Examples 1 and 2 – climate data preparation and basic run

daily_response()

```
window_width = 5
```

	TRWi
2015	1.203
2014	1.051
2013	1.706
2012	0.892
2011	0.942
2010	0.771
2009	1.436
2008	0.747
2007	0.976
2006	1.091
2005	0.763
2004	0.732
2003	0.675
2002	0.83
2001	0.813
2000	0.746
1999	0.671
1998	0.861
1997	1.383
…	…

Temp
-0.6
2.92
0.84
3.54
1.34
-0.64
3.4
-3.18
-6.86
3.76
0.74
-3.58
7.1
4.06
-6.82
0.3
6.08
2.38
1.64
…

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	…
2015	-3.8	0.2	1.7	1	2	1	2.8	-3.2	-4.2	-2.1	1.2	-0.1	-0.2	-1.8	-4.5	…
2014	-4.9	-7.6	-6.1	-5.2	-6.8	-6.4	-2.8	0.8	1.5	2.7	3	3.4	3.4	2.1	0.8	…
2013	2.4	-0.6	0.2	2.5	5.9	9.9	9.6	-1	-1.1	-0.1	1	0.6	0.8	1.9	0.7	…
2012	2.3	-0.3	-0.1	-1.5	-1.6	-1.1	-0.8	3.7	1.7	-0.2	-0.8	3.1	6.6	9	6.8	…
2011	-1.2	-0.1	-0.2	-2.4	-3.6	-2.7	-0.9	3.8	2.5	0.1	0.7	3.2	2.5	0.2	-1.6	…
2010	-7.7	-5.3	-3.8	-0.8	0.9	0.9	-0.3	-3.2	-2.4	-1.2	-0.2	-0.2	-1	-0.6	-1	…
2009	7.9	6.9	7.2	6.4	5.5	6.4	2.1	8	6.2	7	8.9	2.9	-0.7	-1.1	-2.2	…
2008	0.1	1.1	2.5	2.4	0.5	-0.6	3.2	-3.9	-3.2	-2.9	-3.7	-4.5	-2.8	-2	-3.8	…
2007	-4.8	-0.9	-0.3	-3.6	-3	-3.8	-3.6	-5.6	-7.3	-5.8	-6	-10.8	-8.8	-2.9	-2.4	…
2006	-2.7	3.1	6.1	6.1	5.9	10.4	12	0.2	1.6	1.4	-0.6	3.1	6.5	8.4	2.6	…
2005	-2.8	-1.9	-3.8	-7.9	-5.9	-5	-3.4	4.8	4.2	0.4	1	-0.5	0.6	2.2	-1.1	…
2004	1.8	5.1	6.9	6.9	0.4	-2.6	-4.8	1.1	-1.6	-4.6	-4.6	-4.1	-2.4	-2.2	-2.1	…
2003	2.2	0.2	-1.4	-4.6	-3.5	-2.8	-1.8	4.7	8.2	8.6	10	8.4	3.3	5.2	1.5	…
2002	0.3	2.3	0.2	1.2	1.3	2.7	0.5	1	0.5	0	3	7.7	5.6	4	6.5	…
2001	1.3	1	0.6	1.6	1.2	1.6	1.9	-4.5	-7.1	-7.7	-8.9	-8.3	-5.4	-3.8	-2.2	…
2000	8.6	4.2	1.9	4.1	3.3	5.7	8.8	-0.2	0.7	0.8	0.5	0.5	-0.3	0	0.9	…
1999	-3	-2.5	-2	-2.8	-0.8	0.7	1.1	9	10.4	8	6	4.8	5.5	6.1	5.4	…
1998	-1.6	-2.5	-4.2	-7.2	-6.1	-5.3	-3.4	2.7	3.7	3	1.5	3	2.2	2.2	-1.1	…
1997	6.9	2.5	-0.5	-3.3	-1.5											…
…	…	…	…	…	…	…										…

reference_window = "start"

final output matrix

5	0.11									

daily_response()

```
window_width = 5
```

	TRWi
2015	1.203
2014	1.051
2013	1.706
2012	0.892
2011	0.942
2010	0.771
2009	1.436
2008	0.747
2007	0.976
2006	1.091
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2004	0.732
2003	0.675
2002	0.83
2001	0.813
2000	0.746
1999	0.671
1998	0.861
1997	1.383
…	…

Temp
-0.6
2.92
0.84
3.54
1.34
-0.64
3.4
-3.18
-6.86
3.76
0.74
-3.58
7.1
4.06
-6.82
0.3
6.08
2.38
1.64
…

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	…
2015	-3.8	0.2	1.7	1	2	1	2.8	-3.2	-4.2	-2.1	1.2	-0.1	-0.2	-1.8	-4.5	…
2014	-4.9	-7.6	-6.1	-5.2	-6.8	-6.4	-2.8	0.8	1.5	2.7	3	3.4	3.4	2.1	0.8	…
2013	2.4	-0.6	0.2	2.5	5.9	9.9	9.6	-1	-1.1	-0.1	1	0.6	0.8	1.9	0.7	…
2012	2.3	-0.3	-0.1	-1.5	-1.6	-1.1	-0.8	3.7	1.7	-0.2	-0.8	3.1	6.6	9	6.8	…
2011	-1.2	-0.1	-0.2	-2.4	-3.6	-2.7	-0.9	3.8	2.5	0.1	0.7	3.2	2.5	0.2	-1.6	…
2010	-7.7	-5.3	-3.8	-0.8	0.9	0.9	-0.3	-3.2	-2.4	-1.2	-0.2	-0.2	-1	-0.6	-1	…
2009	7.9	6.9	7.2	6.4	5.5	6.4	2.1	8	6.2	7	8.9	2.9	-0.7	-1.1	-2.2	…
2008	0.1	1.1	2.5	2.4	0.5	-0.6	3.2	-3.9	-3.2	-2.9	-3.7	-4.5	-2.8	-2	-3.8	…
2007	-4.8	-0.9	-0.3	-3.6	-3	-3.8	-3.6	-5.6	-7.3	-5.8	-6	-10.8	-8.8	-2.9	-2.4	…
2006	-2.7	3.1	6.1	6.1	5.9	10.4	12	0.2	1.6	1.4	-0.6	3.1	6.5	8.4	2.6	…
2005	-2.8	-1.9	-3.8	-7.9	-5.9	-5	-3.4	4.8	4.2	0.4	1	-0.5	0.6	2.2	-1.1	…
2004	1.8	5.1	6.9	6.9	0.4	-2.6	-4.8	1.1	-1.6	-4.6	-4.6	-4.1	-2.4	-2.2	-2.1	…
2003	2.2	0.2	-1.4	-4.6	-3.5	-2.8	-1.8	4.7	8.2	8.6	10	8.4	3.3	5.2	1.5	…
2002	0.3	2.3	0.2	1.2	1.3	2.7	0.5	1	0.5	0	3	7.7	5.6	4	6.5	…
2001	1.3	1	0.6	1.6	1.2	1.6	1.9	-4.5	-7.1	-7.7	-8.9	-8.3	-5.4	-3.8	-2.2	…
2000	8.6	4.2	1.9	4.1	3.3	5.7	8.8	-0.2	0.7	0.8	0.5	0.5	-0.3	0	0.9	…
1999	-3	-2.5	-2	-2.8	-0.8	0.7	1.1	9	10.4	8	6	4.8	5.5	6.1	5.4	…
1998	-1.6	-2.5	-4.2	-7.2	-6.1	-5.3	-3.4	2.7	3.7	3	1.5	3	2.2	2.2	-1.1	…
1997	6.9	2.5	-0.5	-3.3	-1.5											…
…	…	…	…	…	…	…										…

reference_window = "end"

final output matrix

5					0.11				

daily_response()

```
window_width = 5
```

	TRWi
2015	1.203
2014	1.051
2013	1.706
2012	0.892
2011	0.942
2010	0.771
2009	1.436
2008	0.747
2007	0.976
2006	1.091
2005	0.763
2004	0.732
2003	0.675
2002	0.83
2001	0.813
2000	0.746
1999	0.671
1998	0.861
1997	1.383
…	…

Temp
-0.6
2.92
0.84
3.54
1.34
-0.64
3.4
-3.18
-6.86
3.76
0.74
-3.58
7.1
4.06
-6.82
0.3
6.08
2.38
1.64
…

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	…
2015	-3.8	0.2	1.7	1	2	1	2.8	-3.2	-4.2	-2.1	1.2	-0.1	-0.2	-1.8	-4.5	…
2014	-4.9	-7.6	-6.1	-5.2	-6.8	-6.4	-2.8	0.8	1.5	2.7	3	3.4	3.4	2.1	0.8	…
2013	2.4	-0.6	0.2	2.5	5.9	9.9	9.6	-1	-1.1	-0.1	1	0.6	0.8	1.9	0.7	…
2012	2.3	-0.3	-0.1	-1.5	-1.6	-1.1	-0.8	3.7	1.7	-0.2	-0.8	3.1	6.6	9	6.8	…
2011	-1.2	-0.1	-0.2	-2.4	-3.6	-2.7	-0.9	3.8	2.5	0.1	0.7	3.2	2.5	0.2	-1.6	…
2010	-7.7	-5.3	-3.8	-0.8	0.9	0.9	-0.3	-3.2	-2.4	-1.2	-0.2	-0.2	-1	-0.6	-1	…
2009	7.9	6.9	7.2	6.4	5.5	6.4	2.1	8	6.2	7	8.9	2.9	-0.7	-1.1	-2.2	…
2008	0.1	1.1	2.5	2.4	0.5	-0.6	3.2	-3.9	-3.2	-2.9	-3.7	-4.5	-2.8	-2	-3.8	…
2007	-4.8	-0.9	-0.3	-3.6	-3	-3.8	-3.6	-5.6	-7.3	-5.8	-6	-10.8	-8.8	-2.9	-2.4	…
2006	-2.7	3.1	6.1	6.1	5.9	10.4	12	0.2	1.6	1.4	-0.6	3.1	6.5	8.4	2.6	…
2005	-2.8	-1.9	-3.8	-7.9	-5.9	-5	-3.4	4.8	4.2	0.4	1	-0.5	0.6	2.2	-1.1	…
2004	1.8	5.1	6.9	6.9	0.4	-2.6	-4.8	1.1	-1.6	-4.6	-4.6	-4.1	-2.4	-2.2	-2.1	…
2003	2.2	0.2	-1.4	-4.6	-3.5	-2.8	-1.8	4.7	8.2	8.6	10	8.4	3.3	5.2	1.5	…
2002	0.3	2.3	0.2	1.2	1.3	2.7	0.5	1	0.5	0	3	7.7	5.6	4	6.5	…
2001	1.3	1	0.6	1.6	1.2	1.6	1.9	-4.5	-7.1	-7.7	-8.9	-8.3	-5.4	-3.8	-2.2	…
2000	8.6	4.2	1.9	4.1	3.3	5.7	8.8	-0.2	0.7	0.8	0.5	0.5	-0.3	0	0.9	…
1999	-3	-2.5	-2	-2.8	-0.8	0.7	1.1	9	10.4	8	6	4.8	5.5	6.1	5.4	…
1998	-1.6	-2.5	-4.2	-7.2	-6.1	-5.3	-3.4	2.7	3.7	3	1.5	3	2.2	2.2	-1.1	…
1997	6.9	2.5	-0.5	-3.3	-1.5											…
…	…	…	…	…	…	…										…

reference_window = "middle"

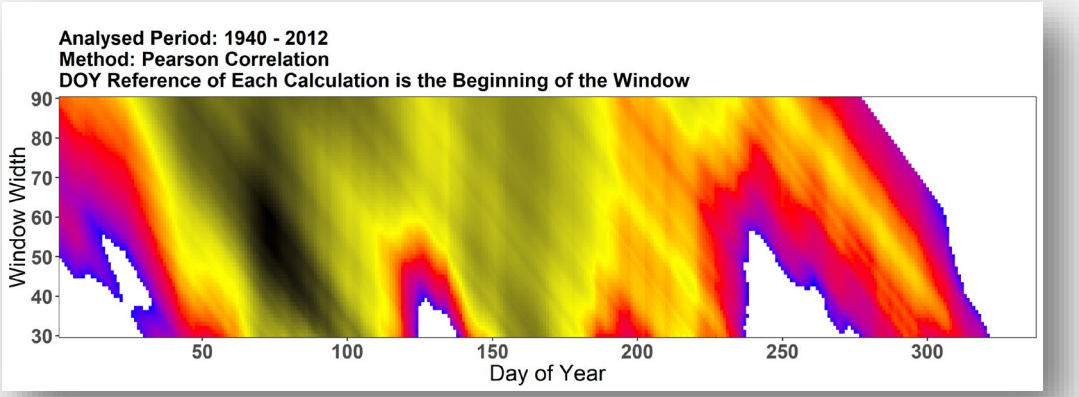
final output matrix

5		0.11							

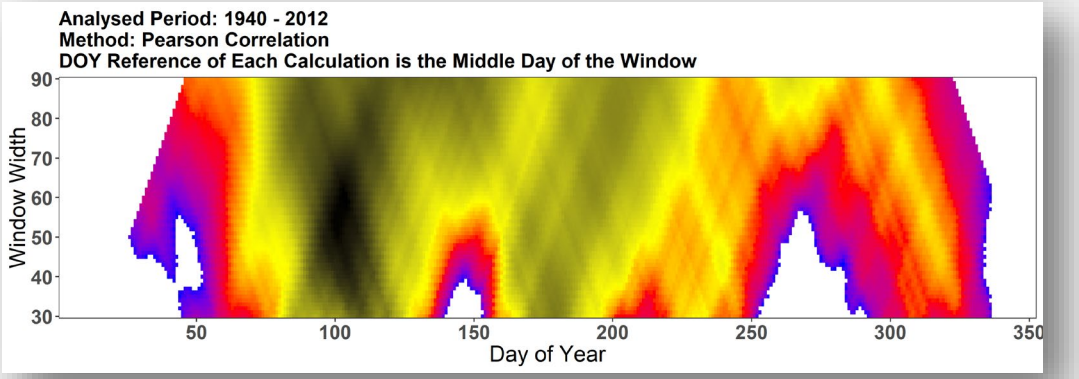
daily_response()

Reference window

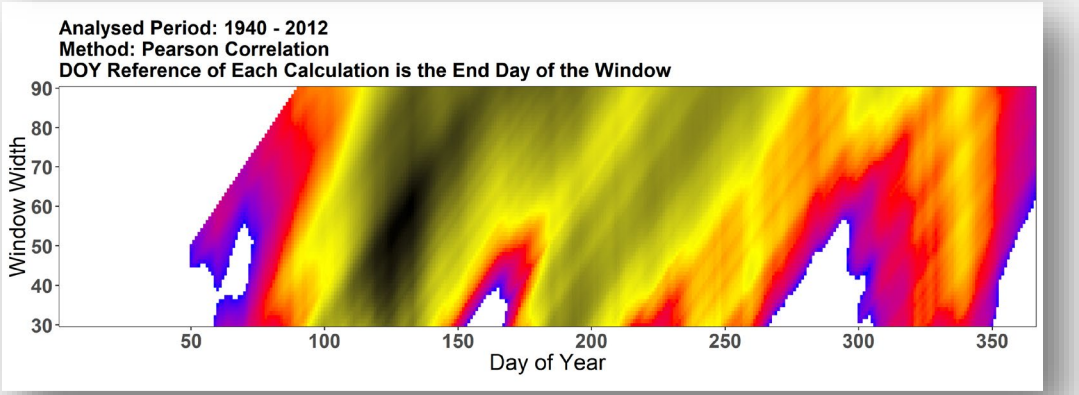
- reference_window = "start"



- reference_window = "middle"

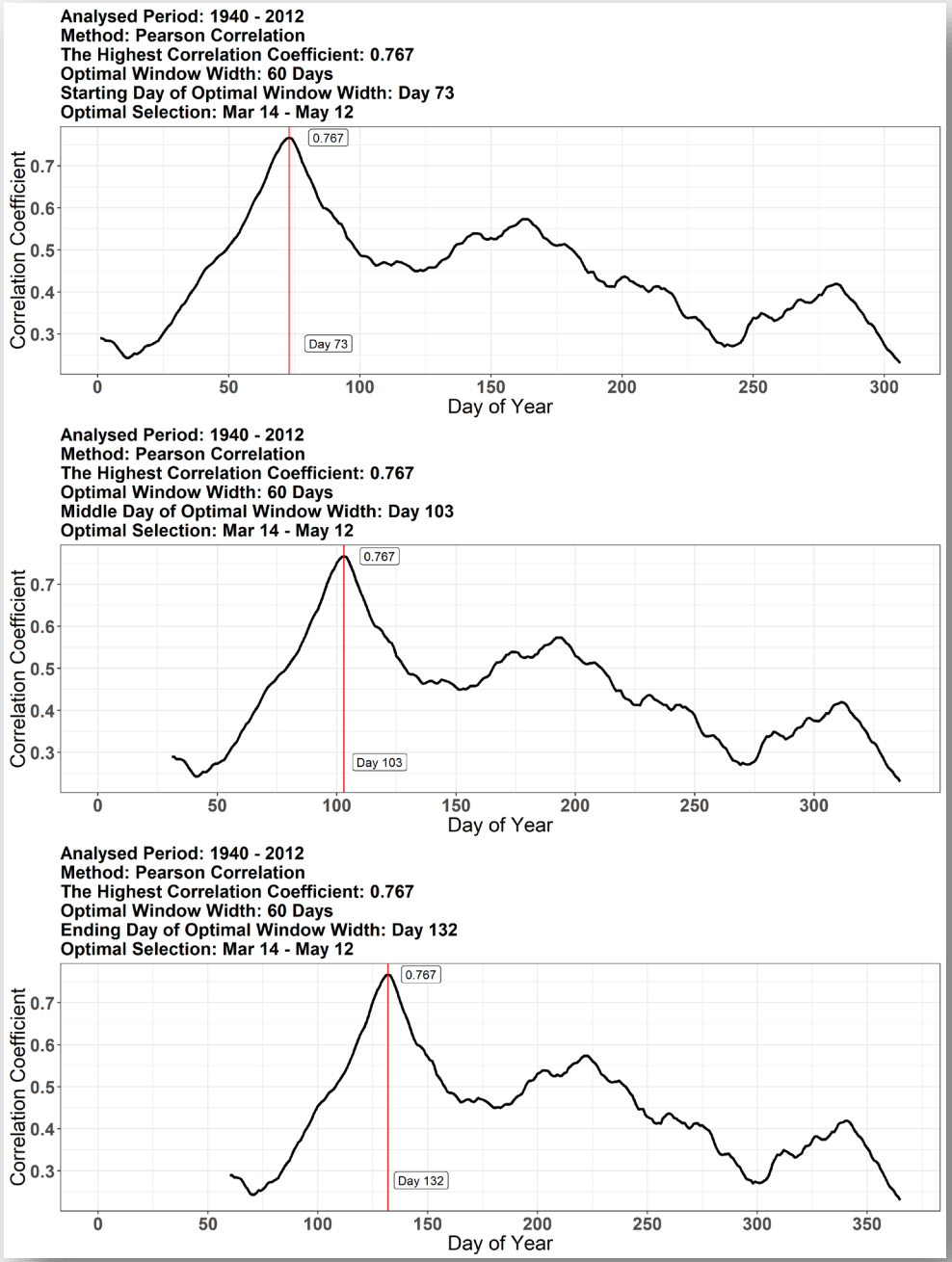


- reference_window = "end"



daily_response()

- reference_window = "start"
- reference_window = "middle"
- reference_window = "end"



Reference window

daily_response()

- temporal_stability = "sequential"
- k = 5

	Period	correlation	p value
1	1940 - 1954	0.564	0.0284
2	1955 - 1968	0.942	0.0000
3	1969 - 1983	0.229	0.4107
4	1984 - 1997	0.789	0.0008
5	1998 - 2012	0.505	0.0548

- temporal_stability = "progressive"
- k = 5

	Period	correlation	p value
1	1940 - 1954	0.564	0.0284
2	1940 - 1968	0.755	0.0000
3	1940 - 1983	0.647	0.0000
4	1940 - 1997	0.678	0.0000
5	1940 - 2012	0.767	0.0000

Temporal stability

daily_response()

- temporal_stability = "running_window"
- k_running_window = 30

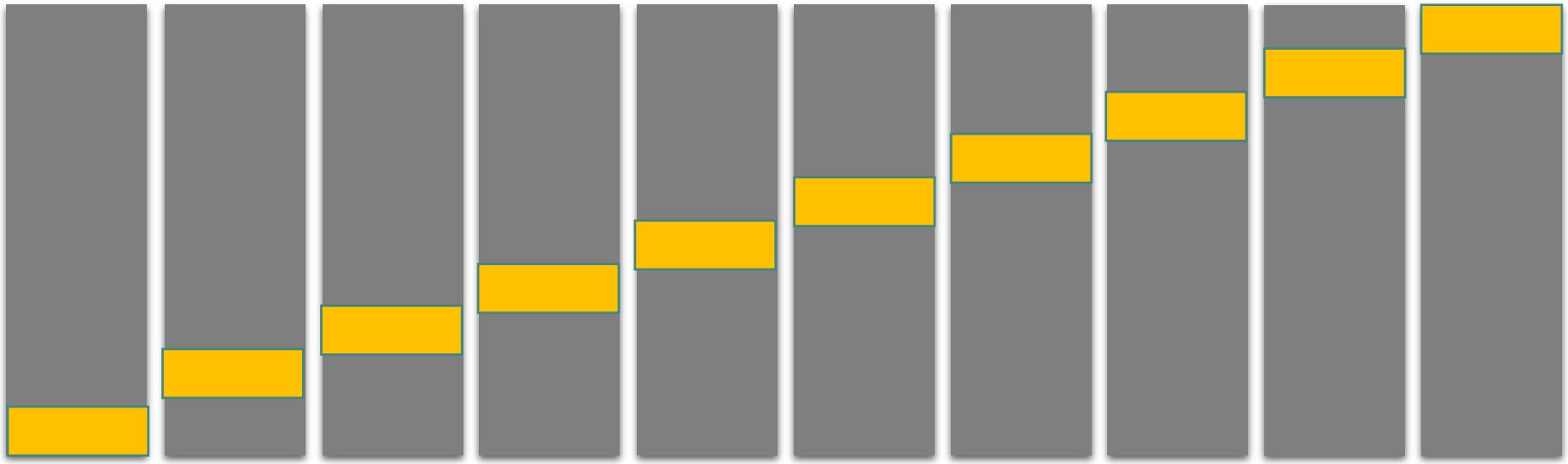
	Period	correlation	p value
1	1940 - 1969	0.754	0.000
2	1941 - 1970	0.743	0.000
3	1942 - 1971	0.722	0.000
4	1943 - 1972	0.683	0.000
5	1944 - 1973	0.664	0.000
6	1945 - 1974	0.671	0.000
7	1946 - 1975	0.698	0.000
8	1947 - 1976	0.691	0.000
9	1948 - 1977	0.738	0.000
10	1949 - 1978	0.752	0.000
11	1950 - 1979	0.767	0.000
12	1951 - 1980	0.760	0.000
13	1952 - 1981	0.725	0.000
14	1953 - 1982	0.718	0.000
15	1954 - 1983	0.669	0.000
16	1955 - 1984	0.701	0.000
17	1956 - 1985	0.713	0.000
18	1957 - 1986	0.707	0.000
19	1958 - 1987	0.694	0.000
20	1959 - 1988	0.684	0.000
21	1960 - 1989	0.700	0.000
22	1961 - 1990	0.702	0.000
23	1962 - 1991	0.648	0.000
24	1963 - 1992	0.644	0.000
25	1964 - 1993	0.671	0.000

daily_response()

Calibration data

Validation (verification) data

10 – fold cross validation



r
RMSE
RE
…

r
RMSE
RE
…

r
RMSE
RE
…

r
RMSE
RE
…

r
RMSE
RE
…

r
RMSE
RE
…

r
RMSE
RE
…

r
RMSE
RE
…

r
RMSE
RE
…

r
RMSE
RE
…

k-fold cross validation

daily_response()

5-fold cross validation

	CV	Period	Years	cor	RMSE	RRSE	d	RE	CE	DE
1	1	Calibration	1955 - 2012	0.8012570	0.7644892	0.5983203	0.8806215	NA	NA	NA
2	1	Validation	1940 - 1954	0.5644108	0.9504678	0.8311539	0.6671163	0.3429730	0.30918311	0.2278828
3	2	Calibration	1940 - 2012	0.7321149	0.8491829	0.6811811	0.8302576	NA	NA	NA
4	2	Validation	1955 - 1968	0.9422981	0.6336769	0.5432212	0.9138158	0.7700865	0.70491067	0.6010305
5	3	Calibration	1940 - 2012	0.8003193	0.7694017	0.5995741	0.8808692	NA	NA	NA
6	3	Validation	1969 - 1983	0.2294841	0.9507887	1.0534615	0.4581923	0.3694569	-0.10978116	-0.1106053
7	4	Calibration	1940 - 2012	0.7667097	0.8556218	0.6419939	0.8567853	NA	NA	NA
8	4	Validation	1984 - 1997	0.7893905	0.5562398	0.6578301	0.8807247	0.5826823	0.56725952	0.4890332
9	5	Calibration	1940 - 1997	0.6781117	0.7678974	0.7349588	0.7891830	NA	NA	NA
10	5	Validation	1998 - 2012	0.5051327	0.9829418	1.0323555	0.6602806	0.7649946	-0.06575788	-0.2499931

daily_response_seascorr()

daily_response_seascorr()

daily_response_seascorr

daily_response_seascorr

Description

Function calculates all possible partial correlation coefficients between tree-ring chronology and daily environmental (usually climate) data. Calculations are based on moving window which is defined with two arguments: lower_limit and upper_limit. All calculated (partial) correlation coefficients are stored in a matrix. The location of stored correlation in the matrix is indicating a window width (row names) and a location in a matrix of daily sequences of environmental data (column names).

Usage

```
daily_response_seascorr(
  response,
  env_data_primary,
  env_data_control,
  lower_limit = 30,
  upper_limit = 90,
  fixed_width = 0,
  previous_year = FALSE,
  pcor_method = "pearson",
  remove_insignificant = TRUE,
  alpha = 0.05,
  row_names_subset = FALSE,
  PCA_transformation = FALSE,
```

daily_response_seascorr()

KEY ARGUMENTS

- response (your TRWi chronology)
- env_data_primary (daily climate data)
- env_data_control(daily climate data)
- ~~method, metric~~
- pcor_method ('pearson', 'spearman', 'kendall')
- aggregate_function_env_data_primary
- aggregate_function_env_data_control

- A partial correlation coefficient is a measure of the strength of the relationship associated with a partial regression coefficient.
- Partial correlation is a method of describing the relationship between two variables while subtracting out the effects of another variable.
- In dendroclimatology, the partial correlation coefficient is often tested to avoid erroneous conclusions based on common correlations between climate variables, e.g., temperature and precipitation.
- *daily_response_seascorr()* replicates the idea of *seascorr*, which is available for Matlab (Meko et al., 2011)* and as a function in the *treeclim* R package (Zang et al., 2015)**.

*Meko, D.M., Touchan, R., Anchukaitis, K.J., 2011. Seascorr: A MATLAB program for identifying the seasonal climate signal in an annual tree-ring time series. Computers & Geosciences 37, 1234-1241.

**Zang, C., Biondi, F., 2015. treeclim: an R package for the numerical calibration of proxy-climate relationships. Ecography 38, 431-436.

Example 3 – compare simple and partial correlations

monthly_response()

monthly_response()

monthly_response *monthly_response*

Description

Function calculates all possible values of a selected statistical metric between one or more response variables and monthly sequences of environmental data. Calculations are based on moving window which slides through monthly environmental data. All calculated metrics are stored in a matrix. The location of stored calculated metric in the matrix is indicating a window width (row names) and a location in a matrix of monthly sequences of environmental data (column names).

Usage

```
monthly_response(
  response,
  env_data,
  method = "cor",
  metric = "r.squared",
  cor_method = "pearson",
  previous_year = FALSE,
  neurons = 1,
  lower_limit = 1,
  upper_limit = 12,
  fixed_width = 0,
  brnn_smooth = TRUE,
  remove_insignificant = TRUE,
  alpha = 0.05,
  row_names_subset = FALSE,
  PCA_transformation = FALSE,
  log_preprocess = TRUE,
  components_selection = "automatic",
  eigenvalues_threshold = 1,
```

monthly_response()

KEY ARGUMENTS

- response (your TRWi chronology)
- **env_data (monthly climate data)**
- method, metric
- aggregate_function
- lower_limit, upper_limit
- cor_method ('pearson', 'spearman', 'kendall')
- row_names_subset
- previous_year
- remove_insignificant
- alpha
- boot, boot_n

	1	2	3	4	5	6	7	8	9	10	11	12
1989	-3.895484	-4.335357	-2.8261290	-3.060333265	2.765483809	4.545000	8.774516	8.252258	5.058000	2.36451608	-3.4419999	-4.142258
1990	-6.546129	-4.392143	-2.7877419	-3.118666597	3.697741853	5.599667	9.334516	8.958387	4.498000	3.05387090	-4.4163332	-8.986129
1991	-6.939677	-10.108928	-2.2025806	-3.542999921	-0.502903215	5.382667	10.239355	10.545161	7.334333	0.61806450	-3.6719999	-6.542580
1992	-5.971613	-6.697586	-4.7780644	-2.232666617	4.185806358	5.433333	9.181935	11.157742	5.193667	-0.59096773	-1.0373333	-5.372581
1993	-4.968710	-7.309643	-6.0758063	-1.291333304	3.959354750	6.869000	7.518064	9.327742	3.803667	0.46838709	-4.6256666	-5.510968
1994	-6.503226	-8.199286	-1.4580645	-3.039666599	3.279032185	6.879667	11.254516	10.282580	5.025333	1.54129029	0.8160000	-3.741613
1995	-9.224193	-4.906071	-7.5309676	-1.418666635	2.568064459	4.583333	10.850000	7.447419	2.477667	4.87419344	-3.7076666	-6.056129
1996	-5.255484	-9.693448	-6.6238708	-1.063333310	3.154193478	7.427000	7.726774	7.489677	2.268333	1.24064513	-3.9929999	-6.107419
1997	-6.165484	-5.735714	-2.7283870	-3.156666596	2.950322515	5.664667	7.012903	9.413871	8.164333	1.90419351	-2.6776666	-5.898387
1998	-6.948064	-3.438928	-5.1351612	-2.491333278	3.446451536	7.256000	9.382903	9.878064	4.509000	0.71709676	-5.8089999	-6.222258
1999	-6.893871	-8.879286	-4.2545160	-1.977999956	4.840967634	5.499667	8.796774	8.767097	6.662000	2.16548382	-4.7286666	-7.186451
2000	-8.087742	-6.123448	-4.1122580	-1.144666641	4.194193455	8.091333	6.698387	9.510645	6.217333	2.18645156	-3.9156666	-4.941290
2001	-8.190968	-7.443571	-2.8716128	-3.714999917	4.784516022	5.317667	8.917742	10.246129	2.115333	4.85064505	-2.3566666	-7.857097
2002	-5.779677	-4.973928	-3.8587096	-1.791666627	2.519677363	8.525333	8.451935	8.120968	4.169667	1.66354835	-2.1596666	-4.994193
2003	-8.395806	-9.403571	-2.6703225	-1.945333290	4.946128922	11.611000	10.290645	12.817096	5.722333	-0.56612902	-0.9453333	-4.647742
2004	-7.923226	-6.195172	-5.4619354	-1.898999958	1.503548353	6.861667	8.375806	8.669677	6.565667	3.39258057	-2.3989999	-5.038064
2005	-6.992903	-10.954643	-4.6912902	-1.294666638	3.921612816	8.286333	8.961613	7.069677	6.339333	3.35999992	-4.0803332	-8.690968
2006	-8.707419	-7.846071	-6.0987095	-0.608666653	3.766774109	8.104333	11.986451	6.076129	9.008000	4.79096763	-0.1983333	-3.139677
2007	-3.859032	-3.951786	-3.6329031	3.768666582	4.846128924	8.146333	9.675161	8.600968	4.731667	2.66483865	-2.7203333	-5.816451
2008	-4.434839	-3.865862	-4.6616128	-1.948666623	4.182257971	8.437666	9.252903	9.730000	4.899000	2.94870961	-3.2739999	-5.750322
2009	-8.446451	-8.168571	-4.4893547	0.638999986	5.649677293	7.865333	10.181935	11.559677	7.759000	2.22064511	-0.5676667	-7.063226
2010	-9.174516	-7.954286	-5.1990321	-0.471999989	2.399032204	7.684666	11.212580	8.388064	5.078333	1.34322578	-2.9443333	-7.658064

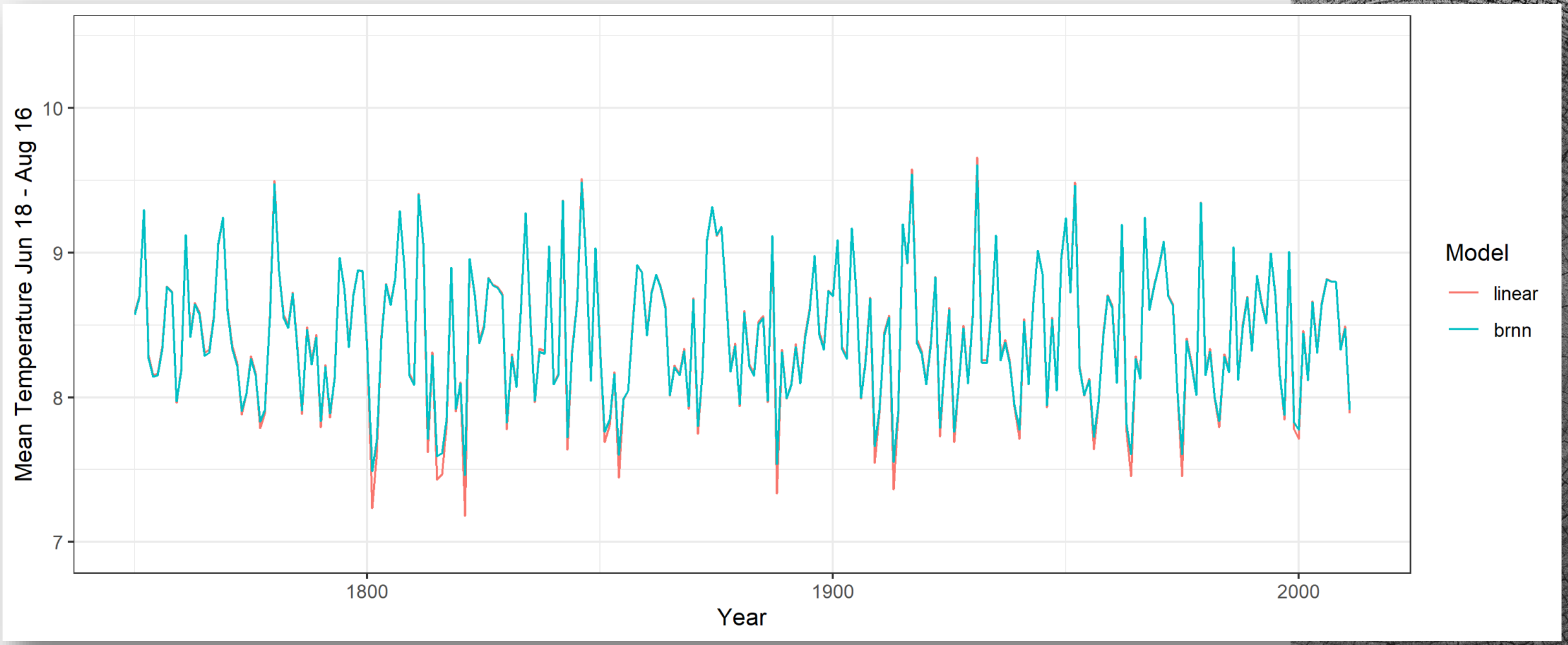
monthly_response_seascorr()

KEY ARGUMENTS

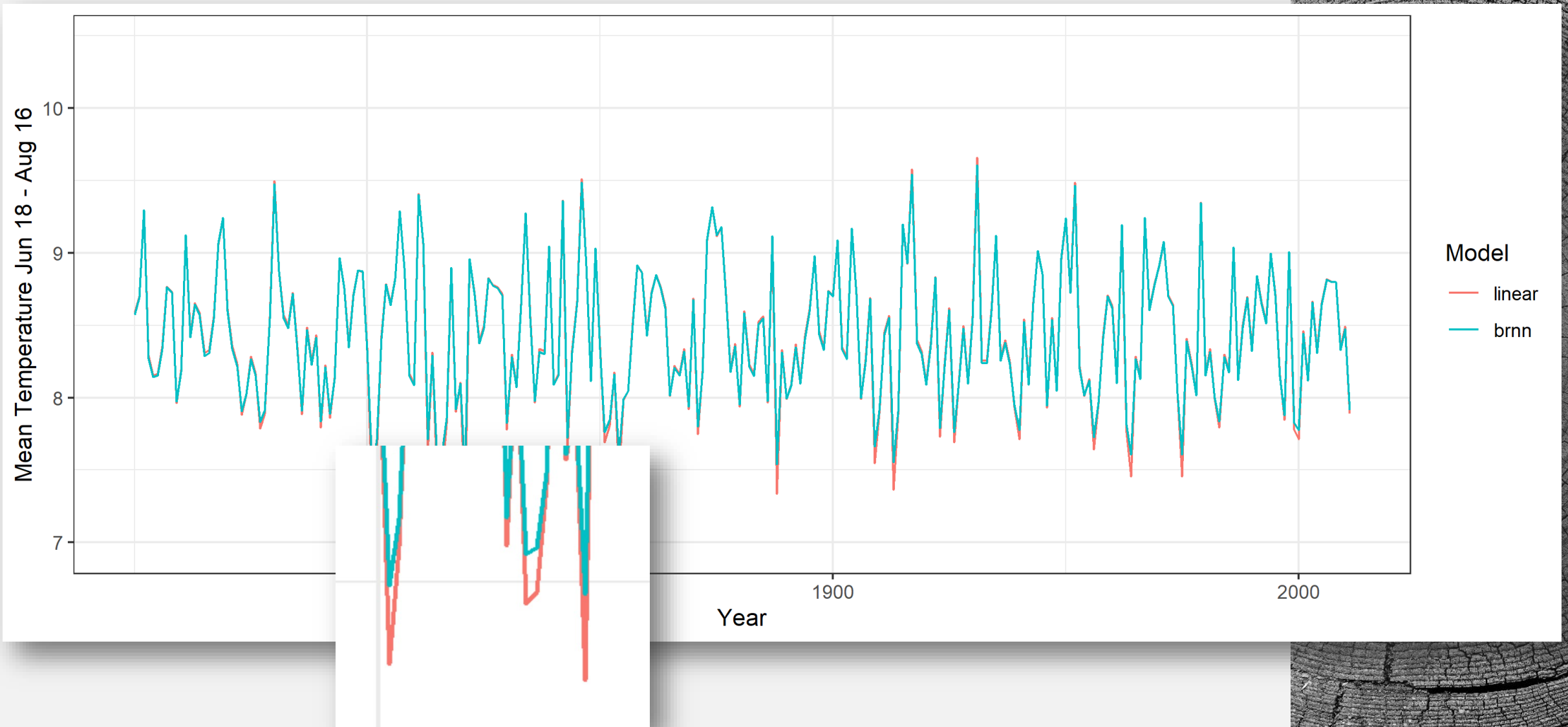
- response (your TRWi chronology)
- **env_data_primary (monthly climate data)**
- **env_data_control (monthly climate data)**
- **aggregate_function_env_data_primary ('mean', 'median', 'sum')**
- **aggregate_function_env_data_control ('mean', 'median', 'sum')**
- cor_method ('pearson', 'spearman', 'kendall')
- row_names_subset
- previous_year
- remove_insignificant
- alpha
- boot, boot_n

Example 4 – monthly_response() and monthly_response_seascorr()

Example 5
climate reconstrction

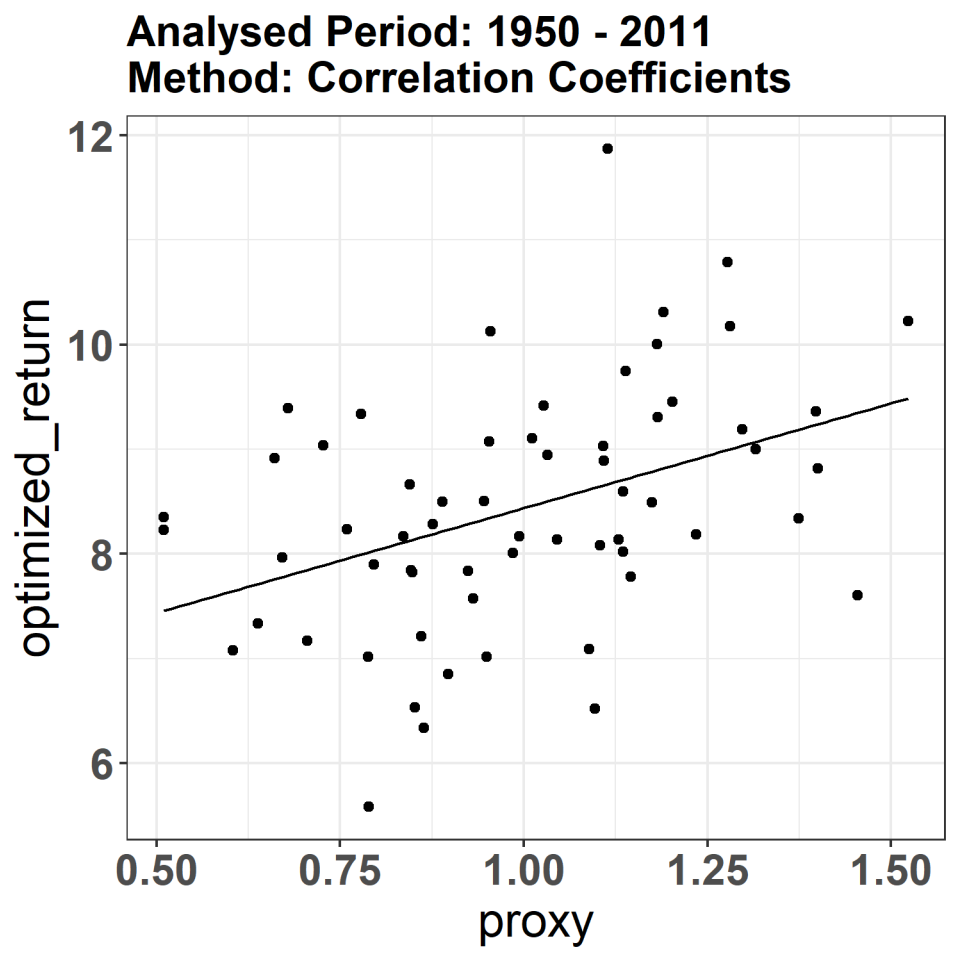


Example 5
climate reconstrction

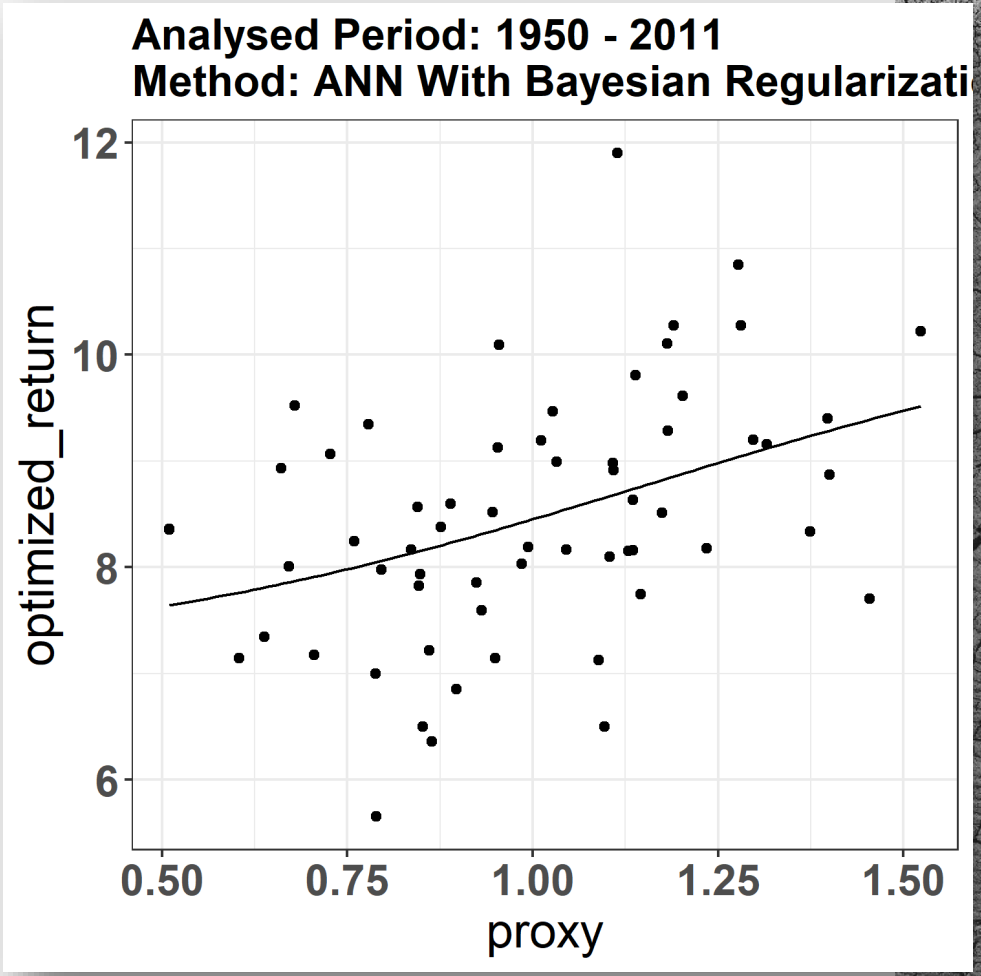


Example 5
climate reconstrction

Linear transfer function

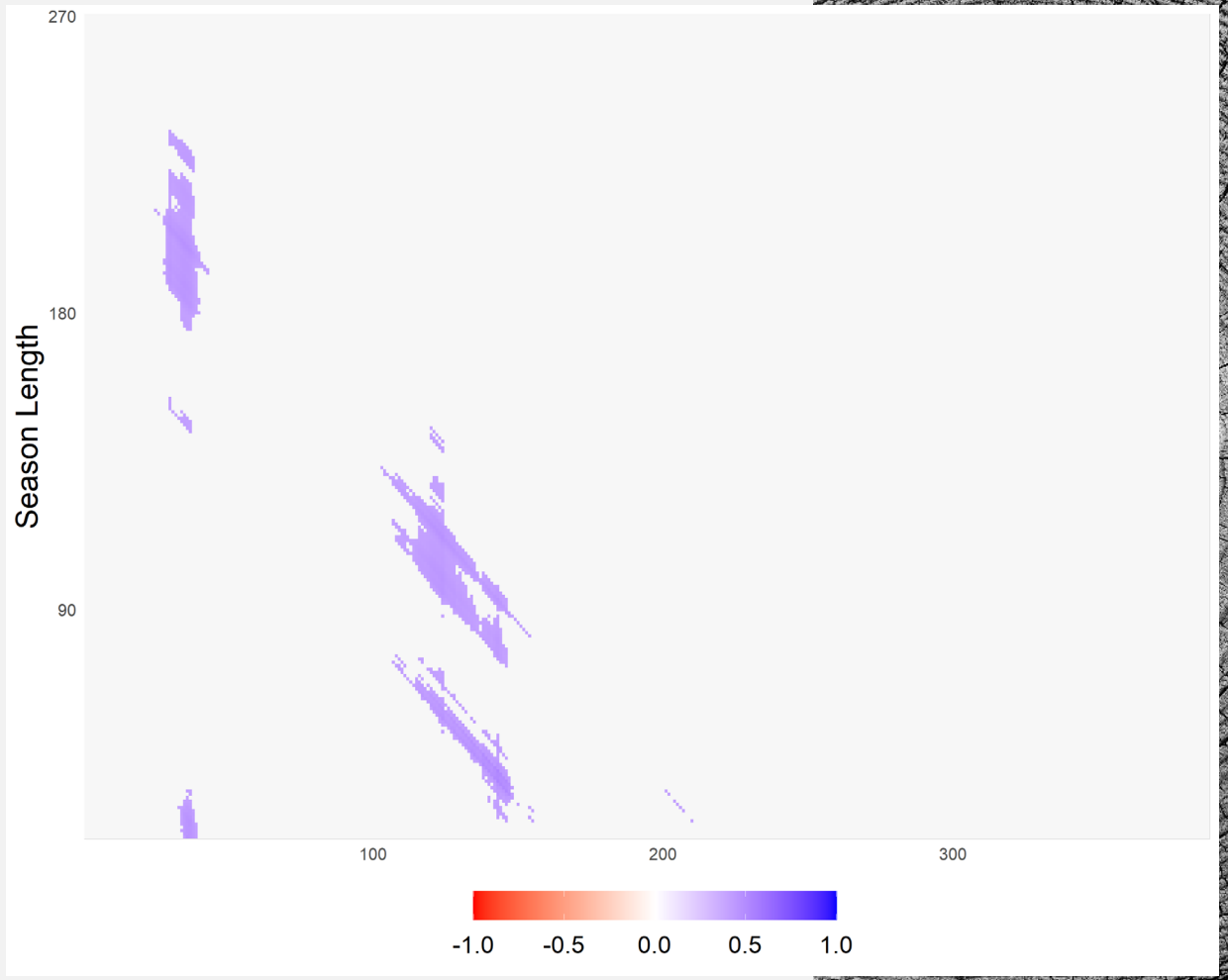


Non-linear BRNN transfer function



Homework: daily SPEI correlations

- See the folder daily SPEI example (only recently added!)
- Use the R codes for step 1 (climatic water deficit) and step 2 to calculate correlations between TRWi and aggregated daily SPEI values.
- Use these R scripts and apply them on your data.



THANKS FOR ATTENDING THE DENDROTOOLS WORKSHOP

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🔗 *https://www.gozdis.si/en/*