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Analysis of meteorological observations for Bulgaria (1905-2022)

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Meteorological data

- Sources: Statistical year-book and и National Institute of Meteorology and Hydrology
- Time period 1905 - 2022
- 37 meteo-stations
- 193 time series
- 67621 monthly averaged values
- Temperature, atmospheric pressure, cloudiness, precipitation, humidity

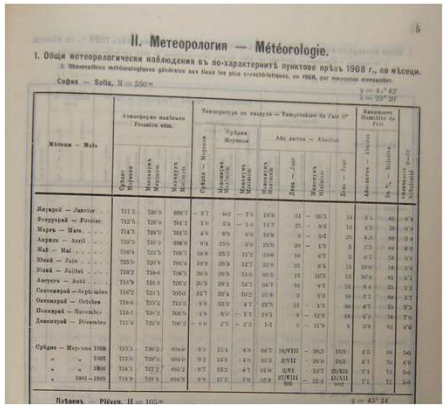
Станция	брой средномесечни стойности
Банско	347
Берковица	239
Бургас	4271
Варна	4719
Велико Търново	1560
Видин	2483
Враца	1919
Габрово	582
Горна Оряховица	1200
Добрич	720
Казанлък	4105
Карнобат	838
Кнежа	581
Кърджали	600
Кюстендил	2639
Левски град	120
Лом	2998
Мусала	2291
Ново Село	1139
Образцов Чифлик, Русе	1476
Павликени	599
Пазарджик	720
Плевен	4236
Пловдив	2859
Радомир	479
Русе	2040
с. Рила	1078
Садово	1443
Сандански	2758
Силистра	1919
София	5012
Хасково	2784
Черни Връх	1151
Чирпан	720
Шумен	3004
Юмрук Чал	287
Ямбол	1345
Общо	**67261**

Data preparation

- Download of scanned images of statistical yearbook, stored in pdf format, from the digital library of the National Statistical Institute
- Optical character recognition using “gimageReader” and “tesseract OCR engine”
- Consolidation of the data in CSV-forma following the table structure of the statistical yearbook
- Reconstruction and aggregation of the time series for each meteo-station and measure, using scripts developed in “Python”, “Anaconda”, “Pandas”
- Data correction – work in progress

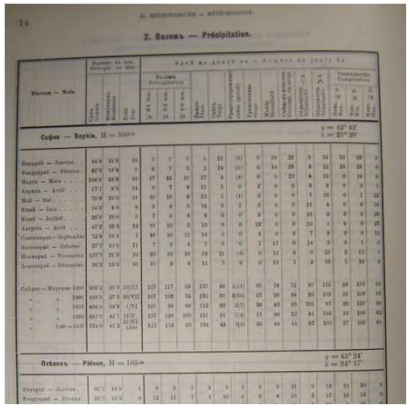
Challenges

- Low quality of the images
- Changes in the yearbook over different periods related to
  - the structure of yearbook
  - format and structure of data and tables
  - location of the meteo-stations
- Periods with missing data
- Erroneous data (for example atmospheric pressure)

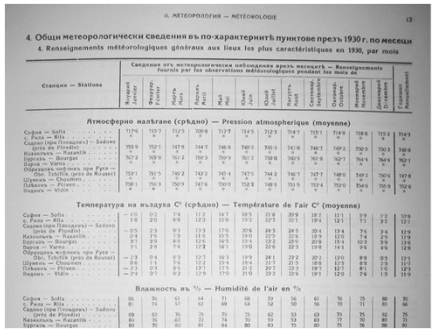


II. Метеорология — Météorologie.

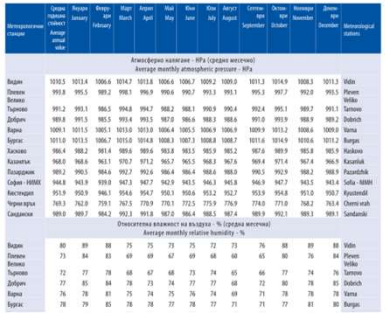
1. Общи метеорологически наблюдения въ по-характернитѣ пунктове презъ 1908 г., по мѣсеци.



2. Валежъ — Précipitation.



4. Общи метеорологически сведения въ по-характернитѣ пунктове презъ 1930 г. по месеци



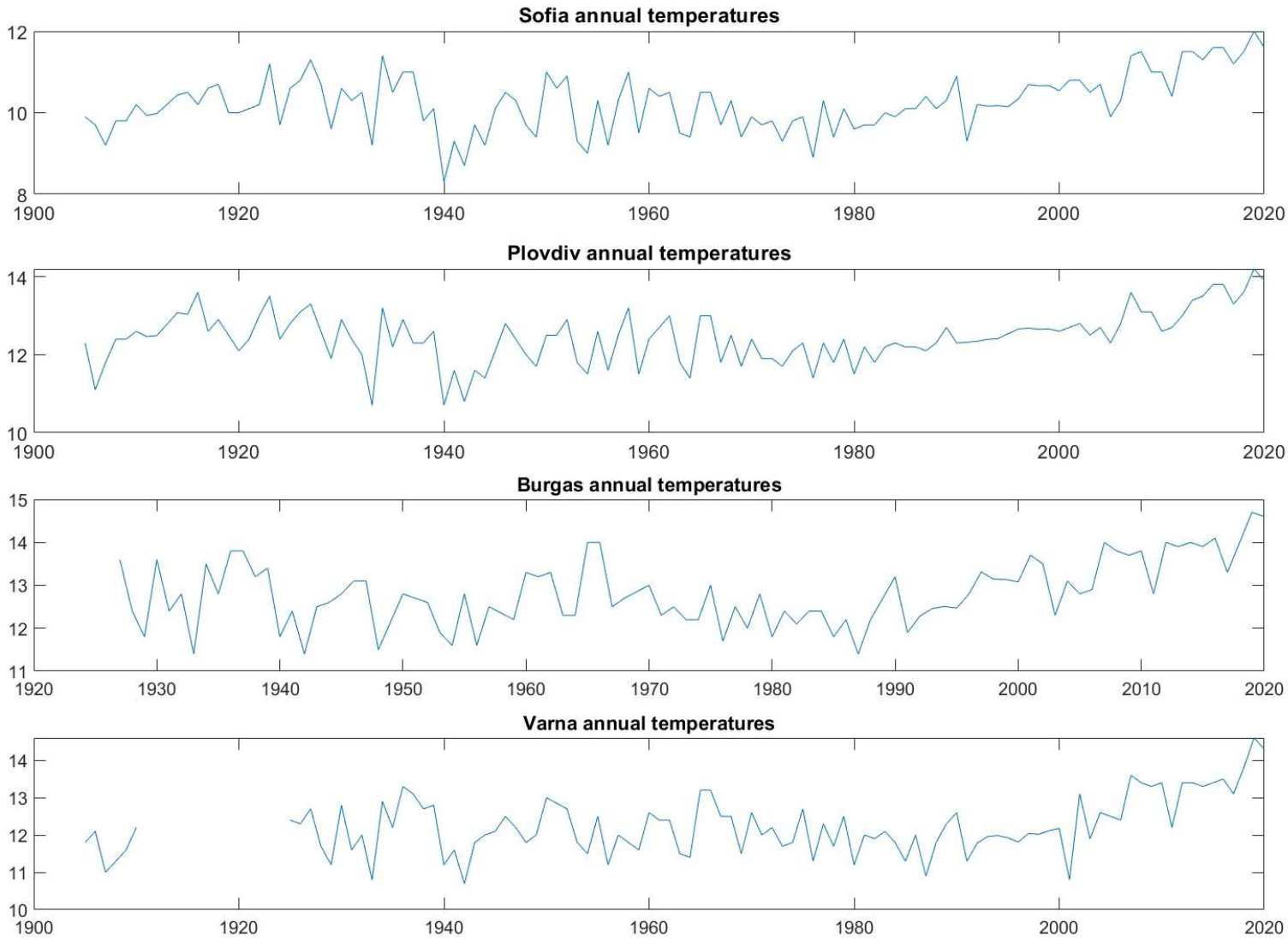
10. Общи метеорологични данни за 2010 г. по месеци

Meteorological data for 2010 by months

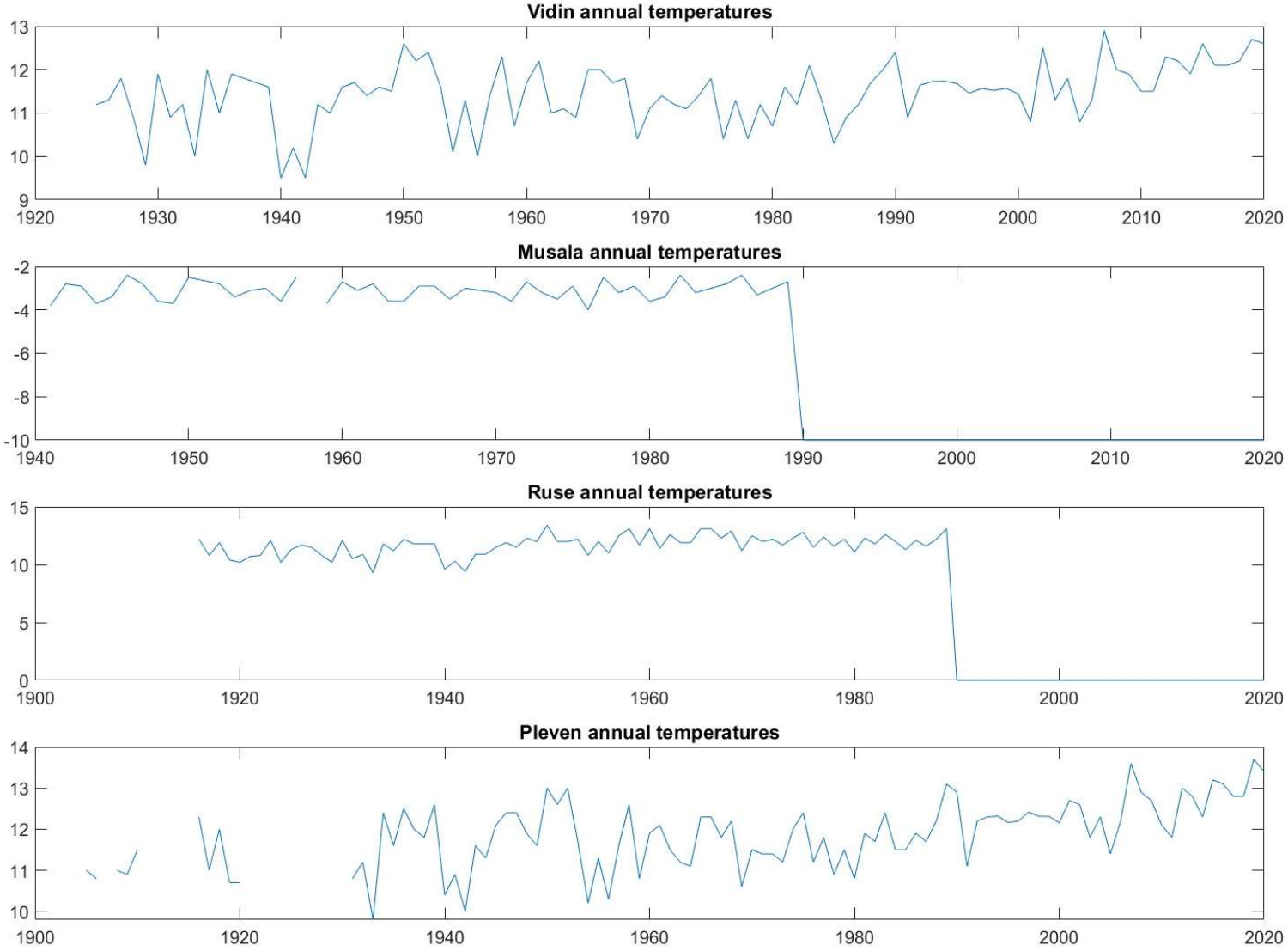
Sample of processed meteo-data in comma separated value (CSV) format

	Бургас					Мусала						Плевен				
година_месец	облачна покривка	влажност	валежи	атм. налягане	температура	облачна покривка	влажност	валежи	атм. налягане	греене слънчево	температура	облачна покривка	влажност	валежи	атм. налягане	температура
1942_january	8	84	70	762.1	-5.3	7.4	84	150.1	523.3	77.6	-14.7	7.3	78	72.6	747.1	-10.1
1942_february	9.7	88	16.3	762.6	0.8	7.6	86	67.9	526.7	93.5	-9.7	8.9	86	32.3	747.6	-3.8
1942_march	7.4	80	67.9	765.1	2.9	7.9	86	84.4	530.3	139.5	-7.2	7.4	83	56.3	749.8	0.7
1942_april	7.5	78	21.7	762.2	9.1	8.7	88	230	531.4	106.2	-5.7	7	76	43.3	746.3	10.3
1942_may	5.6	73	36.1	760.8	16.8	7.3	84	129.3	535.9	208.6	-0.3	4.7	61	27.2	746	19.3
1942_june	4.9	71	53	760	22	6.8	76	79.1	537.9	227.3	4.2	6	69	140.6	745.8	21.4
1942_july	3.6	72	41.6	761.5	22.4	5.2	77	92.6	539	296.3	5.2	3.1	61	43.3	7468	22.5
1942_august	4.4	67	0	761.6	22.9	5.6	75	39.5	539.6	248.8	5	4.1	54	6.1	747.9	22.8
1942_september	3.6	73	5.5	763.7	20	4.9	70	21.7	540.1	243.9	3.7	2.6	56	4.6	749.2	20.7
1942_october	5.6	74	32.2	764	14.5	4.7	76	48.7	536.3	183.1	-1.7	4.7	70	29.5	750.1	12.6
1942_november	7.3	79	58.5	763.5	6.7	6.1	79	176.7	531.5	125.5	-6.3	7.5	86	66.7	749.3	3.6
1942_december	7.2	83	8	768.9	3.7	4.8	86	11.7	535	172.9	-6.1	8.6	91	13	754.1	-0.5
1943_january	7.8	8	51.6	762.3	-0.6	6	8.1	158.8	526.3	121.8	-12.4	6.5	7.8	71.6	748	-5
1943_february	5.9	7.7	9.3	768	3.2	4.3	6.8	42.2	533	178.7	-9.9	4.9	7.8	2	753	1.8
1943_march	7.4	7.3	7.4	767.6	4.4	5.5	6.2	16.2	532.1	212.1	-9.2	5.5	6.1	1.2	752.8	4.7
1943_april	5.3	7	26.4	763	10.5	6.9	8.2	147.3	533.7	152	-5.4	5.8	5.6	42.5	748.6	13
1943_may	6.7	7.1	89.1	760.8	15.2	8	8.8	242.9	534.4	158.2	-2.4	6.9	7.2	135.3	746.9	15.1
1943_june	5.6	7.5	87.7	761.5	19.5	7.5	9.1	208.6	537.3	158.8	1	5.8	7.2	131.6	747.4	19.1
1943_july	3.6	7	23.5	759.4	22.3	6.2	8.3	73.3	538.2	239.3	4.2	3.7	5.5	29.7	745.4	22.8
1943_august	2	7.4	8.3	761.6	23.3	4.5	7.7	51.9	540.6	285.7	6.7	2.7	5.3	4.7	747.4	24.5
1943_september	4.5	7.8	29.5	762.9	20	5.4	7.9	43.4	540.1	240.1	4.8	4.2	6.3	45.4	748.2	20.6
1943_october	7.2	8	24.8	765.7	14.8	5.2	7.2	71.2	538.1	213.4	0.8	6.9	8.2	40.4	751.9	12.3
1943_november	7	8.4	52.8	763.4	11.5	7	7.9	46.5	533.1	128.6	-4.4	7.7	8.4	57.2	748.3	7.7
1943_december	7.2	8.4	95	766.7	5.6	6.8	8.3	82	532.7	101.9	-8.5	8.1	8.6	54.7	751.9	2.6

Annual temperature graphs



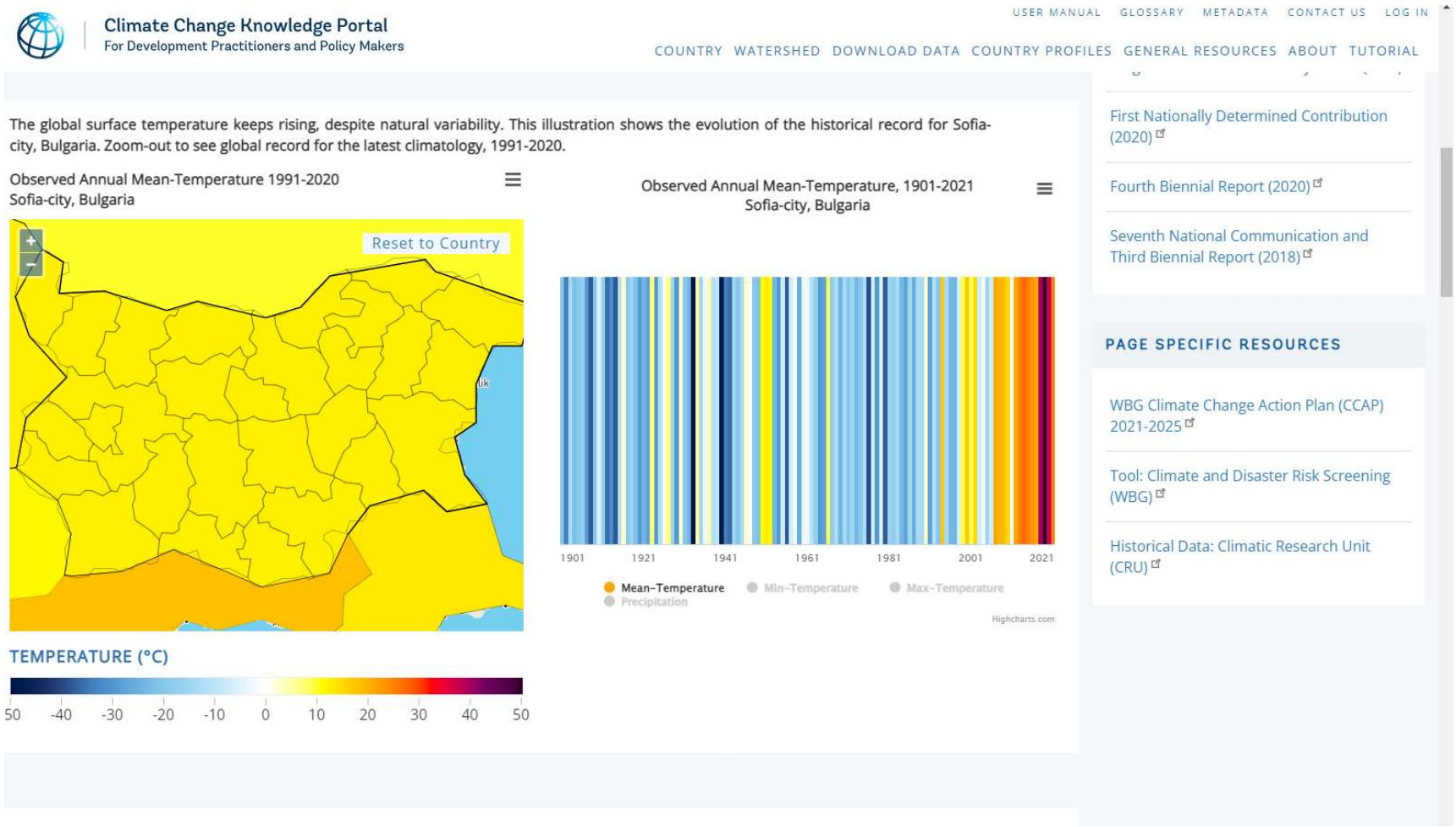
Annual temperature graphs



World Bank Climate Change Knowledge Center

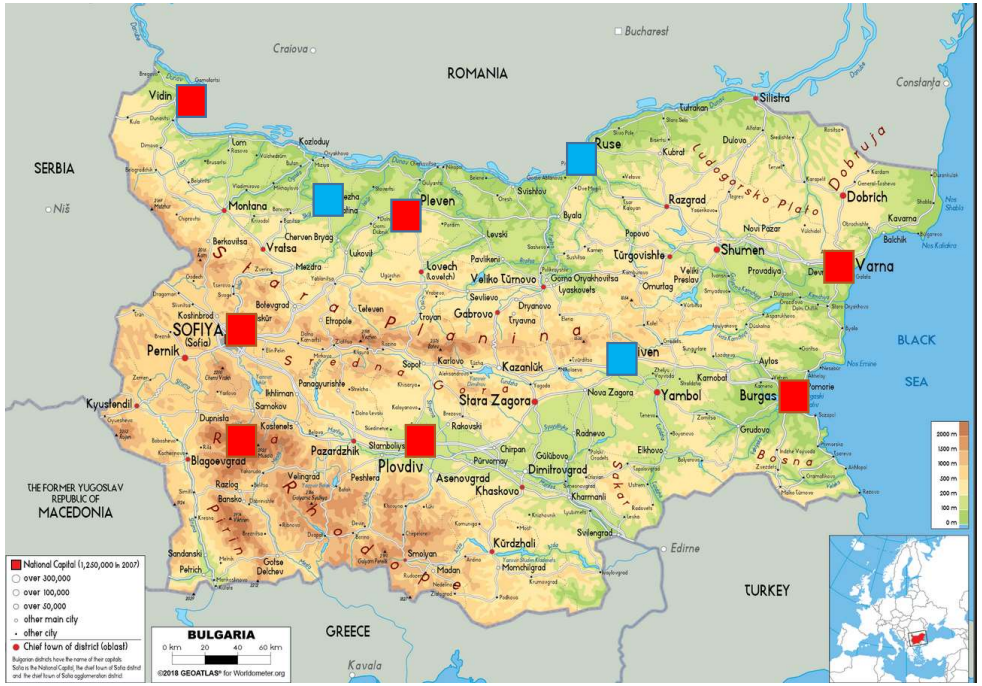
https://climateknowledgeportal.worldbank.org/country/bulgaria/climate-data-historical

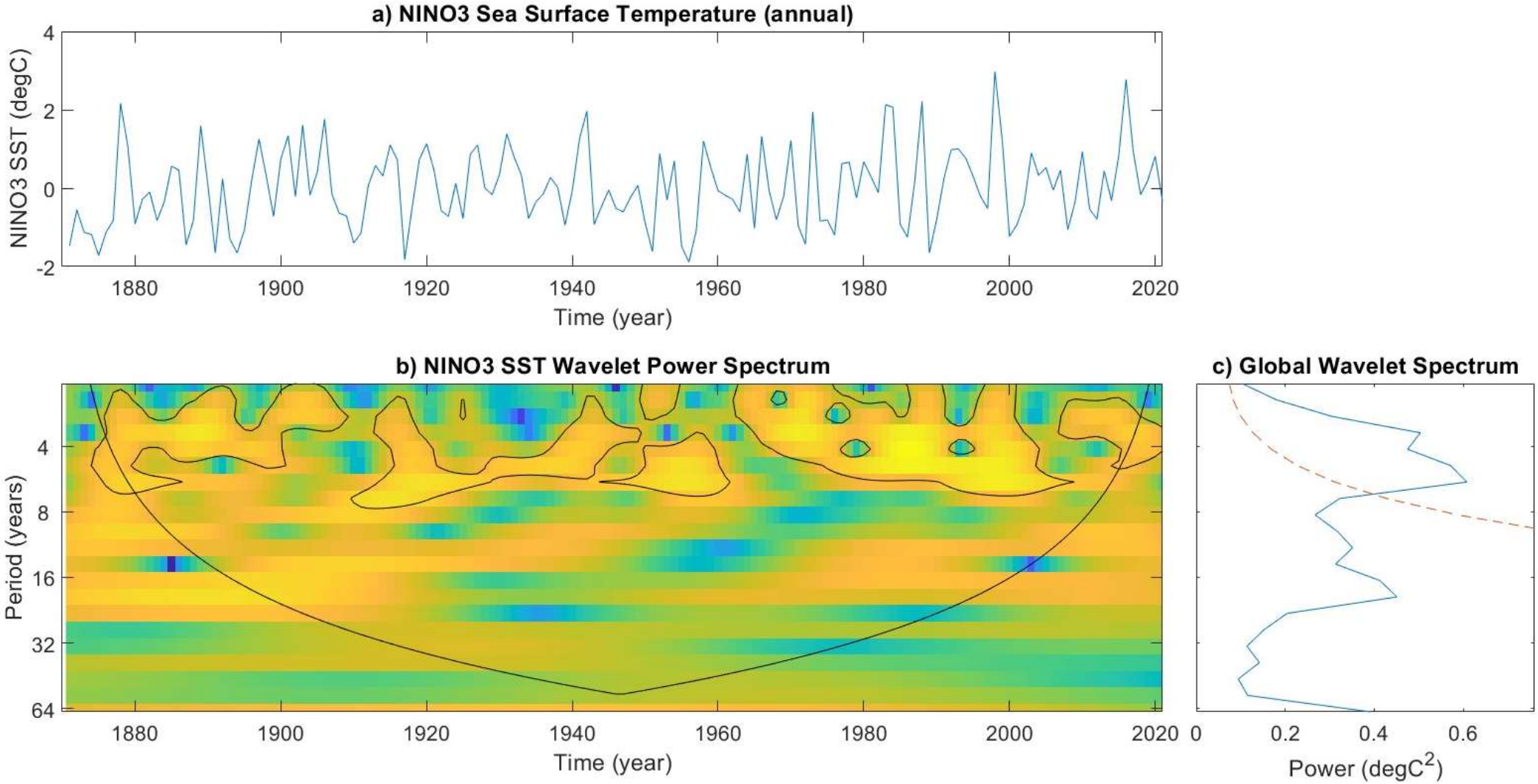
https://climateknowledgeportal.worldbank.org/download-data

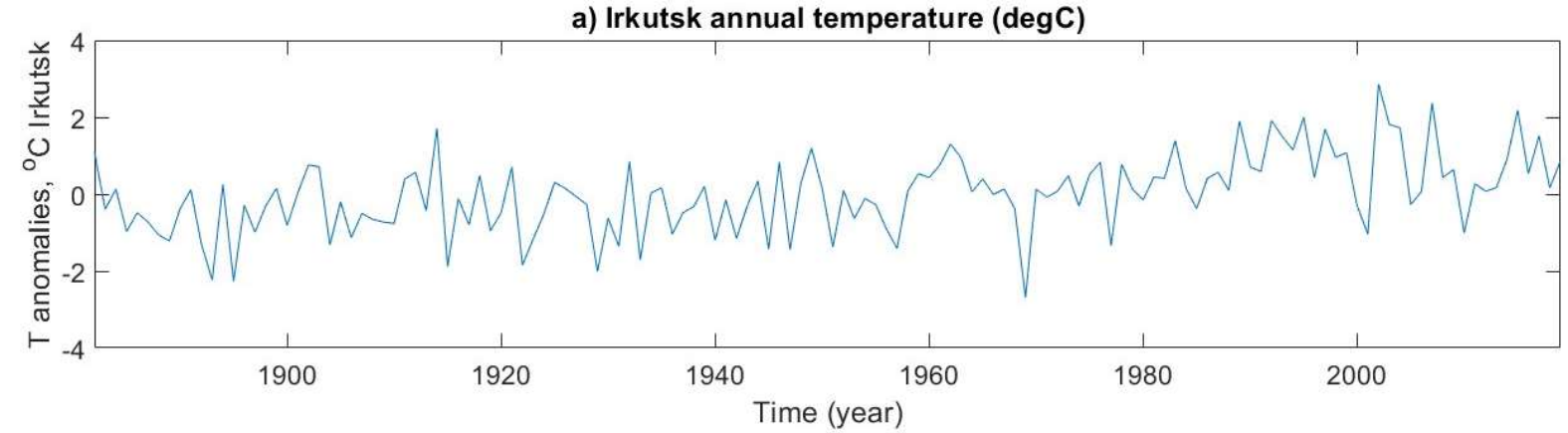


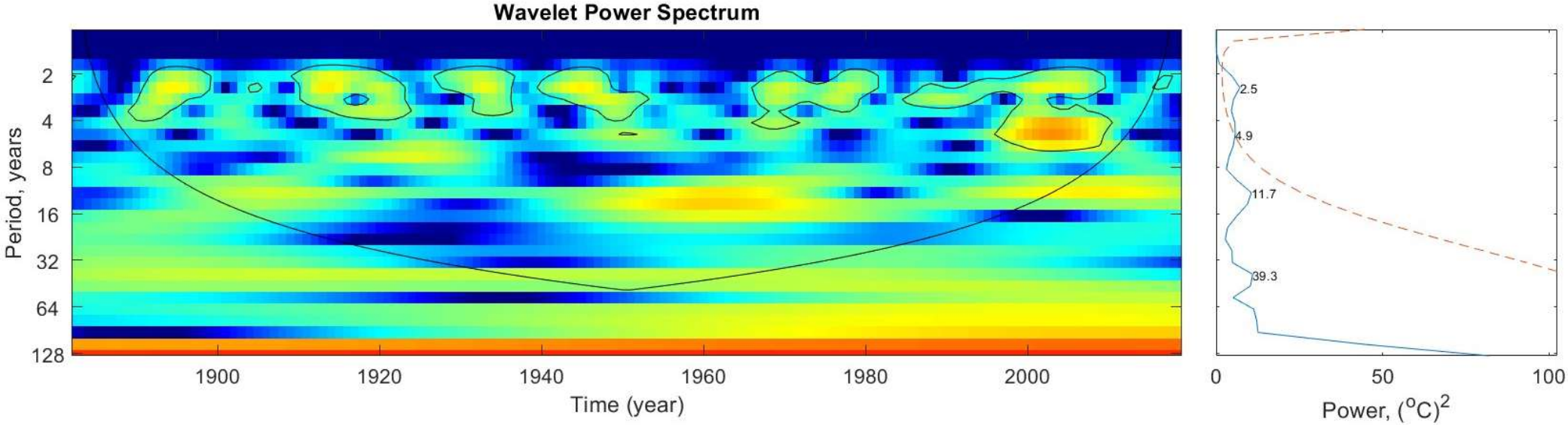
Initial analysis of meteorological data

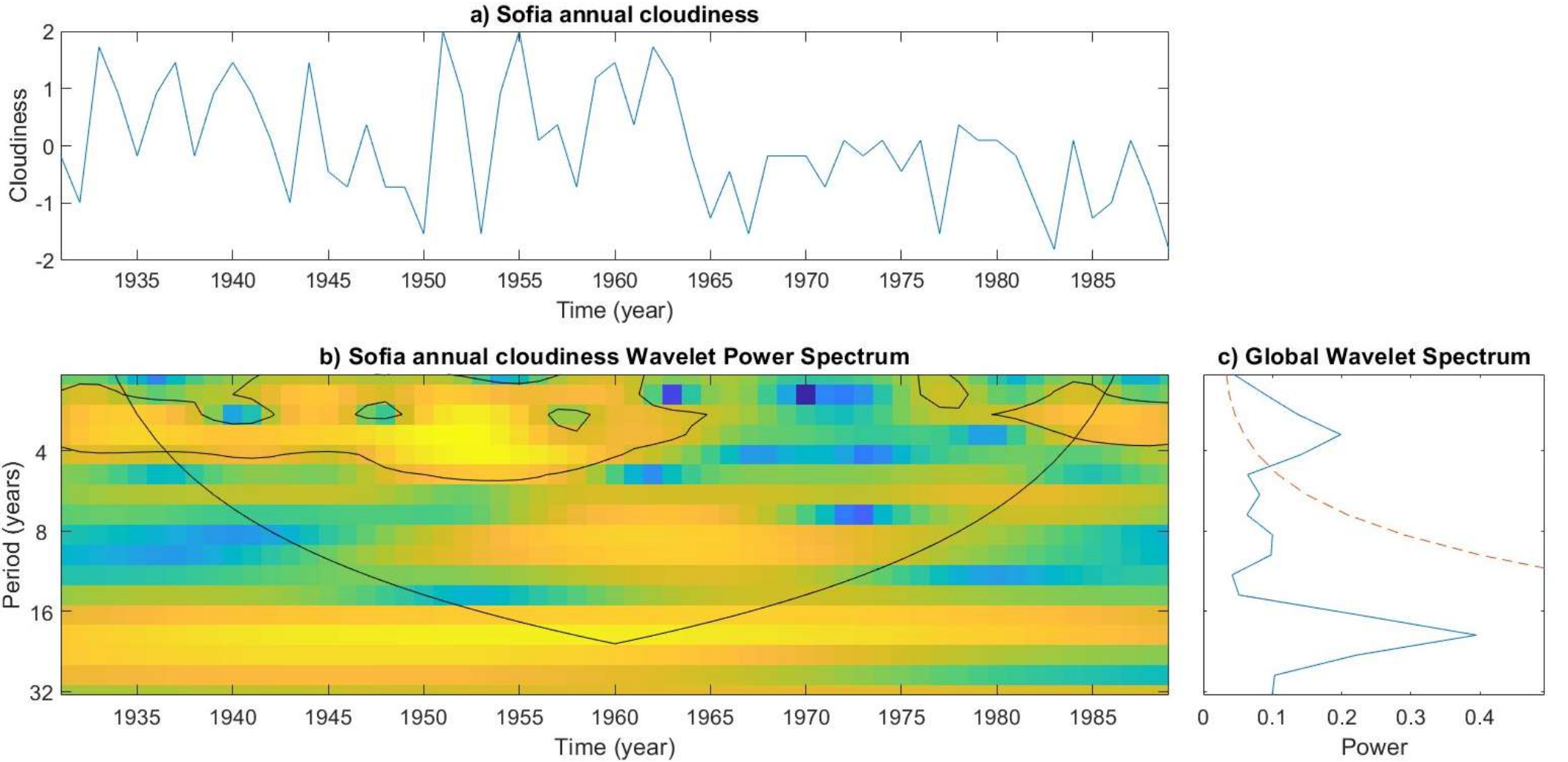
- We have selected several meteo-stations with the longest time series and are located in parts of the country with different climate characteristics, urban, mountainous, valley, seashore.
- The analytical method of choice is wavelet analysis which will allow us to identify patterns in changes of surface temperature and also to localize the different modes in time

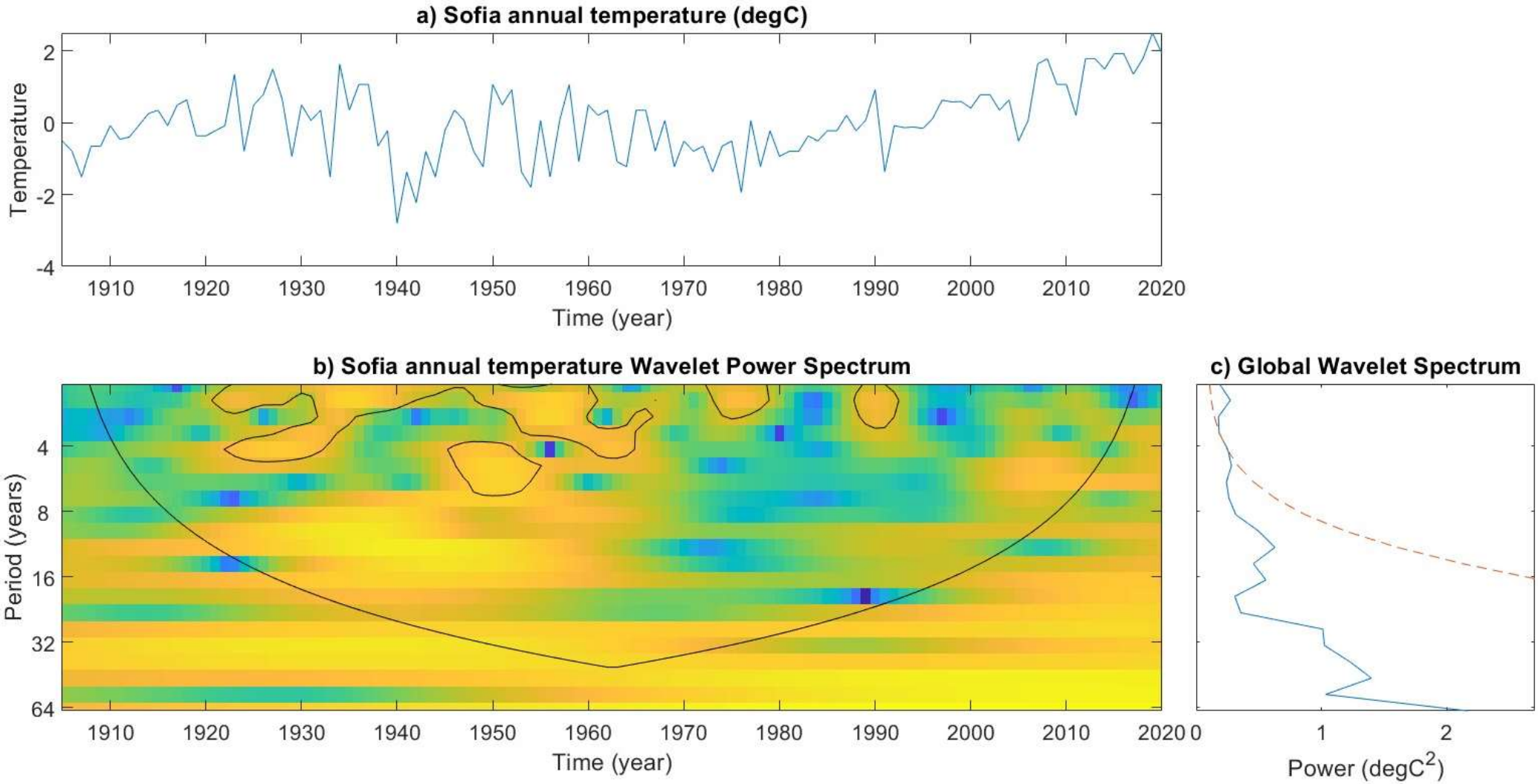


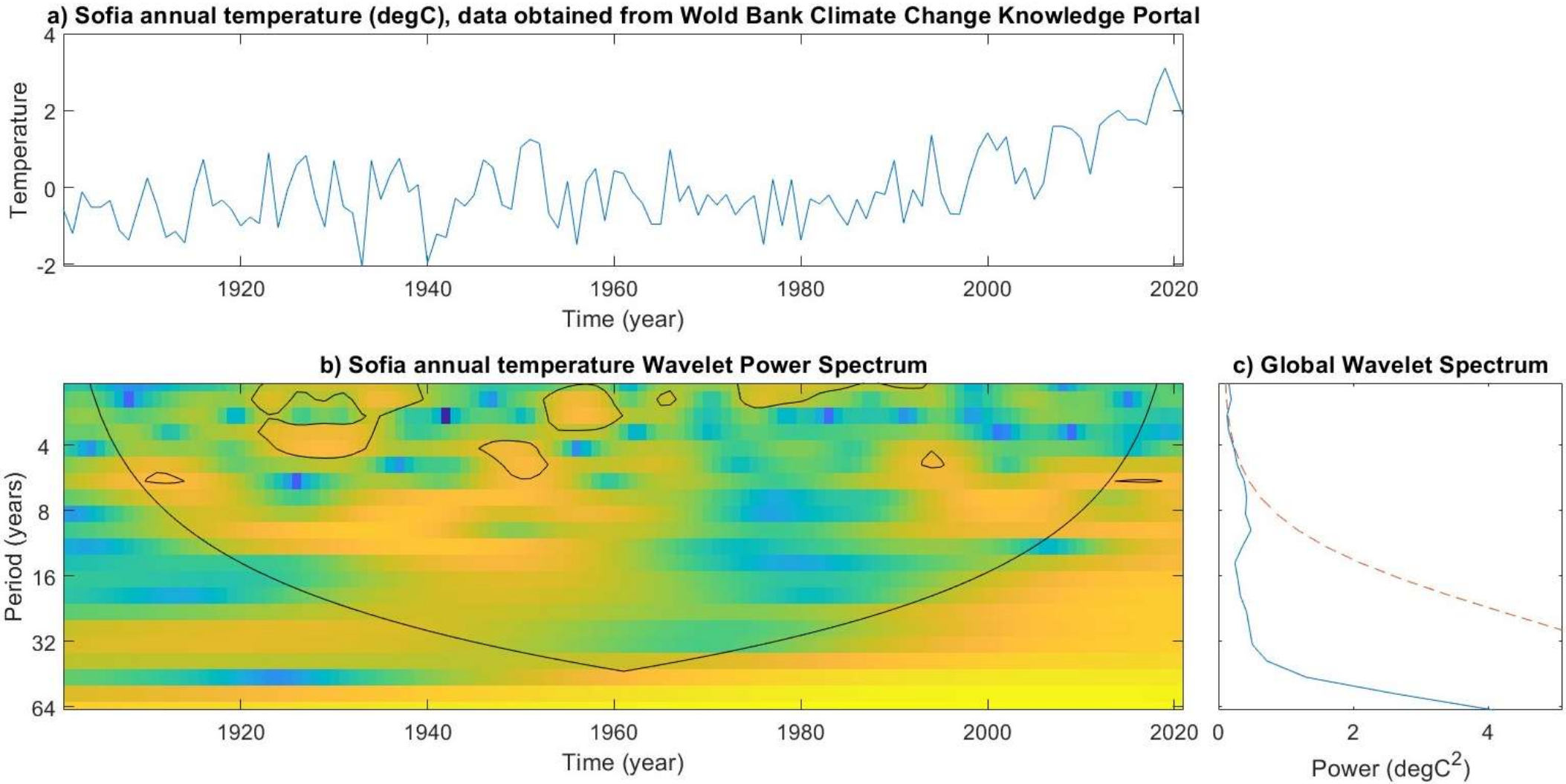

a) NINO3 Sea Surface Temperature (annual)
NINO3 SST (degC)
4
2
0
-2
1880
1900
1920
1940
1960
1980
2000
2020
Time (year)
b) NINO3 SST Wavelet Power Spectrum
Period (years)
4
8
16
32
64
1880
1900
1920
1940
1960
1980
2000
2020
Time (year)
c) Global Wavelet Spectrum
0
0.2
0.4
0.6
Power (degC^2)

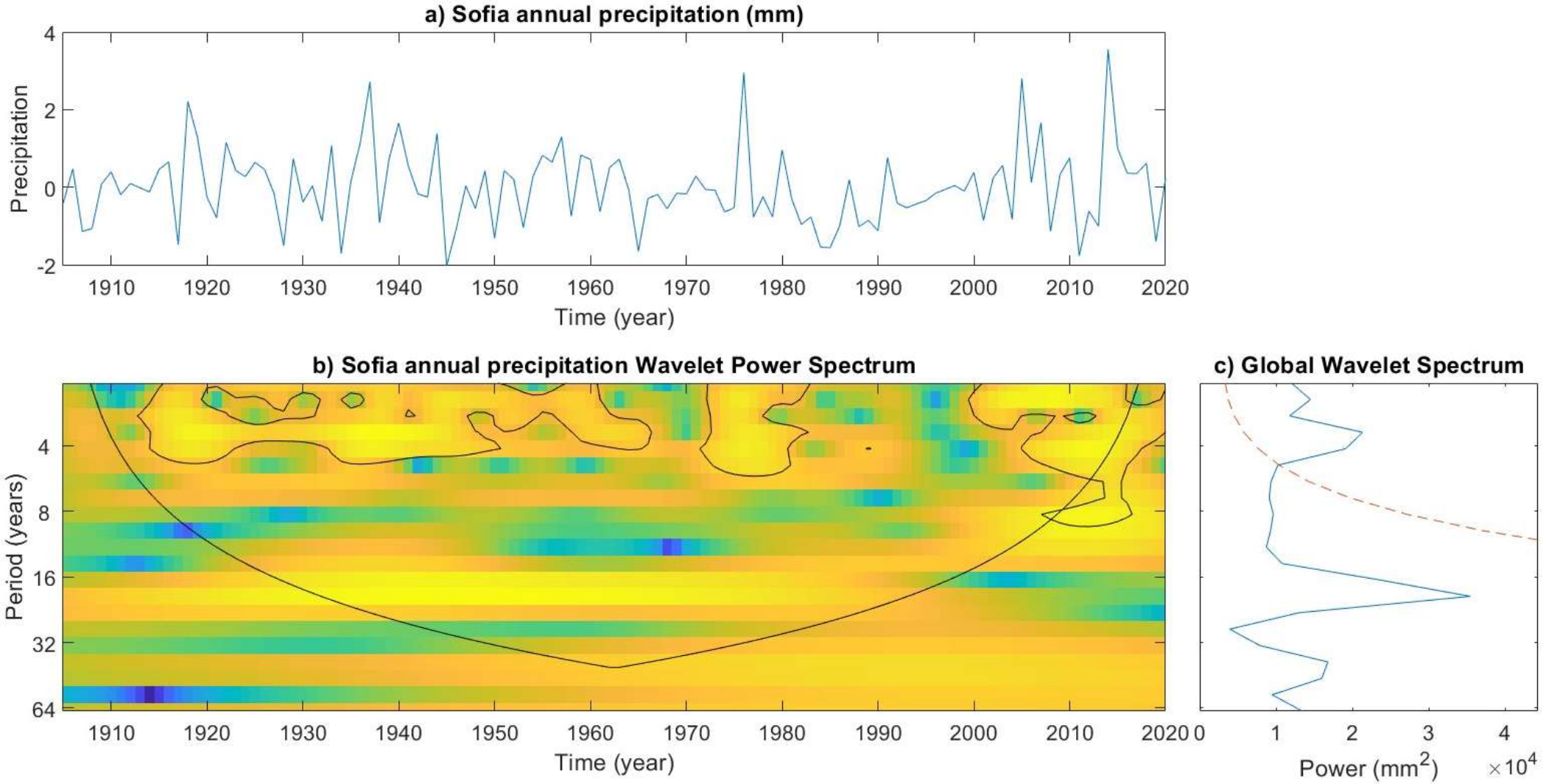

a) Irkutsk annual temperature (degC)
T anomalies, °C Irkutsk
4
2
0
-2
-4
1900
1920
1940
1960
1980
2000
Time (year)

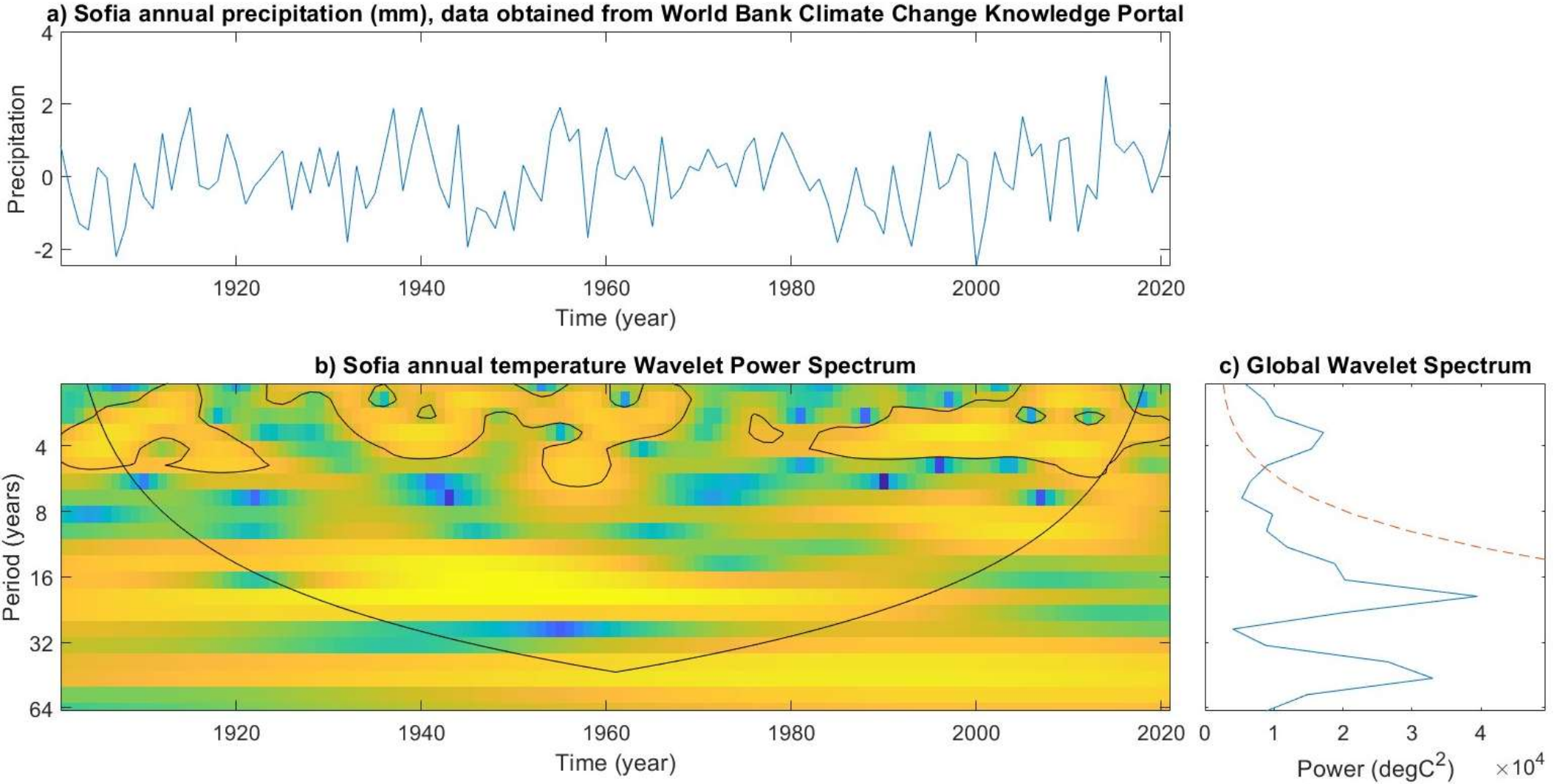

Wavelet Power Spectrum
Period, years
2
4
8
16
32
64
128
1900
1920
1940
1960
1980
2000
Time (year)
2.5
4.9
11.7
39.3
0
50
100
Power, (°C)²

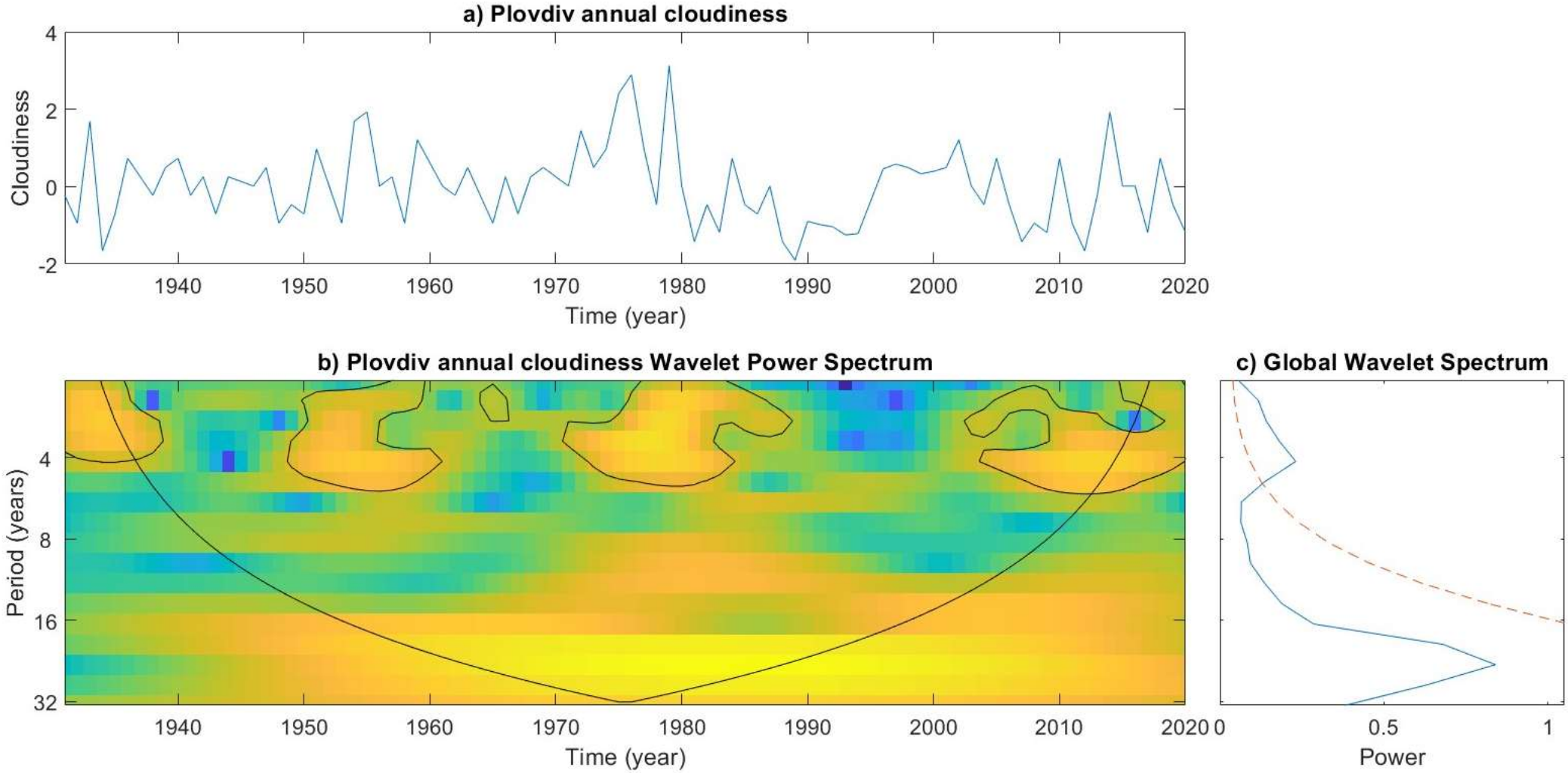

a) Sofia annual cloudiness
Cloudiness
2
1
0
-1
-2
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
Time (year)
b) Sofia annual cloudiness Wavelet Power Spectrum
Period (years)
4
8
16
32
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
Time (year)
c) Global Wavelet Spectrum
0
0.1
0.2
0.3
0.4
Power

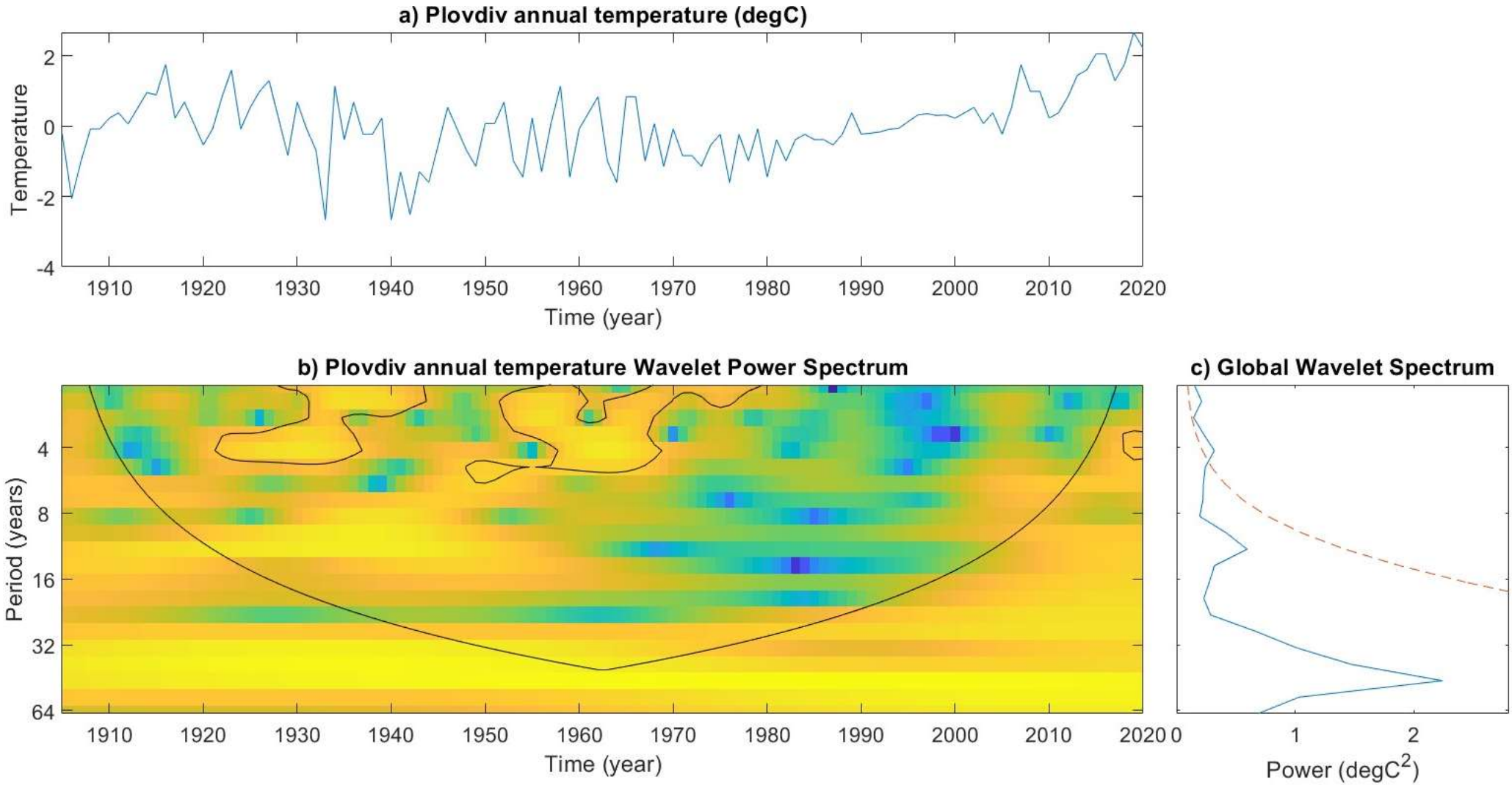

a) Sofia annual temperature (degC)
Temperature
2
0
-2
-4
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
Time (year)
b) Sofia annual temperature Wavelet Power Spectrum
Period (years)
4
8
16
32
64
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
Time (year)
c) Global Wavelet Spectrum
0
1
2
Power (degC^2)

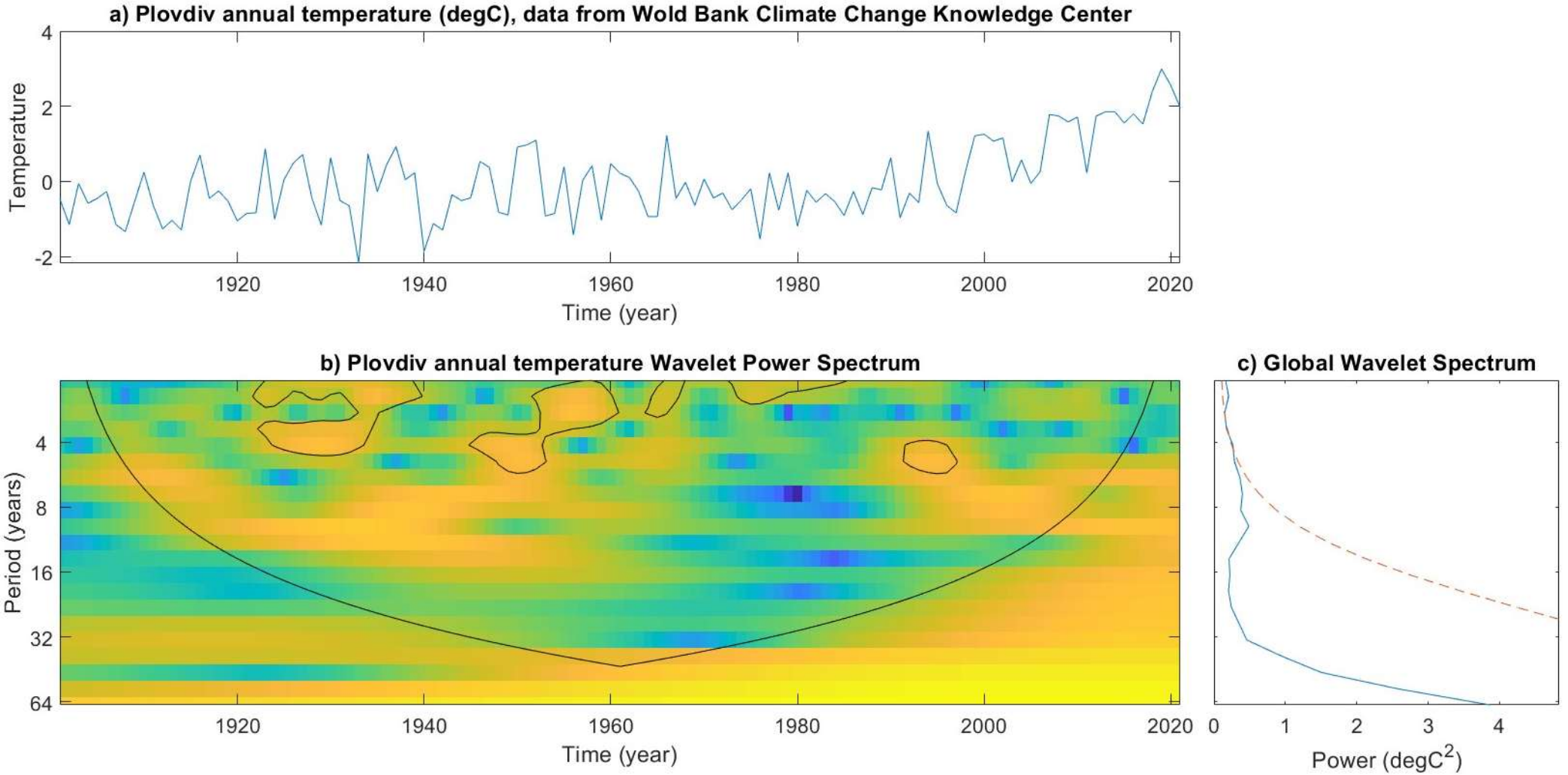

a) Sofia annual temperature (degC), data obtained from Wold Bank Climate Change Knowledge Portal
Temperature
4
2
0
-2
1920
1940
1960
1980
2000
2020
Time (year)
b) Sofia annual temperature Wavelet Power Spectrum
Period (years)
4
8
16
32
64
1920
1940
1960
1980
2000
2020
Time (year)
c) Global Wavelet Spectrum
0
2
4
Power (degC^2)

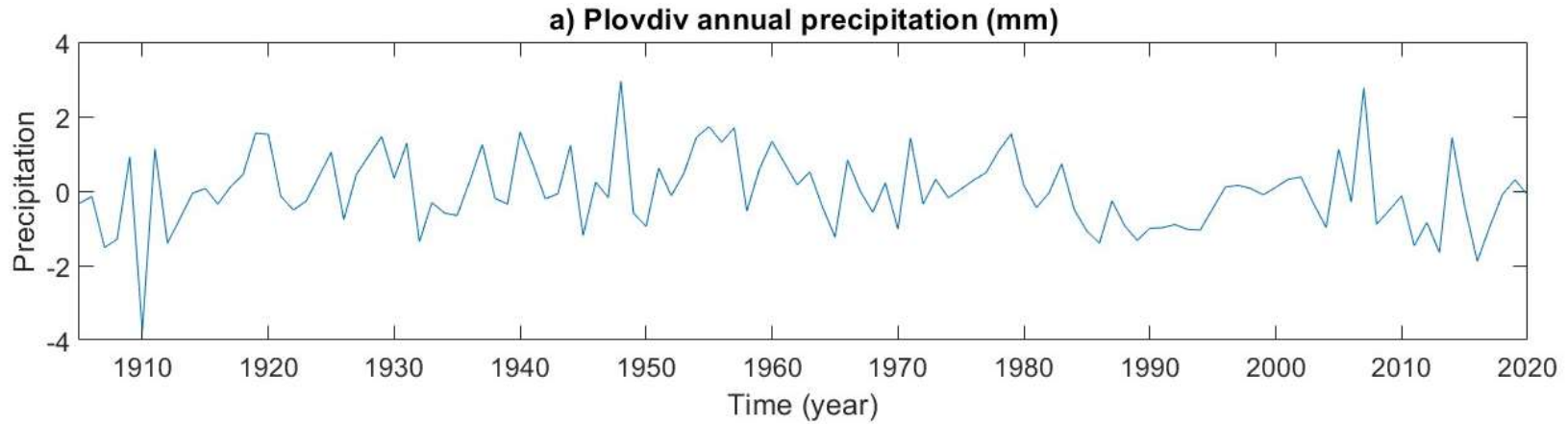

a) Sofia annual precipitation (mm)
Precipitation
4
2
0
-2
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
Time (year)
b) Sofia annual precipitation Wavelet Power Spectrum
Period (years)
4
8
16
32
64
Time (year)
c) Global Wavelet Spectrum
0
1
2
3
4
Power (mm^2)
$\times 10^4$

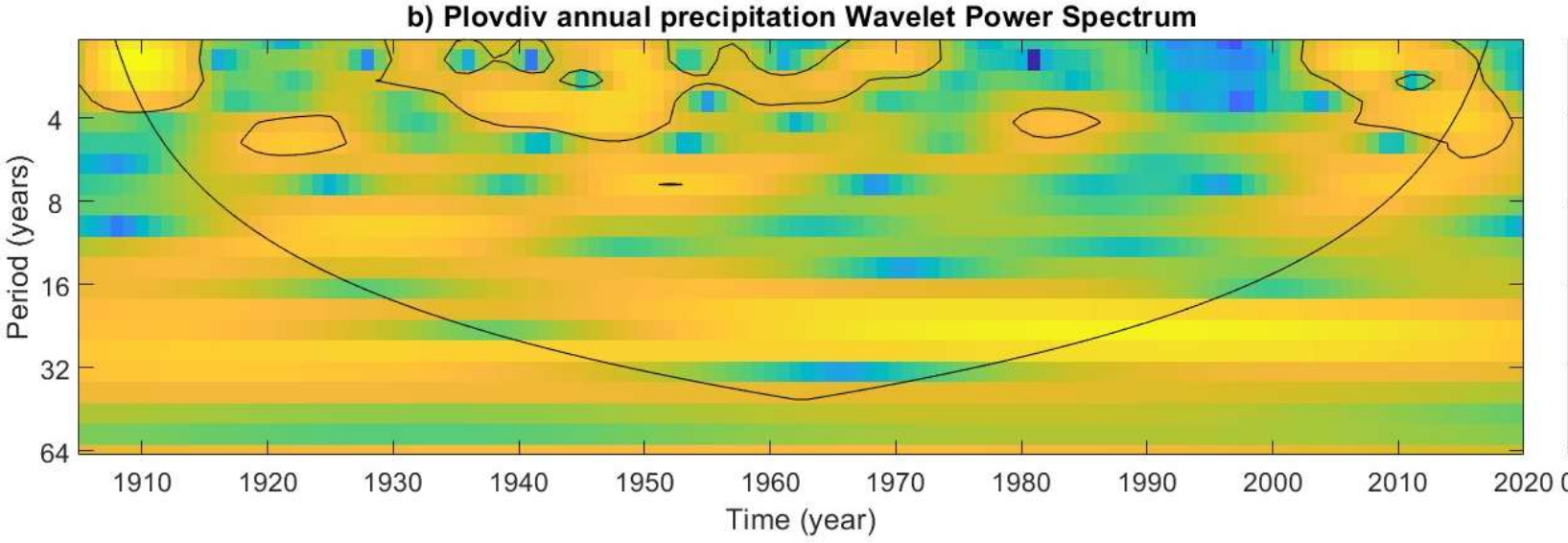

a) Sofia annual precipitation (mm), data obtained from World Bank Climate Change Knowledge Portal
Precipitation
4
2
0
-2
1920
1940
1960
1980
2000
2020
Time (year)
b) Sofia annual temperature Wavelet Power Spectrum
Period (years)
4
8
16
32
64
1920
1940
1960
1980
2000
2020
Time (year)
c) Global Wavelet Spectrum
0
1
2
3
4
Power (degC^2)
$\times 10^4$

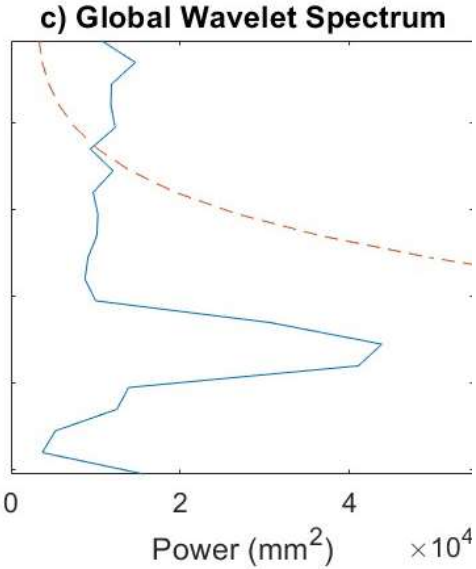

a) Plovdiv annual cloudiness
Cloudiness
4
2
0
-2
1940
1950
1960
1970
1980
1990
2000
2010
2020
Time (year)
b) Plovdiv annual cloudiness Wavelet Power Spectrum
Period (years)
4
8
16
32
1940
1950
1960
1970
1980
1990
2000
2010
2020
Time (year)
c) Global Wavelet Spectrum
0
0.5
1
Power

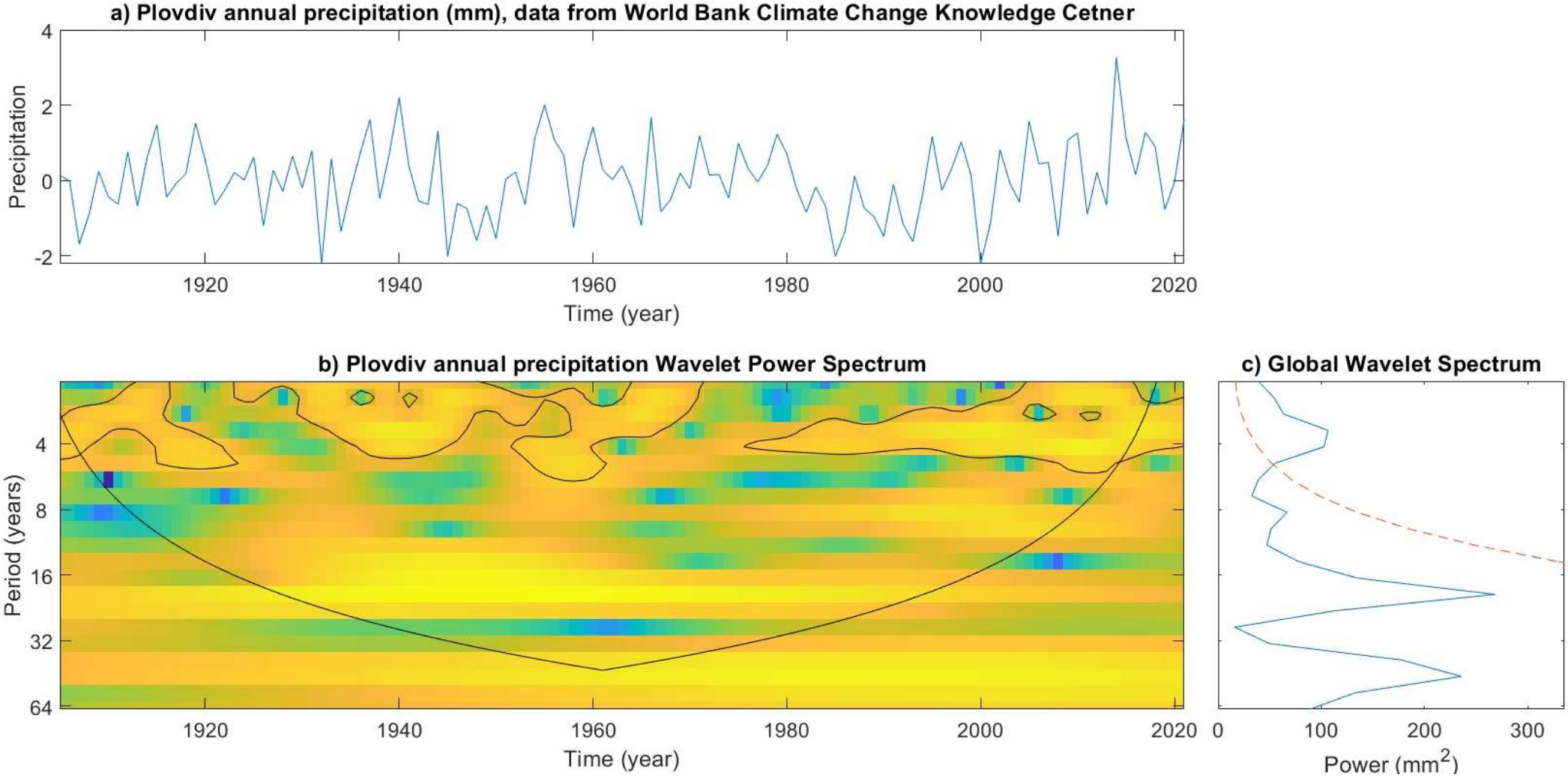

a) Plovdiv annual temperature (degC)
Temperature
2
0
-2
-4
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
Time (year)
b) Plovdiv annual temperature Wavelet Power Spectrum
Period (years)
4
8
16
32
64
Time (year)
c) Global Wavelet Spectrum
0
1
2
Power (degC^2)

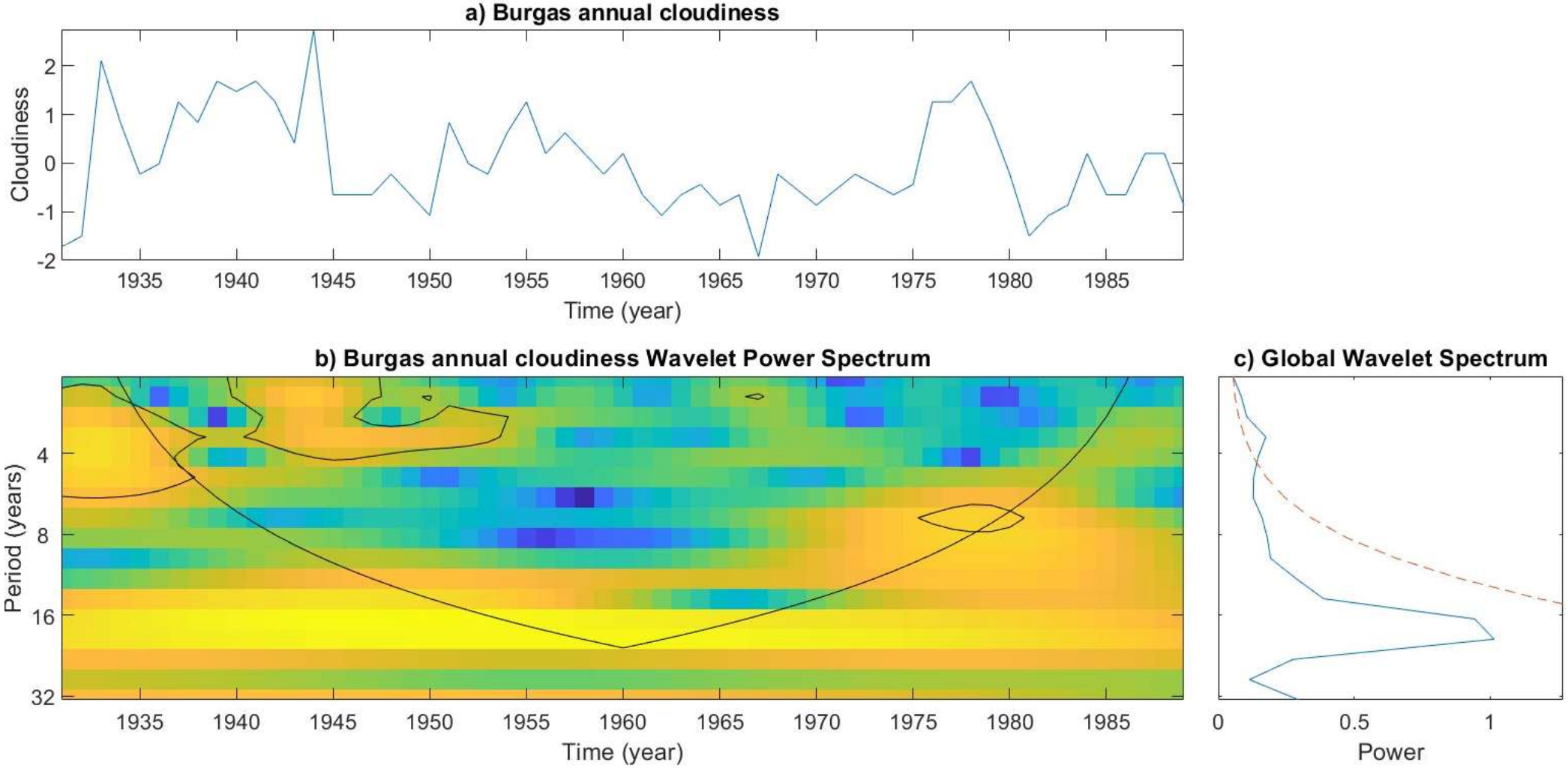

a) Plovdiv annual temperature (degC), data from Wold Bank Climate Change Knowledge Center
Temperature
4
2
0
-2
1920
1940
1960
1980
2000
2020
Time (year)
b) Plovdiv annual temperature Wavelet Power Spectrum
Period (years)
4
8
16
32
64
1920
1940
1960
1980
2000
2020
Time (year)
c) Global Wavelet Spectrum
0
1
2
3
4
Power (degC^2)

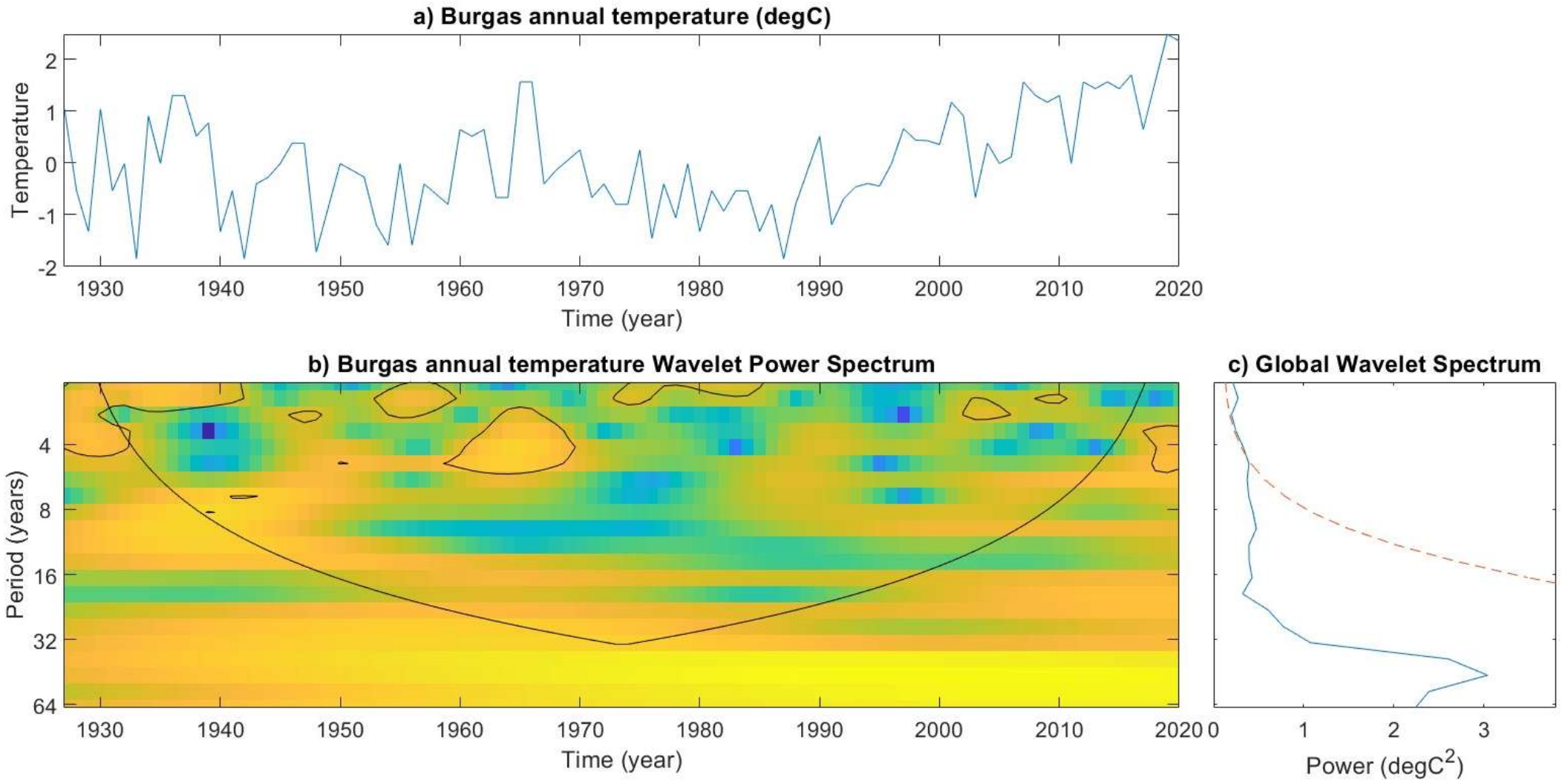

a) Plovdiv annual precipitation (mm)
Precipitation
4
2
0
-2
-4
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
Time (year)

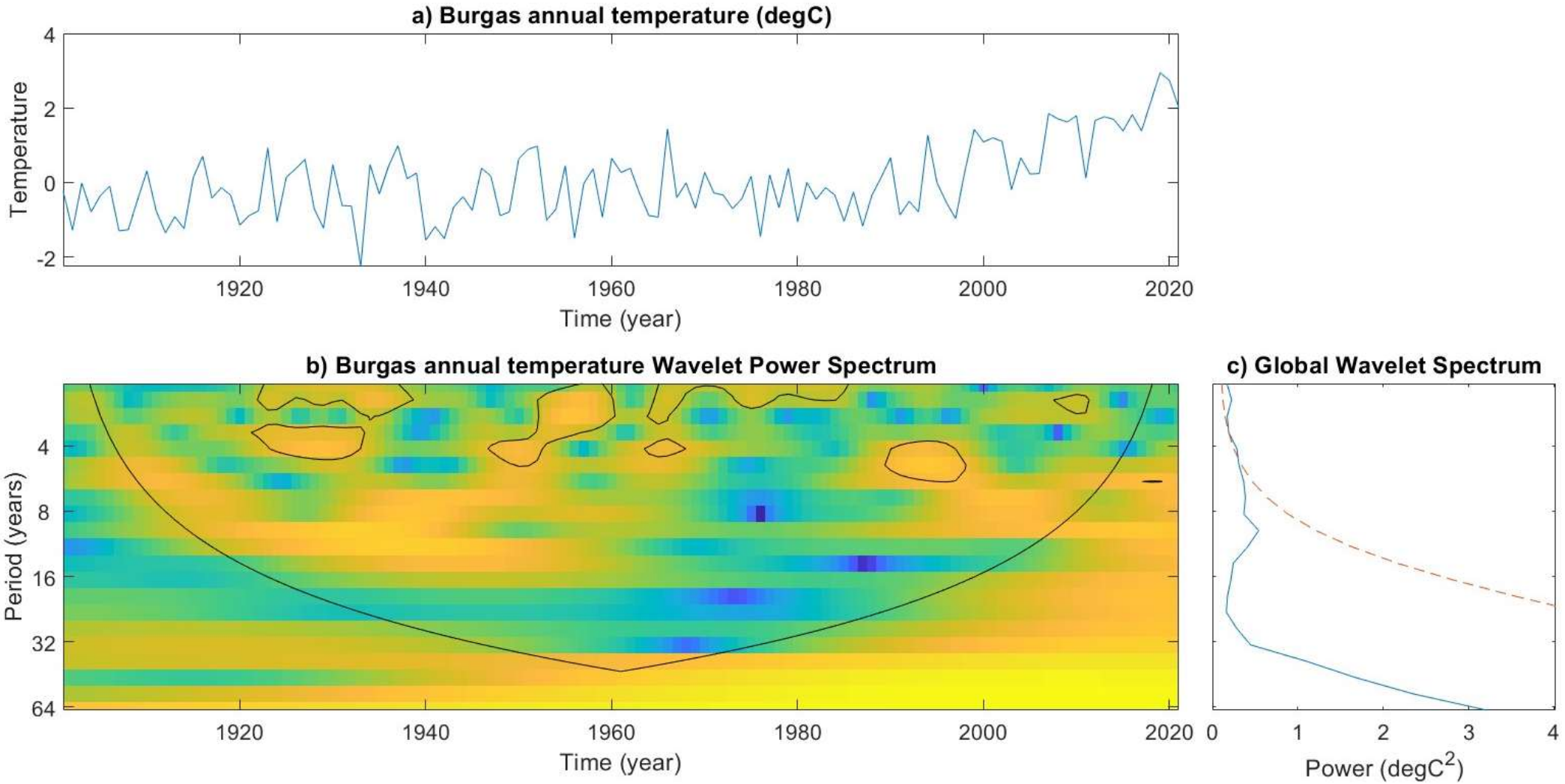

b) Plovdiv annual precipitation Wavelet Power Spectrum
Period (years)
4
8
16
32
64
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
Time (year)

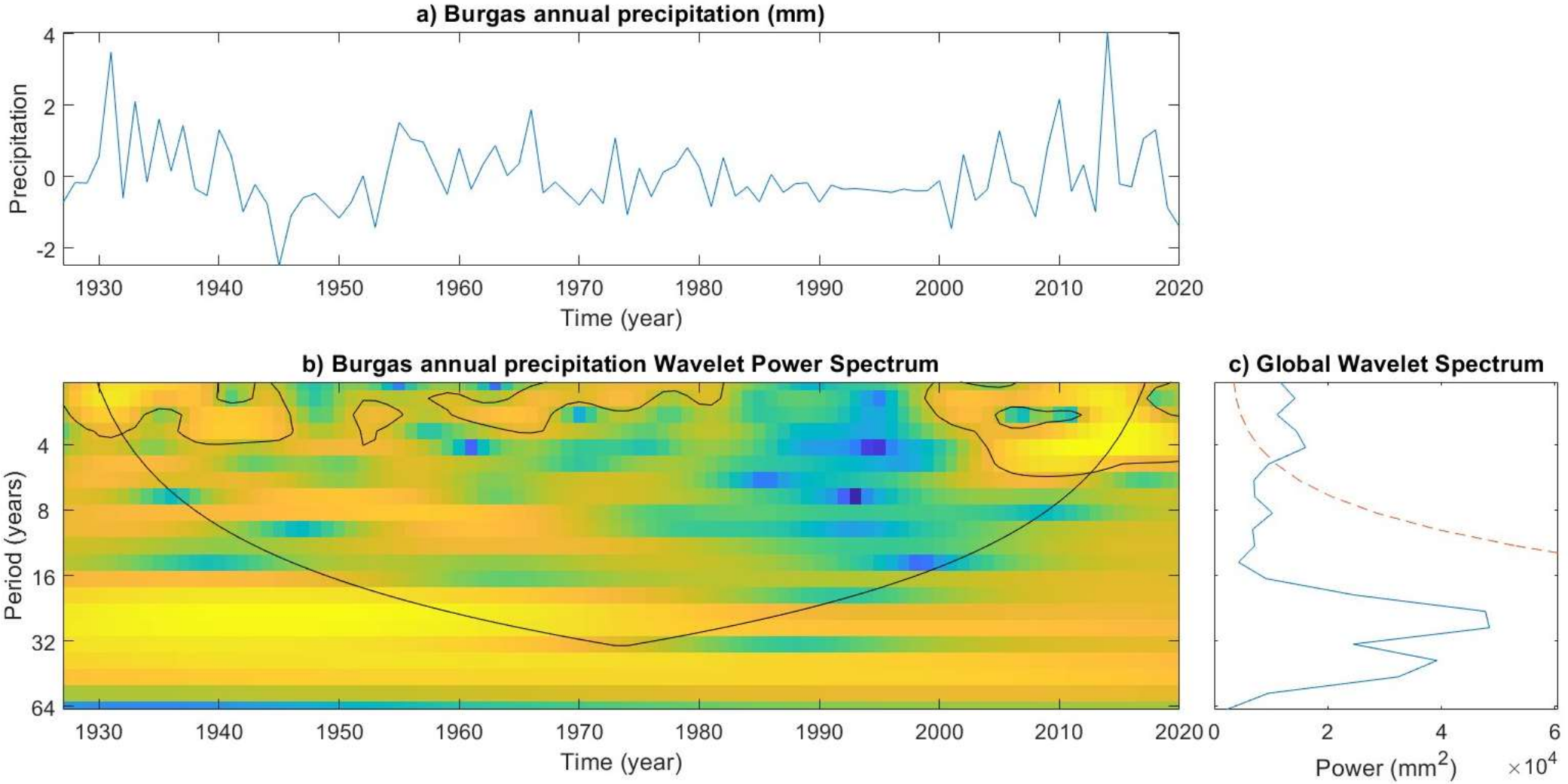

c) Global Wavelet Spectrum
0
2
4
Power (mm^2)
×10^4

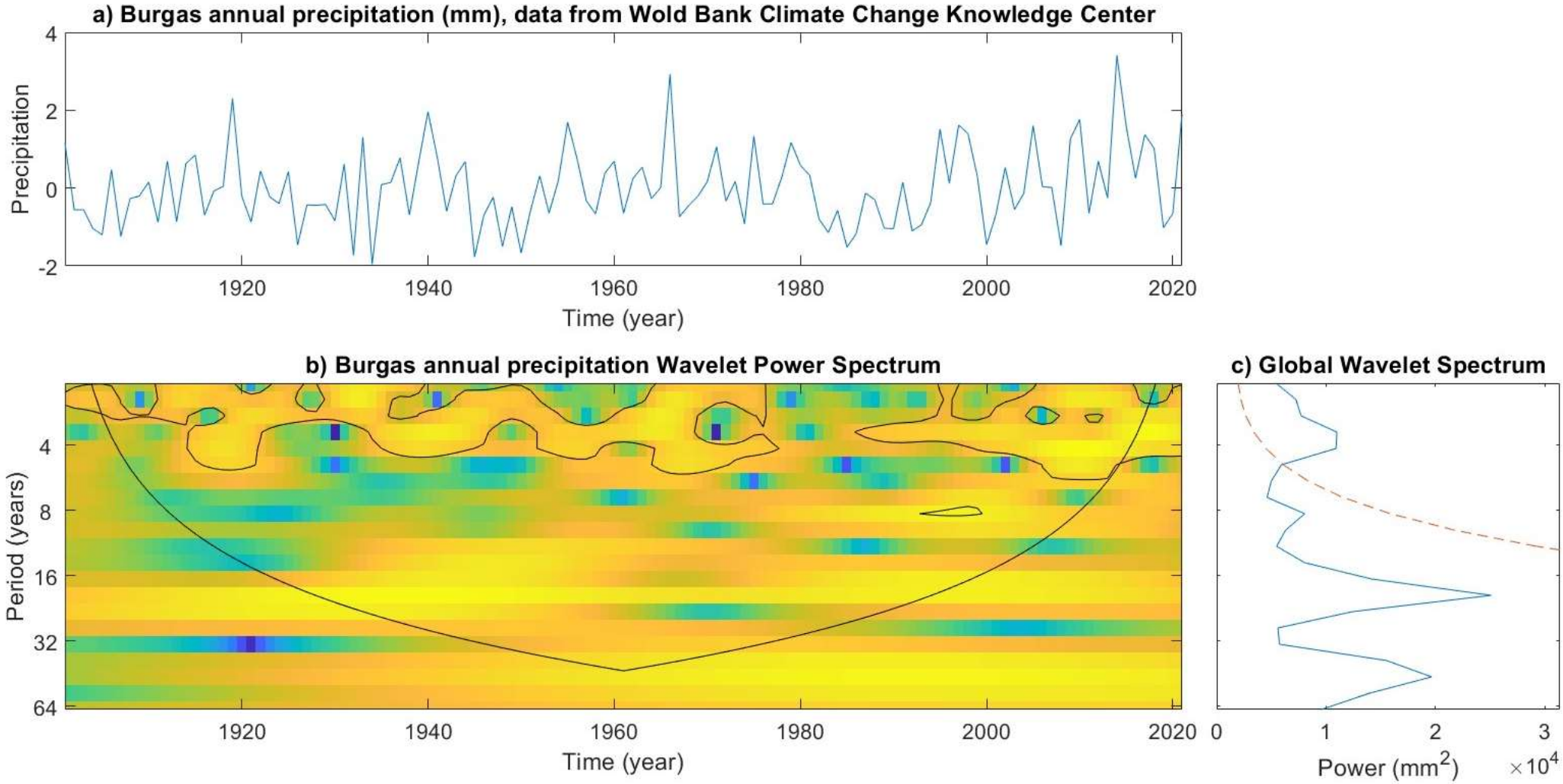

a) Plovdiv annual precipitation (mm), data from World Bank Climate Change Knowledge Cetner
Precipitation
4
2
0
-2
1920
1940
1960
1980
2000
2020
Time (year)
b) Plovdiv annual precipitation Wavelet Power Spectrum
Period (years)
4
8
16
32
64
1920
1940
1960
1980
2000
2020
Time (year)
c) Global Wavelet Spectrum
0
100
200
300
Power (mm2)


a) Burgas annual cloudiness
Cloudiness
2
1
0
-1
-2
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
Time (year)
b) Burgas annual cloudiness Wavelet Power Spectrum
Period (years)
4
8
16
32
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
Time (year)
c) Global Wavelet Spectrum
0
0.5
1
Power


a) Burgas annual temperature (degC)
Temperature
2
1
0
-1
-2
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
Time (year)
b) Burgas annual temperature Wavelet Power Spectrum
Period (years)
4
8
16
32
64
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
Time (year)
c) Global Wavelet Spectrum
0
1
2
3
Power (degC^2)


a) Burgas annual temperature (degC)
Temperature
4
2
0
-2
1920
1940
1960
1980
2000
2020
Time (year)
b) Burgas annual temperature Wavelet Power Spectrum
Period (years)
4
8
16
32
64
1920
1940
1960
1980
2000
2020
Time (year)
c) Global Wavelet Spectrum
0
1
2
3
4
Power (degC^2)


a) Burgas annual precipitation (mm)
Precipitation
4
2
0
-2
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
Time (year)
b) Burgas annual precipitation Wavelet Power Spectrum
Period (years)
4
8
16
32
64
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
Time (year)
c) Global Wavelet Spectrum
0
2
4
6
Power (mm^2)
$\times 10^4$


a) Burgas annual precipitation (mm), data from Wold Bank Climate Change Knowledge Center
Precipitation
4
2
0
-2
1920
1940
1960
1980
2000
2020
Time (year)
b) Burgas annual precipitation Wavelet Power Spectrum
Period (years)
4
8
16
32
64
1920
1940
1960
1980
2000
2020
Time (year)
c) Global Wavelet Spectrum
0
1
2
3
Power (mm^2)
$\times 10^4$

Thank you