	0.527159	07:59:05	17:19:08	560.0551	680.8905	-9.77738	69.17976	20.82024
10	08-Feb-14	12:00:00	2456697	0.141054		318.5217	5435.342	0.016703	1.126245	319.6479	5436.468	0.986472	319.6448	23.43746	23.43529	-37.9409	-14.9235	0.043019	-14.1906	70.4893	0.527191	07:57:12	17:21:07	563.9144	680.8454	-9.78865	68.86727	21.13273
1	09-Feb-14	12:00:00	2456698	0.141081		319.5073	5436.327	0.016703	1.153147	320.6605	5437.481	0.986644	320.6573	23.43746	23.43529	-36.9474	-14.6038	0.043019	-14.2224	70.97527	0.527213	07:55:17	17:23:05	567.8022	680.8136	-9.79661	68.55028	21.44972
2	10-Feb-14	12:00:00	2456699	0.141109		320.493	5437.313	0.016703	1.179691	321.6727	5438.493	0.986821	321.6695	23.43746	23.43529	-35.9571	-14.28	0.043019	-14.2411	71.46462	0.527226	07:53:21	17:25:04	571.7169	680.7949	-9.80127	68.2289	21.7711
13	11-Feb-14	12:00:00	2456700	0.141136		321.4786	5438.299	0.016703	1.205868	322.6845	5439.504	0.987002	322.6813	23.43746	23.43529	-34.97	-13.9522	0.043019	-14.2467	71.95714	0.52723	07:51:23	17:27:02	575.6571	680.7893	-9.80266	67.90326	22.09674

Figure 8: NOAA Data

4 Feature Selection

In order to determine the appropriate features to use in modelling the data a correlation matrix was used. The features which had a correlation above .5 were used in the final dataset. A seaborn heatmap was used to plot the results of the correlation matrix function (*figure 9*). Examples of these correlation matrices can be seen in *figure 10*, *figure 11* and *figure 12*.



Figure 9: Correlation Matrix Syntax

A	utoSave 🧿	s B	9 • (°	- -			M	atrix_data_lg	_2.csv +		_		€ Searc	ch									(Phone	18 -	Edmor	nd Connolly	ت 🕏	n –	σ×
Fi	le Hor	ne Insi	ert Page	e Layout	Formulas	s Data	Review	r View	Kutools	™ Kut	ools Plus	Help															8	Share	P Comments
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	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
1		IE Deman	maxtp RA	mintp RA	glorad RA	soil RA-1	pe RA-1	evap RA-	maxtp RA	mintp RA	soil RA-2	pe RA-2	evap RA-	glorad RA	maxtp RA	mintp RA	soil RA-3	pe RA-3	evap RA-	glorad RA	maxtp RA	mintp RA	soil RA-4	pe RA-4	evap RA-	glorad RA	maxtp RA	mintp RA	glorad RA so
2	IE_Deman	1	-0.56047	-0.50774	-0.52073	-0.63626	-0.52983	-0.52987	-0.58258	-0.46154	-0.64194	-0.54714	-0.55149	-0.50286	-0.59278	-0.45341	-0.6458	-0.56311	-0.56317	-0.5176	-0.59189	-0.46526	-0.63601	-0.56384	-0.56805	-0.52801	-0.58994	-0.43523	-0.53388 -
3	maxtp_RA	-0.56047	1	0.861169	0.505074	0.899585	0.652487	0.594517	0.891001	0.799106	0.880545	0.607969	0.588759	0.47348	0.910722	0.785315	0.884836	0.649257	0.633695	0.508219	0.918317	0.807021	0.889307	0.67363	0.651427	0.539373	0.916567	0.766161	0.548529 0
4	mintp_RA	-0.50774	0.861169	1	0.362629	0.876673	0.518751	0.477744	0.799742	0.850242	0.840794	0.505793	0.487606	0.359609	0.812975	0.870028	0.849021	0.5386	0.518479	0.377509	0.824846	0.873075	0.846888	0.554728	0.531574	0.39563	0.834014	0.85045	0.410537
5	glorad_RA	-0.52073	0.505074	0.362629	1	0.652539	0.896342	0.921572	0.635859	0.316026	0.664037	0.853622	0.860106	0.858928	0.6219	0.332675	0.655701	0.851024	0.858972	0.865365	0.585337	0.318524	0.647558	0.827572	0.839957	0.862028	0.54269	0.265575	0.83753 0
6	soil_RA-1	-0.63626	0.899585	0.876673	0.652539	1	0.715257	0.685824	0.908043	0.794171	0.975835	0.738301	0.724168	0.626588	0.918083	0.80449	0.984157	0.762283	0.74714	0.642355	0.917435	0.809009	0.976417	0.769688	0.752175	0.658297	0.910649	0.768849	0.66275 0
7	pe_RA-1	-0.52983	0.652487	0.518751	0.896342	0.715257	1	0.981309	0.697837	0.44155	0.719083	0.852354	0.847466	0.789172	0.689411	0.4507	0.715711	0.862516	0.861773	0.811248	0.664417	0.43938	0.711236	0.856601	0.855229	0.820087	0.628385	0.388328	0.800972 0
8	evap_RA-	-0.52987	0.594517	0.477744	0.921572	0.685824	0.981309	1	0.656298	0.418877	0.693453	0.855316	0.861269	0.804735	0.650087	0.428345	0.690817	0.861495	0.867662	0.821893	0.626496	0.415243	0.682646	0.854079	0.864233	0.828566	0.594495	0.37067	0.80926 0
9	maxtp_RA	-0.58258	0.891001	0.799742	0.635859	0.908043	0.697837	0.656298	1	0.755789	0.940528	0.784972	0.7594	0.656634	0.96891	0.752637	0.920331	0.788686	0.771674	0.666894	0.947136	0.752966	0.925112	0.784803	0.762595	0.679173	0.919234	0.69275	0.68025 0
10	mintp_RA	-0.46154	0.799106	0.850242	0.316026	0.794171	0.44155	0.4188//	0.755789	1	0.811108	0.480037	0.460324	0.272163	0.777351	0.939048	0.798814	0.505588	0.484074	0.295895	0.795932	0.931/92	0.808274	0.530899	0.509813	0.32844	0.811194	0.899081	0.349321 0
11	SOIL RA-2	-0.64194	0.880545	0.840794	0.664037	0.975835	0.719083	0.693453	0.940528	0.811108	0 700007	0.788897	0.774223	0.6/1/1	0.941294	0.810798	0.989853	0.800539	0.784746	0.674509	0.935544	0.808872	0.98737	0.801945	0.784272	0.687731	0.9218	0.758686	0.688868 0
12	pe_rox-2	-0.34714	0.007505	0.303755	0.055022	0.756501	0.032534	0.0333310	0.764572	0.460037	0.700037	0.004107	0.554157	0.940004	0.730577	0.465033	0.76324	0.05055	0.0531/4/	0.010554	0.725425	0.400052	0.763075	0.927209	0.923213	0.00146	0.001017	0.403255	0.072445
14	clored RA	0.50396	0.47249	0.467000	0.000100	0.724108	0.799172	0.001209	0.7334	0.400324	0.774223	0.334137	0.052002	0.555502	0.756314	0.404257	0.732013	0.950055	0.935247	0.912334	0.506107	0.3939009	0.645707	0.923789	0.920042	0.0333140	0.000795	0.331001	0.878318 0
15	maxto RA	0.50280	0.47340	0.912975	0.6319	0.020388	0.699411	0.650097	0.050034	0.272103	0.07171	0.752077	0.333302	0.627751	0.037751	0.233137	0.033030	0.03002	0.030347	0.552575	0.096572	0.202000	0.043702	0.034213	0.707077	0.504005	0.002070	0.230433	0.701212
16	minto RA	-0.45241	0.795215	0.970029	0.222675	0.90449	0.4507	0.439245	0.752627	0.020049	0.910799	0.492055	0.464227	0.007701	0 770171	1	0.909427	0.516977	0.492579	0.202449	0.78642	0.965641	0.943320	0.520725	0.509094	0.225745	0.79622	0.929997	0.242502
17	coil BA-3	-0.6458	0.884836	0.849021	0.655701	0.984157	0 715711	0.690817	0.920331	0.798814	0.989853	0.76524	0.752619	0.653695	0.93509	0.809427	1	0.794423	0.779948	0.675982	0.934228	0.812122	0.9932	0.800808	0.784233	0.689271	0.924824	0.76635	0.690905 0
18	De RA-3	-0.56311	0.649257	0.5386	0.851024	0.762283	0.862516	0.861495	0.788686	0.505588	0.800539	0.954114	0.95055	0.89002	0.804396	0.516977	0.794423	1	0.997009	0.944607	0.774286	0.499888	0.797874	0.978692	0.97635	0.935637	0.735454	0.43811	0.921215 0
19	evap RA-	-0.56317	0.633695	0.518479	0.858972	0.74714	0.861773	0.867662	0.771674	0.484074	0.784746	0.951747	0.953247	0.898547	0.787166	0.493579	0.779948	0.997009	1	0.956023	0.757108	0.477946	0.781656	0.976023	0.979488	0.946074	0.719105	0.417899	0.930737 0
20	glorad RA	-0.5176	0.508219	0.377509	0.865365	0.642355	0.811248	0.821893	0.666894	0.295895	0.674509	0.904005	0.912554	0.932573	0.680298	0.303449	0.675982	0.944607	0.956023	1	0.641687	0.292395	0.669053	0.91471	0.926195	0.973466	0.597115	0.238657	0.948252 0
21	maxtp RA	-0.59189	0.918317	0.824846	0.585337	0.917435	0.664417	0.626496	0.947136	0.795932	0.935544	0.723429	0.704969	0.596187	0.986573	0.78642	0.934228	0.774286	0.757108	0.641687	1	0.801561	0.94628	0.798357	0.774665	0.669334	0.986506	0.752672	0.67626 0
22	mintp_RA	-0.46526	0.807021	0.873075	0.318524	0.809009	0.43938	0.415243	0.752966	0.931792	0.808872	0.466092	0.449171	0.282808	0.779793	0.965641	0.812122	0.499888	0.477946	0.292395	0.801561	1	0.827724	0.528467	0.504214	0.316095	0.817957	0.959145	0.330659 0
23	soil_RA-4	-0.63601	0.889307	0.846888	0.647558	0.976417	0.711236	0.682646	0.925112	0.808274	0.98737	0.765679	0.750767	0.645702	0.943328	0.819527	0.9932	0.797874	0.781656	0.669053	0.94628	0.827724	1	0.810045	0.79078	0.689123	0.936119	0.777056	0.690745 0
24	pe_RA-4	-0.56384	0.67363	0.554728	0.827572	0.769688	0.856601	0.854079	0.784803	0.530899	0.801945	0.927209	0.923789	0.854219	0.810847	0.530735	0.800808	0.978692	0.976023	0.91471	0.798357	0.528467	0.810045	1	0.994779	0.940015	0.764837	0.467546	0.925392 0
25	evap_RA-	-0.56805	0.651427	0.531574	0.839957	0.752175	0.855229	0.864233	0.762595	0.509813	0.784272	0.925213	0.928642	0.863846	0.787977	0.508094	0.784233	0.97635	0.979488	0.926195	0.774665	0.504214	0.79078	0.994779	1	0.953161	0.743114	0.446752	0.938557 0
26	glorad_RA	-0.52801	0.539373	0.39563	0.862028	0.658297	0.820087	0.828566	0.679173	0.32844	0.687731	0.891868	0.899146	0.904009	0.696101	0.325745	0.689271	0.935637	0.946074	0.973466	0.669334	0.316095	0.689123	0.940015	0.953161	1	0.626506	0.260434	0.973542 0
27	maxtp_RA	-0.58994	0.916567	0.834014	0.54269	0.910649	0.628385	0.594495	0.919234	0.811194	0.9218	0.681817	0.666793	0.552076	0.966585	0.79632	0.924824	0.735454	0.719105	0.597115	0.986506	0.817957	0.936119	0.764837	0.743114	0.626506	1	0.779168	0.644165 0
28	mintp_RA	-0.43523	0.766161	0.85045	0.265575	0.768849	0.388328	0.37067	0.69275	0.899081	0.758686	0.405293	0.391801	0.230435	0.725472	0.928887	0.76635	0.43811	0.417899	0.238657	0.752672	0.959145	0.777056	0.467546	0.446752	0.260434	0.779168	1	0.276375 0
29	glorad_RA	-0.53388	0.548529	0.410537	0.83753	0.66275	0.800972	0.80926	0.68025	0.349321	0.688868	0.872449	0.878918	0.873364	0.701312	0.342503	0.690905	0.921215	0.930737	0.948252	0.67626	0.330659	0.690745	0.925392	0.938557	0.973542	0.644165	0.276375	1 0
30	soil_RA-5	-0.64653	0.885942	0.83789	0.653751	0.971434	0.718086	0.690179	0.921243	0.800479	0.981822	0.77144	0.757169	0.651776	0.94153	0.80987	0.988442	0.806245	0.790594	0.678757	0.945347	0.817977	0.995233	0.819205	0.800912	0.699573	0.937552	0.772673	0.708486
31	pe_RA-5	-0.57014	0.682611	0.576847	0.77901	0.770414	0.822097	0.823647	0.762701	0.560464	0.792952	0.882689	0.882912	0.80301	0.801173	0.552146	0.797169	0.941191	0.939573	0.869739	0.798029	0.552967	0.804288	0.965963	0.964789	0.89697	0.789284	0.520292	0.917039 0
32	evap_RA-	-0.57399	0.647825	0.543401	0.800008	0.746504	0.824251	0.839013	0.737033	0.525905	0.770503	0.886533	0.893584	0.820957	0.771967	0.518212	0.774863	0.94287	0.947381	0.888289	0.766086	0.515665	0.77914	0.962684	0.971214	0.914712	0.755082	0.481471	0.938101 0
33	maxtp_RA	-0.59187	0.884028	0.8402	0.544321	0.925685	0.612756	0.58279	0.908512	0.798049	0.934042	0.67445	0.657739	0.551605	0.932098	0.793961	0.937663	0.706727	0.688592	0.574682	0.943778	0.809495	0.938295	0.719645	0.698561	0.589708	0.945227	0.77453	0.601607 0
34	mintp_KA	-0.51182	0.850103	0.875314	0.381726	0.858284	0.484516	0.447544	0.824353	0.899366	0.862131	0.514266	0.493252	0.345495	0.841265	0.911128	0.860762	0.545805	0.523382	0.361431	0.857915	0.924705	0.872528	0.562168	0.536942	0.381839	0.866763	0.893093	0.392287 0
35	SOIL_RA-6	-0.03104	0.876506	0.838946	0.630498	0.969717	0.695999	0.066557	0.916172	0.79894	0.980266	0.750849	0.734581	0.029106	0.930795	0.805829	0.985059	0.7781	0.760482	0.047247	0.935547	0.812825	0.987708	0.010621	0.016010	0.004162	0.928188	0.766438	0.070286
30	pe_KA-6	0.56354	0.604026	0.53251	0.803445	0.757904	0.80336	0.806893	0.735715	0.483972	0.78447	0.900652	0.898425	0.847079	0.748708	0.491149	0.783162	0.920265	0.915839	0.870676	0.733247	0.470785	0.760967	0.919634	0.916919	0.876586	0.70621	0.4299	0.881083 0
37	evap_KA-	0.50100	0.595755	0.5200//	0.810136	0.74700	0.802563	0.8143/	0.722118	0.470065	0.773204	0.0336/	0.904087	0.854368	0.738158	0.461462	0.772908	0.9214/8	0.92204	0.873080	0.723365	0.4/0/95	0.694272	0.92208	0.920314	0.000104	0.6393001	0.291659	0.093/30 0
20	maxto PA	-0.52150	0.955609	0.919409	0.572714	0.000300	0.621509	0.597009	0.034525	0.34055	0.000700	0.702525	0.697902	0.597629	0.921095	0.330392	0.005055	0.0779269	0.003336	0.600771	0.040778	0.792961	0.004372	0.722049	0.712766	0.505105	0.92961	0.745656	0.619691 0
40	minto RA	-0.51401	0.846529	0.861902	0.409625	0.860223	0.50858	0.467177	0.847423	0.884487	0.972862	0.541266	0.517643	0.377612	0.852053	0.883045	0.86391	0.572127	0.548643	0.392468	0.959908	0.884104	0.932009	0.582659	0.556024	0.412559	0.92501	0.837939	0.425412 0
41	soil RA-7	-0.62711	0.869767	0.839555	0.617143	0.959571	0.676771	0.650208	0.920777	0.806227	0.978829	0.739981	0.724074	0.618675	0.931116	0.807941	0.976699	0.764044	0.746007	0.631416	0.933719	0.810447	0.977407	0.76843	0.748729	0.64454	0.926767	0.762506	0.649817 0
42	pe RA-7	-0.53884	0.554643	0.510761	0.786287	0.734747	0.759197	0.772915	0.706107	0.444258	0.764293	0.888466	0.891567	0.858573	0.710758	0.462834	0.758434	0.886343	0.882492	0.85013	0.691577	0.446308	0.750332	0.870413	0.870745	0.839293	0.667329	0.401754	0.839061 0
43	evap RA-	-0.54057	0.5478	0.499559	0.79161	0.722251	0.761581	0.784739	0.690503	0.439037	0.751323	0.886396	0.896524	0.862063	0.697163	0.457289	0.746883	0.885053	0.886593	0.854356	0.679392	0.441978	0.737692	0.870176	0.877604	0.845229	0.65772	0.398855	0.845101 0
-	1.000	-																											

Figure 10: Correlation Matrix Values



Figure 11: Correlation Matrix - Electricity Demand and Solar Data



Figure 12: Correlation Matrix - Electricity Demand and Meteorological Data

5 Missing Values

There were not a lot of missing values in the dataset. Any missing values were limited to a few features on days throughout the data range in the weather station data. The knn algoithm was used to impute these features. The function used to complete this task can be seen in *figure 13*. The 85 values imputed refer to the original dataset of 2558 rows containing 144 features. Missing values were were imputed on the original dataset to provide as best information as possible for the algorithm. Ultimately this means that some of the values imputed were for features that were not required. This function was adapted from a tutorial from (Jason_Brownlee (2020)).

```
In [11]: # split into input and output elements
data = dataframe.values
ix = [i for i in range(data.shape[1]) if i !=143]
X, y = data[:, ix], data[:, 143]
# print total missing
print('Missing: %d' % sum(isnan(X).flatten()))
# define imputer
imputer = KNNImputer()
# fit on the dataset
imputer.fit(X)
# transform the dataset
Xtrans = imputer.transform(X)
# print total missing
print('Missing: %d' % sum(isnan(Xtrans).flatten()))
Missing: 85
Missing: 0
```

Figure 13: Application of the KNN Algorithm to impute missing values.

6 Encoding Days of the Week

The encoding of the days of the week used a Periodic Cyclic transformation. The purpose of this is to transform the name of the day into variables that still retain a degree of proximity to each other. This is to allow the algorithm using these features to determine that the days follow one another and repeat in a cycle. This is not achieved through one-hot-encoding or by simply giving each day a number. Two variables are created for each day. The formula uses cosine and sin to produce each feature respectively. For an illustration of this formula and the values it returns please see *figure 14*. A scatterplot illustrates how a machine learning algorithm views this Periodic Cyclic encoding.



Figure 14: Encoding the Days of the Week

7 Finalised Data

The completed datasets after the optimal features were selected are illustrated below in *figure 15* and *figure 16*. This data set contains electricity consumption and weather variables from 8 weather stations throughout Ireland for the years 2014 through 2020. Variables from the NOAA are also included and days of the week have been encoded. In total there are 2558 rows of data and 64 features. This dataset contains no missing values and is the finalised data set to be used with both the Sarimax model and the LSTM.

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1	Date	IE_Deman m	axtp_RA mint	p_RA glo	rad_RA sc	il_RA-1 p	e_RA-1 e	vap_RA-:m	axtp_RA mi	ntp_RA so	il_RA-2 p	e_RA-2 e	vap_RA-igl	orad_RA n	haxtp_RA m	intp_RA s	oil_RA-3 pe	E_RA-3 ev	ap_RA-igl	lorad_RAm	naxtp_RA m	intp_RA sc	oil_RA-4 pe	RA-4 er	vap_RA-g	lorad_RAm	haxtp_RA mi	ntp_RA gl	orad_RAs
2	01-Jan-14	2764.58	7.2	3.2	60	4.529	0.6	0.9	6.2	2.8	4.52	0.3	0.4	85	6.6	2.5	3.892	0.3	0.4	65	9.6	2.6	4.014	0.4	0.6	54	10.4	4	53
3	02-Jan-14	3127.4	7.8	4.6	180	5.157	0.5	0.6	8.9	3.6	5.067	0.3	0.4	263	8.3	2.4	4.158	0.1	0.1	260	9.3	3.4	4.253	0.3	0.3	310	9.9	4.7	328
4	03-Jan-14	3252.48	7.3	5.2	37	5.345	1.1	1.8	7.9	3.8	5.492	0.8	1.1	179	6.8	3.1	4.533	0.6	0.7	166	7.3	3.8	4.599	1	1.2	298	8.2	3.6	388
5	04-Jan-14	3013.98	6.3	1.4	163	4.158	0.4	0.5	5	1.5	3.796	0.3	0.3	171	5.2	-0.1	3.725	0	0	324	4.9	0.7	3.625	0.1	0.1	341	5.6	1.2	308
0	05-Jan-14	2914.22	9.2	2.2	112	4.055	0.6	0.9	12.3	2.8	5.058	0.6	0.7	180	11.4	0.6	4.132	0.4	0.5	137	11.5	0.9	4.005	0.5	0.7	144	12.9	1.5	161
	07-Jan-1/	2222.09	9.2	5.0	121	5 749	0.8	1.4	9.6	6.1	6 149	0.5	0.8	150	7.4	5.9	5.012	0.0	0.7	100	9.9	5.9	5 141	0.9	1.2	173	9.5	6.7	220
9	08-Jan-14	3349.32	8.9	3	205	5,561	0.4	0.4	7.8	1.2	5.621	0.1	0.2	140	6.9	3.7	5.009	0.2	0.3	123	7.2	3.5	4.821	0.3	0.4	130	8.3	4.8	133
10	09-Jan-14	3309.33	7.7	3.6	140	4.989	0.4	0.5	8	-2.2	3.84	0.1	0.1	325	6.9	-1.2	4.026	0	0	380	6.2	0.4	3.709	0.1	0.1	385	6.6	0.8	381
11	10-Jan-14	3293.53	8.1	2.5	165	5.038	0.7	0.9	7.8	-0.2	5.193	0.1	0.3	165	7.5	-1.6	4.286	0.1	0.2	106	8.6	0.4	4.474	0.3	0.4	103	9.5	1.6	123
12	11-Jan-14	3033.48	6.8	2.3	253	3.733	0.5	0.5	6.6	-2	2.974	0.1	0.2	353	6.6	-2	3.007	0	0.1	386	5.7	-0.6	2.912	0.1	0.2	398	7	-1.5	401
13	12-Jan-14	2960.6	7.7	3.3	47	4.584	1	1.5	10.2	3.4	5.201	0.6	0.9	45	8.5	1	4.238	0.4	0.6	37	8.9	3	4.081	0.6	0.9	38	8.7	4.1	22
14	13-Jan-14	3330.09	5.9	1.5	224	3.974	0.5	0.6	6.3	-1.7	3.788	0.1	0.3	246	6.4	-2.9	3.171	0.1	0.2	274	6.4	-1.2	3.176	0.2	0.3	262	6.5	0.2	159
15	14-Jan-14	3433.52	6.7	0.2	56	2.989	0.5	0.7	10.4	-0.2	3.579	0.3	0.4	58	9.7	-3.1	2.377	0.2	0.3	76	9.3	-1.8	2.263	0.2	0.4	93	9.9	-0.2	101
16	15-Jan-14	3338.45	10.4	4.6	150	5.5	0.6	0.8	10.1	5.1	7.03	0.2	0.3	309	9.5	3.3	5.448	0.1	0.2	215	9.6	4.6	5.802	0.3	0.4	190	10.9	4.8	143
17	16-Jan-14	3323.68	7.6	2.9	259	4.33	0.3	0.3	7.3	2.3	4.937	0.2	0.3	190	7.9	3.3	4.538	0.2	0.3	279	8.5	3.6	4.328	0.4	0.5	261	9.6	3.8	248
18	17-Jan-14	3285.07	7.2	3.1	179	5.052	0.3	0.4	9.1	2.2	5.59	0.2	0.2	339	7.1	3	4.827	0.2	0.3	172	6.9	3.9	4.769	0.3	0.4	184	7.2	4.3	234
19	18-Jan-14	3004.32	5.2	3.4	122	4.754	0.5	0.6	4.8	1.6	4.278	0.2	0.3	1/8	5.7	1.7	4.02	0.3	0.3	211	5.9	2.4	3.95	0.3	0.5	217	7.4	1.7	72
21	20-Jan-14	3299.95	73	3.4	341	4.011	0.5	0.5	7.6	-0.5	4.127	0.2	0.3	438	7.6	-1	3 434	0.2	0.3	452	6.7	11	3.226	0.3	0.4	447	7.4	1.0	376
22	21-Jan-14	3365.23	8.7	4.7	104	5.1	1.1	1.5	8.6	5	5.56	0.5	0.6	122	8.8	3.4	4.59	0.3	0.5	136	9.2	3.8	4.653	0.6	0.7	174	9.9	3.7	120
23	22-Jan-14	3320.73	8.5	4.7	159	5.384	0.6	0.8	9.1	3.4	5.251	0.3	0.4	361	8.3	1.2	4.563	0.2	0.3	400	8.5	2.7	4.559	0.4	0.5	368	8.7	3.5	339
24	23-Jan-14	3390.9	7.4	2.5	275	4.76	0.8	1.1	8	4.2	5.26	0.5	0.6	182	6.2	3	4.082	0.3	0.5	172	6.1	3.2	3.871	0.5	0.7	162	6.3	3.7	185
25	24-Jan-14	3315.38	10.3	4.4	78	5.732	0.5	0.8	10.6	6.4	7.629	0.3	0.4	73	11	4.6	5.845	0.3	0.4	71	11	4.2	5.896	0.3	0.5	86	11.3	4.3	93
26	25-Jan-14	3033.68	9.2	4.2	122	5.839	1.3	1.9	10.1	4.2	6.674	0.7	0.9	265	9.1	2.9	5.501	0.4	0.6	259	9.3	2.8	5.535	0.7	0.9	233	9.6	3.1	228
27	26-Jan-14	2960.26	7.7	3.4	200	4.938	0.8	1.3	9.8	2.3	5.358	0.2	1	258	8.4	1	4.878	0.3	0.4	364	8.3	1.3	4.476	0.6	0.8	325	10.2	1.6	372
28	27-Jan-14	3366.73	7.8	5.1	123	5.536	0.7	1.1	8.5	3.9	5.205	0.7	0.9	254	7.4	2.7	4.385	0.4	0.6	224	6.9	2.3	3.969	0.5	0.8	217	6.7	2	245
29	28-Jan-14	3389.08	7	5.9	326	5.685	0.9	1.2	8	2	5.73	0.3	0.4	415	6.5	2.4	5.162	0.3	0.4	187	6.3	3.1	5.003	0.5	0.7	104	6.5	3.4	98
30	29-Jan-14	3406.79	7.1	4.4	285	5.455	0.5	0.7	8.5	0.9	4.274	0.3	0.5	516	5.7	2.9	4.281	0.3	0.4	186	5.9	3.8	4.545	0.5	0.6	103	6.4	4	109
31	30-Jan-14	3408.24	4.8	2.6	120	4.565	0.9	1.3	0 4	0.4	4.419	0.3	0.4	160	5.3	2	4.51/	0.4	0.5	144	5.4	2.2	4.339	0.5	0.6	200	0.6	3.5	231
22	01-Eeb-1/	2145 79	7.1	1.5	161	3 905	0.9	1.5	9.2	0.2	4.485	1	1.2	302	8.2	0.5	3 594	0.4	0.0	190	8.1	0.1	3,402	0.4	1.2	192	9.0	0.0	278
34	02-Feb-16	2940.86	7.9	5.3	379	5.037	1.1	1.5	9.1	3.1	5,105	0.8	1.1	313	8.1	2.6	4.554	0.5	0.7	402	8.5	2.7	4.417	0.7	1	477	9	3.2	484
35	03-Feb-14	3353.58	8.9	4.8	174	5,736	1	1.4	9.5	2.9	5,798	0.5	0.9	282	8.3	2.7	5.592	0.4	0.6	190	9.1	3.5	5.541	0.8	1.1	116	8.6	3.3	127
36	04-Feb-14	3383.83	6.7	2	533	4.317	0.7	0.9	7	0.3	3.837	0.6	0.5	405	6.8	-0.7	4.167	0.3	0.5	494	6.9	0.8	3.862	0.4	0.6	482	7.3	1.1	461
37	05-Feb-14	3424.07	7.7	6	260	5.424	0.8	1.2	7.9	6.2	5.973	0.5	0.7	190	9	5.7	5.758	0.5	0.7	280	8.8	6	5.725	0.7	0.9	250	8.2	6	242
38	06-Feb-14	3354.92	8.9	4.3	549	5.586	0.7	0.8	8.2	1	5.334	0.3	0.5	593	7.9	2	5.446	0.3	0.4	520	7.2	1.4	5.134	0.4	0.6	416	7	0.7	335
39	07-Feb-14	3363.04	7.1	3.9	470	4.83	0.9	1.2	7.7	-1.6	3.699	0.8	0.6	362	7	-1	4.456	0.3	0.4	476	7.9	-0.1	3.698	0.4	0.6	567	7.9	0.6	527
40	08-Feb-14	3103.45	7.8	3.9	202	4.955	0.8	1.1	8.5	4.9	5.136	0.8	1.1	224	7.4	3.9	4.942	0.6	0.8	261	8.5	4.9	4.974	1.1	1.5	448	9.5	5.2	421
41	09-Feb-14	2924.8	8.6	3.8	417	5.108	1.1	1.5	8.2	-1.7	5.014	0.5	0.7	592	7.4	-2	4.911	0.4	0.6	503	7	0.1	4.795	0.6	0.9	492	6.9	-1.7	419
42	10-Feb-14	3345.95	7	1.6	176	4.065	0.9	1.2	7.7	-3.2	3.31	0.6	0.7	520	6.2	-4.3	2.898	0.4	0.6	363	5.3	-2.7	2.541	0.4	0.6	379	5.1	-2.5	473
43	11-Feb-14	3448.28	4	0.3	249	3.014	0.7	1.1	4.5	0.6	2.823	0.2	0.7	317	4	0	2.818	0.3	0.5	387	5.5	0	2.629	0.6	0.9	451	5.6	0.1	552
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Figure 15: Finalised Data

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2	0.5	0.7	105	10	3.2	5.7	0.3	0.4	129	7.1	3.6	5.725	0.4	0.6	89	281.067	280.995	0.983	280.992	-22.98	56.969	76.658	13.342	0.067	13.408	0.434	0.316	0.434	-0.901
3	0.2	0.2	302	9.6	1.9	4.675	0.3	0.4	231	9.6	5.6	5.75	0.7	0.8	287	282.053	282.014	0.983	282.011	-22.893	57.134	76.579	13.421	0.066	13.487	-0.434	0.317	-0.434	-0.901
1	1.3	1.7	184	7.6	3.2	4.75	0.9	1.2	173	8.1	3.8	5.825	0.8	1	283	283.038	283.034	0.983	283.031	-22.797	57.313	76.492	13.508	0.066	13.574	-0.975	0.318	-0.975	-0.223
5	0.3	0.4	305	5.1	0	3.25	0.2	0.3	374	6.2	2.2	5.1	0.4	0.5	300	284.024	284.053	0.983	284.05	-22.694	57.505	76.398	13.602	0.065	13.667	-0.782	0.319	-0.782	0.623
,	0.4	0.6	63	11.1	0.6	4.85	0.2	0.4	180	13.4	1.8	5.5	0.6	0.8	21/	285.01	285.072	0.983	285.069	-22.584	57.71	76.296	13.704	0.065	13.769	0 797	0.321	0 792	1
2	0.7	0.9	238	9.3	5.7	6.15	0.5	0.7	274	9.4	6.5	6.2	0.7	0.9	2/0	285.995	287.111	0.983	287.108	-22.341	58.16	76.071	13.929	0.064	13.993	0.975	0.322	0.975	-0.223
2	0.5	0.6	53	7.6	3.8	5.175	0.2	0.3	76	7.9	3.5	6.05	0.2	0.3	124	287.967	288.13	0.983	288.127	-22.208	58.404	75.947	14.053	0.063	14.117	0.434	0.324	0.434	-0.901
0	0.2	0.2	415	7.6	1.4	4.35	0.2	0.3	430	7.9	1	5.35	0.2	0.2	354	288.952	289.149	0.983	289.146	-22.069	58.659	75.816	14.184	0.063	14.247	-0.434	0.326	-0.434	-0.901
1	0.3	0.4	116	8.6	2.5	5.3	0.2	0.3	233	8.1	1.4	5.8	0.2	0.2	151	289.938	290.168	0.983	290.165	-21.921	58.927	75.677	14.323	0.062	14.385	-0.975	0.327	-0.975	-0.223
2	0.2	0.3	435	8	0.1	3.525	0.2	0.3	436	7.4	0.8	4.725	0.2	0.3	396	290.924	291.187	0.983	291.184	-21.767	59.206	75.532	14.468	0.061	14.53	-0.782	0.329	-0.782	0.623
3	0.4	0.7	32	9.5	1.8	6	0.3	0.6	108	10.2	3.7	5.9	0.6	0.9	69	291.909	292.206	0.983	292.203	-21.606	59.497	75.379	14.621	0.061	14.682	0	0.331	0	1
4	0.5	0.6	202	6.2	1.6	3.875	0.4	0.5	305	6.8	0	5.05	0.2	0.3	266	292.895	293.225	0.984	293.222	-21.438	59.798	75.22	14.78	0.06	14.84	0.782	0.332	0.782	0.623
5	0.3	0.5	96	10.2	0.2	6.025	0.4	0.5	100	10.4	0	4.65	0.3	0.4	76	293.88	294.243	0.984	294.24	-21.203	60.111	75.053	14.947	0.059	15.006	0.975	0.334	0.975	-0.223
7	0.3	0.0	343	7.8	4.7	5.45	0.3	0.5	24	8.4	4.0	5.825	0.5	0.5	2/5	294.000	295.202	0.984	295.235	-21.081	60.766	74.00	15 301	0.059	15.359	-0.434	0.338	-0.434	-0.901
8	0.3	0.4	360	8.6	2.7	4,625	0.2	0.3	399	8.3	4.5	5.85	0.2	0.3	293	296.837	297.299	0.984	297,296	-20,697	61.108	74.512	15,488	0.057	15.545	-0.975	0.339	-0.975	-0.223
9	0.3	0.5	186	6.3	1.8	4.6	0.5	0.6	286	5.8	2	5.625	0.3	0.4	129	297.823	298.317	0.984	298.314	-20.495	61.46	74.319	15.681	0.057	15.738	-0.782	0.341	-0.782	0.623
0	0.3	0.4	277	6.5	-0.3	3.675	0.3	0.5	237	6.8	2.4	5.375	0.3	0.5	266	298.809	299.335	0.984	299.332	-20.287	61.82	74.118	15.882	0.056	15.938	0	0.343	0	1
1	0.3	0.4	480	7.8	1.8	3.575	0.3	0.4	509	9.1	1.8	5.025	0.4	0.5	492	299.794	300.353	0.984	300.35	-20.073	62.19	73.911	16.089	0.055	16.144	0.782	0.345	0.782	0.623
2	0.5	0.7	122	9	3.6	5.75	0.3	0.5	190	9	5.3	5.875	0.5	0.7	137	300.78	301.371	0.984	301.367	-19.852	62.568	73.698	16.302	0.054	16.356	0.975	0.348	0.975	-0.223
3	0.4	0.5	431	8.6	3	4.75	0.5	0.6	435	10	5.1	5.875	0.6	0.8	349	301.766	302.388	0.984	302.385	-19.625	62.954	73.479	16.521	0.054	16.575	0.434	0.35	0.434	-0.901
4	0.4	0.5	299	12.2	5.4	5.15	0.7	0.9	263	8.7	5.3	7 375	0.6	0.8	168	302.751	303.405	0.984	303.402	-19.392	63.348	73.253	16.747	0.053	16.8	-0.434	0.352	-0.434	-0.901
6	0.7	0.0	293	10.2	3	6.175	0.5	0.7	300	10.7	5.9	7.05	1.1	1.4	251	303.737	305,439	0.985	305.436	-18 908	64 158	72 783	17 217	0.052	17.052	-0.373	0.354	-0.373	0.623
7	0.5	0.7	322	10.9	0.8	5.725	0.5	0.8	358	10.5	2.6	5,975	0.9	1.3	291	305,708	306.456	0.985	306.453	-18.657	64.574	72,538	17.462	0.051	17.512	0.702	0.359	0.702	1
8	0.7	0.9	353	7.5	2.7	4.4	0.7	1	337	8.5	4.2	5.325	1	1.4	241	306.694	307.472	0.985	307.469	-18.4	64.996	72.289	17.711	0.05	17.761	0.782	0.361	0.782	0.623
9	0.8	1	214	7.1	3.4	4.65	0.8	1.1	229	8.2	3.6	5.675	0.8	1	159	307.68	308.489	0.985	308.485	-18.139	65.425	72.033	17.967	0.049	18.016	0.975	0.363	0.975	-0.223
0	0.6	0.8	309	8.2	2.9	4.1	0.9	1.2	393	8.6	1.6	4.825	0.7	0.8	361	308.665	309.505	0.985	309.501	-17.871	65.86	71.771	18.229	0.048	18.277	0.434	0.366	0.434	-0.901
1	0.6	0.7	205	5	2.1	4.025	0.3	0.4	165	5.7	0	4.625	0.3	0.4	214	309.651	310.52	0.985	310.517	-17.599	66.301	71.504	18.496	0.048	18.543	-0.434	0.368	-0.434	-0.901
2	0.5	0.7	173	8.9	1	5	0.3	0.5	292	8.8	1.5	5.225	0.9	1.3	332	310.636	311.536	0.985	311.532	-17.321	66.747	71.232	18.768	0.047	18.815	-0.975	0.371	-0.975	-0.223
3	0.8	1.2	199	6.6	0.8	3.95	0.6	1	194	8.6	2.5	4.8	1.3	2.1	214	311.622	312.551	0.985	312.548	-17.038	67.199	70.954	19.046	0.046	19.092	-0.782	0.373	-0.782	0.623
4	0.8	1.1	446	9	1.6	4.25	0.6	0.9	598	10.3	4.4	5.325	1.2	1.5	394	312.608	313.566	0.986	313.562	-16.75	60.117	70.671	19.329	0.046	19.375	0 792	0.376	0 792	1
6	0.5	0.8	412	8.2	-0.2	3.725	0.4	0.7	258	9.1	3.4	4.575	0.8	0.9	208	314 579	315.594	0.986	315 591	-16.159	68 582	70.382	19.911	0.045	19.955	0.975	0.381	0.975	-0.223
7	0.8	1.2	195	8,4	4.3	5.65	0.6	0.9	397	9	6.4	5.75	0.9	1.2	240	315.565	316.608	0.986	316.605	-15.857	69.054	69,791	20.209	0.043	20.253	0.434	0.384	0.434	-0.901
8	0.5	0.7	218	6.4	2.8	4.05	0.5	0.7	380	8.6	3.5	5.325	0.6	0.8	485	316.55	317.622	0.986	317.619	-15.55	69.528	69.488	20.512	0.043	20.555	-0.434	0.386	-0.434	-0.901
9	0.3	0.6	503	8	-0.4	3.475	0.4	0.6	325	7.9	1.8	4.525	0.6	0.8	425	317.536	318.635	0.986	318.632	-15.239	70.007	69.18	20.82	0.042	20.862	-0.975	0.389	-0.975	-0.223
0	1.1	1.5	332	7.8	3.3	4.8	0.6	1	365	8.8	4.9	5.15	1.2	1.7	319	318.522	319.648	0.986	319.645	-14.923	70.489	68.867	21.133	0.041	21.174	-0.782	0.392	-0.782	0.623
4	0.9	1.2	607	5.7	1	4.275	0.5	0.8	562	7.9	2	5.25	0.9	1.3	498	319.507	320.66	0.987	320.657	-14.604	70.975	68.55	21.45	0.041	21.49	0	0.394	0	1

Figure 16: Finalised Data

8 Modelling

The implementation of the models took place in an Annaconda environment using python 3. The datasets had been prepared and only needed to be divided into training and testing sets for each model. The Eirgrid data that is to be modelled is plotted in *figure 17*



Figure 17: Electricity Consumption in The Republic of Ireland 2014 - 2020

8.1 Implementation of the Sarimax Model

The data was first loaded into the Annaconda environment in spyder. The index was set to the date field of the dataset (*figure 18*).

The first step in modelling this data was to look at the Auto Correlation Function Graph



Figure 18: Loading the Data and Setting the Index

and the Partial Auto-Correlation Function Graph(*figure 19*). As mentioned previously this gives an indication of how many lags to use for the Auto-Regressive components (*figure 20*) and the Moving Averages components(*figure 21*). The Dickey-Fuller test had already established that the data was not stationary to the critical value for the 5% level of significance (*figure 22*). This indicated that the integration step was required.

Following this the test and train datasets were created and then tested for Seasonality (*figure 23*). The Sarimax model was then trained and fitted (*figure 24* and *figure 25*). The actual values(blue) of the test set were then plotted against the predicted values(red) (*figure 26*) and the evaluation metrics calculated (*figure 27*.



Figure 19: Computing the ACF and the PACF



Figure 20: Auto Correlation Function



Figure 22: Augmented Dickey-Fuller Test

Figure 23: Test for Seasonality

Figure 24: Sarimax Model Implementation

Figure 25: Sarimax Model Implementation Plotting Results

Figure 26: Sarimax Model Implementation Results

Figure 27: Sarimax Model Evaluation Metrics

8.2 Implementation of the Bi-Directional Long Short Term Memory Neural Network

The data was first loaded into the Annaconda environment in spyder. The index was set to the date field of the dataset. Training and test sets were created and the a selection of columns scaled. RobustScaler was used as this function allows the rescaling of data. MinmaxScaler was also considered. The encoded day values were not scaled.Following this the training set was reshaped into a 3 dimensional numpy array for input to the LSTM (*figure 28*). The reshaping of data into a numpy array was created from a tutorial by Hristo_Mavrodief (2019). After this the model was trained with the parameters as discussed in the accompanying document (*figure 29*). A plot to view the validation loss form the validation set was produced. This helped with viewing the convergence of the loss between the datasets and assisted in determining the optimal number of epochs for the training of the LSTM (*figure 30*). Once the model was fitted the results were plotted and the evaluation metrics computed for the results. This involved flattening the the output array and rescaling the values (*figure 31*). The final graph was a comparison between the models predicted values and actual values from the test set (*figure 32*). The metrics for the model can be viewed in *figure 33*

Figure 28: LSTM Preparation

Figure 29: LSTM Training and Fitting

Figure 30: Validation Loss

Figure 31: LSTM Evaluation

Figure 32: Predicted and Actual Values

Figure 33: Metrics

References

$$\label{eq:constraint} \begin{split} & \text{Hristo}_M avrodief(2019). Demand prediction with lst ms using tensor flow 2 and kerasin python. \\ & \textbf{URL:} https://curiousily.com/posts/demand-prediction-with-lst ms-using-tensor flow 2 and kerasin python. \end{split}$$

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