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REGIONAL PARTICULARITIES OF THE METONIC METEOROLOGICAL CYCLE ON EARTH

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Key words: Metonic astronomical cycle, multiples of the Metonic cycle, atmospheric tides, Rossby waves, 19-year cycles of air temperature.

Abstract. This paper intends to demonstrate that, on Terra's surface, there are cycles of air's temperature and of other meteorological elements having a duration of 19 years (the Metonic cycle). These 19-year cycles are recorded on every continent, especially in temperate climate areas where the (planetary) Rossby waves exhibit very clearly. As in the case of other cycles of meteorological elements, the atmospheric tides play a very important role in their occurrence. In the case of this cycle, the atmospheric tides are also generated mainly by Moon's and Sun's attraction.

Introduction

The existence of these cycles for daily maximum and minimum air temperatures on all continents has been demonstrated in previous scientific papers ([3], [4], [5]). In all situations, the demonstration relied on the influence of atmospheric tides generated mainly by Moon's and Sun's attraction. In the case of the 19-year cycle (Metonic cycle), the explanation is also given by the existence of a cycle of atmospheric tides, with the same duration, generated by Moon's and Sun's attraction. This cycle is a lunar-solar one since it consists of an integer number of solar years (19 years), but it also represents cycles in the evolution of several lunar elements. However, there are some differences between the two hemispheres of the Earth (Northern and Southern) regarding the moment when these cycles occur more clearly.

1. The metonic cycle in astronomy

This astronomical cycle was discovered in the fifth century B.C. by the Greek Meton and then the Athenians inscribed his name in letters of gold in the Temple

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of Minerva together with the golden numbers (i.e. the numbers in the calendar which gave the positions of the years in the 19-year cycle).

In fact, the Metonic cycle represents the duration of 19 solar years (1 solar year equals 365.24 days), that is 6939.56 days (approximately 6940 days). After completing the 19 years, the Moon's phases repeat themselves almost perfectly. This fact means that, within this interval, there is an integer number of synodical revolutions (periods) of the Moon, as the following computation shows: 6940 days (19 years) divided to 29.53 days (the synodical period of the Moon) is 235.01≈235. It is important the fact that the same period of time (19 days or 6940 days) represents a multiple for the tropical revolution (period) of the Moon too (which is 27.32 days). This indicates the declination of the Earth's natural satellite (the Moon), as the following computation shows: 6940 days (19 years) divided to 27.32 days (the tropical period of the Moon) is 254.02≈254. Therefore, in 19 years (6940 days), 235 synodical revolutions and 254 tropical revolutions of the Moon are produced. Most important is the fact that the Moon's phases (New Moon, Full Moon, First quarter, Last Quarter) repeat themselves almost perfectly after the 19 years (occurring in the same day of the year). This astronomical cycle is not perfect since the duration of those 19 years does not include an integer number of anomalistic revolutions (periods) of the Moon (27.55 days, mean value). The anomalistic period of the Moon indicates the distance Earth-Moon. A computation shows that 6940 days (19 years) divided to 27.55 days (the anomalistic period of the Moon) is 251.90, which demonstrates the above assertion.

The Metonic astronomical cycle (19 years) refers only to the dates of the Moon's phases and to the daily values of the Moon's declination. Regarding the maximal declination of the Moon, it has a value that oscillates between ±28°36′ and ±18°18′ (+ for the northern hemisphere and − for the southern hemisphere). These values follow from the angle between of the lunar orbit and the terrestrial equatorial plane. The absolute maximum value of 28°36′ and the absolute minimum value of 18°18′ are reached within a cycle of 18 years and 8 months, approximately 6818 days, and hence not in 6940 days (19 years).

In conclusion, the Metonic astronomical cycle refers only the dates of the occurrence of lunar phases within the synodical revolution of the Moon (29.53 days). For example, a full moon occurred on January 18, 1984 and on January 18, 2003 too. Nevertheless, there are situations where the Metonic cycle is reflected both in the air temperature evolution and in the evolution of the atmospheric pressure.

2. The metonic cycle in the air temperature evolution

This cycle can be emphasized especially in the years when absolute maximum values of the Moon's declination of ±28°36′ or close values are recorded. The

Metonic cycle in the evolution of the daily maximum and minimum temperatures can occur in all seasons and all continents, irrespective of the geographic latitude. The explanation consists in the fact that the atmospheric tides generated by Moon's and Sun's attraction influence the characteristics of the Rossby waves which manifests themselves most clearly in the Earth's temperate zones (North and South). In their turn, the (planetary) Rossby waves largely determine the evolution of the atmospheric pressure, whence cyclicality in the atmospheric circulation and in the air temperature evolution follows.

2.1. The Metonic cycle in the air temperature evolution in Europe

In order to demonstrate the existence of this cycle in Europe, the following observation and measurement points were selected: Iasi (Romania), Moscow and Krasnodar (Russia), and Bordeaux Mérignac (France). In Figure 1, there are presented graphs containing the evolution of maximum and minimum air temperatures at the four selected observation points in Europe.

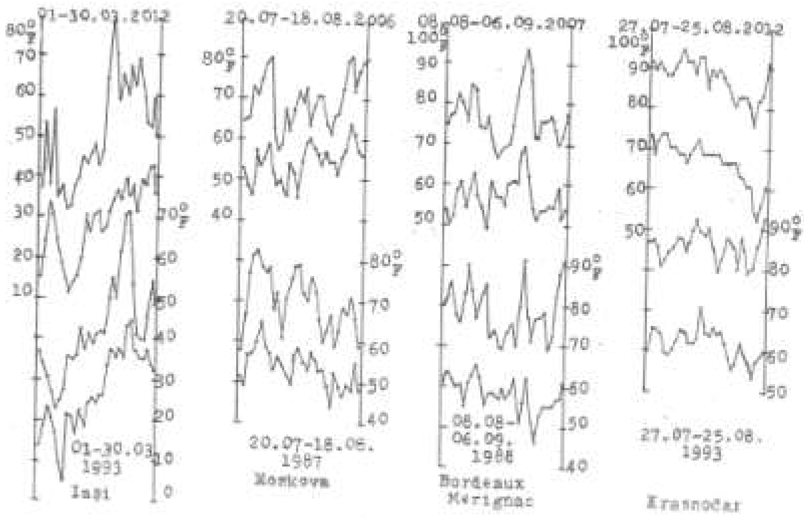

Fig. 1: The evolution of the daily maximum and minimum air temperatures in Iasi, Moscow, Krasnodar and Bordeaux Mérignac

The following conclusions can be drawn by analyzing the graphs in Figure 1. The clarity of the 19-year cycle in the evolution of the daily maximum and minimum air temperatures is obvious especially at Iasi, Moscow and Bordeaux Mérignac. Only the periods of the year when this cycle occurred vary. At Iasi, this cycle occurred in March, at Moscow and Krasnodar in July and August, and at

Bordeaux Mérignac in August and September. The highest amplitudes can be noticed at Iasi, in March of the years 1993 and 2012.

2.2. The Metonic cycle in the air temperature evolution in Asia

The vastness of the Asian continent, both in latitude and longitude, determines special particularities of the Metonic meteorological cycle. In order to emphasize these characteristics of the Metonic cycle, we only have chosen observation points from Russia and China, since in other Asian countries, the meteorological observations and measurements exhibit discontinuities (missing data). The points chosen to emphasize the Metonic meteorological cycle are Beijing from China and Tomsk, Oymyakon and Vladivostok from Russia.

In Figure 2, we present with graphs, the Metonic meteorological cycle in the evolution of the daily maximum and minimum air temperatures at the Asian observation points selected above.

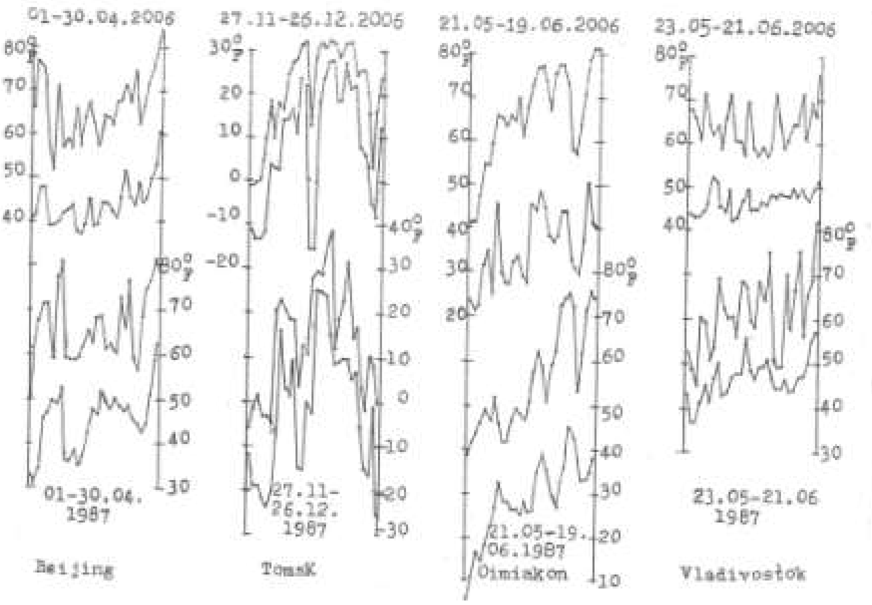

Fig. 2: The Metonic meteorological cycle in the evolution of the daily maximum and minimum air temperatures in Beijing, Tomsk, Oymyakon and Vladivostok

By analyzing the graphs in Figure 2, one can observe the clear similarities in the evolution of the daily maximum and minimum air temperatures, especially in Beijing, Tomsk and Oymyakon. One can notice that the highest amplitudes, both for maximum and for minimum daily temperatures, occur at Tomsk (Central

Siberia) and Oymyakon (Eastern Siberia). The lowest amplitudes are noticed at Vladivostok in a climate with oceanic influence.

2.3. The Metonic cycle in the air temperature evolution in North America

Since the North American continent does not contain significant mountain ranges with longitudinal arrangement, polar and tropical air masses can easily travel causing some particular characteristics in the occurrence of the Metonic cycle, especially in the case of the air temperature.

In order to emphasize these characteristics the following observation points were selected: Minneapolis (45°N), Memphis (30°N), Nome (65°N) and Ottawa (45°N). In Figure 3, we present with graphs, the Metonic meteorological cycle in the evolution of the daily maximum and minimum air temperatures for the selected points Minneapolis, Memphis, Nome and Ottawa.

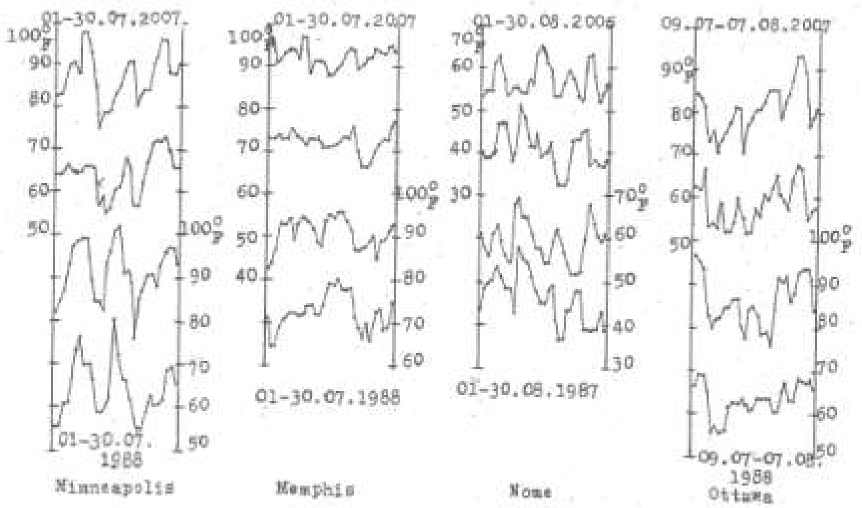

Fig. 3: The Metonic meteorological cycle in the evolution of the daily maximum and minimum air temperatures for North America (Minneapolis, Memphis, Nome and Ottawa)

By analyzing the graphs in Figure 3, the following conclusions can be drawn: a) the clear similarities in the evolution of the air temperatures at all four observation points are obvious; b) the highest amplitudes occur at Minneapolis and Ottawa (situated at latitude 45°N); c) at Memphis (with subtropical influences) and Nome (with polar and oceanic influences), the amplitudes of the daily maximum and minimum air temperatures are lower; d) at Minneapolis, Memphis and Ottawa the Metonic cycle occurred in 1988 and 2007, while at Nome in 1987 and 2006.

2.4. The Metonic cycle in the air temperature evolution in South America

As in North America, the absence of significant mountain ranges with longitudinal arrangement determines some specific particularities in the evolution of the daily maximum and minimum air temperatures in South America.

In order to emphasize the existence of the Metonic cycle in the evolution of the daily maximum and minimum air temperatures in South America, the following observation points were selected: Manaus and Iquitos (equatorial climate), Asuncion (tropical climate) and Comodoro Rivadavia (temperate climate). In Figure 4, we present with graphs, the evolution of the daily maximum and minimum air temperatures for the Metonic meteorological cycle in the selected points (Manaus, Iquitos, Asuncion and Comodoro Rivadavia).

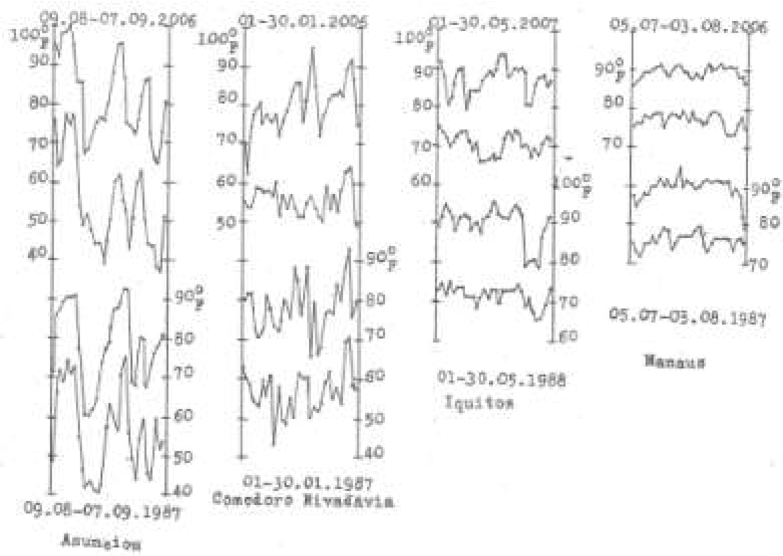

Fig. 4: The Metonic meteorological cycle in the evolution of the daily maximum and minimum air temperatures for South America (Manaus, Iquitos, Asuncion and Comodoro Rivadavia)

By analyzing the graphs in Figure 3, the following conclusions can be drawn: a) the clarity of this cycle is obvious at all observation points; b) the highest amplitudes of the daily maximum and minimum air temperatures occur at Asuncion and Comodoro Rivadavia where air masses with very different origins can penetrate, depending on the season; c) the lowest amplitudes are recorded in Iquitos and Manaus where only equatorial air masses penetrate.

2.5. The Metonic cycle in the air temperature evolution in Africa, New Zeeland and Australia

Although the African territory lies in both hemispheres of the Earth (Northern and Southern), only the data from two observation and measurement points were used, due to the discontinuities in the databases of several countries. There were selected two points: Alexandria, in the Northern Hemisphere and Mediterranean Sea port, and Cape Town, in the Southern Hemisphere and Atlantic Ocean port. In both situations, the Metonic meteorological cycle in the evolution of the daily maximum and minimum temperatures occurs during the transition from the cold season to the warm season. In Figure 5, we present with graphs, the Metonic meteorological cycle in the evolution of the daily maximum and minimum temperatures at the following observation and measurement points: Alexandria and Cape Town (in Africa), Cathan Island (in New Zeeland) and Perth (in Australia). Both in Australia and New Zeeland, there are a few observation and measurement points with complete sequences of observations. For this reason, only the above two points (Cathan Island and Perth) were considered for analysis.

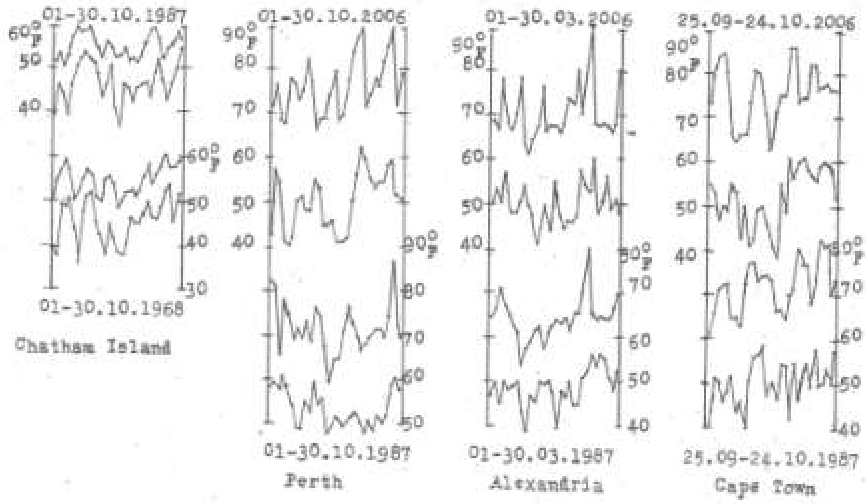

Fig. 5: The Metonic meteorological cycle in the evolution of the daily maximum and minimum air temperatures in Africa (Alexandria and Cape Town), Australia (Perth) and New Zeeland (Cathan Island)

It follows from the analysis of the graphs in the African observation points the following: the similarities in the evolution of the daily maximum and minimum air temperatures are very clear; the amplitude of the temperature oscillations is low since both observation and measurement points are seaports where the influences of the maritime air masses having low thermal variations prevail. By analyzing the graph representing the 19-year (Metonic) cycle in the evolution of the daily maximum and minimum air temperatures for Cathan Island (New Zeeland), one can observe the low oscillations of the (daily maximum and minimum) air temperature due to a very constant temperate maritime climate. By analyzing the graph representing the evolution of the daily maximum and minimum air temperatures for Perth (Australia), one can see that the similarities are obvious. Also, one can observe the moderate amplitude in the evolution of temperatures since Perth is a port on the Indian Ocean where maritime air masses prevail.

2.6. The Metonic cycle in the air temperature evolution in Antarctica

Situated around the South Pole, Antarctica has the coldest climate on Earth. Even under these circumstances, several countries on the other continents possess meteorological observation posts. There are incomplete data sequences at many weather stations due to the very difficult conditions in which those meteorologists are forced to work. However, the data from four observation and measurement points could be used. Of course, the lowest temperatures are recorded in the weather stations located closer to the South Pole and the highest temperatures are recorded in the weather stations located on the ocean shore or on the neighboring islands. In Figure 6, we present, with graphs, the evolution of daily maximum and minimum air temperatures in 19-year (Metonic) cycles at four observation and measurement points. These points (weather stations) are: Esperanza Base, Marambio Base, Neumayer and McMurdo.

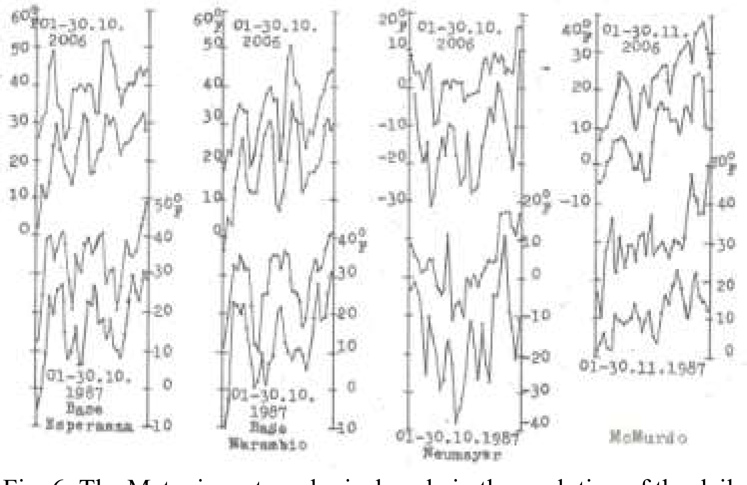

Fig. 6: The Metonic meteorological cycle in the evolution of the daily maximum and minimum air temperatures for Antarctica

The following conclusions can be drawn by analyzing the graphs in Figure 6:

1. The lowest temperatures can be noticed in the graph for Neumayer where the minimum temperatures reach -40°F (-40°C);

2. The highest daily minimum temperatures were recorded in McMurdo in 1987, but also at Esperanza Base and Marambio Base in 2006 with values around 0°F (-17.8°C);

3. The highest daily maximum temperatures were recorded in Esperanza Base and Marambio Base around the value 50°F (10°C) in 2006.

The Metonic meteorological cycles in the evolution of the daily maximum and minimum air temperatures discovered in Antarctica prove that these cycles occur at the South Pole too, but with a higher frequency when passing from the cold season to the warm season. The cycles have been noticed in the months of October and November of the years 1987 and 2006. Further on, we will analyze some special particularities in the evolution of some 19-year meteorological cycles (Metonic cycles) regarding their repetition in time. In Figure 7, we present, with graphs, 19-year (Metonic) cycles in the evolution of daily maximum and minimum air temperatures with three or four repetitions.

The following conclusions can be drawn by analyzing the graphs in fig. 7:

1. The 4 time repetition of the 19-year cycle occurred at Iasi in the month of March of the years 1949, 1968, 1987 and 2006;

2. The 4 time repetition of the 19-year cycle occurred at Minneapolis in the month of October of the years 1949, 1968, 1987 and 2006;

3. The 3 time repetition of the 19-year cycle occurred at Portland in the month of March of the years 1968, 1987 and 2006;

4. The 3 time repetition of the 19-year cycle occurred at Braila in the period April 15 – May 15 of the years 1976, 1995 and 2014;

5. The highest amplitudes of the air temperatures occur at Minneapolis and Iasi since these cycles took place in periods of transition from the warm season to the cold season (for Minneapolis) and from the cold season to the warm season (for Iasi);

6. The lowest amplitudes of the air temperatures at Portland are due to the climate, where the influence of the oceanic air masses prevails;

7. The moderate amplitudes of the air temperatures at Braila are due to the period (the warm season) when the 19-year cycles occurred.

A special category of meteorological cycles in the evolution of air temperatures consists of those cycles which occur only at time intervals which are multiples of 19 years. This category comprises cycles with durations of 38 years (2×19 years), 57 years (3×19 years), 76 years (4×19 years) and 95 years (5×19 years).

In Figure 8, we present, with graphs, cycles of 38 years, 57 years, 76 years and 95 years recorded in Braila in the evolution of daily maximum and minimum air temperatures.

The following conclusions can be drawn by analyzing the graphs in fig. 8:

1. There are situations on Earth where we can emphasize meteorological cycles in the evolution of daily maximum and minimum air temperatures which can have as duration multiples of the 19-year cycle and not the Metonic cycle;

2. At Braila, these cycles occurred in July (38 years), October and November (57 years), May (76 years) and October (95 years), hence in every season;

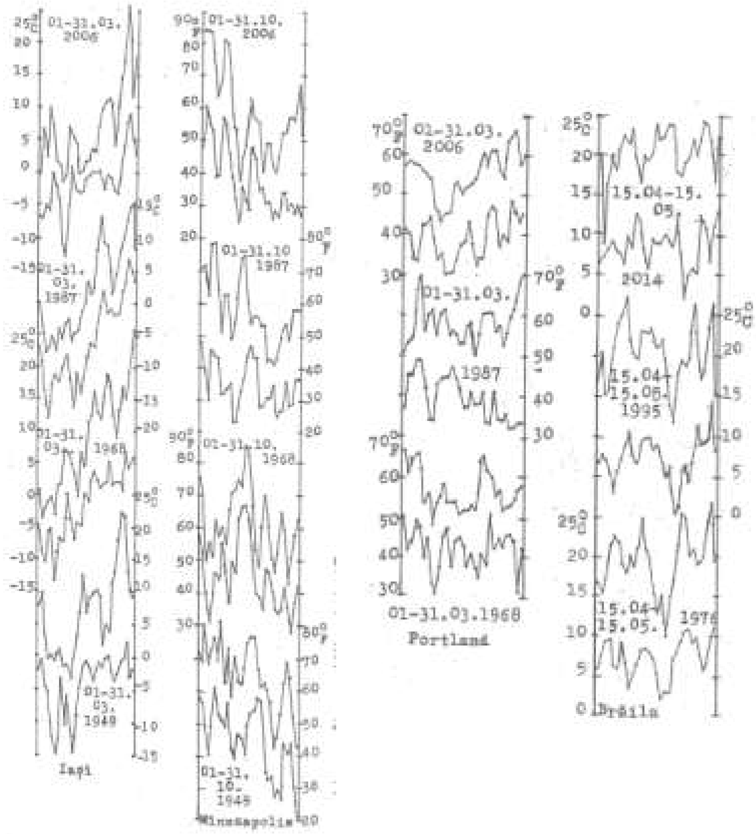

Fig. 7: 19-year (Metonic) cycles in the evolution of daily maximum and minimum air temperatures with a 4 time repetition (at Iasi and Minneapolis) a 3 time repetition (at Portland and Braila)

3. The clear similarities in the evolution of daily maximum and minimum air temperatures are obvious for all cycles;

4. The highest amplitude in the evolution of daily maximum and minimum air temperatures occurred in the 95-year cycle in the month of October of the years 1911 and 2006, but also in the 57-year cycle in the period October 10 – November 5 of the years 1940 and 1997.

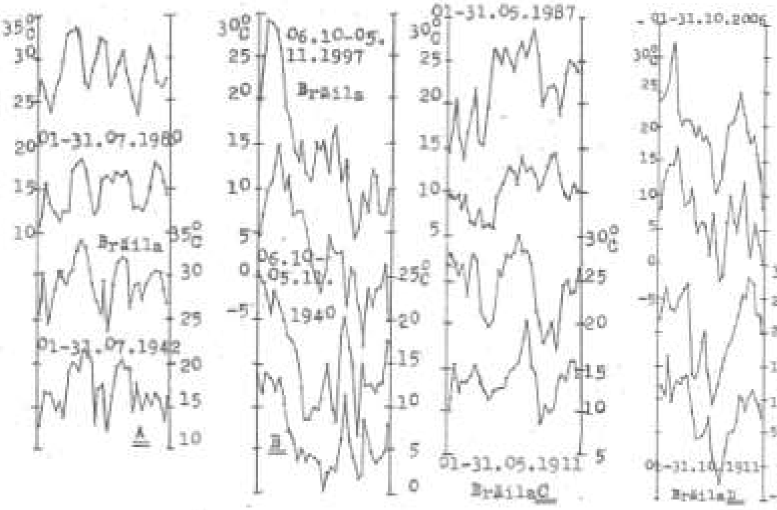

Fig. 8: Cycles in the evolution of daily maximum and minimum air temperatures with durations of 38 years (A), 57 years (B), 76 years (C) and 95 years (D) recorded in Braila

This situation can be explained by the advection of some warm air masses (maximum temperatures around 30°C), followed by the advection of some cold air masses (minimum temperatures around 0°C).

The Metonic meteorological cycle (19 years) can also be emphasized in the evolution of other meteorological elements such as the atmospheric pressure and the atmospheric precipitations.

Next, we will emphasize Metonic meteorological cycles in the evolution of the atmospheric pressure (daily mean values).

In Figure 8, we present, with graphs, the evolution of the atmospheric pressure in 19-year cycles at sea level and at the level of the weather stations Braila, Beijing and Comodoro Rivadavia.

The following conclusions can be drawn by analyzing the graphs in fig. 9:

1. The similarities are more obvious at Braila and Beijing where the highest values of the atmospheric pressure (daily mean values) are close to 1030 mb. At Braila, the daily mean values of the atmospheric pressure are measured at the level

of the weather station (16 m altitude). At Beijing, the daily mean values of the atmospheric pressure are measured at sea level (0 m altitude);

2. At Comodoro Rivadavia (South America) the similarities in the evolution of the atmospheric pressure are less obvious and are measured at sea level (0 m altitude);

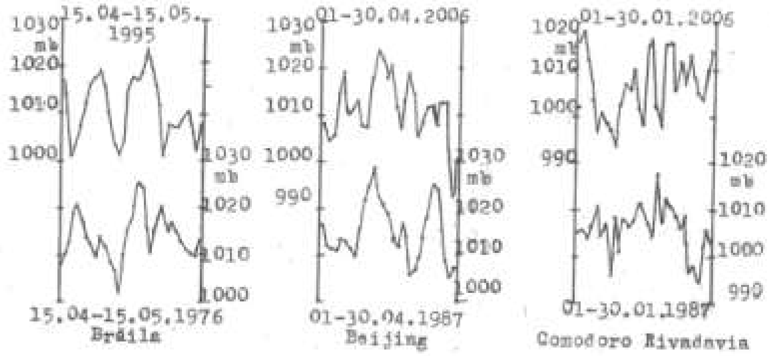

Fig. 9: Cycles in the evolution of the atmospheric pressure (daily mean values) with duration of 19 years (Metonic cycle) at Braila, Beijing and Comodoro Rivadavia

3. These graphs for the atmospheric pressures represents the same periods as those used for the evolution of the air temperature described above. At Braila (Figure 7) we compared the period April 15 – May 15 of 1995 with the period April 15 – May 15 of 1976. At Beijing (Figure 2) we compared the period April 1 – April 30 of 2006 with the period April 1 – April 30 of 1987; At Comodoro Rivadavia (Figure 4) we compared the period January 1 – January 30 of 2006 with the period January 1 – January 30 of 1987;

4. The similarities observed in the evolution of the air temperature are clearer than those observed in the evolution of the atmospheric pressure. This fact is explained by the manner through which the meteorological elements (air temperature and atmospheric pressure) were used in the demonstration of the Metonic meteorological cycle (19 years). For the air temperature, the daily maximum and minimum values were used, while for the atmospheric pressure, the daily mean values were used.

Conclusions

The following conclusions can be drawn by analyzing all the cycles that occur in the evolution of the meteorological elements described in this paper (air temperature and atmospheric pressure especially):

1. All analyzed cycles are based on the Metonic meteorological cycle (19 years);

2. In its turn, the Metonic meteorological cycle is based on the Metonic cycle in astronomy (19 years);

3. The Metonic meteorological cycles in the evolution of the air temperature and the atmospheric pressure occur mainly in the periods when the Moon's declination reaches maximum values of ±28°36′;

4. The occurrence of these cycles and their succession is explained by the atmospheric tides generated by the Moon's and Sun's attraction, which have the same periodicity;

5. In their turn, the atmospheric tides determine the evolution of the (planetary) Rossby waves, especially in the Earth's temperate zones, these waves having a major influence in the atmospheric circulation;

6. It follows from the analysis of the Metonic meteorological cycles in the two hemispheres of the Earth (Northern and Southern) that these cycles have a higher frequency in the periods of transition from the cold season to the warm season;

7. The detailed knowledge of these cycles which are based on the Metonic meteorological cycle (19 years) and of the way they evolve is very important in the elaboration of long-term forecasts (more than 10 days).

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