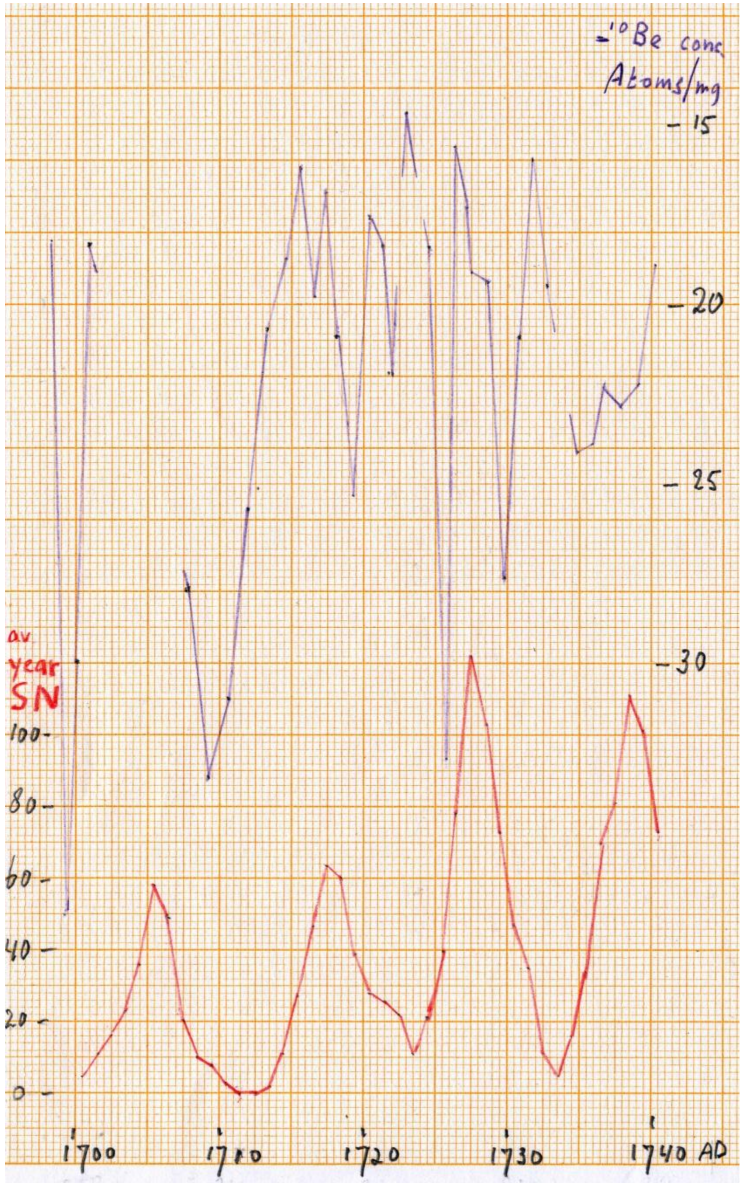
Tracing 300 and 600 year Solar Proton Events by high resolution 10Be data.

FIG13 part 1



High resolution ^{10}Be data Antarctica

In the 3 parts of **FIG 13** has been made the 60 cm long purple curve of the -^{10}Be concentration from 1698 AD to 1994, following the Siple Dome tables and the red curve of the average yearly counted sunspot numbers (SN). For these graphics in curves is chosen because they do reproduce the information of the tables about these periods as well as bar charts and are more practical. The curve of the -^{10}Be concentration in atoms/mg connects the different average values from periods of about 0,5 to 2 year, following the tables of Nishiisumi ea. Over some periods the ^{10}Be concentrations are not examined and these are here to be seen as gaps in the curve. Unfortunately in the dates of the 20th century are so many large gaps that comparison of the purple and red curve here becomes difficult.

Mainly at **FIG 13 part II** it strikes that the long term connection between the SN and the ^{10}Be is rather good as in **FIG 12**. Now however it comes true the connection on the short term of the 11 year sunspot cycle is less. Moreover are in some periods very capricious up and down deflections in the ^{10}Be curve that seem not to have connections with the annual sunspot numbers. By further consideration, however the suggestion may arise that the changes in the ^{10}Be conc. anyhow are witnessing the 11 year sunspot cycle, but in a bi- or more phasical way and that this occurs in some sunspot cycles in an extreme way. The picture of this curious behavior of the ^{10}Be curve and thus the magnetic field in relation to the sunspot number did rise two questions: What is the connection between the SN and the ^{10}Be in a still smaller time scale than about 1 year? What happened in these cycles with the extreme deflections? In answer to the first question I made FIG 14 with curves to compare the monthly averaged sunspot number of two solar cycles with the ^{10}Be conc. For the second question I did some historical investigation and found surprising good confirmation for the suggested sharp fluctuations in the magnetic field. Indeed strong magnetic storms did arise at the time with the speed changes in the ^{10}Be and thus the magnetic field around the Earth.

FIG 13 part II

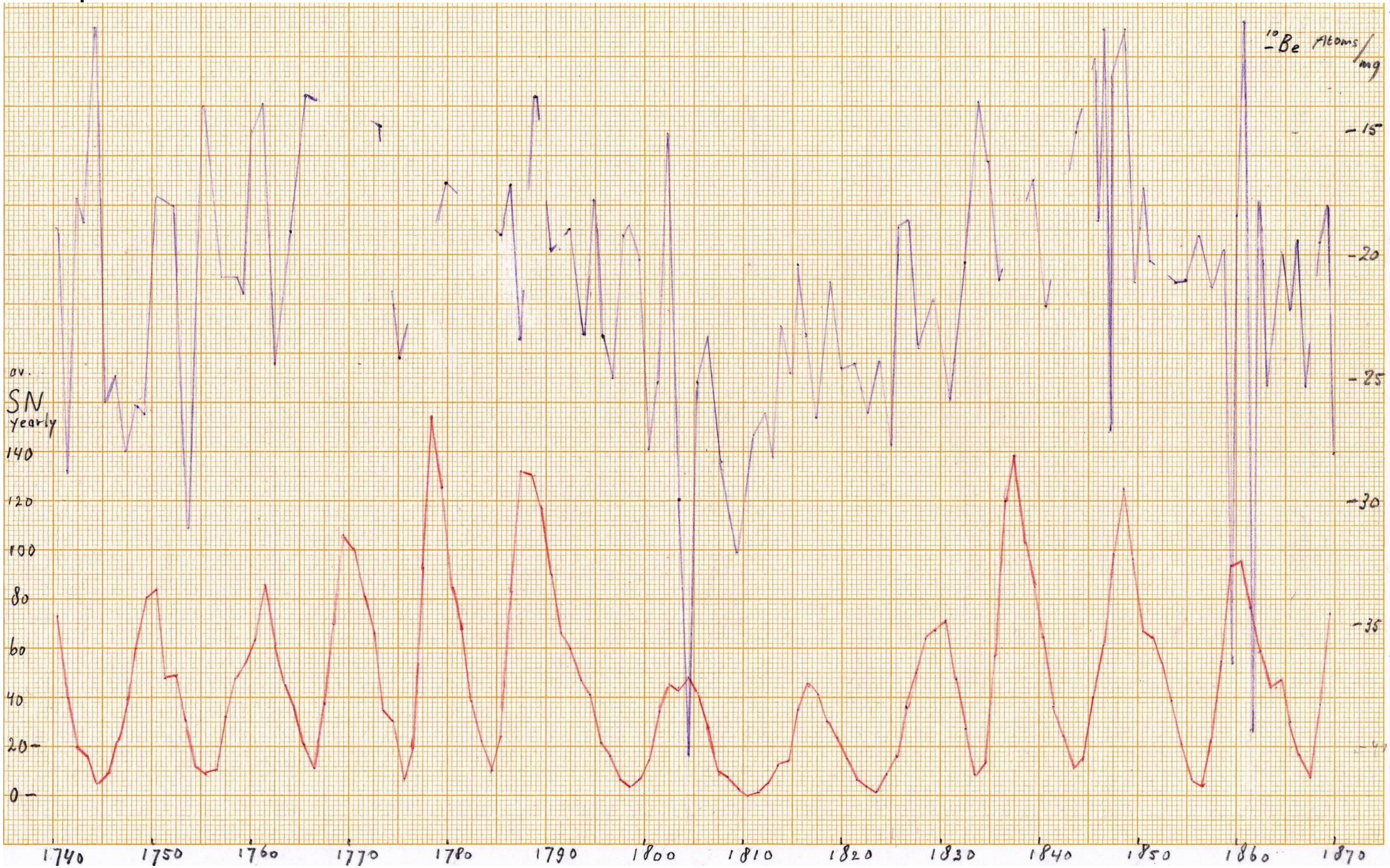
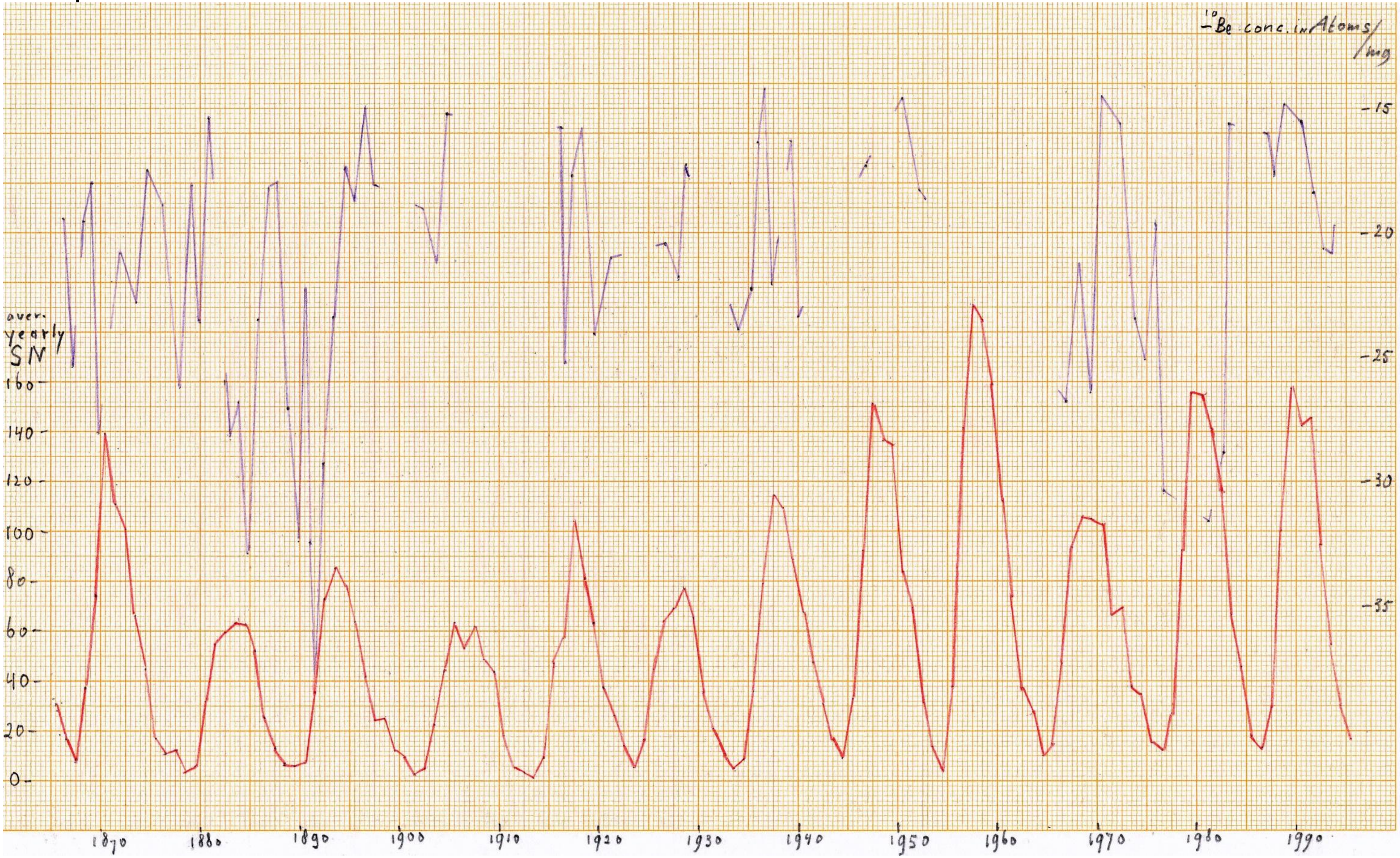


FIG 13 part III



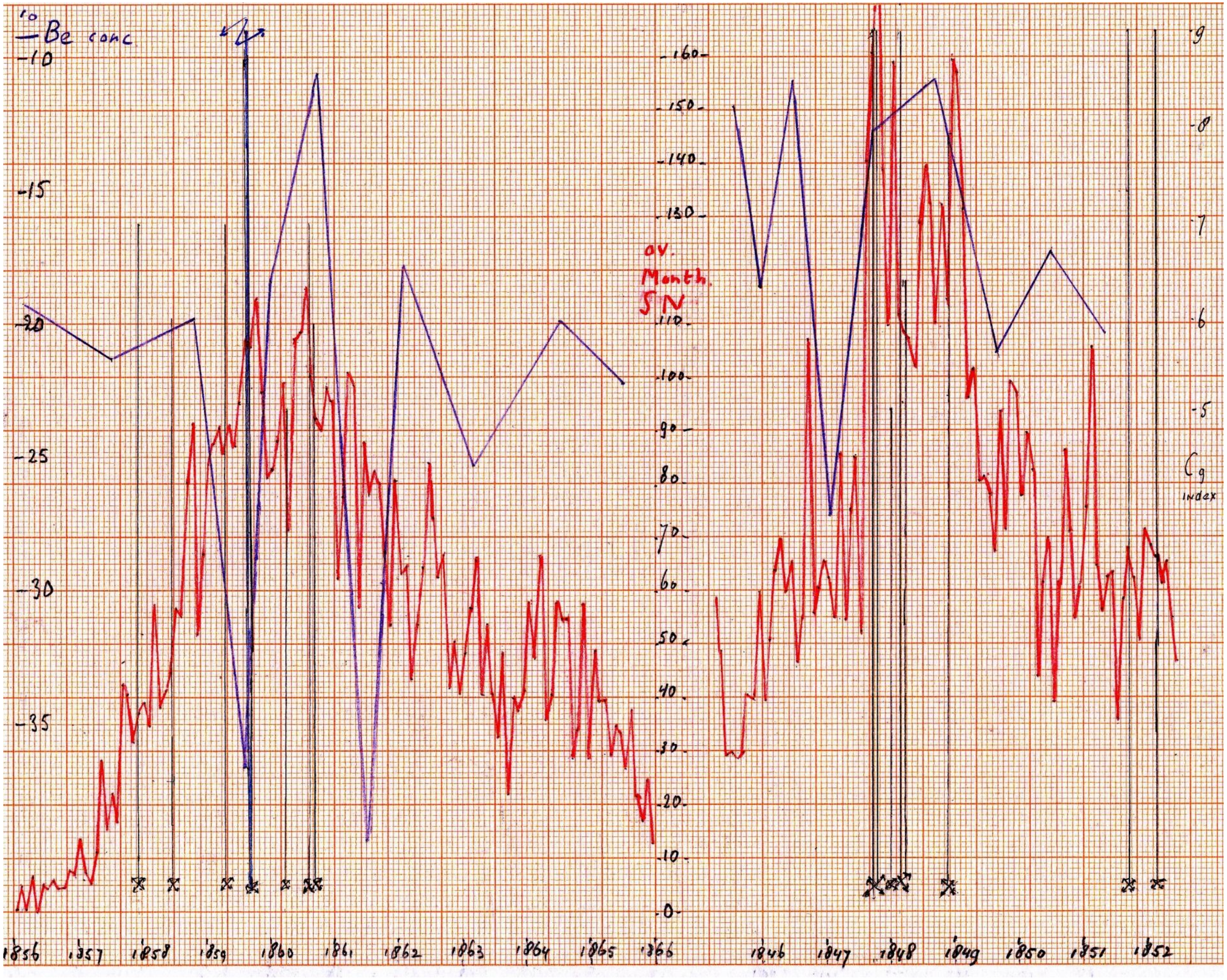


FIG 14

In **FIG 14** the purple curve of the ^{10}Be from the Siple Dome ice core can be compared with the red curve of the average monthly sunspot number in the 10th and 9th solar cycle. The magnetic storms are drawn in as black lines with crossing arrows and with a thick line for the extraordinary storm of aug-sept 1859. The data for the magnetic storms are taken from Heikki Nevanlinna; the C_9 index of st Petersburg as described in that study here is used in the graphic. The time resolution of the ^{10}Be data is the same as in **FIG 13**. The dating of the matter from the ice core layers must be expected, I think, not to be totally accurate for this time scale.

Nevertheless the connection between the changes in the ^{10}Be concentration and the occurrence of the largest magnetic storms is very good. However, for the time of the large magnetic storms of 7 Sept 1851 and 18 Febr 1852 no ^{10}Be concentrations are available for comparison. Also now seems to be a good correlation between the monthly SN and the ^{10}Be concentration for the 9th cycle, so that at that period the magnetic 'firework' also is to be seen in the monthly SN. The SN in fact did have an irregular course in this cycle: The SN was for instance on 36 on August 1st 1847 and 254 on the 16th of August 1847! This is however less the case for the 10th cycle. On the scale of the monthly SN in this curve is maintained the problematic up and down relation of the SN and the ^{10}Be curves that also exists on **FIG 13** with the SN timescale of 1 year. On the daily SN, however, also here some irregularity is to be seen, that is connected with the occurrence of the magnetic storms.

These magnetic storms are very well documented for the period of the 9th and 10th solar cycles (maxima at 1848 and 1859). Also exists some documentation about the magnetic storm(s) of the 5th cycle: In 20 December 1806 on his research to the geomagnetic declination, Alexander von Humboldt [1] observed magnetic fluctuations and extraordinary Aurora Borealis in Berlin at the same time. For the first time that situation was called than magnetic storm and later on scientists speak about geomagnetic storms. However, this should be mentioned properly helio-geomagnetic, because only one integrated magnetic field exists of the Sun and the Earth. This magnetic Sun-Earth connection became evident at another remarkable event: On 1 September 1859 on 11.18 h GT the British astronomer RC Carrington saw by his daily observation a sharp white light at the sun. This flare was located near large sunspots. It expanded fast and fainted away in 5 minutes. The evening of the next day was impressive Aurora in London and also at places of lower altitude as Rome and even at tropical locations as Cuba. 2 September at 5.30 the solar storm arrived on Earth. The 19th century scientists did record this event accurate: [2] At the moment of the sun flare the magnetograph describes the 'crochet', which arises at the moment of the flare by the field that the X-ray radiation of the solar flare provoked in the ionosphere, further how 17,6 hours afterwards the storm begins, but then the pen is driven off scale. Another registration, that of Colaba, Bombay, was totally accomplished and the deflection should be consistent with a Dst index of -1760, following Tsurutani et al. This is probably much larger than the power of the magnetic storm of March 1989 that destroyed the large power grids of Québec, Canada. The very fast moving and changing magnetic fields in 1859 also caused strong electric currents in conductors on the surface, but in that time there were only telegraph cables. In our time a magnetic storm of the size of that of 1859 should cause enormous damage in power grids, on satellites, on computers etc. The storms of the 9th solar cycle with its maximum in 1848 also are well documented. Heikki Nevanlinna [3] studied the large storm of 1859 from the data in Helsinki and st Petersburg and compared the data of different magnetic storms from the period 1847 – 1860 and after 1868. Since 1868 the magnetic activity is uniformly recorded [4] in England and Australia with the aa index in nT. Before that there were local different indices as the C9 index in st Petersburg that is not simply to convert into the aa

[1] See this data from the encyclopedia: http://www.phy.uni-bayreuth.de/theo/tp4/members/EncyGeo/humboldt.pdf and BT Tsurutani, in The interplanetary causes of magnetic storms, substorms and geomanetic quiet, see http://trs-new.jpl.nasa.gov/dspace/bitstream/2014/12903/1/01-1269.pdf . For the research to the geomagnetic inclination and intensities: Edward Sabine, Report on the variations of the magnetic intensity observed at different points on the Earth's surface, London 1838, page 52, http://books.google.nl/books?id=mdA4AAAAMAAJ&pg=PA54&lpg=PA53&ots=Sjm7nyROyl&dq=humboldt+1805+magnetic#v=onepage&q=humboldt%201805%20magnetic&f=false

[2] See EW Cliver and S. Svalgaard in The 1859 Solar-Terrestrial disturbance and the current limits of extreme space weather, in Solar Physics (2004) 224: 407–422. http://www.leif.org/research/1859%20Storm%20-%20Extreme%20Space%20Weather.pdf and Tsurutani, B. T., Gonzalez, W. D., Lakhina, G. S., and Alex, S.: 2003, *J. Geophys. Res.* **108**, No. A7, 1268 10.1029/2002JA009504.

[3] See A study on the great geomagnetic storm of 1859: Comparisons with other storms in the 19th century, Heikki Nevanlinna in Advances in Space Research 38 (2006) 180–187, http://www.ava.fmi.fi/MAGN/HN/1859st~1.pdf

[4] See for the geomagnetic data http://www.geomag.bgs.ac.uk and ftp://ftp.ngdc.noaa.gov/STP

index. The Helsinki activity index gives data that should be compatible with the aa index, but because of the difference in location not easily to be compared with the British-Australian data. Heikki Nevanlinna give an aa value for the 1859 storm of 400, but because of many gaps in the Helsinki data this is an estimation. This may be an underestimation, I think, because of the Colaba registration of -1760, but this measurement is in a tropical location. In the comparison Heikki Nevanlinna the 1859 storm still is very large in the 1847 – 1860 period and even to present. In the graphic of Nevanlinna over 1844-present magnetic storms it however strikes that there are indeed somewhat more large storms during the modern solar maximum, but the storms now are not larger than in the 19th century. Also the Aurora observations indicate the large size of the storms around the solar maximum of 1848: JM Vaquero[5] ea describe the occurrence of Aurora's during the storms of 24 Oct. 1847 and 17 Nov.1848 in southern Spain, near Cadiz (36,5 North) and Cartagena (37,6 North). Also were severe disturbances at the telegraphic communication in different countries by the storms of 1847; 1848; 1851; 1852 and others, see **http://aurora.fmi.fi/gic_service/images/EffectsList.pdf**

Already these data give good evidence for the reliability of the ^{10}Be concentration and flux as a proxy for magnetic solar activity. The more so as some points still must be taken into account: The SN is determined by only one aspect of the helio-magnetic activity, but the ^{10}Be production in the atmosphere is determined by the helio-geomagnetic field. The interaction of the magnetic field of the Earth by the changing magnetic field of the Sun on location is very important for understanding the converses in the ^{10}Be. The cloud of solar plasma that reaches the Earth brings a complicated magnetic field which is determined by the density of the cloud, the speed of the loaded particles and their direction. Dependent on the direction of the preexistent geomagnetic field at that location and the direction of the field lines of the moving plasma, the local magnetic field may be strengthened or weakened. Also the direction of the field lines is changed by the passing plasma clouds of the Sun. This can be examined easily on the surface with magnets as compass needles. After a short time when the bulk of the plasma has passed the compass needle becomes quiet and follows the again dominating geomagnetic field, indicating the magnetic North. On some distance from the surface the preexistent geomagnetic field may be longer changed or disturbed by the solar plasma because some smaller quantities of loaded particles still arrive from the Sun and may also stay there, turning around the Earth by the gravity of the planet. That means for the ^{10}Be production very near to the magnetic pole mostly decrease, because the normal geomagnetic field there is feeble, with field lines straight to the surface that cannot stop the cosmic radiation, so that the Sun only can strengthen the field on that location. On a smaller (geo)magnetic latitude the field lines will become more oblique by the magnetic cloud and the field thus becomes more feeble as protector against the cosmic radiation. The cosmic radiation and the production of ^{10}Be will thus often rise by the interaction of the plasma clouds near to Earth. The distance of the location Siple Dome from the magnetic and geomagnetic poles is not very large, but still some 3000 and 2000 km. The effect of the arrival of a magnetic cloud on the ^{10}Be production at that place will probably be some decrease. The precipitation of ^{10}Be with the snow there will decrease at first, but after some time the precipitation may increase sharply, because than arrives the large amount of ^{10}Be that was produced in areas on lower latitude in the atmosphere above Siple Dome. The precipitation than diminishes again if the helio-geomagnetic system again is stabilized, but this may last much longer than is to be seen on the compass needles on Earth, because of the larger influence of the Sun and smaller of the Earth on the magnetic fields at a somewhat longer distance from the surface. Much further in the solar system of course only is the influence of the complicated moving and changing magnetic field of the Sun and more activity in this without disturbance of the field of the Earth always means better protection against cosmic radiation and decrease of ^{10}Be production. This is to be seen in the long term resolution of the ^{10}Be in a good correlation with the SN. The short and very short term resolutions of the ^{10}Be concentration and

[5] See: Sporadic aurora from Spain, J. M. Vaquero ea, *Earth Planets Space*, **59**, e49–e51, 2007, http://www.igidl.ul.pt/Ricardo/Vaquero_Trigo_Gallego_2007.pdf

flux, however may be very sensible proxies for changes in the geomagnetic field by magnetic plasma clouds from the Sun.

General and local effects of solar activity

The solar wind is present in the total heliosphere, that is in the total solar system and even far beyond the orbits of Neptune and Pluto. That solar wind is the corpuscular radiation from the Sun and carries with it magnetic activity into space, generated by the energy of the Sun. Those magnetic fields are created by the tumbling over of the charged particles (ions) in the solar wind, so inducing electric currents and electric-magnetic fields. Increase of the solar wind in all directions over some period of time causes increase of the size of the heliosphere and the intensity of its magnetic fields. As a consequence of this less cosmic radiation can penetrate into the solar system. The signs of the scientific observation of increasing solar wind are: decreasing production of the radionuclide's as is 10Be at the longer term; increase of the sunspot numbers, also at the longer term, so between the maxima in the 11 year cycles; increase of the longer term observations of disturbances at the natural magnetic field on the surface and of the aurora (polar light) especially at lower latitude. That is the impact of the solar wind on the large scale of the solar system. The Earth as well as the Sun is an 'electromagnet' in that both generate magnetic fields by circular movements of charged particles, so by circular electric currents, within the body of the Sun and Earth. The magnetic field of the Earth exists also at some larger distance of the planet because it is carried, like the Sun's, by charged particles that are held in specific movements by the gravity- and the magnetic field of the planet. That charged particles, however are produced by the Sun and the cosmic radiation. The magnetic field of the Earth captures the charged particles and keep them in the van Allen belts. The circular moving particles on their turn induce magnetic fields and so strengthen and enlarge the geomagnetic sphere. The solar wind in the neighborhood of the Earth is variable and some stronger events cause geomagnetic storms. The van Allen belts, which are the conveyer belts of the charged particles around the planet, are overloaded than and the particles stream into the atmosphere. Those streaming charged particles are electric currents and they cause radiation of light in specific colors by ionizations of the gas molecules in the atmosphere, in the same way as in a tubular lighting. This phenomenon is the aurora or polar light. The strongest geomagnetic storms, however, will disturb the magnetic field of the Earth in a way that is well measurable with magnetometers on the surface. The field lines around the Earth may be sharply deviated by the strong solar storm, the passing magnetic plasma cloud of the Sun. By these violent movements the geomagnetic sphere may be weakened and shrunken, because many particles may leak into the atmosphere or are taken away by the passing plasma cloud. The relation between these geomagnetic signs and the number of the sunspots (SN) should be obvious: The SN is a proxy of the general magnetic solar activity and the aurora and geomagnetic variations are the local consequences of it on or nearby Earth. The surface of the Sun often is turbulent and sometimes by this large quantities of plasma, so charged particles, are blown from the solar corona into space. This happens mostly in periods with much solar activities, but may occur also in relative quite periods. Most of the magnetic plasma clouds travel through the space at large distances from Earth, but sometimes Earth is hit by a passage at small distance of even with a direct hit. Besides the distance, the size and intensity of the magnetizing clouds of charged particles also the situation of the magnetic field of the Earth itself is important for the consequences. The impact on Earth is based on change of the existing magnetic field, so inducing electric currents in the atmosphere and on the surface. By the electric currents some atoms high in the atmosphere are ionized and begin to radiate specific quant's of light when the atoms fall back to their basic state of energy. This is visible as the aurora. Also on the surface electric currents pass through conductors as are the cables people use for communication or transport of energy. That cables and other technical stuff of people may be damaged if the current generated by the solar storm is relative strong. Possibly those electric currents on the surface sometimes may be so strong that they are able to cause electrolysis in the oceans. I think no specific scientific observations can confirm this, but it is theoretically possible that the magnetic fields from the sun and their currents are strong enough to cause some electrolysis in the oceans for months or years. Consequences of such events must be traceable by the chemical changes they cause as in the pH of the ocean and the release of hydrogen gas into the atmosphere, which can be found within the small gas bells in the ice cores. At the available scientific observations of the events the solar storms cause on Earth are the measurements of the direction magnetic field lines on the surface by magnetometers and the observation of the aurora intensity especially at lower geomagnetic latitude. Data of the geomagnetic field are standardized as the aa index and are measured in this since 1868. The aa indices are published on the site of the British Geological Survey and the NOAA site, see footnote 47. In another publication of Heikki Nevanlinna[6] are more able graphics of the magnetic intensities over the period 1844 -1912. Also exist graphics about the Aurora, as the number of the nights with Aurora in Tromsö, published on internet by Jennifer MCClure [7] . These data can be compared with the proxy of the general solar activity the number of the sunspots (SN) as is done here in **FIG 13 part IIIb**. The new data however of the radionuclide's as ^{10}Be with high time resolution give a more clarifying insight in these events and I think they are until now not seriously studied for information about this important problem. The events at the large magnetic storm of 1859 are to be seen on **FIG 14**. At the time of the magnetic storm, less than 18 hours after the solar flare, the global 10Be production is sharp increased for a short time, but the precipitation of the ^{10}Be by this is large in a longer period. This probably is caused by the cosmic radiation the sun itself has produced now. By such a direct hit of a solar CME very fast protons of the Sun can reach Earth within some 15 minutes and can split nitrogen atoms in the atmosphere, so producing ^{10}Be as does the cosmic radiation. The bulk of the plasma cloud, however reaches Earth after 18 hours and causes magnetic changes. The effect of these magnetic changes only is to be seen in the ^{10}Be concentration after the ^{10}Be produced by the solar flare or CME has disappeared from the atmosphere, which may last 1 to 2 years. The magnetic plasma cloud also may cause more phasic effects on the ^{10}Be concentration at a location as Siple Dome as described here above. The magnetic field around the Earth also may fluctuate for a longer time after this large impact. It seems probable that parts of the magnetic cloud will stay in the neighborhood of the Earth because of the gravity of the planet, but will only gradually be transformed and arranged following the lines of the Earth's magnetic field at some larger distance of the planet. So some years after the magnetic field on the surface is normalized following the magnetometers and compasses, this is not the case at some distance from the planet. The strange magnetic field there keeps to interfere with that of the Earth.

Stronger geomagnetic storms at long term solar minima.

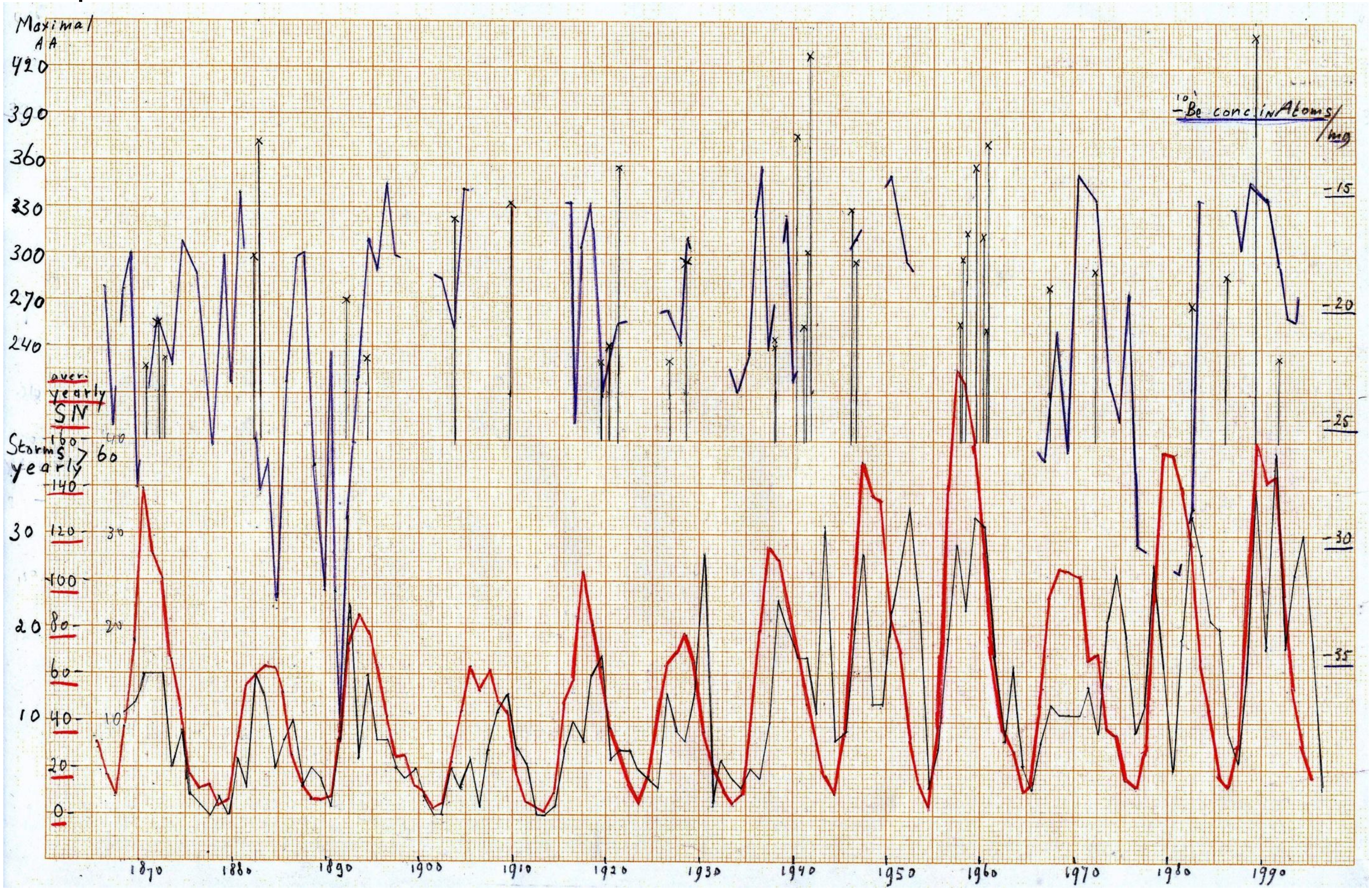
This study also gives some indications about the relation between solar activity and the occurrence of magnetic storms. As expected all the storms do occur in or near to the maxima in the 11 year cycle and there is a good positive connection between the magnetic storms and the SN in the 11 year solar cycles. The curves of **FIG 13 part II**, however indicate that the long term variation in SN and magnetic activity of the Sun has a negative connection with the occurrence of large magnetic storms: Thus the chance on a large magnetic storm may be larger during a period minimal to moderate SN at the 11 year maxima than in a period with a grand solar maximum. The ^{10}Be data on these data of about 300 years do give an indication for this. It strikes for instance that in the Dalton minimum should have been some strong magnetic storms. Also the historical data about abnormal Aurora, electric currents and geomagnetic measurements indicate: the largest magnetic storms in the 19th century were heavier than in the 20th century with its grand solar maximum. The data about this however are too few and incomplete, so that there is no strong evidence. Anyway also the knowledge about the physical causes of magnetic storms should confirm this, I think, although I cannot find direct information in the consulted literature about the relation between the long term solar variation and the occurrence of magnetic storms, see Tsurutani: http://trs-new.jpl.nasa.gov/dspace/bitstream/2014/12903/1/01-1269.pdf and the Max Planck Institut: http://www.mps.mpg.de/de/publikationen . The issue than is that the geomagnetic field in a period of a grand solar maximum may be

[6] Results of the Helsinki magnetic observatory 1844 -1912, H. Nevanlinna in Annales Geophysicae (2004) 22: 1691–1704, http://hal.archives-ouvertes.fr/docs/00/31/73/52/PDF/angeo-22-1691-2004.pdf

[7] See http://www.iop.org/activity/groups/subject/env/Essay_Competition/file_9280.pdf

more resistant to the many ‘attacks’ of the large magnetic clouds in her neighborhood. This seems plausible because the continuous solar wind is stronger and the size of the heliosphere larger during the long term maximum. This makes the shock smaller that the large and fast magnetic clouds can provoke on the geomagnetic field. Also the geomagnetic field indeed is larger by that larger continuous solar wind, because more charged particles of the sun were entered into the magnetosphere of the Earth and are kept within it. The magnetic field of Earth is still more fed by the charged particles of the Sun during the (sub)storms of the former 11 year maxima, also that particles cannot easily escape from it. By all this the geomagnetic field is larger and stands more stiff in the solar wind during a grand maximum. A huge magnetic storm by a direct hit of a very large CME may nevertheless damage the geomagnetic field, causing loss of loaded particles and enfeeblement for some time also in a grand solar maximum. It, however seems probable that this is more likely to happen in a period of moderate or low solar activity, when the geomagnetic field is smaller and softer. The damage by the storms than can make the field still more weak for a longer time in such periods. So a good model for insight in the arise of magnetic storms by the long term variance in solar activity is the picture of a flag in the wind. The wind than is the solar wind or pressure of the interplanetary gas (plasma) and the flag is the Earth’s magnetic field. If the wind blows hard the flag clappers: It moves with high frequency and low amplitude by the variations in the wind. If the wind is feeble the flag is waving and it moves with low frequency, but with large amplitudes. These large amplitudes in the movements of the geomagnetic field are the large magnetic storms. The measure of the movements of the magnetic field and not its size, induces electric currents and brings the energy of the plasma clouds to the Earths’ atmosphere and surface. **So if the sun becomes quiet, we should become disquiet and take measures to prevent the enormous damage by the large magnetic storms.** The Sun now is in a decline since 1960 in the sunspot numbers. Some researchers forecast more decline of the Sun. Anyway it is probable that the Sun will have a more moderate activity in the 21st century than in the 20th century, when he was very active in the scale of 10000 year. Also is possible the Sun now comes to a grand minimum. This all will enlarge the change on dangerous large magnetic storms! This is still speculative, but also a possible rising change on these problems is a good reason, I think, for scientists to make more study of the relation between the occurrence of large geomagnetic storms and the long term variation in the magnetic activity of the Sun.

FIG 13 part III b



Also on **FIG 13 part III b** are given some data about the magnetic activity in comparison with the radio nuclide proxy ^{10}Be and the SN. As in **FIG 13**: The purple curve of the -^{10}Be concentration following the Siple Dome tables and the red curve of the average yearly counted sunspot numbers (SN). At the red curve of the SN now has been drawn a black curve of the number of the yearly magnetic disturbances [8] with an AA index ≥ 60. At the top op **FIG 13 part III b** between the purple curve of the ^{10}Be now are given the 35 largest magnetic storms over the period 1868-1995 following the AA index [9]. These storms have been drawn as vertical black lines with the little x on the top. Unfortunately the gaps in the ^{10}Be observations make comparison difficult. As the cause of those gaps probably is: problems in dating back the superficial snow and ice layers within this time resolution, because of irregularities by compilation in snow storms, the reliability of the here given data of the ^{10}Be concentrations in these very superficial layers must be also less. There is anyway also here an indication for connections between the occurrence of the larger magnetic storms and the sharp changes in the ^{10}Be. There are many storms at and shortly after the maximum of 19th solar cycle in 1957, which is a grand maximum in the longer term solar variability. The largest storms, however were at some distance of that grand maximum in 1941 and 1989. So the indication of **FIG 13 part II**: at a period with smaller solar activity(in SN) the chance on large and harmful magnetic storms becomes larger, here also is present but less obvious. The occurrence of the many much smaller magnetic disturbances, as given on the black curve, further has a better connection with the ^{10}Be than the SN's do. This curve of the number of the many, mostly small to moderate magnetic disturbances is well known and it is also published on the here referred NOAA site. These data of the AA index from magnetometers in observatories in England and Australia cover the long period from 1868 to present. It strikes on these curves that the magnetic activity increases to the grand maximum of about 1960 and then maintains that high level also in the last solar cycle, which is not drawn in the curve here. Whatever may be the cause of this remaining high level of moderate magnetic activity, it will protect, I suppose, the geomagnetic field against large and harmful disturbances by direct hits of the magnetic plasma clouds from the Sun. If the magnetosphere of the Earth is no longer fed by so many charged particles, it will become more vulnerable for these large magnetic clouds. This vision, however may be a debatable jumping to conclusions in the very complicated problem of the magnetic field of the Earth. This field or terrestrial magnetosphere primary is determined by the existence and movements of liquid and solid iron and nickel within the Earth. By this field and the gravity charged particles from the Sun are captured. In this the field is like a trap for the particles: they can enter the magnetosphere by some holes, but they cannot leave it. On the other hand also all the charged particles, or plasma, from the Sun creates their own magnetic fields and only as far as the magnetic field of the Earth dominates and determines the direction in the movements of the charged particles, so far reaches the magnetosphere of Earth. In spite of the experience of 200 years in measurements by magnetometers on the surface it still is difficult to get a good insight in the size and intensity of the magnetosphere. The results of these measurements depend on the location of the observatory. If more observatories are used also the extreme values are more moderated. So the ap and AP index from 13 observatories, which are registered since 1932, differ from the aa index in that both indices describe the same storms with somewhat different values, so that the sequence and the threshold values also are different. More important is the question whether the parameters by magnetometers, so the magnetic flow, will describe well the potential energy of the field, thus the capacity to induce electric currents in conductors. This yet is the speed in the change of the magnetic flow as it also is in the simple dynamo of your bike: by cycling faster the electric current increases and the lamp gives more light. For this the observations of the very currents and the occurrence of the Aurora on smaller magnetic latitudes is a better parameter than the magnetometers, I think. Following the Aurora observations the magnetic storms of the 19th century, at periods with smaller SN's, should have been larger than those of the 20th century.

[8] The geomagnetic data are taken from the tables, published on the sites: http://www.geomag.bgs.ac.uk and ftp://ftp.ngdc.noaa.gov/STP

[9] The AA is the maximum average 24-hour global magnetic disturbance based on linear aa, the average of the nearly antipodal observatories in England and Australia.

High resolution ^{10}Be data Greenland

Lately also became available high resolution data from the NGRIP ice core (75° North) by the publication of A.M. Berggren, J. Beer ea [10]. The tables show nearly complete averaged annual values of the ^{10}Be concentration and flux over the period 1389 -1994 AD. In this article the authors did compare these data with the data of the Dye 3 ice core (65° North) over about the same period in 14 cm long curves. Unfortunately I could not find the tables of the Dye 3 ice core, but I think it also is interesting to draw 120 cm curves from these NGRIP data for studying the course of the ^{10}Be concentration and flux, in comparison with the sunspot numbers (SN), the AA index and the high resolution ^{10}Be data from the Siple Dome Ice core (81° South). In **FIG 15** is show the black curves the annual -^{10}Be concentration. The authors do not give the exact begin and end time of the periods at each the probes for the ^{10}Be determinations, but they should be from annual layers, so each with averaged values of one year, which is given in the curves as a point in the middle of each year. Only in the period 1481 – 1534 the time resolution is a little different, 0,5 – 1,5 year for some intervals. There are only 6 gaps of 1 year and 1 of 3 years in the data as are drawn here in the curves. The red brown curves for the flux are made for better surveyability on a much smaller scale than the curves for the concentration. The actual variation in the flux, however, is much larger than in the concentrations. The ^{10}Be data also here are inversed by x-1 for better comparison with the sunspot numbers and AA index data. The correlation between the flux is globally good but not perfect and seems less here than in the case of the Dome Fuji data of **FIG 12b**. For instance many strong fluctuations in the concentration are confirmed by the flux data (as for 1460), but some are not (as for 1437). The question then raises what approaches the variation in the ^{10}Be production better: the concentration or the flux. This here is probably the concentration, because the concentration gives better information about the production than the flux does in the case of wet precipitation, thus of ^{10}Be together with snowfall. For the dry precipitation the flux is the only measure, because the snowfall will dilute the ^{10}Be concentration in that case. If the climate is not extreme dry the wet precipitation must be dominant: The very fine particles with ^{10}Be are nuclei for formation of water droplets and crystals in the air. Why should crystals with ^{10}Be fall down when crystals without ^{10}Be do not fall? Dry particles with ^{10}Be are still smaller than the ^{10}Be in crystals and will have a very small chance to fall. These are the most essential principles in the ^{10}Be fate in the atmosphere, I think. This topic is described in the literature [RC Finkel, IG Usoskin]. The determination of the ^{10}Be flux further more is questionable in this high time resolution of 1 year. The tables reveal a large variation in the ice accumulation: from 31,5 to 6,7 cm/year. It is not likely that this variation only is caused by differences in snowfall between the years. After the snowfall the wind will of course move the snow and this is the most likely main cause of these large variations in the annual layers here. If this is true these differences in the accumulation by the wind after the snowfall was disturbing for the determination of the ^{10}Be flux in the area as a measure of the ^{10}Be production. In smaller time resolutions the hazardous variation in the accumulation by wind is much smaller by sampling. In very dry climates the wind may have less grip on the snow and perhaps then more reliable calculations are to be made for the flux in a larger resolution. Also is an exact dating essential for the determination of the flux; otherwise you will multiply the concentrations with the wrong accumulations. Exact dating also is very difficult in these high resolution data. So the reliability of the ^{10}Be concentration as a measure for the production here is a priori larger than the flux but it also is debated. This reliability can be tested by comparing far remote data as the Greenland concentrations with those of Antarctica, which excludes bias by common events in the atmospheric and meteorological fields and with data of another origin or fate such as the sunspot numbers, the observed aurora's, the measured geomagnetic storms, the actual measured cosmic radiation in neutrons, the ^{14}C quantities, etc. The light red curve below of the sunspot numbers (S N) following Wolf.

[10] See AM Berggren, J Beer ea in the geophysical Research Letters, Vol 36, 2 june 2009, http://www.eawag.ch/organisation/abteilungen/surf/publikationen/2009_berggren.pdf, A 600 year 10Be record from the NGRIP ice core, Greenland. The tables were published by NOAA, ftp://ftp.ncdc.noaa.gov/pub/data/paleo/icecore/greenland/summit/ngrip/ngrip-10be.txt

To this here are added in some places by the red dotted line new reconstructions of the SN in 1700-1715 [JA Eddy the Maunder minimum] and in 1792-1797 [IG Usoskin, a solar cycle lost in 1793-1800] . The black line below is the number of magnetic storms in o ne year with AA index ≥ 60, like in **FIG 13 part III b**.

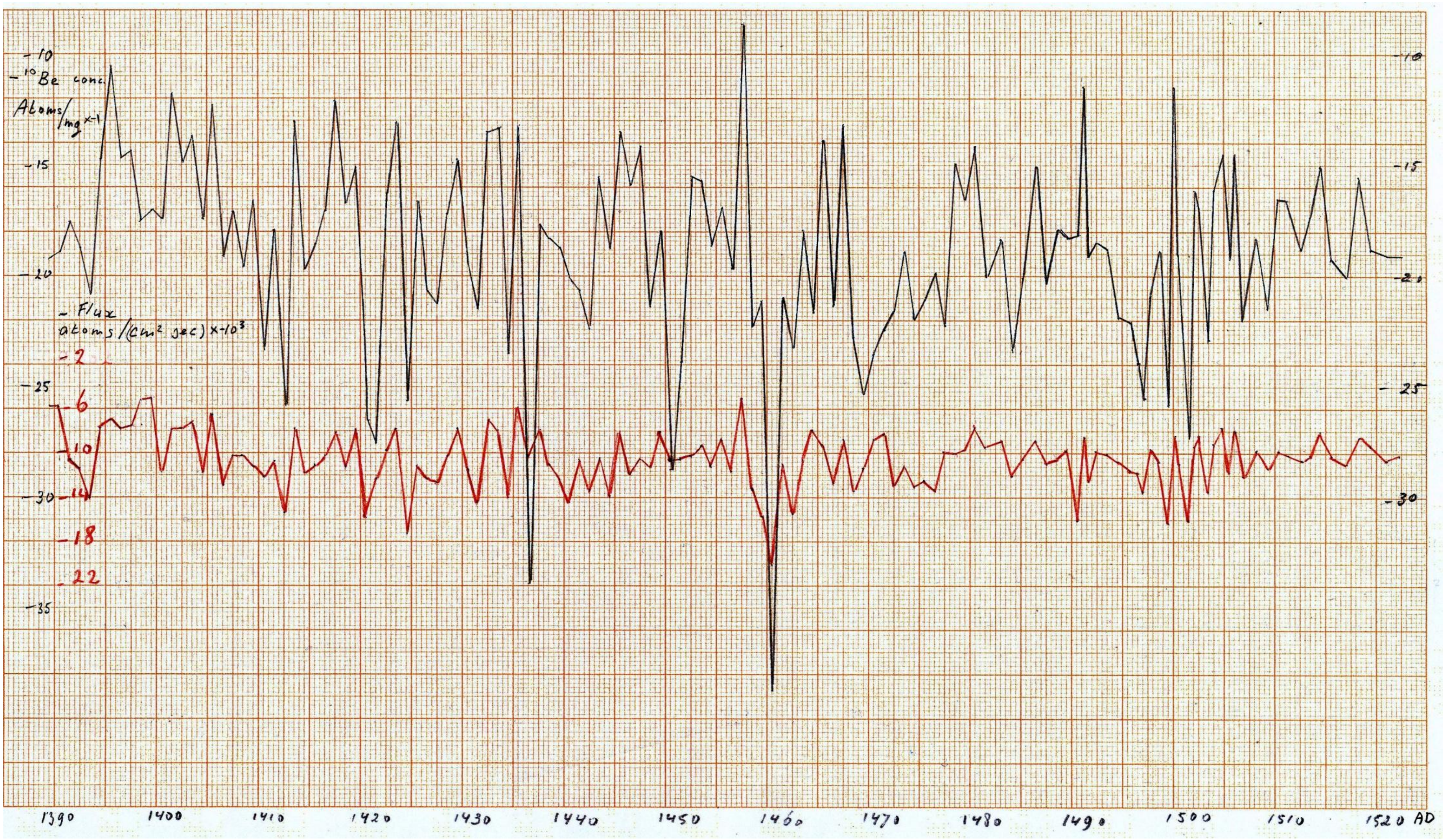
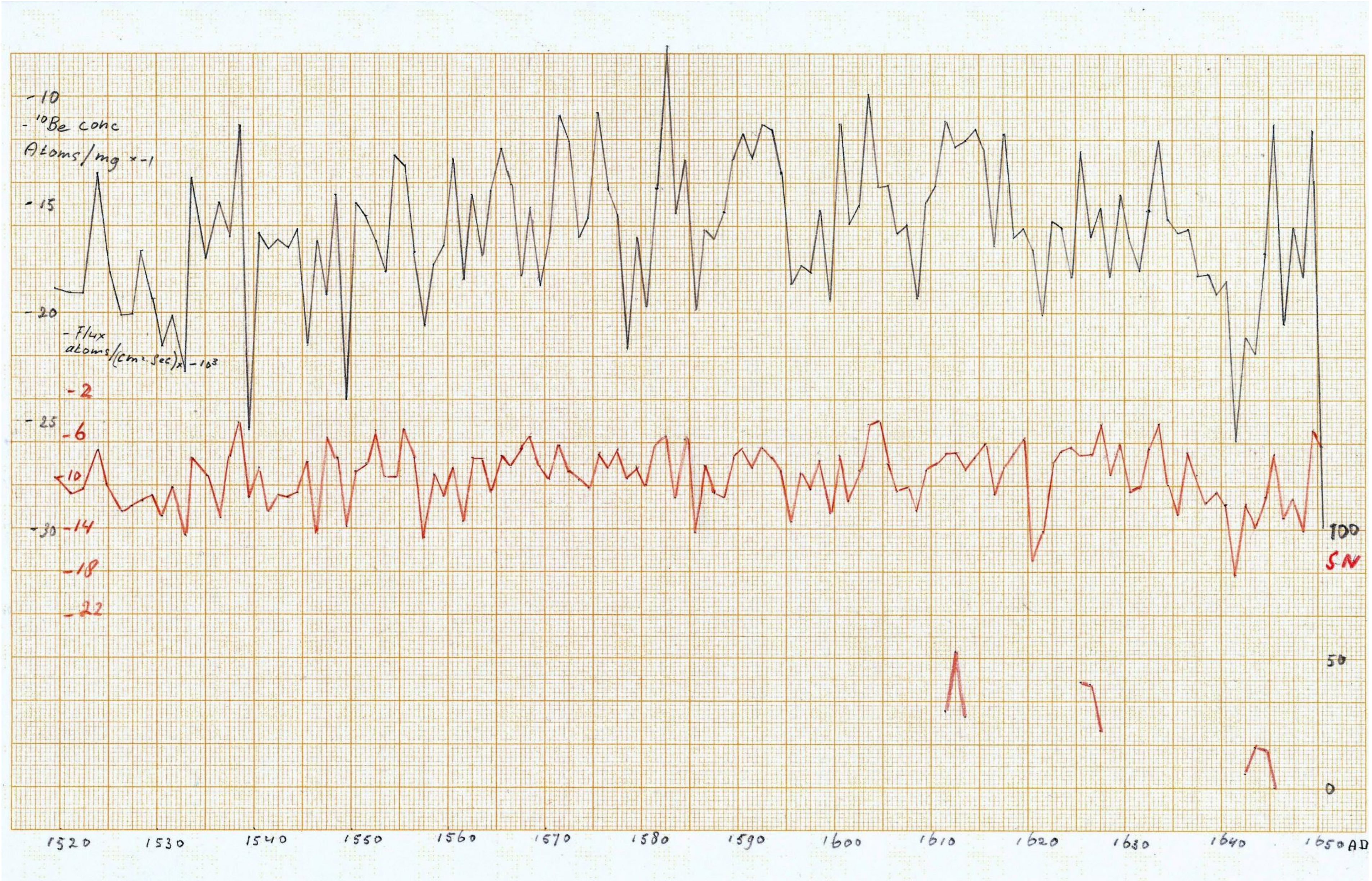


FIG 15 part I

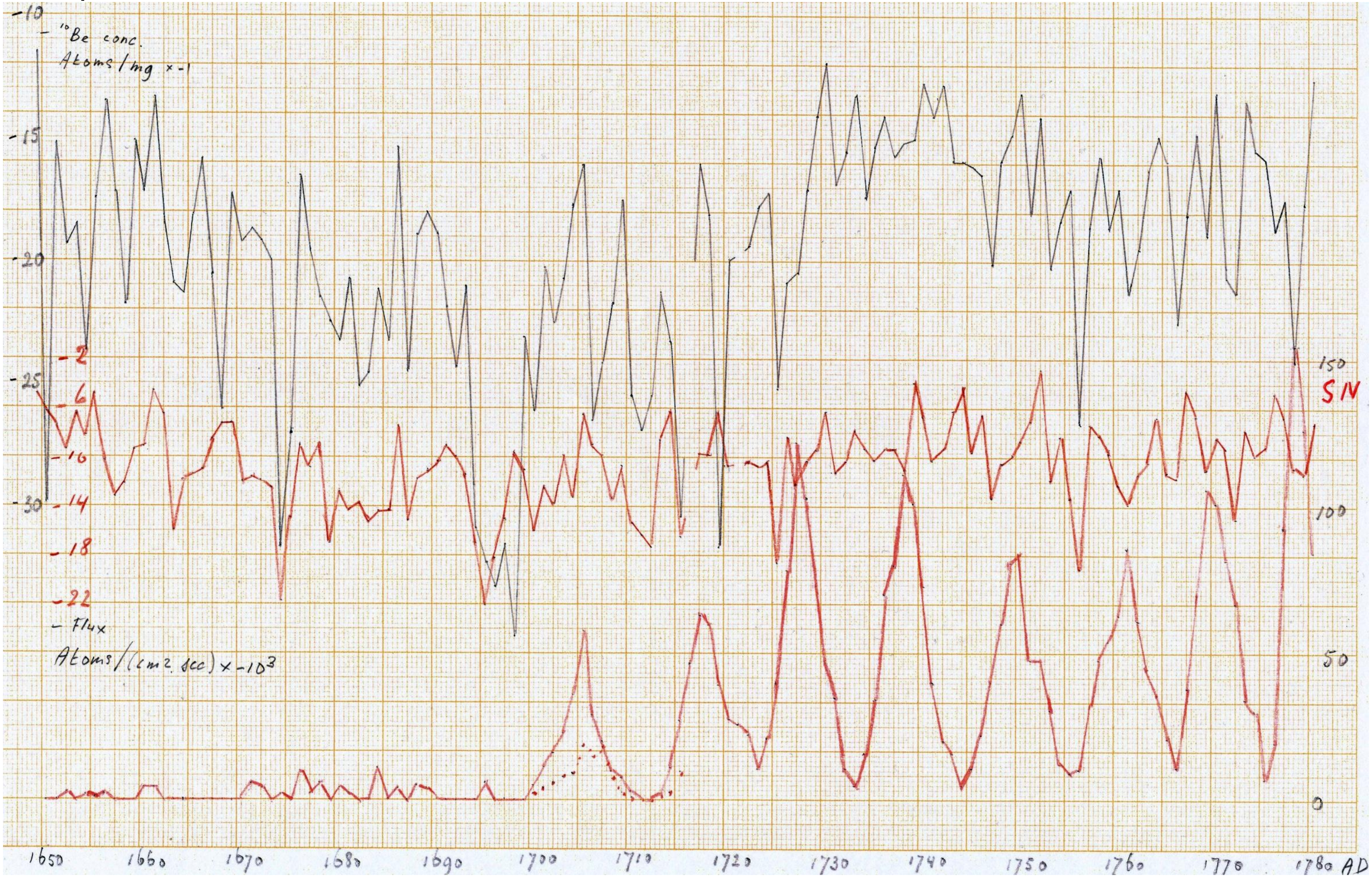
In this NGRIP curve as in the Siple Dome curve of **FIG 13** is a good correlation of the ^{10}Be data with the sunspot numbers on the longer term. The course of the ^{10}Be data on the short term here again are very capricious, with less connection at the SN's. Also here seems more relation



between the AA index and the annual ^{10}Be data than with the sunspot numbers. The sharp up and down deflections in the ^{10}Be data here also is present in the years before 1700.

FIG 15 part II

FIG 15 part III



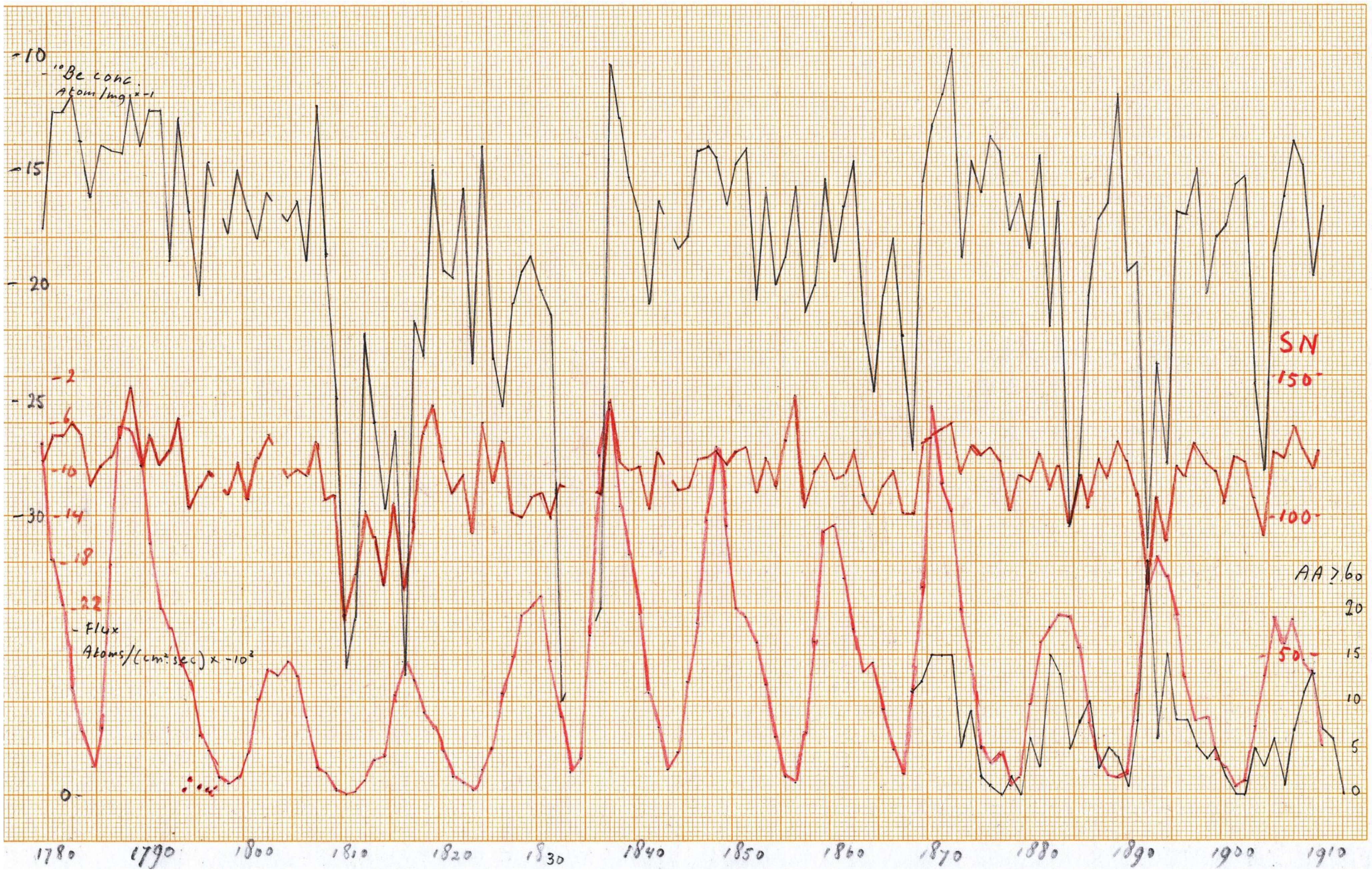
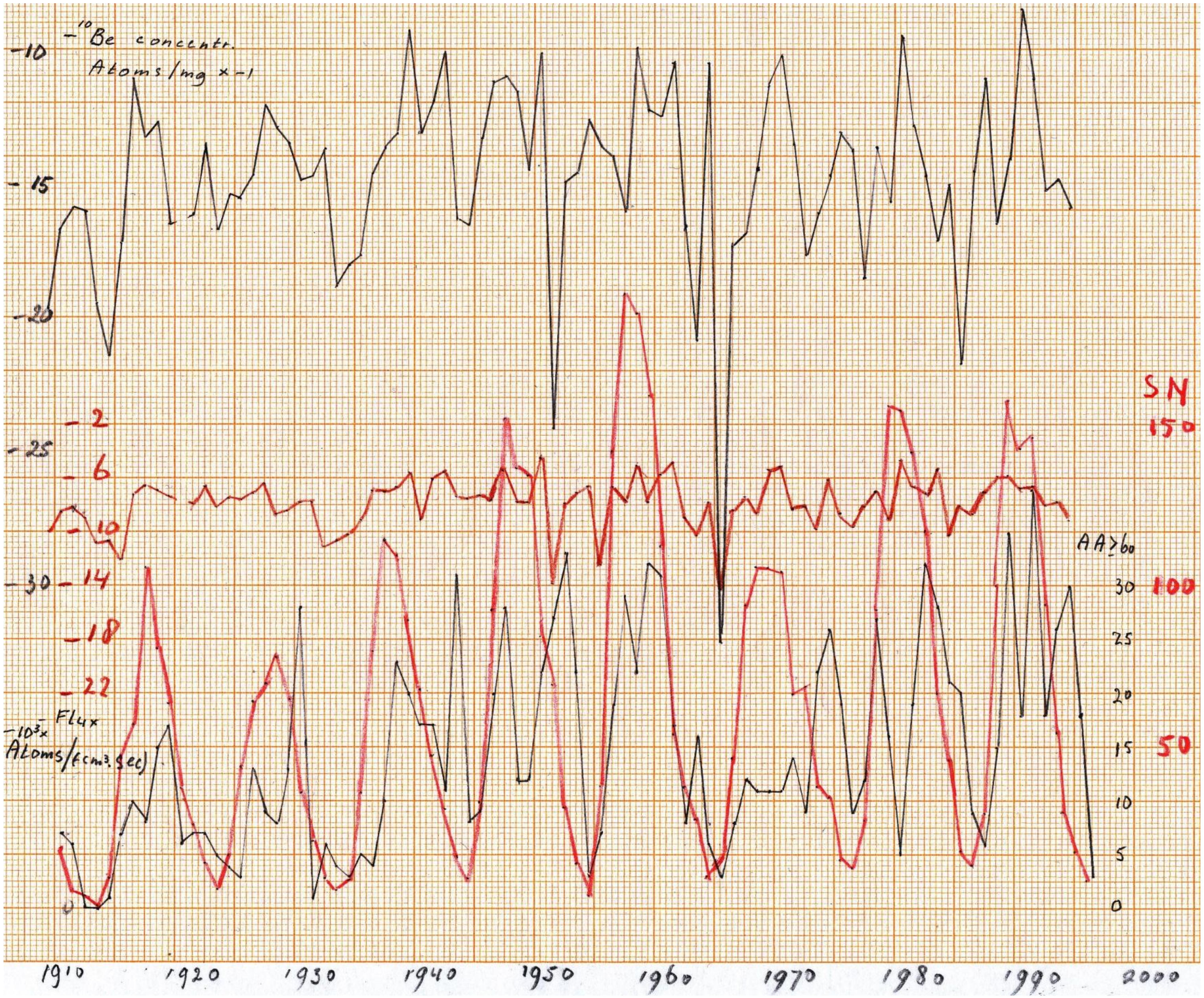


FIG 15 part IV

Of special value here is the study of the Maunder minimum. As J Eddy [Litt list] describes in Science of 8 June 1976, the astronomers in the 2nd half of the 17th century did complaint about the boring sun from which they seldom could reveal sunspots, just than when they did improve their telescopes and discovered many interesting objects in the solar system. So the registration of the sunspot numbers at the Maunder minimum should be reliable. But now in our days we can discover, if we could believe the ^{10}Be data, that the sun was not boring at all at the Maunder minimum! There were relative large fluctuations in the open magnetic field of the sun especially at the begin and the end of that era now is the message from the ice of Greenland. This can give new insights in the functioning of the solar dynamo in these grand minima.

FIG 15 part V

Also the large fluctuations in the ^{10}Be that seems to be related with the large magnetic storms of the 19th century here are probably present. Curious are further the large up and down movements in the ^{10}Be course around the grand modern maximum of 1960. All these things are very obvious to be seen at these **FIG 15** curves here, but they are better to be studied in comparison with the Siple Dome data.



Comparison Greenland – Antarctica in high resolution ^{10}Be data

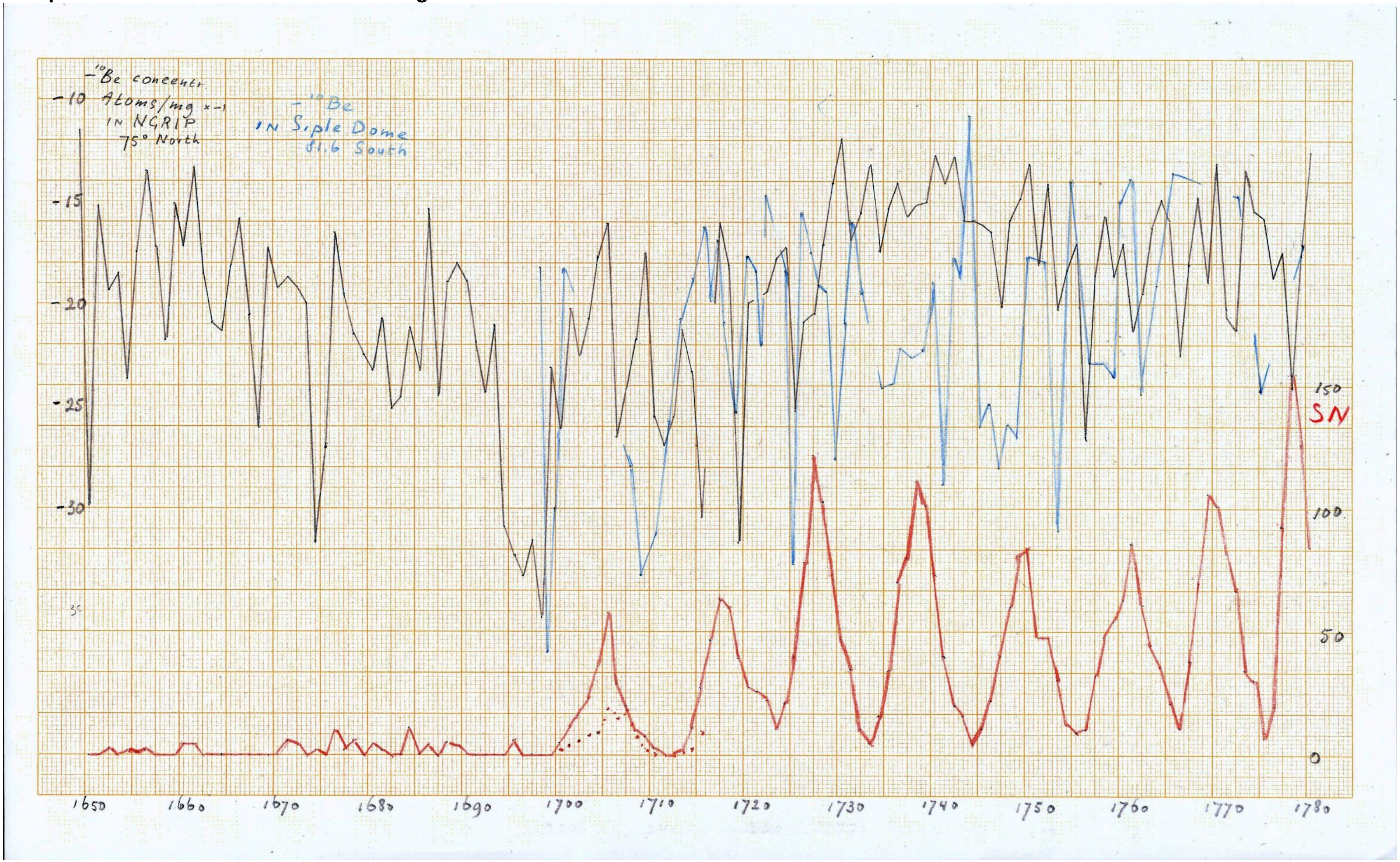


FIG 16 part I

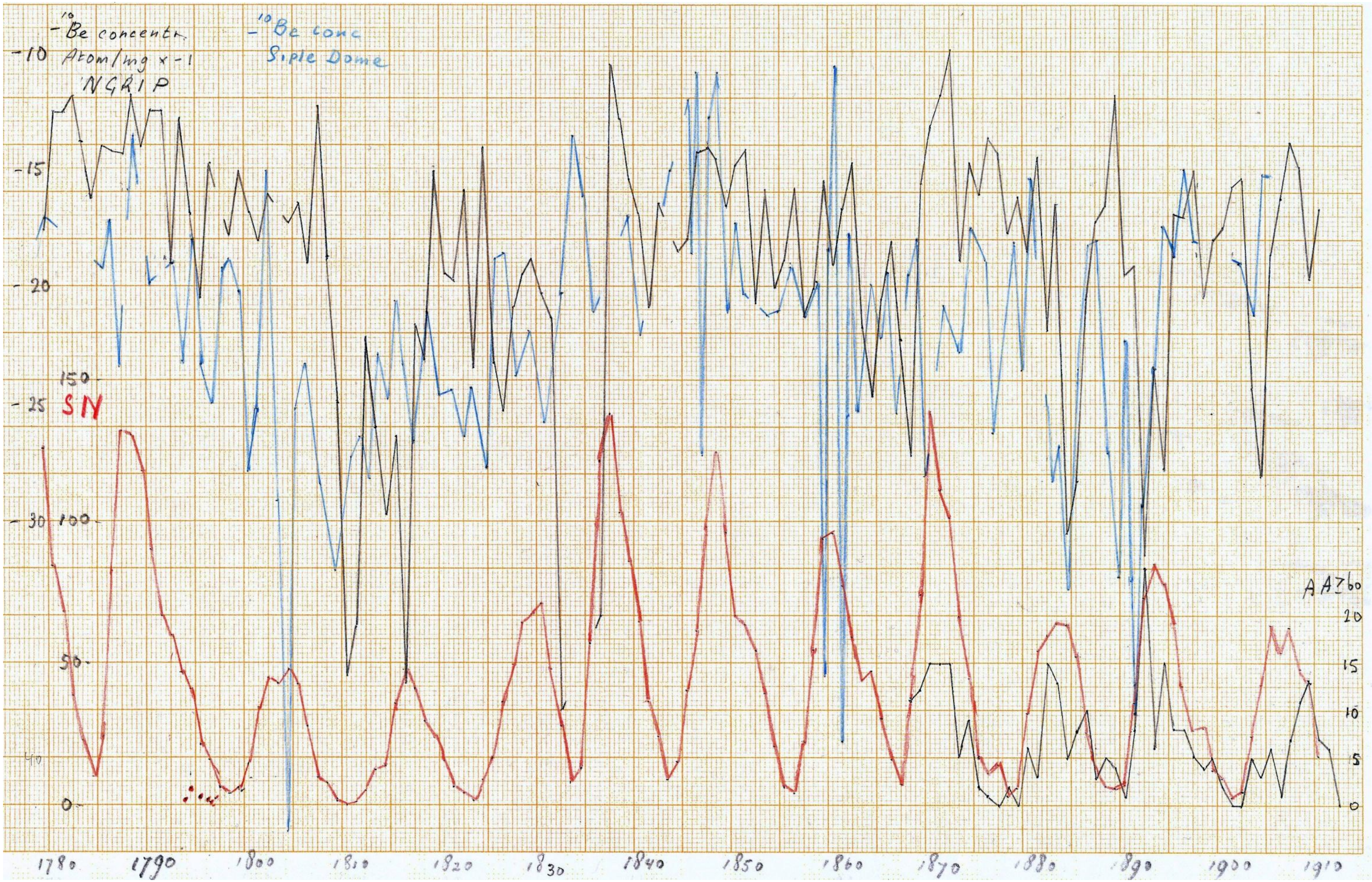


FIG 16 part II

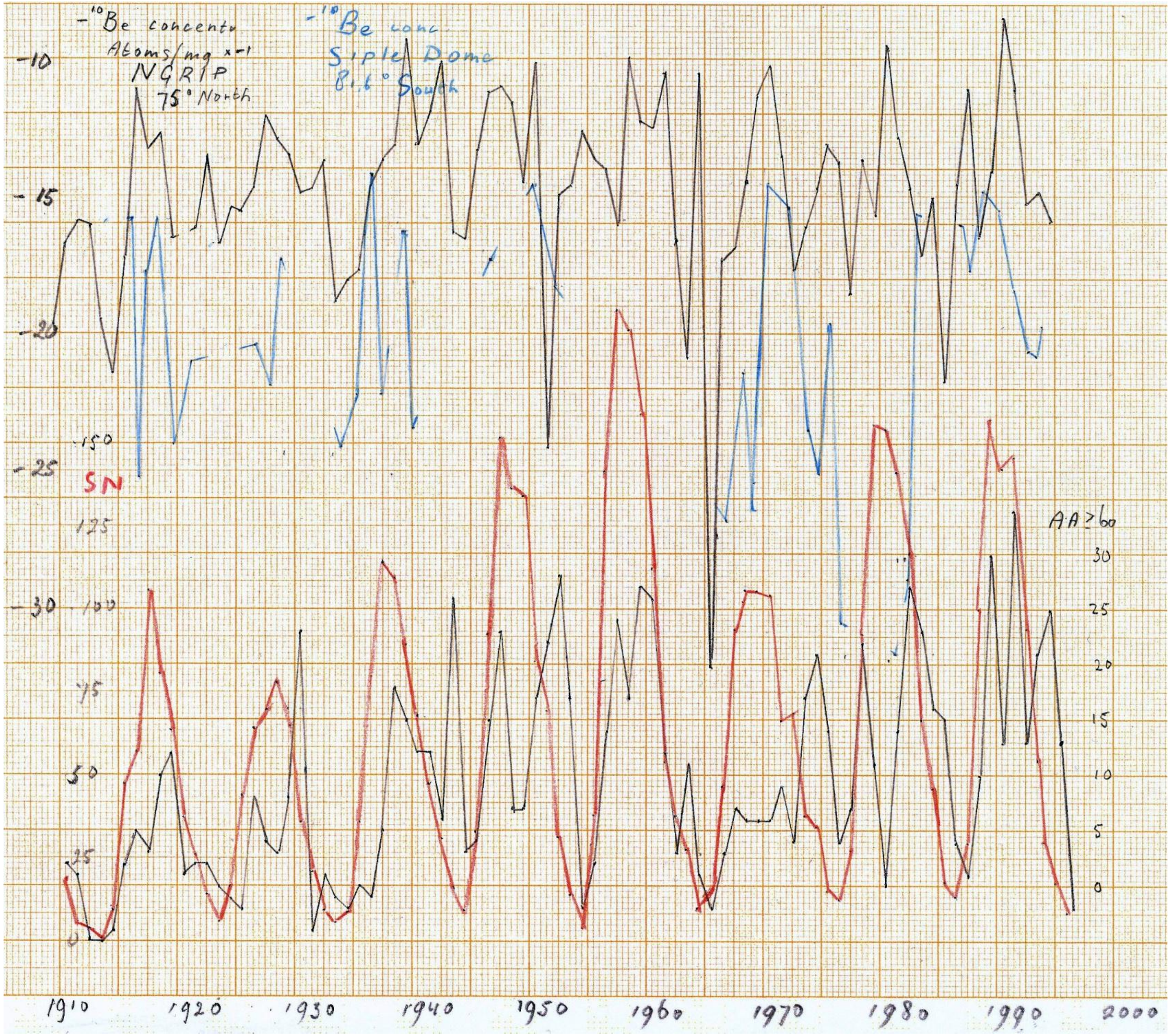
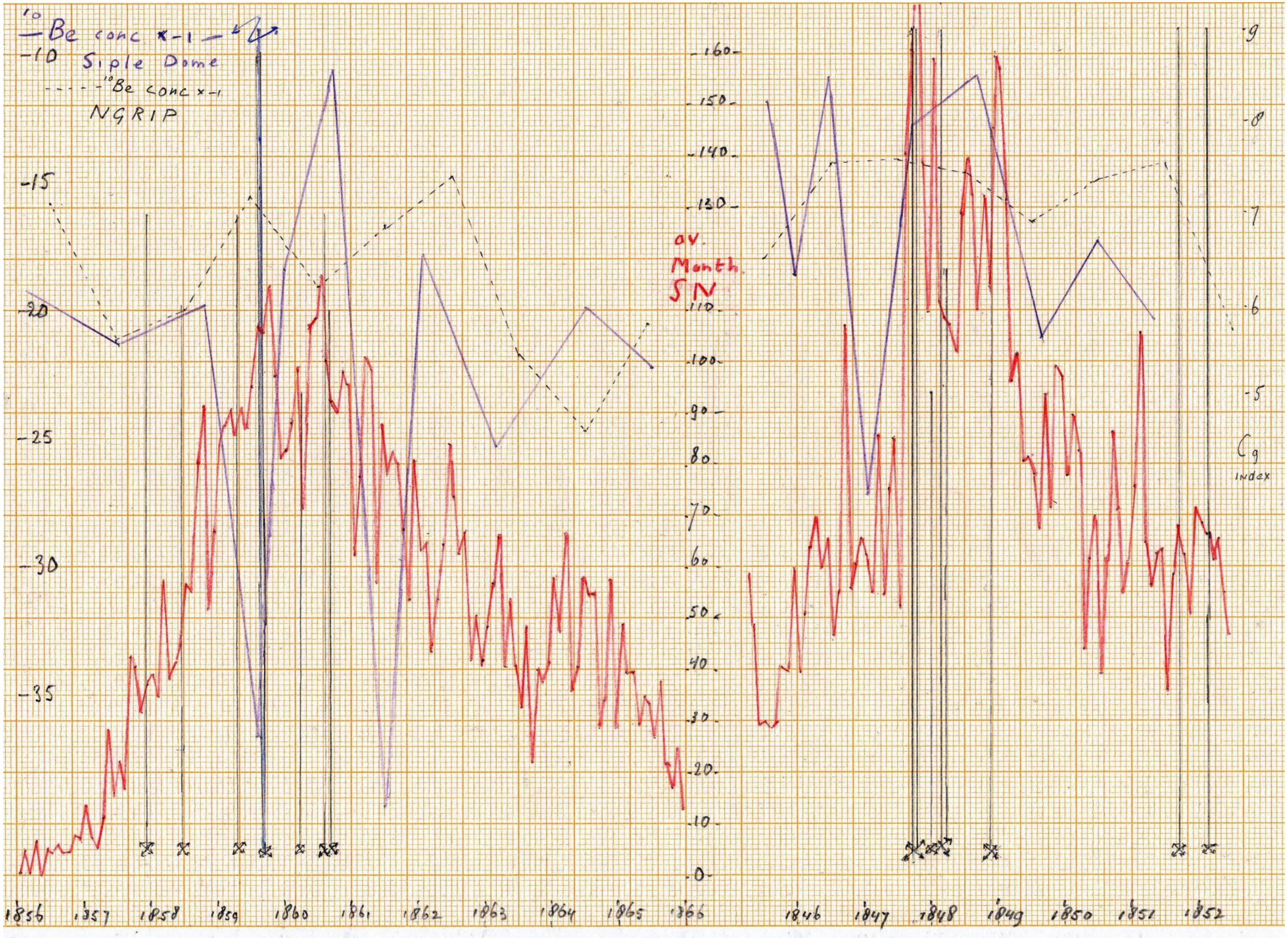


FIG 16 part III

In **FIG 16** has been drawn the blue curve of the Siple Dome -10Be concentration from 1698 over the black -10Be curve of the NGRIP ice core. At a first glance seems to be a good correlation over some periods as for 1710 – 1725 and less over others; often by difference in dating than is the first supposition. It is, however, difficult to judge the connections of the curves over periods they both show an about regular pattern of up and down excursions. The more extreme movements of the curves probably are a better tool for this. Comparison of the large fluctuations in the ^{10}Be curves of the 19th century suggests that these deflections in the Siple Dome curve indeed return on the NGRIP curve. Indeed the deflections on the blue curve over the period 1800-1815 are present with some differences in amplitude on the black curve over the period 1806-1820. The picture on the blue curve at 1858-1862 also seems to be present on the black curve as a broader figure at 1862-1870. In the capricious course from 1882 – 1895 both curves are good in phase. The very fine movements on the blue curve at 1847-1850 are not to be seen on the black curve. There some explanations possible for these forms of connection between the both curves of the ^{10}Be concentration. As pointed out on page 43 the sharp converses in the -^{10}Be concentrations do not indicate changes in the total interplanetary magnetic field as it is produced by the solar wind of plasma particles. The cause of these ^{10}Be converses probably are magnetic disturbances in the neighborhood of the Earth by a more intense magnetic plasma cloud. The magnetic storms with the aurora's and thus the modulation of the ^{10}Be production may have been different on these locations. At the polar area the solar storms strengthen the magnetic shield against the cosmic radiation (CR), but on the lower latitude the disturbances by the solar cloud will weaken the normal terrestrial field and there the CR and the ^{10}Be production must have increased. The signal of this: large ^{10}Be concentrations in the snow will somewhat later arrive at the polar area. The transport process from the lower altitudes is probably different for these both locations. There may have been differences in the dating for these high resolution projects. In relation to the dating and the time resolution the question of the mobility by wind of the snow masses after fall is very important. If the snow freezes together after one year this is the absolute border of the time resolution. It is to be expected that this period will be somewhat variable at the same site and different at various locations. For the period 1846-1850 are time resolutions of 6 to 10 months at the Siple Dome data at which the ^{10}Be concentrations often were very different. So this indicates that the formation of stable layers must have been fast here. At the NGRIP data no sharp differences were at or about this period. Possible is however that these differences here are blown in the wind, so disappeared by sampling after snowfall.

On **FIG 14a** the -^{10}Be data of NGRIP was drawn in as the black dotted line on the data of **FIG 14**. So the purple line shows the -^{10}Be concentration of Siple Dome, the vertical black lines are the C_9 intensities of the magnetic storms and the red curve are the monthly sunspot numbers. The relation between the Siple Dome ^{10}Be and the magnetic storms, as is suggested by the purple curve, now is not directly affirmed by the NGRIP data. This relation between the ^{10}Be deposition and magnetic disturbances by solar storms also are not obvious negated by the NGRIP data. As described here above This sign may have been present also in the ^{10}Be production on the Northern hemisphere, but difficult to reproduce by differences in dating as well as in the actual ^{10}Be deposition. It would be useful and interesting to compare the high resolution !10Be data of other sites with each other and the occurrence of these magnetic storms. A positive result for the correlation would be a convincing argument for the reliability of the ^{10}Be as a proxy for the magnetic interaction between the sun and the earth.

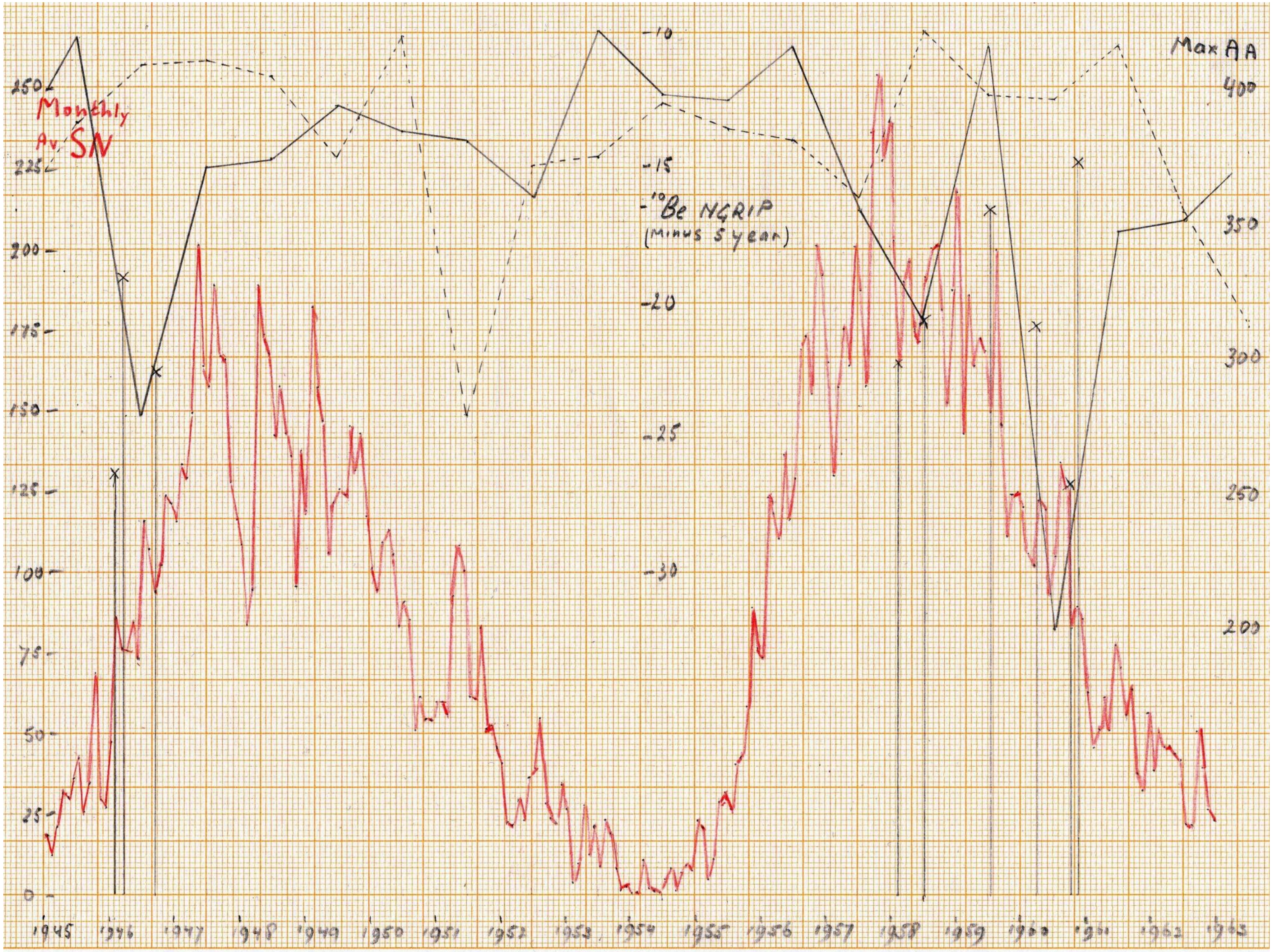
On **FIG 14b** is shown the picture of the monthly sunspot numbers of the 18th and 19th solar cycle, so the period of the grand maximum in the longer term variation in solar activity. Also here are reproduced the intensities in the AA index of the magnetic storms from that period. The occurrence of the storms in the time seems to have some relation with irregularities in the course of the monthly sunspot numbers. Unfortunately are no ^{10}Be data available about this period from the Siple Dome tables. The -^{10}Be course from the NGRIP tables was drawn in here as the black dotted line. With the other black line the NGRIP ^{10}Be data are shifted: they are placed 5 years earlier in the time. In that shifted line the NGRIP ^{10}Be course is in relation to the magnetic storms and the irregularities in the SN in the same way as is the Siple Dome ^{10}Be course at the 9th and 10th cycle as shown on **FIG 14(a)**. It is not obvious whether or not the shift is a realistic placement of the production of ^{10}Be in the timeline of the other events. There are some dubious indications the this could be right, but more research can give evidence. It seems worthy to check this for more insight not only in the reliability of the ^{10}Be as a proxy, but also in the functioning of the solar dynamo.



10Be conc ×-1
Siple Dome
10Be conc ×-1
NGRIP
av.
Month
SN
Cg
index
1856
1857
1858
1859
1860
1861
1862
1863
1864
1865
1866
1846
1847
1848
1849
1850
1851
1852

FIG 14a

FIG 14b



Monthly Av. SN
Max AA
^{10}Be NGRIP
(minus 5 year)
250
225
200
175
150
125
100
75
50
25
0
-10
-15
-20
-25
-30
400
350
300
250
200
1945
1946
1947
1948
1949
1950
1951
1952
1953
1954
1955
1956
1957
1958
1959
1960
1961
1962
1963