A POSSIBLE ORIGIN OF LONG-TERM GLOBAL CIRCULATION VARIATIONS AND 1920-1940 YEARS WARMING

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ABSTRACT

During the 1920-1940 years warming weather regimes changed in certain order. The order appears as the result of the modulation of the flows by a large-scale disturbance moved in the direction opposite to the Earth's rotation and twice revolved around the Earth from early 1910s to 1950s. We discuss whether this feature could be a consequence of decrease in the period of solar cycles during this time interval.

1. INTRODUCTION

Short-term climate fluctuations (of the order of 20-30 years) attract attention because of the next reasons:

- climate changes, which are believed to be a result of greenhouse effect, occur approximately on this time scale;
- their time-scale is close to the period of variations of solar activity, that is considered after paper of Friis-Christensen and Lassen (1991) as one of the main sources of climate variability.

It would be very important to separate these two factors: natural and antropogenic, because they are different in view of long-term variability. Variations of solar activity are cyclic. But technogenic changes will increase in time.

The main feature of long-term variations of mean North hemisphere temperature in 1920-1940 was warming coincided in time with period of relatively short solar cycles. After 1940 temperature began to decrease, but in 70^{th} the increase in temperature continued. In order to find the reasons for temperature increase in the first half of 20^{th} century it is necessary to study the features of general circulation of the atmosphere (GCA) in this time interval. In regard of high variability of synoptic processes, this problem seems very complicated. For its solution one of the typization systems of weather regimes could be used.

At least two systems, namely Vangengeim-Girs and Dzerdzeevsky systems had got wide acceptance and are used in super-long-term forecasts (Dzerdzeevsky, 1975; Girs, 1974). Vangengeim-Girs system is based on the 850 mb and 700 mb geopotential height fields and is aimed to extract long waves in free atmosphere. Dzerdzeevsky tipization is of much more details and is based on localisation of leading air flow directions by the use of sea-level pressure maps. Because these flows are in accordance with positions and orientations of free atmosphere long waves, tipizations could compliment each other. In what follows we'll use, basically, Dzerdzeevsky typization.

2. DZERDZEEVSKY TYPIZATION SCHEMA

Dzerdzeevsky system consists of 13 basic typical schemas of **elementary circulation mechanisms (ECM)** in North hemisphere. Regimes differ from each other by the number of polar air injections tracks or north-eastward tracks of south cyclones. They are united into 4 groups:

1. Zonal circulation. There are no polar injections tracks, 2 or 3 tracks of south cyclones injections. Types of ECM are 1 and 2.
2. Break down of zonal flows. There are 1 polar injection track, and from 1 to 3 tracks of south cyclones injections. Types of ECM are 3-7.
3. Meridional north circulation. There are from 2 to 4 of polar injection tracks, and from 2 to 4 south cyclones tracks. Types of ECM are 8-12.
4. Meridional south circulation. There are no polar injections tracks, and from 2 to 4 tracks of south cyclones injections, penetrating into polar region. Type of ECM is 13.

Each type of ECM is divided into subtypes differed by direction of polar air injections and tracks of south cyclones. The total number of subtypes is 41. The reality of types of ECM was the subject of a number of researches. The independent testing showed that likelihood of non-random change of ECM is very high and is not lower than 95%.

For studying the long-term variations of circulation in the North hemisphere as a whole all ECM were united into groups of "zonal" and "meridional" circulation forms. For time interval from 1899 to 1978 three circulation epochs were revealed with dominance of "meridional" (1899~1915, 1951~1978) and "zonal"

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(1916~1950) forms of circulations. These definitions are enclosed in quotes, because they do not correspond correctly to definition of zonal and meridional circulation, specifically "zonal" forms consist of ECM with one blocking. We think it would be better to call this group as a group of cyclonic processes in which the injections of south cyclones and activity of arctic fronts suppress the development of polar anticyclone and lead to decrease of quantity of polar air injections. Correspondingly, the group of "meridional" forms is a group of anticyclonic circulation processes with well-developed polar anticyclone and increased number of polar air injections. Note that the new interpretation is also rather conditional: in the frame of such definition it would be better to include ECM of 13th type into group of cyclonic processes because its feature is the cyclone at pole (C-A system). Such inclusion was made in first papers of Dzerdzeevsky. But then such classification was rejected.

3. CIRCULATION EPOCHS

Unfortunately, in this schema the key to understanding of reasons for changes of circulation regimes and circulation epochs was not suggested. From our point of view some illuminating features could be lost in classification of ECM, when types are united into groups.

During our analysis of frequencies of "zonal" and "meridional" forms of ECM the doubts appear on the correctness of specifying the epochs. Only with a big portion of arbitrariness one can consider the second epoch of meridional circulation similar to first. In both cases an increase in frequencies of meridional forms took place, but during the second epoch this increase was not compensated by corresponding decrease in frequency of zonal forms. Before the beginning of 50th years the total number of ECM of all types always was constant, oscillations occurred as a result of redistribution of quantity of ECM of first and second group. But since the middle of 50th the total number of ECM increased. In Dzerdzeevsky system it happened because of increasing frequency of "meridional" forms and in a C-A system it occurred because of increasing frequency of ECM of both groups.

4. THE MOST FREQUENT ECM

In order to specify the circulation types that are responsible for increase of total number of ECM we analysed the changes in time of frequencies of all types of winter and summer ECM.

The most noticeable result is an increase of 12 and 13 ECM types frequencies from the second half of 40th years (i.e. during transition to second epoch of meridional circulation). In the first epoch of meridional circulation 12th type of ECM was seen fewer, especially in winter. An increase of frequency of 13th type says about total increase of cyclonic character of the hemisphere, first of all, in high-latitude zone. Along with increase of ECM of 12th type, it says most likely about instability of circulation in polar region, fast change of south cyclonic and polar injections. It corresponds to total increase of quantity of ECM mentioned above. Possibly, in 50th not a repeat of meridional circulation epoch took place but transition of ECM into some new state. Change of relationship between types of ECM of the same group indicates the difference in character of circulation in first and second "meridional" circulation epoch. During the first and second epoch in winter, respectively, the 5th (polar injections into Asia) and 7th (polar injections into America) type of "meridional" circulation dominated. Thus epochs differ from each other by a degree of development of anticyclonic centres of actions in Atlantic-Euro-Asian and Pacific-American sectors.

Our analysis shows that increase in frequency of 13th type of ECM, at least, partially is caused by replacement of some zonal ECM. This suggestion is supported by observation in C-A system of one additional variation in summer in 50th that coincided in time with awaiting next pulse of "zonal" ECM forms increase. In some degree it supports the inclusion of 13th ECM type into group of "zonal" circulation. Possibly the replacement of some zonal ECM occurred as a consequence of methodical reasons as well, because the identification of 13th type of ECM became possible only after drift of USSR polar station SP-1 in 1937.

Many questions appear also while analysing epoch of "zonal" circulation. There is a strong seasonal dependence of ECM variations. Both in winter and in summer variations have a form of two consequent pulses, but character of pulses is different. In winter and in summer first pulse is caused by intensification of, respectively, "meridional" and "zonal" circulation. Moreover, summer variations are longer than winter ones and they begin later. In more details the seasonal dependence of ECM dynamics was studied by Dzerdzeevsky (1975). Six seasons were specified, namely, winter, summer, spring, autumn, pre-spring, and pre-winter. In all cases variations are different, and not only amplitudes but periods of oscillations as well. An open question is what are the reasons of these differences and can we unite all these variations into one epoch taking as the base the average characteristics.

5. ECM VARIATIONS ARE THE RESULT OF THE WAVE WITH 18 YEAR PERIOD

Analysis of integral characteristics does not answer on appearing questions, but variations of types and subtypes of ECM, ordered in some specific row, permit to suppose a hypothesis which can explain the features of ECM variations during "zonal" circulation epoch.

Figure 1 shows graphics of ECM frequencies in such a way that it is possible to reveal the order of development of variations. For convenience of visual analysis graphics are shifted along ordinate axis and smoothed on several points. Upper and lower figures show graphics of ECM, respectively, in summer and in winter. Graphics for summer are smoothed on 4 points, but for winter on 2 points because length of variations in summer is slightly larger than in winter. Graphics show numbers of corresponding types and subtypes in summer or in winter. In the right part of the figure the directions of polar injections corresponding to these ECM are depicted. Initially we depicted graphics for all subtypes of ECM, but then were forced to unite some subtypes, because their frequencies was insufficient for extraction of variations. For summer period we united subtypes of groups 2 and 7 and for winter types 1,5,7. We did not also show frequencies for those types and subtypes, which were observed relatively rarely, namely, 8, 9, 10, 12a, 12g.

The results of sorting of graphics appeared very unexpected. Variations of ECM frequencies had a form of disturbance that moved to the west and during 35 years twice revolved around the Earth. Especially apparently the motion of disturbance is seen in graphics of change of "zonal" ECM types in summer period. The direction of polar air injections changed in the next sequence: polar injections into Atlantic, then into America, Pacific Ocean and Asia. When disturbance moved in the west hemisphere the number of pure "zonal" ECM of type 2 increased, and frequencies of "meridional" types decreased. When disturbance moved in East hemisphere "zonal" circulation types were replaced by "meridional" that had in summer and in winter, respectively, two and three main tracks. In winter the main polar injections corresponded to mean climate position of pressure crest, that linked Siberian and American anticyclones across Arctic. The third polar injection had tendency to move along longitude in western direction, likely, lags behind the main disturbance. In summer period the increases in frequencies of meridional circulation types were longer than in winter and finally decayed after moving of disturbance into western hemisphere.

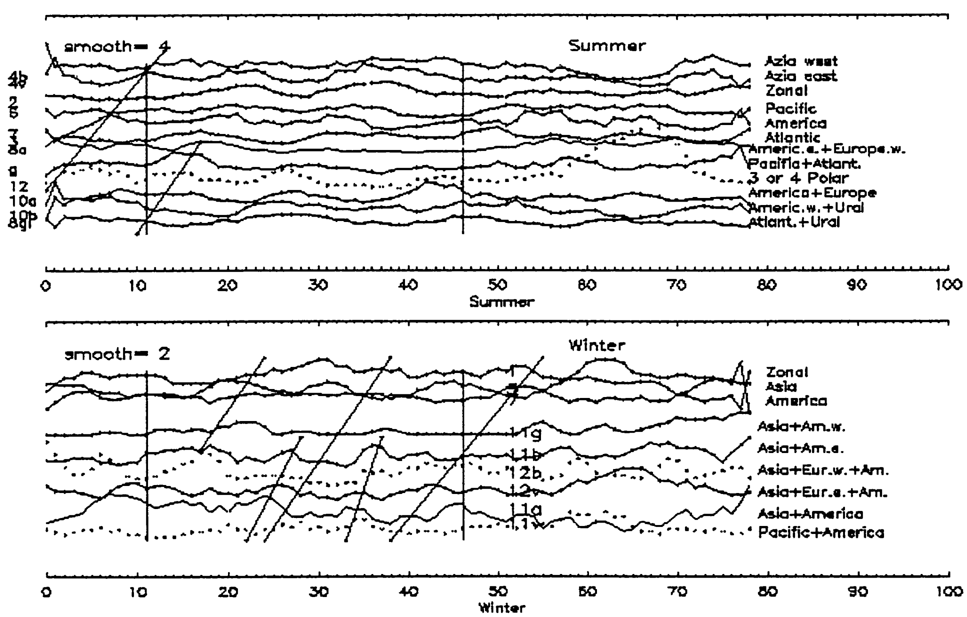

Figure 1: Smoothed graphics of summer and winter ECM frequencies, constructed with due account of directions of polar injections.

Unfortunately, synoptic maps at the beginning of 20 century were not of high quality, so to determine time of appearance of disturbance by the use of graphics of ECM frequencies is, in practice, impossible. The motion of disturbance is clearly seen from the instance of time, determined by Dzerdzeevsky as a beginning of "zonal" circulation epoch, and disappearance of disturbance occurred, likely, at the instance of time of its finish. One can suppose that these events were connected and appearance of disturbance became the source (or result) of increase, on an average, of "zonal" circulation and increase of mean temperature in North hemisphere during first half of 20th century. Break down of the wave, in its turn, gave rise to global restructuring of ECM in 50th years and to decrease in temperature (or was its consequence).

6. CAN IT BE THE SOLAR INFLUENCE ?

In the frame of our idealised schema the reason for change of subtypes of ECM is the drift in western direction of the axis of main polar injections, and transition from one form of circulation to another was caused by interaction of disturbance with continental and ocean areas. In Asia the disturbance initialised the development of "meridional" forms of circulations, and above oceans and America of "zonal" types. Extrapolating on later period one can suppose that warming in 70th-90th years was also connected with appearance of such kind of disturbance. Indirect proof of this supposition is substantial difference of spatial structure of temperature and pressure anomaly fields during first and second phase of warming in 1977-1988 and 1989-1994 years, that were revealed by Volodin and Galin (1999). The difference is so substantial that anomaly fields are well described by orthogonal functions. Authors suggested two different mechanisms of warming: in 1977-1988 as a result of increase of sea surface temperature (SST) in tropics, and in 1989-1994 years as a result of decrease in ozone concentration in lower stratosphere. Such division seems not very logic although it is supported by calculations. In the frame of our model a drift of disturbance can cause the difference in spatial structure.

Keeping in mind that period of revolution is approximately of 18 years, quasiorthogonaity of pressure and temperature field anomalies during first and second phase of warming is explained by shift of disturbance approximately on 180 degrees. Considering high correlation of mean temperature in North hemisphere and SST in tropics, one can suggest that mechanism of pumping of disturbance has heat nature and is connected with anomalies of ocean circulations. This conclusion is very important for understanding of nature of ECM dynamics during last decades.

Of course, the simplicity of the suggested model is relative. In atmosphere and ocean the inter-annual, decadal and centennial variations of climate characteristic are known, but mechanisms of their development and connections at global scale are studied very poor. To some extent study of long-term variations of ocean circulation replaced the searches of external sources of climate variations among which the best known were variations of solar activity. Researches of Friis-Christensen and Lassen (1991) reanimated the interest to solar-terrestrial relationships. But they limited themselves by analysis of mean climate characteristics.

With higher spatial resolution specific structure of global atmosphere circulation variations in the first half of 20th century is revealed. This structure looks like the modulation of zonal and meridional circulation forms by a wave-like disturbance that slowly moved in westward direction. We speculate, that the interaction of "disturbance" with surface gave rise to change of circulation forms, and then to temperature changes. We know that during considered period of time solar cycles were shorter. Possibly transition of the Sun to another, short cycle period regime could trigger the development of such terrestrial waves. Mechanism of triggering and support of such waves is unknown at present. Probably under some conditions terrestrial atmosphere becomes unstable to excitation of specific largest-scale wave; this wave controls excitation of smaller-scale vortical flows and is supported through the mechanism of interaction with them. One of such kind of mechanism was studied in our previous paper (Tikhomolov, 1996) and gave very promising results for interpretation of a number of effects. Investigation of possibility of application of this mechanism to the terrestrial atmosphere is the next step of our researches.

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