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Intra-seasonal Vagaries of the Indian Summer Monsoon Rainfall

Ashwini Kulkarni, S S Sabade
and
R H Kripalani

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Indian Institute of Tropical Meteorology
Dr. Homi Bhabha Road, Pashan Pune - 411 008
Maharashtra, India

E-mail : lip@tropmet.res.in Fax : 91-020-25893825
Web : http://www.tropmet.res.in Telephone : 91-020-25893600

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Ashwini Kulkarni, S S Sabade and R H Kripalani
Indian Institute of Tropical Meteorology
Email : ashwini@tropmet.res.in

ABSTRACT

The summer monsoon rainfall for India as a whole (AIMR) shows a lot of year to year variability. 1961 (Std AIMR = 1020 mm) was the best monsoon while 1877 (Std AIMR = 604 mm) was the worst monsoon over India during the period 1871-2005. This rainfall variability is partly due to the external surface boundary forcing and partly due to its internal dynamics. The variability associated with internal dynamics is inherently unpredictable. The intra-seasonal variability (ISV) during the monsoon season constitutes this internal dynamics. The nature and magnitude of the intra-seasonal variability play a dominant role in deciding the seasonal monsoon strength.

The main aim of this report is to study the interannual variability of intraseasonal behaviour of all-India daily rainfall. This report presents the All India Daily Monsoon Rainfall (AIDR) patterns for 1 June to 30 September for the period of 105 years, 1901-2005. AIDR depicts two dominant periodicities, 30-60 days and 10-20 days, hence we also present band-pass filtered time series associated with these two frequency bands along with the daily rainfall anomalies and study their characteristics.

These temporal patterns reveal that years having similar All India Monsoon Rainfall (AIMR) need not have similar rainfall distribution over the season. However all the drought years are associated with extended breaks or more frequent short breaks.

We have tried to bring out the most recurring patterns of intra-seasonal variability by looking into the analogues. It is seen that 60% of the occasions the first analogue has correlation coefficient (CC) greater than 0.4, suggesting that the patterns do repeat.

1. INTRODUCTION

The behaviour of monsoon during the season has been a topic of curiosity since long time. The day-to-day behaviour of the monsoon plays important role in deciding the strength of seasonal monsoon. The rainfall distribution over India varies significantly from day to day. The intermittent behaviour of rainfall is associated with hierarchy of quasi-periods, viz. 3-7 days, 10-20 days and 30-60 days. While 3-7 days periodicity is associated with oscillations of the monsoon trough, the 10-20 days periodicity or quasi-biweekly oscillations are associated with the westward moving waves or synoptic scale convective systems generated over the warm Bay of Bengal, propagating inland and contributing substantial rainfall. The 30-60 days oscillations, popularly known as Madden-Julian Oscillations (MJOs, Madden and Julian, 1971) are the dominant component of the intra-seasonal variability (ISV) in the tropical atmosphere. It consists of large-scale coupled patterns in atmospheric circulation and deep convection, propagating eastward slowly (~5 m/s) through the Indian and Pacific oceans where the sea surface is warm. These two periods, 10-20 days and 30-60 days have been related with the active and break cycles of the monsoon rainfall over the Indian region. This MJO is intriguing since it influences the variability of rainfall over Pacific islands, in the monsoon regions of Asia (Lau and Chan, 1986 ; Sui and Lau, 1992 ; Lawrence and Webster, 2000 ; Gadgil, 2003) and many other regions of the world like Australia (Hendon and Libermann,1990), North America (Jones, 2000), South America (Libermann et al 2004) and Africa (Mathews,2004). The most exhaustive knowledge of ISV can be obtained in Wang B (2004, 2005), Lau and Waliser (2005), Zhang (2006) and Waliser (2006). It is important to note that MJO is dominant but not the only component of tropical ISV. Due to its importance in tropical circulation a lot of efforts have been put on prediction of ISV. Storch and Xu (1990) made first attempt to predict ISV, who examined Principal Oscillation Patterns (POPs) of equatorial 200 hPa velocity potential anomalies. They found that forecast based on first pair of POPs produced forecasts that had useful skill out to about 15 days. Years later Waliser et al (1999) developed empirical method to forecast ISV. This model was based on singular value decomposition and used previous and present pentads of filtered OLR to predict future pentads of OLR. Also Lo and Hendon (2000), Wheeler and Weickmann (2001) worked on this problem. Goswami and Xavier (2003) noted that break monsoon conditions are more predictable than active phases of monsoon. Webster and Hoyos (2004) have developed an empirical model for predicting ISV in Indian district rainfall. This model illustrates considerable skill over 20-25 days. Chen and Alpert (1990), Lau and Chang (1992), Hendon et al (2000), Jones et al (2000) used dynamical forecast models to predict ISV. Kripalani et al (2005) have showed how intrasesonal oscillations could be a major hindrance to seasonal predictability.

The strength of seasonal monsoon depend on the frequency and duration of spells of active and break periods associated with these intra-seasonal oscillations. Hence to understand the role of intra-seasonal oscillations in the monsoon strength, the characteristic features of these oscillations have been investigated by applying a band-pass filter to the AIDR series for 1 June to 30 September for each year, 1901-2005, The Interannual changes in ISV are important potential source of Interannual fluctuations of AIMR strength (Ferranti et al, 1997; Goswami, 1998; Krishnamurti and Shukla, 2002).

The arrangement of text is as follows. Section 2 explains the data used in this report. The characteristic features of AIDR are discussed in section 3 and intra-seasonal oscillations in AIDR are depicted in section 4. Finally sections 5 conclude the report.

2. DATA

Daily rainfall data for 365 stations spread over the country for 1 June to 30 September for the period 1901-1990 is obtained from India Meteorological Department, Pune. From these station data the averages for 52 blocks each of size 2.5 deg lat/long have been prepared (Kulkarni et al 1992). These 52 blocks are averaged for every day to get daily rainfall data for India. (Kripalani et al, 1991). The AIDR for the period 1991-2005 have been collected from Daily Weather Summary of India Meteorological Department (1991-2005).

Fig. 1 shows average pattern (bars) and the coefficient of variation (CV, continuous curve) of the AIDR for the summer monsoon period 1 June to 30 September. It is seen that the AIDR increases sharply from the end of June, attains maximum in the month of July till mid August and then gradually starts decreasing. The withdrawal of monsoon is rather gradual and systematic as compared to increase at the start of season. The maximum average AIDR is of the magnitude of 12 mm(mid July). The variability as a percentage of mean is maximum in June (70%), then it decreases , minimum in the end of July (32%), again starts increasing, attains maximum at the end of season, of the order of 65%. In the active months of monsoon, July and August, the variability is very less , less than 40%.

3. CHARACTERISTICS OF AIDR

AIMR shows a large year-to-year variability. The long time series of AIMR for the period 1871-2005 can be obtained from the website www.tropmet.res.in. This time series has a long-term mean of 852 mm and a CV of 10%When the standardized AIMR is greater (less) than 1 (-1) ,it is defined to be all-India flood (drought) and when it is between -1 and +1, it is a normal monsoon.

In this report we have made an attempt to study the characteristic features of daily rainfall within the season of all-India droughts and floods. We use various methods to study these features, like probability density functions (PDF), frequency and length of spells of dry and wet days, most recurring patterns of daily rainfall during the season etc.

3.1 PDF

Fig. 2 depicts PDFs of daily rainfall anomalies for all the years 1901-2005 (top panel), for droughts only (middle panel) and for floods only (bottom panel). The PDF of daily rainfall anomalies is almost Gaussian, symmetric around zero, with mean and mode at zero. The probability of negative anomalies (48%) is almost same as that of positive anomalies (52%). In the all-India droughts the distribution is negatively skewed as expected with 60% anomalies to the negative side and 40% to the positive. The mode of this distribution is at -2 i.e. there are more frequent days with less than normal rainfall. During all-India droughts the days with less than normal rainfall are 20% more than the days with more than normal. During all-India floods the distribution is bimodal, with modes at 0 and 2. This distribution is positively skewed. Probability of positive anomalies is 66%, double of that for negative anomalies 33%. Thus in all-India floods the days with more than normal rainfall are twice the days with less than normal rainfall. In all-India floods probability of getting more than 4 mm rainfall per day is almost double than that during drought years. i.e. heavy rainfall events are recurring in flood years .If we see the panels together it is well observed that second panel (droughts) is shifted to left, towards negative anomalies while bottom panel (floods) has preference to positive anomalies.

3.2 Dry and Wet spells

To study the characteristic features of daily rainfall in drought and flood years, we computed spell of dry and wet days in these years, A day is defined to be dry (wet) if the rainfall on that day is less (more) than mean-1 standard deviation (mean+1 standard deviation) of that day. We observe that during the drought year there is at least one spell of dry days of minimum 7 days. The spell length of dry days in drought years (total 22) varies from 7 days (1920, 1951, 1982) to 31 days (2002). The average spell length is of 10 days. The severe droughts like 1911, 1918, 1972, 1979 have two spells of dry days of 8 – 15 days while the worst drought of 2002 has a dry spell in the entire July. In all severe drought years more than 60% days the rainfall is below normal. Almost all these spells occur in July and first half of August. Drought years do not have any spell of wet days of length more than 5 days. Maximum length of spells of wet days in flood years is 5 – 10 days. Out of 15 flood years, 10 years have maximum spell length in September. Thus rainfall in September does play an important role in making up the seasonal rainfall. The average spell length is of 7 days. The spell lengths in flood years do not show any conspicuous features.

3.3 Most recurring patterns

By the late 1980s, many characteristics of the ISV of Indian monsoon were fairly well documented and it was clear that the dominant modes of ISV exhibit a number of reproducible features from one event to another and in events between the years. The most recurring pattern of AIDR are obtained using pattern correlation. We set the level of correlation to be 0.4 to get a dominant pattern. When all 105 (1901-2005) patterns are correlated we get three most recurring representative patterns of AIDR. Fig 3 depicts these patterns. Top panel shows the most recurring pattern which corresponds to 1908 which is a normal monsoon year for India with standardized AIMR +0.58. The pattern is dominated by positive daily anomalies of large magnitude in July and August. Thus the active phase of rainfall in July and August is the most common feature of AIMR. The second (middle panel) correspond to 1930 (Std AIMR = -0.53). There are two dominant spells of negative anomalies in first half of July and middle of August. But the positive anomalies at the end of June and middle of September make up the total seasonal rainfall to be normal. Since there are large breaks in July and August the seasonal rainfall is normal but to the negative side. Third most dominant pattern corresponds to 1909 (Std AIMR = +0.49). There is only one extended spell of large negative anomalies in August but June, July and September have a number of days with more than normal rainfall and hence AIMR is much to the positive side of normal. It is interesting to see that though AIMR is normal its daily distribution varies significantly. The dominant patterns during droughts are depicted in Fig. 4 (a and b).The level of correlation coefficient is taken to be 0.4 to bring out the most recurring patterns. We get 2 significant patterns. The first corresponds to 1968 (Std AIMR = -1.14) and the second one corresponds to 1966 (Std AIMR = -1.32). In the first dominant pattern (Fig, 4 a) the negative anomalies are seen in the beginning of the season and in August end continued up to middle of September. Though more positive anomalies are seen here during the season, the magnitude of negative anomalies is more and the extended spell of negative anomalies is of about 25 days. The second dominant pattern (Fig 4 b) shows two spells of negative anomalies, one in mid July, the other at the end of the season. Interestingly though the AIMR is deficient in both these years, the behaviour during the season is almost opposite. It is important to note that the most dominant pattern of all-India drought is not the severe drought over the country (Std AIMR is not less than -2).

Bottom two panels of Fig. 4 (c and d) correspond to most recurring patterns during floods, 1942 (Std AIMR = 1.32) and 1916 (Std AIMR = 1.24). In both these patterns a large number of anomalies are positive and of greater magnitude. There are some very short spells of negative anomalies of very small magnitude resulting in overall flood over India. In the first pattern (Fig. 4 c) the rainfall activity is good in July – August while in second pattern (Fig. 4 d) June and September are active. These two patterns again do not have any similarity between them though AIMR is almost same. It is interesting to note that in (a) and (b) there are no long spells of above normal rainfall and in (c) and (d) there are no long spells of below normal rainfall days. Also in (a) and (b) days with positive (negative) anomalies do occur but with less (more) magnitude as compared to (c) and (d).

4. INTRA-SEASONAL OSCILLATIONS (ISO)

Beginning around the mid to late 1970s, a number of studies began to identify intra-seasonal fluctuations with periods around 30-60 days, associated with the Asian summer monsoon. These were well observed in both cloudiness (Murakami, 1976; Yasunari, 1979, 1980) and wind variability (Dakshinamurti and Keshavmurty, 1976, Murakami, 1977). The canonical space-time structures of a typical boreal summer ISO event have been well represented by Chen and Murakami(1988), Goswami et al (1998), Annamalai et al (1999), Annamalai and Slingo (2001), Lawrence and Webster (2002), Kemball-Cook and Wang (2001), Hsu et al (2004).

In addition to the prevalence of ISV with a nominal time scale of 30-60 days, there is also considerable ISV at higher frequencies, at time scales around 10-20 days. Detection of these higher frequency fluctuations came from early studies on cloudiness and conventional synoptic observations (Krishnamurti and Bhalme, 1976; Murakami, 1976; Yasunari 1979; Krishnamurti and Ardanuy, 1980). 10-20 day mode accounted for about ¼ of the subseasonal monsoon variability while 30-60 day accounted for about 2/3 (Annamalai and Slingo, 2001). In contrast to the low frequency ISO, variability of this mode is focused almost entirely over East Asia and the Northwest Pacific region. Also 30-60 days mode originate in equatorial Indian Ocean and propagate northward/northeastward (Kripalani et al, 1999 ; Singh and Kripalani, 1985, 1986, 1990 ; Kripalani et al, 1991) but 10-20 days mode originates in the equatorial western Pacific and propagates westward/northwestward in the form of Rossby waves at about 5m/s. Another noteworthy feature of 10-20 days mode is that it has a relatively strong seasonal variation, in particular during early summer monsoon perid (May-July). There is considerable 30-60 day variability exhibited at and near the equator and in particular in the Indian sector, as compared to that of 10-20 days

We applied Butterworth's band pass filter (Murakami, 1979) for 30-60 and 10-20 days bands to AIDR anomalies of the years 1901-2005. The daily rainfall anomalies for each of these years (bars) the filtered anomalies for 30-60 days (red curve) and 10-20 days band (blue curve) are presented in Fig. 5. The variance retained in every band is computed for each year. The main results of this analysis are: the fast moving 3-7 and 10-20 days modes are enhanced in very good monsoon or flood years while 30-60 days mode is enhanced in drought years in more than 90% of the cases. The active monsoon spells are strengthened when the positive phases of both the oscillations occur simultaneously i.e. when they are in phase while when monsoon activity is suppressed when they are out of phase. In more than 70% of the flood years the variance retained in 10-20 or 3-7 days mode is significantly more than that retained in 30-60 days mode (Kripalani et al, 2004). While in 40% of the droughts the 30-60 days mode is dominant. The significance has been tested by applying F test. Also it is clearly seen that in drought years 30-60 days oscillations are more organized.

5 CONCLUSIONS

The intra-seasonal variability makes up an extremely important part of the character and evolution of Indian summer monsoon . Its most pronounced influence is associated with its direct connection to active and break phases of monsoon, the other effect includes its modulation of high frequency variability and the role it may play in determining interannual variability.

Intraseasonal characteristics of AIDR have been studied in this report. The significant results are:

(1) The PDF of daily rainfall is highly negatively (positively) skewed in all-India droughts (floods)

(2) The drought years are dominated by one or more spells of dry days of length more than 7 days particularly in July – August, while flood years are characterized by wet spells of minimum 5 days. The making up of the seasonal rainfall is largely done in the end of the season i.e. September.

(3) The most recurring patterns are drastically different and hence have no implications for forecasting.

(4) The faster moving oscillations 3-7 days or 10-20 days are dominant in good monsoons over India.

As the monsoon season progresses the core region of 30-60 day variability moves northeastward with strong 10-20 day variability developing in the East Asian and Northwestern tropical Pacific ocean. The high variability of 10-20 days and 30-60 days co-occur in this region during the later half of monsoon. Hence this period and the monsoon region are challenging to diagnose, understand and model. Moreover the role of 10-20 days mode in modulating monsoon, either separate or in conjunction with 30-60 day mode is still an outstanding problem.

There are still large gaps in our knowledge about how these two oscillations interact, how El Nino Southern Oscillation and other low frequency variations can modulate intra-seasonal variations and the extent intra-seasonal oscillations contribute to interannual variability of monsoon. It is difficult to say whether good monsoon force the faster oscillations or whether changes in intra-seasonal variabilities force changes in monsoon strength. More over since these oscillations play significant role in seasonal monsoon strength, if some statistical/ dynamical or combined scheme could foreshadow the behaviour of these oscillations, it will go a long way in serving as a guiding tool for extended range forecasting.

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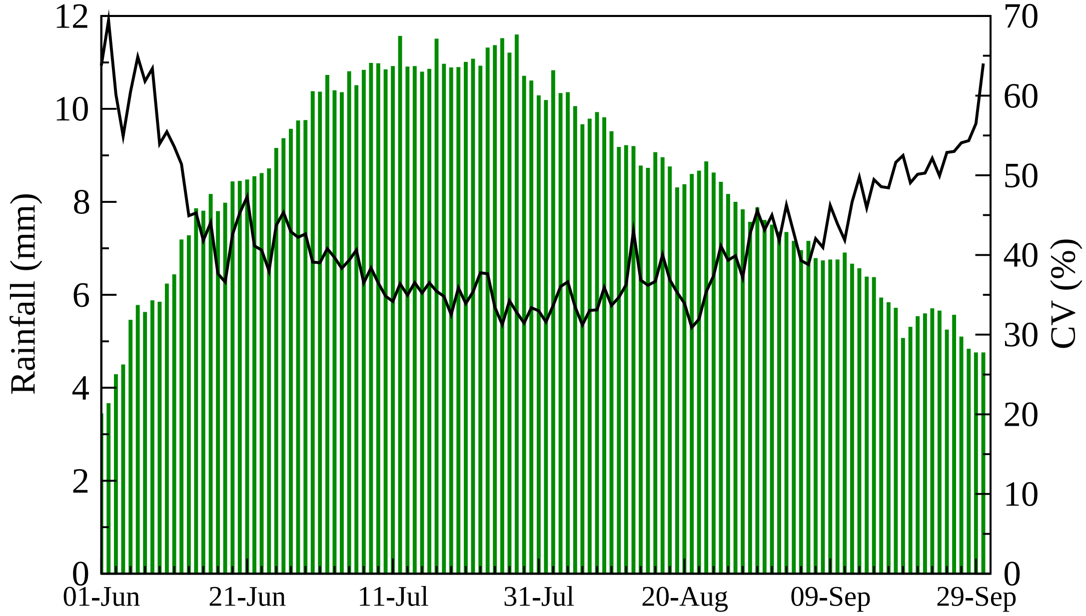


Fig. 1

Fig. 1 : Mean in mms (bars) and Coefficient of Variation in % (curve) of all-India daily rainfall for 1June to 30 September based on 105 years, 1901-2005

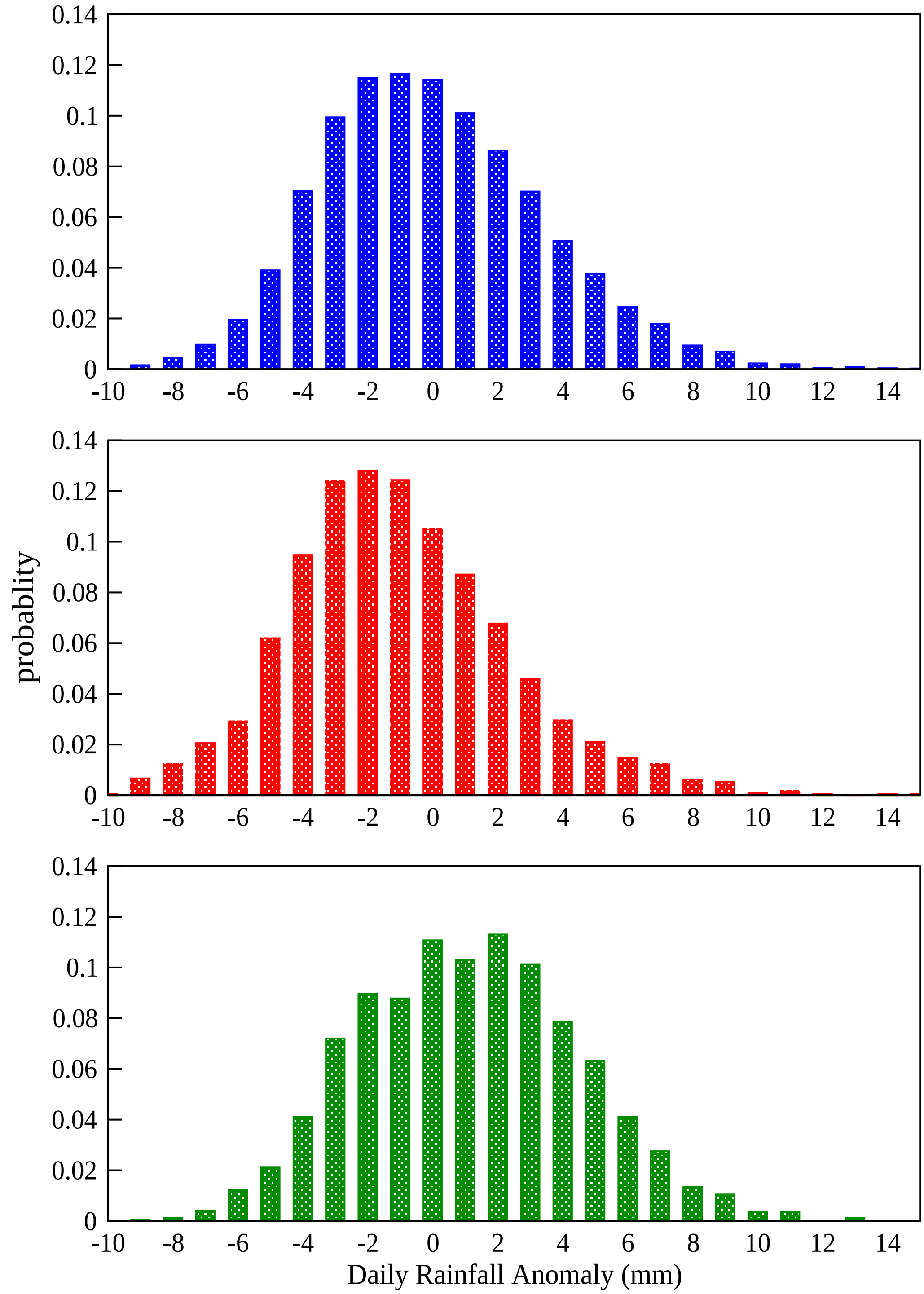


Fig. 2

1901-2005 (top panel), all-India droughts (middle panel) and all-India floods (bottom panel)

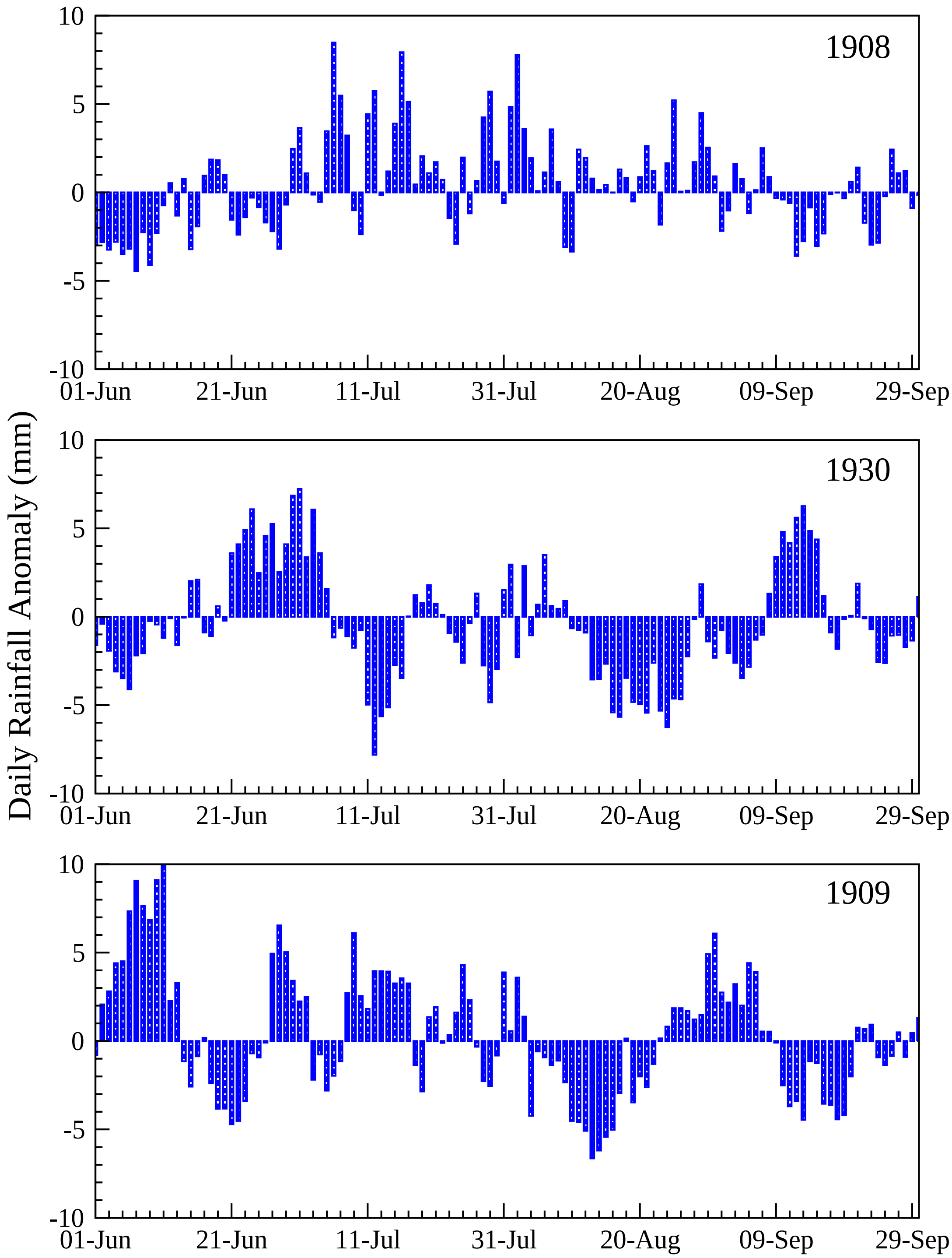

Daily Rainfall Anomaly (mm)
1908
1930
1909
10
5
0
-5
-10
01-Jun
21-Jun
11-Jul
31-Jul
20-Aug
09-Sep
29-Sep

Fig. 3

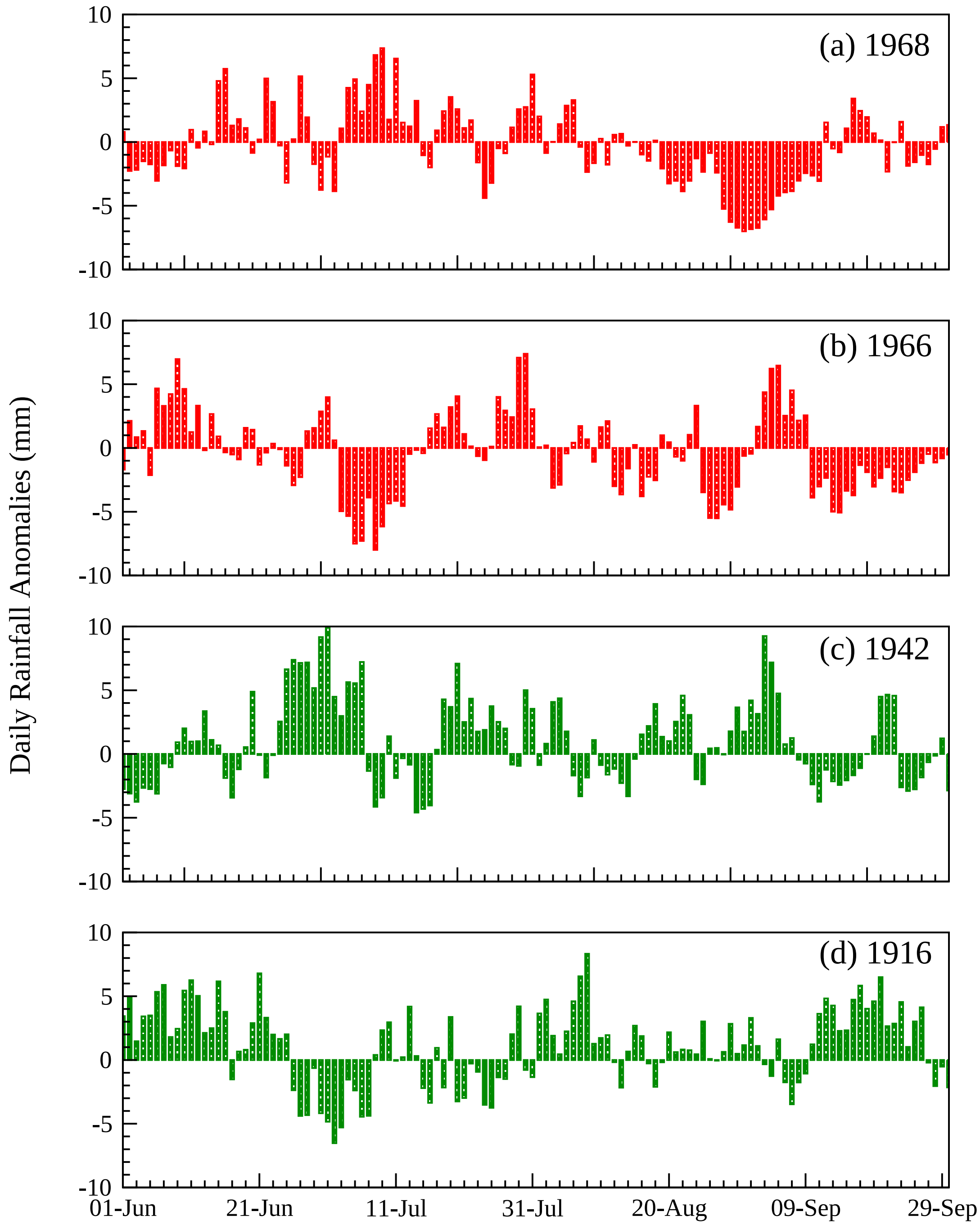


Fig. 4

Fig.4 : Same as Fig.3 but for all-India droughts (a) and (b) and for all-India floods (c) and (d)

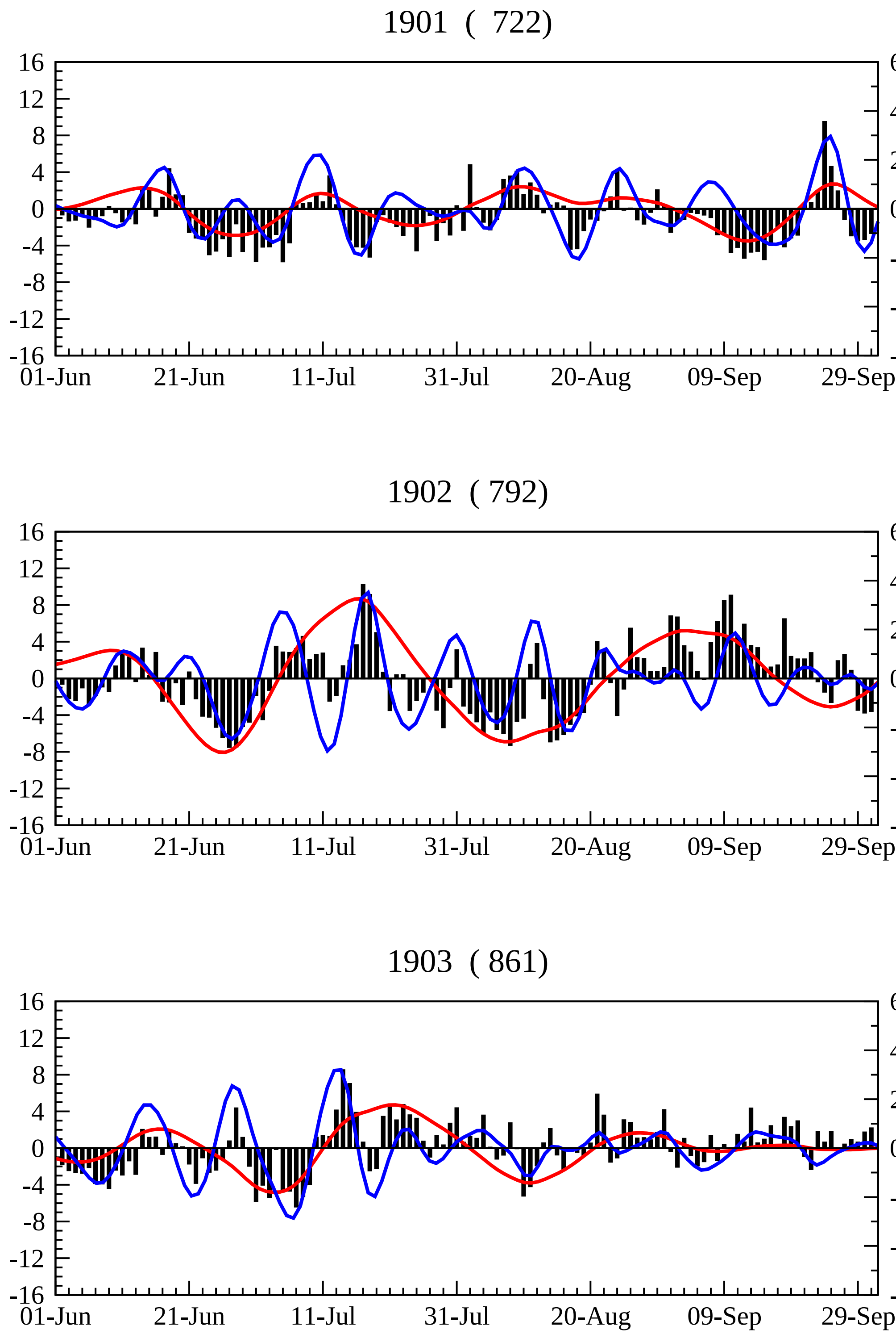
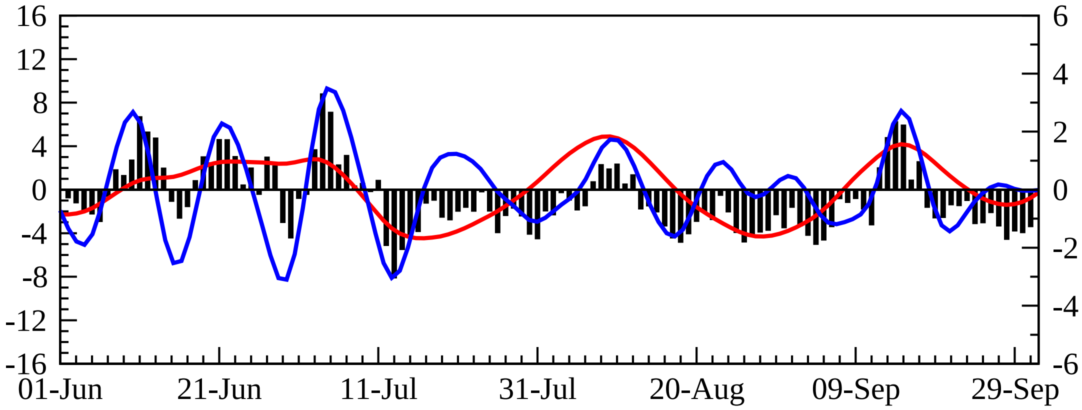


Fig. 5

Fig. 5 : All-India daily rainfall anomalies (bars), 30-60 days (red curve) and 10-20 days (blue curve) filtered anomalies for 1 June to 30 September for the period 1901-2005. The scale for daily rainfall anomalies is left Y axis while that of daily filtered anomalies is right Y axis. Figures in the bracket indicate AIMR for corresponding year

1904 (750)



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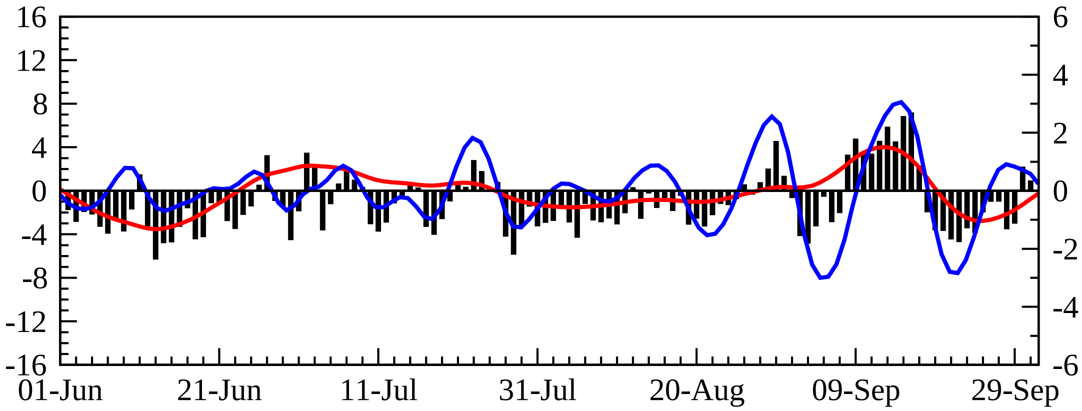


1906 (885)

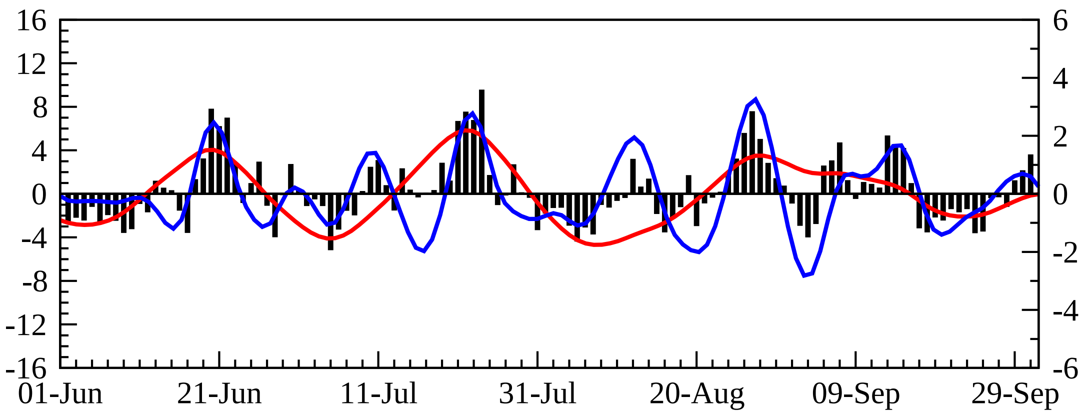
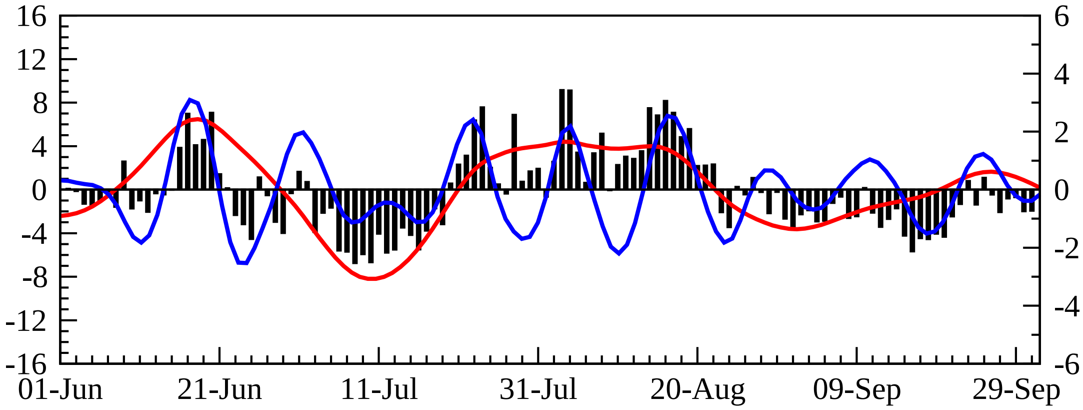
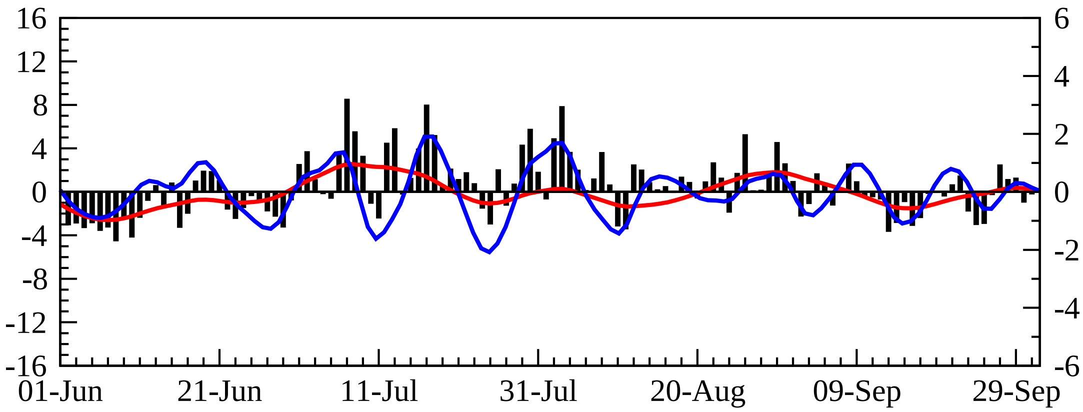


Fig. 5 contd.

1907 (778)



1908 (897)



1909 (889)

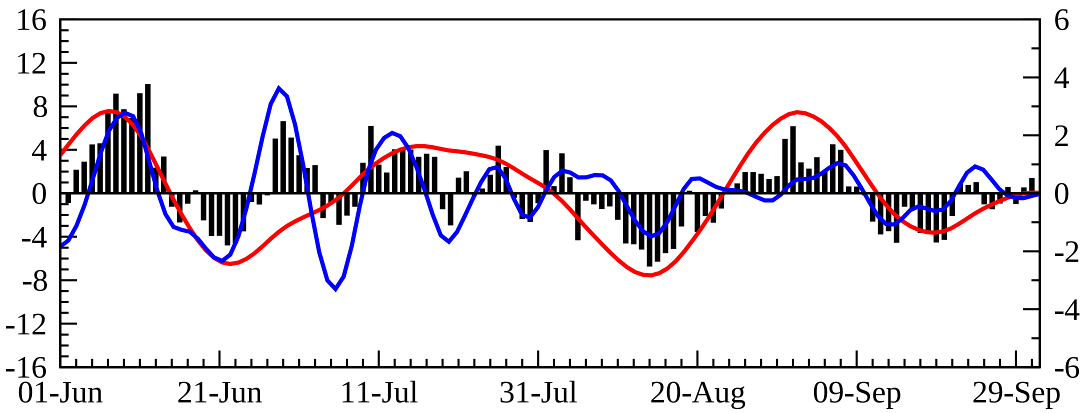
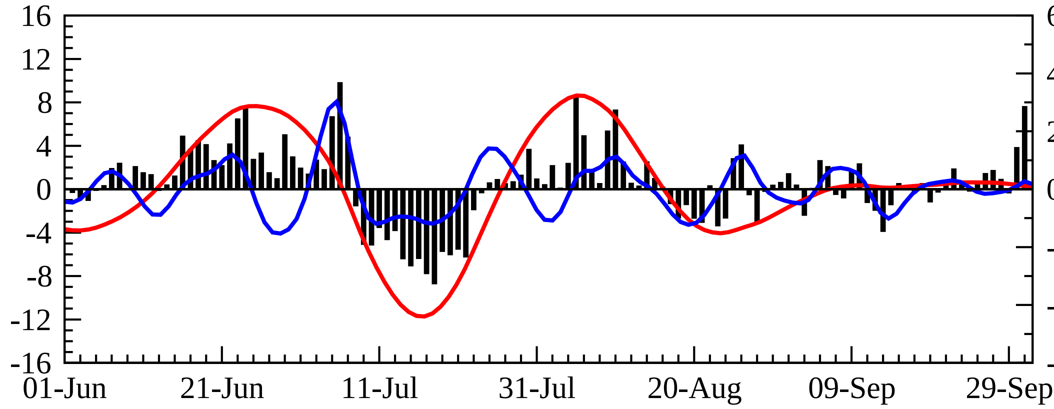
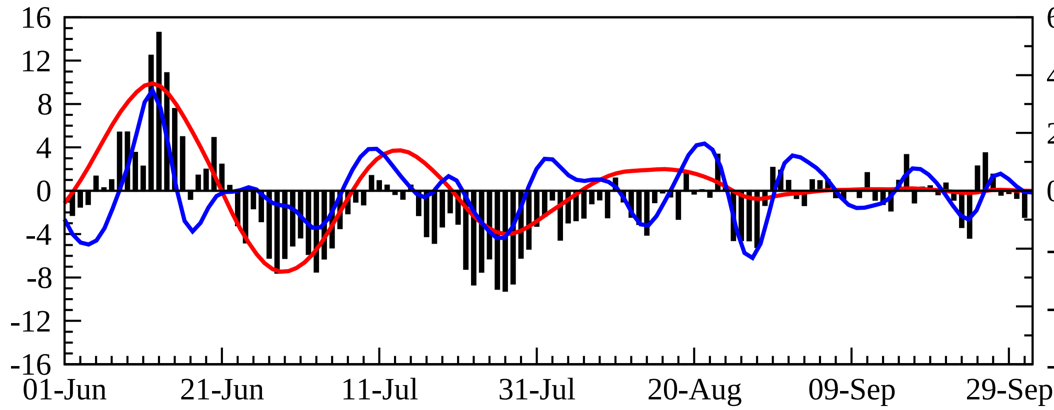


Fig. 5 contd.

1910 (935)



1911 (737)



1912 (806)

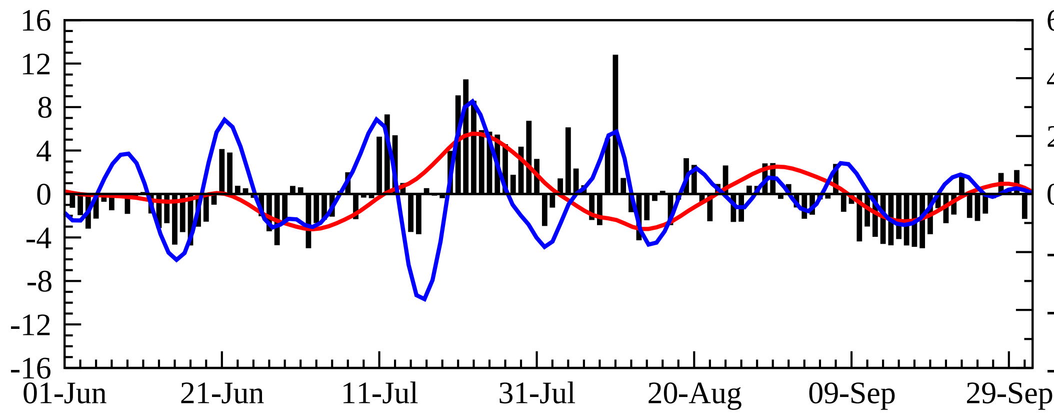
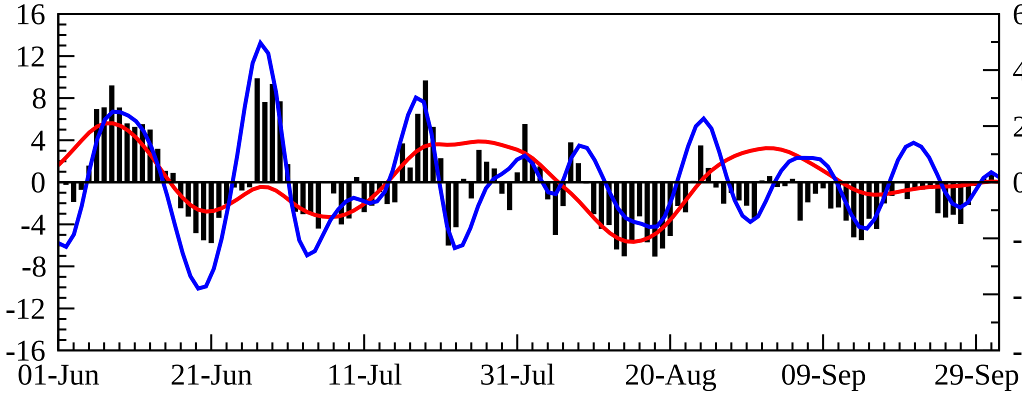
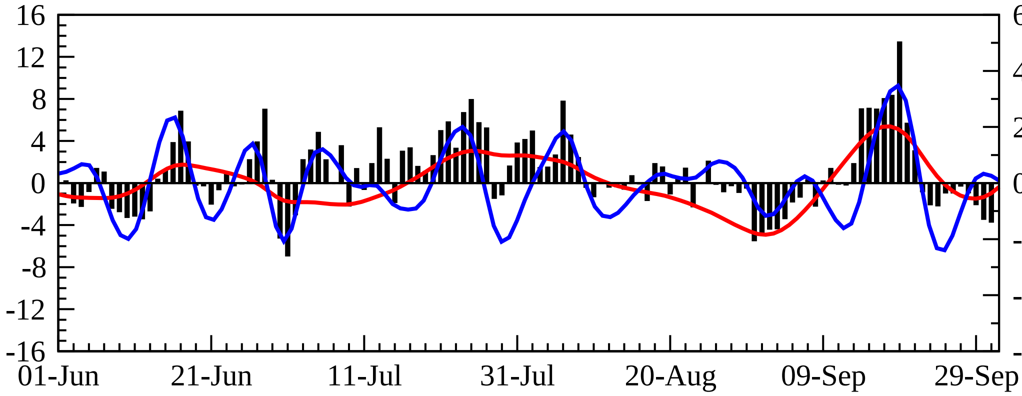


Fig. 5 contd.

1913 (785)



1914 (898)



1915 (781)

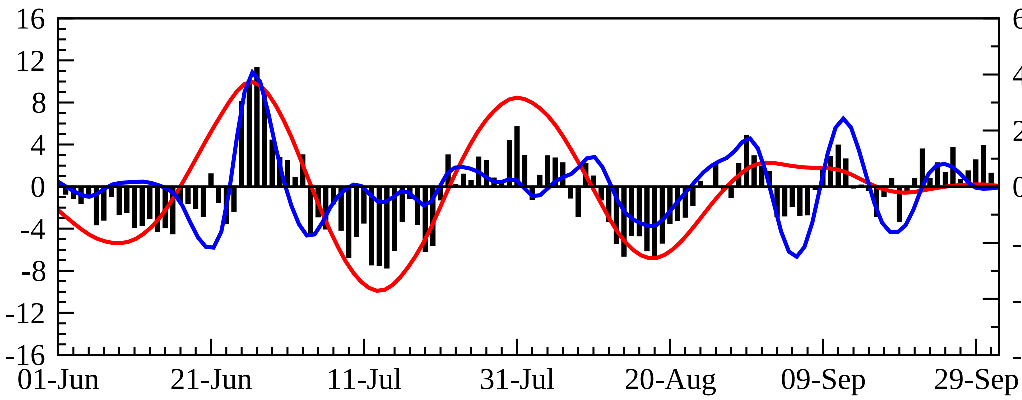


Fig. 5 contd.

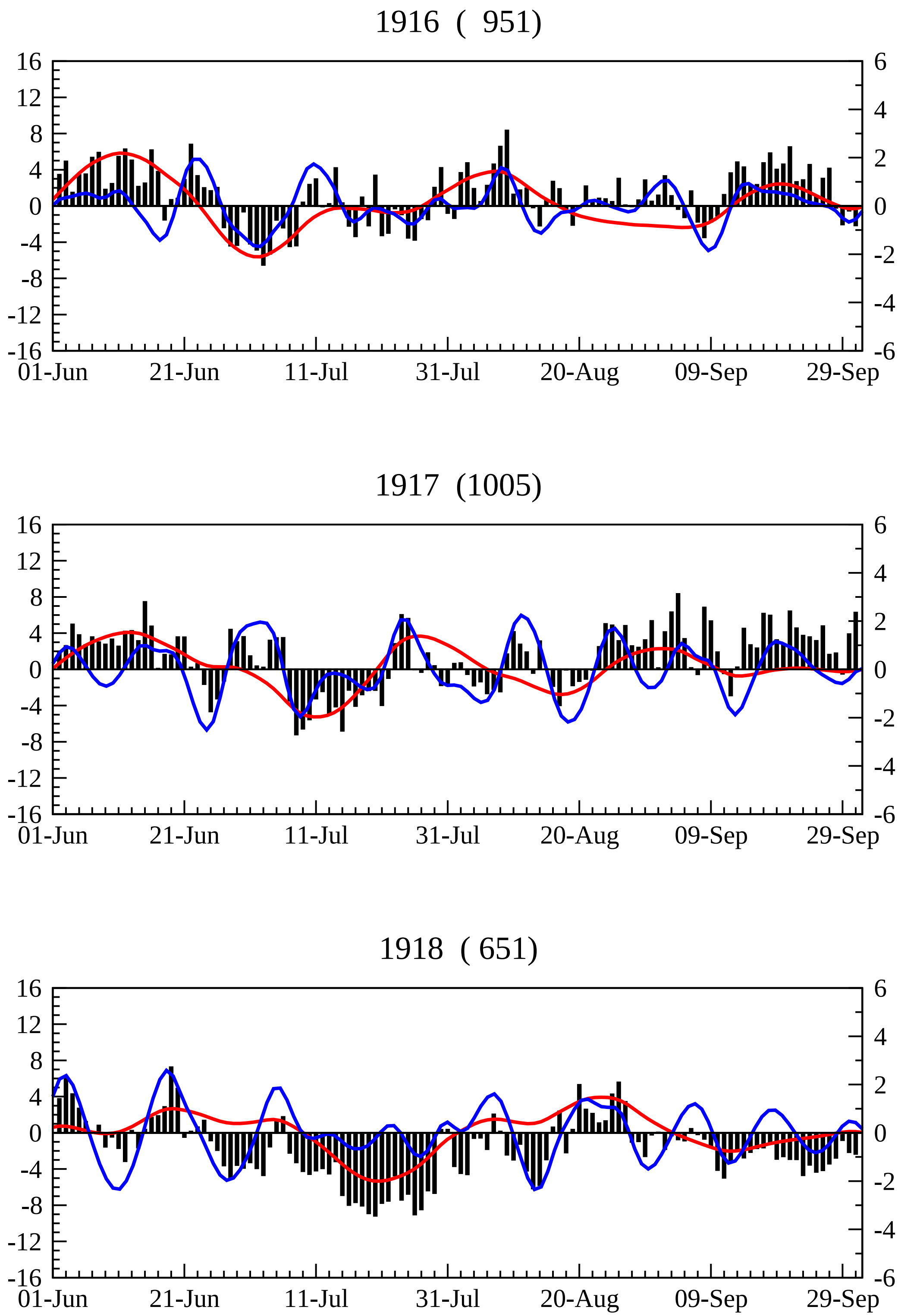

1916 (951)
16
12
8
4
0
-4
-8
-12
-16
6
4
2
0
-2
-4
-6
01-Jun
21-Jun
11-Jul
31-Jul
20-Aug
09-Sep
29-Sep
1917 (1005)
16
12
8
4
0
-4
-8
-12
-16
6
4
2
0
-2
-4
-6
01-Jun
21-Jun
11-Jul
31-Jul
20-Aug
09-Sep
29-Sep
1918 (651)
16
12
8
4
0
-4
-8
-12
-16
6
4
2
0
-2
-4
-6
01-Jun
21-Jun
11-Jul
31-Jul
20-Aug
09-Sep
29-Sep

Fig. 5 contd.

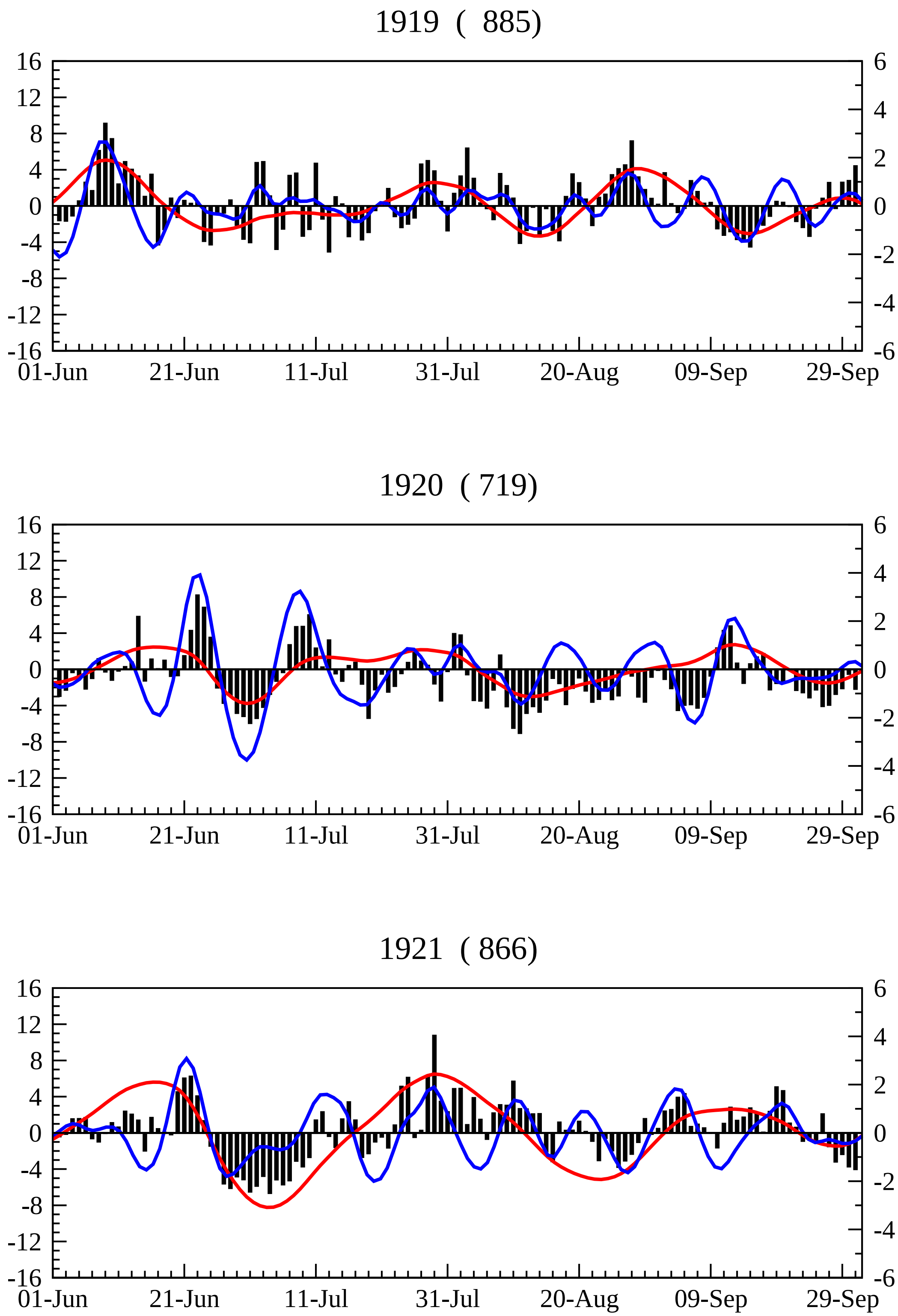
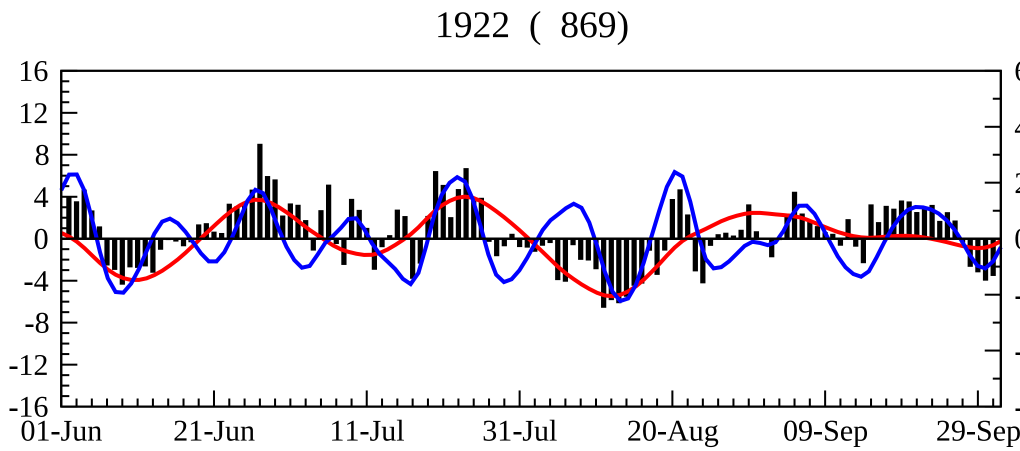

1919 (885)
1920 (719)
1921 (866)
16
12
8
4
0
-4
-8
-12
-16
6
4
2
0
-2
-4
-6
01-Jun
21-Jun
11-Jul
31-Jul
20-Aug
09-Sep
29-Sep

Fig. 5 contd.


1922 (869)
16
12
8
4
0
-4
-8
-12
-16
6
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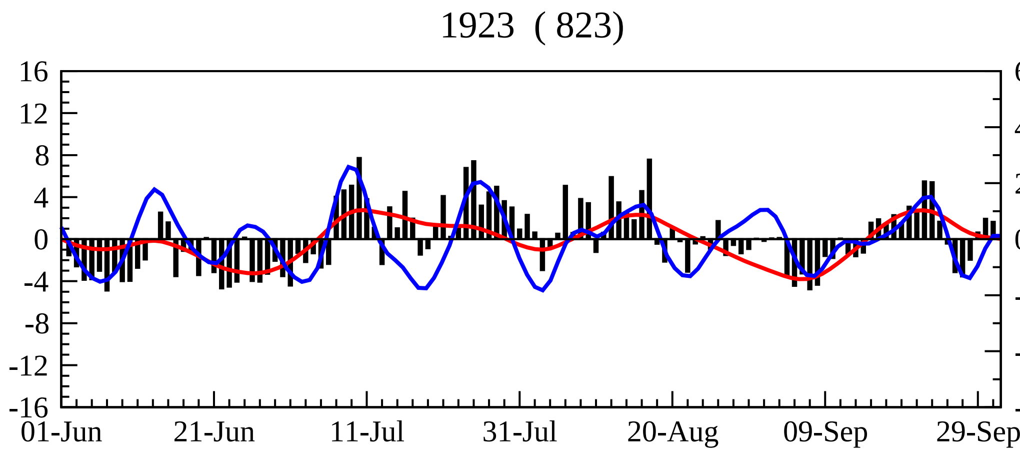
2
0
-2
-4
-6
01-Jun
21-Jun
11-Jul
31-Jul
20-Aug
09-Sep
29-Sep


1923 (823)
16
12
8
4
0
-4
-8
-12
-16
6
4
2
0
-2
-4
-6
01-Jun
21-Jun
11-Jul
31-Jul
20-Aug
09-Sep
29-Sep

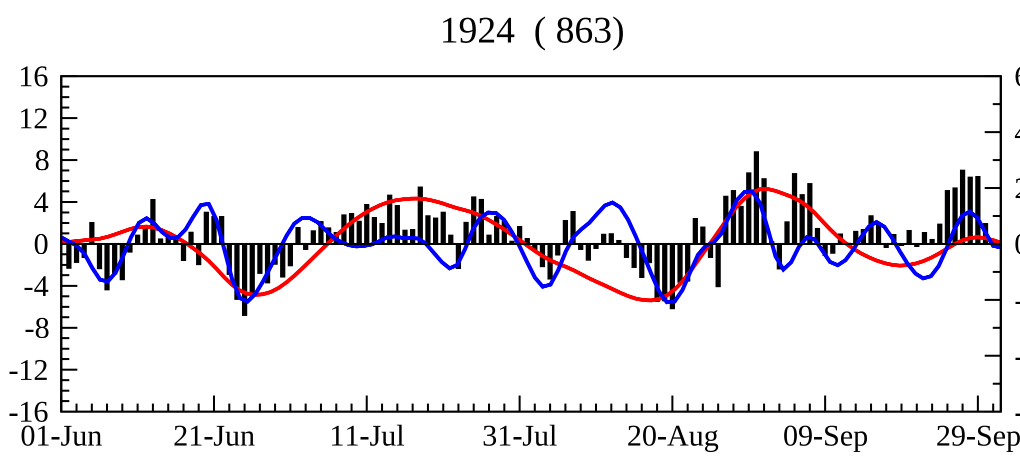

1924 (863)
16
12
8
4
0
-4
-8
-12
-16
6
4
2
0
-2
-4
-6
01-Jun
21-Jun
11-Jul
31-Jul
20-Aug
09-Sep
29-Sep

Fig. 5 contd.

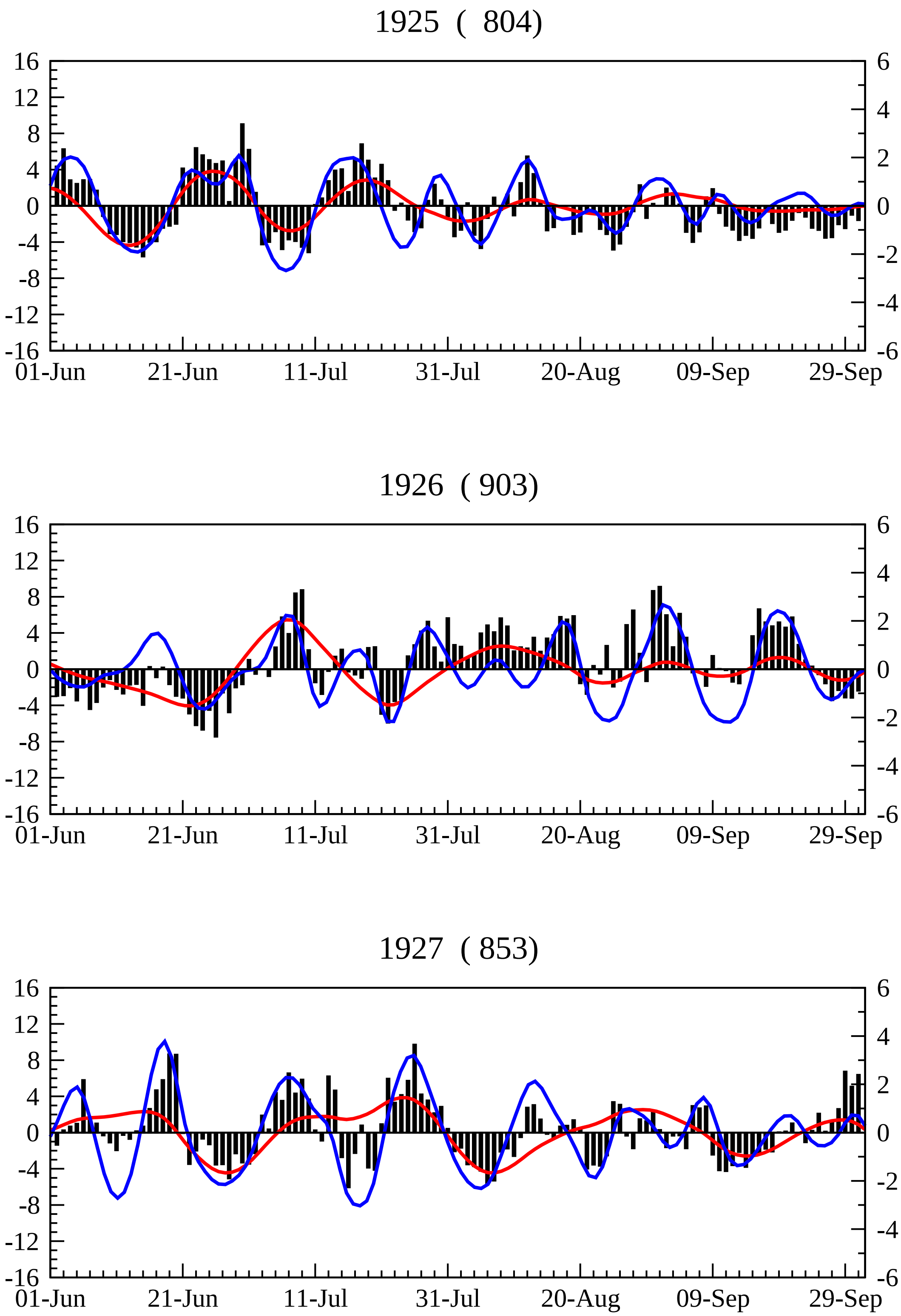
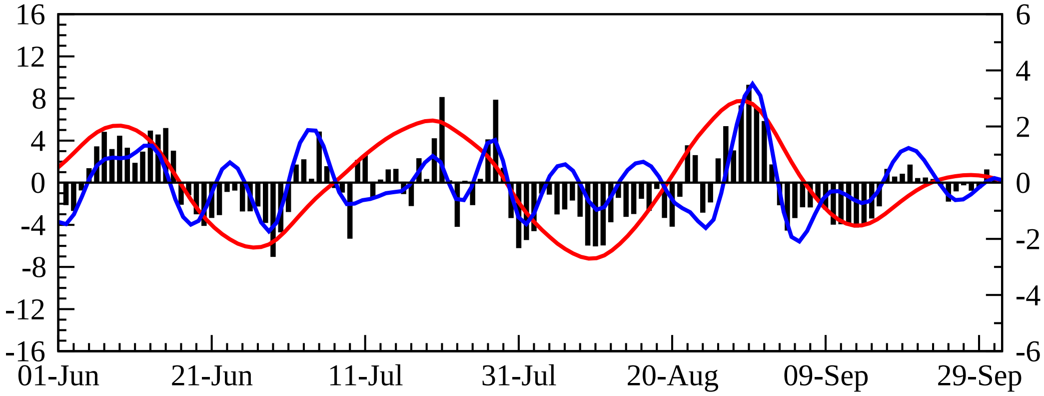
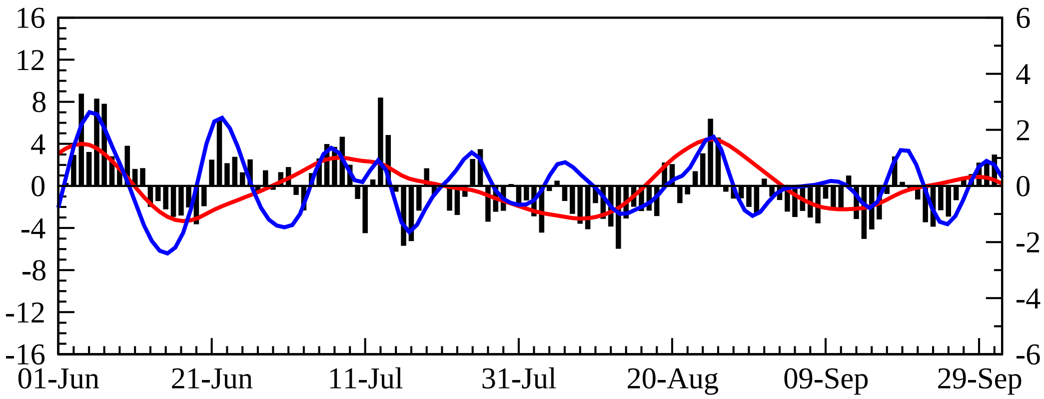

1925 (804)
16
12
8
4
0
-4
-8
-12
-16
6
4
2
0
-2
-4
-6
01-Jun
21-Jun
11-Jul
31-Jul
20-Aug
09-Sep
29-Sep
1926 (903)
16
12
8
4
0
-4
-8
-12
-16
6
4
2
0
-2
-4
-6
01-Jun
21-Jun
11-Jul
31-Jul
20-Aug
09-Sep
29-Sep
1927 (853)
16
12
8
4
0
-4
-8
-12
-16
6
4
2
0
-2
-4
-6
01-Jun
21-Jun
11-Jul
31-Jul
20-Aug
09-Sep
29-Sep

Fig. 5 contd.

1928 (768)



1929 (821)



1930 (805)

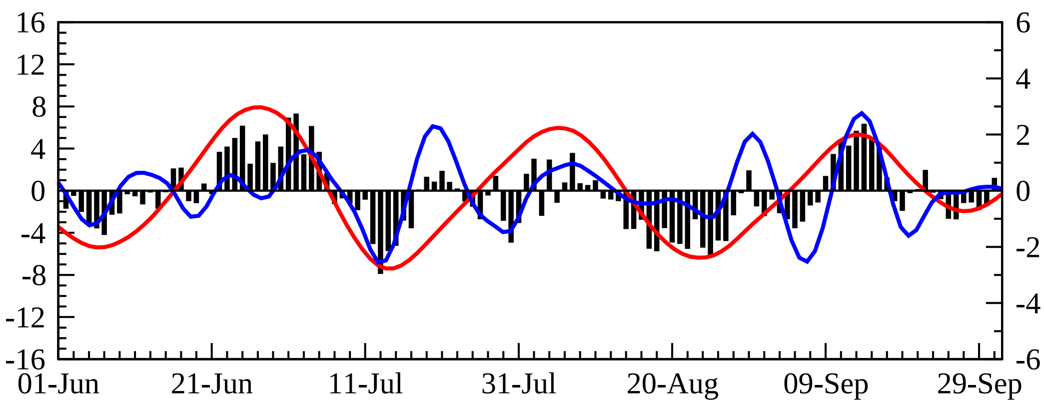
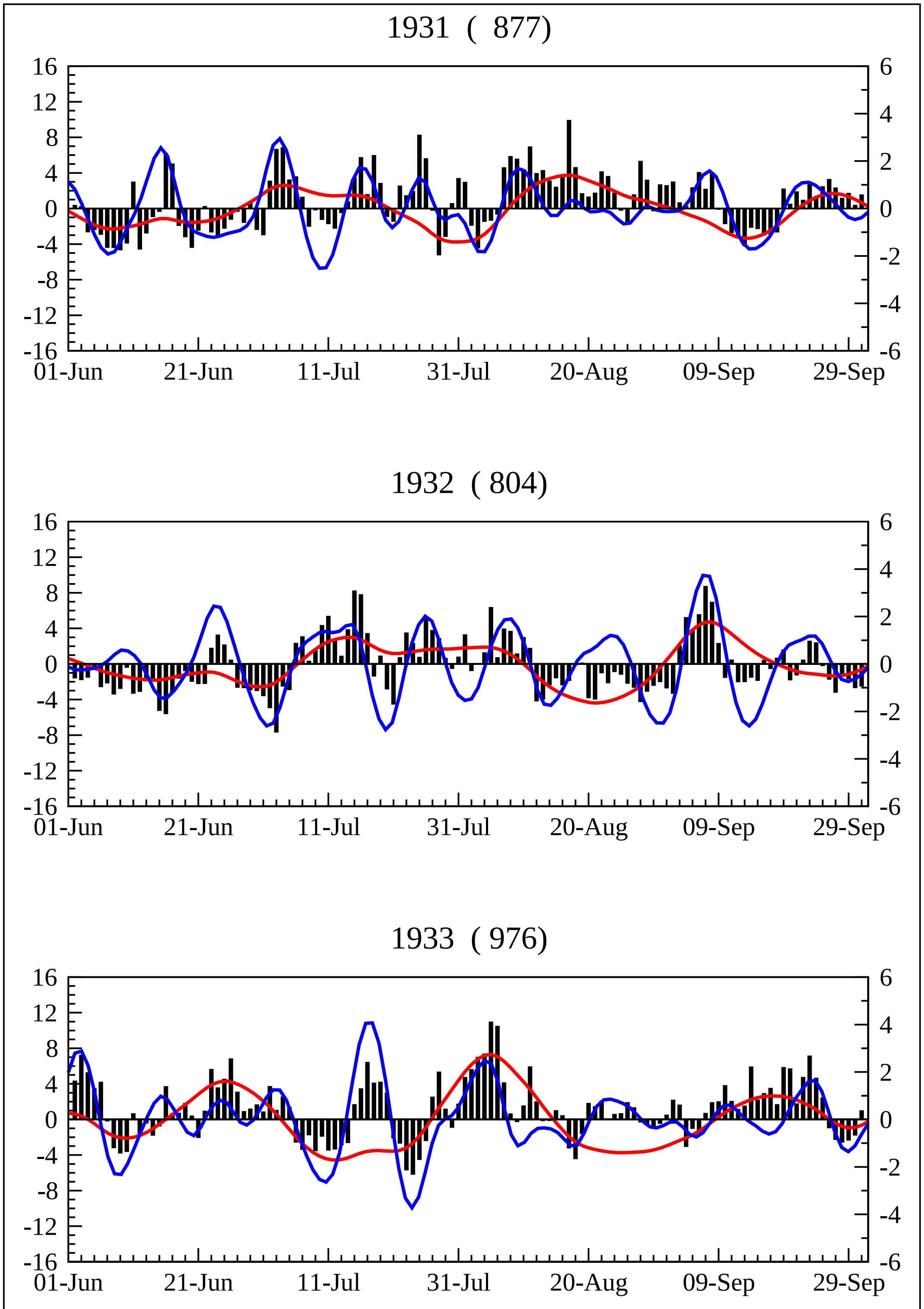


Fig. 5 contd.



1931 (877)
16
12
8
4
0
-4
-8
-12
-16
6
4
2
0
-2
-4
-6
01-Jun
21-Jun
11-Jul
31-Jul
20-Aug
09-Sep
29-Sep
1932 (804)
1933 (976)

Fig. 5 contd.

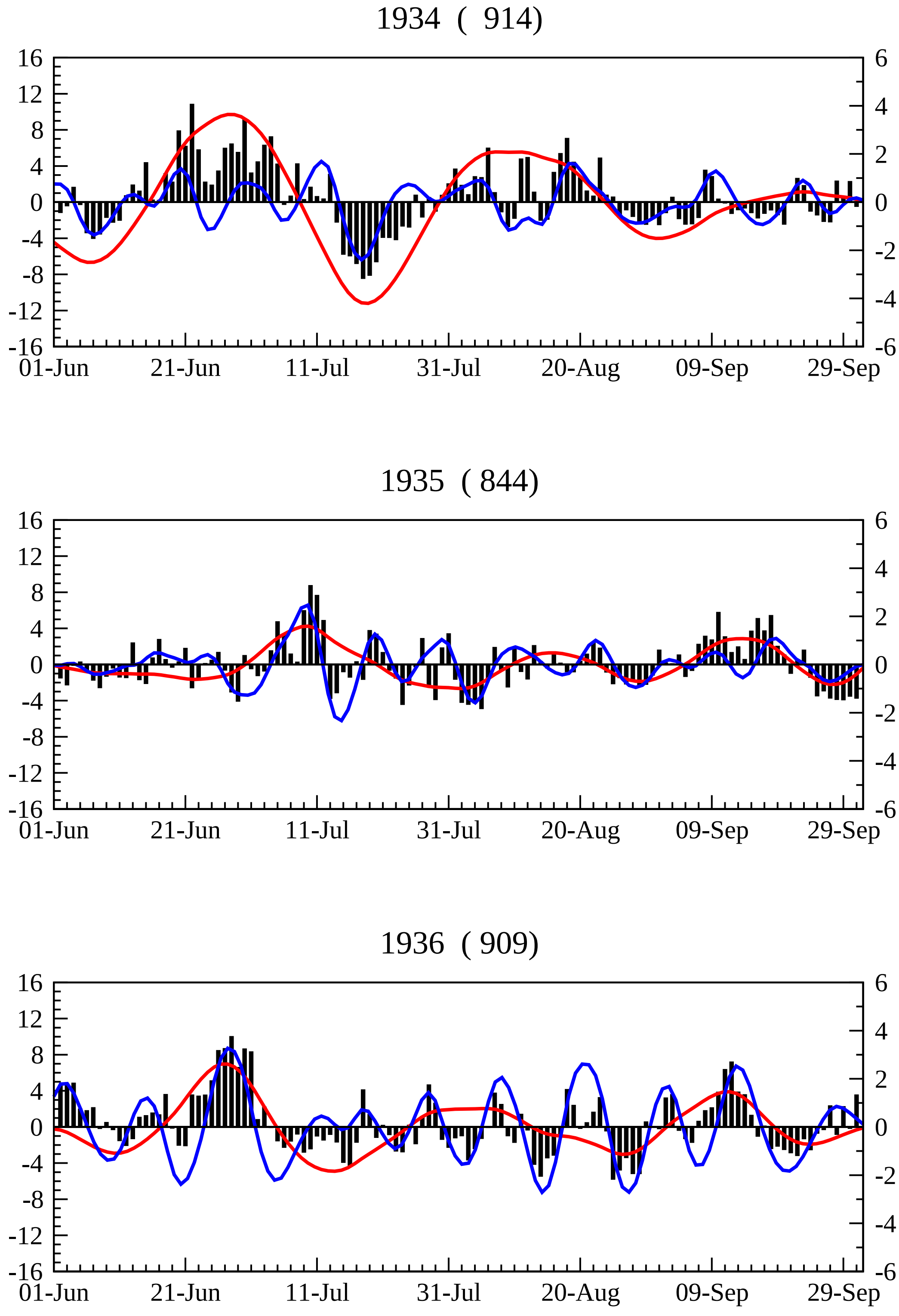

1934 (914)
1935 (844)
1936 (909)
16
12
8
4
0
-4
-8
-12
-16
6
4
2
0
-2
-4
-6
01-Jun
21-Jun
11-Jul
31-Jul
20-Aug
09-Sep
29-Sep

Fig. 5 contd.

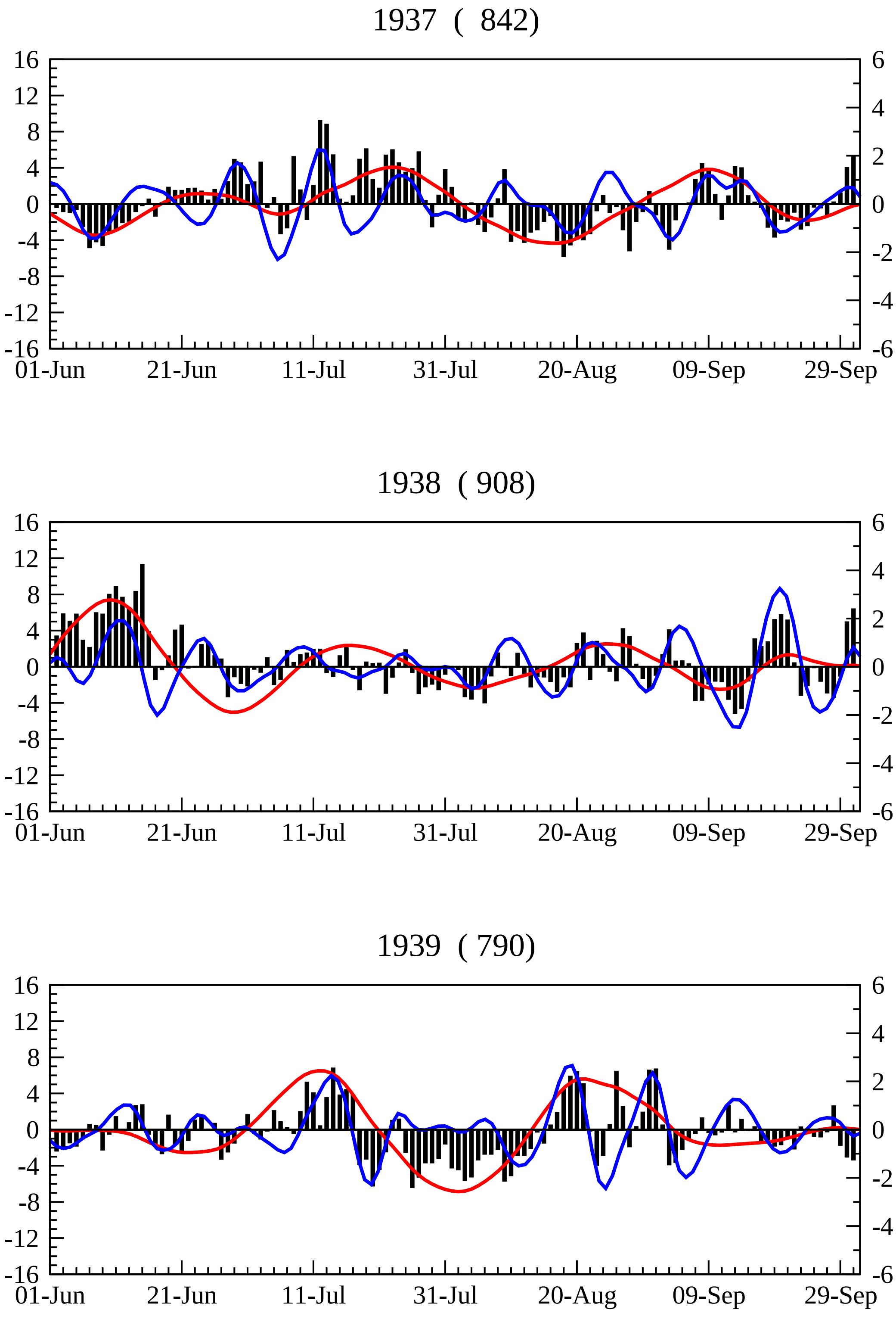
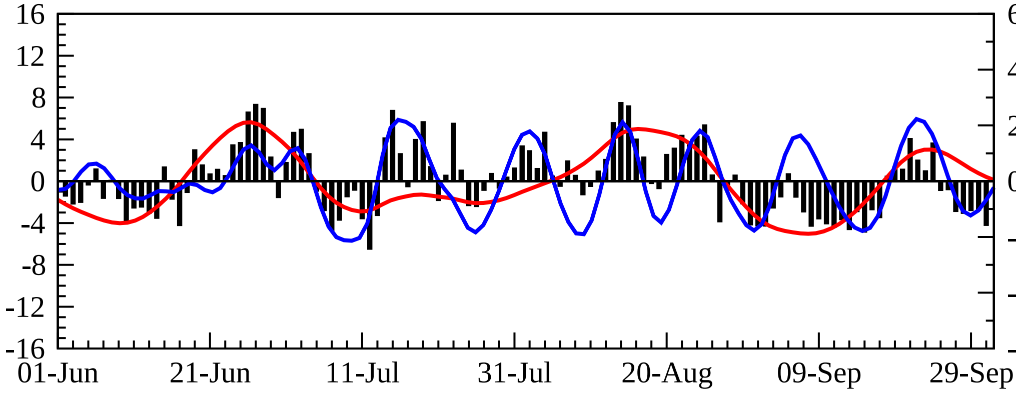
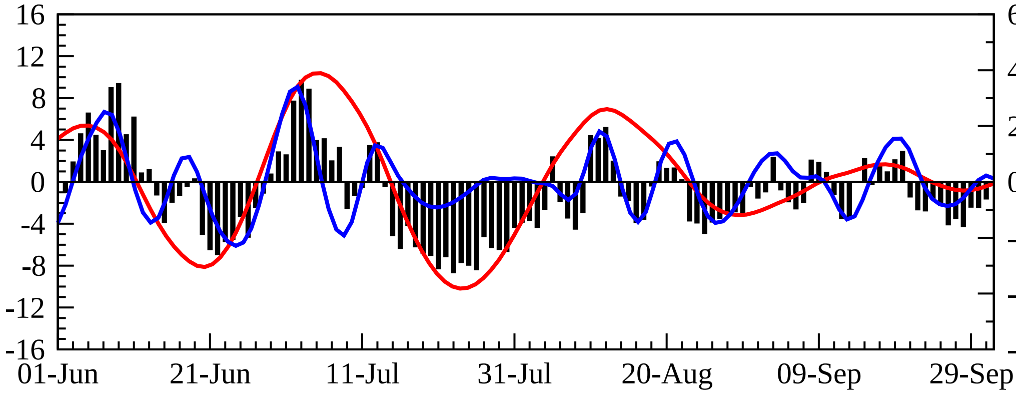

1937 (842)
16
12
8
4
0
-4
-8
-12
-16
6
4
2
0
-2
-4
-6
01-Jun
21-Jun
11-Jul
31-Jul
20-Aug
09-Sep
29-Sep
1938 (908)
1939 (790)

Fig. 5 contd.

1940 (854)



1941 (728)



1942 (958)

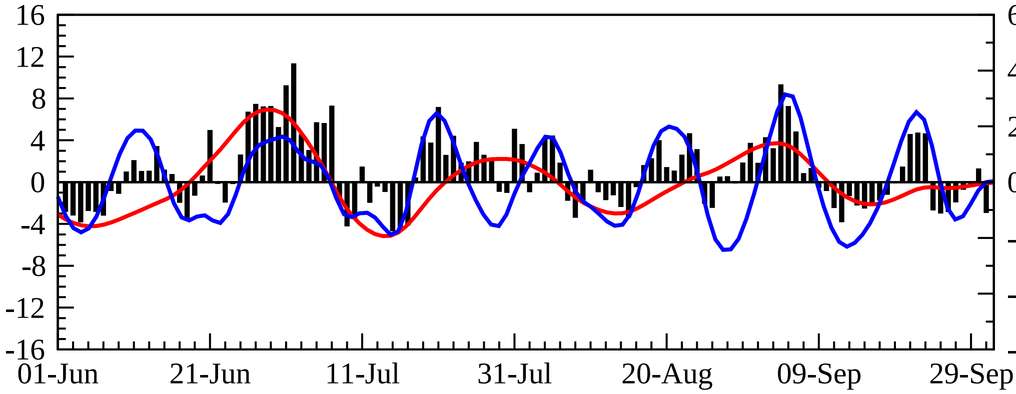
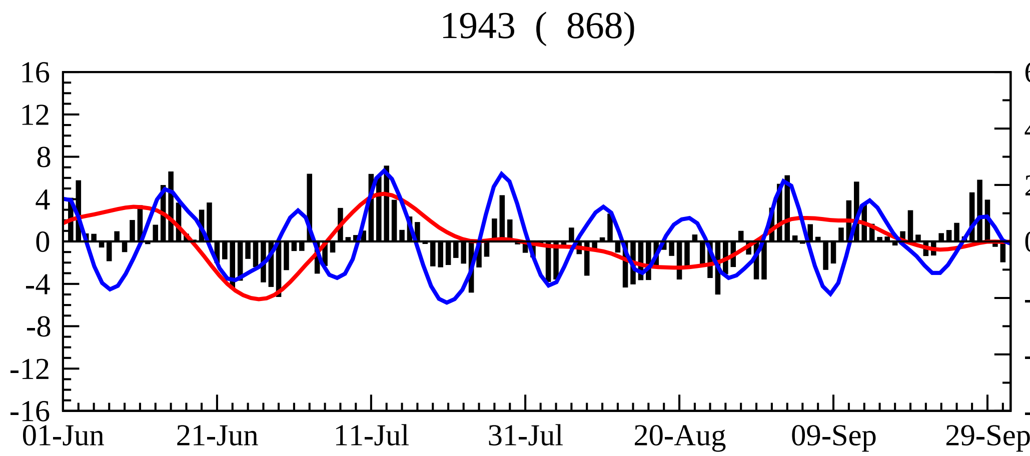
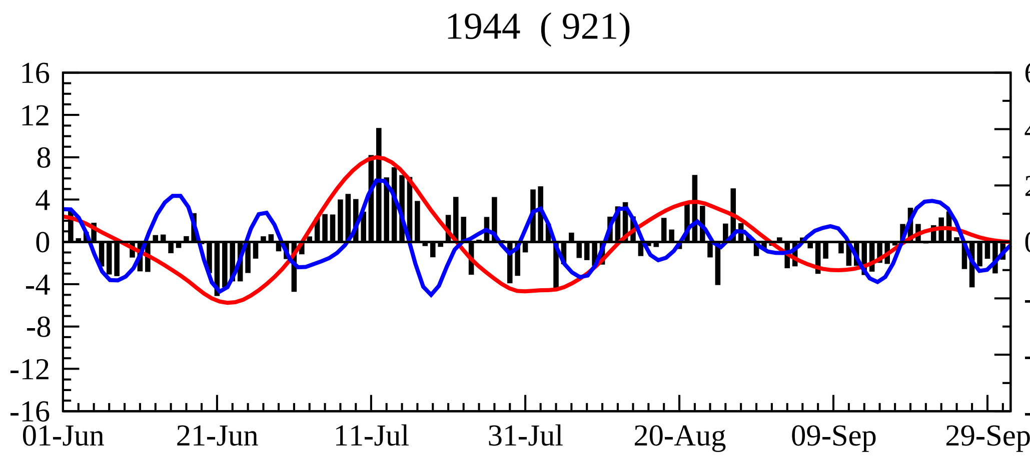


Fig. 5 contd.


1943 (868)
16
12
8
4
0
-4
-8
-12
-16
6
4
2
0
-2
-4
-6
01-Jun
21-Jun
11-Jul
31-Jul
20-Aug
09-Sep
29-Sep


1944 (921)
16
12
8
4
0
-4
-8
-12
-16
6
4
2
0
-2
-4
-6
01-Jun
21-Jun
11-Jul
31-Jul
20-Aug
09-Sep
29-Sep

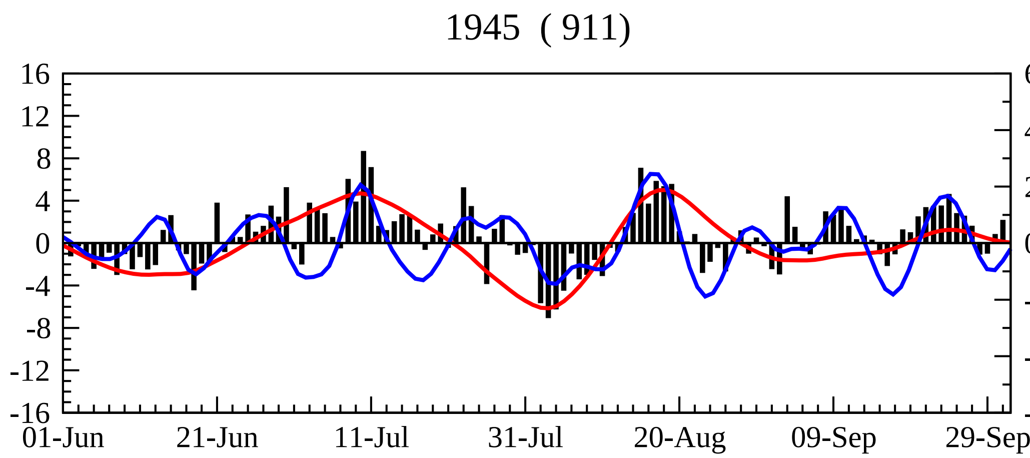
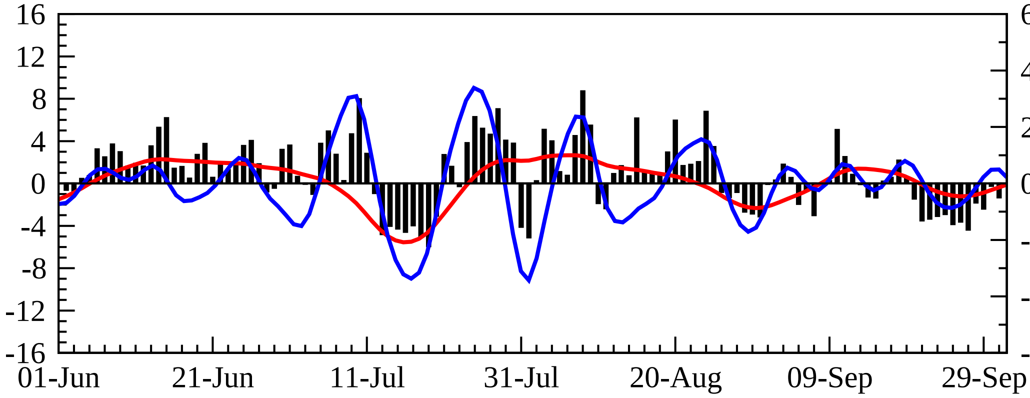
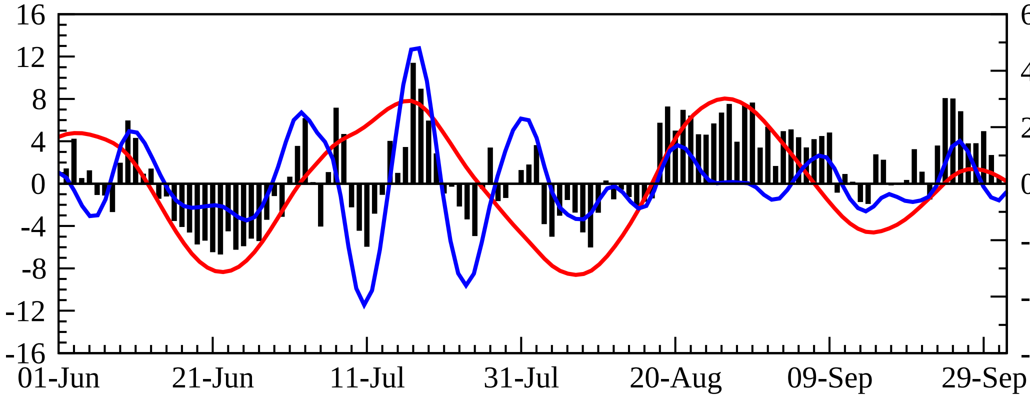

1945 (911)
16
12
8
4
0
-4
-8
-12
-16
6
4
2
0
-2
-4
-6
01-Jun
21-Jun
11-Jul
31-Jul
20-Aug
09-Sep
29-Sep

Fig. 5 contd.

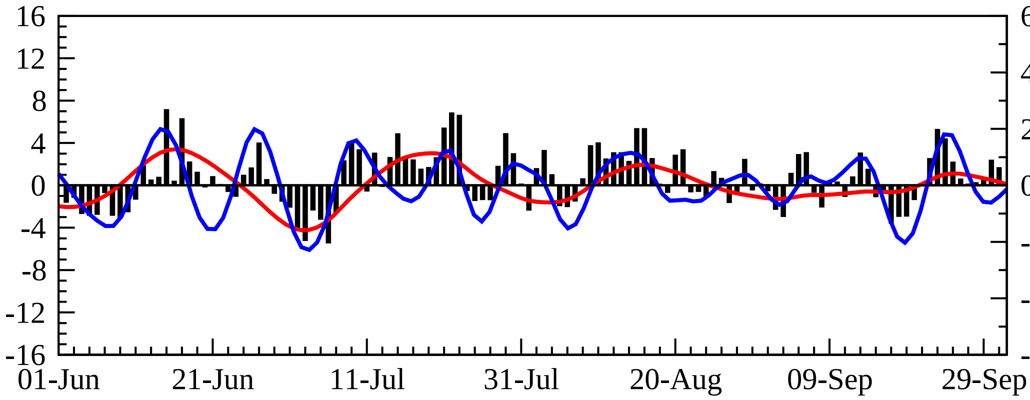
1946 (904)



1947 (946)



1948 (874)



16

Fig. 5 contd.

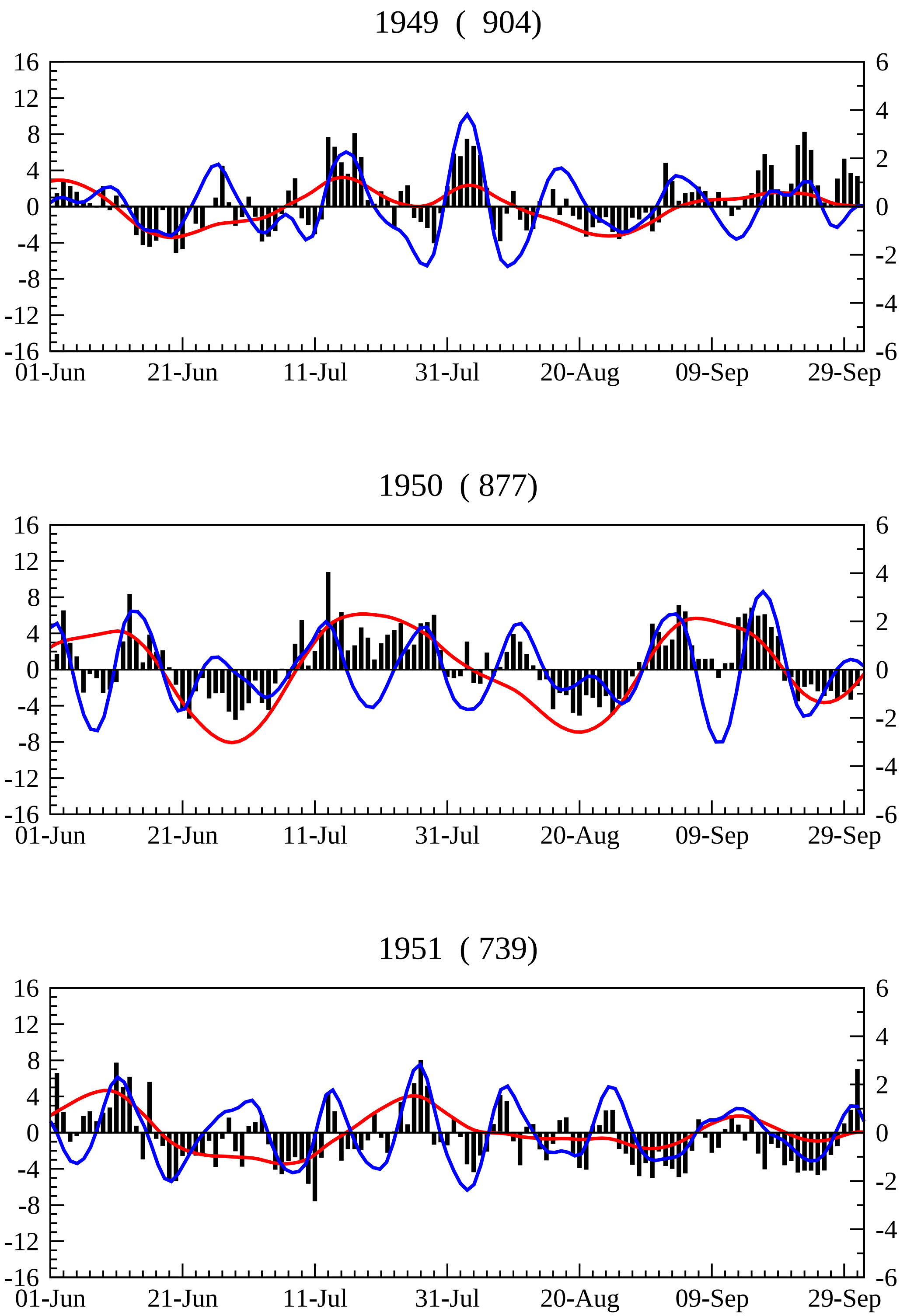

1949 (904)
1950 (877)
1951 (739)
16
12
8
4
0
-4
-8
-12
-16
6
4
2
0
-2
-4
-6
01-Jun
21-Jun
11-Jul
31-Jul
20-Aug
09-Sep
29-Sep

Fig. 5 contd.

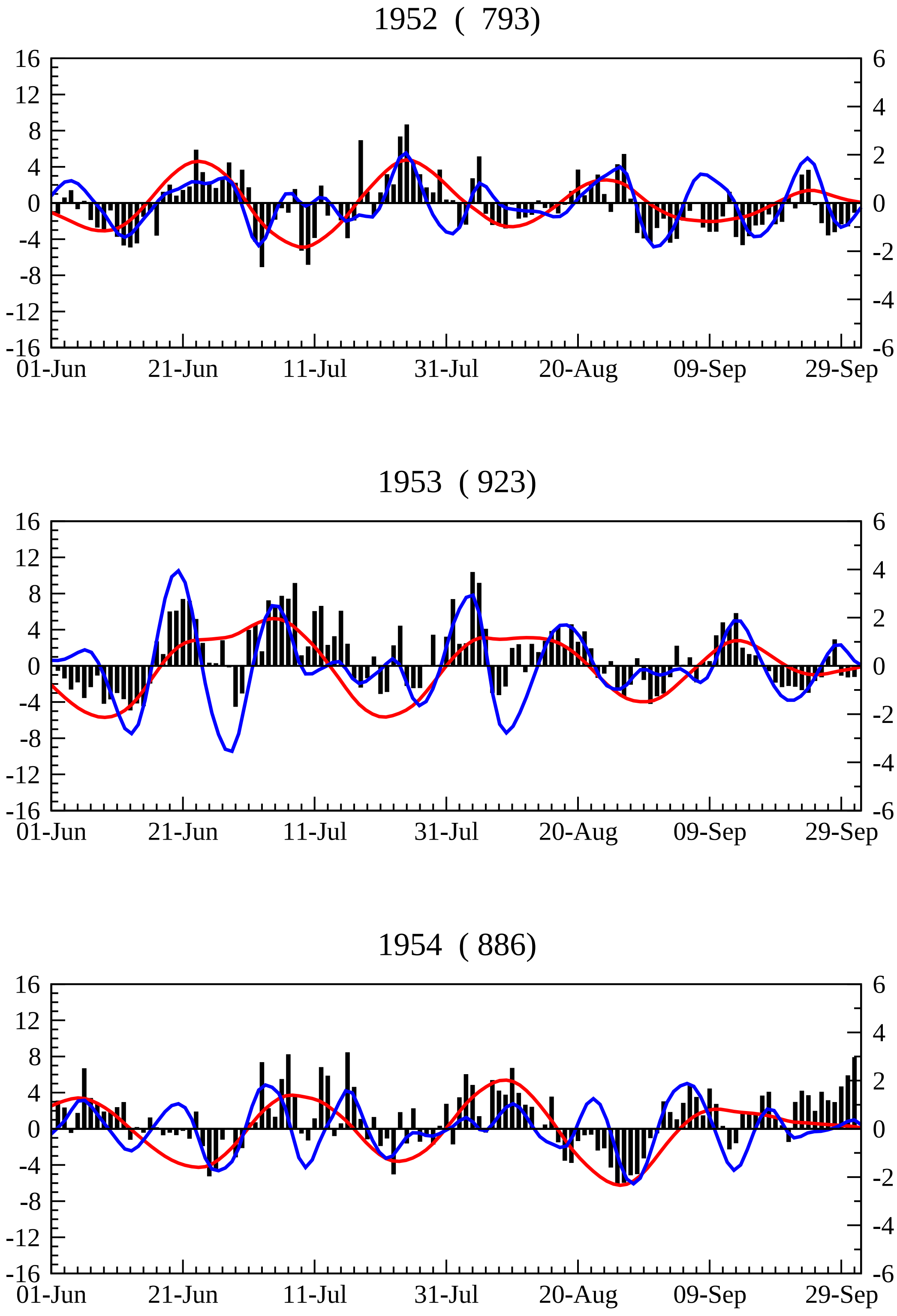

1952 (793)
1953 (923)
1954 (886)
16
12
8
4
0
-4
-8
-12
-16
6
4
2
0
-2
-4
-6
01-Jun
21-Jun
11-Jul
31-Jul
20-Aug
09-Sep
29-Sep

Fig. 5 contd.

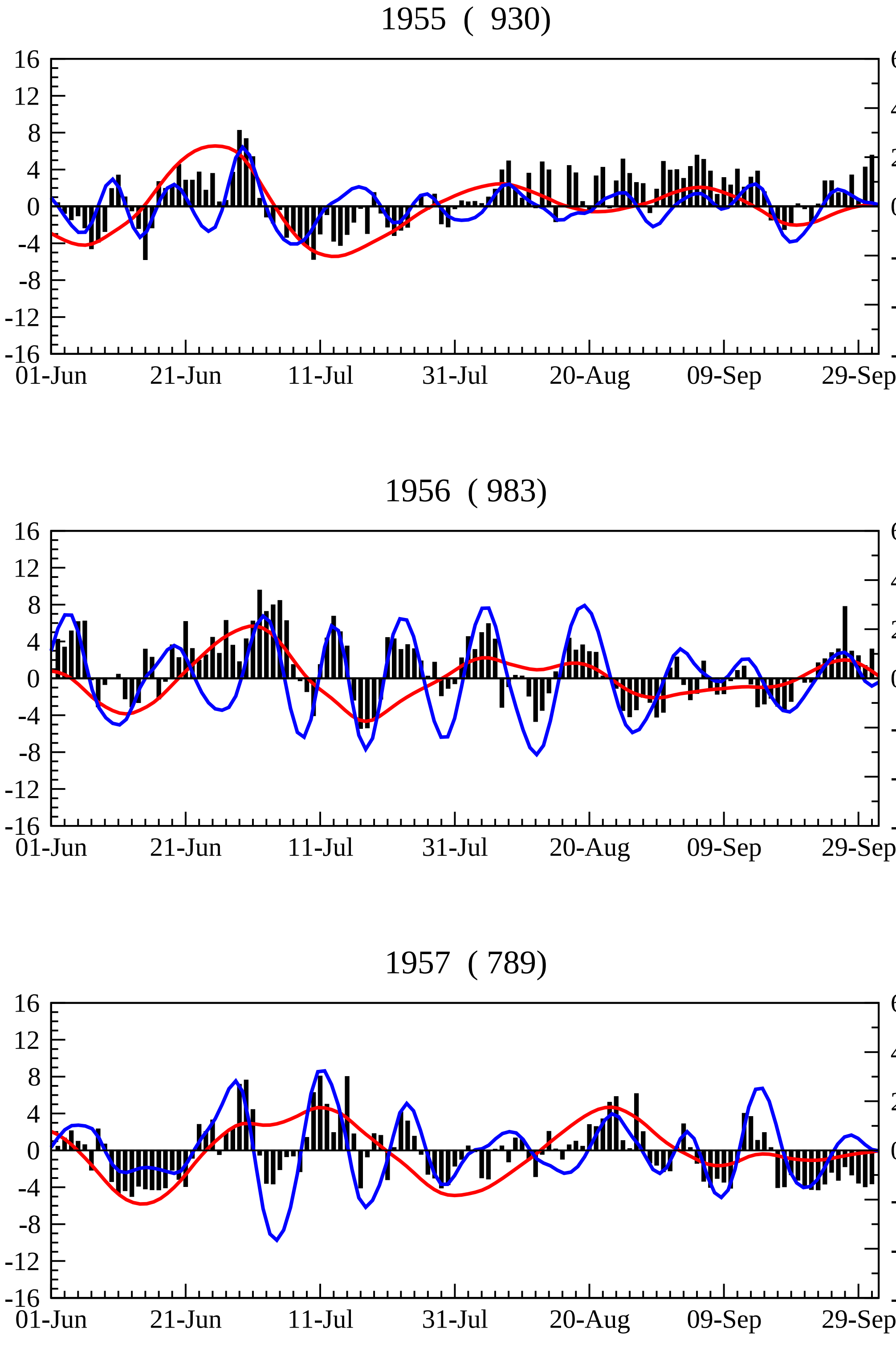
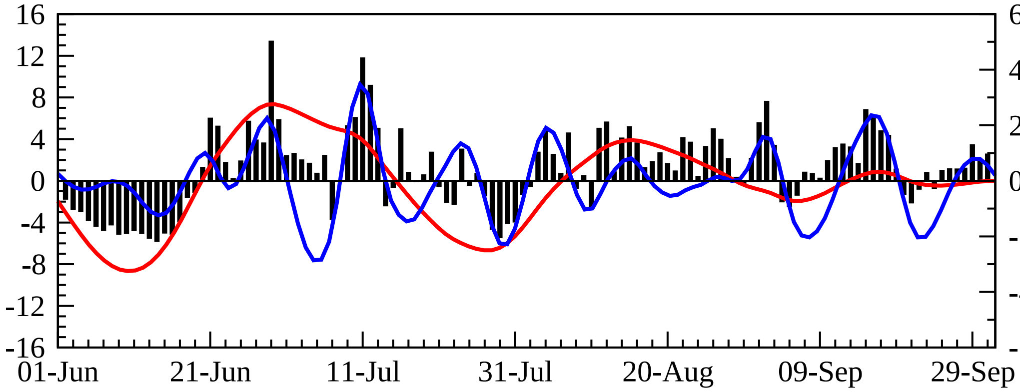
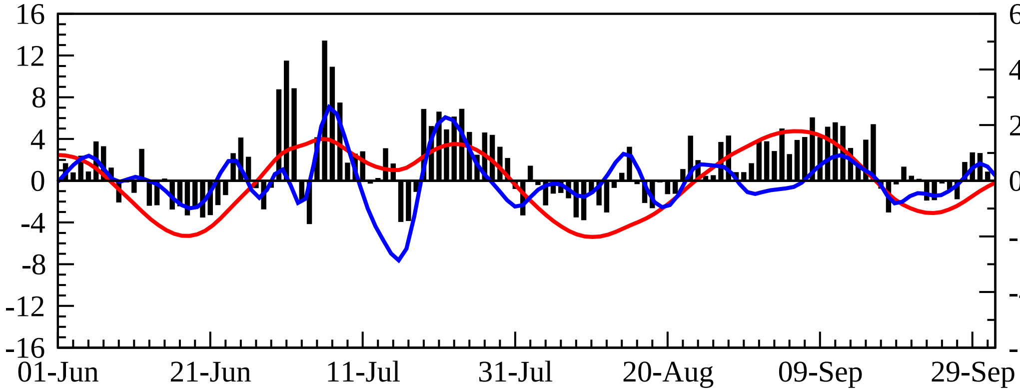

1955 (930)
16
12
8
4
0
-4
-8
-12
-16
6
4
2
0
-2
-4
-6
01-Jun
21-Jun
11-Jul
31-Jul
20-Aug
09-Sep
29-Sep
1956 (983)
1957 (789)

Fig. 5 contd.

1958 (889)



1959 (944)



1960 (840)

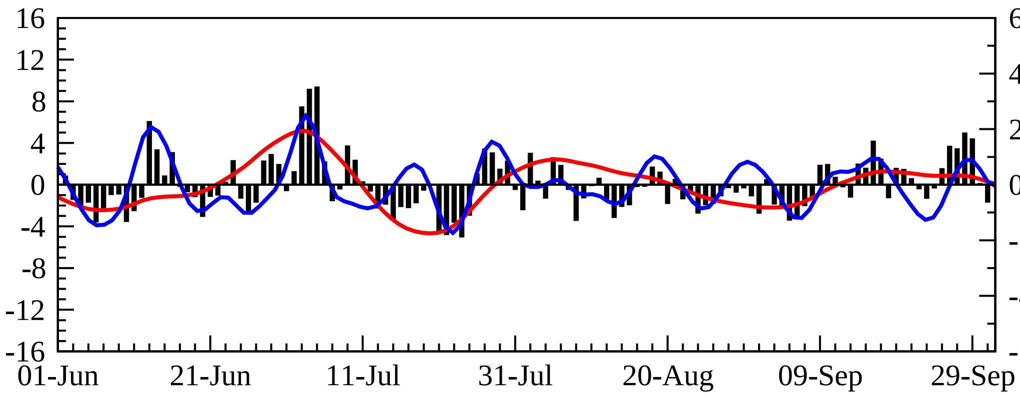


Fig. 5 contd.

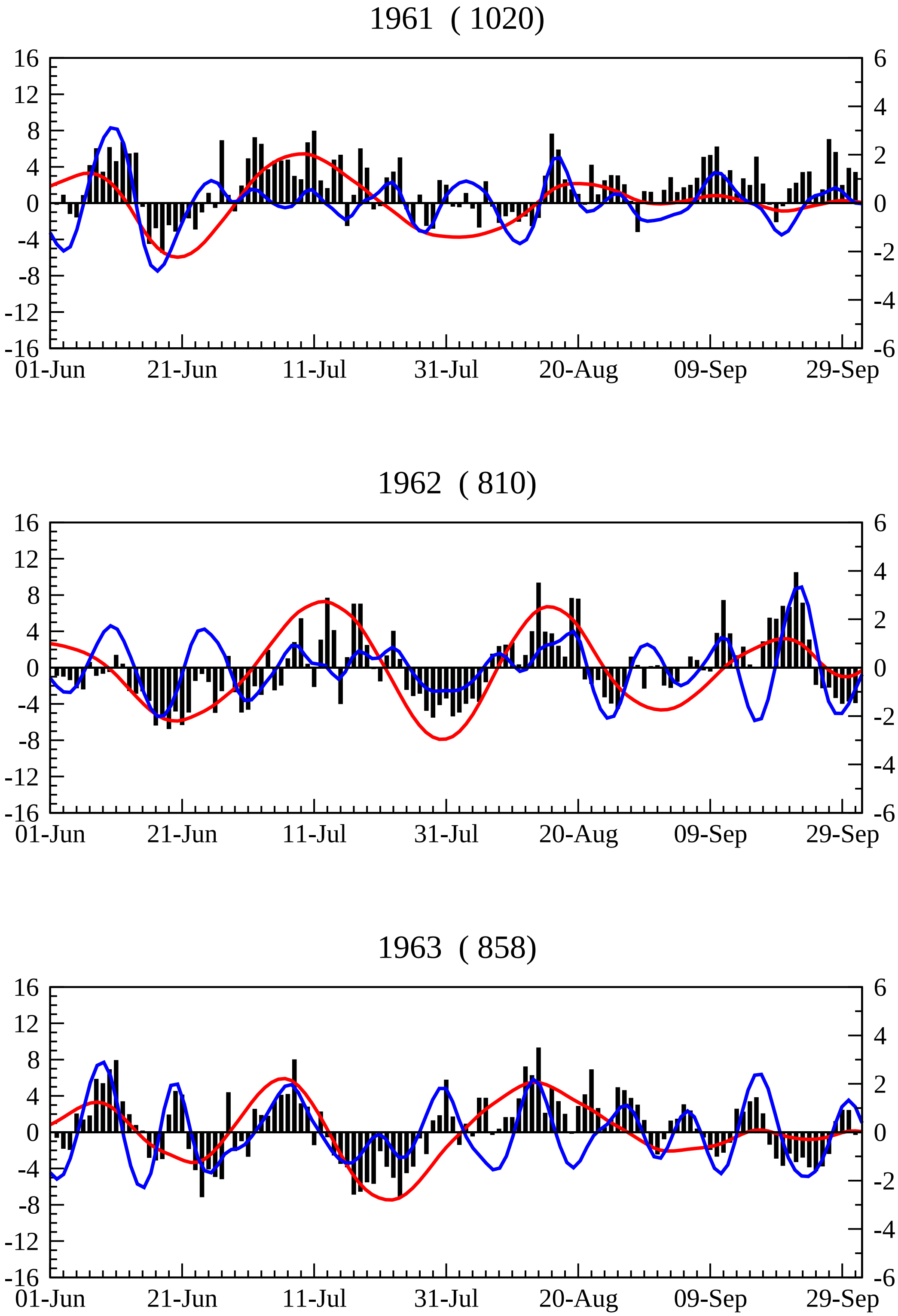
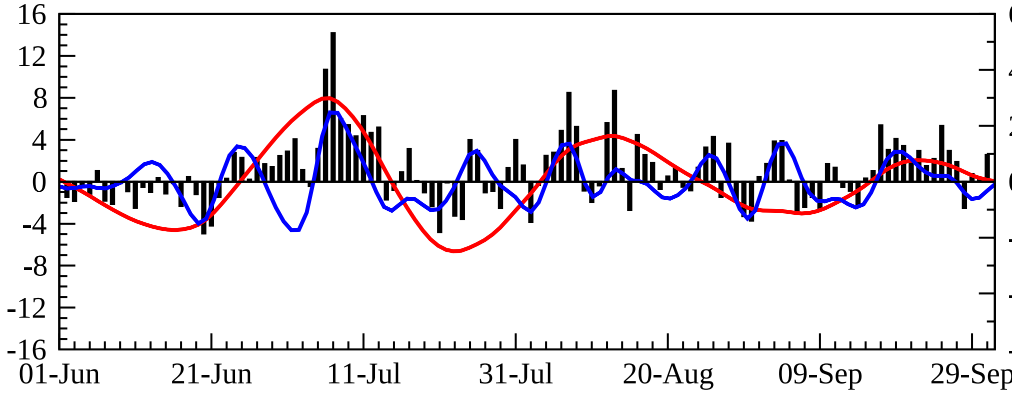
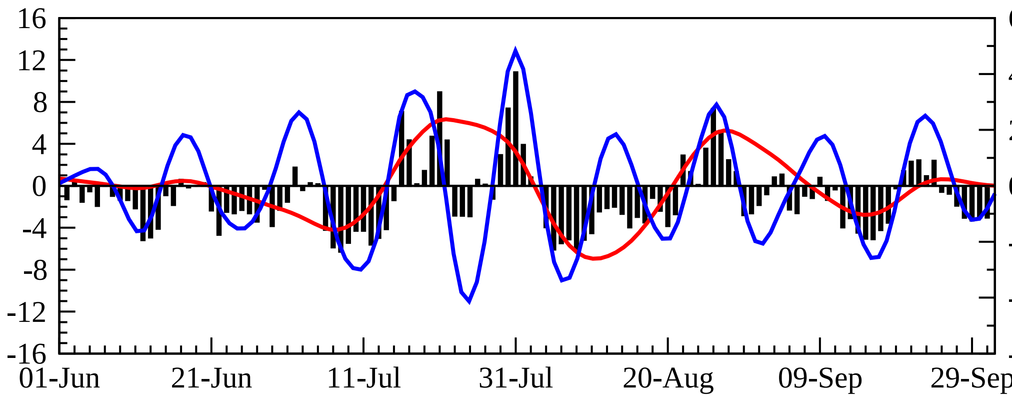

1961 (1020)
1962 (810)
1963 (858)
16
12
8
4
0
-4
-8
-12
-16
6
4
2
0
-2
-4
-6
01-Jun
21-Jun
11-Jul
31-Jul
20-Aug
09-Sep
29-Sep

Fig. 5 contd.

1964 (923)



1965 (709)



1966 (740)

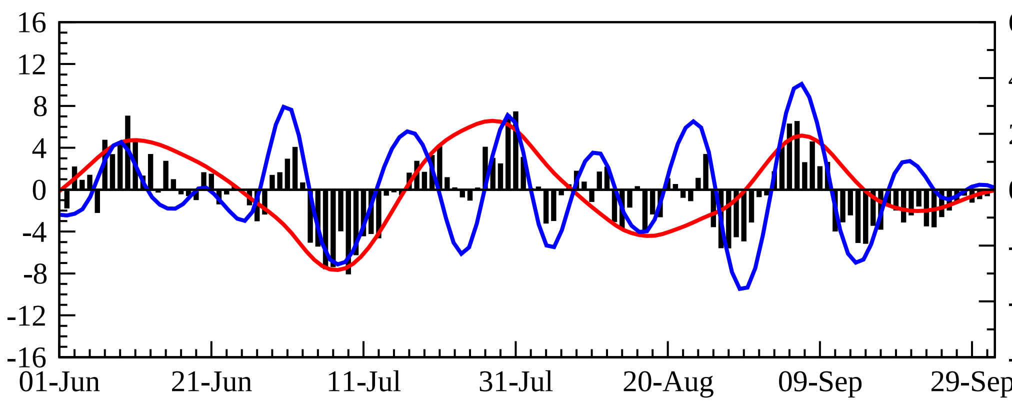


Fig. 5 contd.

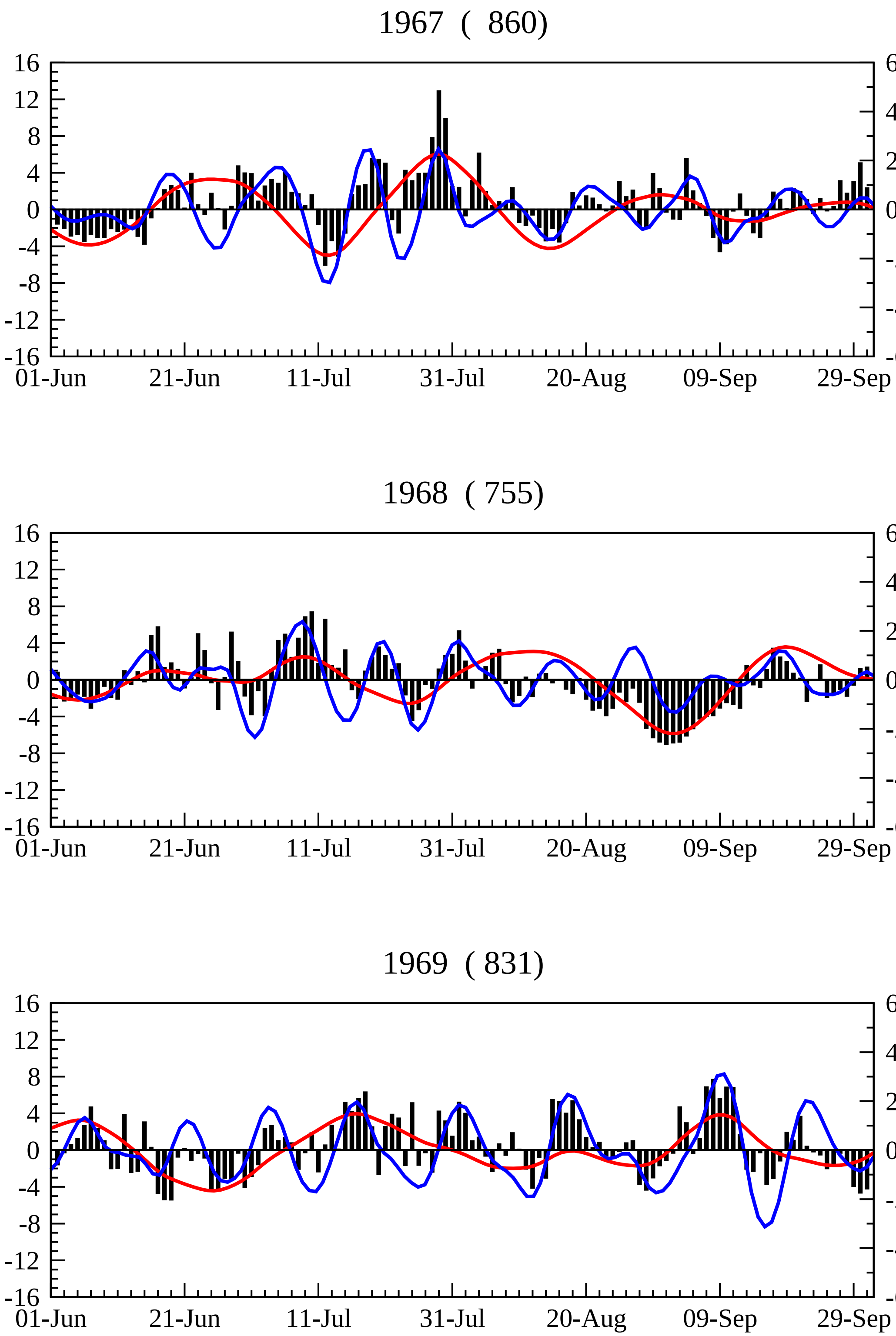
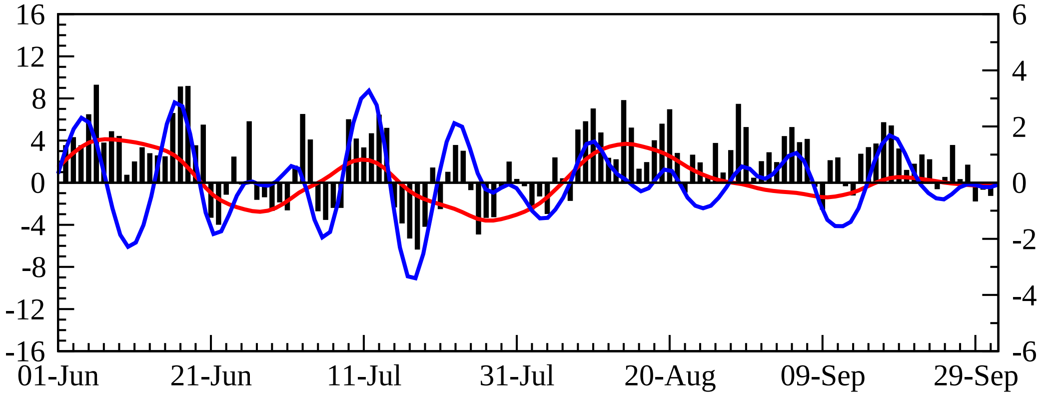
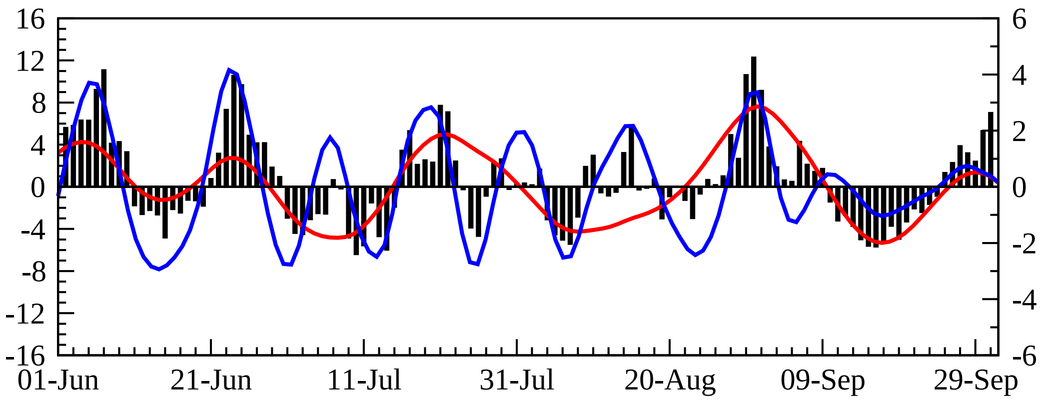

1967 (860)
1968 (755)
1969 (831)
16
12
8
4
0
-4
-8
-12
-16
6
4
2
0
-2
-4
-6
01-Jun
21-Jun
11-Jul
31-Jul
20-Aug
09-Sep
29-Sep

Fig. 5 contd.

1970 (940)



1971 (887)



1972 (653)

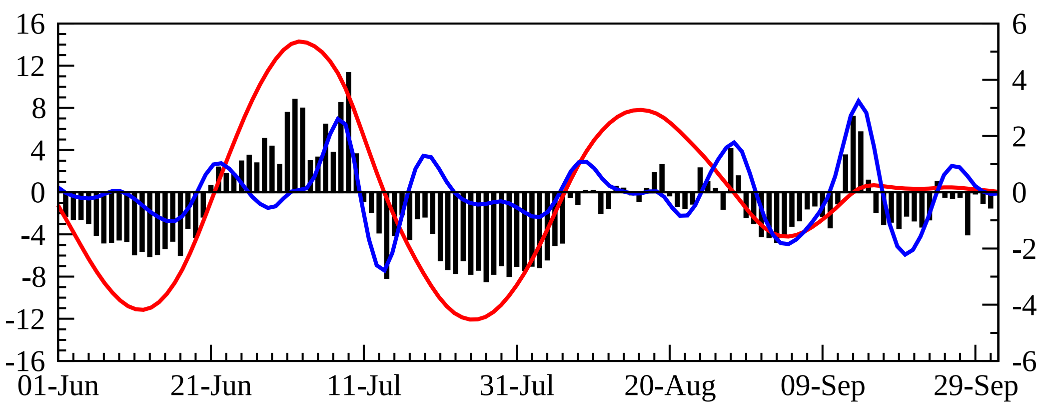


Fig. 5 contd.

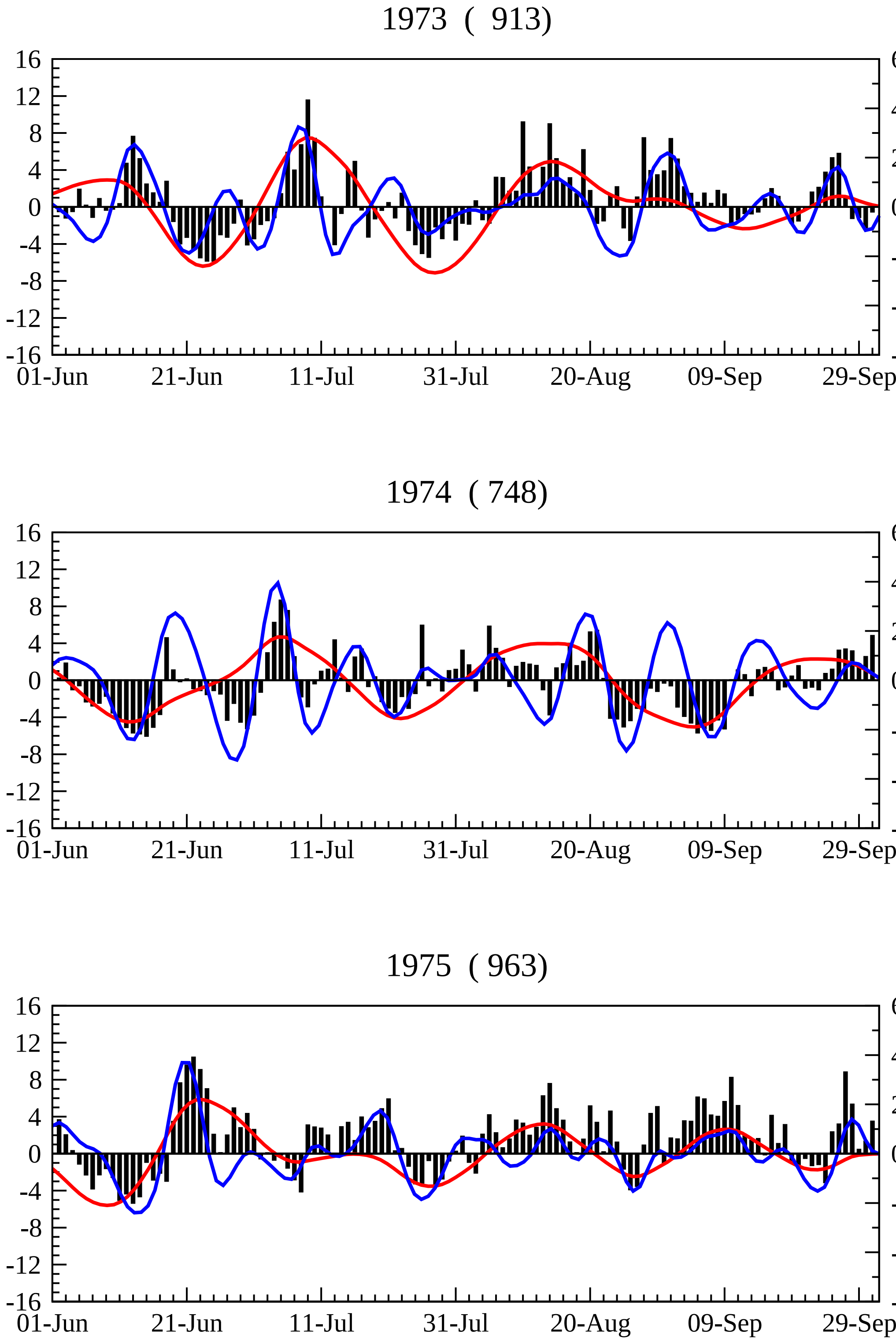

1973 (913)
1974 (748)
1975 (963)
16
12
8
4
0
-4
-8
-12
-16
6
4
2
0
-2
-4
-6
01-Jun
21-Jun
11-Jul
31-Jul
20-Aug
09-Sep
29-Sep

Fig. 5 contd.

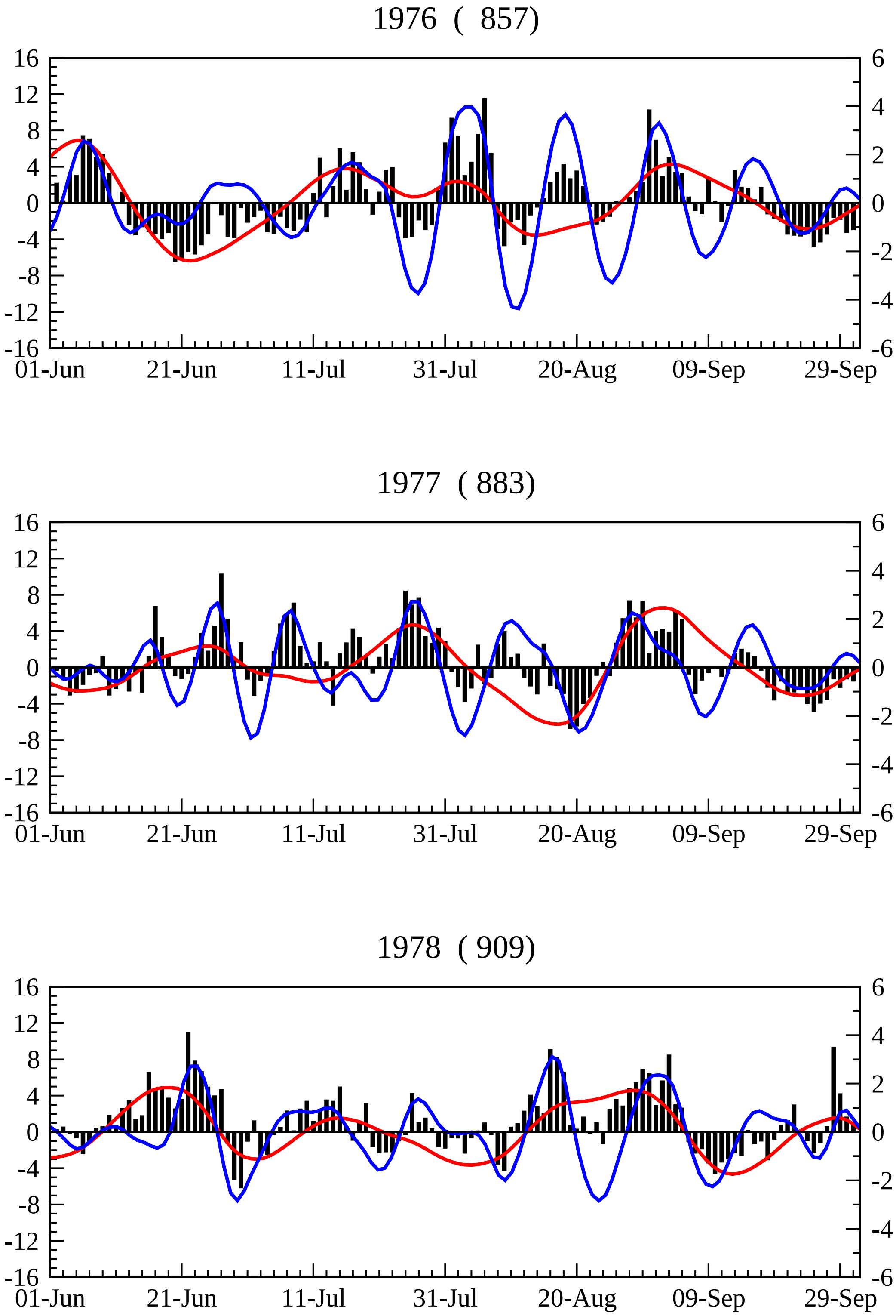
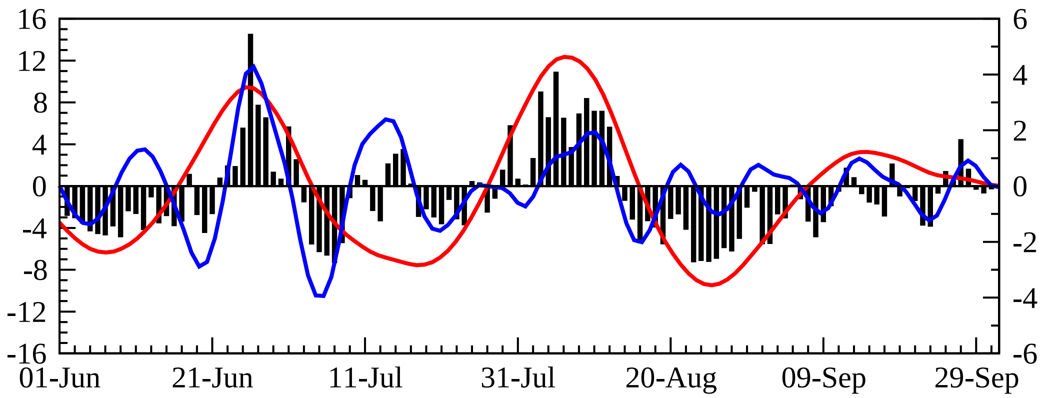
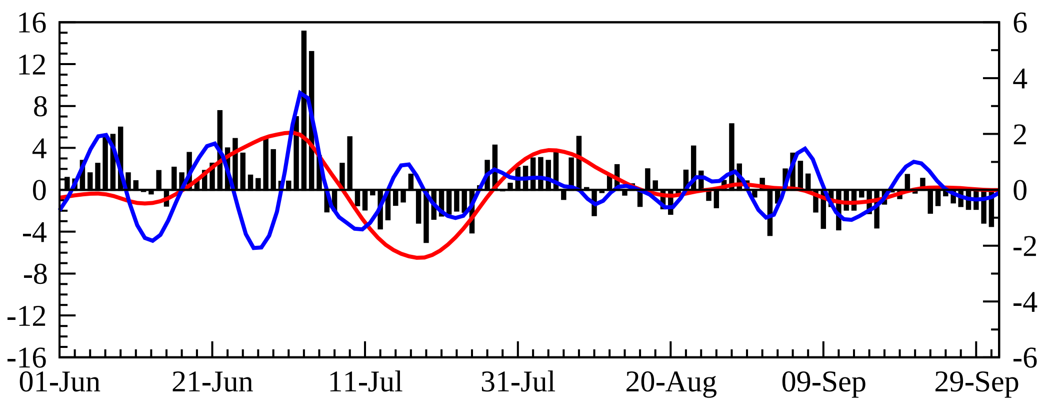

1976 (857)
1977 (883)
1978 (909)
16
12
8
4
0
-4
-8
-12
-16
6
4
2
0
-2
-4
-6
01-Jun
21-Jun
11-Jul
31-Jul
20-Aug
09-Sep
29-Sep

Fig. 5 contd.

1979 (708)



1980 (883)



1981 (852)

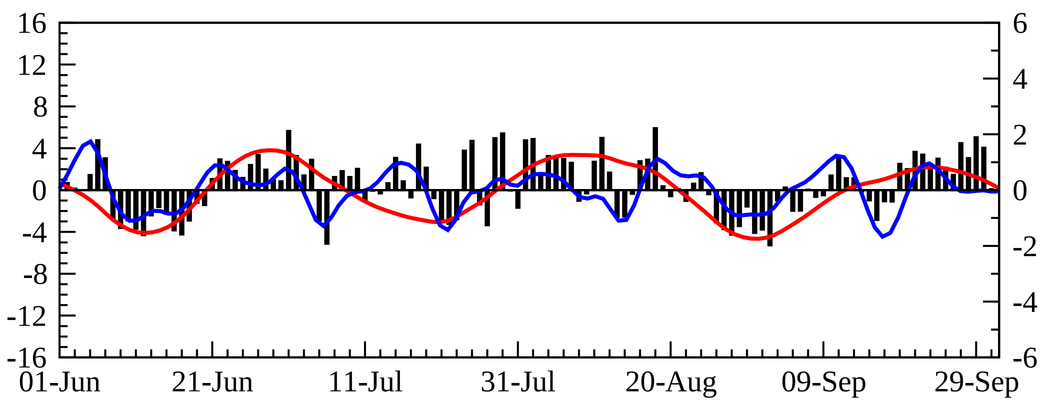


Fig. 5 contd.

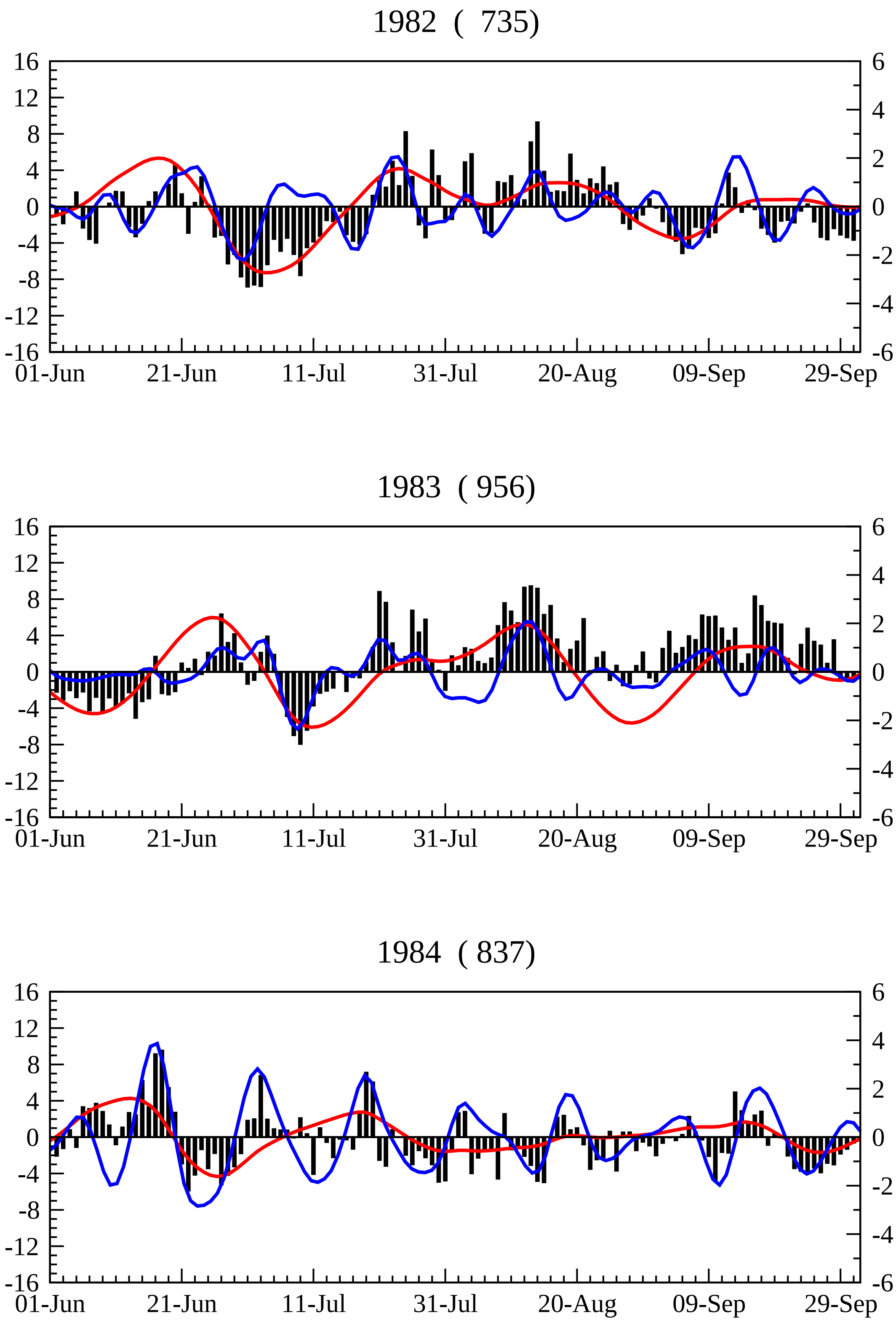
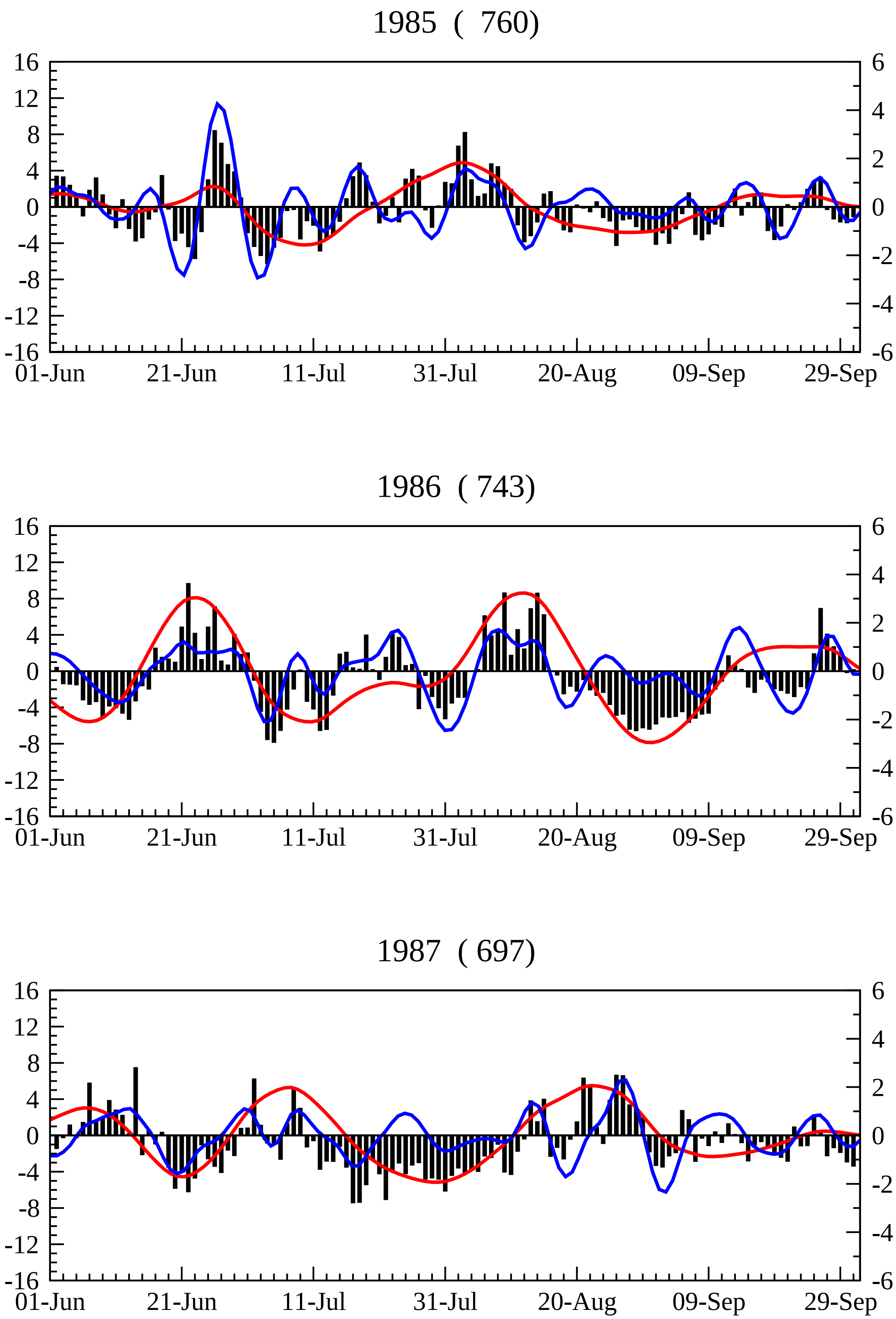

1982 (735)
1983 (956)
1984 (837)
16
12
8
4
0
-4
-8
-12
-16
6
4
2
0
-2
-4
-6
01-Jun
21-Jun
11-Jul
31-Jul
20-Aug
09-Sep
29-Sep

Fig. 5 contd.


1985 (760)
16
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8
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0
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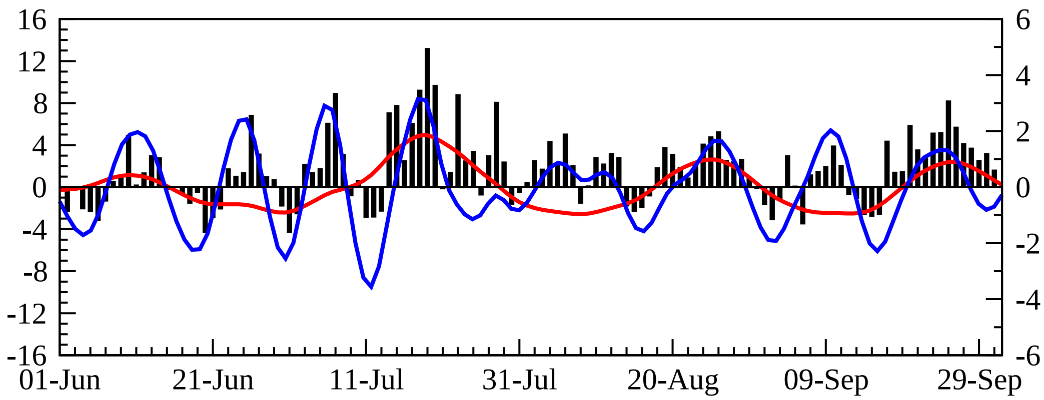
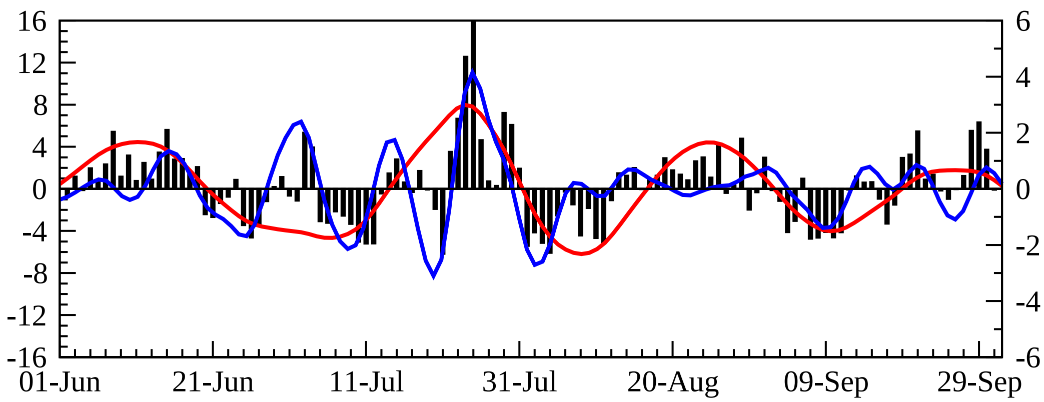
-8
-12
-16
6
4
2
0
-2
-4
-6
01-Jun
21-Jun
11-Jul
31-Jul
20-Aug
09-Sep
29-Sep
1986 (743)
16
12
8
4
0
-4
-8
-12
-16
6
4
2
0
-2
-4
-6
01-Jun
21-Jun
11-Jul
31-Jul
20-Aug
09-Sep
29-Sep
1987 (697)
16
12
8
4
0
-4
-8
-12
-16
6
4
2
0
-2
-4
-6
01-Jun
21-Jun
11-Jul
31-Jul
20-Aug
09-Sep
29-Sep

Fig. 5 contd.

1988 (961)



1989 (867)



1990 (909)

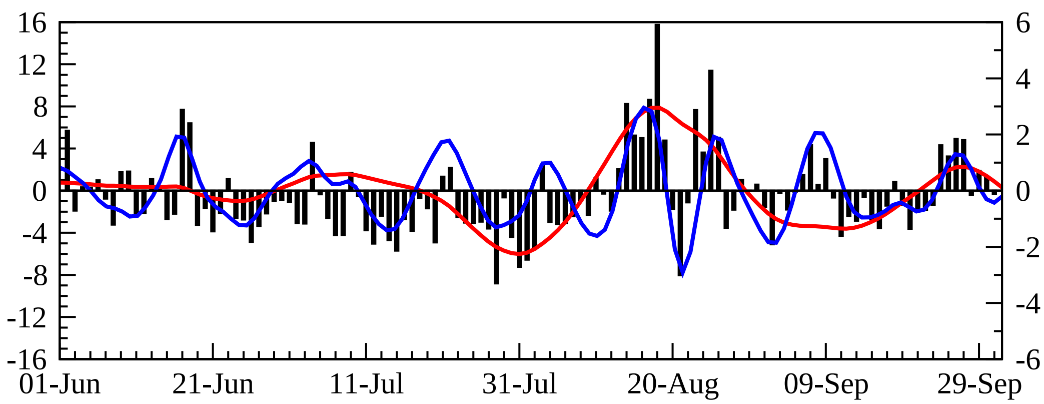


Fig. 5 contd.

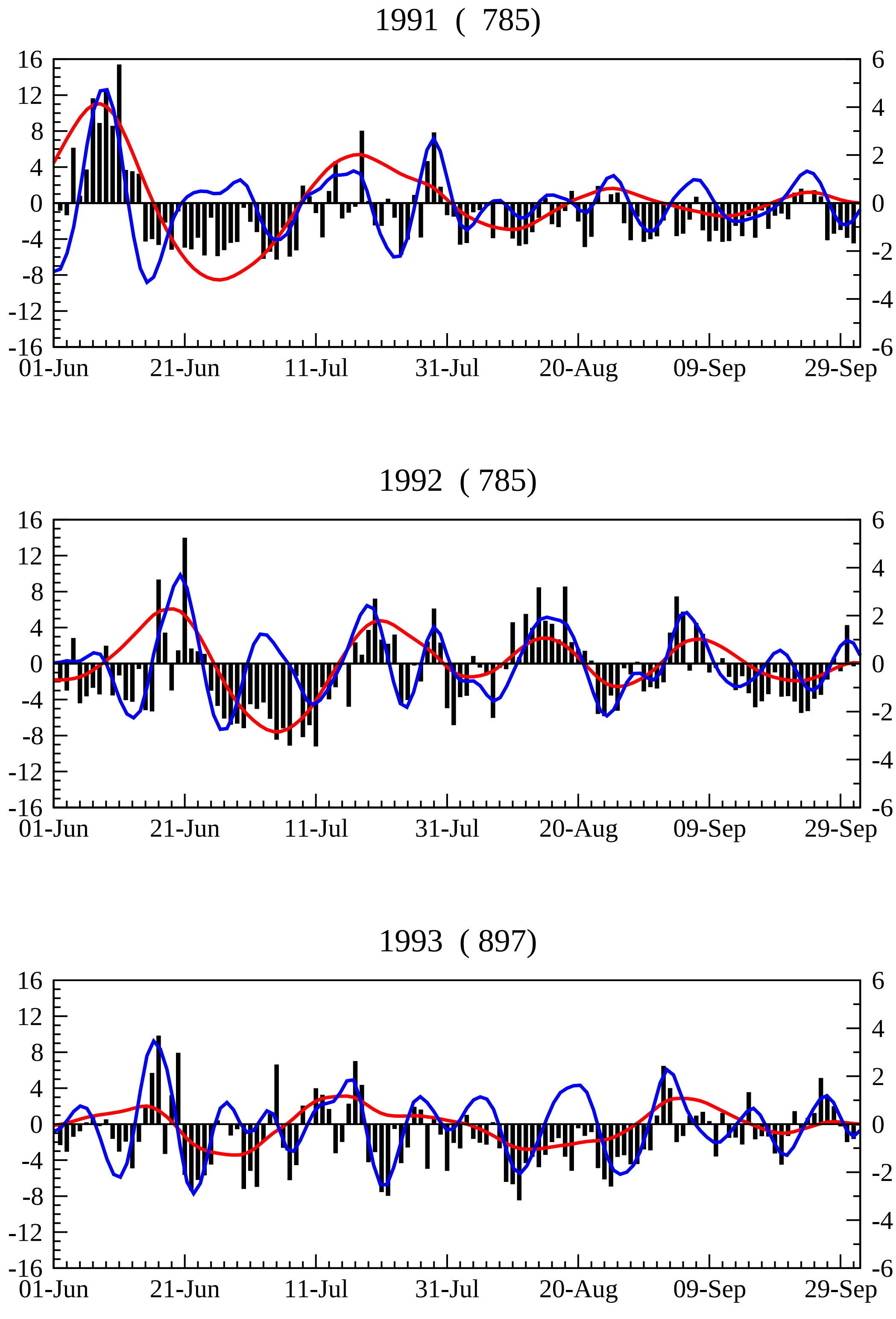

1991 (785)
1992 (785)
1993 (897)
16
12
8
4
0
-4
-8
-12
-16
6
4
2
0
-2
-4
-6
01-Jun
21-Jun
11-Jul
31-Jul
20-Aug
09-Sep
29-Sep

Fig. 5 contd.

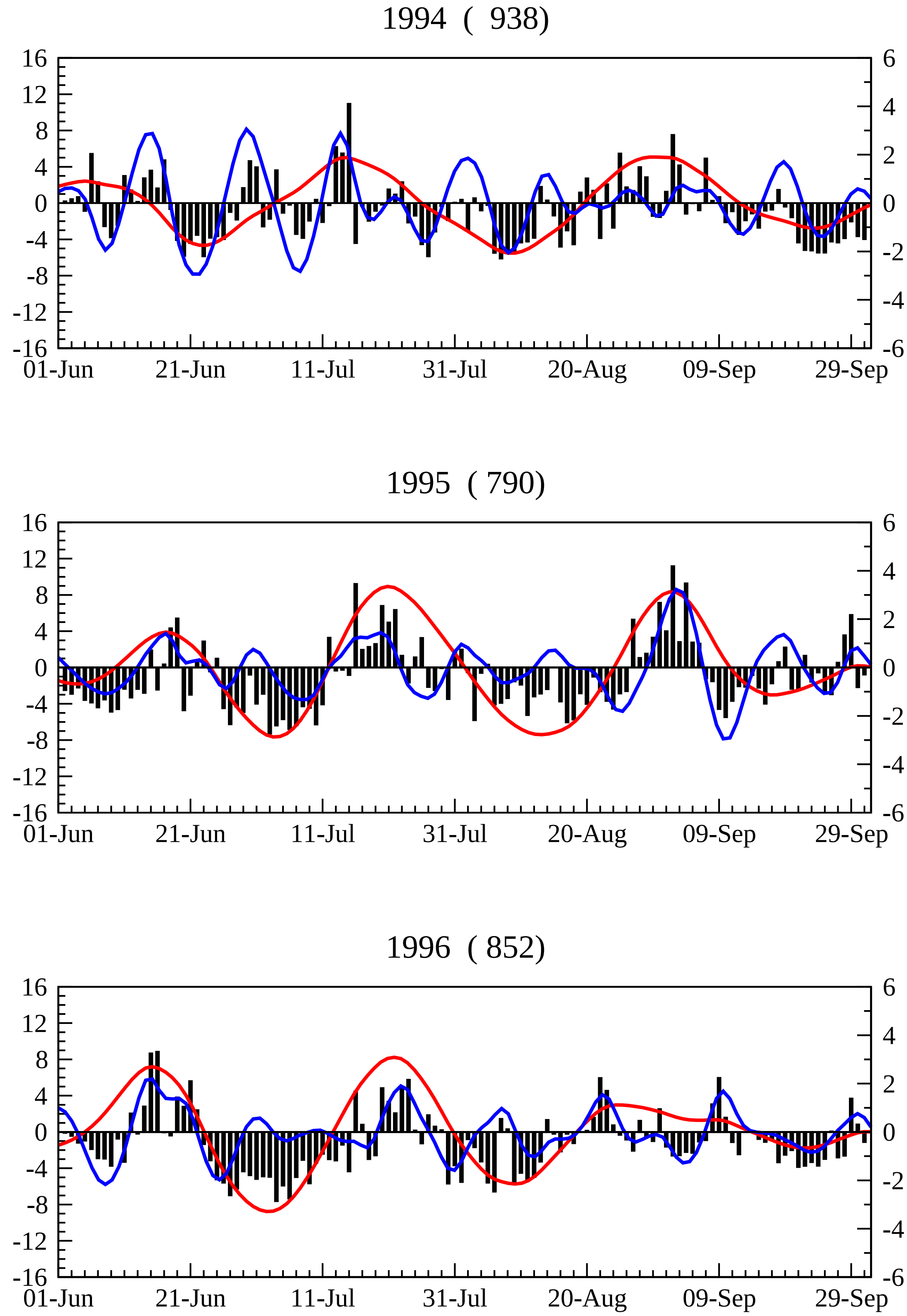
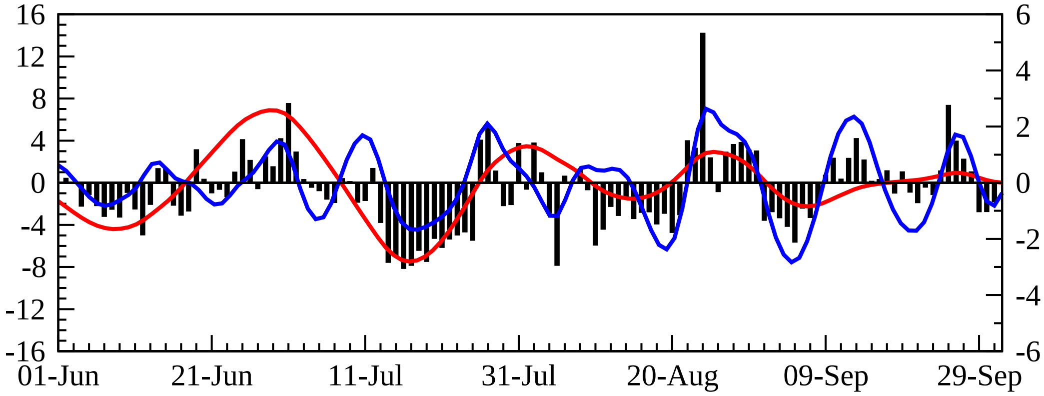
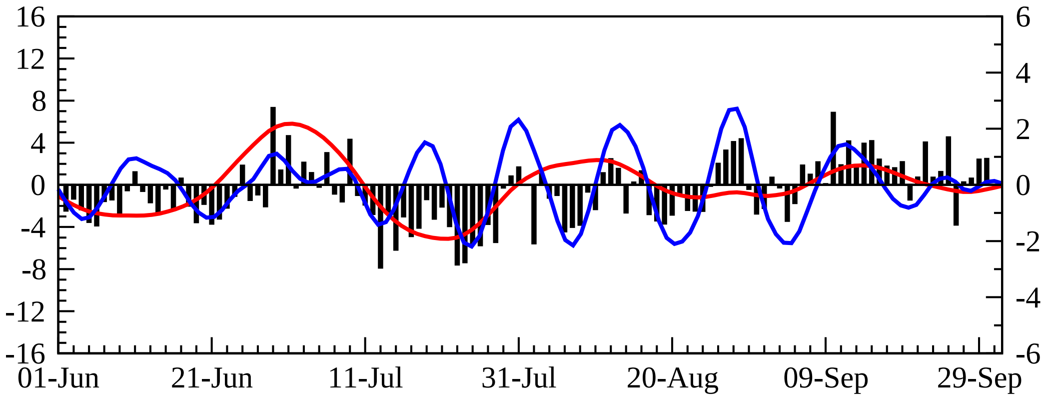

1994 (938)
1995 (790)
1996 (852)
16
12
8
4
0
-4
-8
-12
-16
6
4
2
0
-2
-4
-6
01-Jun
21-Jun
11-Jul
31-Jul
20-Aug
09-Sep
29-Sep

Fig. 5 contd.

1997 (871)



1998 (851)



1999 (821)

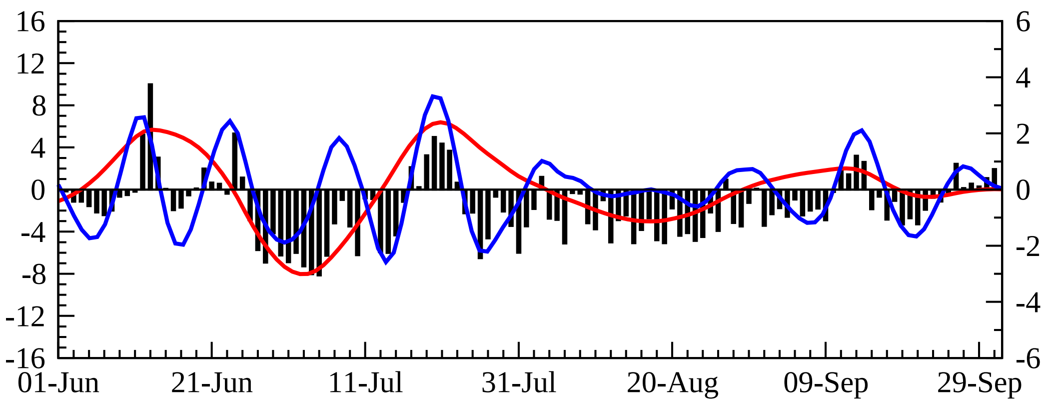
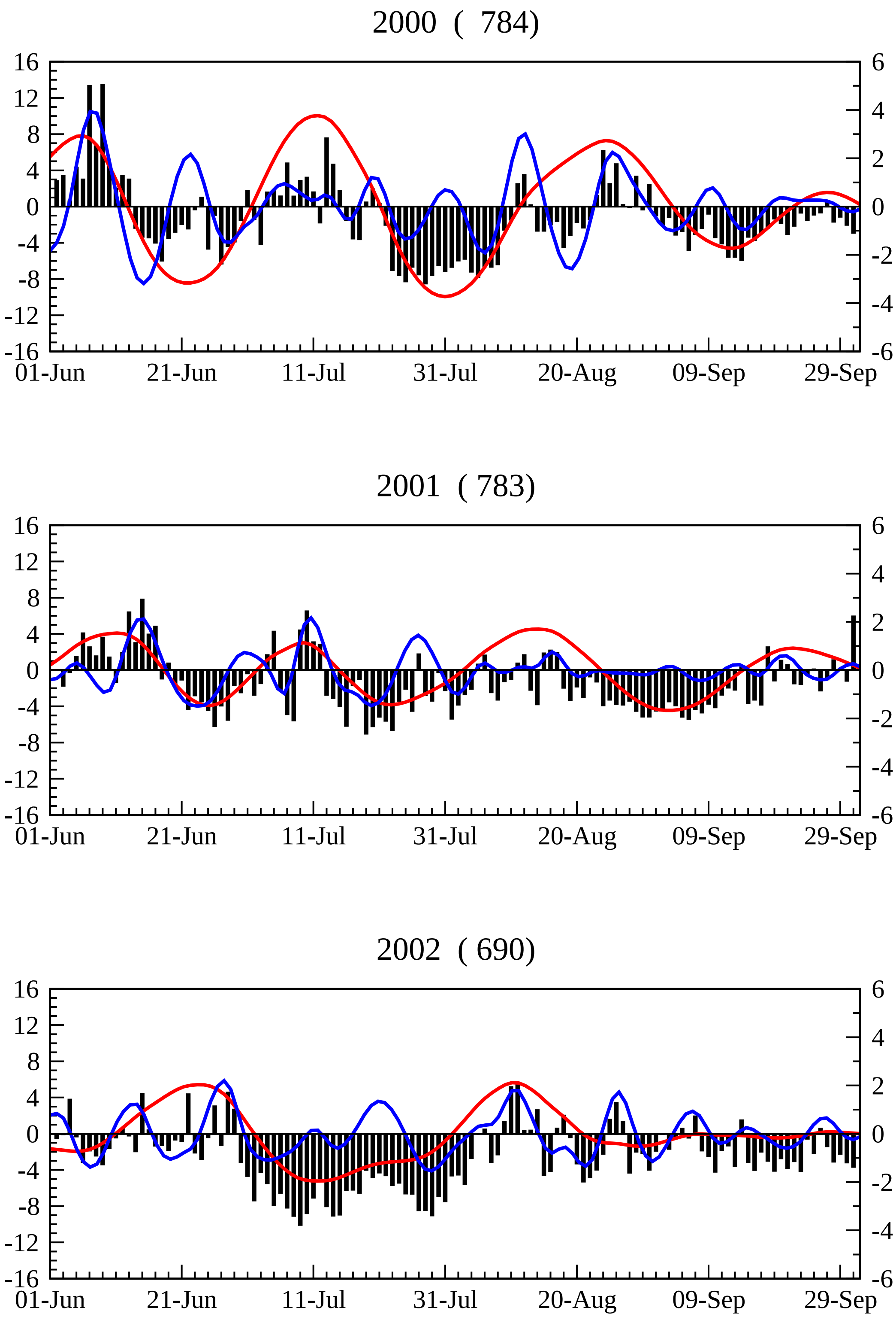
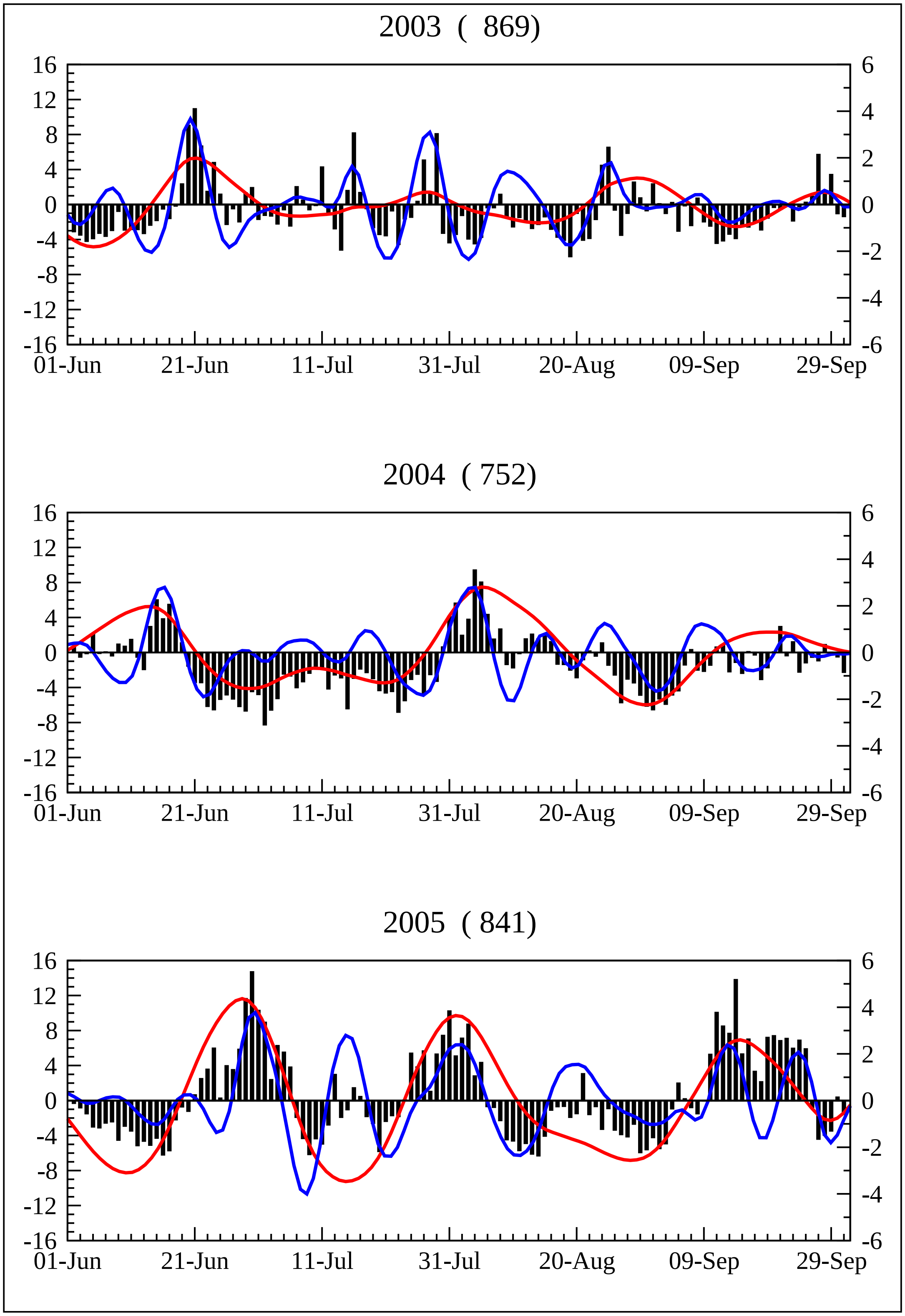


Fig. 5 contd.



2000 (784)
2001 (783)
2002 (690)
16
12
8
4
0
-4
-8
-12
-16
6
4
2
0
-2
-4
-6
01-Jun
21-Jun
11-Jul
31-Jul
20-Aug
09-Sep
29-Sep

Fig. 5 contd.


2003 (869)
16
12
8
4
0
-4
-8
-12
-16
6
4
2
0
-2
-4
-6
01-Jun
21-Jun
11-Jul
31-Jul
20-Aug
09-Sep
29-Sep
2004 (752)
2005 (841)