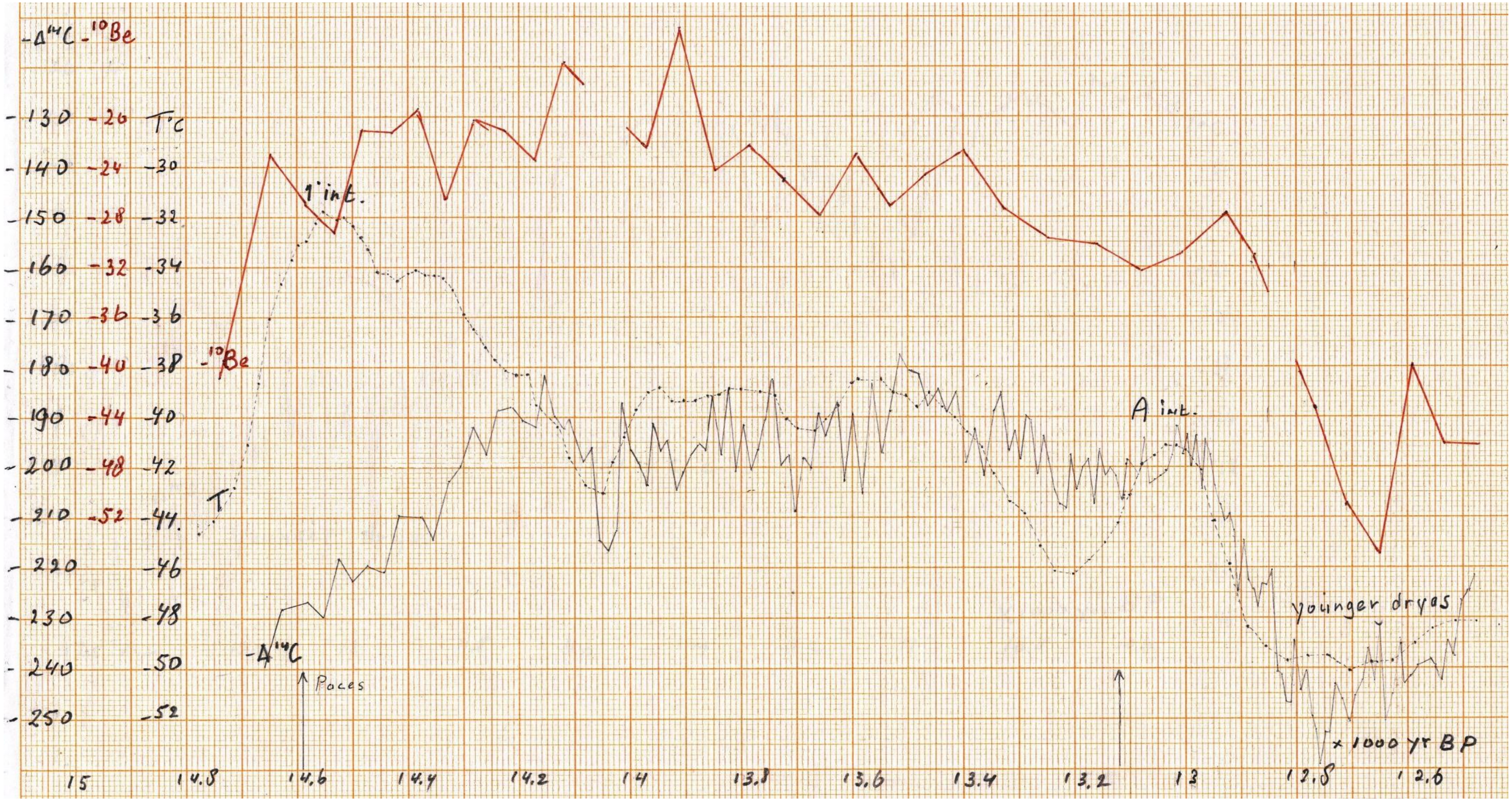
The 10Be and 14C solar proxies in relation to the the temperature at the end of the ice age and the climate transit to the Holocene

The red curve in FIGURE 1 and 2 is the -^{10}Be concentration in atoms per mg. The data from the tables are multiplied by -1 for better comparison as a solar proxy. These data from the GISP 2 ice core (Greenland) are taken from the table published by **Finkel, R.C.** The negative 10Be conc. or -1 x the 10Be concentration is taken for more convenient examination to a connection with the temperature. The black curve of the –Δ14C in ‰ is from the data of the Carioca Basin ^{14}C calibration following **Hughen, K.** ea. The dotted black curve in FIG 1 and 2 is the plot from the temperature reconstruction in centigrades.

FIGURE 1



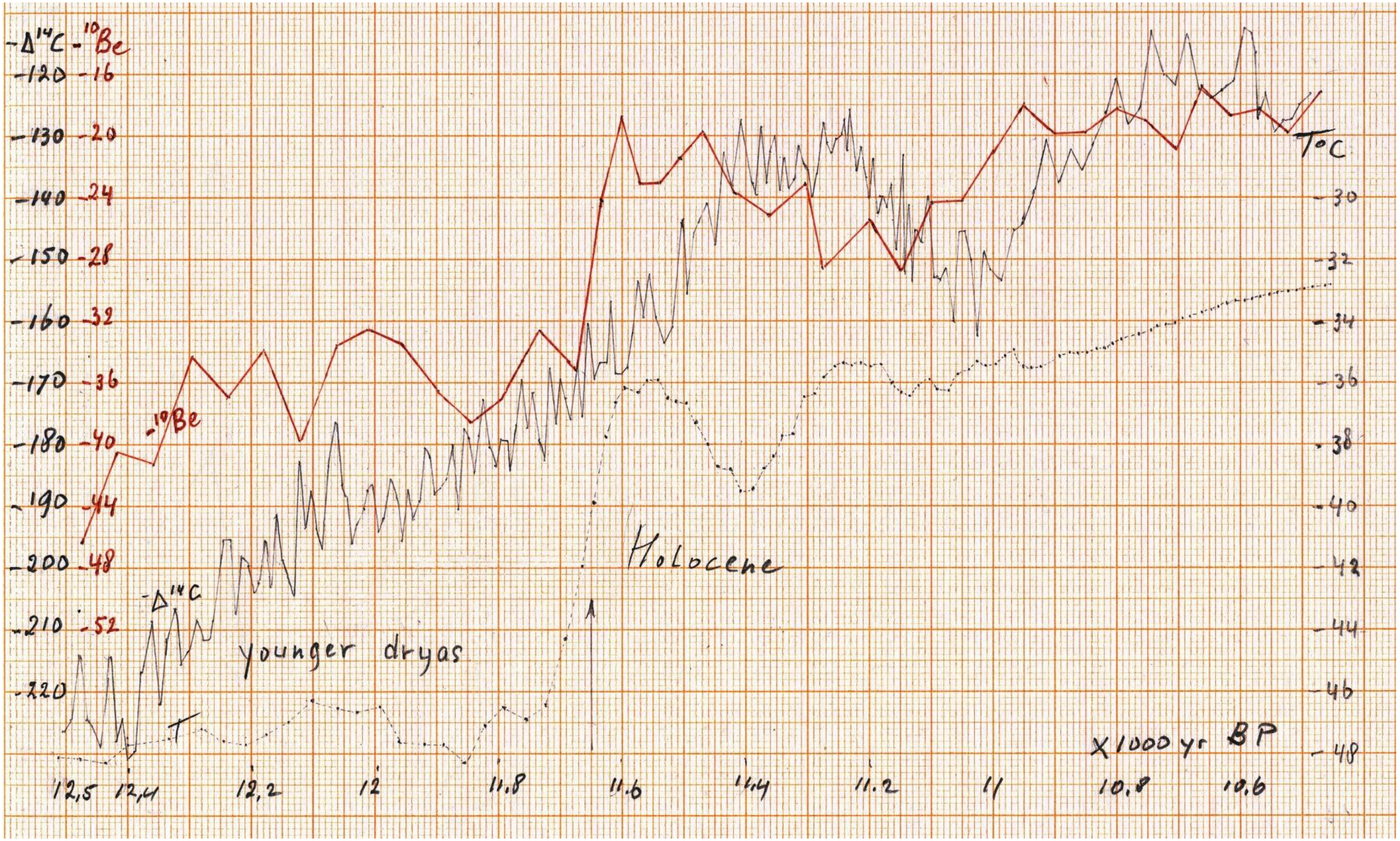


FIGURE 2

The thicker dots stand on the determinations following the table. This temperature interpretation is based on analysis of the stable isotopes, so the δD and the δ18O, from the GISP 2 ice core has been made by **Alley P.B**. At the temperature curve are given some names of climate era's. The influence of these climates were over large area's especially in the Northern hemisphere but not all were totally global. So was about 14550 – 14300 BP the period of the 1st interstadial (1° int.) with climate conditions nearly as warm as during the Holocene. Calculated ever since the present this was the first of some 20 of such warm periods during the last ice age. A int. is the Allerød interstadial a period of relative warm climate about 13100 – 12970 BP. After this begins the younger dryas the last period with a basic glacial climate, so that the forests were replaced in many areas again in tundra vegetation with plants as the dryas octopetala. After some 1400 years of coldness the temperature rises very fast all over the world and then begins the current warm climate era of the Holocene with much less temperature fluctuations than in the ice ages of the Pleistocene. Notice the very fast temperature changes here with increases of about 9 degrees in a century at the onset to the 1st interstadial and to the Holocene level and a decrease of some 7 degrees in a century to the younger dryas. Research in a higher time resolution reveals ever sharper changes to more than 3 degrees in a decennium. The time scale of these graphics is in thousands of calibrated years BP, before present, in which present is 1950 AD. The arrows below indicate the 1470 year paces of rapid climate change as described by **S. Ramstorf ea**. These climate paces are probably linked with the Gleissberg and the de Vries solar periodicities as **H. Braun** pointed out.

The solar proxies ^{10}Be and ^{14}C are radionuclides, which arise in the atmosphere in this time scale mainly by galactic cosmic radiation (GCR). By more intense solar wind and magnetic solar activity the GCR is shielded in the solar system and so is expected a negative correlation between solar activity, also in its other forms, and the production of these radionuclides. This relation in our time indeed is observed by research. These radionuclides however do have uncertainties as an indirect parameter of solar activity. Other causes for variations in the production of the radionuclides are the geomagnetic field of the earth, the primary changes in the GCR from outside the solar system and explosive events on the sun (the SPE's) by which the sun itself brings corpuscular radiation into the interplanetary space for short periods. These 3 factors are probably not important confounders here for the conception of the solar signal in the fluctuations of the radionuclides, because they do have other timescales in their variations and can often be traced by other research. A large problem however is the reconstruction of the production of the radionucleides from the quantities of the tracers that are found at the research at things like ice cores and organic matter in sediments. The deposition of ^{10}Be in the ice can be measured as the concentration of ^{10}Be in the ice and then also can be calculated the fluxus from this by multiplying the concentration and the ice accumulation over a certain period. Both measures of the 10Be deposition are influenced by atmospheric factors as are the quantity of the precipitation, the speed of scavenging of the isotope from the atmosphere, the transport of the ^{10}Be into the troposphere by the contact between the atmospheric layers, etc. Also in a large distance from the location of the ice core these disturbing atmospheric factors may be important. Because of the importance of events at large distance and of the small and relative constant precipitation at the site I did prefer here the concentration to the fluxus as a better measure for the 10Be production in the atmosphere. The ^{14}C also arises in the atmosphere by the GCR, at which the ^{14}C carbon is oxidized to CO_2. The $^{14}CO_2$ leaves the atmosphere by its solution in the oceans and by the photosynthesis of autotrophic organisms. So it comes into the carbon cycles and these complex cycles do not work always at the same speed. By that the scavenging of newly formed ^{14}C from the atmosphere is influenced by factors as seawater pH, temperature and the extend of the sea ice. Also of importance are the activities of organic live on earth. More activity of the autotrophic plants, algae, etc also can cause faster scavenging, but in all the processes with increased carbon absorption of ^{14}C of course also the stable carbon isotopes are taken away, so that the atmospheric concentration of ^{14}C remains constant. This is however is not the case if also the output of CO_2 from the ocean and the organisms is increased, because then in the larger exchange between the various stocks of CO_2 the 'new' carbon in the atmosphere may be replaced by older carbon with other ^{14}C quantities, belonging to the solar activity in the past, or by the radioactive decay . This is obvious if heterotrophic organisms that consume old plant remainders and bring their carbon in the atmosphere, begin to grow extensively by temperature increase. Now this phenomenon is of particular importance, because some very(?) intelligent organisms, called people, dig up fossil carbon and bring it in large quantities into the atmosphere. By that the ^{14}C of the last ca 150 year is useless for research to solar activity and for radiocarbon dating.

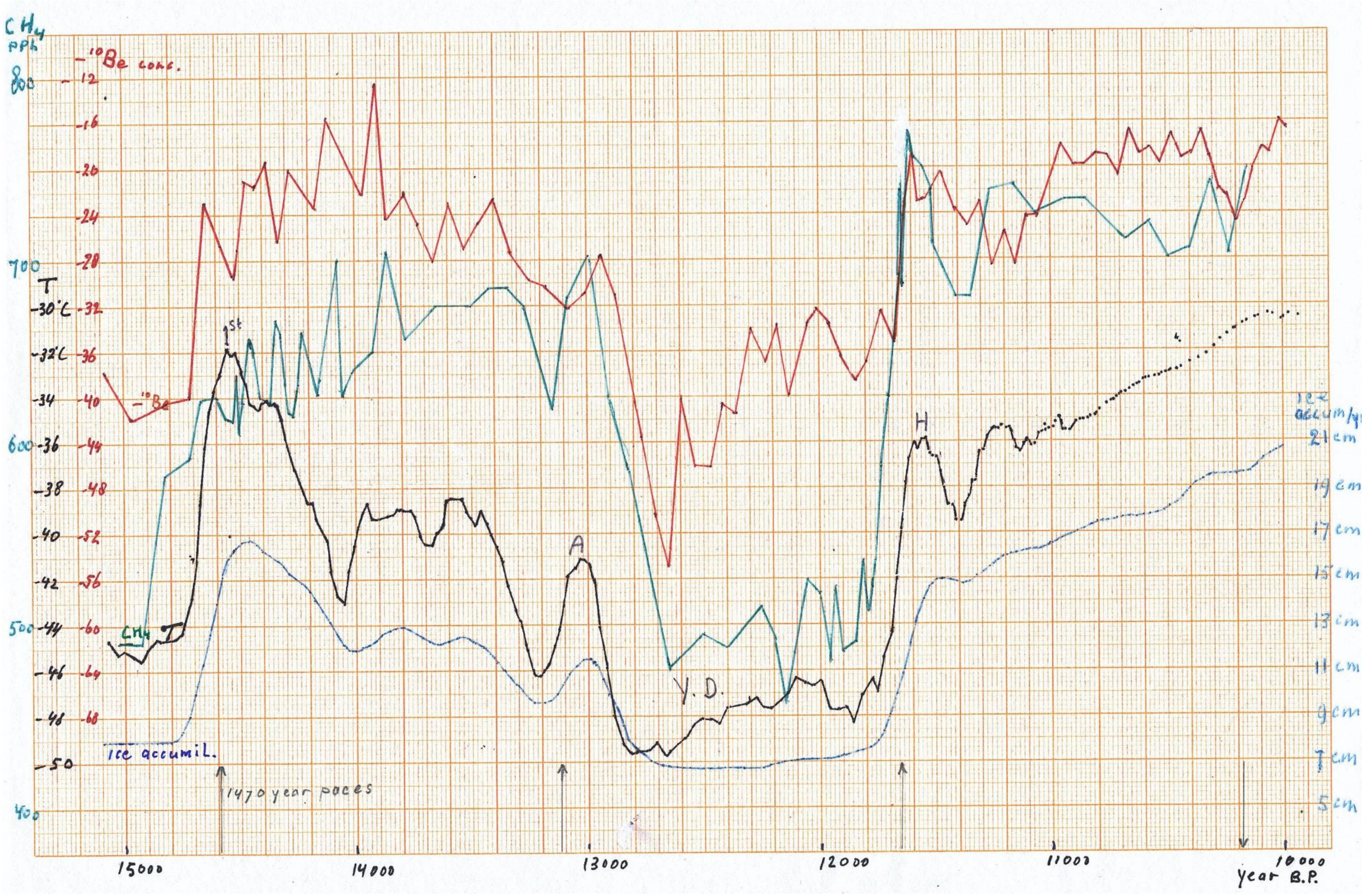

CH4
ppb
-10Be conc.
T
1st
A
Y.D.
H
CH4
-10Be
Ice accumil.
1470 year paces
Ice accum/yr
15000
14000
13000
12000
11000
10000
year B.P.

FIGURE 3

Important also is the speed of the radioactive decay of these both radionuclides as given by the half-live times. In 14,4 million years the half of the ^{10}Be is decayed, so its decay is negligible small in this time frame. The half-live of ^{14}C however is 5736 year. This makes ^{14}C (=radiocarbon) very useful in much scientific disciplines for the dating of organic matter. At this research it appeared that the radiocarbon times of the objects were often not in conformity with the dating by other methods, as by use of tree rings, seasonal layers (varves) in sediments, etc. Also this research of **K. Hughen** ea is an example of calibrating the radiocarbon (decay) times by other data. In this case the sea sediment layers, formed by algae, from the Carioca Basin (Venezuela) show specific characteristics by smaller and larger climate changes, which allow dating them in comparance with other locations especially with the isotope temperature of the GISP2 ice, of which a curve here also is shown. So the issue of the research of **K. Hughen ea** is not solar activity, but this radiocarbon calibration. The difference between the time following only the ^{14}C decay en the actual dating is called $\Delta^{14}C$. The variation in the $\Delta^{14}C$ mainly is attributed to the geomagnetic field, by these authors, but here are substantial variations in less than 100 year, which indicates solar variation, thus probably than also in somewhat larger timescales. Remarkable is further that this research to radiocarbon calibration points to a fine tuned consistency of the many climate changes in different very remote locations, which often is trivialized by climatologists. This phenomenon, however indicates the sun as a potential important climate driver

In Figure 3 some events just before, and at the great climate transit are shown for more clarifying the fullness. Here is again the red curve of the -10Be concentration from the GISP2 ice core (**Finkel, R.C ea)**. The black curve here shows the temperature reconstruction following **Alley, BP**. Also here are mentioned some climate era's: the first interstadial (1st), the Allerød interstadial (A), the Younger Dryas (YD), the begin of the Holocene (H). The green curve shows the CH_4 (Methane) concentration within the small air bubbles in the ice at the GISP2 site. These data are taken from the tables of **Brook EJ ea**. Notice that the dating in the air bubbles, the air ages, differs from the dating of the ice samples. The ice layers are formed gradually from the snow. The firn, at the surface of the glacier, however, is porous and the air within it is in open contact with the atmosphere over some tens of centimeters. So the air in the bubbles dates back from the time they were sealed and that is later than the occurrence of the snowfall. This difference in the dating is difficult to estimate. In the study of **C. Huber** ea an air temperature proxy, $\delta^{15}N$, was used for more accurate comparison of changes in temperature and gas quantities of the atmosphere at some point of time. That research gives evidence for the fact that the temperature increase is ever some tens of years before the increase in the greenhouse gasses at the interstadials. A graphic from the curves of that research is shown here at "Sun, greenhouse gas and temperature". So it is probable that on Figure 3 the curve of the CH_4 does have a small deviation in the timing in relation to the other curves, because of difference in the ice- and air ages. The blue curve of the ice accumulation gives together with the ^{10}Be concentration information about the total local ^{10}Be deposition, the ^{10}Be fluxus. So is obvious that the curve of the -10Be fluxus is much more flat than that of the concentration in Figure 3. This is because the relatively large differences in precipitation in this period, which is much more than in general in the Pleistocene with anyway huge temperature variation. So in the period before 15 ky BP are also in the ^{10}Be fluxus large variations, because there the precipitation ever is some 5 to 7 cm. Although the large relative differences in the 10Be concentrations in absolute figures the quantities and the differences in precipitation are small also in this period and this is the reason why I do prefer the ^{10}Be concentrations here to the fluxus as a more reliable proxy . The dynamics of the ^{10}Be in the atmosphere are very complicated and it is anyway not quite obvious what is exactly the fate of that stuff, but it is evident that the deposition, in concentration, is little influenced by the precipitation figures in an area where the precipitation is much less than in the surroundings. Such an area is central Greenland, at least in the present, the precipitation there now is less than 20 cm, while at the south point of Greenland it may exceed 150 cm. The ^{10}Be

which is produced in such an arid area is mainly deposited in much more wet areas and ^{10}Be arisen in remote areas will not reach dry areas, because it is deposited previously on the way in the wet areas. So the premise is: If the precipitation increases from 7 cm annual to 20 cm the local input of ^{10}Be in the troposphere continuously exceeds the local output by deposition and that also the 'export' remains much more the 'import' of ^{10}Be to the dry area. In this situation is little or none influence on the ^{10}Be concentration by the precipitation, if it increases somewhat but remains small in absolute figures and much smaller than in the surroundings. The concentration than gives better information about the ^{10}Be production than the fluxus does. The arrows below indicate also here the 1470 year paces of rapid climate change as described by **S. Ramstorf** and **H. Braun ea**.

At the figures 1,2 and 3 some striking things are to be seen. The comparison of the ^{10}Be and the ^{14}C curves at figure 1 and 2 shows a good correlation. The deposition of the ^{10}Be and ^{14}C quantities is influenced by solar variation, but also by various physical interactions in the systems on earth. So those interactions are confounders for the signal of the sun one wants to examine. These two radionuclides, however, do have differences in these interactions and their physical fate in the atmosphere and other systems is quite different. So the correlation in the ^{10}Be and ^{14}C curves gives evidence these curves of the radionuclides do give information about the solar variation. Furthermore this evidence is strengthened if the differences in the ^{10}Be and ^{14}C curves are to be explained by the different physical fates of these stuffs. Indeed is expected that the deposition of the produced ^{14}C in matter as tree and sediment layers is later than the deposition of ^{10}Be, because of the much longer residence time of CO_2 in the atmosphere. Newly formed CO_2 with ^{14}C may remain some 30 – 100 year in the atmosphere, dependent on the absorbing capacities of the biosphere and the oceans, but the solid BeO with ^{10}Be adheres on particles and ice crystals and so remains seldom more than one year in the atmosphere. This also makes the Δ14C a less sensible proxy than 10Be for minor fluctuations. Because of this it is unfavorable that the time resolution of the $\Delta^{14}C$ data here is much larger than the 10Be data. By that brief solar variations cannot be traced by the both radionuclides in these curves. If an increase of solar activity is accompanied by climate warming, as is expected, this changes the interactions with the systems on Earth and will generally buffer the decrease of the $\Delta^{14}C$. The reason is obvious: A warmer climate brings more exchange between the atmosphere and the oceans and higher bio-organic activity. By these both mechanisms more 'older' carbon returns into the atmosphere and the present carbon of the atmosphere - with its lower ^{14}C concentration - is taken away faster. So is during a period of climate warming more ^{14}C in the atmosphere (giving a lower $-\Delta^{14}C$) than matching with the ^{14}C production by the cosmic radiation. This may explain why the $-\Delta^{14}C$ has a more gradual course than the -10Be in the 1st interstadial, at the onset of the Holocene and just after that. Remarkable is further that in periods where is a dissociation between the curves of the Greenland temperature and the radionuclides, the -10Be and the - Δ14C remain correlated. This is the case in the periods: 14,5 – 14.1 ky BP; 13,4 – 13 ky BP; 12,6 – 11,8 ky BP, the Younger Dryas; 11,5 – 10,5 ky BP. This also makes the interactions in the systems on Earth less probable as a cause for the variations in the ^{10}Be and ^{14}C quantities and so indicates the signal of the cosmic radiation and the sun. In this is the incline of the - $\Delta^{14}C$ more gradual throughout the total Younger Dryas and continues at the onset of the Holocene whereas the $-^{10}Be$ inclines only in the first half of the younger Dryas and sharply at the onset of the Holocene. This difference between the radionuclides here, however, may be explained by the interactions from a more active carbon cycle. Notice that the Greenland temperature and precipitation in the period of the Younger Dryas is nearly constant and more different from both the radionuclides. This all also is present here at the first millennium of the Holocene. Interesting also is the comparison with the CH_4 curve. In the period 14,5 – 13 ky BP the both curves of -10Be and $-\Delta^{14}C$ do have more correlation with the CH_4 curve than with the Greenland temperature and precipitation. This may indicate the temperature course in larger areas and the global average could have deviated relative much from the

Greenland temperature in this period and so the global temperature should have been more in concordance with the solar proxies. In the other periods are however less dissociations between the Greenland temperature and the CH_4. Furthermore the 1470 year paces, indicating an important aspect of the solar periodicity in the Pleistocene, show also here some concordance with the solar proxies, at least at the onset of the 1st interstadial and the Holocene. At the Allerød interstadial, however, the Greenland temperature and the CH_4 increase is at the pace, but here is no obvious indication in the -10Be and -Δ^{14}C data for increase to a maximum. Probable is that the time resolutions of the ^{10}Be data by the research and the ^{14}C data by the physical fate are too small to trace here a solar maximum. The interesting topic of the 1470 year paces is described here further at 'The timeliness of the Pleistocene climate and sun paces'.

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