

2021_Wavelets

#ALEXANDER #Read in Data

##Reading in a 10 year hourly temperature time series dataset from Alexander Pond called "APH" (Alexander Pond Historical)

```
APH <- read.csv("Alexander_Historical_2.csv")
```

APH\$date <- lubridate::mdy_hm(APH\$Date_Time) #convert dates to POSIXct format and bin by hour

#Check for missing data

```
missing_data <- APH[!complete.cases(APH),]
```

```
missing_data
```

##	Date_Time	Temp	date
## 7562		NA	<NA>
## 39325		NA	<NA>
## 41690		NA	<NA>
## 52949		NA	<NA>
## 57966		NA	<NA>
## 58011	12/3/2017 19:00	NA	2017-12-03 19:00:00
## 58012	12/3/2017 20:00	NA	2017-12-03 20:00:00
## 58013	12/3/2017 21:00	NA	2017-12-03 21:00:00
## 58014	12/3/2017 22:00	NA	2017-12-03 22:00:00
## 58015	12/3/2017 23:00	NA	2017-12-03 23:00:00
## 58016	12/4/2017 0:00	NA	2017-12-04 00:00:00
## 58017	12/4/2017 1:00	NA	2017-12-04 01:00:00
## 58018	12/4/2017 2:00	NA	2017-12-04 02:00:00
## 58019	12/4/2017 3:00	NA	2017-12-04 03:00:00
## 58020	12/4/2017 4:00	NA	2017-12-04 04:00:00
## 58021	12/4/2017 5:00	NA	2017-12-04 05:00:00
## 58022	12/4/2017 6:00	NA	2017-12-04 06:00:00
## 58023	12/4/2017 7:00	NA	2017-12-04 07:00:00
## 58024	12/4/2017 8:00	NA	2017-12-04 08:00:00
## 58025	12/4/2017 9:00	NA	2017-12-04 09:00:00
## 58026	12/4/2017 10:00	NA	2017-12-04 10:00:00
## 58027	12/4/2017 11:00	NA	2017-12-04 11:00:00
## 58028	12/4/2017 12:00	NA	2017-12-04 12:00:00
## 58029	12/4/2017 13:00	NA	2017-12-04 13:00:00
## 58030	12/4/2017 14:00	NA	2017-12-04 14:00:00
## 58031	12/4/2017 15:00	NA	2017-12-04 15:00:00
## 58032	12/4/2017 16:00	NA	2017-12-04 16:00:00
## 58033	12/4/2017 17:00	NA	2017-12-04 17:00:00
## 58034	12/4/2017 18:00	NA	2017-12-04 18:00:00
## 58035	12/4/2017 19:00	NA	2017-12-04 19:00:00
## 58036	12/4/2017 20:00	NA	2017-12-04 20:00:00
## 58037	12/4/2017 21:00	NA	2017-12-04 21:00:00
## 58038	12/4/2017 22:00	NA	2017-12-04 22:00:00

```
## 58039 12/4/2017 23:00 NA 2017-12-04 23:00:00
## 58040 12/5/2017 0:00 NA 2017-12-05 00:00:00
## 58041 12/5/2017 1:00 NA 2017-12-05 01:00:00
## 58042 12/5/2017 2:00 NA 2017-12-05 02:00:00
## 58043 12/5/2017 3:00 NA 2017-12-05 03:00:00
## 58044 12/5/2017 4:00 NA 2017-12-05 04:00:00
## 58045 12/5/2017 5:00 NA 2017-12-05 05:00:00
## 58046 12/5/2017 6:00 NA 2017-12-05 06:00:00
## 58047 12/5/2017 7:00 NA 2017-12-05 07:00:00
## 58048 12/5/2017 8:00 NA 2017-12-05 08:00:00
## 58049 12/5/2017 9:00 NA 2017-12-05 09:00:00
## 58050 12/5/2017 10:00 NA 2017-12-05 10:00:00
## 58051 12/5/2017 11:00 NA 2017-12-05 11:00:00
```

#Wavelets require a complete dataset with no missing data. Since there is missing data in this dataset, we will need to interpolate

#Bin data by hour

APH\$hour <- lubridate::round_date(APH\$date, unit="hour") #Before we interpolate, let's bin by hour

head(APH) #check the dataset start date, use for "hour" sequence

```
##          Date_Time    Temp          date          hour
## 1 12/16/2010 13:11 5.667778 2010-12-16 13:11:00 2010-12-16 13:00:00
## 2 12/16/2010 14:11 5.770000 2010-12-16 14:11:00 2010-12-16 14:00:00
## 3 12/16/2010 15:11 5.821111 2010-12-16 15:11:00 2010-12-16 15:00:00
## 4 12/16/2010 16:11 5.770000 2010-12-16 16:11:00 2010-12-16 16:00:00
## 5 12/16/2010 17:11 5.692778 2010-12-16 17:11:00 2010-12-16 17:00:00
## 6 12/16/2010 18:11 5.565000 2010-12-16 18:11:00 2010-12-16 18:00:00
```

tail(APH) #check the dataset end date, use for "hour" sequence

```
##          Date_Time    Temp          date          hour
## 92848 11/24/2021 9:00 7.619 2021-11-24 09:00:00 2021-11-24 09:00:00
## 92849 11/24/2021 10:00 7.569 2021-11-24 10:00:00 2021-11-24 10:00:00
## 92850 11/24/2021 11:00 7.544 2021-11-24 11:00:00 2021-11-24 11:00:00
## 92851 11/24/2021 12:00 7.494 2021-11-24 12:00:00 2021-11-24 12:00:00
## 92852 11/24/2021 13:00 7.494 2021-11-24 13:00:00 2021-11-24 13:00:00
## 92853 11/24/2021 14:00 7.519 2021-11-24 14:00:00 2021-11-24 14:00:00
```

#Create hourly sequence to ensure all missing data is accounted for

hour <- seq(mdy_h('12/16/2010 13'),mdy_h('11/24/2021 14'),by = "hour")

#Create an object that goes hour by hour for the entire time series to ensure that ALL missing data is accounted for

hour <- as.data.frame(hour) #convert "hour" to data frame

APH <- left_join(hour, APH) #left join hour and dataset

Joining, by = "hour"

```
missing_data <- APH[!complete.cases(APH),]
missing_data #Now we are sure that all the missing hour time steps are included.
```

##		hour	Date_Time	Temp	date
##	7562	2011-10-27 14:00:00	<NA>	NA	<NA>
##	7563	2011-10-27 15:00:00	<NA>	NA	<NA>
##	7564	2011-10-27 16:00:00	<NA>	NA	<NA>
##	7565	2011-10-27 17:00:00	<NA>	NA	<NA>
##	7566	2011-10-27 18:00:00	<NA>	NA	<NA>
##	7567	2011-10-27 19:00:00	<NA>	NA	<NA>
##	7568	2011-10-27 20:00:00	<NA>	NA	<NA>
##	7569	2011-10-27 21:00:00	<NA>	NA	<NA>
##	7570	2011-10-27 22:00:00	<NA>	NA	<NA>
##	7571	2011-10-27 23:00:00	<NA>	NA	<NA>
##	7572	2011-10-28 00:00:00	<NA>	NA	<NA>
##	7573	2011-10-28 01:00:00	<NA>	NA	<NA>
##	7574	2011-10-28 02:00:00	<NA>	NA	<NA>
##	7575	2011-10-28 03:00:00	<NA>	NA	<NA>
##	7576	2011-10-28 04:00:00	<NA>	NA	<NA>
##	7577	2011-10-28 05:00:00	<NA>	NA	<NA>
##	7578	2011-10-28 06:00:00	<NA>	NA	<NA>
##	7579	2011-10-28 07:00:00	<NA>	NA	<NA>
##	7580	2011-10-28 08:00:00	<NA>	NA	<NA>
##	7581	2011-10-28 09:00:00	<NA>	NA	<NA>
##	7582	2011-10-28 10:00:00	<NA>	NA	<NA>
##	7583	2011-10-28 11:00:00	<NA>	NA	<NA>
##	7584	2011-10-28 12:00:00	<NA>	NA	<NA>
##	7585	2011-10-28 13:00:00	<NA>	NA	<NA>
##	7586	2011-10-28 14:00:00	<NA>	NA	<NA>
##	7587	2011-10-28 15:00:00	<NA>	NA	<NA>
##	7588	2011-10-28 16:00:00	<NA>	NA	<NA>
##	7589	2011-10-28 17:00:00	<NA>	NA	<NA>
##	7590	2011-10-28 18:00:00	<NA>	NA	<NA>
##	7591	2011-10-28 19:00:00	<NA>	NA	<NA>
##	7592	2011-10-28 20:00:00	<NA>	NA	<NA>
##	7593	2011-10-28 21:00:00	<NA>	NA	<NA>
##	7594	2011-10-28 22:00:00	<NA>	NA	<NA>
##	7595	2011-10-28 23:00:00	<NA>	NA	<NA>
##	7596	2011-10-29 00:00:00	<NA>	NA	<NA>
##	7597	2011-10-29 01:00:00	<NA>	NA	<NA>
##	7598	2011-10-29 02:00:00	<NA>	NA	<NA>
##	7599	2011-10-29 03:00:00	<NA>	NA	<NA>
##	7600	2011-10-29 04:00:00	<NA>	NA	<NA>
##	7601	2011-10-29 05:00:00	<NA>	NA	<NA>
##	7602	2011-10-29 06:00:00	<NA>	NA	<NA>
##	7603	2011-10-29 07:00:00	<NA>	NA	<NA>
##	7604	2011-10-29 08:00:00	<NA>	NA	<NA>
##	7605	2011-10-29 09:00:00	<NA>	NA	<NA>
##	7606	2011-10-29 10:00:00	<NA>	NA	<NA>

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## 7657	2011-10-31 13:00:00	<NA>	NA	<NA>
## 7658	2011-10-31 14:00:00	<NA>	NA	<NA>
## 7659	2011-10-31 15:00:00	<NA>	NA	<NA>
## 7660	2011-10-31 16:00:00	<NA>	NA	<NA>
## 7661	2011-10-31 17:00:00	<NA>	NA	<NA>
## 7662	2011-10-31 18:00:00	<NA>	NA	<NA>
## 7663	2011-10-31 19:00:00	<NA>	NA	<NA>
## 7664	2011-10-31 20:00:00	<NA>	NA	<NA>
## 7665	2011-10-31 21:00:00	<NA>	NA	<NA>
## 7666	2011-10-31 22:00:00	<NA>	NA	<NA>
## 7667	2011-10-31 23:00:00	<NA>	NA	<NA>
## 7668	2011-11-01 00:00:00	<NA>	NA	<NA>
## 7669	2011-11-01 01:00:00	<NA>	NA	<NA>
## 7670	2011-11-01 02:00:00	<NA>	NA	<NA>
## 7671	2011-11-01 03:00:00	<NA>	NA	<NA>
## 7672	2011-11-01 04:00:00	<NA>	NA	<NA>
## 7673	2011-11-01 05:00:00	<NA>	NA	<NA>
## 7674	2011-11-01 06:00:00	<NA>	NA	<NA>
## 7675	2011-11-01 07:00:00	<NA>	NA	<NA>
## 7676	2011-11-01 08:00:00	<NA>	NA	<NA>
## 7677	2011-11-01 09:00:00	<NA>	NA	<NA>
## 7678	2011-11-01 10:00:00	<NA>	NA	<NA>
## 7679	2011-11-01 11:00:00	<NA>	NA	<NA>
## 7680	2011-11-01 12:00:00	<NA>	NA	<NA>
## 7681	2011-11-01 13:00:00	<NA>	NA	<NA>
## 7682	2011-11-01 14:00:00	<NA>	NA	<NA>
## 7683	2011-11-01 15:00:00	<NA>	NA	<NA>
## 7684	2011-11-01 16:00:00	<NA>	NA	<NA>
## 7685	2011-11-01 17:00:00	<NA>	NA	<NA>
## 7686	2011-11-01 18:00:00	<NA>	NA	<NA>
## 7687	2011-11-01 19:00:00	<NA>	NA	<NA>
## 7688	2011-11-01 20:00:00	<NA>	NA	<NA>
## 7689	2011-11-01 21:00:00	<NA>	NA	<NA>
## 7690	2011-11-01 22:00:00	<NA>	NA	<NA>
## 7691	2011-11-01 23:00:00	<NA>	NA	<NA>
## 7692	2011-11-02 00:00:00	<NA>	NA	<NA>
## 7693	2011-11-02 01:00:00	<NA>	NA	<NA>
## 7694	2011-11-02 02:00:00	<NA>	NA	<NA>
## 7695	2011-11-02 03:00:00	<NA>	NA	<NA>
## 7696	2011-11-02 04:00:00	<NA>	NA	<NA>
## 7697	2011-11-02 05:00:00	<NA>	NA	<NA>
## 7698	2011-11-02 06:00:00	<NA>	NA	<NA>
## 7699	2011-11-02 07:00:00	<NA>	NA	<NA>
## 7700	2011-11-02 08:00:00	<NA>	NA	<NA>
## 7701	2011-11-02 09:00:00	<NA>	NA	<NA>
## 7702	2011-11-02 10:00:00	<NA>	NA	<NA>
## 7703	2011-11-02 11:00:00	<NA>	NA	<NA>
## 7704	2011-11-02 12:00:00	<NA>	NA	<NA>
## 7705	2011-11-02 13:00:00	<NA>	NA	<NA>
## 7706	2011-11-02 14:00:00	<NA>	NA	<NA>

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## 7907	2011-11-10 23:00:00	<NA>	NA	<NA>
## 7908	2011-11-11 00:00:00	<NA>	NA	<NA>
## 7909	2011-11-11 01:00:00	<NA>	NA	<NA>
## 7910	2011-11-11 02:00:00	<NA>	NA	<NA>
## 7911	2011-11-11 03:00:00	<NA>	NA	<NA>
## 7912	2011-11-11 04:00:00	<NA>	NA	<NA>
## 7913	2011-11-11 05:00:00	<NA>	NA	<NA>
## 7914	2011-11-11 06:00:00	<NA>	NA	<NA>
## 7915	2011-11-11 07:00:00	<NA>	NA	<NA>
## 7916	2011-11-11 08:00:00	<NA>	NA	<NA>
## 7917	2011-11-11 09:00:00	<NA>	NA	<NA>
## 7918	2011-11-11 10:00:00	<NA>	NA	<NA>
## 7919	2011-11-11 11:00:00	<NA>	NA	<NA>
## 7920	2011-11-11 12:00:00	<NA>	NA	<NA>
## 7921	2011-11-11 13:00:00	<NA>	NA	<NA>
## 7922	2011-11-11 14:00:00	<NA>	NA	<NA>
## 7923	2011-11-11 15:00:00	<NA>	NA	<NA>
## 7924	2011-11-11 16:00:00	<NA>	NA	<NA>
## 7925	2011-11-11 17:00:00	<NA>	NA	<NA>
## 7926	2011-11-11 18:00:00	<NA>	NA	<NA>
## 7927	2011-11-11 19:00:00	<NA>	NA	<NA>
## 7928	2011-11-11 20:00:00	<NA>	NA	<NA>
## 7929	2011-11-11 21:00:00	<NA>	NA	<NA>
## 7930	2011-11-11 22:00:00	<NA>	NA	<NA>
## 7931	2011-11-11 23:00:00	<NA>	NA	<NA>
## 7932	2011-11-12 00:00:00	<NA>	NA	<NA>
## 7933	2011-11-12 01:00:00	<NA>	NA	<NA>
## 7934	2011-11-12 02:00:00	<NA>	NA	<NA>
## 7935	2011-11-12 03:00:00	<NA>	NA	<NA>
## 7936	2011-11-12 04:00:00	<NA>	NA	<NA>
## 7937	2011-11-12 05:00:00	<NA>	NA	<NA>
## 7938	2011-11-12 06:00:00	<NA>	NA	<NA>
## 7939	2011-11-12 07:00:00	<NA>	NA	<NA>
## 7940	2011-11-12 08:00:00	<NA>	NA	<NA>
## 7941	2011-11-12 09:00:00	<NA>	NA	<NA>
## 7942	2011-11-12 10:00:00	<NA>	NA	<NA>
## 7943	2011-11-12 11:00:00	<NA>	NA	<NA>
## 7944	2011-11-12 12:00:00	<NA>	NA	<NA>
## 7945	2011-11-12 13:00:00	<NA>	NA	<NA>
## 7946	2011-11-12 14:00:00	<NA>	NA	<NA>
## 7947	2011-11-12 15:00:00	<NA>	NA	<NA>
## 7948	2011-11-12 16:00:00	<NA>	NA	<NA>
## 7949	2011-11-12 17:00:00	<NA>	NA	<NA>
## 7950	2011-11-12 18:00:00	<NA>	NA	<NA>
## 7951	2011-11-12 19:00:00	<NA>	NA	<NA>
## 7952	2011-11-12 20:00:00	<NA>	NA	<NA>
## 7953	2011-11-12 21:00:00	<NA>	NA	<NA>
## 7954	2011-11-12 22:00:00	<NA>	NA	<NA>
## 7955	2011-11-12 23:00:00	<NA>	NA	<NA>
## 7956	2011-11-13 00:00:00	<NA>	NA	<NA>

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## 8107	2011-11-19 07:00:00	<NA>	NA	<NA>
## 8108	2011-11-19 08:00:00	<NA>	NA	<NA>
## 8109	2011-11-19 09:00:00	<NA>	NA	<NA>
## 8110	2011-11-19 10:00:00	<NA>	NA	<NA>
## 8111	2011-11-19 11:00:00	<NA>	NA	<NA>
## 8112	2011-11-19 12:00:00	<NA>	NA	<NA>
## 8113	2011-11-19 13:00:00	<NA>	NA	<NA>
## 8114	2011-11-19 14:00:00	<NA>	NA	<NA>
## 8115	2011-11-19 15:00:00	<NA>	NA	<NA>
## 8116	2011-11-19 16:00:00	<NA>	NA	<NA>
## 8117	2011-11-19 17:00:00	<NA>	NA	<NA>
## 8118	2011-11-19 18:00:00	<NA>	NA	<NA>
## 8119	2011-11-19 19:00:00	<NA>	NA	<NA>
## 8120	2011-11-19 20:00:00	<NA>	NA	<NA>
## 8121	2011-11-19 21:00:00	<NA>	NA	<NA>
## 8122	2011-11-19 22:00:00	<NA>	NA	<NA>
## 8123	2011-11-19 23:00:00	<NA>	NA	<NA>
## 8124	2011-11-20 00:00:00	<NA>	NA	<NA>
## 8125	2011-11-20 01:00:00	<NA>	NA	<NA>
## 8126	2011-11-20 02:00:00	<NA>	NA	<NA>
## 8127	2011-11-20 03:00:00	<NA>	NA	<NA>
## 8128	2011-11-20 04:00:00	<NA>	NA	<NA>
## 8129	2011-11-20 05:00:00	<NA>	NA	<NA>
## 8130	2011-11-20 06:00:00	<NA>	NA	<NA>
## 8131	2011-11-20 07:00:00	<NA>	NA	<NA>
## 8132	2011-11-20 08:00:00	<NA>	NA	<NA>
## 8133	2011-11-20 09:00:00	<NA>	NA	<NA>
## 8134	2011-11-20 10:00:00	<NA>	NA	<NA>
## 8135	2011-11-20 11:00:00	<NA>	NA	<NA>
## 8136	2011-11-20 12:00:00	<NA>	NA	<NA>
## 8137	2011-11-20 13:00:00	<NA>	NA	<NA>
## 8138	2011-11-20 14:00:00	<NA>	NA	<NA>
## 8139	2011-11-20 15:00:00	<NA>	NA	<NA>
## 8140	2011-11-20 16:00:00	<NA>	NA	<NA>
## 8141	2011-11-20 17:00:00	<NA>	NA	<NA>
## 8142	2011-11-20 18:00:00	<NA>	NA	<NA>
## 8143	2011-11-20 19:00:00	<NA>	NA	<NA>
## 8144	2011-11-20 20:00:00	<NA>	NA	<NA>
## 8145	2011-11-20 21:00:00	<NA>	NA	<NA>
## 8146	2011-11-20 22:00:00	<NA>	NA	<NA>
## 8147	2011-11-20 23:00:00	<NA>	NA	<NA>
## 8148	2011-11-21 00:00:00	<NA>	NA	<NA>
## 8149	2011-11-21 01:00:00	<NA>	NA	<NA>
## 8150	2011-11-21 02:00:00	<NA>	NA	<NA>
## 8151	2011-11-21 03:00:00	<NA>	NA	<NA>
## 8152	2011-11-21 04:00:00	<NA>	NA	<NA>
## 8153	2011-11-21 05:00:00	<NA>	NA	<NA>
## 8154	2011-11-21 06:00:00	<NA>	NA	<NA>
## 8155	2011-11-21 07:00:00	<NA>	NA	<NA>
## 8156	2011-11-21 08:00:00	<NA>	NA	<NA>

## 8157	2011-11-21 09:00:00	<NA>	NA	<NA>
## 8158	2011-11-21 10:00:00	<NA>	NA	<NA>
## 8159	2011-11-21 11:00:00	<NA>	NA	<NA>
## 8160	2011-11-21 12:00:00	<NA>	NA	<NA>
## 8161	2011-11-21 13:00:00	<NA>	NA	<NA>
## 8162	2011-11-21 14:00:00	<NA>	NA	<NA>
## 8163	2011-11-21 15:00:00	<NA>	NA	<NA>
## 8164	2011-11-21 16:00:00	<NA>	NA	<NA>
## 8165	2011-11-21 17:00:00	<NA>	NA	<NA>
## 8166	2011-11-21 18:00:00	<NA>	NA	<NA>
## 8167	2011-11-21 19:00:00	<NA>	NA	<NA>
## 8168	2011-11-21 20:00:00	<NA>	NA	<NA>
## 8169	2011-11-21 21:00:00	<NA>	NA	<NA>
## 8170	2011-11-21 22:00:00	<NA>	NA	<NA>
## 8171	2011-11-21 23:00:00	<NA>	NA	<NA>
## 8172	2011-11-22 00:00:00	<NA>	NA	<NA>
## 8173	2011-11-22 01:00:00	<NA>	NA	<NA>
## 8174	2011-11-22 02:00:00	<NA>	NA	<NA>
## 8175	2011-11-22 03:00:00	<NA>	NA	<NA>
## 8176	2011-11-22 04:00:00	<NA>	NA	<NA>
## 8177	2011-11-22 05:00:00	<NA>	NA	<NA>
## 8178	2011-11-22 06:00:00	<NA>	NA	<NA>
## 8179	2011-11-22 07:00:00	<NA>	NA	<NA>
## 8180	2011-11-22 08:00:00	<NA>	NA	<NA>
## 8181	2011-11-22 09:00:00	<NA>	NA	<NA>
## 8182	2011-11-22 10:00:00	<NA>	NA	<NA>
## 8183	2011-11-22 11:00:00	<NA>	NA	<NA>
## 8184	2011-11-22 12:00:00	<NA>	NA	<NA>
## 8185	2011-11-22 13:00:00	<NA>	NA	<NA>
## 8186	2011-11-22 14:00:00	<NA>	NA	<NA>
## 8187	2011-11-22 15:00:00	<NA>	NA	<NA>
## 8188	2011-11-22 16:00:00	<NA>	NA	<NA>
## 8189	2011-11-22 17:00:00	<NA>	NA	<NA>
## 8190	2011-11-22 18:00:00	<NA>	NA	<NA>
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## 61045	2017-12-01 22:00:00	<NA>	NA	<NA>
## 61090	2017-12-03 19:00:00 12/3/2017 19:00	NA	2017-12-03 19:00:00	
## 61091	2017-12-03 20:00:00 12/3/2017 20:00	NA	2017-12-03 20:00:00	
## 61092	2017-12-03 21:00:00 12/3/2017 21:00	NA	2017-12-03 21:00:00	
## 61093	2017-12-03 22:00:00 12/3/2017 22:00	NA	2017-12-03 22:00:00	
## 61094	2017-12-03 23:00:00 12/3/2017 23:00	NA	2017-12-03 23:00:00	
## 61095	2017-12-04 00:00:00 12/4/2017 0:00	NA	2017-12-04 00:00:00	
## 61096	2017-12-04 01:00:00 12/4/2017 1:00	NA	2017-12-04 01:00:00	
## 61097	2017-12-04 02:00:00 12/4/2017 2:00	NA	2017-12-04 02:00:00	
## 61098	2017-12-04 03:00:00 12/4/2017 3:00	NA	2017-12-04 03:00:00	
## 61099	2017-12-04 04:00:00 12/4/2017 4:00	NA	2017-12-04 04:00:00	
## 61100	2017-12-04 05:00:00 12/4/2017 5:00	NA	2017-12-04 05:00:00	


```
## 61101 2017-12-04 06:00:00 12/4/2017 6:00 NA 2017-12-04 06:00:00
## 61102 2017-12-04 07:00:00 12/4/2017 7:00 NA 2017-12-04 07:00:00
## 61103 2017-12-04 08:00:00 12/4/2017 8:00 NA 2017-12-04 08:00:00
## 61104 2017-12-04 09:00:00 12/4/2017 9:00 NA 2017-12-04 09:00:00
## 61105 2017-12-04 10:00:00 12/4/2017 10:00 NA 2017-12-04 10:00:00
## 61106 2017-12-04 11:00:00 12/4/2017 11:00 NA 2017-12-04 11:00:00
## 61107 2017-12-04 12:00:00 12/4/2017 12:00 NA 2017-12-04 12:00:00
## 61108 2017-12-04 13:00:00 12/4/2017 13:00 NA 2017-12-04 13:00:00
## 61109 2017-12-04 14:00:00 12/4/2017 14:00 NA 2017-12-04 14:00:00
## 61110 2017-12-04 15:00:00 12/4/2017 15:00 NA 2017-12-04 15:00:00
## 61111 2017-12-04 16:00:00 12/4/2017 16:00 NA 2017-12-04 16:00:00
## 61112 2017-12-04 17:00:00 12/4/2017 17:00 NA 2017-12-04 17:00:00
## 61113 2017-12-04 18:00:00 12/4/2017 18:00 NA 2017-12-04 18:00:00
## 61114 2017-12-04 19:00:00 12/4/2017 19:00 NA 2017-12-04 19:00:00
## 61115 2017-12-04 20:00:00 12/4/2017 20:00 NA 2017-12-04 20:00:00
## 61116 2017-12-04 21:00:00 12/4/2017 21:00 NA 2017-12-04 21:00:00
## 61117 2017-12-04 22:00:00 12/4/2017 22:00 NA 2017-12-04 22:00:00
## 61118 2017-12-04 23:00:00 12/4/2017 23:00 NA 2017-12-04 23:00:00
## 61119 2017-12-05 00:00:00 12/5/2017 0:00 NA 2017-12-05 00:00:00
## 61120 2017-12-05 01:00:00 12/5/2017 1:00 NA 2017-12-05 01:00:00
## 61121 2017-12-05 02:00:00 12/5/2017 2:00 NA 2017-12-05 02:00:00
## 61122 2017-12-05 03:00:00 12/5/2017 3:00 NA 2017-12-05 03:00:00
## 61123 2017-12-05 04:00:00 12/5/2017 4:00 NA 2017-12-05 04:00:00
## 61124 2017-12-05 05:00:00 12/5/2017 5:00 NA 2017-12-05 05:00:00
## 61125 2017-12-05 06:00:00 12/5/2017 6:00 NA 2017-12-05 06:00:00
## 61126 2017-12-05 07:00:00 12/5/2017 7:00 NA 2017-12-05 07:00:00
## 61127 2017-12-05 08:00:00 12/5/2017 8:00 NA 2017-12-05 08:00:00
## 61128 2017-12-05 09:00:00 12/5/2017 9:00 NA 2017-12-05 09:00:00
## 61129 2017-12-05 10:00:00 12/5/2017 10:00 NA 2017-12-05 10:00:00
## 61130 2017-12-05 11:00:00 12/5/2017 11:00 NA 2017-12-05 11:00:00
## 84820 2020-08-18 13:00:00 <NA> NA <NA>
```

#z score to control for outliers

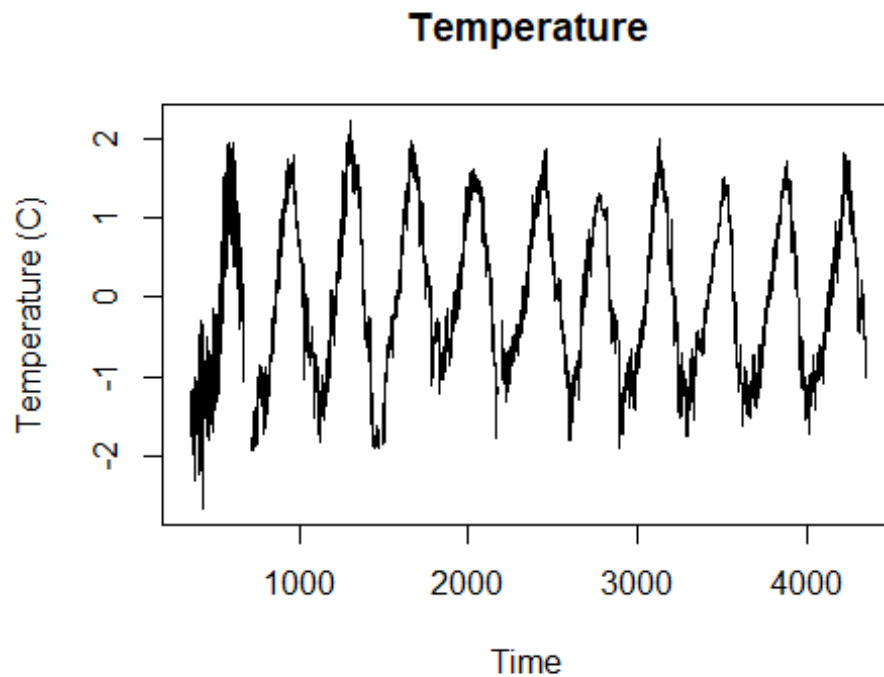
```
APH$zTemp <- zscore(APH$Temp)
```

#Convert to time series

```
APH_ts <- ts(APH$zTemp, start = c(351, 13), frequency = 24) # This time
series starts on 16 Dec 2010 at~13:00, so it starts on day 351 at hour 13 and
the frequency is 24 (24 hours per day)
```

#####This is very confusing and I still don't fully understand how to convert data to time series so may want to ask Albert for clarification.

```
ts.plot(APH_ts,main="Temperature",ylab = "Temperature (C)", xlab = "Time")
```



#Interpolate missing data

#Run ARIMA to interpolate missing data

y <- APH_ts

date_s <- APH\$hour

y_na <- ifelse(is.na(y),0,NA)

fit <- auto.arima(y,trace=TRUE) *#fit limited number of models (faster)*

##

Fitting models using approximations to speed things up...

##

## ARIMA(2,0,2)(1,1,1)[24] with drift	: Inf
## ARIMA(0,0,0)(0,1,0)[24] with drift	: -180159.6
## ARIMA(1,0,0)(1,1,0)[24] with drift	: -455692.7
## ARIMA(0,0,1)(0,1,1)[24] with drift	: -151172.4
## ARIMA(0,0,0)(0,1,0)[24]	: -180160.3
## ARIMA(1,0,0)(0,1,0)[24] with drift	: -450186.9
## ARIMA(1,0,0)(2,1,0)[24] with drift	: -463544.8
## ARIMA(1,0,0)(2,1,1)[24] with drift	: Inf
## ARIMA(1,0,0)(1,1,1)[24] with drift	: Inf
## ARIMA(0,0,0)(2,1,0)[24] with drift	: -184292.9
## ARIMA(2,0,0)(2,1,0)[24] with drift	: Inf
## ARIMA(1,0,1)(2,1,0)[24] with drift	: -346161
## ARIMA(0,0,1)(2,1,0)[24] with drift	: -152991.4
## ARIMA(2,0,1)(2,1,0)[24] with drift	: -350220.9
## ARIMA(1,0,0)(2,1,0)[24]	: -463546.7

```

## ARIMA(1,0,0)(1,1,0)[24] : -455694.7
## ARIMA(1,0,0)(2,1,1)[24] : Inf
## ARIMA(1,0,0)(1,1,1)[24] : Inf
## ARIMA(0,0,0)(2,1,0)[24] : -184292.5
## ARIMA(2,0,0)(2,1,0)[24] : Inf
## ARIMA(1,0,1)(2,1,0)[24] : -346162.9
## ARIMA(0,0,1)(2,1,0)[24] : -152986.9
## ARIMA(2,0,1)(2,1,0)[24] : -350222.8
##
## Now re-fitting the best model(s) without approximations...
##
## ARIMA(1,0,0)(2,1,0)[24] : Inf
## ARIMA(1,0,0)(2,1,0)[24] with drift : Inf
## ARIMA(1,0,0)(1,1,0)[24] : Inf
## ARIMA(1,0,0)(1,1,0)[24] with drift : Inf
## ARIMA(1,0,0)(0,1,0)[24] with drift : Inf
## ARIMA(2,0,1)(2,1,0)[24] : Inf
## ARIMA(2,0,1)(2,1,0)[24] with drift : Inf
## ARIMA(1,0,1)(2,1,0)[24] : -461214
##
## Best model: ARIMA(1,0,1)(2,1,0)[24]

summary(fit) #Take a closer look at the best fitted model

## Series: y
## ARIMA(1,0,1)(2,1,0)[24]
##
## Coefficients:
##          ar1      ma1      sar1      sar2
##      0.9796  0.0360 -0.2904 -0.2942
## s.e.  0.0007  0.0024  0.0032  0.0032
##
## sigma^2 estimated as 0.0004044: log likelihood=230612
## AIC=-461214 AICc=-461214 BIC=-461166.6
##
## Training set error measures:
##              ME          RMSE          MAE          MPE          MAPE
MASE
## Training set 9.161849e-06 0.02010788 0.008321832 1.233202 6.684451
0.1293441
##              ACF1
## Training set -0.3061128

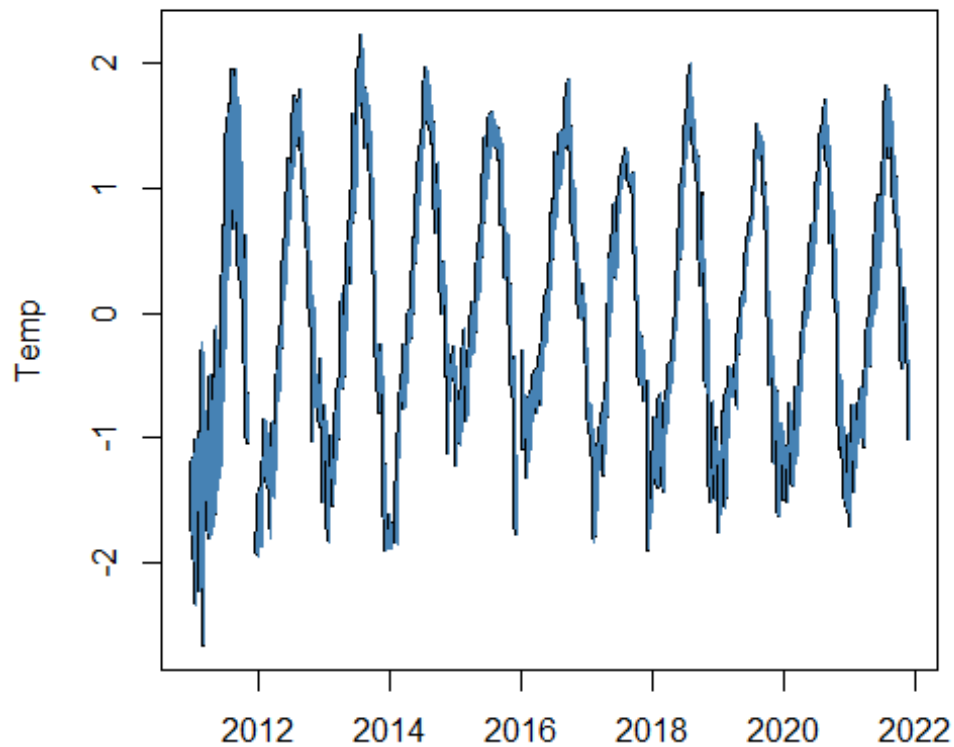
forecast_fit <- forecast(y,model=fit) #Predict values using the calibration
dataset

#Plot interpolated data

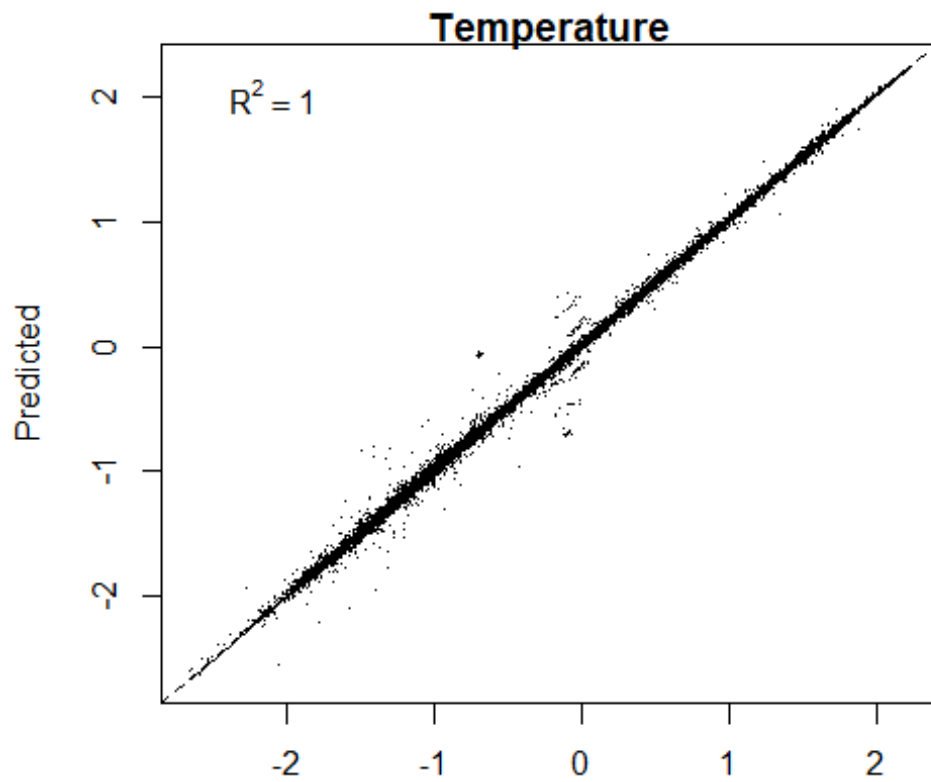
#Plot the observed and interpolated temperature regimes
par(mar=c(2,4,1,1))

```

```
plot(date_s,y,xlab="Time",ylab="Temp",lwd=2,type="l")
lines(date_s,forecast_fit$fitted,col="steelblue")
```



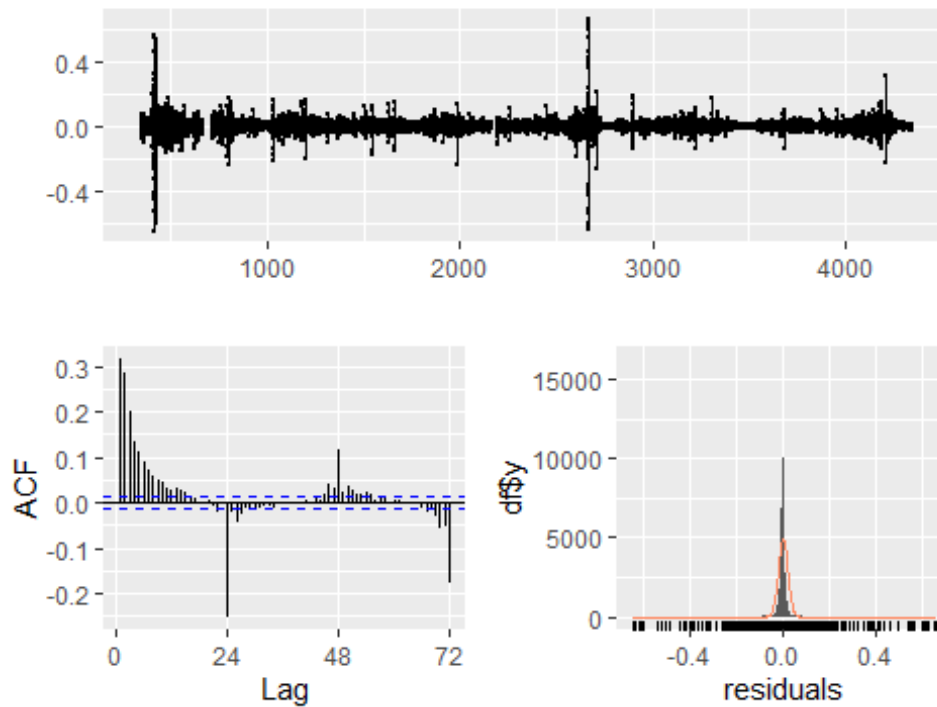
```
#Plot predicted versus observed values
scatter.smooth(y,forecast_fit$fitted,xlab="Observed",ylab="Predicted",pch="."
,main = "Temperature")
abline(0,1,lty=2)
R2 = round(cor.test(y,forecast_fit$fitted,na.rm=T)$estimate^2,2)
mtext(side=3,line=-2,adj=0.1,bquote(R^2 == .(R2)))
```



#Check residuals of interpolated data

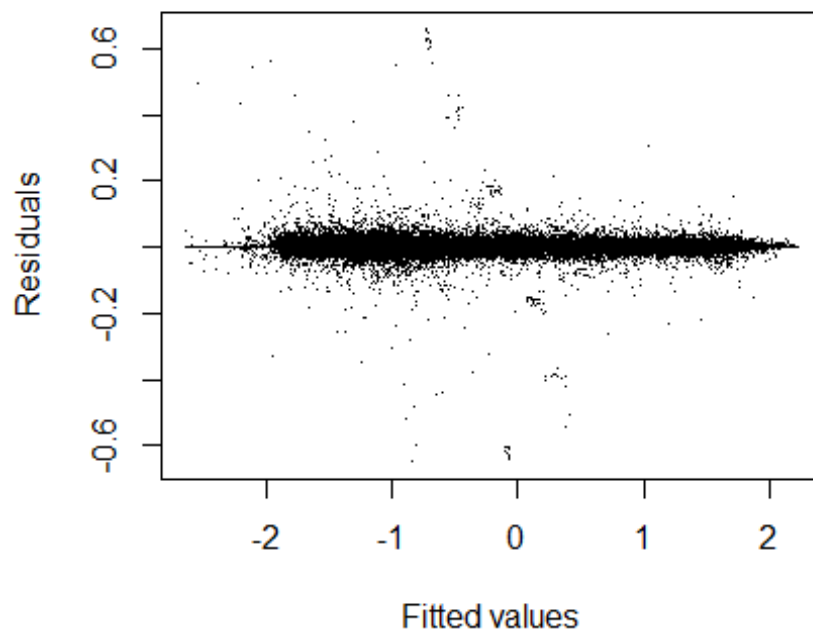
#Check residuals of the interpolation process
checkresiduals(fit) #also gives the results for the Ljung_Box test with H_0 =
randomly distributed errors (white noise)

Residuals from ARIMA(1,0,1)(2,1,0)[24]



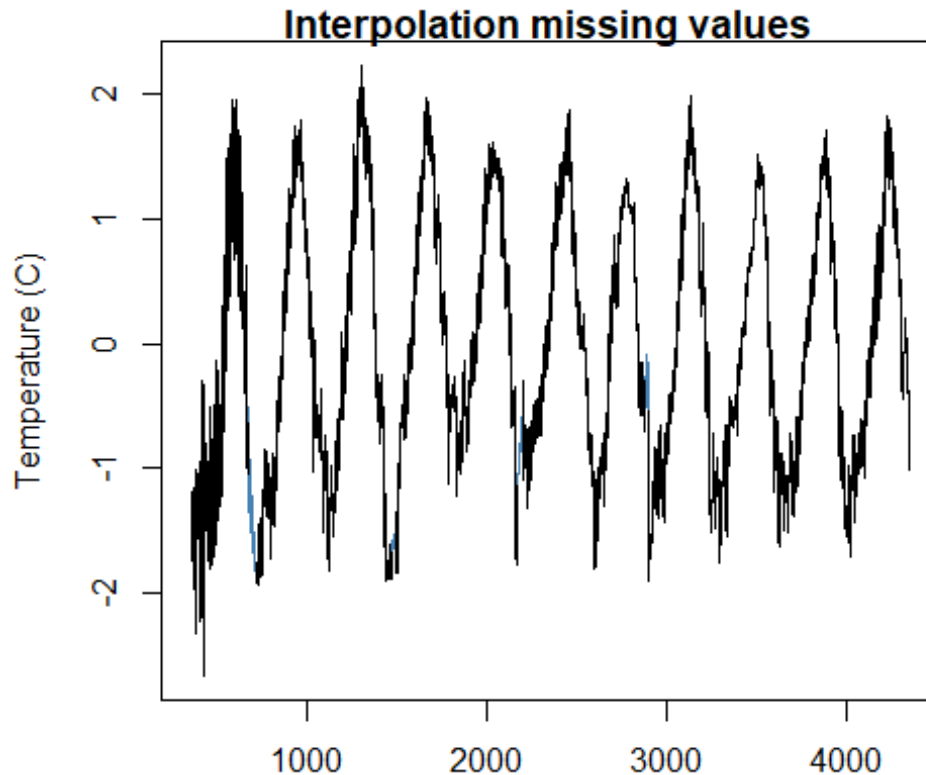
```
##
##  Ljung-Box test
##
## data:  Residuals from ARIMA(1,0,1)(2,1,0)[24]
## Q* = 180154, df = 44, p-value < 2.2e-16
##
## Model df: 4.    Total lags used: 48

#plot residuals versus fitted values (=check for heterosedasticity); if
#problems try to transform the data
par(mar=c(4,4,4,4))
scatter.smooth(forecast_fit$fitted,forecast_fit$residuals,pch =
".",ylab="Residuals",xlab="Fitted values")
```



#Smooth interpolated data ##NOTE: This chunk takes FOREVER beware

```
#Interpolate missing values using a Kalman filter (=smoother)  
y_inter <- na_kalman(y,model=fit$model) #use the fitted model  
#Plot the results  
par(mar=c(2,4,1,1))  
plot(y_inter,xlab="",ylab="Temperature  
(C)",col="steelblue",main="Interpolation missing values")  
lines(y,col="black")
```



```
#save output as an rds
saveRDS(y_inter, "y_inter_Alexander.rds")
```

```
#read in your data
y_inter <- readRDS("y_inter_Alexander.rds")
```

```
#Format interpolated time series into a dataframe
```

```
#Put the interpolated temperature dataset (y_inter) into a dataset with the correct dates (this does not work using the time series object because I had to designate hourly steps when making the time series, so the dates are messed up. There is probably a better way to do this...).
x <- as.data.frame(y_inter) #change y_inter from a ts to a dataframe
x$ID <- seq.int(nrow(x)) #add a unique ID, check it is correct length
date <- as.data.frame(APH$hour) #make the unique "hour" index from APH into a separate dataframe
date$ID <- seq.int(nrow(date)) #give that a unique ID that aligns with x
y_inter_df <- merge(x,date,"ID") #merge the two dataframes
colnames(y_inter_df)<-c("ID","temp","date") #rename columns
```

```
#Wavelet
```

```
#run the wavelet
my.w <- analyze.wavelet(y_inter_df, "temp",
                        loess.span = 0,
                        dt = 1/24, # this is the time resolution, here 24 samples per day)
```



```

        make.pval = TRUE, n.sim = 10, # number of simulations,
should be much higher for a paper
        date.format = "%Y-%m-%d-%h")

```

```
## Starting wavelet transformation...
```

```
## ... and simulations...
```

```
## |
|                                     | 0%
|=====| 10%
|=====| 20%
|=====| 30%
|=====| 40%
|=====| 50%
|=====| 60%
|=====| 70%
|=====| 80%
|=====| 90%
|=====| 100%

```

```
## Class attributes are accessible through following names:
```

```
## series loess.span dt dj Wave Phase Ampl Power Power.avg Power.pval
Power.avg.pval Ridge Period Scale nc nr coi.1 coi.2 axis.1 axis.2 date.format
date.tz
```

```
str(my.w) # Output
```

```
## List of 22
```

```
## $ series      : 'data.frame': 95933 obs. of 2 variables:
```

```
## ..$ date: POSIXct[1:95933], format: "2010-12-16 13:00:00" "2010-12-16
14:00:00" ...
```

```
## ..$ temp: num [1:95933] -1.48 -1.45 -1.44 -1.45 -1.47 ...
```

```
## $ loess.span   : num 0
```

```
## $ dt          : num 0.0417
```

```
## $ dj          : num 0.05
```

```
## $ Wave        : cplx [1:280, 1:95933] -0.197+0.042i -0.226+0.052i -
0.254+0.063i ...
```

```
## $ Phase       : num [1:280, 1:95933] 2.93 2.91 2.9 2.88 2.85 ...
```

```
## $ Ampl        : num [1:280, 1:95933] 0.714 0.808 0.896 0.972 1.034 ...
```

```
## $ Power       : num [1:280, 1:95933] 0.51 0.653 0.803 0.945 1.069 ...
```

```
## $ Power.avg   : num [1:280] 0.00223 0.00229 0.00217 0.00192 0.00158 ...
```

```
## $ Power.pval  : num [1:280, 1:95933] 1 1 1 1 0.8 0.8 0.8 0.8 0.9 0.9
```

```

...
## $ Power.avg.pval: num [1:280] 1 1 1 1 1 1 1 1 1 1 ...
## $ Ridge         : num [1:280, 1:95933] 0 0 0 0 0 0 0 0 0 0 ...
## $ Period        : num [1:280] 0.0833 0.0863 0.0893 0.0925 0.0957 ...
## $ Scale         : num [1:280] 0.0796 0.0824 0.0853 0.0883 0.0914 ...
## $ nc           : int 95933
## $ nr           : int 280
## $ coi.1         : num [1:95937] 0.979 0.979 1 1.042 1.083 ...
## $ coi.2         : num [1:95937] 10.39 -3.61 -20.63 -4.02 -3.02 ...
## $ axis.1        : num [1:95933] 1 1.04 1.08 1.12 1.17 ...
## $ axis.2        : num [1:280] -3.58 -3.53 -3.48 -3.43 -3.38 ...
## $ date.format   : chr "%Y-%m-%d-%h"
## $ date.tz       : NULL
## - attr(*, "class")= chr "analyze.wavelet"

saveRDS(my.w, "my.w_Alexander")

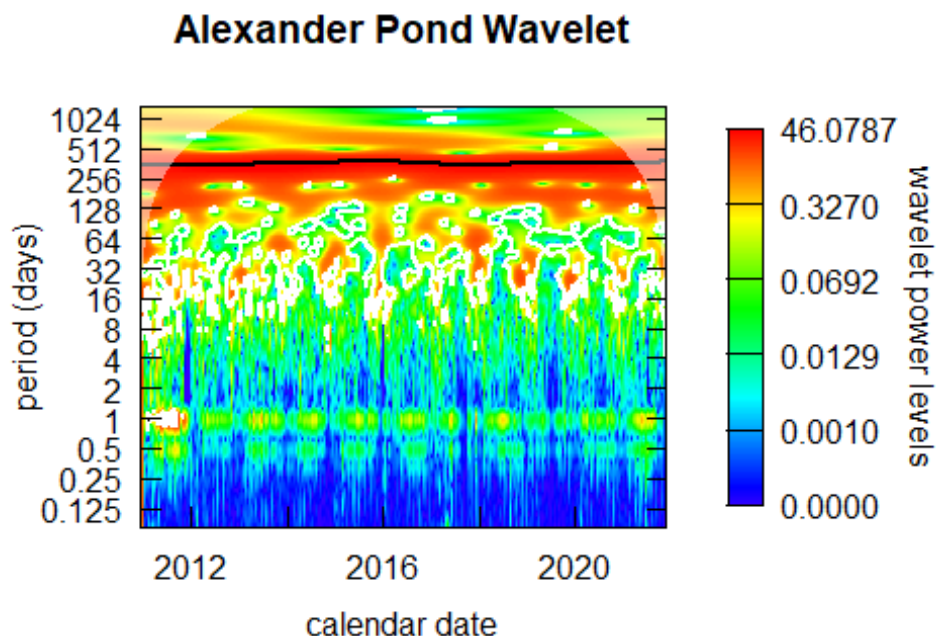
```

```
#Wavelet Image
```

```

wt.image(my.w, color.key = "quantile", n.levels = 250, main = "Alexander Pond
Wavelet",
        legend.params = list(lab = "wavelet power levels", mar = 6.5,
lab.line=4, label.digits = 4), label.time.axis=TRUE, show.date=TRUE,
        periodlab = "period (days)")

```



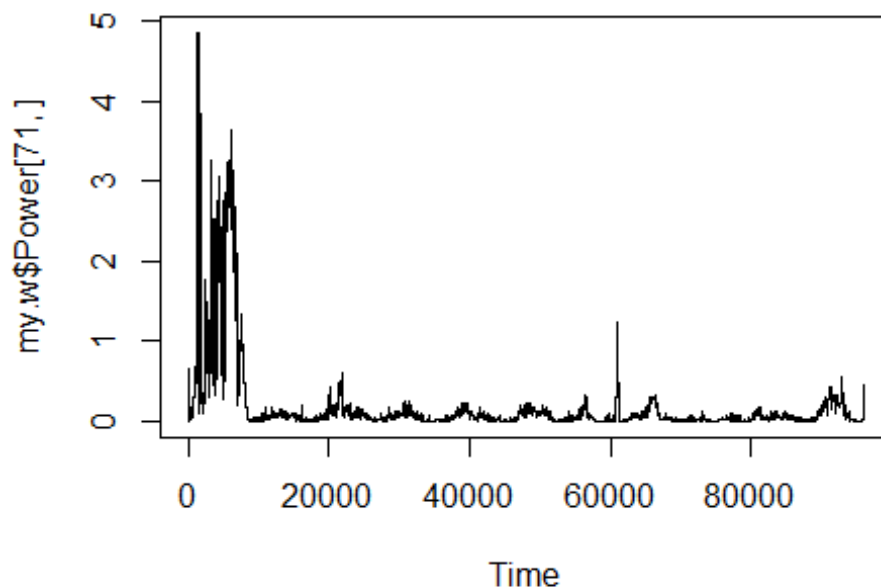
```
#Pull a specific period (i.e. see wavelet frequencies at a specific period, such as 24 hr or 365
days)
```

my.w\$Period # We will be targeting row #71 (period ~ hourly)

```
## [1] 8.333333e-02 8.627208e-02 8.931446e-02 9.246412e-02 9.572486e-02
## [6] 9.910059e-02 1.025954e-01 1.062134e-01 1.099590e-01 1.138367e-01
## [11] 1.178511e-01 1.220071e-01 1.263097e-01 1.307640e-01 1.353754e-01
## [16] 1.401494e-01 1.450918e-01 1.502084e-01 1.555055e-01 1.609894e-01
## [21] 1.666667e-01 1.725442e-01 1.786289e-01 1.849282e-01 1.914497e-01
## [26] 1.982012e-01 2.051907e-01 2.124268e-01 2.199180e-01 2.276734e-01
## [31] 2.357023e-01 2.440143e-01 2.526194e-01 2.615280e-01 2.707508e-01
## [36] 2.802988e-01 2.901835e-01 3.004168e-01 3.110110e-01 3.219788e-01
## [41] 3.333333e-01 3.450883e-01 3.572578e-01 3.698565e-01 3.828995e-01
## [46] 3.964024e-01 4.103815e-01 4.248535e-01 4.398360e-01 4.553468e-01
## [51] 4.714045e-01 4.880286e-01 5.052389e-01 5.230561e-01 5.415016e-01
## [56] 5.605976e-01 5.803670e-01 6.008336e-01 6.220220e-01 6.439576e-01
## [61] 6.666667e-01 6.901766e-01 7.145156e-01 7.397130e-01 7.657989e-01
## [66] 7.928047e-01 8.207629e-01 8.497071e-01 8.796719e-01 9.106935e-01
## [71] 9.428090e-01 9.760571e-01 1.010478e+00 1.046112e+00 1.083003e+00
## [76] 1.121195e+00 1.160734e+00 1.201667e+00 1.244044e+00 1.287915e+00
## [81] 1.333333e+00 1.380353e+00 1.429031e+00 1.479426e+00 1.531598e+00
## [86] 1.585609e+00 1.641526e+00 1.699414e+00 1.759344e+00 1.821387e+00
## [91] 1.885618e+00 1.952114e+00 2.020955e+00 2.092224e+00 2.166006e+00
## [96] 2.242390e+00 2.321468e+00 2.403335e+00 2.488088e+00 2.575830e+00
## [101] 2.666667e+00 2.760706e+00 2.858063e+00 2.958852e+00 3.063196e+00
## [106] 3.171219e+00 3.283052e+00 3.398828e+00 3.518688e+00 3.642774e+00
## [111] 3.771236e+00 3.904229e+00 4.041911e+00 4.184449e+00 4.332013e+00
## [116] 4.484781e+00 4.642936e+00 4.806669e+00 4.976176e+00 5.151660e+00
## [121] 5.333333e+00 5.521413e+00 5.716125e+00 5.917704e+00 6.126391e+00
## [126] 6.342438e+00 6.566104e+00 6.797657e+00 7.037376e+00 7.285548e+00
## [131] 7.542472e+00 7.808457e+00 8.083822e+00 8.368897e+00 8.664026e+00
## [136] 8.969562e+00 9.285873e+00 9.613338e+00 9.952352e+00 1.030332e+01
## [141] 1.066667e+01 1.104283e+01 1.143225e+01 1.183541e+01 1.225278e+01
## [146] 1.268488e+01 1.313221e+01 1.359531e+01 1.407475e+01 1.457110e+01
## [151] 1.508494e+01 1.561691e+01 1.616764e+01 1.673779e+01 1.732805e+01
## [156] 1.793912e+01 1.857175e+01 1.922668e+01 1.990470e+01 2.060664e+01
## [161] 2.133333e+01 2.208565e+01 2.286450e+01 2.367082e+01 2.450556e+01
## [166] 2.536975e+01 2.626441e+01 2.719063e+01 2.814950e+01 2.914219e+01
## [171] 3.016989e+01 3.123383e+01 3.233529e+01 3.347559e+01 3.465610e+01
## [176] 3.587825e+01 3.714349e+01 3.845335e+01 3.980941e+01 4.121328e+01
## [181] 4.266667e+01 4.417130e+01 4.572900e+01 4.734163e+01 4.901113e+01
## [186] 5.073950e+01 5.252883e+01 5.438125e+01 5.629900e+01 5.828438e+01
## [191] 6.033978e+01 6.246766e+01 6.467057e+01 6.695118e+01 6.931220e+01
## [196] 7.175649e+01 7.428698e+01 7.690671e+01 7.961882e+01 8.242657e+01
## [201] 8.533333e+01 8.834261e+01 9.145800e+01 9.468326e+01 9.802226e+01
## [206] 1.014790e+02 1.050577e+02 1.087625e+02 1.125980e+02 1.165688e+02
## [211] 1.206796e+02 1.249353e+02 1.293411e+02 1.339024e+02 1.386244e+02
## [216] 1.435130e+02 1.485740e+02 1.538134e+02 1.592376e+02 1.648531e+02
## [221] 1.706667e+02 1.766852e+02 1.829160e+02 1.893665e+02 1.960445e+02
## [226] 2.029580e+02 2.101153e+02 2.175250e+02 2.251960e+02 2.331375e+02
## [231] 2.413591e+02 2.498706e+02 2.586823e+02 2.678047e+02 2.772488e+02
## [236] 2.870260e+02 2.971479e+02 3.076268e+02 3.184753e+02 3.297063e+02
```

```
## [241] 3.413333e+02 3.533704e+02 3.658320e+02 3.787330e+02 3.920890e+02
## [246] 4.059160e+02 4.202306e+02 4.350500e+02 4.503920e+02 4.662751e+02
## [251] 4.827182e+02 4.997413e+02 5.173646e+02 5.356094e+02 5.544976e+02
## [256] 5.740520e+02 5.942959e+02 6.152536e+02 6.369505e+02 6.594125e+02
## [261] 6.826667e+02 7.067409e+02 7.316640e+02 7.574661e+02 7.841781e+02
## [266] 8.118321e+02 8.404613e+02 8.701001e+02 9.007841e+02 9.325501e+02
## [271] 9.654365e+02 9.994825e+02 1.034729e+03 1.071219e+03 1.108995e+03
## [276] 1.148104e+03 1.188592e+03 1.230507e+03 1.273901e+03 1.318825e+03

plot.ts(my.w$Power[71,])
```



```
#STENDER #Read in Data
```

```
##Reading in a 10 year hourly temperature time series dataset from Alexander
Pond called "APH" (Alexander Pond Historical)
SPH <- read.csv("Stender_Historical_2.csv")
SPH$date <- lubridate::mdy_hm(SPH$Date_Time) #convert dates to POSIXct format
and bin by hour

#Check for missing data
missing_data <- SPH[!complete.cases(SPH),]
missing_data

##           Date_Time Temp           date
## 7586              NA      <NA>
## 7587              NA      <NA>
## 7588              NA      <NA>
```

## 7589	NA	<NA>
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## 34336 1/27/2015 11:11	NA 2015-01-27 11:11:00	
## 34337 1/27/2015 11:15	NA 2015-01-27 11:15:00	
## 34338 1/27/2015 11:15	NA 2015-01-27 11:15:00	
## 34339 1/27/2015 11:15	NA 2015-01-27 11:15:00	
## 34340 1/27/2015 11:18	NA 2015-01-27 11:18:00	
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## 58177 12/1/2017 23:00	NA 2017-12-01 23:00:00	
## 58178 12/2/2017 0:00	NA 2017-12-02 00:00:00	
## 58179 12/2/2017 1:00	NA 2017-12-02 01:00:00	
## 58180 12/2/2017 2:00	NA 2017-12-02 02:00:00	
## 58181 12/2/2017 3:00	NA 2017-12-02 03:00:00	
## 58229 12/4/2017 3:00	NA 2017-12-04 03:00:00	

```
## 58230 12/4/2017 4:00 NA 2017-12-04 04:00:00
## 58231 12/4/2017 5:00 NA 2017-12-04 05:00:00
## 58232 12/4/2017 6:00 NA 2017-12-04 06:00:00
## 58233 12/4/2017 7:00 NA 2017-12-04 07:00:00
## 58234 12/4/2017 8:00 NA 2017-12-04 08:00:00
## 58235 12/4/2017 9:00 NA 2017-12-04 09:00:00
## 58236 12/4/2017 10:00 NA 2017-12-04 10:00:00
## 58237 12/4/2017 11:00 NA 2017-12-04 11:00:00
## 58238 12/4/2017 12:00 NA 2017-12-04 12:00:00
## 58247 12/4/2017 21:00 NA 2017-12-04 21:00:00
## 58248 12/4/2017 22:00 NA 2017-12-04 22:00:00
## 58249 12/4/2017 23:00 NA 2017-12-04 23:00:00
## 58250 12/5/2017 0:00 NA 2017-12-05 00:00:00
## 58251 12/5/2017 1:00 NA 2017-12-05 01:00:00
## 58252 12/5/2017 2:00 NA 2017-12-05 02:00:00
## 58253 12/5/2017 3:00 NA 2017-12-05 03:00:00
## 58254 12/5/2017 4:00 NA 2017-12-05 04:00:00
## 58255 12/5/2017 5:00 NA 2017-12-05 05:00:00
## 58256 12/5/2017 6:00 NA 2017-12-05 06:00:00
## 58257 12/5/2017 7:00 NA 2017-12-05 07:00:00
## 58258 12/5/2017 8:00 NA 2017-12-05 08:00:00
## 58259 12/5/2017 9:00 NA 2017-12-05 09:00:00
## 58260 12/5/2017 10:00 NA 2017-12-05 10:00:00
## 58261 12/5/2017 11:00 NA 2017-12-05 11:00:00
## 58262 12/5/2017 12:00 NA 2017-12-05 12:00:00
## 91933 NA <NA>
```

#Wavelets require a complete dataset with no missing data. Since there is missing data in this dataset, we will need to interpolate

#Bin data by hour

```
SPH$hour <- lubridate::round_date(SPH$date, unit="hour") #Before we
interpolate, let's bin by hour
head(SPH) #check the dataset start date, use for "hour" sequence
```

```
##          Date_Time    Temp          date          hour
## 1 12/16/2010 13:08 9.533889 2010-12-16 13:08:00 2010-12-16 13:00:00
## 2 12/16/2010 14:08 8.866111 2010-12-16 14:08:00 2010-12-16 14:00:00
## 3 12/16/2010 15:08 8.916111 2010-12-16 15:08:00 2010-12-16 15:00:00
## 4 12/16/2010 16:08 8.866111 2010-12-16 16:08:00 2010-12-16 16:00:00
## 5 12/16/2010 17:08 8.767222 2010-12-16 17:08:00 2010-12-16 17:00:00
## 6 12/16/2010 18:08 8.567778 2010-12-16 18:08:00 2010-12-16 18:00:00
```

```
tail(SPH) #check the dataset end date, use for "hour" sequence
```

```
##          Date_Time    Temp          date          hour
## 100449 11/24/2021 9:00 6.433 2021-11-24 09:00:00 2021-11-24 09:00:00
## 100450 11/24/2021 10:00 6.357 2021-11-24 10:00:00 2021-11-24 10:00:00
## 100451 11/24/2021 11:00 6.331 2021-11-24 11:00:00 2021-11-24 11:00:00
## 100452 11/24/2021 12:00 6.281 2021-11-24 12:00:00 2021-11-24 12:00:00
```

```
## 100453 11/24/2021 13:00 6.281 2021-11-24 13:00:00 2021-11-24 13:00:00
## 100454 11/24/2021 14:00 6.281 2021-11-24 14:00:00 2021-11-24 14:00:00
```

```
#Create hourly sequence to ensure all missing data is accounted for
hour <- seq(mdy_h('12/16/2010 13'),mdy_h('11/24/2021 14'),by = "hour")
#Create an object that goes hour by hour for the entire time series to ensure that ALL missing data is accounted for
hour <- as.data.frame(hour) #convert "hour" to data frame
SPH <- left_join(hour, SPH) #left join hour and dataset
```

```
## Joining, by = "hour"
```

```
missing_data <- SPH[!complete.cases(SPH),]
missing_data #Now we are sure that all the missing hour time steps are included.
```

##		hour	Date_Time	Temp	date
## 7584	2011-10-28	12:00:00	<NA>	NA	<NA>
## 7585	2011-10-28	13:00:00	<NA>	NA	<NA>
## 7586	2011-10-28	14:00:00	<NA>	NA	<NA>
## 7587	2011-10-28	15:00:00	<NA>	NA	<NA>
## 7588	2011-10-28	16:00:00	<NA>	NA	<NA>
## 7589	2011-10-28	17:00:00	<NA>	NA	<NA>
## 7590	2011-10-28	18:00:00	<NA>	NA	<NA>
## 7591	2011-10-28	19:00:00	<NA>	NA	<NA>
## 7592	2011-10-28	20:00:00	<NA>	NA	<NA>
## 7593	2011-10-28	21:00:00	<NA>	NA	<NA>
## 7594	2011-10-28	22:00:00	<NA>	NA	<NA>
## 7595	2011-10-28	23:00:00	<NA>	NA	<NA>
## 7596	2011-10-29	00:00:00	<NA>	NA	<NA>
## 7597	2011-10-29	01:00:00	<NA>	NA	<NA>
## 7598	2011-10-29	02:00:00	<NA>	NA	<NA>
## 7599	2011-10-29	03:00:00	<NA>	NA	<NA>
## 7600	2011-10-29	04:00:00	<NA>	NA	<NA>
## 7601	2011-10-29	05:00:00	<NA>	NA	<NA>
## 7602	2011-10-29	06:00:00	<NA>	NA	<NA>
## 7603	2011-10-29	07:00:00	<NA>	NA	<NA>
## 7604	2011-10-29	08:00:00	<NA>	NA	<NA>
## 7605	2011-10-29	09:00:00	<NA>	NA	<NA>
## 7606	2011-10-29	10:00:00	<NA>	NA	<NA>
## 7607	2011-10-29	11:00:00	<NA>	NA	<NA>
## 7608	2011-10-29	12:00:00	<NA>	NA	<NA>
## 7609	2011-10-29	13:00:00	<NA>	NA	<NA>
## 7610	2011-10-29	14:00:00	<NA>	NA	<NA>
## 7611	2011-10-29	15:00:00	<NA>	NA	<NA>
## 7612	2011-10-29	16:00:00	<NA>	NA	<NA>
## 7613	2011-10-29	17:00:00	<NA>	NA	<NA>
## 7614	2011-10-29	18:00:00	<NA>	NA	<NA>
## 7615	2011-10-29	19:00:00	<NA>	NA	<NA>
## 7616	2011-10-29	20:00:00	<NA>	NA	<NA>
## 7617	2011-10-29	21:00:00	<NA>	NA	<NA>

[illegible]

## 7668	2011-11-01 00:00:00	<NA>	NA	<NA>
## 7669	2011-11-01 01:00:00	<NA>	NA	<NA>
## 7670	2011-11-01 02:00:00	<NA>	NA	<NA>
## 7671	2011-11-01 03:00:00	<NA>	NA	<NA>
## 7672	2011-11-01 04:00:00	<NA>	NA	<NA>
## 7673	2011-11-01 05:00:00	<NA>	NA	<NA>
## 7674	2011-11-01 06:00:00	<NA>	NA	<NA>
## 7675	2011-11-01 07:00:00	<NA>	NA	<NA>
## 7676	2011-11-01 08:00:00	<NA>	NA	<NA>
## 7677	2011-11-01 09:00:00	<NA>	NA	<NA>
## 7678	2011-11-01 10:00:00	<NA>	NA	<NA>
## 7679	2011-11-01 11:00:00	<NA>	NA	<NA>
## 7680	2011-11-01 12:00:00	<NA>	NA	<NA>
## 7681	2011-11-01 13:00:00	<NA>	NA	<NA>
## 7682	2011-11-01 14:00:00	<NA>	NA	<NA>
## 7683	2011-11-01 15:00:00	<NA>	NA	<NA>
## 7684	2011-11-01 16:00:00	<NA>	NA	<NA>
## 7685	2011-11-01 17:00:00	<NA>	NA	<NA>
## 7686	2011-11-01 18:00:00	<NA>	NA	<NA>
## 7687	2011-11-01 19:00:00	<NA>	NA	<NA>
## 7688	2011-11-01 20:00:00	<NA>	NA	<NA>
## 7689	2011-11-01 21:00:00	<NA>	NA	<NA>
## 7690	2011-11-01 22:00:00	<NA>	NA	<NA>
## 7691	2011-11-01 23:00:00	<NA>	NA	<NA>
## 7692	2011-11-02 00:00:00	<NA>	NA	<NA>
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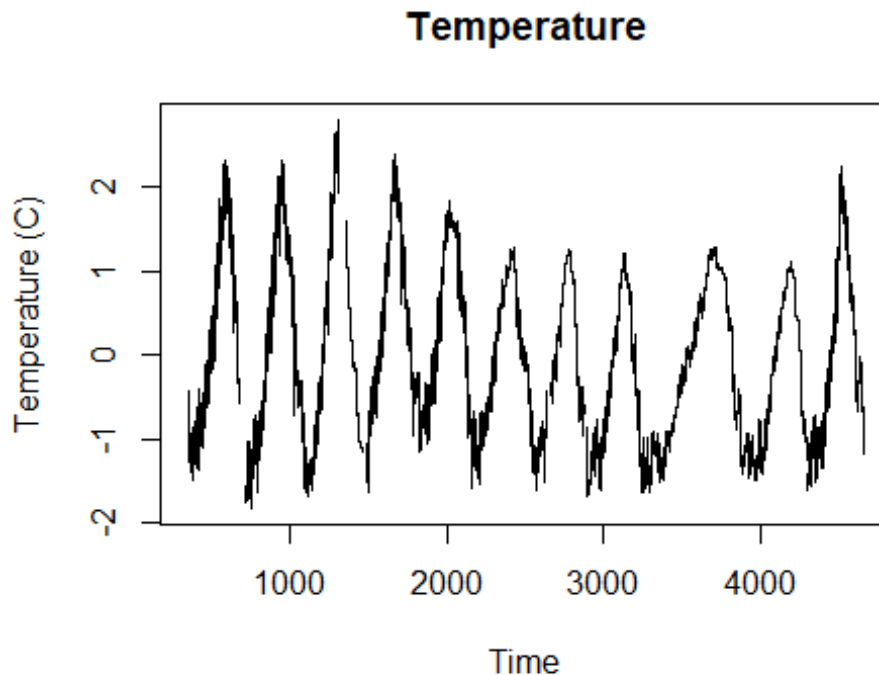
#z score to control for outliers

```
SPH$zTemp <- zscore(SPH$Temp)
```

#Convert to time series

```
SPH_ts <- ts(SPH$zTemp, start = c(351, 13), frequency = 24) # This time
series starts on 16 Dec 2010 at~13:00, so it starts on day 351 at hour 13 and
```

the frequency is 24 (24 hours per day)
 #^^^This is very confusing and I still don't fully understand how to convert data to time series so may want to ask Albert for clarification.
 ts.plot(SPH_ts,main="Temperature",ylab = "Temperature (C)", xlab = "Time")



#Interpolate missing data

```
#Run ARIMA to interpolate missing data
y2 <- SPH_ts
date_s2 <- SPH$hour
y_na2 <- ifelse(is.na(y2),0,NA)

fit2 <- auto.arima(y2,trace=TRUE) #fit limited number of models (faster)

##
## Fitting models using approximations to speed things up...
##
## ARIMA(2,0,2)(1,1,1)[24] with drift : Inf
## ARIMA(0,0,0)(0,1,0)[24] with drift : -214977.1
## ARIMA(1,0,0)(1,1,0)[24] with drift : Inf
## ARIMA(0,0,1)(0,1,1)[24] with drift : -293411.7
## ARIMA(0,0,0)(0,1,0)[24] : -214976.4
## ARIMA(0,0,1)(0,1,0)[24] with drift : -293136.8
## ARIMA(0,0,1)(1,1,1)[24] with drift : -294401.7
## ARIMA(0,0,1)(1,1,0)[24] with drift : -294313.2
## ARIMA(0,0,1)(2,1,1)[24] with drift : -294559.4
## ARIMA(0,0,1)(2,1,0)[24] with drift : -294201.1
```

```

## ARIMA(0,0,1)(2,1,2)[24] with drift : -294587.1
## ARIMA(0,0,1)(1,1,2)[24] with drift : -294402.4
## ARIMA(0,0,0)(2,1,2)[24] with drift : -183150.8
## ARIMA(1,0,1)(2,1,2)[24] with drift : Inf
## ARIMA(0,0,2)(2,1,2)[24] with drift : -368593.8
## ARIMA(0,0,2)(1,1,2)[24] with drift : -368442.3
## ARIMA(0,0,2)(2,1,1)[24] with drift : -368159.5
## ARIMA(0,0,2)(1,1,1)[24] with drift : -368452.1
## ARIMA(1,0,2)(2,1,2)[24] with drift : Inf
## ARIMA(0,0,3)(2,1,2)[24] with drift : -417015.9
## ARIMA(0,0,3)(1,1,2)[24] with drift : -416732
## ARIMA(0,0,3)(2,1,1)[24] with drift : -416091.3
## ARIMA(0,0,3)(1,1,1)[24] with drift : -416666
## ARIMA(1,0,3)(2,1,2)[24] with drift : Inf
## ARIMA(0,0,4)(2,1,2)[24] with drift : -449608.3
## ARIMA(0,0,4)(1,1,2)[24] with drift : -448985.7
## ARIMA(0,0,4)(2,1,1)[24] with drift : -448763.6
## ARIMA(0,0,4)(1,1,1)[24] with drift : -448800.3
## ARIMA(1,0,4)(2,1,2)[24] with drift : Inf
## ARIMA(0,0,5)(2,1,2)[24] with drift : -471490.3
## ARIMA(0,0,5)(1,1,2)[24] with drift : -471272.3
## ARIMA(0,0,5)(2,1,1)[24] with drift : -470562.8
## ARIMA(0,0,5)(1,1,1)[24] with drift : -471100
## ARIMA(1,0,5)(2,1,2)[24] with drift : Inf
## ARIMA(0,0,5)(2,1,2)[24] : -471474.5
##
## Now re-fitting the best model(s) without approximations...
##
## ARIMA(0,0,5)(2,1,2)[24] with drift : Inf
## ARIMA(0,0,5)(2,1,2)[24] : Inf
## ARIMA(0,0,5)(1,1,2)[24] with drift : Inf
## ARIMA(0,0,5)(1,1,1)[24] with drift : -544057.7
##
## Best model: ARIMA(0,0,5)(1,1,1)[24] with drift

summary(fit2) #Take a closer look at the best fitted model

## Series: y2
## ARIMA(0,0,5)(1,1,1)[24] with drift
##
## Coefficients:
##          ma1      ma2      ma3      ma4      ma5      sar1      sma1      drift
##          1.7500  2.1459  1.8663  1.1753  0.4220 -0.5075  0.2327         0
## s.e.    0.0037  0.0064  0.0065  0.0044  0.0024  0.0147  0.0173         0
##
## sigma^2 estimated as 0.0002425: log likelihood=272037.9
## AIC=-544057.7 AICc=-544057.7 BIC=-543971.8
##
## Training set error measures:
##              ME      RMSE      MAE      MPE      MAPE

```

```

MASE
## Training set -2.014778e-06 0.01556897 0.0106746 0.195905 5.954043
0.1806112
##                               ACF1
## Training set 0.1827068

```

```

forecast_fit2 <- forecast(y2,model=fit2) #Predict values using the
calibration dataset

```

```

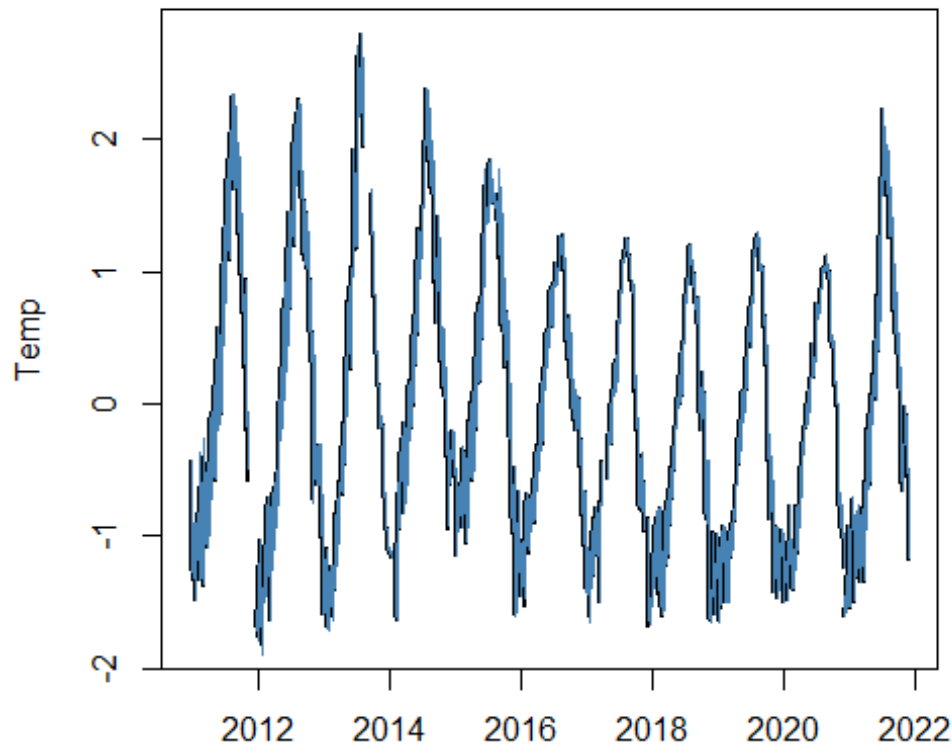
#Plot interpolated data

```

```

#Plot the observed and interpolated temperature regimes
par(mar=c(2,4,1,1))
plot(date_s2,y2,xlab="Time",ylab="Temp",lwd=2,type="l")
lines(date_s2,forecast_fit2$fitted,col="steelblue")

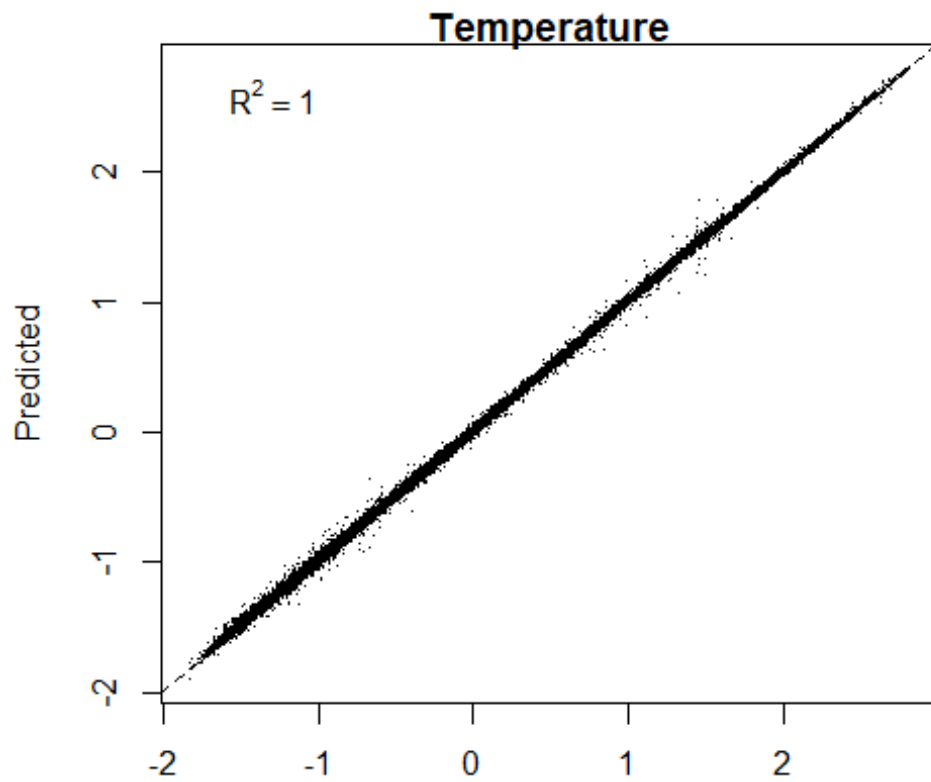
```



```

#Plot predicted versus observed values
scatter.smooth(y2,forecast_fit2$fitted,xlab="Observed",ylab="Predicted",pch="
.",main = "Temperature")
abline(0,1,lty=2)
R2 = round(cor.test(y2,forecast_fit2$fitted,na.rm=T)$estimate^2,2)
mtext(side=3,line=-2,adj=0.1,bquote(R^2 == .(R2)))

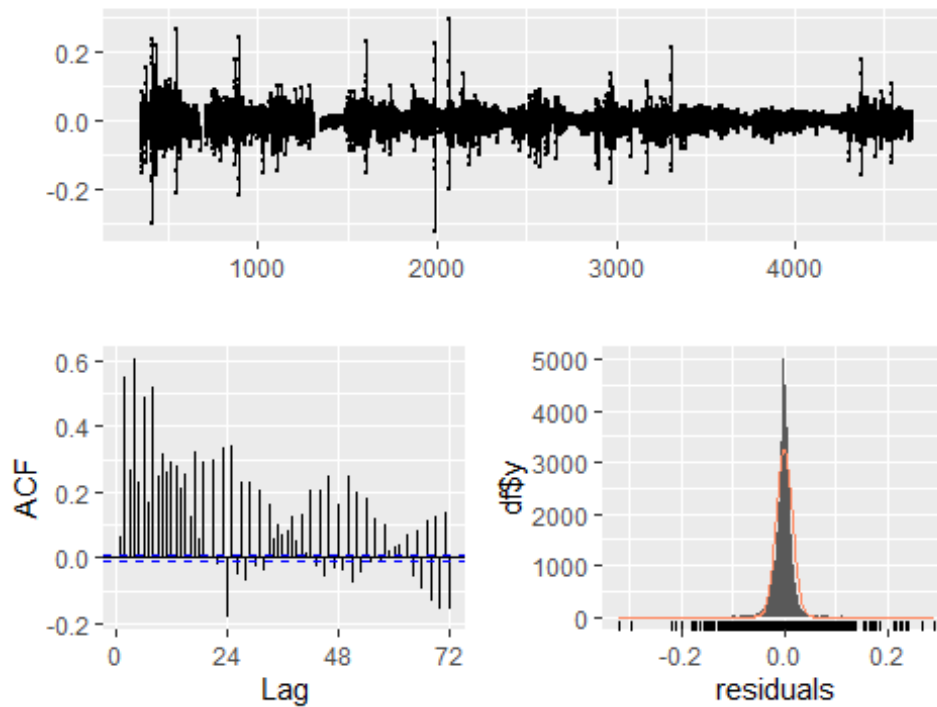
```

#Check residuals of interpolated data

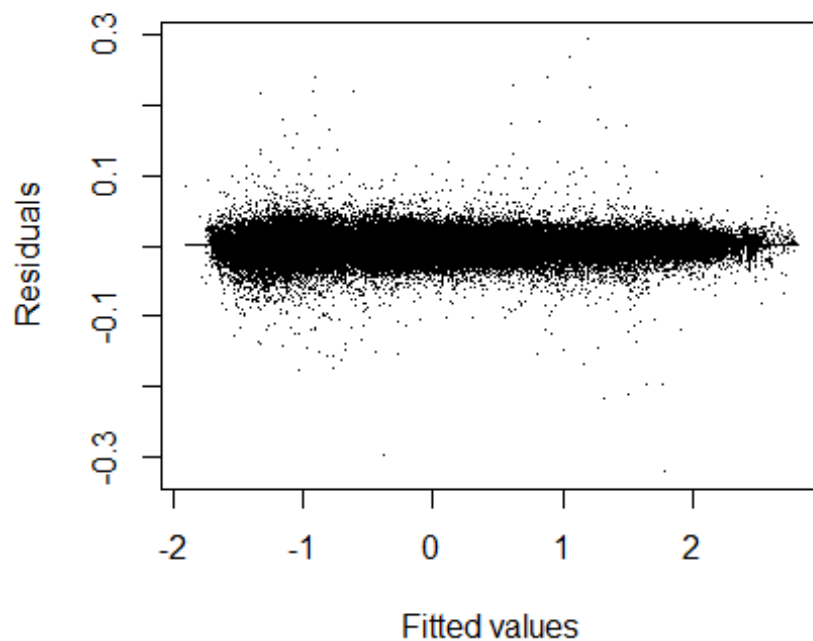
#Check residuals of the interpolation process
`checkresiduals(fit2)` *#also gives the results for the Ljung_Box test with H_0 = randomly distributed errors (white noise)*

Residuals from ARIMA(0,0,5)(1,1,1)[24] with drift



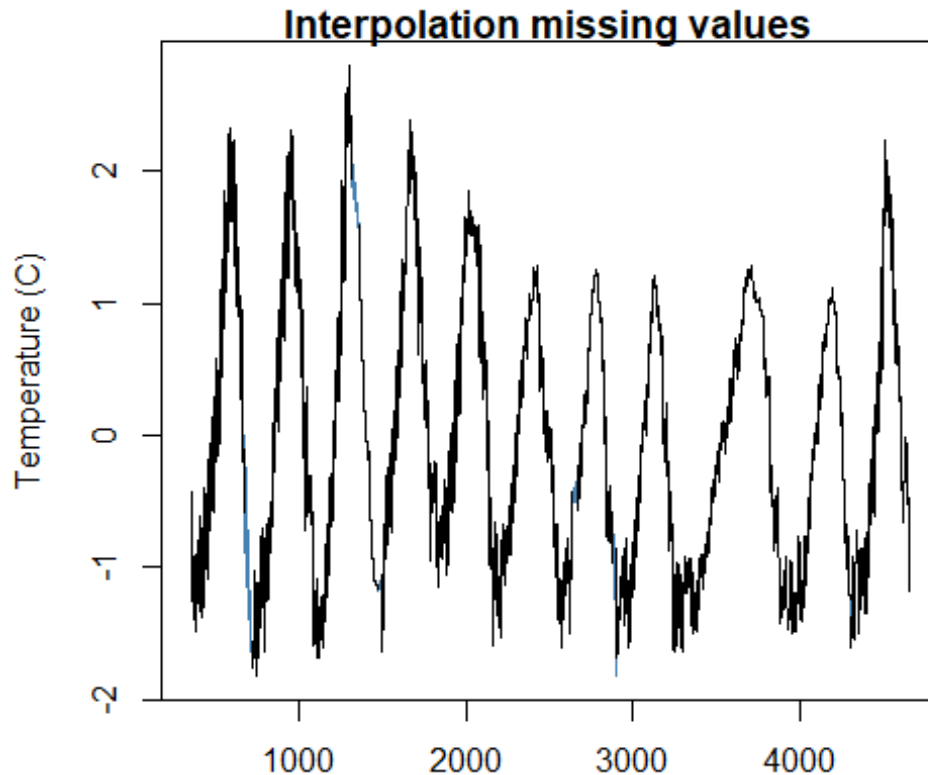
```
##
##  Ljung-Box test
##
## data:  Residuals from ARIMA(0,0,5)(1,1,1)[24] with drift
## Q* = 741908, df = 40, p-value < 2.2e-16
##
## Model df: 8.    Total lags used: 48

#plot residuals versus fitted values (=check for heteroscedasticity); if
#problems try to transform the data
par(mar=c(4,4,4,4))
scatter.smooth(forecast_fit2$fitted,forecast_fit2$residuals,pch =
".",ylab="Residuals",xlab="Fitted values")
```



#Smooth interpolated data ##NOTE: This chunk takes FOREVER beware

```
#Interpolate missing values using a Kalman filter (=smoother)  
y_inter2 <- na_kalman(y2,model=fit2$model) #use the fitted model  
#Plot the results  
par(mar=c(2,4,1,1))  
plot(y_inter2,xlab="",ylab="Temperature  
(C)",col="steelblue",main="Interpolation missing values")  
lines(y2,col="black")
```



```
#save output as an rds
saveRDS(y_inter2, "y_inter_Stender.rds")
```

```
#read in your data
y_inter2 <- readRDS("y_inter_Stender.rds")
```

```
#Format interpolated time series into a dataframe
```

```
#Put the interpolated temperature dataset (y_inter) into a dataset with the correct dates (this does not work using the time series object because I had to designate hourly steps when making the time series, so the dates are messed up. There is probably a better way to do this...).
```

```
x2 <- as.data.frame(y_inter2) #change y_inter from a ts to a dataframe
x2$ID <- seq.int(nrow(x2)) #add a unique ID, check it is correct length
date2 <- as.data.frame(SPH$hour) #make the unique "hour" index from APH into a separate dataframe
date2$ID <- seq.int(nrow(date2)) #give that a unique ID that aligns with x
y_inter2_df <- merge(x2,date2,"ID") #merge the two dataframes
colnames(y_inter2_df)<-c("ID","temp","date") #rename columns
```

```
#Wavelet
```

```
#run the wavelet
my.w2 <- analyze.wavelet(y_inter2_df, "temp",
                        loess.span = 0,
                        dt = 1/24, # this is the time resolution, here 24 samples per day)
```

```

        make.pval = TRUE, n.sim = 10, # number of simulations,
should be much higher for a paper
        date.format = "%Y-%m-%d-%h")

## Starting wavelet transformation...
## ... and simulations...
## |
|                                     | 0%
|=====                           | 10%
|=====                           | 20%
|=====                           | 30%
|=====                           | 40%
|=====                           | 50%
|=====                           | 60%
|=====                           | 70%
|=====                           | 80%
|=====                           | 90%
|=====                           | 100%
## Class attributes are accessible through following names:
## series loess.span dt dj Wave Phase Ampl Power Power.avg Power.pval
Power.avg.pval Ridge Period Scale nc nr coi.1 coi.2 axis.1 axis.2 date.format
date.tz

str(my.w2) # Output

## List of 22
## $ series      : 'data.frame': 103302 obs. of 2 variables:
## ..$ date: POSIXct[1:103302], format: "2010-12-16 13:00:00" "2010-12-16
14:00:00" ...
## ..$ temp: num [1:103302] -0.434 -0.587 -0.575 -0.587 -0.609 ...
## $ loess.span   : num 0
## $ dt           : num 0.0417
## $ dj           : num 0.05
## $ Wave         : cplx [1:282, 1:103302] -0.0357+0.0195i -0.0411+0.0237i
-0.0463+0.0283i ...
## $ Phase       : num [1:282, 1:103302] 2.64 2.62 2.59 2.56 2.53 ...
## $ Ampl        : num [1:282, 1:103302] 0.144 0.165 0.186 0.205 0.223 ...
## $ Power       : num [1:282, 1:103302] 0.0208 0.0273 0.0345 0.0421
0.0495 ...
## $ Power.avg    : num [1:282] 0.000116 0.000136 0.000152 0.000162

```

```

0.000167 ...
## $ Power.pval      : num [1:282, 1:103302] 1 1 1 0.9 0.9 0.9 0.9 1 1 1 ...
## $ Power.avg.pval: num [1:282] 1 1 1 1 1 1 1 1 1 1 ...
## $ Ridge          : num [1:282, 1:103302] 0 0 0 0 0 0 0 0 0 0 ...
## $ Period         : num [1:282] 0.0833 0.0863 0.0893 0.0925 0.0957 ...
## $ Scale          : num [1:282] 0.0796 0.0824 0.0853 0.0883 0.0914 ...
## $ nc             : int 103302
## $ nr             : int 282
## $ coi.1          : num [1:103306] 0.979 0.979 1 1.042 1.083 ...
## $ coi.2          : num [1:103306] 10.49 -3.61 -20.63 -4.02 -3.02 ...
## $ axis.1         : num [1:103302] 1 1.04 1.08 1.12 1.17 ...
## $ axis.2         : num [1:282] -3.58 -3.53 -3.48 -3.43 -3.38 ...
## $ date.format    : chr "%Y-%m-%d-%h"
## $ date.tz        : NULL
## - attr(*, "class")= chr "analyze.wavelet"

saveRDS(my.w2, "my.w2_Stender")

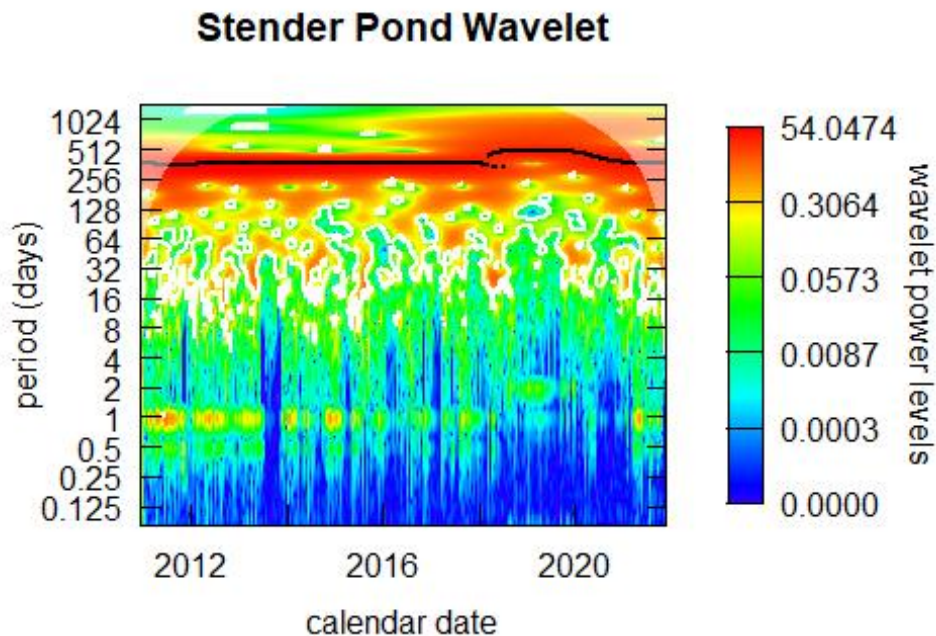
```

```
#Wavelet Image
```

```

wt.image(my.w2, color.key = "quantile", n.levels = 250, main = "Stender Pond
Wavelet",
        legend.params = list(lab = "wavelet power levels", mar = 6.5,
lab.line=4, label.digits = 4), label.time.axis=TRUE, show.date=TRUE,
        periodlab = "period (days)")

```



#Pull a specific period (i.e. see wavelet frequencies at a specific period, such as 24 hr or 365 days)

my.w2\$Period *# We will be targeting row #71 (period ~ hourly)*

```
## [1] 8.333333e-02 8.627208e-02 8.931446e-02 9.246412e-02 9.572486e-02
## [6] 9.910059e-02 1.025954e-01 1.062134e-01 1.099590e-01 1.138367e-01
## [11] 1.178511e-01 1.220071e-01 1.263097e-01 1.307640e-01 1.353754e-01
## [16] 1.401494e-01 1.450918e-01 1.502084e-01 1.555055e-01 1.609894e-01
## [21] 1.666667e-01 1.725442e-01 1.786289e-01 1.849282e-01 1.914497e-01
## [26] 1.982012e-01 2.051907e-01 2.124268e-01 2.199180e-01 2.276734e-01
## [31] 2.357023e-01 2.440143e-01 2.526194e-01 2.615280e-01 2.707508e-01
## [36] 2.802988e-01 2.901835e-01 3.004168e-01 3.110110e-01 3.219788e-01
## [41] 3.333333e-01 3.450883e-01 3.572578e-01 3.698565e-01 3.828995e-01
## [46] 3.964024e-01 4.103815e-01 4.248535e-01 4.398360e-01 4.553468e-01
## [51] 4.714045e-01 4.880286e-01 5.052389e-01 5.230561e-01 5.415016e-01
## [56] 5.605976e-01 5.803670e-01 6.008336e-01 6.220220e-01 6.439576e-01
## [61] 6.666667e-01 6.901766e-01 7.145156e-01 7.397130e-01 7.657989e-01
## [66] 7.928047e-01 8.207629e-01 8.497071e-01 8.796719e-01 9.106935e-01
## [71] 9.428090e-01 9.760571e-01 1.010478e+00 1.046112e+00 1.083003e+00
## [76] 1.121195e+00 1.160734e+00 1.201667e+00 1.244044e+00 1.287915e+00
## [81] 1.333333e+00 1.380353e+00 1.429031e+00 1.479426e+00 1.531598e+00
## [86] 1.585609e+00 1.641526e+00 1.699414e+00 1.759344e+00 1.821387e+00
## [91] 1.885618e+00 1.952114e+00 2.020955e+00 2.092224e+00 2.166006e+00
## [96] 2.242390e+00 2.321468e+00 2.403335e+00 2.488088e+00 2.575830e+00
## [101] 2.666667e+00 2.760706e+00 2.858063e+00 2.958852e+00 3.063196e+00
## [106] 3.171219e+00 3.283052e+00 3.398828e+00 3.518688e+00 3.642774e+00
## [111] 3.771236e+00 3.904229e+00 4.041911e+00 4.184449e+00 4.332013e+00
## [116] 4.484781e+00 4.642936e+00 4.806669e+00 4.976176e+00 5.151660e+00
## [121] 5.333333e+00 5.521413e+00 5.716125e+00 5.917704e+00 6.126391e+00
## [126] 6.342438e+00 6.566104e+00 6.797657e+00 7.037376e+00 7.285548e+00
## [131] 7.542472e+00 7.808457e+00 8.083822e+00 8.368897e+00 8.664026e+00
## [136] 8.969562e+00 9.285873e+00 9.613338e+00 9.952352e+00 1.030332e+01
## [141] 1.066667e+01 1.104283e+01 1.143225e+01 1.183541e+01 1.225278e+01
## [146] 1.268488e+01 1.313221e+01 1.359531e+01 1.407475e+01 1.457110e+01
## [151] 1.508494e+01 1.561691e+01 1.616764e+01 1.673779e+01 1.732805e+01
## [156] 1.793912e+01 1.857175e+01 1.922668e+01 1.990470e+01 2.060664e+01
## [161] 2.133333e+01 2.208565e+01 2.286450e+01 2.367082e+01 2.450556e+01
## [166] 2.536975e+01 2.626441e+01 2.719063e+01 2.814950e+01 2.914219e+01
## [171] 3.016989e+01 3.123383e+01 3.233529e+01 3.347559e+01 3.465610e+01
## [176] 3.587825e+01 3.714349e+01 3.845335e+01 3.980941e+01 4.121328e+01
## [181] 4.266667e+01 4.417130e+01 4.572900e+01 4.734163e+01 4.901113e+01
## [186] 5.073950e+01 5.252883e+01 5.438125e+01 5.629900e+01 5.828438e+01
## [191] 6.033978e+01 6.246766e+01 6.467057e+01 6.695118e+01 6.931220e+01
## [196] 7.175649e+01 7.428698e+01 7.690671e+01 7.961882e+01 8.242657e+01
## [201] 8.533333e+01 8.834261e+01 9.145800e+01 9.468326e+01 9.802226e+01
## [206] 1.014790e+02 1.050577e+02 1.087625e+02 1.125980e+02 1.165688e+02
## [211] 1.206796e+02 1.249353e+02 1.293411e+02 1.339024e+02 1.386244e+02
## [216] 1.435130e+02 1.485740e+02 1.538134e+02 1.592376e+02 1.648531e+02
## [221] 1.706667e+02 1.766852e+02 1.829160e+02 1.893665e+02 1.960445e+02
```

```
## [226] 2.029580e+02 2.101153e+02 2.175250e+02 2.251960e+02 2.331375e+02
## [231] 2.413591e+02 2.498706e+02 2.586823e+02 2.678047e+02 2.772488e+02
## [236] 2.870260e+02 2.971479e+02 3.076268e+02 3.184753e+02 3.297063e+02
## [241] 3.413333e+02 3.533704e+02 3.658320e+02 3.787330e+02 3.920890e+02
## [246] 4.059160e+02 4.202306e+02 4.350500e+02 4.503920e+02 4.662751e+02
## [251] 4.827182e+02 4.997413e+02 5.173646e+02 5.356094e+02 5.544976e+02
## [256] 5.740520e+02 5.942959e+02 6.152536e+02 6.369505e+02 6.594125e+02
## [261] 6.826667e+02 7.067409e+02 7.316640e+02 7.574661e+02 7.841781e+02
## [266] 8.118321e+02 8.404613e+02 8.701001e+02 9.007841e+02 9.325501e+02
## [271] 9.654365e+02 9.994825e+02 1.034729e+03 1.071219e+03 1.108995e+03
## [276] 1.148104e+03 1.188592e+03 1.230507e+03 1.273901e+03 1.318825e+03
## [281] 1.365333e+03 1.413482e+03
```

```
plot.ts(my.w2$Power[71,])
```

