

THE RELATIONSHIP BETWEEN NEAR-SPACE INDICES
AND WEATHER CONDITIONS IN ISTANBUL

by

R. Gül Sevin Pekmezci

B.S. in Astronomy and Space Sciences, Ankara University, 2004

Submitted to the Institute of Environmental Sciences in partial fulfillment of
the requirements for the degree of
Master of Science
in
Environmental Sciences

Boğaziçi University

2007

FOREWORD

Once the ancient philosophers decided that the most virtuous profession was to think. This was what made a human advanced and meaningful. Physical works would not ascend the mind. The ideal way to succeed it was celestial sciences.

Agreeing with the classical philosophy, I let the Luna and planets guide my consciousness. The hardest of sciences, cosmology became my reason to survive.

However, something was not right. While the life's own was suffering, my path would have not mattered, though how heavenly it was. What was the most virtuous struggle had to be serving to the Earth; the planet I exist and survive...

GülSevin Pekmezci

ACKNOWLEDGEMENTS

I would like to thank my advisor, Prof.Dr. Orhan Yenigün, for permitting me study an unordinary topic compared to the general interests of the institute, for saving time for me in his busy schedule and for patiently taking care of my problematic period of thesis submission.

I am so thankful to my other advisor, Assoc.Prof.Dr. Atila Özgüç, for helping me at every stage of my thesis preparation, for guiding me throughout important scientific conferences, and more important, for dealing with my daily issues like a father.

I would also like to thank all of the members of Institute of Environmental Sciences, because they did not distinguish between me and environmental engineers to give knowledge but divided me from them to give extra care since my academic background was not appropriate for chemical studies, especially Prof.Dr. Melek Saçan, Prof.Dr. Işıl Balcıoğlu, Assoc.Prof.Dr. Nadim Copty, Assoc.Prof.Dr. Andzrej Furman, Assoc.Prof.Dr. Ali Saysel and Assoc.Prof.Dr. Nilgün Cılız.

I thank my family from the bottom of my heart, because I could not make it without the devotions of my sisters and brothers, and the support of my parents.

ABSTRACT

The main subject occupying the scientists' mind recently is the very reason of climate change. This question has to be immediately answered, because that change treats the existence of life on the Earth.

Equal to the anthropogenic processes like high concentration of greenhouse gases emission, electromagnetic pollution, loss of forests and biodiversity, untreated disposals, and many more, the scientists think the near-space of Earth, especially the Sun is responsible for global warming as well.

To detect any solar or cosmic signal on climate, local weather parameters are applied world-wide since they are not able to be measured globally. Due to this empirical approach, some of Istanbul's meteorological data for almost one century like air temperature, air pressure, precipitation and wind velocity are investigated in order to find any possible coherencies with space indices like sunspot number, interplanetary magnetic field, geomagnetic activity and cosmic ray number. And it turned out that the Earth's outer vicinity is not significantly responsible for the local weather of Istanbul, especially for the last three decades.

ÖZET

Son yıllarda bilim adamlarının aklının kurcalayan ana konu, iklim deęişiminin asıl sebebidir. Bu sorunun acilen yanıtlanması gerekmektedir; çünkü deęişim, Dünya’da hayatın varlığını tehdit etmektedir.

Yüksek konsantrasyonda sera gazı salınımı, elektromanyetik kirlilik, ormanların ve biyoçeşitliliğin kaybolması, bertaraf edilmemiş atıklar ve daha bunlar gibi insan kaynaklı birçok prosese eşdeğer olarak, bilim adamları yakın uzayın, özellikle de Güneş’in küresel ısınmadan sorumlu olduğunu düşünmektedir.

İklim üzerinde herhangi Güneşsel veya kozmik etkinin izini araştırmak için, dünya çapında, yerel hava parametreleri kullanılmaktadır; çünkü bunlar küresel olarak ölçülememektedirler. Bu yaklaşım ışığında, İstanbul’un neredeyse bir asırlık hava sıcaklığı, hava basıncı, yağış ve rüzgar hızı gibi bazı meteorolojik verileri; Güneş leke sayısı, gezegenlerarası manyetik alan, jeomanyetik aktivite ve kozmik ışınlar gibi uzay indisleriyle aralarındaki muhtemel ilişkilerini bulmak üzere irdelenmiştir. Ve Dünya’nın yakın uzay çevresinin, İstanbul’un yerel hava şartları üzerinde, özellikle de son otuz yıldır önemli derecede etkili olmadığı ortaya çıkmıştır.

TABLE OF CONTENTS

FOREWORD.....	iii
ACKNOWLEDGMENTS.....	iv
ABSTRACT.....	v
ÖZET.....	vi
LIST OF FIGURES.....	ix
LIST OF TABLES.....	xiii
LIST OF SYMBOLS/ABBREVIATIONS.....	xv
1. INTRODUCTION.....	1
1.1. Celestial Phenomena.....	3
1.1.1. The Sun and Solar Activity.....	4
1.1.2. The Interplanetary Magnetic Field.....	6
1.1.3. Earth's Magnetic Field and Geomagnetic Activity.....	7
1.1.4. Cosmic Rays.....	9
1.2. Terrestrial Phenomena.....	11
1.2.1. Kandilli Observatory.....	11
1.2.2. Air Temperature.....	12
1.2.3. Air Pressure.....	13
1.2.4. Precipitation.....	13
1.2.5. Wind Velocity.....	14
2. LITERAL SURVEY.....	17
3. RESULTS AND DISCUSSION.....	28
3.1. Air Temperature.....	31
3.1.1. Solar Activity.....	32
3.1.2. Interplanetary Magnetic Field.....	35
3.1.3. Geomagnetic Activity.....	37
3.1.4. Cosmic Rays.....	40

3.2. Air Pressure.....	43
3.2.1. Solar Activity.....	43
3.2.2. Interplanetary Magnetic Field.....	44
3.2.3. Geomagnetic Activity.....	46
3.2.4. Cosmic Rays.....	47
3.3. Precipitation.....	50
3.3.1. Solar Activity.....	50
3.3.2. Interplanetary Magnetic Field.....	53
3.3.3. Geomagnetic Activity.....	53
3.3.4. Cosmic Rays.....	53
3.4. Wind Velocity.....	56
3.4.1. Solar Activity.....	56
3.4.2. Interplanetary Magnetic Field.....	57
3.4.3. Geomagnetic Activity.....	59
3.4.4. Cosmic Rays.....	59
4. CONCLUSIONS.....	62
REFERENCES.....	66
APPENDIX A. Maximum and Minimum Plots.....	74

LIST OF FIGURES

Figure 1.1.	The estimated global climate forcings between AD 1850 and 2000 separated into anthropogenic and natural forcings.....	2
Figure 1.2.	The sunspots.....	5
Figure 1.3.	Yearly averaged international sunspot number for the period 1610-2000.....	5
Figure 1.4.a.	Interplanetary magnetic field around the Sun.....	6
Figure 1.4.b.	Interplanetary magnetic field through the Earth.....	6
Figure 1.5.a.	Magnetosphere of the Earth.....	7
Figure 1.5.b.	An aurora borealis.....	7
Figure 1.6.	Inverted cosmic ray number due to Climax Neutron Monitor and relative sunspot number.....	10
Figure 1.7.	Location of Kandilli Observatory.....	12
Figure 2.1.	The $\Delta^{18}\text{O}$ record of a stalagmite from the Spannagel cave in the central Alps covering the last 2000 year, compared to ^{14}C production rate.....	22
Figure 2.2.	global surface air temperature changes and atmospheric CO_2 concentration, geomagnetic activity, solar activity, changes in temperature according to	

historical data, CO₂ concentration as determined from C content of tree rings, residual conference $\Delta^{14}\text{C}$ series showing four temperature minima, temperature changes during the last 1000 years, auroral frequency, temperature changes for the last 12,000 years obtained from pollen data and alpine glaciers, residuum ΔT changes based on radiocarbon dating of tree rings.....27

Figure 3.1.a. Istanbul's five-year running mean air temperature and solar activity.....36

Figure 3.1.b. Istanbul's five-year running mean air temperature and interplanetary magnetic field.....36

Figure 3.2.a. Istanbul's five-year running-mean air temperature and geomagnetic activity.....41

Figure 3.2.b. Istanbul's five-year running-mean air temperature and cosmic rays.....41

Figure 3.3.a. Istanbul's five-year running mean air pressure and solar activity.....45

Figure 3.3.b. Istanbul's five-year running mean air pressure and interplanetary magnetic field.....45

Figure 3.4.a. Istanbul's five-year running-mean air pressure and geomagnetic activity.....48

Figure 3.4.b. Istanbul's five-year running-mean air pressure and cosmic rays.....48

Figure 3.5.a. Istanbul's five-year running total mean precipitation amount and solar activity.....52

Figure 3.5.b. Istanbul's five-year running mean total precipitation amount and interplanetary magnetic field.....52

Figure 3.6.a.	Istanbul's five-year running-mean total precipitation amount and geomagnetic activity.....	54
Figure 3.6.b.	Istanbul's five-year running-mean total precipitation amount and cosmic rays.....	54
Figure 3.7.a.	Istanbul's five-year running mean wind velocity and solar activity.....	58
Figure 3.7.b.	Istanbul's five-year running mean wind velocity and interplanetary magnetic field.....	58
Figure 3.8.a.	Istanbul's five-year running-mean wind velocity and geomagnetic activity....	60
Figure 3.8.b.	Istanbul's five-year running-mean wind velocity and cosmic rays.....	60
Figure A.1.a.	Istanbul's five-year running mean maximum air temperature and solar activity.....	74
Figure A.1.b.	Istanbul's five-year running mean maximum air temperature and interplanetary magnetic field.....	74
Figure A.2.a.	Istanbul's five-year running-mean maximum air temperature and geomagnetic activity.....	75
Figure A.2.b.	Istanbul's five-year running-mean maximum air temperature and cosmic rays.....	75
Figure A.3.a.	Istanbul's five-year running mean minimum air temperature and solar activity.....	76

Figure A.3.b. Istanbul's five-year running mean minimum air temperature and interplanetary magnetic field.....	76
Figure A.4.a. Istanbul's five-year running-mean minimum air temperature and geomagnetic activity.....	77
Figure A.4.b. Istanbul's five-year running-mean minimum air temperature and cosmic rays.....	77
Figure A.5.a. Istanbul's five-year running mean maximum air pressure and solar activity...	78
Figure A.5.b. Istanbul's five-year running mean maximum air pressure and interplanetary magnetic field.....	78
Figure A.7.a. Istanbul's five-year running-mean maximum air pressure and geomagnetic activity.....	79
Figure A.7.b. Istanbul's five-year running-mean maximum air pressure and cosmic rays....	79
Figure A..a. Istanbul's five-year running mean minimum air pressure and solar activity....	80
Figure A.5.b. Istanbul's five-year running mean minimum air pressure and interplanetary magnetic field.....	80
Figure A.6.a. Istanbul's five-year running-mean minimum air pressure and geomagnetic activity.....	81
Figure A.6.b. Istanbul's five-year running-mean minimum air pressure and cosmic rays.....	81

LIST OF TABLES

Table 1.1.	Annually averaged ion production rates in the global atmosphere from different natural ionization sources.....	16
Table 3.1.	Steps of calculating five-year running-mean of an annually dataset.....	30
Table 3.2.	Steps of calculating the correlation coefficient of an annually dataset.....	31
Table 3.3.	The maximum and minimum years of sunspot number and mean/ maximum/ minimum air temperature with the phase lags in the 20th century.....	35
Table 3.4.	The maximum and minimum years of geomagnetic storm strength and mean/maximum/minimum air temperature with the phase lags in the 20th century.....	39
Table 3.5.	The maximum and minimum years of cosmic ray number and mean/maximum/ minimum air temperature with the phase lags in the 20th century.....	43
Table 3.6.	The maximum and minimum years of sunspot number and mean/maximum/ minimum air pressure with the phase lags in the 20th century.....	44
Table 3.7.	The maximum and minimum years of interplanetary magnetic field strength and mean/ maximum/minimum air pressure with the phase lags in the 20th century.....	46

Table 3.8.	The maximum and minimum years of geomagnetic storm strength and mean/ maximum/minimum air pressure with the phase lags in the 20th century.....	47
Table 3.9.	The maximum and minimum years of cosmic ray number and mean/ maximum/ minimum air pressure with the phase lags in the 20th century.....	50
Table 3.10.	The maximum and minimum years of sunspot number, geomagnetic activity strength, interplanetary magnetic field strength, cosmic ray flux and total precipitation amount of Istanbul with the phase lags in the 20th century.....	55
Table 3.11.	The maximum and minimum years of sunspot number, geomagnetic activity strength, interplanetary magnetic field strength, cosmic ray flux and average wind velocity of Istanbul with the phase lags in the 20th century.....	61
Table 3.12.	The correlation coefficients between five-year running-mean space indices and five-year running-mean Istanbul weather parameters.....	61

LIST OF SYMBOLS/ABBREVIATIONS

Symbol	Explanation	Units used
SSN	Sunspot Number	
IMF	Interplanetary Magnetic Field Strength	nanotesla (nT)
AA	Geomagnetic Activity Magnitude	nanotesla (nT)
CR	Cosmic Ray Number	
T _{mean}	Mean Air Temperature	Degrees Celsius (°C)
T _{max}	Maximum Air Temperature	Degrees Celsius (°C)
T _{min}	Minimum Air Temperature	Degrees Celsius (°C)
P _{mean}	Mean Air Pressure	millimeter mercury (mmHg)
P _{max}	Maximum Air Pressure	millimeter mercury (mmHg)
P _{min}	Minimum Air Pressure	millimeter mercury (mmHg)
Prec.	Total Precipitation Amount	millimeter (mm)
W.V.	Wind Velocity	meter/second (m/sec)
yr	Year	

1. INTRODUCTION

The Earth is a crustal planet in a monostellar system which locates in the Virgo Branch of the Milky Way Galaxy. What makes the Earth special but an ordinary planet is that it is the unique habitable place in the Universe as far as known and what made life possible on it is not a chain of coincidences. First of all, it places in a matteral universe and the galaxy it belongs to locates relatively far from the neighbor ones. Its star, the Sun, is a moderately big and stable one locating at a distant branch of the galaxy, safe from the possible black hole in the center. The Earth's distance from the Sun keeps it cool enough to possess water liquidly, and warm enough to process biochemically. It has one satellite, the Moon, which keeps the planet balanced in the orbit around the Sun. Its magnetosphere protects the planet against energetic particles from the space, and the atmosphere renders the material transfer within the different components of the Earth possible. The priceless features of the Earth continue on and on, and the life is too sensitive to the littlest variations in any single one of them.

Changes can be harmful for life, however they are also crucial since they lead to the evolution; a reliable continuum of life. Adaptable changes result in fitter individuals that are the priorities for the survival of the species. The most obvious variation is in the form of climate. Thanks to its very special location, orbital ecliptic, axial tide and atmosphere, the climate is a phenomenon for the Earth.

Climate's complete meaning is more than only circling seasons, regular rises and drops in temperature or sequent ice/warm ages. The reasons and results for this natural progress are still so complicated to be wholly understood, despite advanced knowledge in physical and chemical disciplines. But since a planet without climate simply means "dead", the studies of history, mechanisms and interactions with many factors of it are required for a better insight of the fragility of the unique, beautiful Earth.

Evidence for recent and important climatic variations during the past millennia comes from many different sources such as fossils, continental and marine sediments, stalagmites, tree rings, pollen, ice, glacier fluctuations and texts. [1] There are several physical factors that are believed to influence Earth's climate: Orbital changes in Earth's motion around the Sun is believed to cause ice ages, internal variability in the climate system, like changes in atmospheric and ocean circulation or large volcanic eruptions. [2] The last decade has seen a revival of various hypotheses of scientists from the different fields of astronomy, climate and weather, space physics and hydrology; claiming a strong correlation between solar activity and a number of terrestrial climate parameters, especially links between cosmic rays and cloud cover, and between solar cycle lengths and Northern Hemisphere land temperatures. [3,4]

However, there is an obvious increase in global air temperature in the last century, as reported from various places and by various scientists. This very steep and ongoing accession divides the scientific world in defining the reason: the ones claim that it is natural; the ones claim that it is anthropogenic. In this case, the determination of the proportion, by which different processes can affect the global change, is an important issue of the study of climate change. These processes are generally considered to be the greenhouse effect, aerosol particles, cloudiness, solar radiation, geomagnetic activity and galactic cosmic rays. [6] The determination of the natural climate variability is therefore of decisive importance for a credible estimation of the man-made signal (Figure 1.1). [7]

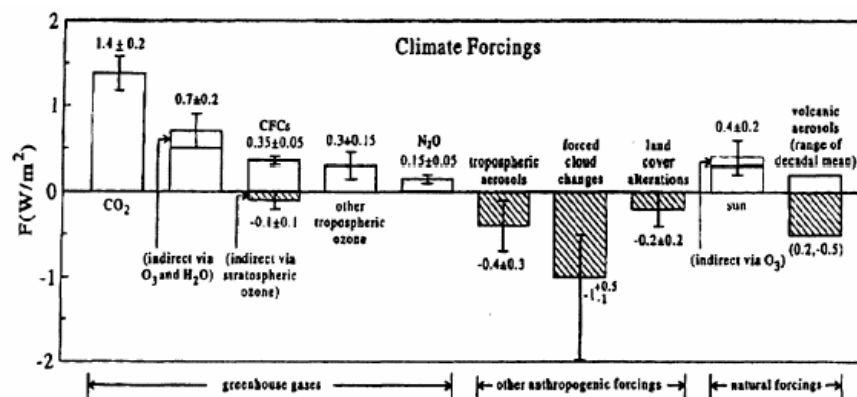


Figure 1.1. The estimated global climate forcings between AD 1850 and 2000 separated into anthropogenic and natural forcings [5]

The thesis therefore aims to determine if there is any relationship between some space phenomena like solar activity and cosmic rays and weather parameters of Istanbul, especially if there is any space signal in the increasing trend of its air temperature. There is almost no single piece about the climatologic features or changes of the region are available in literature. Thus, articles which argued about the measurements from world-wide meteorological stations are often referred in the report. Also, the ones written by solar physicists and astronomers are especially researched for the study, since climatologists and environmentalists have already been aware of global warming phenomenon for long time, and they directly attributed it to anthropogenic factors. The thesis is of importance for representing a combination of astronomical and meteorological phenomena on an environmental basin for the region and also for being for a particular location which is affected by both European and Asian climate regimes. In the following section, the space-sourced factors which are applied for the thesis are described.

1.1. Celestial Phenomena

Interplanetary space seems dark, still, and empty, a transparent void through which we see only distant points of starlight. However, discoveries made since the beginning of the space program in 1958 reveal that the Earth's near-space environment is not empty. It is filled with magnetic fields, electric currents, plasma, matter, energy, and activity invisible to the naked eye but readily apparent to more sensitive scientific instruments. This environment has traditionally been explored and studied as a system of independent component parts - the interplanetary region, the magnetosphere, the ionosphere, and the upper atmosphere. From these early explorations, it was known that geospace is a complex system of highly interactive parts. [8,9]

Beside cosmology, the contemporary space studies focus on the Earth's vicinity as well, since the global warming is the most significant and emergent issue of the world. The recent satellites launched by famous space institutes like NASA or ESA often aim to observe the Sun, geomagnetosphere and space between the Sun and the Earth. The scientists analyze those data,

and try to make connections between them and climate concepts. Hence, it supplies a wider grasp of the Earth's outer environment in order to distinguish between space-sourced and anthropogenic factors influencing the climate.

Astronomical forcings are of interest as possible influences on terrestrial climate. In addition to orbital insolation changes are intrinsic variations of the Sun and its space environment. The study of the sun-climate relation is complex because both the physical and statistical properties of the Sun's radiative and corpuscular emissions and the Earth's internal climatic factors are not well understood. Beyond the Sun per se, galactic cosmic rays, modulated by the varying solar magnetic wind, have been implicated in changes of terrestrial clouds. [10]

1.1.1. The Sun and Solar Activity

The Sun of the solar system is a typical star of intermediate size and luminosity. Its radius is about 696000 km, and it rotates with a period that increases with latitude from 25 days at the equator to 36 days at poles. Its mass is approximately 2×10^{30} kg, consisting mainly of hydrogen (90%) and helium (10%), with some other elements in trace amounts. The Sun emits gamma rays, X rays, radio waves, and energetic particles in addition to visible light. The total energy output, solar constant, is about 3.8×10^{33} ergs/sec. [11,12]

The outer solar atmosphere, the corona, is structured by strong magnetic fields. Where these fields are closed, often above sunspot groups, the confined solar atmosphere can suddenly and violently release eruptions of gas and magnetic fields called coronal mass ejections. A large coronal mass ejection can contain a billion tons of matter accelerated to several million miles per hour in a spectacular explosion. Solar material streaks out through the interplanetary medium, impacting planets or spacecraft in path. [12,13]

The concept of continuous solar wind developed in 1950's. First, Ludwig Biermann, one of the past directors of Astrophysics Department in Max-Planck Institute, observed comet tails as they passed close to the Sun, and explained the observed tail deflection by a continuous flux

of protons from the Sun. Then Parker showed that the solar corona must expand, and called the outward streaming coronal gas 'solar wind'. Some of its energy finds its way into the Earth's magnetosphere and atmosphere, and drives the magnetospheric convection system and energizes much of the plasma on the Earth's magnetic field lines and other geomagnetic pulsations and large neutral atmospheric winds, and heats the polar upper atmosphere. [14,15]

Beside ejections, there occur dark areas on the solar surface, containing transient, concentrated magnetic fields, called sunspots. They are the most prominent visible features on the Sun; a moderate-sized sunspot is about as large as Earth, forming and dissipating over periods of days or weeks. They occur when strong magnetic fields emerge through the solar surface and allow the area to cool slightly, from a background value of 5800 °C down to about 4200 °C. The darkest area at the center of a sunspot is where the magnetic field strengths are the highest. Sunspots rotate with the solar surface, taking about 27 days to make a complete rotation as seen from Earth (Figure 1.2). [16,17] The traditional direct way to observe the Sun's activity is recording the sunspot number. Sunspots are known since the year AC 1000, and they are systemically recorded since the inventory of the telescope, 17th century (Figure 1.3). They exhibit a period, close to eleven years, which can be defined as solar climate, but generally are known as solar cycles.



Figure 1.2. The sunspots [17]

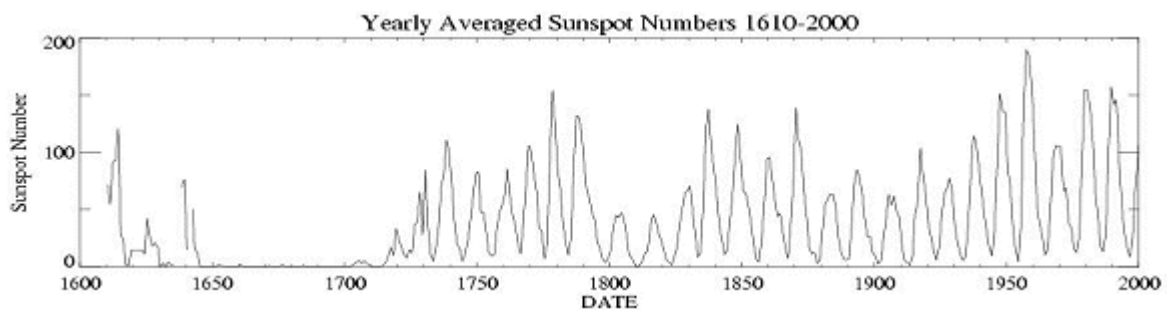


Figure 1.3. Yearly averaged international sunspot number for the period 1610-2000 [18]

The Royal Greenwich Observatory sunspot number data have been appended with data obtained by the US Air Force Solar Optical Observing Network since 1977. This newer data have been reformatted to conform to the older Greenwich data and both are available in a local

directory of ASCII files. Each file contains records for a given year with individual records providing information on the daily observations of active regions. [18] The sunspot data used in the study are received via the FTP server webpage of NASA Goddard Space Flight Center addressed ftp://ftp.ngdc.noaa.gov/STP/SOLAR_DATA/SUNSPOT_NUMBERS/.

1.1.2. The Interplanetary Magnetic Field

The interplanetary magnetic field is a part of the Sun's magnetic field carried into interplanetary space by the solar wind (Figure 1.4.a), and their lines are said to be frozen in to the solar wind plasma. Because of the Sun's rotation, the interplanetary magnetic field, like the solar wind, travels outward in a spiral pattern that is often compared to the pattern of water sprayed from a rotating lawn sprinkler. The field originates in regions on the Sun where the magnetic field lines emerging from one region which does not return to a conjugate region but extend virtually indefinitely into space (Figure 1.4.b). The direction (polarity, sense) of the field in the Sun's northern hemisphere is opposite to that of the field in the southern hemisphere and the polarities reverse with each solar cycle. [19,20]

The interplanetary magnetic field is a weak field, varying in strength near the Earth from 1 to 37 nT, with an average value of ~ 6 nT. When its and geomagnetic field's lines are oriented opposite or antiparallel to each other, they can merge or reconnect, resulting in the transfer of energy and momentum from the solar wind flow to magnetosphere. [19]

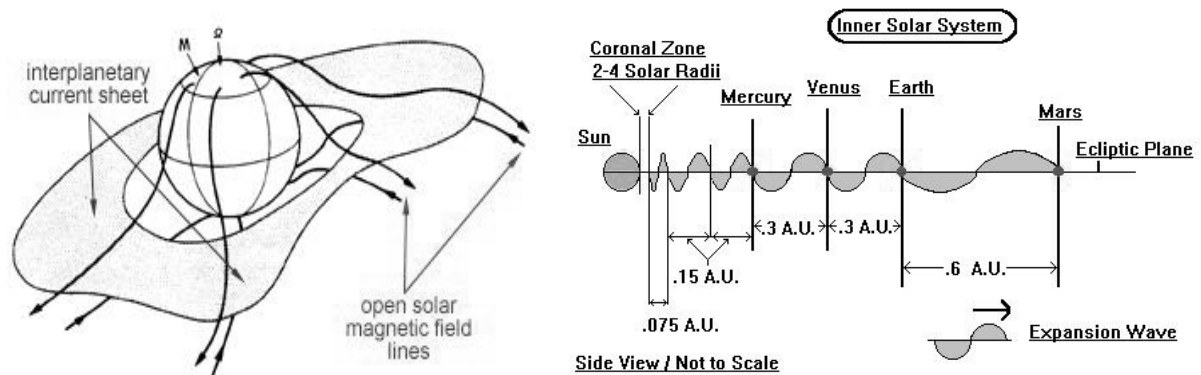


Figure 1.4. Interplanetary magnetic field a) around the Sun b) through the Earth [19]

IMF data are supplied from National Aeronautics and Space Administration, Goddard Space Flight Center for the period of 1967 – 2006 on the page addressed <http://omniweb.gsfc.nasa.gov/form/dx1.html>.

1.1.3. Earth's Magnetosphere and Geomagnetic Activity

Earth is one of the planets that have a strong internal magnetic field. In the absence of any external drivers, the geomagnetic field can be approximated by a dipole field with an axis tilted about 11 degrees from the spin axis. The forcing by the solar wind is able to modify this field, creating a cavity called the magnetosphere. This cavity shelters the surface of the planet from the high energy particles of the solar wind. The outer boundary of the magnetosphere is called the magnetopause. In front of the dayside magnetopause another boundary called the bow shock is formed because the solar wind is supersonic. The region between the bow shock and the magnetopause is called the magnetosheath. At low-altitude limit, magnetosphere ends at the ionosphere and it is filled with plasma that originates both from the ionosphere and the solar wind (Figure 1.5.a). [22]

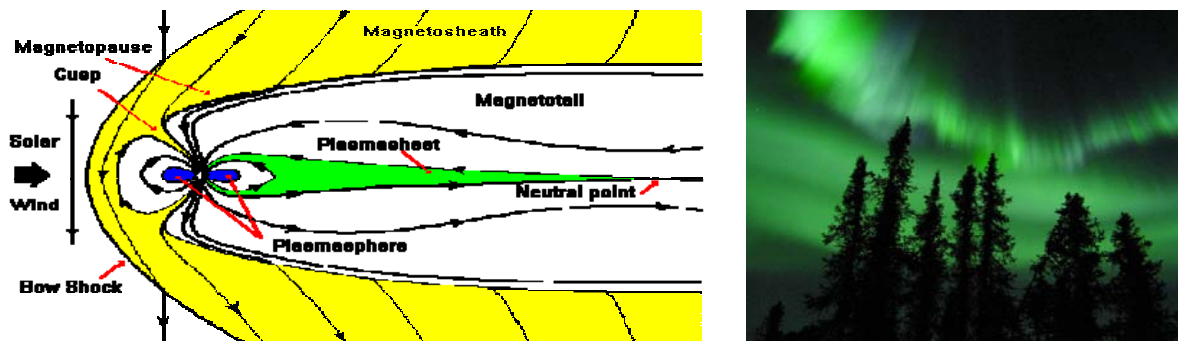


Figure 1.5. a) Magnetosphere of the Earth [22] b) An aurora borealis [23]

Solar wind and the magnetic field it carries along modify the form of the magnetosphere, by pushing it in the dayside and creating a long magnetotail in the nightside. As a consequence, the distance of the magnetopause from the Earth is only about 10 Earth's radii in the dayside, while the tail is more than 10 times longer. The magnetic field in the tail points

towards the Earth in the northern half and away in the southern half, this geometry being supported by a cross-tail current (neutral sheet). [24,25]

Geomagnetic field lines can guide energetic electrons and protons from magnetosphere or magnetosheath down to Earth's atmosphere. Precipitating particles lose their energy via collisions with the neutral particles and ionize them at approximately the same altitude range than solar UV radiation when creating the ionosphere. In addition, some of the atmospheric constituents are excited to higher energy levels: this can lead to emission of auroral light. Most of this activity occurs within auroral oval. [26]

Because of the solar wind, Earth is hit by hot, magnetized, supersonic and collisionless plasma carrying a large amount of kinetic and electrical energy. Some of this energy finds its way into our magnetosphere creating geomagnetic activity which consists of geomagnetic storms, substorms, and aurora (Figure 1.5.b). It has been shown that solar wind speed correlates well with geomagnetic activity at time scales longer than about one month. The level of the geomagnetic activity is measured using different activity indices, most of which are based on ground-based magnetometer recordings. [27]

Except particles, there is also radiation coming from the near-space. Naturally occurring sources of radiation in the space environment are trapped radiation belts, galactic cosmic rays and solar proton events. The radiation belt has two sublevels: Inner (the Van Allen radiation) belt is a torus of energetic charged particles around the Earth, trapped by Earth's magnetic field. It is relatively static, arising from cosmic ray atmospheric neutron decay, and affects indirectly atmospheric changes. Inner belt proton fluxes are higher at solar minimum when atmospheric densities are lower. Outer belt consists mainly of high energy electrons trapped by the geomagnetosphere. Its electron fluxes are higher on average during the declining phase of the solar activity. [28,29]

Magnetospheric substorms represent a basic form of interaction between the solar wind, the magnetosphere, and the ionosphere. Early case studies and statistical analyses led to the understanding that substorms occurred when the interplanetary magnetic field turned

southward; allowing a more direct energy input from the solar wind into the magnetosphere, later letting the explosive energy release during the substorm expansion phase. [8]

To characterize the variability of the Earth's magnetic field, in all its complexity, in a single number, geomagnetic indices have been developed. There are many such indices that each characterizes a different aspect or time-frame of the dynamic geomagnetic field. The preferred one for the study, aa index, is a simple global geomagnetic activity index, with units of 1 nT, which is produced from the K indices from two approximately antipodal observatories. At present these are Hartland Observatory in the UK and Canberra Observatory in Australia. Since it is based on data from only two observatories, it is the simplest of all the 3-hourly planetary indices. However, provided averages over 12-hours or longer are used, the index strongly correlates with the ap and am indices, which are derived using data from more extensive observatory networks. [30] The main advantage in using aa indices for research purposes is that the time series spans further back, to 1868, than the other planetary indices time series. Also, updated values are produced and made available weekly, giving nearer to real time availability than other planetary indices. The data are published by the International Service for Geomagnetic Indices in France; yet it is best available online on the following address of United States National Ocean and Atmosphere Administration's webpage: ftp://ftp.ngdc.noaa.gov/STP/SOLAR_DATA/RELATED_INDICES/AA_INDEX. [31]

1.1.4. Cosmic Rays

Cosmic rays are high energy charged particles, originating in outer space and strike the Earth from all directions. The term "cosmic rays" usually refers to galactic cosmic rays, which originate in sources outside the solar system, distributed throughout the Milky Way Galaxy. They were discovered in 1912 by Victor Hess, the radiologist, when he found that an electroscope discharged more rapidly as he ascended in a balloon. He attributed this to a source of radiation entering the atmosphere from above, and in 1936 was awarded the Nobel Prize for his discovery. [32]

It is believed that most galactic cosmic rays derive their energy from supernova explosions, which occur approximately once every fifty years in Milky Way. There is considerable evidence that cosmic rays are accelerated as the shock waves from these explosions travel through the surrounding interstellar gas. They include essentially all of the elements in the periodic table; about 89% of the nuclei are hydrogen, 10% helium, and the rest is heavier elements. Their energy is usually measured in units of mega or giga electron volts and most galactic cosmic rays have energies between 100 MeV and 10 GeV (almost tantamount to velocity of light). [33]

The cosmic rays are affected by the interplanetary magnetic field embedded in the solar wind and therefore have difficulty reaching the inner solar system. Spacecrafts venturing out towards the boundary of the solar system found that the intensity of galactic cosmic rays increases with distance from the Sun. As solar activity varies over the 11 year solar cycle, the intensity of cosmic rays at Earth also varies, in anti-correlation with the sunspot number (Figure 1.6) [33,34]

However, especially in minimum solar activity years, the high energy cosmic rays manage to reach the Earth's vicinity. When they undergo collisions with atoms of the upper atmosphere, they produce a cascade of secondary particles that shower down through the atmosphere to the Earth's surface. Secondary cosmic rays include pions which quickly decay to produce muons, neutrinos and gamma rays, as well as electrons and positrons produced by muon decay and gamma ray interactions with atmospheric atoms. The number of particles reaching the ground is related to the energy of the cosmic ray that struck the upper atmosphere. [34]

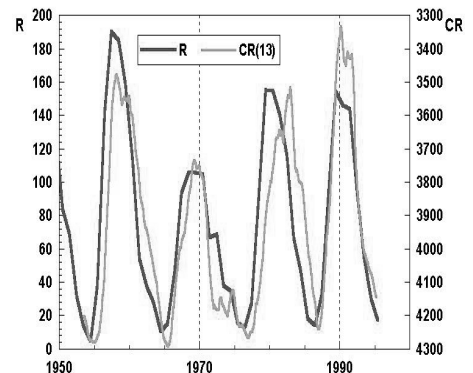


Figure 1.6. Inverted cosmic ray number due to Climax Neutron Monitor (light) and relative sunspot number (R) [32]

Ground-based neutron monitors detect variations in the approximately 500 MeV to 20 GeV portion of the primary cosmic ray spectrum. This class of detector is more sensitive in the approximate 500 MeV to 4 GeV portion of the cosmic ray spectrum than are cosmic ray muon detectors. The portion of the cosmic ray spectrum reaching the Earth's atmosphere is controlled by the geomagnetic cutoff which varies from a minimum at the magnetic poles to a vertical cosmic ray cutoff of about 15 GV in the equatorial regions. [13,35] Beside location, the most characteristic feature of a neutron monitor is cutoff rigidity, R_c , which is the lowest rigidity that a charged particle can possess and still arrive at a specific point on the Earth's surface. The cutoff rigidity of any geographic location is a function of the zenith and azimuth angles of arrival, the altitude and the geomagnetic conditions at the time of the desired value. [36]

For the study, the daily pressure-corrected cosmic ray intensity is derived from the Huancayo (Peru 12.03 Degrees South, 75.37 Degrees West, 3400 m altitude with $R_c = 12.92\text{GV}$ for 1953 – 1991) and Haleakala (Hawaii 20N, 156W, 3030m, $R_c = 12.91\text{GV}$ for 1991 – 2006) Neutron Monitors whose data are available on the United States National Ocean and Atmosphere Administration webpage addressed ftp://ftp.ngdc.noaa.gov/STP/SOLAR_DATA/COSMIC_RAYS/huancayo.tab.

The general definitions of applied space parameters have just been outlined. In the following section, the atmospheric phenomena used in the study are briefly described.

1.2. Terrestrial Phenomena

The data used for investigating atmospheric phenomena for Istanbul region are supplied from Kandilli Observatory E.R.I. In this section, the geological characteristics of this station are mentioned and the applied weather factors are defined.

1.2.1. Kandilli Observatory

The Education Minister of the reign, Emretullah Efendi, assigned Fatin Gökmen as the president of the Observatory of Istanbul on June 21, 1910. After proper researches, Mr.

Gökmen decided to construct the observatory on the Icadiye Hill, as it has been located since. Beginning with only a tower and a hut, the observatory was converted into a first-class meteorological station via the interactions with Prof. Angot from France. The measurements have been continued at the same location since July, 1911. The extracurricular units of the Observatory were constructed after 1925 and in time, it has turned into a complex station dealing with both celestial and terrestrial studies. The meteorological section was the unique station for both weather and climate until 1929, when Governmental Meteorological Affairs Administration was founded and the Observatory was conjoined to Boğaziçi University in 1982. As known now, Kandilli Observatory and Earthquake Research Institute is located on the top of a hill at 110 m above the sea level in Vaniköy-Icadiye, the east coast of the Phosphorus (Figure 1.7). The coordinations of the observation station are 41 degrees 3 minutes 45.08 seconds North, 29 degrees 3 minutes 29.38 seconds East and 114.5 meter from marine level. [37] The Observatory's data of the meteorological parameters except wind velocity that extends to 1926 have been systematically measured since 1912.

Below are found the atmospheric parameters which are measured at Kandilli Observatory and used for the study. The atmosphere is a gigantic, though inefficient, heat engine, transforming the potential energy represented by the heat differences into kinetic energy of the mean motion. [38] To understand those mechanisms and to grasp those processes as many parameters as possible need to be analyzed.



Figure 1.7. Location of Kandilli Observatory [37]

1.2.2. Air Temperature

The temperature of the atmosphere is a measure of the heat content of the air, and it is controlled by a complex set of interactions between the biosphere, lithosphere and atmosphere. Energy is constantly being exchanged between the surface and the air above a place, as well as circulating around the globe. The factors maintaining the temperature variations and transport are solar radiation as the principle source of heating the surface, longwave terrestrial radiation

as the source for heating the air and daily/seasonal lag periods. Also, clouds are good absorbers of longwave terrestrial radiation, creating the natural greenhouse effect to warm up the planet as required for life. [39]

Air temperature in Kandilli Observatory is measured by a thermometer stated on a platform at 2 m. higher than the ground, in the unit of degrees Celsius.

1.2.3. Air Pressure

Atmospheric pressure is simply the weight of air above an object. The weight of air is directly related to the number of air molecules in a given volume, and air pressure depends on the number of those molecules in a given volume above an object and how fast the molecules are moving. Although the changes are usually too slow to observe directly, air pressure is almost always changing. This change in pressure is caused by changes in air density, and air density is related to temperature. Warm air is less dense than cooler air because the gas molecules in warm air have a greater velocity and are farther apart than in cooler air. [40]

Atmospheric pressure in Kandilli Observatory is recorded on the observatory tower of 17.5 meters, in the unit of mmHg and normalized to sea level values.

1.2.4. Precipitation

Precipitation is defined as any liquid or solid aqueous deposit that forms in a saturated atmosphere and falls from clouds to the ground surface. Water droplets and ice crystals can only fall to surface if they grow to a size that can overcome updrafts. Conditions for growth can develop in clouds via two different processes. In clouds with temperatures above freezing, turbulent atmospheric mixing can cause droplets to grow through the processes of collision and coalescence. If enough atmospheric mixing occurs the larger droplets can expand by up to 250 times and can become heavy enough to fall to the Earth's surface. [41]

Precipitation in Kandilli Observatory is recorded as total amount for a day by a pluviograph in the unit of mm which is equivalent of m^2/kg .

1.2.5. Wind Velocity

Wind can be defined simply as air in motion. This motion can be in any direction, but in most cases the horizontal component of wind flow greatly exceeds the flow that occurs vertically. It develops as a result of spatial differences in atmospheric pressure. Generally, these differences occur because of uneven absorption of solar radiation at the Earth's surface. Wind speed tends to be at its greatest during the daytime when the greatest spatial extremes in atmospheric temperature and pressure exist. [41]

Wind is often described by two characteristics: wind speed and wind direction. Wind speed is the velocity attained by a mass of air traveling horizontally through the atmosphere. Horizontally, at the Earth's surface wind always blows from areas of high pressure to areas of low pressure, usually at speeds determined by the rate of air pressure change between pressure centers. Wind speed is a function of the steepness or gradient of atmospheric air pressure found between high and low pressure systems. [41]

Wind velocity in Kandilli Observatory is measured horizontally, on the tower where the air pressure is also measured, in the units of m/sec and normalized to 10 m. values.

Among the potential contributors to climate change, solar forcing is by far the most controversial. The Sun can influence climate through mechanisms that are not fully understood but which can be linked to the Earth's orbit around the Sun, solar variations of luminosity, magnetic field, UV radiation, solar flares and modulation of the cosmic ray intensity. [5,42] The equilibrium temperature close to the surface of the Earth is determined primarily by electromagnetic radiations from the Sun, covering a broad range of wavelengths, which

presently amount to some 342 Wm^{-2} at the top of the atmosphere. The amounts of energy reflected from the top of clouds, aerosols and atmosphere ($\sim 77 \text{ Wm}^{-2}$) and from the Earth's surface ($\sim 30 \text{ Wm}^{-2}$) define the Earth's albedo. The atmosphere absorbs 67 Wm^{-2} and 168 Wm^{-2} reach the Earth's surface, where they are also absorbed. Based on Stefan's law, one can estimate that the resulting present-day equilibrium temperature of the Earth should be on the order of $-18 \text{ }^\circ\text{C}$. However, 390 Wm^{-2} is re-emitted at infrared wavelengths by the Earth's surface towards the atmosphere, of which 155 Wm^{-2} are again emitted back towards the Earth's surface due to the presence of greenhouse gases, raising the equilibrium temperature to $\sim +15 \text{ }^\circ\text{C}$. The main greenhouse gas is H_2O , accompanied by CO_2 , CH_4 , and other more minor constituents. [43,44]

Solar forcing of the Earth's climate can be classified into direct and indirect processes. The simplest direct mechanism is through variations in solar radiative output which is known to vary by 0.1% over the last solar cycle, this corresponds to a change of 0.3 W/m^2 at the top of the Earth's atmosphere. Indirect effects include solar induced changes in atmospheric transparency influencing the radiative budget of the planet. [45] The 80-120 year solar Wolf-Gleissberg cycles have wide effects on the Earth's environment, as well. It has a controlling effect on space weather from the interplanetary space, to the magnetosphere, ionosphere and consequently down to the troposphere. They induce effects on global temperature, pressure and thus the general wind circulation and precipitation. [46] However, in some geographic regions solar cycle correlate, and in other regions, anti-correlates with meteorological parameters. No convincing physical mechanism causing this correlation and/or anti-correlation has been proposed. [47] Some models might be inadequate in their parameterizations of climate feedbacks and atmosphere-ocean coupling, and in their neglect of indirect response by the stratosphere and of possible additional climate effects linked to solar magnetic field, UV radiation, solar flares and cosmic ray intensity modulations. [42]

Cosmic rays could in turn act on climate in three ways: through changes in the concentration of cloud condensation nuclei; thunderstorm electrification; ice formation in cyclones. [47] Being the only source of ionization in the atmosphere at the altitudes between 3 km and 35 km, cosmic rays play a very important role in many atmospheric processes. They

produce atmospheric electric charges; conductivity of air and provide the operation of global electric circuit and light ions adhering to aerosols; nuclides of water vapor condensation. The difference in the supersaturation values for negative and positive charged aerosols to form water droplets gives the thunderstorm electricity and space separation of electric charges in thunderclouds, which influence the Earth's temperature (Table 1.1). [48]

Table 1.1. Annually averaged ion production rates in the global atmosphere from different natural ionization sources [43]

Ionization source	Rate, ion pairs/sec
Natural radioactivity ($h < 3$ km)	$< 10^{24}$
Galactic cosmic rays (everywhere in the atmosphere)	$\sim (10^{27} - 10^{28})$
Solar cosmic rays and precipitation (polar latitudes, sporadic)	$\sim (10^{26} - 10^{27})$
UV - and X - solar irradiation (upper atmosphere, $h > 50$ km)	$\sim 10^{28}$
Solar wind (ionosphere)	$\sim 10^{26}$
Lightning (regions with thunderstorm activity, $h < 10$ km)	$\sim (10^{27} - 10^{28})$

The interplanetary and Earth's magnetic field are essential for weather conditions, as well. Especially in electrically occurring events, they are potent to build or disturb the interactions between clouds, the formation of precipitation or even maybe the directions of the winds.

Completing the general properties of applied celestial and terrestrial events, the relations between the two can be investigated. Some scientists reported good correlations and anticorrelations between local or global climate and near-space, and some reported they could not find any. This study aims to clarify whether the space phenomena are effective on Istanbul's weather conditions or not. In the following section, the concept of climate change and the space effects on it are summarized based on articles from different disciplines and institutes.

2. LITERATURE SURVEY

The Earth's climate system has shown irregular changes during the second half of the 20th century, especially for the last three decades. Since the climate system depends on many parameters, such as evaporation, wind, pressure, rainfall, temperature etc, climate change phenomenon is a very complex problem and the contribution of each parameter to this change is not clear. [49]

Especially to show the Sun-climate connection, many indicators have been used in the literature like sunspot numbers, sunspot areas, sunspot decay rates, solar rotation rates, solar cycle lengths, geomagnetic aa indices, solar irradiance changes, solar radius through solar irradiance and long-term solar activity data obtained from ^{14}C and ^{10}Be isotope concentrations. These data sets are compared with climatic parameters such as surface temperature, rainfall, lake level and air pressure. Among these, temperature is the most commonly, presumably the most accurately, measured parameter. [49]

Vincent Courtillot, the chairman of the Scientific Council of the City of Paris, summarized the main features of temperature variations over the past 100 years: they included warming from the end of the 19th century to the early 1940s, followed by little change or even cooling until ~1970, and then warming since then, the trend becoming steeper after the mid-1980s. According to him, cooling from 1940 to 1970 was often disregarded as being part of the noise, or variability. [48,50] The mean global surface temperature has increased by about 0.3 to 0.6 °C since the late 19th century; and by about 0.2 to 0.3 °C over the last 40 years. [51]

When the satellite technology let continuous observations of the Sun and the Earth first in the 1970s, the scientists noticed that the solar constant was not exactly constant. The changes in total irradiance and in different wavelength radiations of the Sun excited the

physicists and prompted them to think that global warming could be explained by the direct result of solar parameters only. However, on the other hand, when the ozone layer hole was also first discovered by the satellites, the chemists showed that it was a result of increasing concentrations of chlorofluorocarbons and aerosols in the air resulted from human activities. The physicists did not accept at first that anthropogenic effects could cause a huge impact while there was such a marvelous candidate, the Sun. However, although the satellite data did show a clear reduction at solar minimum, from University of Colorado at Boulder, George Reid's suggestion of a physical link due to the abundance of good correlations between solar activity and climate parameters could not be confirmed when direct measurements in space of solar irradiance became available.[7]

The articles from different disciplines had hot debates about the natural and anthropogenic effects on climate. Solar and space physicists claimed that space impacts were what drove the atmospheric circulations, thus they had to be responsible for the global warming, while climatologists attributed this to the human. This argument still continues today, and much effort in observational as well as in model studies has been spent to date to understand recent climatic changes. [5] There are abundant scientists in the world who still do not consider global warming as a treat since they think it is totally natural; like Raymond Bradley from Climate System Research Center of University of Massachusetts who said: "Human influences on the atmosphere are considered to be the main cause leading to global warming. Whatever anthropogenic impacts on climate occur in the future, they will be superimposed on a background of natural climatic processes that may mask, or magnify, such impacts." [52] Yet, some physicists who were so strict about their old beliefs in naturally occurring global warming have begun accepting that anthropogenic activities might involve in the recent trend of air temperature increase, and some even think that a big contribution belongs to human activities, like Eigil Friis-Christensen, the director of the Danish National Space Center and from the Danish National Space Centre, Henrik Svensmark who noted in their article : "In addition to natural climate changes, the risk of human influence on climate has recently been seriously considered by the Intergovernmental Panel on Climate Change. Any factor that alters the radiation received from the Sun or lost to space will affect climate.

This concern is associated with the effect of the increasing amount of greenhouse gases, in particular CO₂, which is due to human activities related to the burning of fossil fuel.” [7]

In the 1995’s report, the Intergovernmental Panel on Climate Change first time stated that the observed increase of the global average temperature during this century is unlikely to be due to natural variations in the climate only. [7] And some scientists tried to synthesize the solar and greenhouse gases effects together, in order to explain the recent temperature increase. Drew Shindell, an atmospheric chemist working at NASA, investigated the Sun’s function on atmospheric chemicals and concluded that solar variability directly affected both ozone photochemistry and local heating, modifying ozone abundances, which in turn further alter local heating rates as well as the radiation field at other levels. And he noted that upper stratospheric ozone has decreased significantly since the 1970s as a result of halogens released from chlorofluorocarbons. This ozone decrease may have limited the ability of solar irradiance changes to affect climate over recent decades, or may have even offset those effects. [53]

Various scientists from different regions supported this way of considering the climatic changes. A physicist from Akdeniz University, Ali Kılıçık, attributed them to three main factors: greenhouse gases, aerosols and solar activity changes noting that these factors were not all-independent. [49] George Golitsyn from the Institute of Atmospheric Physics in Russian Academy of Sciences found that essential seasonal distinction of the temperature response in the region of mesopause to solar activity was obviously caused by peculiarities of the altitude distributions of some chemically active gas components and by changes of the Sun UV radiation in many respects determining the altitude distribution of temperature. [53] Studies with general circulation models have discussed the possibility of an indirect dynamical response to direct changes in solar irradiance and ozone in the stratosphere, but a physical mechanism explaining the solar influence on the atmosphere is still missing. [5]

Courtillot remarked that warming before 1950 and after 1980 was generally believed to be due to increases in the concentration of greenhouse gases, lack of volcanic activity, enhanced solar irradiance and internal variability of the coupled atmosphere–ocean system, adding that exponential rise of greenhouse gases due to human activity in the past 150 year

was well documented; nothing is found about that the last 60 year was a period of unusually high solar activity (possibly unique in the past 8000 year). [48]

It did not take so long for some other scientists to consider greenhouse gases as effective as the Sun, since the high present-day concentration of them has never before been observed [5,52]. Benjamin Santer, a climate researcher at Lawrence Livermore National Laboratory and Tom Wigley, the director of the Climatic Research Unit of University of East Anglia in UK, claimed that solar and anthropogenic forcing together were enough to explain overall warming trend. [49] The contemporary concept for climate change is that the Earth's climate system would have been controlled by the Sun before the pre-industrial era, but later anthropogenic effects began to dominate, as pointed by Thomas Crowley, a marine geologist and climatologist in the Department of Oceanography at Texas University or Sami Solanki, the current director of the Max Planck Institute for Solar System Research, and Peter Foukal, a solar astronomer working for Heliophysics Inc. in Massachusetts. [48,49]

Jean-Louis Le Mouél from the Institute of Physics of Globe de Paris noted that global temperature departed from all other solar and magnetic indicators in the late 1980s and he suggested that this was when the signal, which possibly corresponding to anthropogenic warming, started emerging from noise. This was in agreement with the estimates of a physicist in Duke University, Nicola Scafetta and Bruce West, the Director of the Center for Nonlinear Science in University of North Texas, in which the solar contribution dropped by a factor of 2 (or more) after 1980. Similar results were found when temperature evolution was compared to that of solar cycle length or cosmic ray flux. [48]

On some other article, Le Mouél discussed that solar irradiance co-varied with long-term averages in global temperature of the lower atmosphere until approximately 1990, when the temperature curve sharply diverged upward. After 1980, however, the Earth's temperature exhibited a remarkably steep rise, while irradiance did not. The loss of correlation between temperature on one hand, solar irradiance and magnetic indices on the other hand, said Le Mouél, might have been an interesting way to attempt to date when anthropogenic global warming emerged from noise to become a robust physical observation. [54]

To have more precise conclusions, Thomas Crowley, an oceanographer in Texas A&M's College of Geosciences, calculated the individual temperature responses to changes in solar variability, CO₂ and volcanism using a linear upwelling/diffusion energy balance model. This model calculates the temperature of a vertically averaged mixed-layer ocean/atmosphere as a function of forcing changes and radiative damping. He found that volcanic forcing displayed random-like spikes of short duration, about a year, up to 20 Wm⁻² in amplitude, solar variability resulted in forcing with decadal to millennial fluctuations with amplitude ~1-2 Wm⁻². The range for CO₂, which became significant mainly after 1800, was ~2 Wm⁻². He concluded that as much as 41 to 64% of pre-anthropogenic (pre-1850) decadal scale temperature variations were due to changes in solar irradiance and volcanism. [48] And, it is simply normal to find solar and cosmic traces in climate for pre-industrial ages since there was no other significant factor which could be attributed to it.

Solanki used the reconstructed irradiance to tackle the question of recent warming trend. [51] He estimated that if UV irradiance was the main channel by which the Sun influences climate, then the Sun has contributed less than 30% to the temperature increase since 1970. He showed that even in the extreme case that solar variability caused all the global climate change prior to 1970, it cannot have been responsible for more than this ratio (50% for the intercalibration by Willson), for the strong global temperature rise for about 35 years. [44,55]

Similarly, according to Cseh, assuming a climate sensitivity of 1 °C/Wm², the enhancement of the total solar irradiance of 0.14% from 1900 to 1990 can only be responsible for 0.25 °C of the 0.6 °C surface warming. [56] Like Courtillot, Scafetta and West corroborated Solanki's calculation, based on an empirical model with four timescale-dependant climate sensitivities to solar variation, that ~75% of the 1900–1980 global warming has a solar origin, whereas the figure drops to ~30% for the period 1980–2000. They also noted that peaking of global sulfur emissions in the 1980s and rapid decline since could account for part of the warming in the past two or three decades. [48]

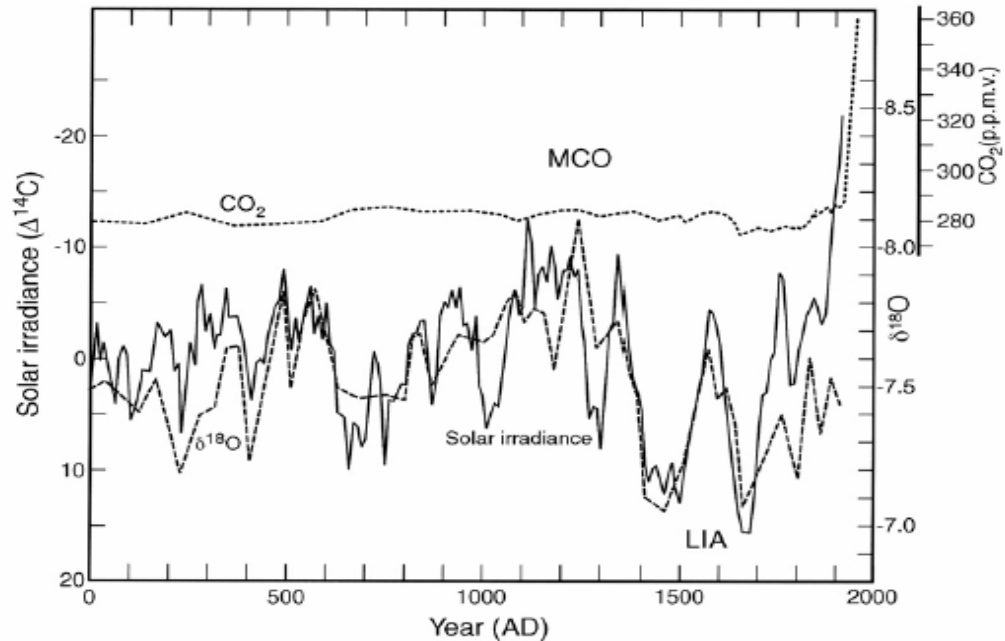


Figure 2.1. The $\Delta^{18}\text{O}$ record of a stalagmite from the Spannagel cave in the central Alps (dashed line) covering the last 2000 year, compared to ^{14}C production rate ($\Delta^{14}\text{C}$) (full line with reversed scale), a proxy for solar irradiance. MCO is the warm Medieval Climate Optimum and LIA stands for Little Ice Age. [48]

Wigley and Mick Kelly from Climatic Research Unit of University of East Anglia and Michael Schlesinger from Meteorology Department of Atmospheric Sciences University of Illinois used the solar cycle length as a proxy for total solar irradiance. They both found that variations in solar irradiance have been contributing to the observed global temperature change since 1860 but their calculations also indicated that greenhouse gases have been the dominant contributor since the nineteenth century. [7] Similarly, Foukal approved that the variations in the Sun's total energy output measured from spacecraft since 1978 were too small to have contributed appreciably to accelerate global warming over the past 30 years. He showed that detailed analysis of these small output variations has greatly advanced the understanding of solar luminosity change, and it indicated that brightening of the Sun was unlikely to have had a significant influence on global warming since the seventeenth century, like also Victor Ermakov from Central Aerology Observatory in Moscow and Yuri Stozhkov from Russian Academy of Sciences concluded in their article. [43,56] Marcus Christl from

Institute for Environmental Physics in University of Heidelberg also noted that a direct solar irradiance effect on climate was generally considered to be too small to cause the observed temperature change. [57]

To make sure about the quality of recent studies, Peter Laut from Technical University of Denmark analyzed a number of published graphs which have played a major role in these debates and which have been claimed to support solar hypotheses. He showed that the apparent strong correlations displayed on these graphs have been obtained by an incorrect handling of the physical data and conclusions based upon these graphs lead to futility of reducing the emissions of man-made greenhouse gases. His findings did not by any mean rule out the existence of important links between solar activity and terrestrial climate by showing that the apparent strong correlations were not supported by the underlying physical observations. [3] Similarly Václav Bucha from Faculty of Mathematics and Physics of Charles University in Prague reported that a hypothesized Sun-weather relationship was not supported by a plausible and testable physical hypothesis or trigger mechanism. The correlation coefficients remained statistically significant for only short periods, after which they change sign to exist so that the results cannot be used to make detailed predictions, he added. [38]

Unlike the usual studies on temperature and solar connections, Cristoph Jacobi from the Meteorological Institute of Leipzig University and Dierk Kürschner from the Institute for Geophysics and Geology of the same college studied space impacts on central winds over Europe and they found that the signal of the 11-year solar cycle that was visible in the prevailing winds was weak and no clear solar signal was visible in the semidiurnal tides. [58]

Foukal remarked that additional climate forcing by changes in the Sun's output of ultraviolet light, and of magnetized plasma, could not be ruled out; and the suggested mechanisms were too complex to evaluate meaningfully at present. [56] Moreover, Ón Kristjánsson and Jørn Kristiansen from Department of Geophysics in University of Oslo and Eigil Kaas from Danish Meteorological Institute showed that the argument for using detrended data was that the general downward trend might be caused by variability or change in the climate system that had nothing to do with solar-related forcing. [50] Due to the general

consideration of recent studies, Jean-Pierre Rozelot from the Cote d'Azur Observatory in France and Sandrine Lefebvre from the Department of Physics and Astronomy in University of California in Los Angeles thought that the attempt to find a solar signature in the current Earth's climatic warming seemed audacious as, on one hand, solar output variability on the atmosphere was far to be understood, and on the other hand, there was evidence that most of the warming observed over the last 50 years could be attributed to human activities. [59] And Foukal suggested that the climate sensitivity may be provided in terms of the change in the Earth's equilibrium temperature in response to a change in radiative forcing corresponding to a doubling of the CO₂ concentration. [7]

Besides these examples, the suggestion of a link between variations in solar irradiance and low cloud cover has been of interest for the understanding of past climate variations, since it may indicate a reinforcement of the solar signal by the climate system, like a positive feedback. However, Kristjansson, Kristiansen and Kaas told that it was not of significance for the global warming, because solar irradiance did not appear to have increased over the last 50 years. Likewise, such a mechanism would not explain the recent downward trend in low latitude cloud cover indicated by Wielicki, who works for Radiation Sciences at NASA. [50]

Clouds are specific parameters which are especially studied by famous scientists like Svensmark or Brian Tinsley from University of Texas and thought that they are strongly influenced by cosmic rays. In general, the following interpretations are found possible about low cloud cover and the solar and cosmic effects: [50]

1. There is no causal relationship between either total solar irradiance or galactic cosmic rays and low cloud cover, and the relatively high correlations between total solar irradiance and low cloud cover are purely coincidental. [50]

2. There is causal relationship acting through galactic cosmic rays and low clouds. The high correlation with total solar irradiance is an indirect consequence of the relation between solar irradiance and the interplanetary magnetic field. [50]

3. There is a causal relationship between total solar irradiance and low clouds. The high correlation between galactic cosmic rays and low clouds between 1983 and 1993 is an indirect consequence of the relationship between cosmic rays and solar irradiance. [50]

4. There is no causal relationship at all. The relatively high correlations are artifacts due to the way the ISCCP data are processed, resulting in a spurious solar signal. [50]

Due to this summary, Kristjansson, Kristiansen and Kaas conclude: “Clearly, if global warming was largely caused by a reduction in cosmic ray flux and a consequent reduction in low cloud cover, as suggested by Svensmark, detrending (of the cloud cover-cosmic ray flux) would not be required.” [50]

The correlations are mainly on rather long time scales, like associated with the 11-year solar cycle, pointed Kristjansson, Kristiansen and Kaas, while the high-pass filtered data did not show any correlation. Enric Pallé and John Butler from Armagh Observatory in North Ireland also found no correlation between cosmic ray events on short time scales and cloud amount, but their cloud analysis was only regional in nature and did not distinguish between clouds at different levels. [50]

The assumption of a significant decrease in galactic cosmic ray flux during the 20th century was based on an investigation by Michael Lockwood from Rutherford-Appleton Laboratory suggesting a 40% increase in the solar magnetic field between 1964 and 1996 and more than a doubling during the 20th century. This result has recently been challenged by Ian Richardson from Astrophysics Science Division in NASA, who found no significant trends for sunspots, cosmic ray flux or the interplanetary magnetic field over the last 50 years. Positive trends in sunspot number and aa index during the first half of the 20th century are undisputed, however. [50]

The simple climate models rely on the assumption that the global climate can be calculated simply by means of global averages of radiative forcings, some of which are assumed to be relatively well described. As a first-order approximation, these models may be

appropriate but global mean values may not necessarily provide an adequate description of the very complex atmospheric processes that determine the average global temperature. Although energy-balance models are only intended to consider the globally-mean response to different forcings, a globally-mean climate sensitivity is not necessarily applicable, taking into account the multitude of non-linear effects that is characteristic of the Earth's climate. The different radiative forcings, including solar irradiance, greenhouse gases, and anthropogenic sulphate aerosols, all have different spatial distributions and, in case of the latter, a particularly inhomogeneous distribution. [7]

“Things are complicated by the fact that anthropogenic changes lie on top of natural climate variability.” said Solanki, and added that human activity led to radiative forcing by changing the atmospheric concentrations of greenhouse gases and aerosols. [51] Due to burning of fossil fuel during the last 100 years there has been an increase in atmospheric CO₂ concentration from about 280 to 365 ppm, beyond others (Figure 3.2). [51,2] In late 1990s, Bucha predicted that in case of an increase of the global temperature after the year 2000, the greenhouse gas forcing will have a stronger influence than the natural climatic factors. [38] Sandor Cseh and Pal Bencze from Geodetic and Geophysical Research Institute in Hungary also manifested that greenhouse gases were responsible for global warming, noting that the experimental temperature trends could qualitatively be explained by an increasing atmospheric greenhouse effect. [6] Similarly, Kristjansson, Kristiansen and Kaas agreed with Blanca Mendoza from Institute of Geophysics in Mexico on that the temperature trend behavior from 1930 onwards has generally been attributed by many scientists to the increasing concentration of greenhouse gases and aerosols in the atmosphere due to human activity, like also does Bucha or Kılçık. [60,50,38,49,5,7]

Summarizing the evolution of the concept of climate change and global warming as comprehended by various scientists, the analysis of weather trends of Istanbul for almost one century is discussed and compared with the findings of other locations in the following section.

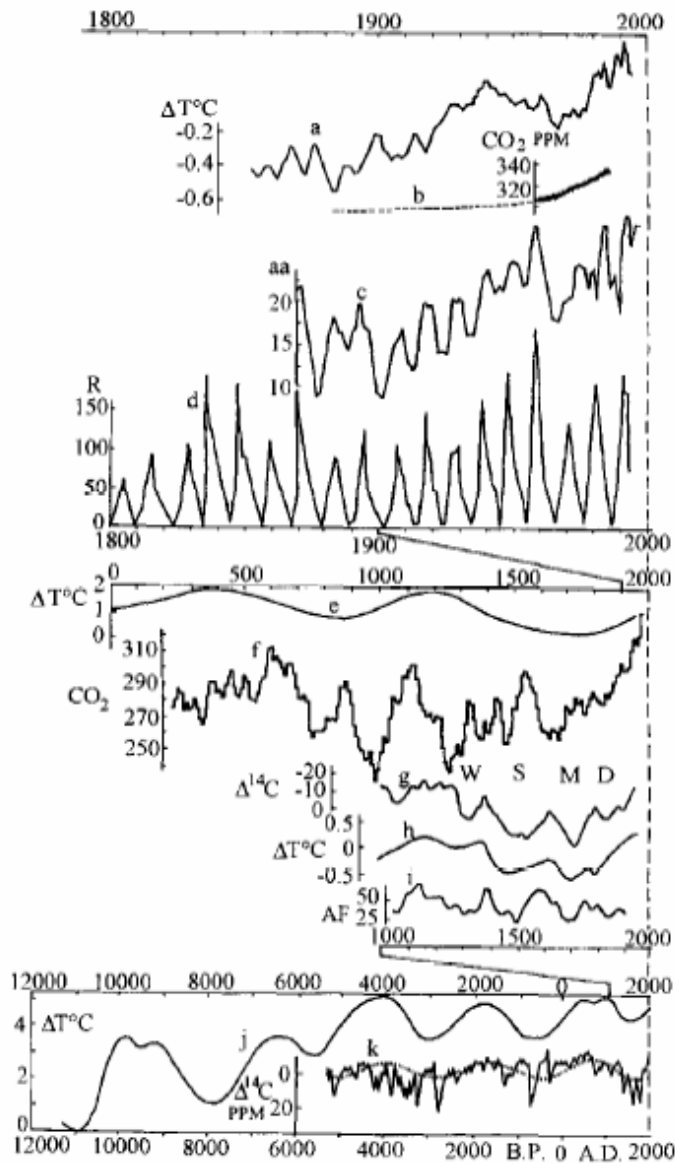


Figure 2.2. a) global surface air temperature changes (five year running mean) b) changes in the atmospheric CO₂ concentration c) changes in geomagnetic activity (au indices) d) changes in solar activity (R numbers) e) changes in temperature according to historical data f) changes in CO₂ concentration as determined from C content of tree rings g) the residual conference Δ¹⁴C series showing four temperature minima h) temperature changes during the last 1000 years i) auroral frequency j) temperature changes for the last 12,000 years obtained from pollen data and alpine glaciers k) residuum Δ T changes based on radiocarbon dating of tree rings [38]

3. RESULTS and DISCUSSION

The Earth's climate has been continually changing. Any change in the average energy from outside the magnetosphere that ultimately reaches the Earth's atmosphere may affect the climate. This includes, but is not limited to, cosmic radiation as well as solar energy inputs in various forms. [36] It is seen that no forcing factor, be it changes in CO₂ concentration in the atmosphere or changes in cosmic ray flux modulated by solar activity and geomagnetism, or possibly other factors, can at present be neglected or shown to be the overwhelming single driver of climate change in the past century. Most of the time, the prime, joint forcing factor is in solar variations (at the decadal time scale) or orbital forcing (at the Milankovic scale). [48] The climate response to a given forcing is strongly dependent on feedback mechanisms connected with clouds, water vapor, ice-cover, albedo, atmospheric and ocean circulation, etc. [55] Since the Earth's climate system is composed of several interacting sub-systems, the relationships between the 11 year solar cycle and different climate variables, different dominant timescales and phases in climate variables in different geographical areas and seasons are expected to be a function of location, season, and physical parameters. [61]

Climate change is a global phenomenon. However, weather parameters like atmospheric pressure, precipitation amount or wind velocity do not make sense in a global basin. Often applied global average temperature is not able to be measured for the whole planet, as well, it is calculated via the records of world-wide meteorological stations. The scientists therefore, consider an alternative, empirical approach, [44] and local studies are of significance in climate, being the only clues to trace the global warming. Like the tree rings, which exhibit the climatic conditions of the year they are formed within are inferred from, one expects that any weather parameter will react to the changes in the space phenomena within the year they occur. A phase lag between the compared parameters for about one year is natural, since averaged data are applied and a five-year running-mean method is used.

The monthly series were used as annually bases and five-year moving average method was applied to the annually values. Thus, it has to be noted that the year values shown on plots in fact represent a mean value over the following four years including themselves. The coherencies between anomaly values of meteorological data and space indices were almost exact, so the measured values were preferred to put on the report. Table 3.12 represents the correlation coefficients calculated between space-sourced and meteorological factors, and the plots represent relationships between the Sun, cosmic rays, interplanetary magnetic field and geomagnetic activity and meteorological phenomena. Minimum and maximum values of air temperature and air pressure were also plotted in order to point out the negative and positive correlations better, respectively.

The data which are given out in daily average format, on the other hand, were converted into monthly averages by simple arithmetic methods and they are found in tables in monthly mean values. Since the aggregate data extends in 95 years, using monthly values for estimations was unpractical and 12 months of each year were averaged to one number representing the mean value of the year and then plotted. However, the graphs derived from annually values still did not obtain clear lines to follow and analyze them. To have a smooth transition between the consecutive numbers, and to observe the trends easily, five-year running-mean calculations were applied to the annually data. Running-mean method was preferred to arithmetic averaging since it conceives the correlations better, keeps the data more entire and values more interacting with followers. In fact, moving average is a special kind of low-pass filter and taking moving average weakens the independence of the dataset. [4]

Calculating running-mean values of a series for five sequent entries is as followed:

Table 3.1. Steps of calculating five-year running-mean of an annually dataset

$S = x_1, x_2, x_3, \dots, x_n$ $x_1' = [x_1 + x_2 + x_3 + x_4 + x_5] / 5 \quad x_2' = [x_2 + x_3 + x_4 + x_5 + x_6] / 5$ $x_3' = [x_3 + x_4 + x_5 + x_6 + x_7] / 5 \quad x_{n-4}' = [x_{n-4} + x_{n-3} + x_{n-2} + x_{n-1} + x_n] / 5$ $S' = x_1', x_2', x_3', \dots, x_n'$ <p style="text-align: center;">S: annually data set x_i: value of the year i</p> <p style="text-align: center;">S': 5-year running-mean values series x_i': 5-year running-mean value of the year i</p>

When a series is smoothed via running-mean method, it gives better correlation coefficients out. The linear correlation coefficient is a number between -1 and +1 which measures how close to a straight line a set of points falls, in x-y coordinates. The closer to 0, the correlation coefficient is, the less the points fall on a straight line, through the x axis meaning the series are not dependent to each other. The closer to +1, the more the points will fall along a line stretching from the lower left to the upper right through the y axis meaning the two series correlate. And the closer to -1, the more the points will fall along a line stretching from the upper left to the lower right, through the negative y axis meaning the series anticorrelate. [62] However, as Svensmark says, a good correlation does not guarantee a physical cause and effect. [2]

The correlation coefficient is calculated as the following: [62]

Table 3.2. Steps of calculating the correlation coefficient of an annually dataset

$S_1 = x_1, x_2, x_3, \dots, x_n$	$S_2 = y_1, y_2, y_3, \dots, y_n$
$\langle x \rangle = 1/N [x_1 + x_2 + x_3 \dots + x_n]$	$\langle y \rangle = 1/N [y_1 + y_2 + y_3 \dots + y_n]$
$\sigma_x = \sqrt{\frac{1}{N} [(x_1 - \langle x \rangle)^2 + (x_2 - \langle x \rangle)^2 + (x_3 - \langle x \rangle)^2 + \dots + (x_N - \langle x \rangle)^2]}$	
$\sigma_y = \sqrt{\frac{1}{N} [(y_1 - \langle y \rangle)^2 + (y_2 - \langle y \rangle)^2 + (y_3 - \langle y \rangle)^2 + \dots + (y_N - \langle y \rangle)^2]}$	
$\sigma_{xy} = \frac{1}{N} [(x_1 - \langle x \rangle)(y_1 - \langle y \rangle) + (x_2 - \langle x \rangle)(y_2 - \langle y \rangle) + (x_3 - \langle x \rangle)(y_3 - \langle y \rangle) + \dots + (x_N - \langle x \rangle)(y_N - \langle y \rangle)]$	
$r = \frac{\sigma_{xy}}{\sigma_x \sigma_y}$	
<p>S_i: annually data set $\langle x \rangle$: average value of S_1 $\langle y \rangle$: average value of S_2</p> <p>σ_x: standard deviation of S_1 σ_y: standard deviation of S_2</p> <p>σ_{xy}: covariance between S_1 and S_2 r: correlation coefficient</p>	

3.1. Air Temperature

Air temperature is the most applied parameter to guess either the weather conditions to forecast a few days, or the climatic ages for millions of years. It is convenient to measure, and easy to trace the variations of, by changes it causes within the bionic masses.

3.1.1. Solar Activity

Cyclic variations in Earth's orbit around the Sun govern the long-term (ten to a million year) climatic changes on Earth, leading to alternate glacial and interglacial periods. However, climatic variations also exist over much shorter, decadal to centennial time scales which cannot be simply related to orbital (Milankovic) forcing. During the past millennium, these variations include the Little Ice Age (~AD 1550 to 1850) and the Medieval Warm Period (~AD 900 to ~1300). Such anomalies are generally interpreted as reflecting long-term variations in solar activity, in particular solar irradiance. It is usually thought that the Earth's climate was colder during periods of lessened sunspot and warmer during periods of frequent sunspot occurrence. However, the coldest period of the Little Ice Age, at the end of the 16th century and beginning of the 17th century, preceded the Maunder minimum (~AD 1645–1715) and did not coincide with low solar activity, although changes in the solar output of ultra violet radiation affects temperatures in the stratosphere through absorption by ozone, which has the potential to influence the large-scale dynamics of the troposphere [1,45]

In general, solar variability can be separated into two main components: the variation of radiative output and the modulation of the interplanetary magnetic field via the solar open magnetic flux. Direct satellite-based observations of these two parameters exist only for the last few decades, and we have little knowledge of both the Sun's long-term variability and the coupling between radiative solar output and open magnetic flux. [57]

Some evidences have appeared indicating the existence of a significant solar forcing of the Earth's climate through solar and solar-related phenomena not involving the solar irradiance. Several studies indicate a good correlation between Earth's temperature and the length of the solar cycle, geomagnetic activity or cosmic ray flux. Furthermore, Laut and Jesper Gundermann from Danish Energy Agency showed an improved agreement between the solar cycle length and the temperature by subtracting an anthropogenic contribution to the historical warming trend. [60] Past climatic changes prior to the industrial era could only be explained if solar variability changes are taken into account. [7,5]

The recent glacial/interglacial cycles provide an example of climate response over the shorter timescales of tens of thousands to millions of years. The driving force here appears to be mainly variations in insolation, that is, the latitudinal and seasonal distribution of solar energy incident on the Earth, rather than in solar irradiance itself. Such variations are thought to be caused by cyclic and predictable changes in the Earth's orbital parameters, the primary forcing effect being amplified by feedbacks involving CO₂. [56] In fact a non-linear regression model to separate natural and anthropogenic forcing since 1850 is consistent with a solar contribution of about 40% to the global warming during the last 140 years. [55]

Documenting a relationship between solar and climate variability on a decadal timescale is more problematic than that on paleoclimate timescales. On the 11 year timescale, the Sun's total irradiance or the “solar constant” only changes about 0.1%, which is small compared with the estimated radiative forcing by anthropogenic greenhouse gases to the climate system, argued by the major critics like International Panel on Climate Change. Other arguments include that we have not yet found good correlations between solar indices and climate variables that are consistently significant on the decadal timescale for different regions and different time sections. [61] Robert Dickinson from Georgia Institute of Technology said that the most plausible source of notable changes in the lower atmosphere due to solar activity would be significant changes in the absorption of solar radiation or the emission of infrared radiation for example by changes in the distribution of cloudiness. [7]

Eigil Friis-Christensen, the director of the Danish National Space Center and Knud Lassen, the head of the Intergovernmental Panel on Climate Change, found a close correlation between cycle length and northern hemisphere land air temperature, and George Reid from NOAA's Aeronomy Laboratory in Boulder found a good correlation between the sea surface temperature record and the 11 year solar cycle. Similarly, Mendoza analyzed minimum extreme temperature data of central Mexico finding some evidence of solar signals, particularly those identified in sunspot numbers, magnetic solar cycle, cosmic ray fluxes and geomagnetic activity. [63] However, Moustafa Yousef from Astronomy and Meteorology Department of Cario University noted that there was a reverse correlation between solar cycle length and global mean temperature. [46]

In this study, the sunspot numbers clearly exhibit the eleven-year solar cycles though they were smoothed by five-year running mean method. The behaviors of mean and maximum temperatures of Istanbul are similar and the correlation coefficients with sunspot number are 0.21 and 0.34, respectively. The mean values clearly anticorrelate with sunspot number till mid-1940s like also maximum ones do (Figure 3.1.a, A.1.a, A.3.a). However this possible connection gets weaker or even lost as the years pass, as inferred from the phase lags getting bigger. The correlation coefficient between minimum air temperature and sunspot number is 0.14 and to take a parallelism between them into account is not that possible.

Close to results calculated for Istanbul, Dimitar Valev from Bulgarian Academy of Sciences found a statistical relationship between the global surface air temperature and sunspots with correlation coefficient of 0.27. This correlation was significant, yet quite low. But the cross-correlation analysis that he did showed no statistically significant global temperature lag behind the sunspots as well as correlation between the temperature anomalies and solar indices. [52]

Both of sunspot number and Istanbul's air temperature have numerous minimum and maximum points since 1910s, many of them can be noted to be related (Table 3.3). Yet those points might be just coincidences since both of the phenomena draw saw-like lines and a clear physical mechanism is still missing, also a strict phase lag is unknown. However, the spectral analysis of the minimum extreme temperature by Dolores Maravilla from Mexican Institute of Geophysics showed a conspicuous signal around 5 years in each of the three stations in Northern Mexico. [63] Unlikely, the yearly averaged minimum temperature values of Ebre Observatory (40.8 °N, 0.5 °E) did not represent any significant peak about that period while the yearly averaged maximum temperature displayed a period near 11 years. [64]

Table 3.3. The maximum (M) and minimum (m) years of sunspot number and mean/maximum/minimum air temperature with the phase lags (Δ) in the 20th century

SSN	T _{mean}	Δ (yr)	T _{max}	Δ (yr)	T _{min}	Δ (yr)
m~20	M~23	~3	M~23	~3	M~23	~3
M~25	m~29	~4	m~29	~4	M~34	~3
m~31	M~35	~4	M~34	~3	m~41	~5
M~36	m~40	~4	m~40	~4	--	--
M~46	--	--	--	--	M~51	~5
m~51	--	--	M~58	~7	--	--
M~67	m~72	~5	m~72	~5	m~72	~5
m~93	M~98	~5	M~98	~5	M~98	~5

Over the years a number of correlations between solar activity variations and climate changes have been reported; however, there has been a lack of plausible physical mechanisms to account for these correlations. [36] A simple linear correlation analysis may result in a misleading conclusion for a nonlinear Sun–climate forcing–response relationship, so that a conclusion to reject a Sun–climate relationship that is solely based on statistical analysis should be re-examined. [61]

3.1.2. Interplanetary Magnetic Field

Interplanetary magnetic field strength is not much more than another definition for solar activity, yet it has not been widely studied for the cases of climate. For last four decades, it gives a clear reflection of solar cycles, but mean temperature values exhibit strong variations not affectedly by them (Figure 3.1.b, A.1.b, A.3.b). The mean air temperature trend appears totally independent from it, with a correlation coefficient of -0.09. The only coupled climaxes are minimum points of IMF in ~1973 and ~1993 and maximum points of T_{mean} in ~1975 and ~1998, respectively. The correlation coefficients for maximum and minimum temperature values are too almost zero, -0.11 and 0.08, and no relatable extreme points between their trend lines could be found on the plots.

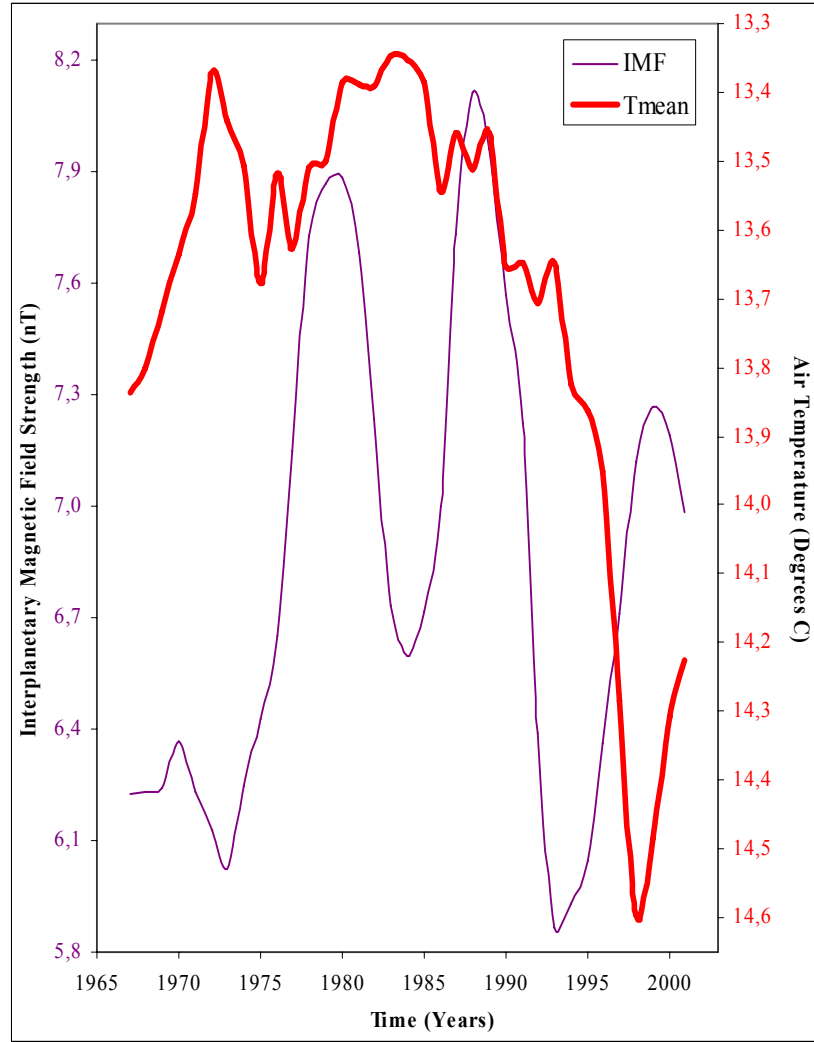
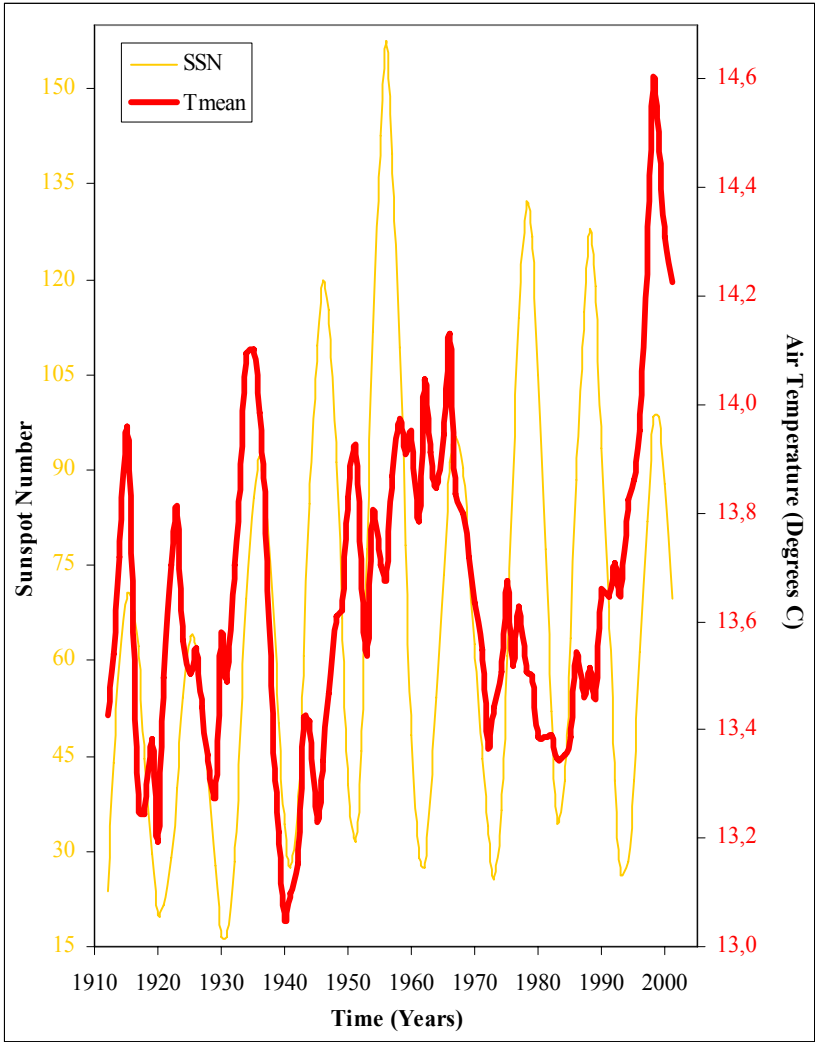


Figure 3.1. Istanbul's five-year running mean air temperature and a) solar activity b) interplanetary magnetic field

3.1.3. Geomagnetic Activity

The overall magnetic trend correlates well with the evolution of solar irradiance. If solar activity is correlated to climate over much of historical times, it might be expected that the overall magnetic trend would correlate with the recent evolution of global temperature, and this is indeed the case up to the mid-1980s, but not since then. So far, observed correlations between Earth's climate and geomagnetism have involved mostly that part of magnetic changes which is controlled by external (solar), not internal (core) variations. Yet, moving on to longer time scales may have uncovered links between the internal field and climate. [48] However, magnetism has seldom been invoked to the observed increase in global surface temperature over the past 150 years occurred prior to the 1940s and after the 1980s, yet evidence for connections between climate and magnetic field variations has received little attention. Correlation between decadal changes in amplitude of geomagnetic variations of external origin, solar irradiance and global temperature is stronger. The most intriguing feature may be the recently proposed archeomagnetic jerks, i.e. fairly abrupt (~100 year long), geomagnetic field variations found at irregular intervals over the past few millennia, using the archeological record from Europe to the Middle East. [48]

The work of Le Mouél based on very sensitive yet robust magnetic indices, showing that this situation might have prevailed until the mid-1980s. At longer time scales, he has seen that changes in the internal geomagnetic field: archeomagnetic jerks might be the only evidence that changes in the internal magnetic field itself and could at times have a significant influence on climate, possibly through the cosmic-ray/low-cloud connection at times of external tilt of the dipole. [48] The geomagnetic field could have a smaller axial dipole component during archeomagnetic jerks, which could be responsible for centennial climate change. [1]

Holocene paleointensity records derived from the St-Lawrence Estuary in Canada sediments recently led Guillaume St-Onge from University of Quebec to propose that the geomagnetic field might control the millennial- and perhaps some centennial-scale fluctuations in the production of cosmogenic isotopes. The author further envisaged a connection between the geomagnetic field and climate change over these time scales. [1]

Valev revealed that the correlation coefficient for the global surface air temperature and the aa-index was approximately two times higher than the correlation coefficient for the global surface air temperature and sunspots, reaching 0.51. However, the cross-correlation analysis showed no statistically significant lag of the global temperature behind the aa-index. [52]

In the study, the aa index is also likely to draw five-year oscillations, because geomagnetic storms generally occur when a solar events occur. The ones matching with high solar activity years are explained by the increased solar winds and when the solar activity goes minimum, geomagnetic activity reacts reverse. It is probably because of that cosmic ray fluxes go maximum when the Sun is at minimum, and this also results high geomagnetic activity.

If the correlation coefficient, 0.01, was not that small, then it wouldn't be suspicious to notice an anticorrelation between mean air temperature and geomagnetic activity values in the plots, especially between 1915 and 1940 (Figure 3.2.a, A.2.a, A.4.a). The correlation coefficient found for minimum temperature values is 0.00, and there seems an anticorrelation between minimum air temperature and aa index on the plots except the period of late 1960s – early 1990s. However, mean and minimum temperature values and aa index exhibit many decreases/increases within the last century, the paired extreme points are probably coincidences (Table2.4). Although there is a weak correlation between maximum values and geomagnetic activity with a correlation coefficient of 0.34, it is hard to follow a close harmony between their trend lines. The phase lags between similar maneuvers of both parameters do not seem approximately constant.

Table 3.4. The maximum (M) and minimum (m) years of geomagnetic storm strength and mean/maximum/minimum air temperature with the phase lags (Δ) in the 20th century

AA	T _{mean}	Δ (yr)	T _{max}	Δ (yr)	T _{min}	Δ (yr)
m~12	--	--	M~15	~3	M~15	~3
M~16	m~17	~1	--	--	--	--
m~21	M~23	~2	M~23	~2	M~23	~2
M~26	m~29	~3	m~29	~3	m~29	~3
m~32	M~34	~2	--	--	M~34	~2
M~39	m~40	~1	m~40	~1	m~41	~2
M~48	m~53	~5	--	--	--	--
m~52	M~98	~3	M~58	~6	--	--
m~63	--	--	M~98	~3	M~66	~3
m~95	--	--	--	--	M~98	~3

According to kinetic gas theory, increased external force on atmosphere is expected to result in increased temperatures as well. Thus, higher geomagnetic activity is supposed to offer an increase in air temperature since it means more ions in the air--more fractions lead to heating of the particles in the atmosphere. But since the results show the opposite of this expectation, a more advanced knowledge in atmospheric electricity and its interactions with atmosphere and magnetosphere is required.

Sami Solanki, the current director of the Max Planck Institute for Solar System Research, and Le Mouél claimed a good correlation between magnetic field changes, solar irradiance and global temperature from the late 19th century to the mid-1980s. The observed correlation between temperature and magnetism failed after the mid-1980s, when solar irradiance and magnetic activity dropped, whereas temperature continued an accelerated rise. This was when anthropogenically-induced global warming might first become apparent. Having lost the “Sun–Magnetism–Climate connection”, which seems to have prevailed over geological until very recent times, may be a worrying loss, Courtillot remarked. [48]

3.1.4. Cosmic Rays

A leading candidate to explain the link between relatively feeble solar fluctuations and climate is the effect of solar modulated galactic cosmic rays on cloud formation, though contribution of clouds to the global radiative forcing is not well known. The level of scientific grasp of cloud-forming tropospheric aerosols is very low, their contribution to the global radiative climate forcing is estimated to be $\sim -28 \text{ W/m}^2$. This is one order of magnitude larger than the radiative forcing caused by the anthropogenic greenhouse gases due to IPCC. [57]

The correlation between cosmic ray flux and cloud cover was first noted by Svensmark, and Friis-Christensen over one solar cycle, and linked to low-altitude clouds by two lead weather scientists at the Danish National Space Centre, Nigel Marsh and Svensmark: cosmic ray flux varies by 15% on average (and up to 50% at the poles) over this time period. The Earth's magnetic field acts as a more or less efficient, time-varying shield on these high-energy charged particles. The relation between cosmic rays and clouds showed a geographical pattern, with areas of highly significant correlation and almost no correlation in other areas. Higher cosmic ray flux would lead to more low clouds and thus higher albedo and lower Earth surface temperatures. The cosmic ray variation over one solar cycle translates as a change of energy input to the atmosphere on the order of 1.5 W m^{-2} , which is not negligible compared for instance to the estimated radiative forcing from anthropogenic CO_2 emissions ($\sim 2 \text{ Wm}^{-2}$). And cosmic ray intensity has varied in the past millennia by as much as a factor of 4 compared to recent solar cycles. However, the cosmic ray flux–cloud correlation has been criticized. Bradley not find any evidence at a global scale over the longer time period from 1950 to 1995. Laut estimated inconsistencies in Svensmark and Friis-Christiansen's paper and considered that they largely overestimated the relation between solar activity and Earth's climate. The difficulty in obtaining uncontroversial evidence for a cosmic ray flux–cloud correlation over several decades could be due either to difficulties in observations with satellite data, or to an overprint resulting from other mechanisms, such as ENSO-like atmosphere–ocean coupling. Ilya Usoskin from Sodankylä Geophysical Observatory of University of Oulu, found that periods of higher solar activity and lower cosmic ray flux tended to be associated with warmer climate and vice-versa. He also showed that cosmic ray flux correlated with temperature better

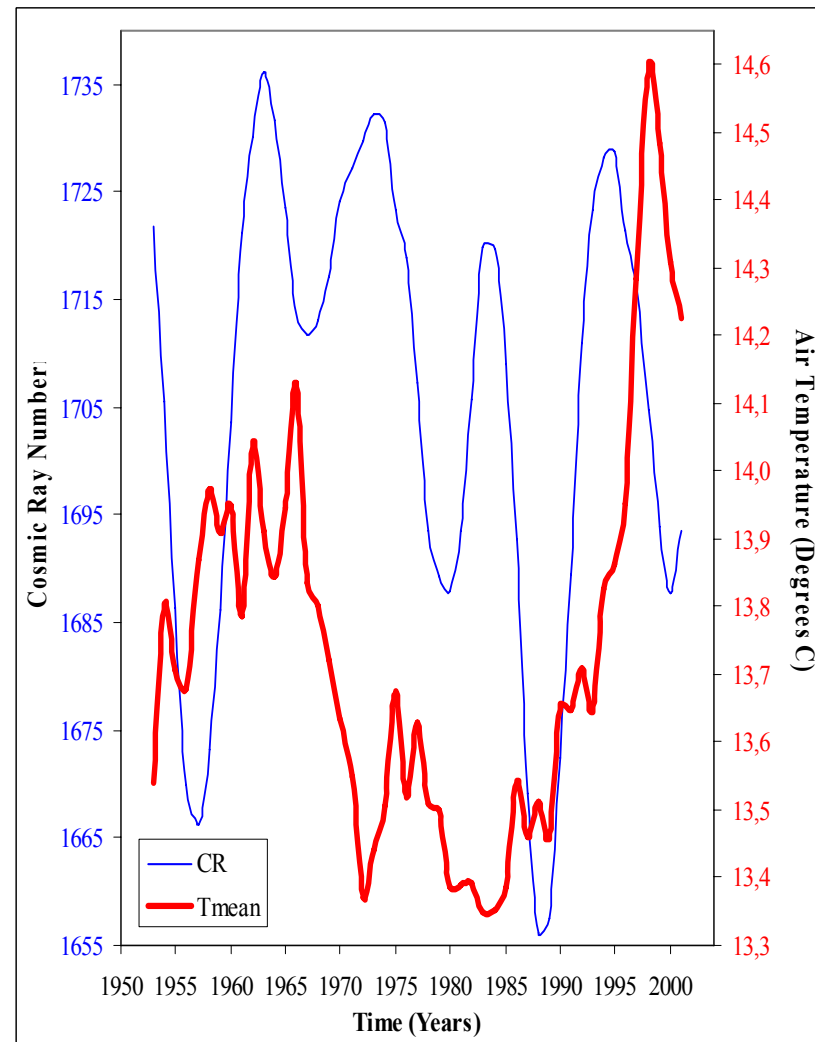
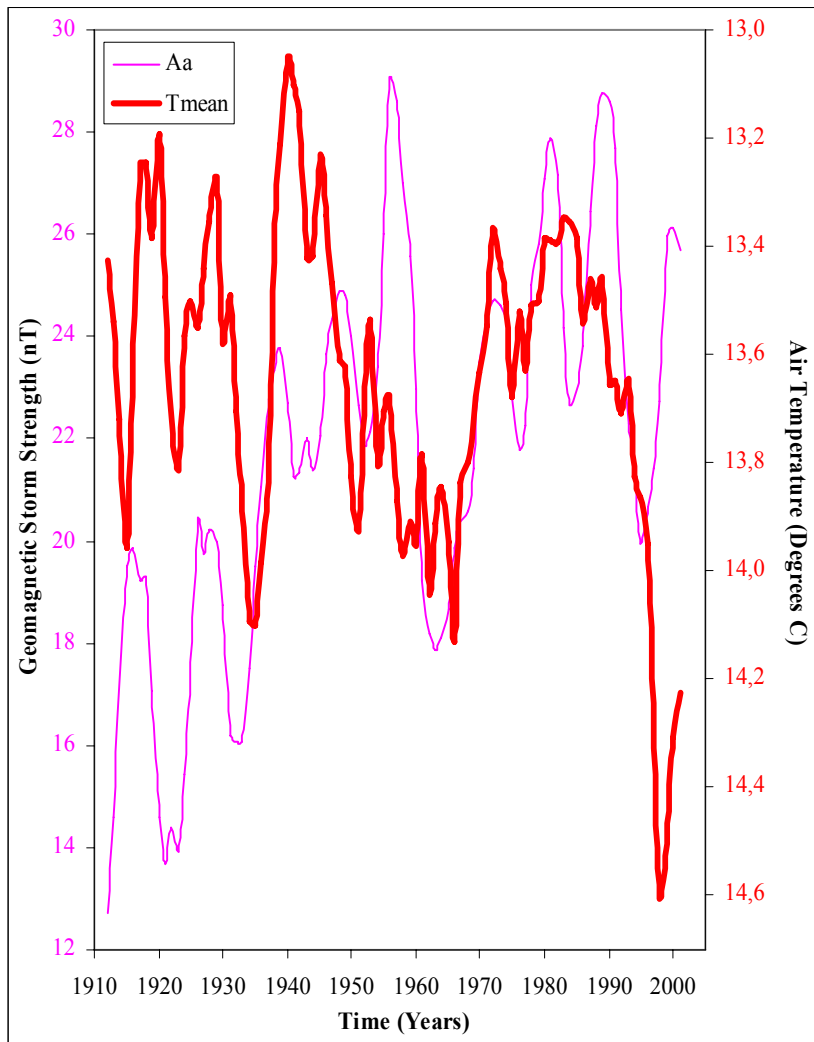


Figure 3.2. Istanbul's five-year running-mean air temperature and a) geomagnetic activity b) cosmic rays

than with sunspot numbers and that a positive correlation between geomagnetic dipole moment and temperature further supported the role of cosmic rays. [48,60]

Margaret Shea from University of Alabama and Frederick Smart from Space Vehicles Directorate for US Air Force Research Laboratory noted that the average solar cycle modulation of the galactic cosmic radiation over the past four solar cycles has been ~8% in the equatorial regions and ~18% at high latitudes. In addition there have been short lived transient events when the modulation has been more than 25% at high latitudes. They found that the changes in the high-energy cosmic ray exposure at low latitudes over a solar cycle were comparable to the changes. [36,50] Due to another study, about 20% of cosmic ray intensity increase in Climax Neutron Monitor during solar cycle corresponded to about 4% increase of global cloud covering, which could give sufficient change in radiation balance influenced on climate change. [65,66] And Mikhail Pudovkin from Institute of Physics of St. Petersburg in Russia pronounced decrease of temperature took place mainly in the middle troposphere on the first 2-3 days after the cosmic ray decrease onset in Sodankylä (Finland, $\phi \approx 67^\circ$). [67]

Istanbul's mean air temperature values always start to ascend or descend independently from variations in cosmic ray number and the correlation coefficient, 0.02, means no relationship between them at all (Figure 3.2.b, A.2.b, A.4.b). A few climaxes of the trend lines can be matched, however, not supporting a reliable continuum (Table 3.5). The maximum and minimum air temperature trends look totally independent from cosmic ray flux on the plots as well, as also supported by the correlation coefficients of -0.09 and -0.07, respectively. Some of the sharp decreases are visible on both of the trend lines, however if analyzed carefully, it is noticed that the maximum temperature line has been gone previous to the cosmic ray changes.

Mendoza's results did not support a good anticorrelation, either, from 1930 onwards between the 11-years average of the Northern Hemisphere marine and land temperature and the cosmic ray flux. [60]

Table 3.5. The maximum (M) and minimum (m) years of cosmic ray number and mean/maximum/minimum air temperature with the phase lags (Δ) in the 20th century

CR	T _{mean}	Δ (yr)	T _{max}	Δ (yr)	T _{min}	Δ (yr)
m~57	--	--	M~58	~1	--	--
M~63	--	--	--	--	M~66	~3
m~67	m~72	~5	--	--	m~72	~5
M~73	M~73	~0	--	--	--	--
m~80	m~83	~3	--	--	--	--
M~83	--	--	M~86	~3	--	--
M~95	M~98	~3	M~98	~3	M~98	~3

3.2. Air Pressure

Atmospheric pressure is one of the most important parameters for weather; it is responsible of starting many processes like heat and mass transportations. It is commonly applied to study local climatic trends and carries clues about determining characteristics and components of the air.

3.2.1. Solar Activity

A positive relationship is expected between air pressure values and sunspot number. In active years, the Sun blows more often and denser winds out and with all the momenta and particles they consist, more force is experienced by the atmosphere. However, the correlation coefficient of mean air pressure and sunspot numbers is too small to conclude an interaction with solar activity, 0.13, and notwithstanding sunspot numbers' regular sinusoidal trend, mean air pressure exhibits a more complicated and disfigured pattern within the last century. Some extreme points are likely to match, but there is no warranty for that they are really subject to be related since both of them exhibit a bunch of variations within the last century (Table 3.6).

A clear and quick-acting response of air can generally be followed on the plots except the periods of late 1930s-early 1970s, when the air pressure draws a complicated pattern (Figure

3.3.a, A.5.a, A.7.a). However, the correlation coefficient is too low to consider, 0.14, like of minimum values, 0.12. If the coupled extreme points of the trend lines are chosen correctly, the relationship between sunspot number and maximum air pressure values gets stronger in time. Regarding that the both trend lines exhibit many increases and decreases in time, atmospheric composition and density variations due to air pollution and small correlation coefficient, it is not that reliable to get this conclusion, though.

Table 3.6. The maximum (M) and minimum (m) years of sunspot number and mean/maximum/minimum air pressure with the phase lags (Δ) in the 20th century

SSN	P _{mean}	Δ (yr)	P _{max}	Δ (yr)	P _{min}	Δ (yr)
M~15	M~17	~2	m~15	~0	M~17	~2
m~20	m~22	~2	m~22	~2	--	--
M~25	--	--	M~28	~3	--	--
m~31	m~36	~5	m~35	~4	m~35	~4
M~36	m~36	~0	--	--	--	--
m~41	--	--	M~45	~4	M~42	~1
M~46	--	--	m~51	~5	--	--
m~51	m~51	~0	--	--	--	--
M~67	M~70	~3	--	--	--	--
m~73	m~76	~3	m~74	~1	m~74	~1
M~78	M~82	~4	M~82	~4	--	--
m~83	--	--	m~84	~1	--	--
M~88	M~89	~1	M~89	~1	--	--
m~93	m~94	~1	m~94	~1	--	--

3.2.2. Interplanetary Magnetic Field

As magnetic strength reaching the atmosphere increases, a more powerful impulse on the air is occurred and it is supposed to lead to increased pressure on air. The correlation coefficient of mean air pressure values and interplanetary magnetic field strength is relatively high compared to the previous indices, 0.53, and a clear harmony between them is observable (Figure 3.3.b, A.5.b, A.7.b). The maximum values also exhibit very similar trends to interplanetary magnetic field for four decades, also with a higher correlation coefficient, 0.67,

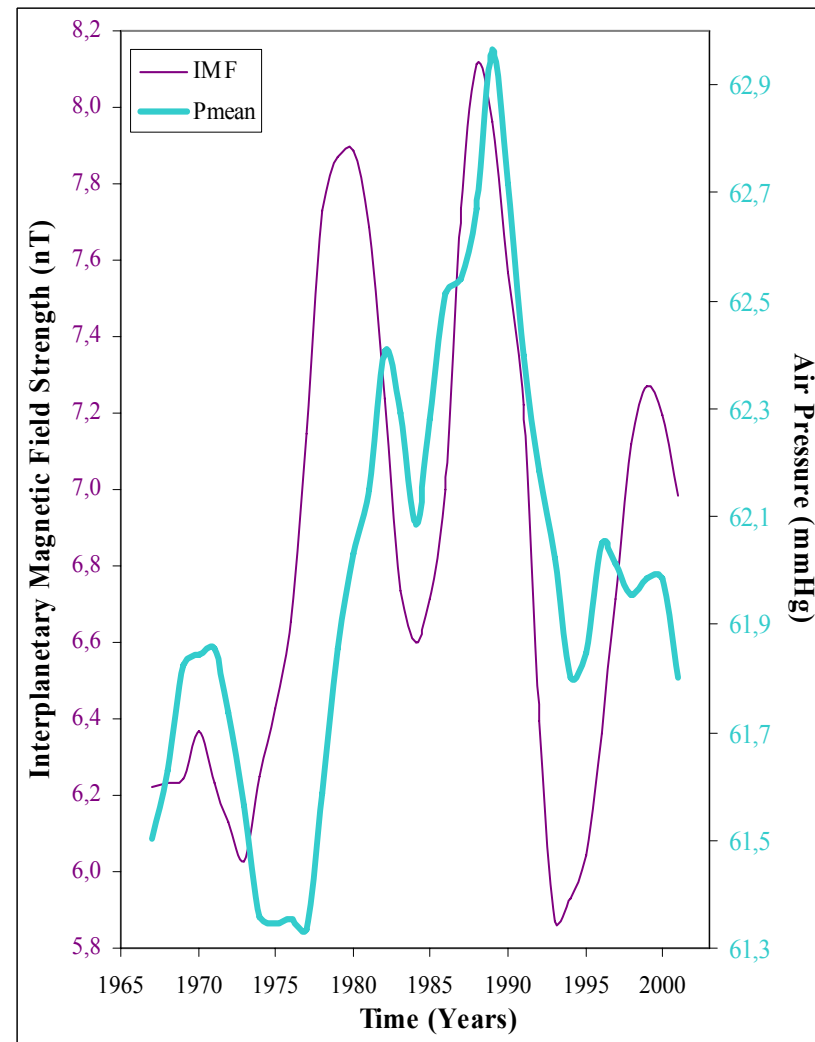
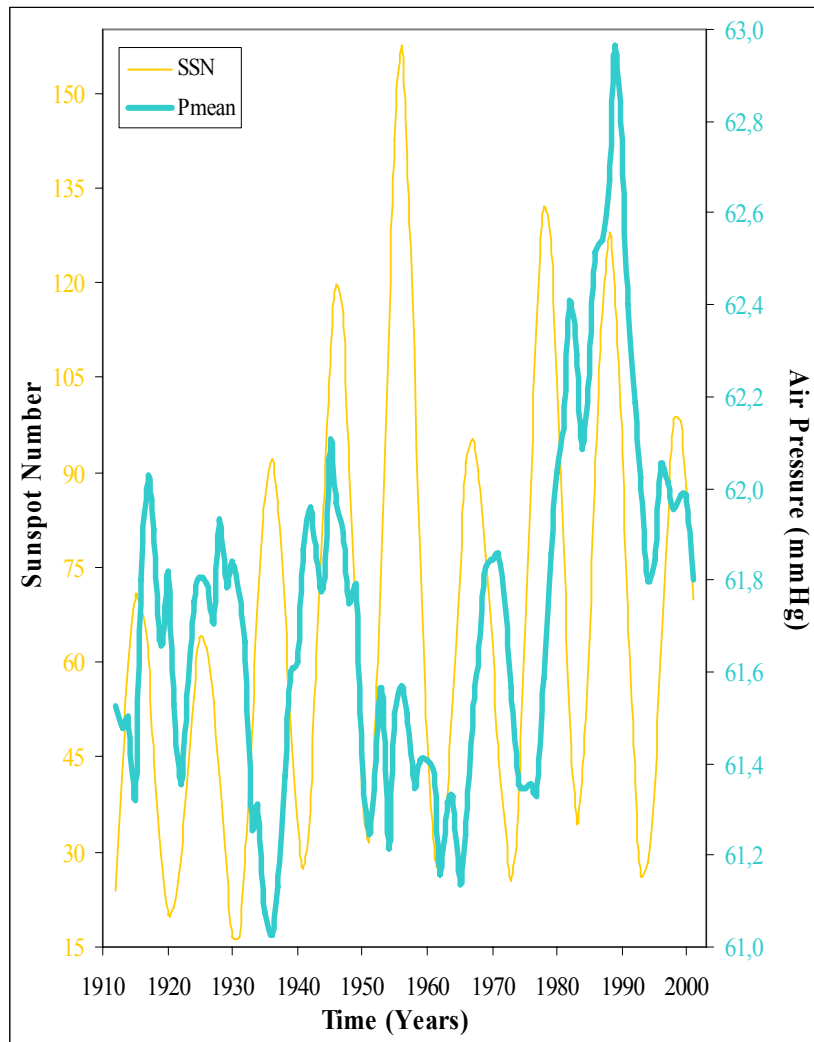


Figure 3.3. Istanbul's five-year running-mean air pressure and a) solar activity b) interplanetary magnetic field

appropriate for what is expected. The respond given by the atmosphere is rapid as seen on the maximum air pressure plots. Although the interacted extreme points of the trend lines are not that many, they supply a trustable positive connection between them, with small phase lags (Table 3.7).

The minimum air pressure values also roughly follow the interplanetary magnetic field until late 1980s, but with a lower correlation coefficient, 0.22. Also it has to be noted that the interplanetary magnetic field strength's trend line is too simple due to short available period for data, and this maybe the reason of high correlation rates.

Table 3.7. The maximum (M) and minimum (m) years of interplanetary magnetic field strength and mean/maximum/minimum air pressure with the phase lags (Δ) in the 20th century

IMF	P_{mean}	Δ(yr)	P_{max}	Δ(yr)	P_{min}	Δ(yr)
m~73	--	--	m~74	~1	M~74	~1
M~79	M~82	~3	M~82	~3	--	--
m~84	m~84	~0	m~84	~0	--	--
M~88	M~89	~1	M~89	~1	--	--
m~93	m~94	~1	m~94	~1	--	--

3.2.3. Geomagnetic Activity

Bucha reported high correlation coefficients between geomagnetic activity and the sea level atmospheric pressure, occurring with a positive sign in the middle Atlantic and southern Europe, in the south-eastern part of North America and in the Western Atlantic but with a negative sign in the Northern Atlantic, the Icelandic Low, the Baltic Sea and Canada. [38]

It is firstly thought of a parallelism between geomagnetic activity and air pressure; more particles lead to more pressure. Local increase of the atmospheric pressure for Sodankylä has been revealed in the whole troposphere and lower stratosphere coinciding with the zonal pressure changes in the latitudinal belt during geomagnetic disturbances. [67] A relation

between mean air pressure and geomagnetic activity is supported for Istanbul too, even not that strongly, since the correlation coefficient between mean air pressure and aa index is 0.43; for maximum values of air pressure, 0.34, for minimum ones 0.25. Sometimes the trend line of minimum pressure values draws similar variations with that of aa indices, however a smooth and continuous harmony between aa index and maximum air pressure could not be found (Figure 3.4.a, A.6.a, A.8.a). Both phenomena behave complicated and not all of the climaxes of air pressure are supposed to be influenced by geomagnetic activity. Also, the phase lags calculated for matched extreme points vary within an inconsiderable limit (Table 3.8).

Table 3.8. The maximum (M) and minimum (m) years of geomagnetic storm strength and mean/maximum/minimum air pressure with the phase lags (Δ) in the 20th century

AA	P _{mean}	Δ (yr)	P _{max}	Δ (yr)	P _{min}	Δ (yr)
M~16	M~17	~1	M~17	~1	M~17	~1
m~21	m~22	~1	m~22	~1	--	--
M~26	M~28	~2	--	--	--	--
m~32	--	--	m~37	~5	m~35	~3
M~39	M~42	~3	--	--	--	--
M~48	m~51	~3	--	--	--	--
m~52	--	--	M~56	~4	--	--
M~72	m~76	~4	--	--	--	--
m~63	--	--	m~67	~4	--	--
M~71	--	--	--	--	m~73	~2
M~81	M~82	~1	M~82	~1	--	--
m~84	m~84	~0	M~89	~5	--	--
m~95	--	--	M~96	~1	--	--

3.2.4. Cosmic Rays

The cosmic rays can influence the change of the ground pressure. The air ionization at the expense of cosmic rays can considerably influence the processes where the generation of water aerosols takes place. In the atmosphere the physical-chemical conditions always exist in which the changes of the ground pressure by approximately 1/6 mb will take place. In this case, in the warmer and wetter atmosphere such changes can be stronger by a factor of 2-3. [68]

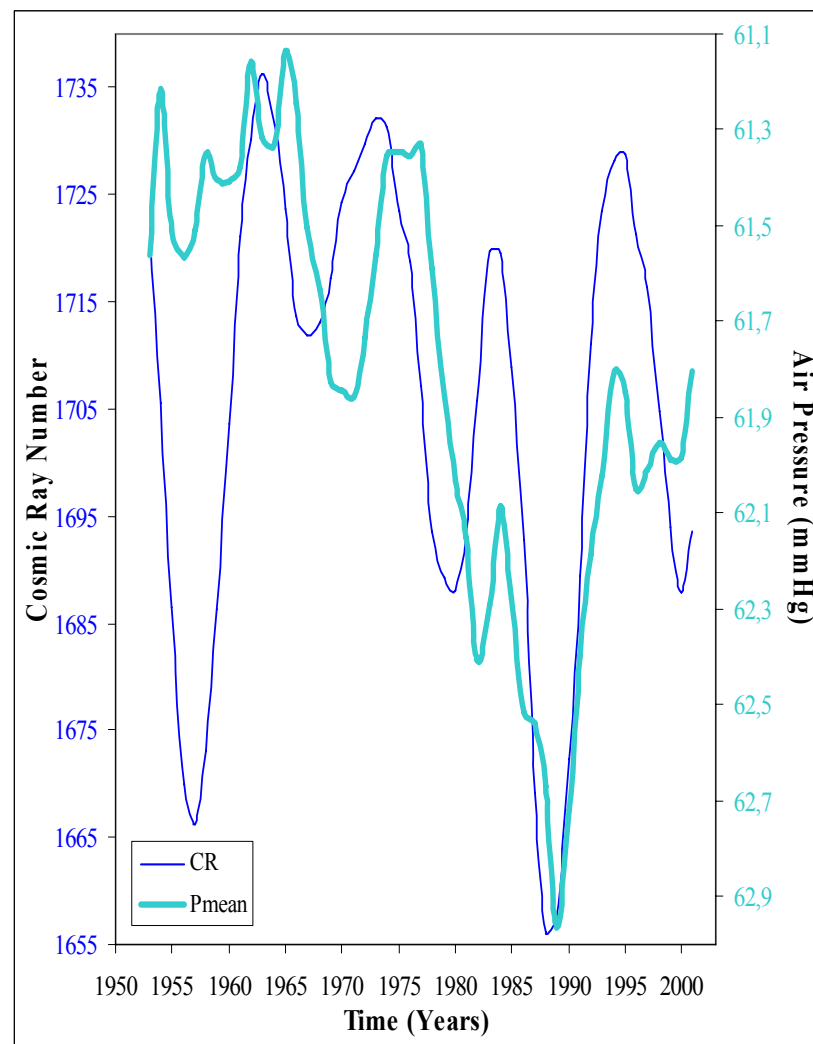
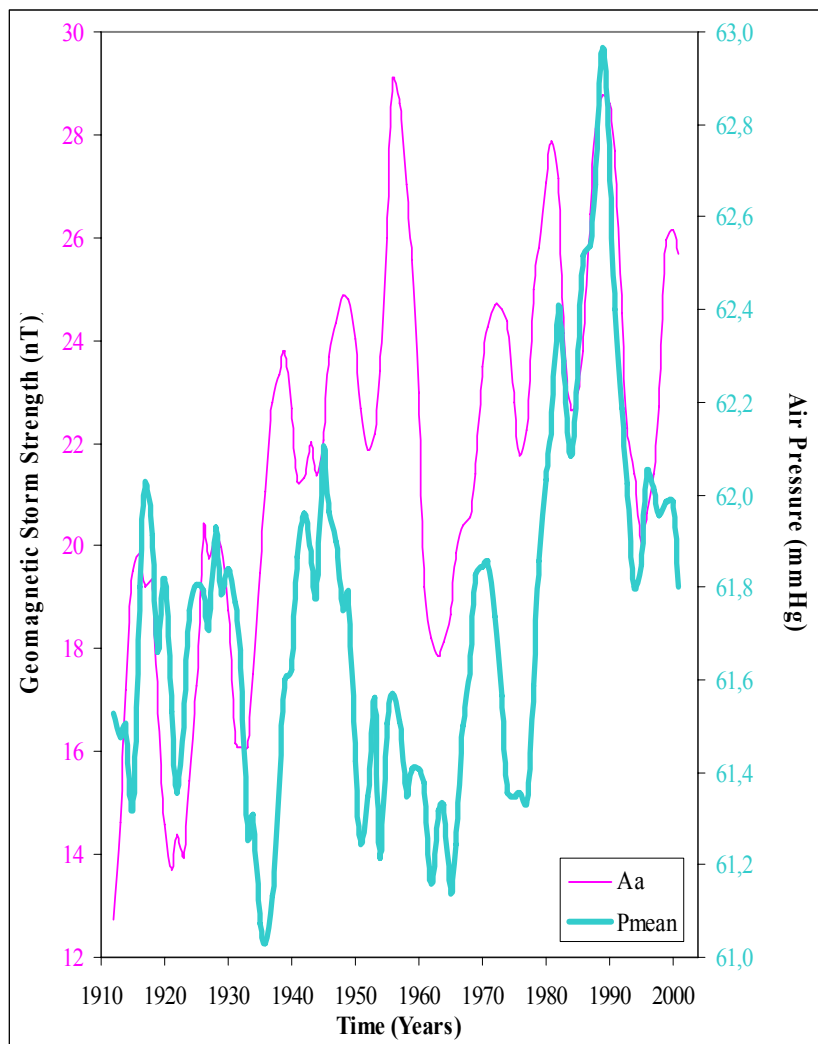


Figure 3.4. Istanbul's five-year running-mean air pressure and a) geomagnetic activity b) cosmic rays

A positive correlation between the air pressure and cosmic ray flux is what was expected at the beginning, because more particles in atmosphere result in a stronger impulsive force on the air. However cosmic rays demonstrate in the air in solar minimum years and their total mass are smaller than solar particles. On the other hand, cosmic rays are more energetic than the solar ones and kinetic energy is as significant as the mass, chemodynamically.

In a study for Sodankylä, it was found that the decreases in cosmic ray number were accompanied by the pressure increase in the whole troposphere, the maximum of the effect taking place on the 3–4th day after the event onset. Simultaneously, the temperature decrease was observed in the troposphere during the first few days of those decreases. The authors concluded that the pressure increase might be related to the changes of wind characteristics in the middle and upper troposphere; however a possible mechanism of the observed effects seemed to involve radiation budget changes in the atmosphere due to the cloudiness variations associated with decreases of the galactic cosmic rays. [67]

The correlation coefficient between Istanbul's mean air pressure and cosmic ray numbers is considerable, -0.46, and though not that rapidly, the mean air pressure trend generally exhibits the opposite pattern of that of the cosmic ray, like also maximum pressure values do (Figure 3.4.b, A.6.b, A.8.b). Since early 1950s, the anticorrelation between maximum values and cosmic rays is noticeable, with a correlation coefficient -0.48, yet it is hard to find exact pairs of extreme points of two trend lines (Table 3.9). The anticorrelation between the minimum values and cosmic rays is close to the others with a correlation coefficient of -0.41; however the harmony in trend lines is lost after 1980s.

The expectations and results do not match and this hardens to build a reliable mechanism between cosmic ray flux and air pressure. A suggestion for this anticorrelation can be that the cosmic rays lose momentum via transporting energy to atmospheric particles. Thus the stimulated atoms can resist to the gravity more strongly and elevate, so that the air pressure decreases. This also may be some of the explanations to the particle-losing procedure of Earth throughout the space.

Table 3.9. The maximum (M) and minimum (m) years of cosmic ray number and mean/maximum/minimum air pressure with the phase lags (Δ) in the 20th century

CR	P _{mean}	Δ (yr)	P _{max}	Δ (yr)	P _{min}	Δ (yr)
M~57	--	--	--	--	m~57	~0
M~63	--	--	m~65	~2	--	--
m~67	M~70	~3	m~69	~2	M~69	~2
M~73	m~76	~3	m~74	~1	m~74	~1
m~80	M~82	~2	M~82	~2	M~83	~3
m~88	M~89	~1	M~89	~1	--	--

3.3. Precipitation

Precipitation is a very complex phenomenon relying on many conditions at the same time in order to occur. On the other hand, it is one of the most defining parameter to draw climatic properties and one of the most crucial needs for the natural material cycles.

3.3.1. Solar Activity

Precipitation is considered to be linked to the solar activity and there have been numerous studies for the connection between them, and in several locations, the smoothed precipitation cycles follow the pattern of solar cycles with two precipitation cycles for each solar cycle. [46] For example, Guo who's working for Photovoltaic Science and Engineering, Military Optics thought that super floods might more easily occur in the years of maximum solar activity because the increase of energy from the Sun would cause an enhancement in the thermo-mechanical function of the Earth's atmosphere. However, in an activity minimum year, super floods are also easier to occur because of the spontaneous magnetostriction effect. Dirk Verschuren from Department of Biology in Ghent University presented a decade-scale reconstruction of rainfall and drought series in equatorial east Africa over the past 1100 years. His analyses indicated that the 'Little Ice Age' (~AD 1270–1850) was interrupted by three prolonged dry periods, 1390–1420, 1560–1625 and 1760–1840, that these dry periods were all

broadly coeval with phases of high solar radiation, while the intervening periods of increased moisture were coeval with phases of low solar radiation. [4]

Similarly, Ulrich Neff from Heidelberg Academy of Sciences investigated the relationship between solar variability and the monsoon rainfall in Oman between 9 and 6 thousand year ago. He found an excellent correlation between the two datasets suggesting that one of the primary controlling factors of centennial- to decadal-scale changes in tropical rainfall and monsoon intensity during this time was the variation in the solar radiation. Likewise, an environmental and meteorological scientist from NASA, Dominic Kniveton suggested that small changes in solar output could indeed cause significant changes in Earth's climate. Also Leszek Starkel from the Institute of Geography of the Polish Academy of Sciences investigated the change in the frequency of extreme events as an indicator of climatic change in the Holocene. He attributed the above-average rainfall during the Little Ice Age to solar influence. [4]

More locally, the results of a study for Beijing area indicated that the annual precipitation was closely related to the variation of sunspot numbers, and that solar activity probably played an important role in influencing the precipitation on land. In another study for the area, the authors claimed that the solar cycle variability might play a significant role in annual precipitation in there, even though the extent of its influence on the precipitation was not clear. Because one study gave the correlation coefficient between sunspot number and precipitation as -0.22, and the other one gave it as 0.60. [4,69]

It is obvious that the changes in air temperature and pressure affect the formation, duration and amount of the precipitation more directly and faster than the particle fluxes from space do. In Istanbul, precipitation's trend waves in wider time compared to those of air temperature and pressure (Figure 3.5.a). The eleven-year solar cycles are not observable in precipitation trends within the last century either in a correlated or anticorrelated way. The paired extreme points of both phenomena are not that likely to support a regular and continuous connection between them, despite not so small correlation coefficient, 0.32 (Table

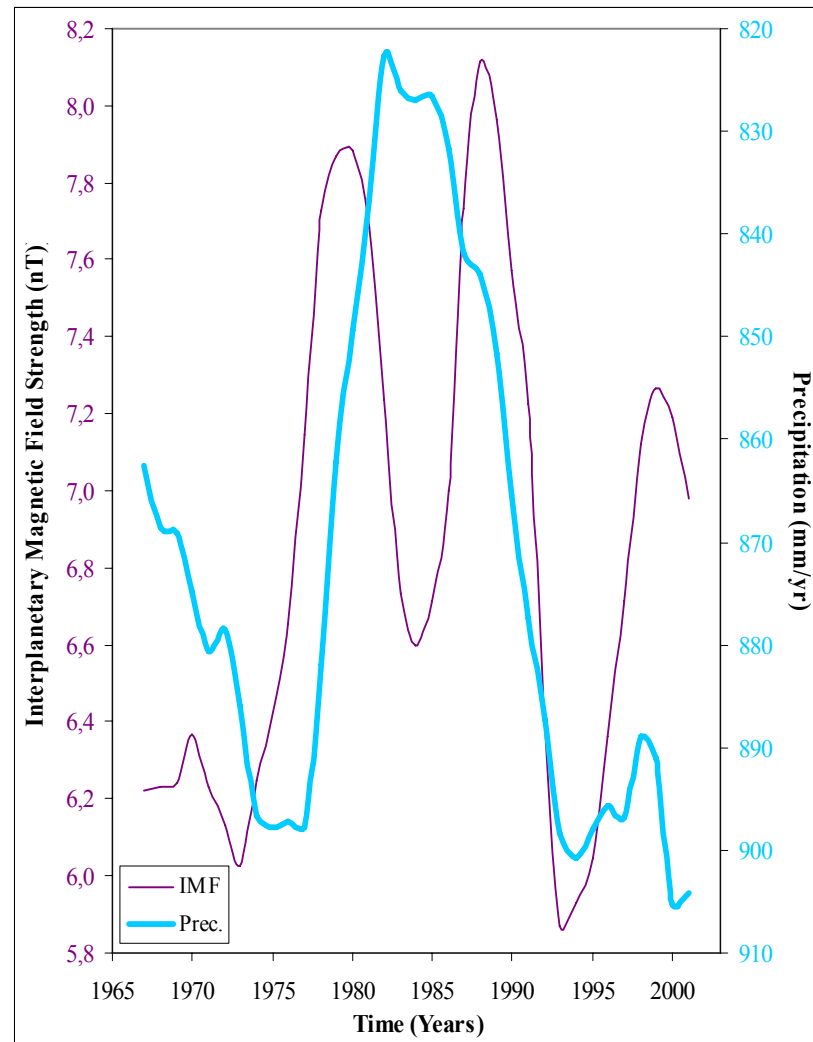
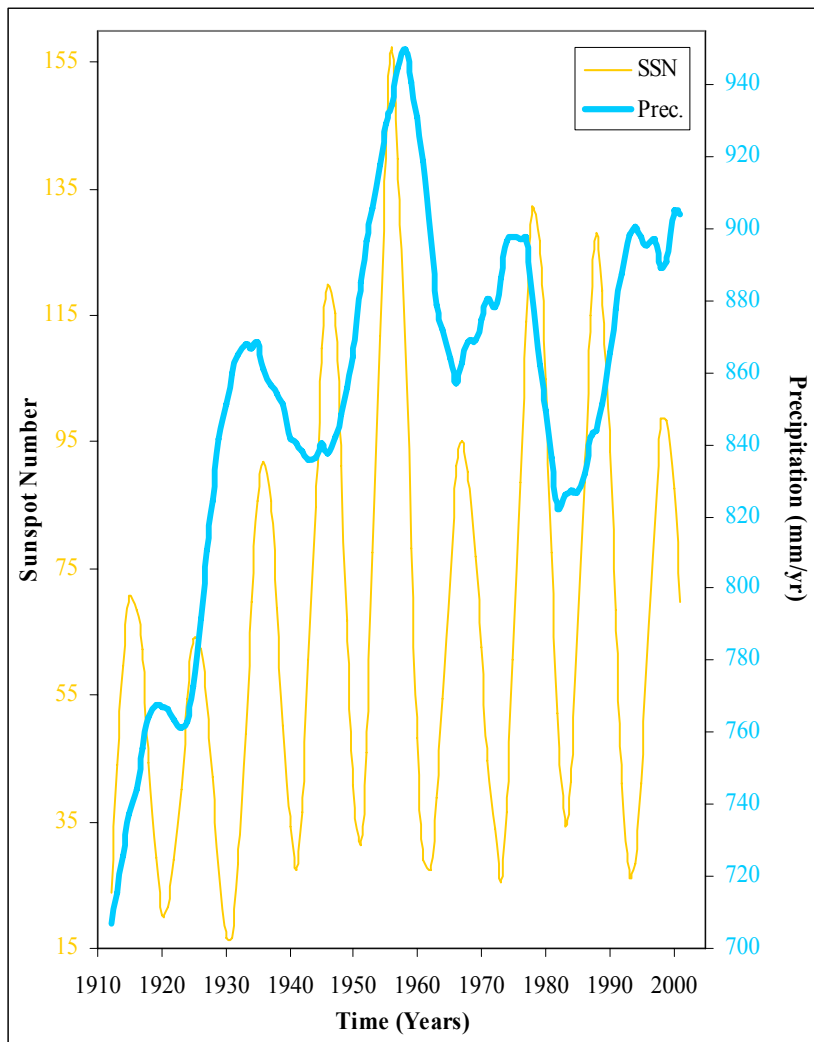


Figure 3.5. Istanbul's five-year running-mean total precipitation amount and a) solar activity b) interplanetary magnetic field

3.10). Similar to this result, the yearly rainfall values of Ebre Observatory did not represent any significant peak about the 11-year period of the Sun. [64]

3.3.2. Interplanetary Magnetic Field

Interplanetary magnetic field is an important phenomenon for atmospheric electricity, and ionization is the triggering factor for cloud activity and formation. Despite the considerable correlation coefficient, -0.41, there is not a visible coherency on the plots (Figure 3.5.b). However, an indirect connection between interplanetary magnetic field strength and precipitation can still be expected.

3.3.3. Geomagnetic Activity

Since the connections between the clouds are electrical and the geomagnetic field is naturally in connection with atmospheric electric field all the times and from Southern Regional Space Research Center in Brazil, Galina Pugacheva's study suggested the existence of a mechanism linking the latter with terrestrial weather parameters to the magnetospheric disturbances. A correlation was expected between aa index and precipitation amount, and found with a coefficient rate of 0.57. Some extreme points of precipitation amount can be considered as direct results of same or oppositely directed aa indices, however, it is hard to observe a general harmony between their trend lines (Figure 3.6.a, Table 3.10). [47]

3.3.4. Cosmic Rays

In their study, Cseh and Bencze claimed that by the increase of the effectivity of the precipitation formation, the water leaving the cloud as precipitation increased from 10% to 11%, taking a speed of the rainfall of 1 cm/hr, and it would produce an energy flux of about 10^{-1} W/cm² for the heating of the atmosphere. Considering the limited spatial extension and period of the rainfall, this energy flux would represent an increase of the energy flux supplied to the atmosphere by the galactic cosmic ray flux of 10^{-10} by a factor of 10^9 . [6] In another paper

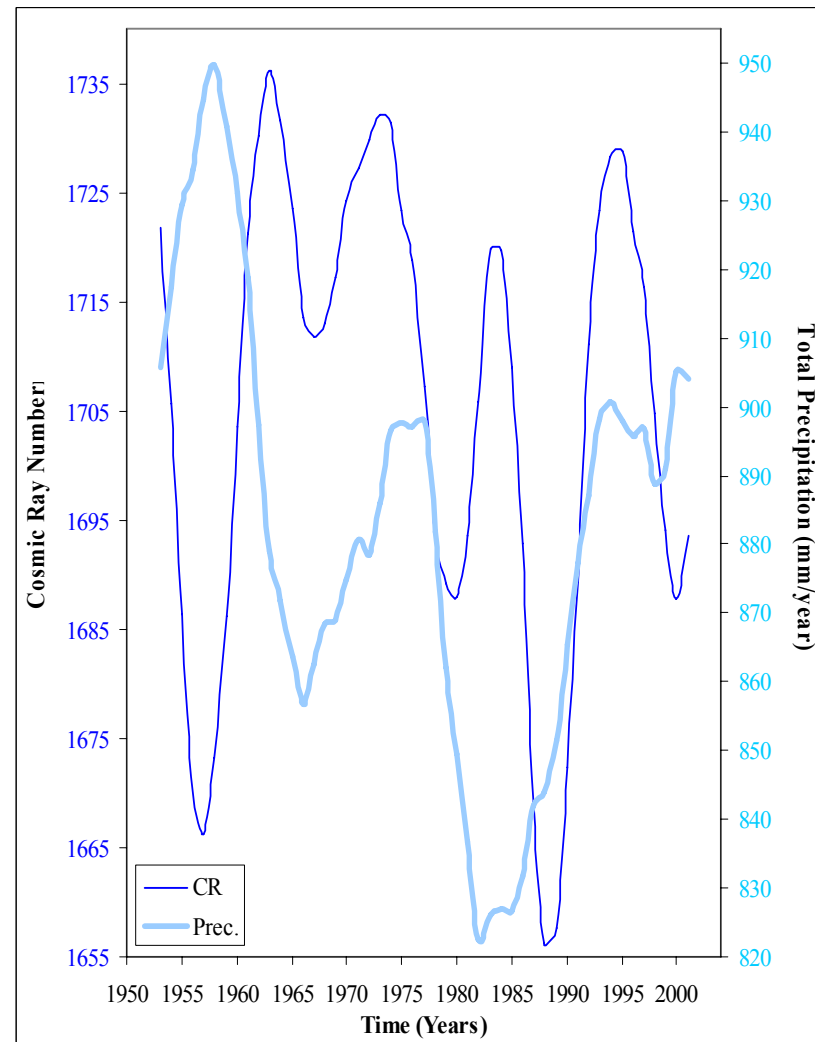
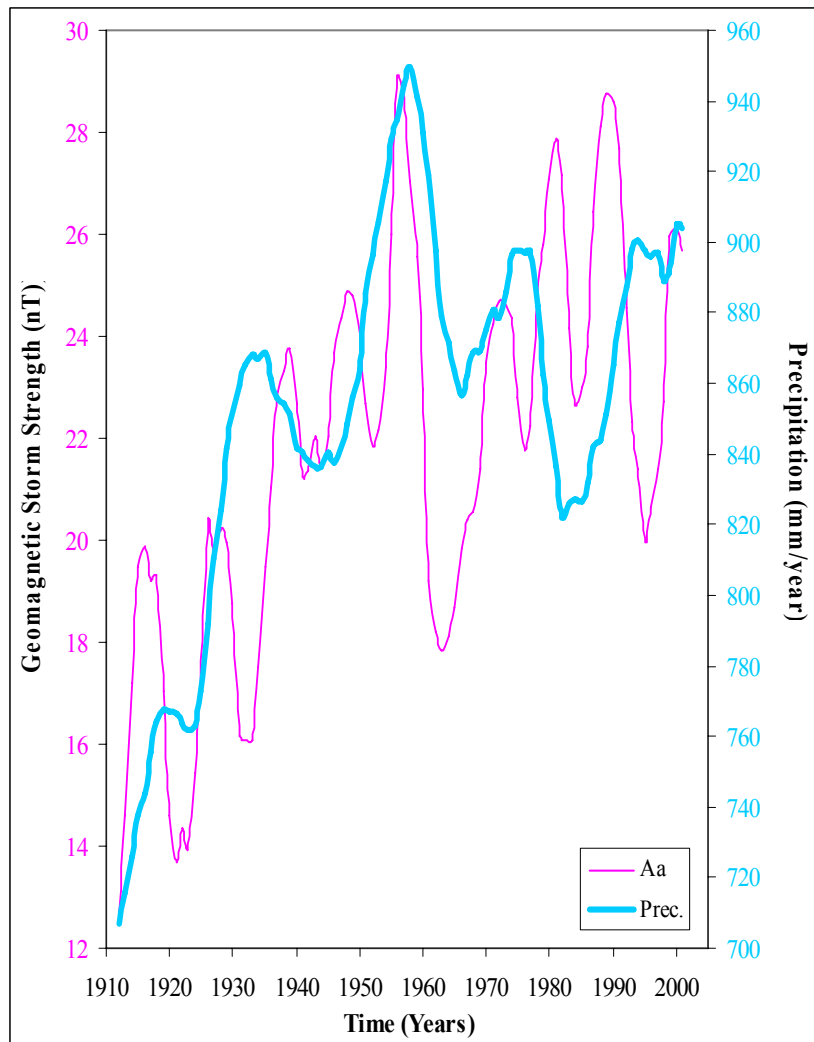


Figure 3.6. Istanbul's five-year running-mean total precipitation amount and a) geomagnetic activity b) cosmic rays

about the cosmic rays and precipitation in Okayama and Hirosaki, Japan, the correlation coefficients were calculated as -0.43 and -0.75, respectively. [70]

Though cosmic rays are very effective on cloud covering, they do not influence Istanbul's precipitation at all, giving a correlation coefficient of -0.04. However, a good correlation was expected between precipitation amount and cosmic ray flux, since cloud formation is considered to be strongly related to cosmic particles in the atmosphere. The precipitation seems like correlated with cosmic ray number some years, and anticorrelated other years, especially between early 1950s and mid-1960s (Figure 3.6.b).

Similar to Istanbul's, Pugacheva reported that the absence of correlation between Brazil's rainfalls and cosmic ray decreases, and also recognizing the phase change of rainfall - sunspot number correlation, and that there was a different phase of the correlation for different geographical locations. He showed that the local variation of an ionization produced by energetic charged particle flux variations were not able to produce an immediate effect on the local weather not being responsible for the long time solar activity-Brazilian weather correlation. [47]

Table 3.10. The maximum (M) and minimum (m) years of sunspot number, geomagnetic activity strength, interplanetary magnetic field strength, cosmic ray flux and total precipitation amount of Istanbul with the phase lags (Δ) in the 20th century

SSN	Prec.	Δ(yr)	AA	Prec.	Δ(yr)	IMF	Prec.	Δ(yr)	CR	Prec.	Δ(yr)
M~15	M~19	~4	m~32	M~34	~2	M~79	m~82	~3	m~57	M~58	~1
M~25	M~33	~8	M~56	M~58	~2	m~93	M~93	~1	M~63	m~66	~3
M~56	M~58	~2	m~63	m~66	~3	--	--	--	M~73	M~75	~2
m~73	M~76	~3	M~81	m~82	~1	--	--	--	m~80	m~82	~2
m~88	M~93	~5	M~78	m~82	~4	--	--	--	--	--	--
--	--	--	M~88	M~93	~5	--	--	--	--	--	--
--	--	--	M~89	M~94	~5	--	--	--	--	--	--
--	--	--	m~93	m~94	~1	--	--	--	--	--	--

3.4. Wind Velocity

Wind is an indirect parameter, result of variations in local temperature and pressure values and also many other factors like Earth's rotation or seasons, and it has not been a common one to study the climate. However, they play a very important role for weather conditions like transportation of heat or movement of clouds, and any change in them will disturb the general trend of winds both in magnitude and geographical coordination cases.

3.4.1. Solar Activity

Enhanced ultraviolet radiation during solar maxima leads to an enhanced ozone production in the upper stratosphere (maximal 3% near 5 hPa from the subtropics to higher latitudes, estimated by 2-D chemical models; the observed ozone signal is even higher) depending on the time of the year. The enhanced UV radiation as well as the enhanced ozone leads to a greater short-wave heating rate in the stratosphere during solar maxima than during solar minima. The thermal gradient induced directly in the upper stratosphere (near the stratopause at a height of 50 km) can alter the whole mean meridional circulation from the stratosphere down to the troposphere by affecting the planetary wave propagation in the winter hemisphere. Kunihiko Kodera from Meteorological Research Institute in Ibaraki, Japan, pointed out that the Sun produced wind anomalies in the upper subtropical stratosphere in early winters. Such wind anomalies changed the propagation properties for planetary waves and affect the polar night jet formation at higher latitudes through wave-mean flow interactions, he continued, and the wind anomalies propagate, via this positive feedback mechanism, poleward and downward during wintertime from the upper stratosphere at lower latitudes to the lower stratosphere at higher latitudes. Koder confirmed the observed modulation between solar signals during winter and assumed that the solar activity triggered the interannual variability of the stratosphere. [5]

However, in annual basin, wind velocity values for Istanbul have nothing to do with sunspot number as seen on the plots (Figure 3.7.a). The paired extreme points of both trend

lines do not supply a reliable interaction, and the correlation coefficient, -0.08, is almost zero (Table 3.11).

There is some similar study of Libo Liu from the Institute of Geology and Geophysics in China, about the connection between winds at Wuhan and solar activity, though it focused on the vertical components of winds, only. The study pointed that the solar cycle variability of thermospheric circulation was one of the outstanding questions involving the upper atmosphere. However, it needed to be identified due to the latitude and longitude dependence of neutral winds. Due to this study, current models and measurements showed that, although neutral compositions and temperature in the thermosphere clearly and strongly depended on the level of solar activity, the solar activity variations of thermospheric meridional winds were complex and different at particular sites. He reported that, with increasing solar activity, the diurnal amplitudes of meridional winds decreased at some locations. But opposite trends were found in some seasons and some locations. [71]

Liu also remarked that the winds at mid-latitudes had no clear dependence on the solar activity level though the daily mean and amplitudes of tidal components of vertical component of equivalent winds decreased with the increasing solar activity. The meridional neutral winds from the EISCAT radar showed F10.7 (a solar radioactivity index) dependence: the mean winds were larger during low solar activity periods, while the trends were opposite in the semidiurnal components. Decrease in diurnal amplitudes of the derived winds with solar activity levels was found at a mid-latitude station, Boulder (40.0°N, 254.7 °E). While at another mid-latitude station in the southern hemisphere, King George Island (62.2°S, 58.8°W), the amplitudes of winds decreased from low to high solar activity levels in spring and summer, but increase in winter. Thus the details of the solar cycle and/or seasonal analyses differed from study to study and from location to location. [71]

3.4.2. Interplanetary Magnetic Field

Liu reported that increased ion drag during solar maximum might play an important role in the interpretation of the decrease in diurnal amplitude of winds with increased solar activity.

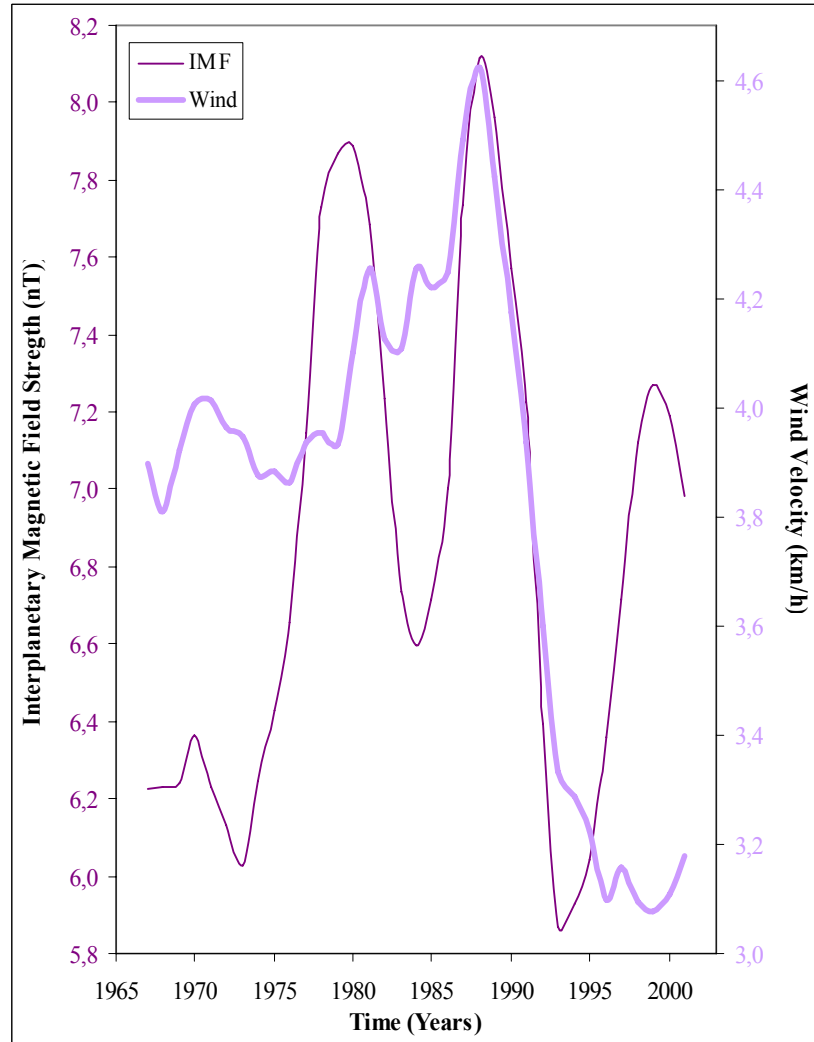
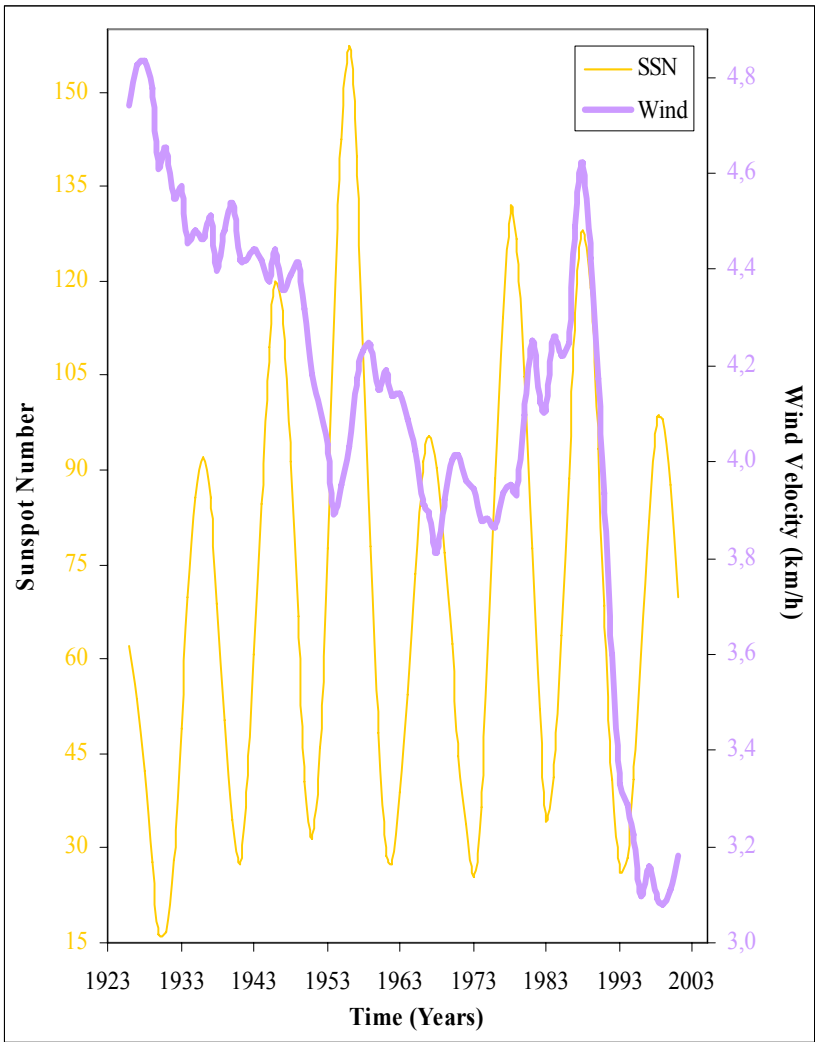


Figure 3.7. Istanbul's five-year running-mean wind velocity and a) solar activity b) interplanetary magnetic field

[71] Despite a moderate correlation coefficient, 0.41, wind velocity values for Istanbul do not exhibit a harmonic pattern with interplanetary magnetic field strength (Figure 3.7.b).

3.4.3. Geomagnetic Activity

Bucha's analysis of the temperature distribution for the duration of 1970-1996 in the northern hemisphere at times of low geomagnetic activity showed positive anomalies in the area of the western part of North America, in the Eastern Atlantic, East Africa, West and East Asia where the warm air flows to the north, and negative anomalies in the eastern part of North America, Europe, Central Asia and the Pacific where the cold air penetrates to the south. On the other hand, at times of high geomagnetic activity, the warm air flowing originally to the north was deflected by the intense Icelandic Low to the east and he observed a belt of above normal temperatures with the eastward moving warm air across the southern part of North America, the Atlantic, Europe and North Asia forming a ring in mid-latitudes along the cold air in polar areas. He also showed that at a time of high geomagnetic activity, an intensification of the winds could be observed not only in the thermosphere but also in the troposphere. [38]

As a consequence of heat input during geomagnetic disturbances, the atmosphere may be affected by creating and strengthening the reverse circulation at high latitudes in the middle atmosphere, as well as extending it to mid-latitudes. [6] However, the general patterns of aa index and wind velocity values of Istanbul do not show any similarity (Figure 3.8.a). The coupled extreme points also give irrelevant phase lags and the small correlation coefficient, -0.17, guaranteeing the independence of wind speeds from geomagnetic activity. A few extreme points of both trends can be matched, however they are not significant since a stable phase lag is not found (Table 3.11).

3.4.4. Cosmic Rays

The correlation coefficient, -0.31, offers a weak anticorrelation between them, but wind velocity's trend line does not seem to be relevant to cosmic ray's, except between 1980s and 1990s (Figure 3.8.b). This parallelism is probably apparent in plots only, not relying on a

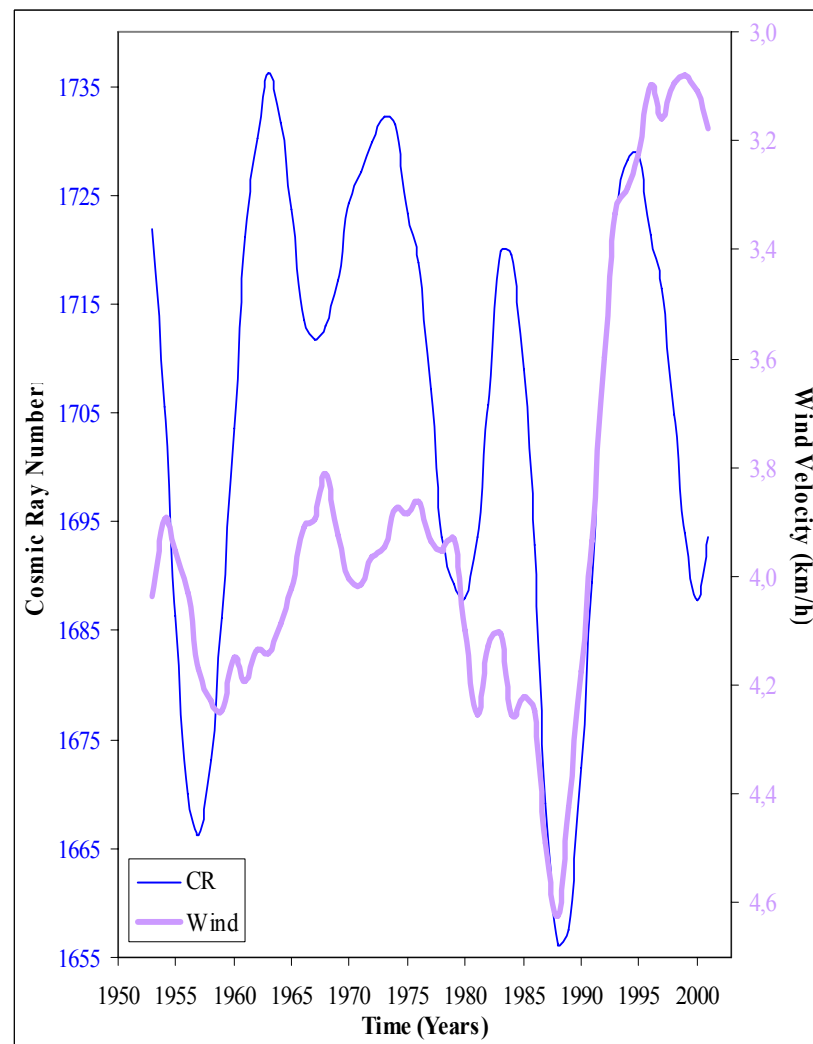
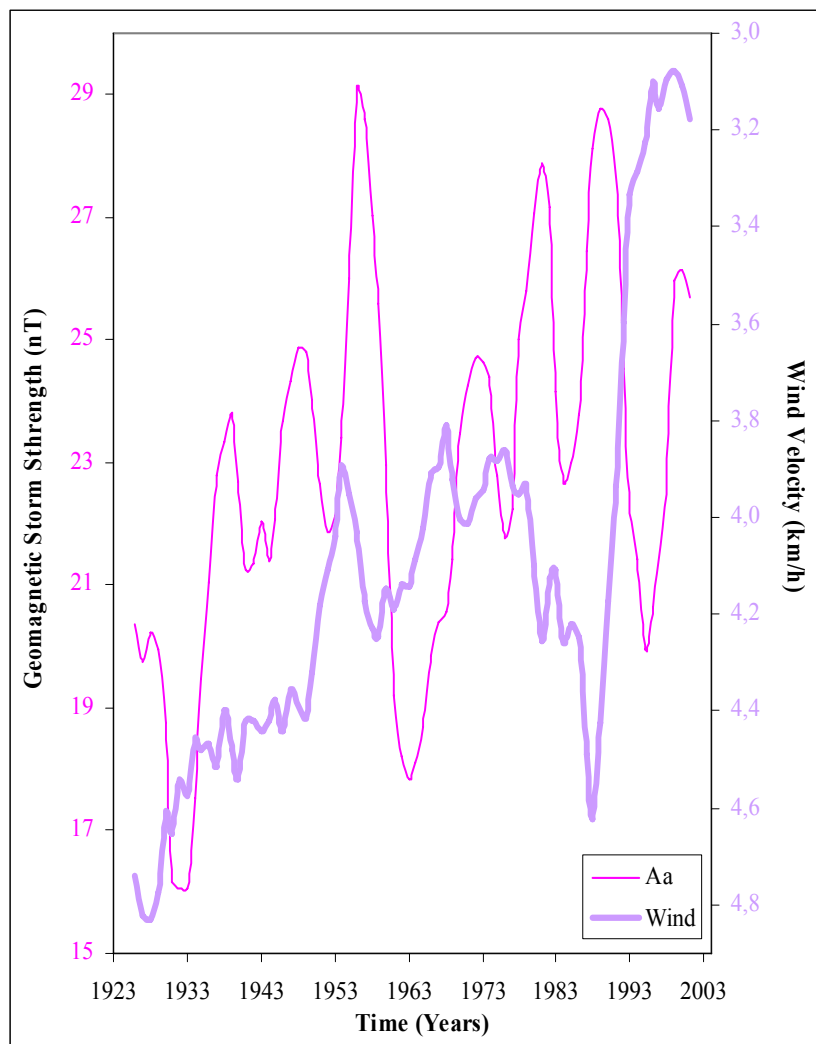


Figure 3.8. Istanbul's five-year running-mean wind velocity and a) geomagnetic activity b) cosmic rays

physical interaction. On the other hand, pronounced changes in the wind direction (strengthening of the northern component) took place mainly in the middle troposphere on the first 2-3 days after the cosmic ray decrease onset in Sodankylä. [67]

Table 3.11. The maximum (M) and minimum (m) years of sunspot number, geomagnetic activity strength, interplanetary magnetic field strength, cosmic ray flux and average wind velocity of Istanbul with the phase lags (Δ) in the 20th century

SSN	W.V.	Δ (yr)	AA	W.V.	Δ (yr)	CR	W.V.	Δ (yr)	IMF	W.V.	Δ (yr)
m~51	m~54	~3	m~52	m~54	~2	m~77	m~78	~1	m~94	m~96	~2
m~62	m~68	~6	m~84	M~88	~4	M~83	M~88	~5	--	--	--
M~67	m~68	~1	m~95	m~96	~1	--	--	--	--	--	--
M~88	M~88	~0	--	--	--	--	--	--	--	--	--
m~93	m~96	~3	--	--	--	--	--	--	--	--	--

Table 3.12. The correlation coefficients between five-year running-mean space indices and five-year running-mean Istanbul weather parameters

vs	SSN	IMF	AA	CR
Tmax	0,34	-0,11	0,34	-0,09
Tmean	0,21	-0,09	0,01	0,02
Tmin	0,14	0,08	0,00	-0,07
Pmax	0,14	0,67	0,34	-0,48
Pmean	0,13	0,53	0,43	-0,46
Pmin	0,12	0,22	0,25	-0,41
Prec.	0,32	-0,41	0,57	-0,04
Wind	-0,08	0,41	-0,17	-0,31

After all of the terrestrial and celestial parameters used for the study are discussed, the results from the study are summarized and the conclusion is drawn in the following section.

4. CONCLUSIONS

A butterfly's wing beat can result in a storm on a far away place of Earth, due to the butterfly effect theory. This is true, but how come can the scientists not simply think what is responsible of a thunderstorm in Asia is a butterfly in America? Climate is a very complex and sensitive system, and numerous factors are effective on it at the same time. Thus, it is not that reliable to be sure about the contribution ratios of those factors. As long as any external foreigner does not influence the system, it will not lose the balance.

In the light of this study, Istanbul's air temperature seems like affected by solar activity due to sunspot numbers and geomagnetic storm strength a little bit and the clearest anticoherency is determined on the maximum values. However, the antirelationship observed on the plots does not agree with the correlation coefficient, because it offers a low-moderate parallelism. In this case, it is confusing what is true to prefer, the coefficient or the plots and this disagreement between plots and correlation rates hardens to offer a mechanism model for Sun-Earth connection as well. Considering that the period studied includes both relatively clear (not pre-industrial but before nuclear weapons, low human popularity and greener) and polluted years of the environment, it is not surprising to find abnormal results and disagreements between calculation methods.

Cosmic ray number is expected to give the opposite way of relationship to solar activity with air temperature; however it gives zero anticorrelation like the interplanetary magnetic field. And a reverse relationship between cosmic rays and temperature can be traced on the plots, similar to sunspot number. Actually, if the Sun correlates, then cosmic rays anticorrelate with an atmospheric factor. Here is another physical disagreement: cosmic rays result to same behavior with the Sun, and do not give reverse signed correlation coefficient for air temperature of Istanbul.

The sunspot affection on air pressure of Istanbul is too weak, not worthy accepting a reliable interaction. However, the interplanetary magnetic field gives a good correlation with it, verifying the force of the magnetic aspect of solar winds on the atmosphere. And this conclusion is also found on

plots, the parallelism between the trend lines is apparent. The variations in geomagnetic field strength act the way interplanetary magnetic field does, and give a close correlation rate.

As expected, the cosmic rays give a negative correlation rate with air pressure of the location, unlike the magnetic effects, and the antiparallelism is observable on the plots as well. This harmony between plots and calculations and among space factors allow one to conclude that there is a reliable interaction going on between solar and cosmic effects and Istanbul's air pressure.

The cosmic rays are expected to be influencing on the precipitation amount according to the newly discovered cloud-cosmic ray relationship; however they do not affect the precipitation in Istanbul at all. The precipitation weakly correlates with sunspot number in the last century, but more strongly with geomagnetic field (due to correlation rate only; in plots a discord exists between them). This is acceptable since cloud and thunderstorm formation processes occur under electrical conditions. However, while precipitation correlates with geomagnetic field, it anticorrelates with interplanetary magnetic field. Both of them are magnetic fields, generally resulting from the solar activity and cause electrical charging of the atmosphere; but they interact with precipitation in reverse ways. This type of an inconsistency is observed in air temperature as well, and seemingly precipitation is the second most influenced parameter by the disrupted Nature.

The sunspot number and geomagnetic aa index are not effective on average wind velocity in Istanbul, while interplanetary magnetic field moderately correlates, and cosmic rays anticorrelate with it. The opposite way of behavior between cosmic rays and interplanetary magnetic field is good for the expectations; however the dramatic decrease of wind velocity in last years can not be explained by any of the space-sourced phenomena, like the steep increase in air temperature.

Most of the expectations and results in this study do not match and some of the correlation coefficients do not predicate the type of relationship between terrestrial and celestial parameters observed on the plots. In the celestial-terrestrial couples which give considerable coefficients exhibit parallel behaviors in trends only to mid-1900s, and the harmony is generally lost after then. This consequence points only one deliverance: anthropogenic global warming.

There is no doubt that the Earth is climatically affected by its outer vicinity the way it is affected gravitationally, especially in an electrical aspect regarding to the particles and waves it receives.

However, space phenomena are traceable in climate only for long durations, like a thousand year. Or they are significant when they disturb the climatic balances via some immediate events like auroral jets or solar proton fluxes, yet those effects are contemporary; they cause a shock in a local weather for a few hours to a few days, then things in the magnetosphere and atmosphere get recovered back. And it still does not mean much to find strong correlations between space indices and climatic parameters for long years, as long as reliable physical mechanisms are not mathematically explained. The Sun, stellar explosions or space radiation will no way treat the life on the Earth, because it has been already evolved in this Universe, having dust of nebulas in the tissues of. Considering long years and permanent conditions, especially the global warming phenomenon, it is apparently a wiser movement to consider anthropogenic factors more serious than the outer space.

Yet, the greenhouse gases are not the only perturbation created by man. The physical conditions of the atmosphere are at least as significant for the climate as the chemical composition of it. The synthetic electric and magnetic waves lead to pollution in atmosphere in their own way. The electromagnetic fields diffused from devices are potent to have a very important role in ascending trend of air temperature, and sensitive instruments show that electronic technology within a typical home or work environment is sufficient to overpower the Earth's natural magnetic field by up to 16 times. [72] Thus, it is not correct to define the global warming as only increasing air temperature. What increases, in fact, is the atmospheric energy, and the temperature rising is just a direct result of it. This theory is based on the concept of entropy in statistical mechanics telling that when chaos is created and the order is disturbed, the energy of a processes.

The sharp and continuous ascend in atmospheric temperature values for Istanbul since early 1980s is the reflection of the increasing atmospheric energy, local and global warming, which also leads to dramatic descend in wind velocity values. Because neither the Sun's own, nor the cosmic rays, or any other space-sourced phenomena perfectly fit with the temperature, wind or precipitation.

Even if the outer space were responsible for the 99% of the global warming, and only the rest was anthropogenic, people just could not continue blaming the Sun and living the way they are used to. They can not interfere in the solar activity or can not strengthen the magnetosphere; but they can change the way they treat the planet. People can stop the increasing of human population, start diminishing the pollutants, give space to the nature to find its fitness and learn respecting the natural processes without breaking or fastening them. Because the disturbances created by the human, civilization, the search for

comfort and advanced technology ask for the payment by the loss of species, rainforests, the elemental needs like clean air and pure water. Man's ignorance about the fragility of the Nature costs a planet he will never be able to recreate. However, it is still in his hands to slacken the coming of the end of himself. There is no boundary in talent, as long as the power of pure science is kept on minds.

Unfortunately, there is a significant gap in scientific studies: interdisciplinary collaborations. A member of a specific branch generally tends to think what he studies is the most effective or the only contributor to the global warming. The solar physicists have advocated (wanted, actually) that the most significant parameter on the Earth's climate was the Sun, and space physicists have defended that it was cosmic rays. In one case, these two are correct, however, they are not the origin of the recent warming. The 11-year solar cycle is almost regular for centuries, and the amount of the reaching particles to the Earth's surface is controlled by the geomagnetosphere and atmosphere, especially the ozone layer. But both of the controllers are compositionally and electrically changed due to anthropogenic processes, as known by satellite photographs since 1970s. In some plots, parallel trends with weather conditions and cosmic or solar activities can be found, however those actually reflect that the geomagnetic field and ozone layer are weakened, not a direct and quick-acting relationship between those rays and weather.

The environmentalists have been alerting the world for the dangers of the continuum of the global warming for years; however they can not stand strong against the climatologists who claim that it is all about the natural processes. On the other hand, environmentalists separate subtopics in that field as well, and unfortunately they mostly care about only their own issues. Discrepancies exist even between studies on marine, soil and air pollutions. Because the Planet Earth is a whole system, one unique habitat; and separating the aqua-, aero-, litho- and magneto-spheres lead the scientists wrong. If a successful bridge is managed to be built between different disciplines, the reasons of climate change will be better understood and more efficient solutions will be produced.

REFERENCES

- 1 Gallet, Y., Genevey, A., Fluteau, F., 2005. Does Earth's magnetic field secular variation control centennial climate change?. *Earth and Planetary Science Letters*, 236, 339-347.
- 2 Svensmark, H., 2000. Cosmic rays and Earth's climate. *Space Science Reviews*, 93, 175-185.
- 3 Laut, P., 2003. Solar activity and terrestrial climate: An analysis of some purported correlations. *Journal of Atmospheric and Solar-Terrestrial Physics*, 65, 801-812.
- 4 Zhao, J., Han, Y.B., Li, Z.A, 2004. The effect of solar activity on the annual precipitation in the Beijing area. *Chinese Journal of Astronomy and Astrophysics*, 4, 189-197.
- 5 Labitzke, K., Matthes, K., 2003. Eleven-year solar cycle variations in the atmosphere: Observations, mechanisms and models. *The Holocene*, 13, 311-317.
- 6 Cseh, S., Bencze, P., 2005. Long-term variations of temperature, wind and precipitable water in the troposphere and lower stratosphere over Budapest, Hungary. *Quarterly Journal of the Hungarian Meteorological Service*, 109, 189-202.
- 7 Friis-Christensen, E., Svensmark, H., 1997. What do we really know about the Sun-climate connection?. *Advanced Space Researches*, 20, 913-921.
- 8 Green, J.L., 2007. "The Magnetosphere",
ssdoo.gsfc.nasa.gov/education/lectures/magnetosphere.html.

9 Pulkkinen, T.I., Baker, D.N., Turner, N., Singer, H.J., Blake, J.B., Spence, H., Frank, L.A., Sigwarth, J.B., Mukai, T., Kokubun, S., Nakamura, R., Russell, C.T., Kawano, H., Mozer, F., Slavin, J.A., Lepping, R., Anderson, R., Reeves, G., Zelenyi, L.M., 1996. A multispacecraft ISTP study: Substorm evolution from the solar wind to the magnetosphere and ionosphere. *ISTP Newsletter* 6, 7-18.

10 Soon, W., Baliunas, S., Posmentier, E.S., Okeke, P., 2000. Variations of solar coronal hole area and terrestrial lower tropospheric air temperature from 1979 to mid-1998: Astronomical forcings of change in Earth's climate?. *New Astronomy*, 4, 563-579.

11 Crooker, N. U., Siscoe, G. L., Russell, C. T., Smith, E. J., 1982. Factors controlling degree of correlation between ISEE 1 and ISEE 3 interplanetary magnetic field measurements. *Journal of Geophysical Researches*, 87, 2224.

12 Ojima, M., Kakinuma, T., 1990. Solar cycle dependence of global distribution of solar wind speed. *Space Science Reviews*, 53, 173-222.

13 Mavromichalaki, H., Souvatzoglou, G., Sarlanis, C., Mariatos, G., Gerontidou M., Papaioannou, A., Plainaki, A., Tatsis, S., Belov, A., Eroshenko, E., Yanke, V., 2005. The New Athens Center on data processing from the neutron monitor network in real time. *Annales Geophysicae*, 23, 1-8.

14 Ickett, B.J., Coles, W.A., 1991. Evolution of the solar wind structure over a solar cycle: Interplanetary scintillation velocity measurements compared with coronal observations. *Journal of Geophysical Researches*, 96, 1717-1736.

15 Russell, C.T., Siscoe, G.L., Smith, E.J., 1980. Comparison of ISEE-1 and -3 interplanetary magnetic field observations. *Geophysical Research Letters*, 7, 381-389.

16 Arker, E.N., 1959. Extension of the solar corona into interplanetary space. *Journal of Geophysical Researches*, 64, 1675.

17 NASA Solar Information Page. <http://www.sec.noaa.gov/primer/primer.html>. (accessed June 2007).

18 Hathaway, D.H., 2007. "The Sunspot Cycle",
<http://solarscience.msfc.nasa.gov/SunspotCycle.shtml>.

19 NASA Interplanetary Magnetic Field Page.
<http://pluto.space.swri.edu/image/glossary/IMF.html>. (accessed June 2007).

20 University Corporation for Atmospheric Research Page.
<http://www.windows.ucar.edu/tour/link=/glossary/IMF.html&edu=high>. (accessed June 2007).

21 KeelyNet Interplanetary Magnetic Field Page.
<http://www.keelynet.com/spider/magfield.htm>. (accessed June 2007).

22 Russell, C. T., 1975. On the possibility of deducing interplanetary and solar parameters from geomagnetic records. *Solar Physics*, 42, 259-269.

23 Deep Alaska Aurora Borealis Page.
<http://www.mosquitonet.com/~deepalaska/ImagesMarch05/>. (accessed June 2007).

24 Crooker, N.U., Cliver E.W., 1994. Postmodern view of M-regions. *Journal of Geophysical Researches*, 99, 23383-23390.

25 Chernosky, E.J., 1966. Double sunspot-cycle variation in terrestrial magnetic activity, 1884-1963. *Journal of Geophysical Researches*, 71, 965-974.

26 Cliver, R.W., Boriakoff V., Bounar K.H., 1996. The 22-year cycle of geomagnetic and solar wind activity. *Journal of Geophysical Researches*, 101, 27091-27109.

- 27 Russell, C.T., McPherron, M.L., 1973. Semi-annual variation of geomagnetic activity. *Journal of Geophysical Researches*, 78, 92.
- 28 Czeplia, S.A., 1997. *The Charging of Composites in the Space Environment*, MS Thesis, MIT.
- 29 Aikio, A., Sergeev, V., Shuktina, M., Vagina, L., Angelopoulos, V., Reeves, G., 1998. Characteristics of Magnetospheric Substorms and Pseudobreakups, *Proceedings of 23rd Convention on Radio Science and Remote Sensing Symposium*, Espoo, Finland, August 24-25, 1998.
- 30 Geomagnetic Data from Australia Page.
http://www.ga.gov.au/oracle/geomag/geomagnetism_indices.jsp. (accessed June 2007).
- 31 British Geological Survey, aa Index Home Page.
<http://www.geomag.bgs.ac.uk/gifs/aaindex.html>. (accessed June 2007).
- 32 Mewaldt, R.A., 2007. "Cosmic Rays",
http://www.srl.caltech.edu/personnel/dick/cos_encyc.html.
- 33 Simpson, J. A., 1983. Elemental and isotopic composition of the galactic cosmic rays. *Annual Reviews of Nuclear and Particle Science*, 33, 323-381.
- 34 Jokipii, J. R., McDonald, F.B., 1994. Quest for the limits of the Heliosphere. *Scientific American*, 272, 58-63.
- 35 Coffey, H.E., 2007. "Cosmic Rays",
http://www.ngdc.noaa.gov/stp/SOLAR/COSMIC_RAYS/cosmic.html.
- 36 Shea, M.A., Smart, D.F., 2004. Preliminary study of cosmic rays, geomagnetic field changes and possible climate changes. *Advances in Space Research*, 34, 420-425.

- 37 Kandilli Observatory Main Page. <http://www.koeri.boun.edu.tr/meteoroloji/default.htm>.
- 38 Bucha, V., Bucha Jr, V., 1998. Geomagnetic forcing of changes in climate and in the atmospheric circulation. *Journal of Atmospheric and Solar-Terrestrial Physics*, 60, 145-169.
- 39 Ritter, M., 2006. "The Physical Environment",
http://www.uwsp.edu/geo/faculty/ritter/geog101/uwsp_lectures/lecture_atmospheric_temperature.html.
- 40 An Online School for Weather: Air Pressure Page.
<http://www.srh.weather.gov/srh/jetstream/atmos/pressure.htm>. (accessed June 2007).
- 41 Ritter, M.E., 2006. "The physical environment: An Introduction to Physical Geography",
http://www.uwsp.edu/geo/faculty/ritter/geog101/textbook/title_page.html.
- 42 Scafetta, N., West, B. J., 2005. Estimated solar contribution to the global surface warming using the ACRIM TSI satellite composite. *Geophysical Research Letters*, 32, 18713- 18717.
- 43 Ermakov, V.I., Stozhkov, Y.I., 2003. Cosmic Ray Fluxes in the Atmospheric Processes, *Proceedings of ISCS 2003 Symposium: Solar Variability as an Input to the Earth's Environment*, June 23-28, 2003, Tatranska Lomnica, Slovak Republic, 359-362.
- 44 Krivova, N.A., Solanki, S., 2004. Solar variability and global warming: A statistical comparison since 1850. *Advances in Space Research*, 34, 361-364.
- 45 Marsh, N.D., Svensmark, H., 2000. Low cloud properties influenced by cosmic rays. *Physical Review Letters*, 85, 5004-5007.
- 46 Yousef, S. M., 2006. 80-120 yr long-term solar induced effects on the Earth, past and predictions. *Physics and Chemistry of the Earth*, 31, 113-122.

- 47 Pugacheva, G., Almeida, A., Gusev, A., Martin, I., Pankov, V., Spjeldvik, W., 2001. New Evidences of Space Weather Impact on Weather and Climate in Southern Hemisphere, Proceedings of 27th International Cosmic Ray Conference Hamburg, Germany, 07-15 August 2001, 4153-4156.
- 48 Courtillot, V. Gallet, Y., Le Mouél, J.L., Fluteau, F. Genevey, A., 2007. Are there connections between the Earth's magnetic field and climate?. *Earth and Planetary Science Letters*, 253, 328-339.
- 49 Kılçık, A., 2003. Regional Sun-climate interaction. *Hvar Observatory Bulletin*, 29, 261-270.
- 50 Kristjansson, J. E., Kristiansen, J., Kaas, E., 2004. Solar activity, cosmic rays, clouds and climate – An update. *Advances in Space Research*, 34, 407-415.
- 51 Krivova, N. A., Solanki, S., 2003. Solar Total and Spectral Irradiance: Modelling and a Possible Impact on Climate, Proceedings of ISCS: Solar Variability as an Input to the Earth's Environment, June 23-28, 2003, Tatranska Lomnica, Slovak Republic, 535.
- 52 Valev, D., 2006. Statistical relationships between the surface air temperature anomalies and the solar and geomagnetic activity indices. *Physics and Chemistry of the Earth*, 31, 109-112.
- 53 Shindell, D., Rind D., Balachandran, N., Lean, J., Lonergan, P., 1999. Solar cycle variability, ozone and climate. *Science* 284, 305-308.
- 54 Le Mouél, L.J., Kossobokov, V., Courtillot, V., 2005. On long-term variations of simple geomagnetic indices and slow changes in magnetospheric currents: The emergence of anthropogenic global warming after 1990?. *Earth and Planetary Science Letters*, 232, 273-286.
- 55 Beer, J., Mende, R., Stellmacher, R., 2000. The role of the Sun in climate forcing. *Quaternary Science Reviews*, 19, 403-415.

56 Foukal, P., Fröhlich, C., Spruit, H., Wigley, T.M.L., 2006. Variations in solar luminosity and their effect on the Earth's climate. *Nature*, 443, 161-166.

57 Christl, M., Mangini, A., Holzkämper, S., Spötl, C., 2004. Evidence for a link between the flux of galactic cosmic rays and Earth's climate during the past 200,000 years. *Journal of Atmospheric and Solar-Terrestrial Physics*, 66, 313-322.

58 Jacobi, C., Kürschner, D., 2006. Long-term trends of MLT region winds over Central Europe. *Physics and Chemistry of the Earth*, 31, 16-21.

59 Rozelot, J. P., Lefebvre, S., 2006. Is it possible to find a solar signature in the current climatic warming?. *Physics and Chemistry of the Earth*, 31, 41-45.

60 Mendoza, B., Ramirez, J., Cordero, G., 2004. Cosmic rays and terrestrial temperature: Is there a direct long-term relation?. *Advances in Space Research*, 34, 416-419.

61 Weng, H., 2005. The influence of the 11 yr solar cycle on the interannual–centennial climate variability. *Journal of Atmospheric and Solar-Terrestrial Physics*, 67, 793-805.

62 NASA Linear Correlation Coefficient Page.

<http://ssed.gsfc.nasa.gov/lepedu/IA-CorrCoeff.html>. (accessed May 2007).

63 Maravilla, D., 2004. The main periodicities in the minimum extreme temperature in Northern Mexico and their relation with solar variability. *Advances in Space Research*, 34, 365-369.

64 Altadill, D., Curto, J.J., Gaya-Piqué, L.R., Solé, J.G., Torta, J.M., 2000. Coherency between Solar Activity and Meteorological Parameters at 11 Year Period, Proceedings of the 1st Solar and Space Weather Euroconference, 25-29 September 2000, Santa Cruz de Tenerife, Tenerife, Spain, 473.

- 65 Belov, A.V., Dorman, L.I., Gushchina, R.T., Obridko, V.N., Shelting, B.D., Yanke, V.G., 2005. Prediction of expected global climate change by forecasting of galactic cosmic ray intensity time variation in near future based on solar magnetic field data. *Advances in Space Research*, 35, 491-495.
- 66 Dorman, L.I., 2005. Estimation of long-term cosmic ray intensity variation in near future and prediction of their contribution in expected global climate change. *Advances in Space Research*, 35, 496-503.
- 67 Pudovkin, M. I., Veretenenko, S.V., Pellinen, R., Kyro, E., 1997. Meteorological characteristic changes in the high-latitudinal atmosphere associated with Forbush decreases of the galactic cosmic rays. *Advanced Space Researches*, 20, 1169-1172.
- 68 Timofeev, V.E. Grigoryev, V.G., Skryabin, N.G., Samsonov, S.N. , 2003. Action on Cosmic Rays on Latent Energy of the Atmosphere, *Proceedings of the 28th International Cosmic Ray Conference*. July 31-August 7, 2003, Japan, 3519.
- 69 Juan, Z., Yanben, H., 2005. Determination of precipitation cycle in Beijing area and comparison with solar activity cycle. *Earth; Moon and Planets*, 97, 69-78.
- 70 Iyono, A., Group, L., 2003. The Meteorological Effects of Cosmic Ray Intensity at Sea Level Observed at Multiple EAS Arrays in LAAS Experiments, *Proceedings of 28th International Cosmic Ray Conference*, Tsukuba, Japan, July 31 - August 7, 2003, 203-206.
- 71 Liu, L., Lei, J., Luan, X., Wan, W., 2003. Solar activity dependence of effective winds derived from ionospheric data at Wuhan. *Advanced Space Researches*, 32, 1719.
- 72 Volkrodt, W., 2007. "Electromagnetic Pollution of the Environment", http://www.emrpolity.org/science/forum/volkrodt_elect_pollution_environ.pdf.

APPENDIX A. MAXIMUM AND MINIMUM PLOTS

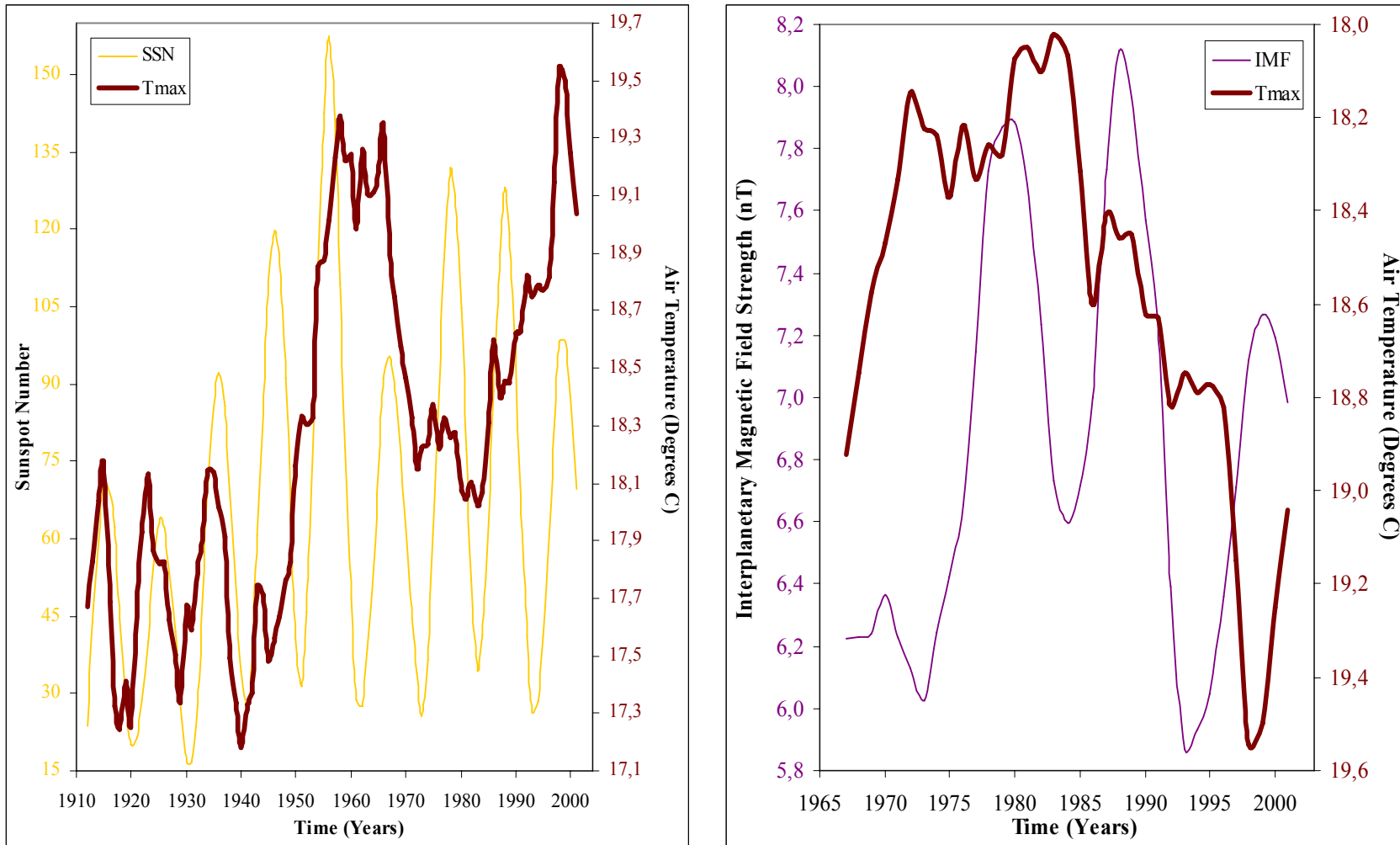


Figure A.1. Istanbul's five-year running mean maximum air temperature and a) solar activity b) interplanetary magnetic field

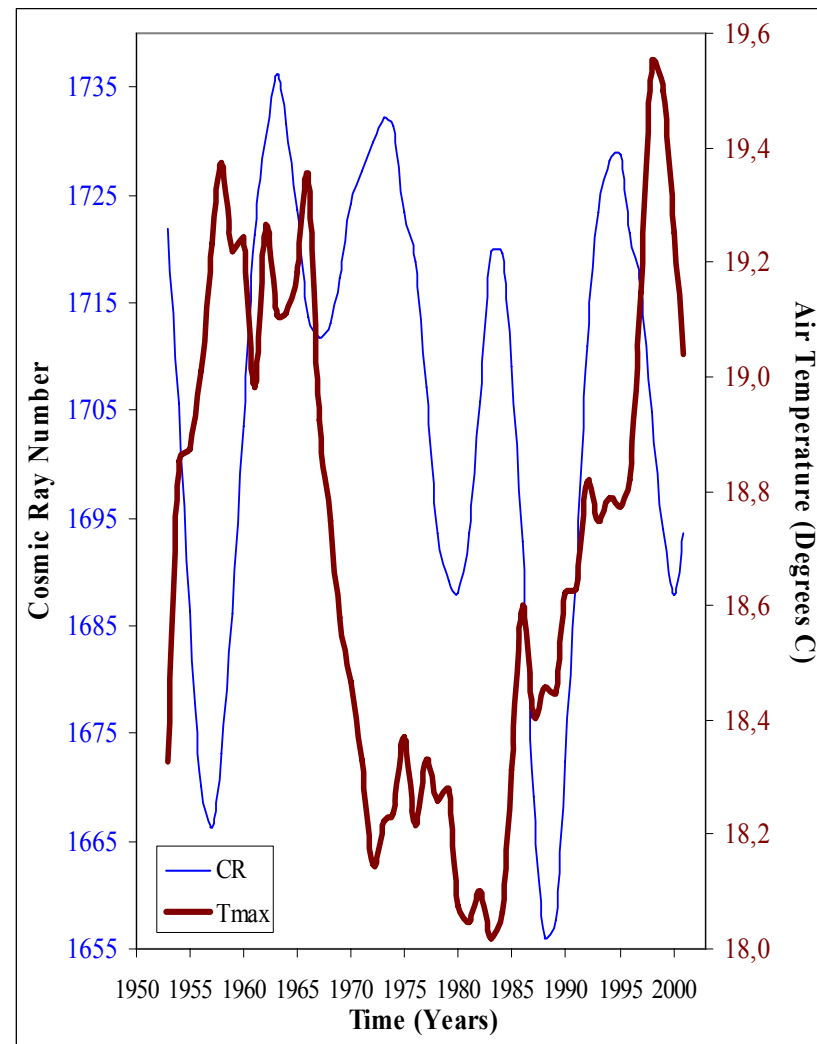
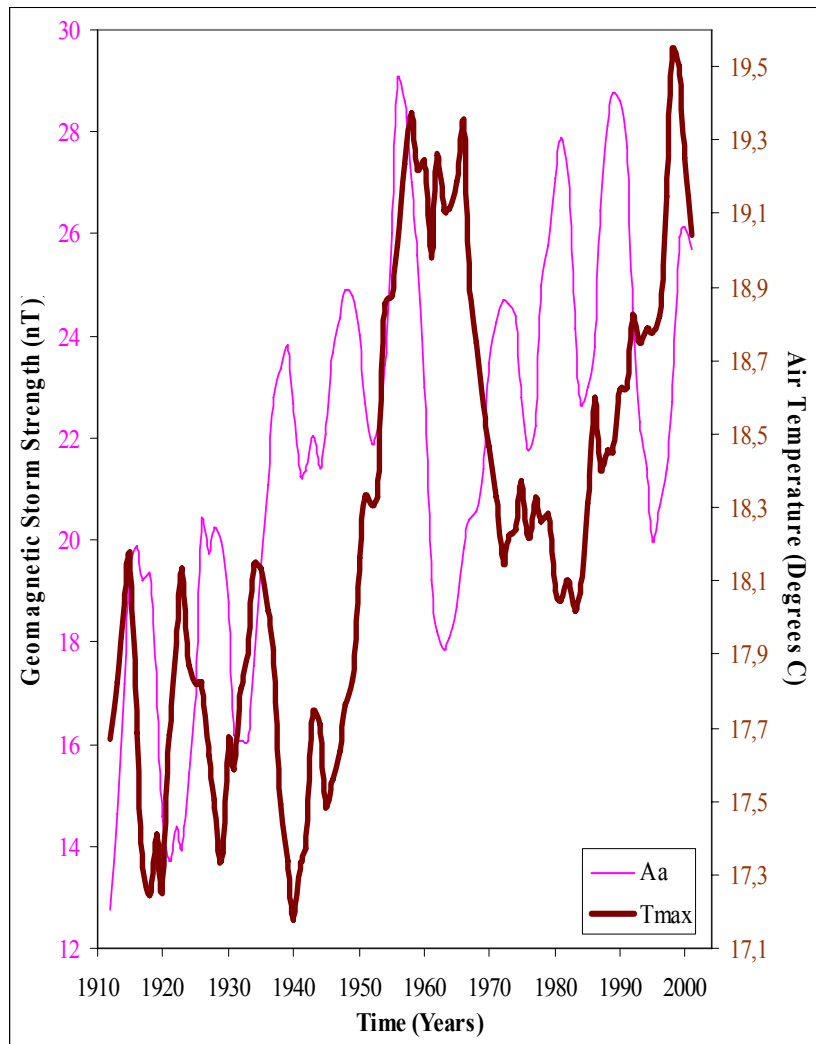


Figure A.2. Istanbul's five-year running mean maximum air temperature and a) geomagnetic activity b) cosmic rays

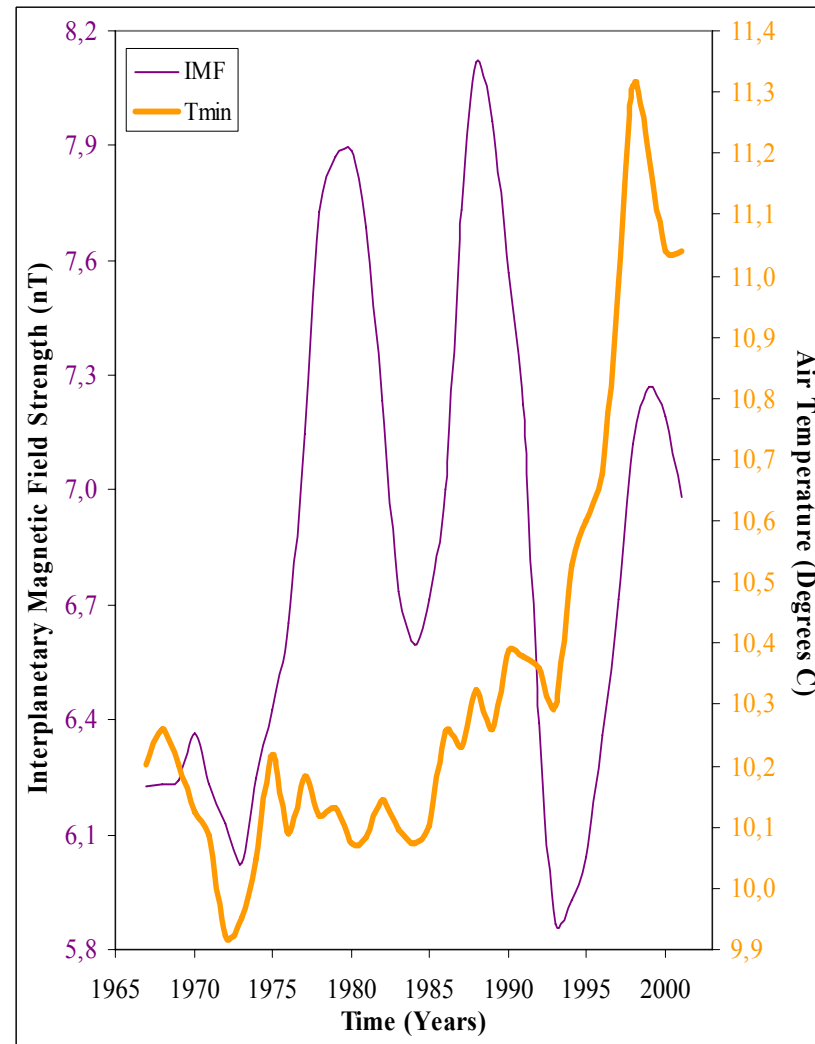
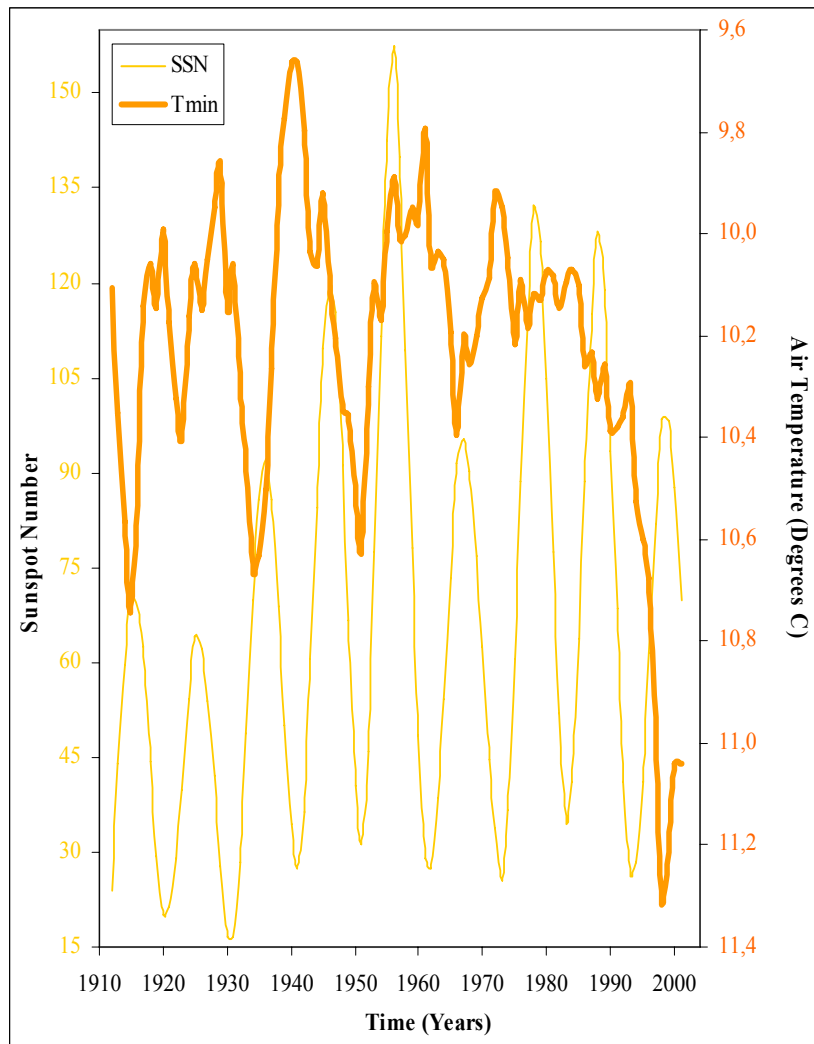


Figure A.3. Istanbul's five-year running mean minimum air temperature and a) solar activity b) interplanetary magnetic field

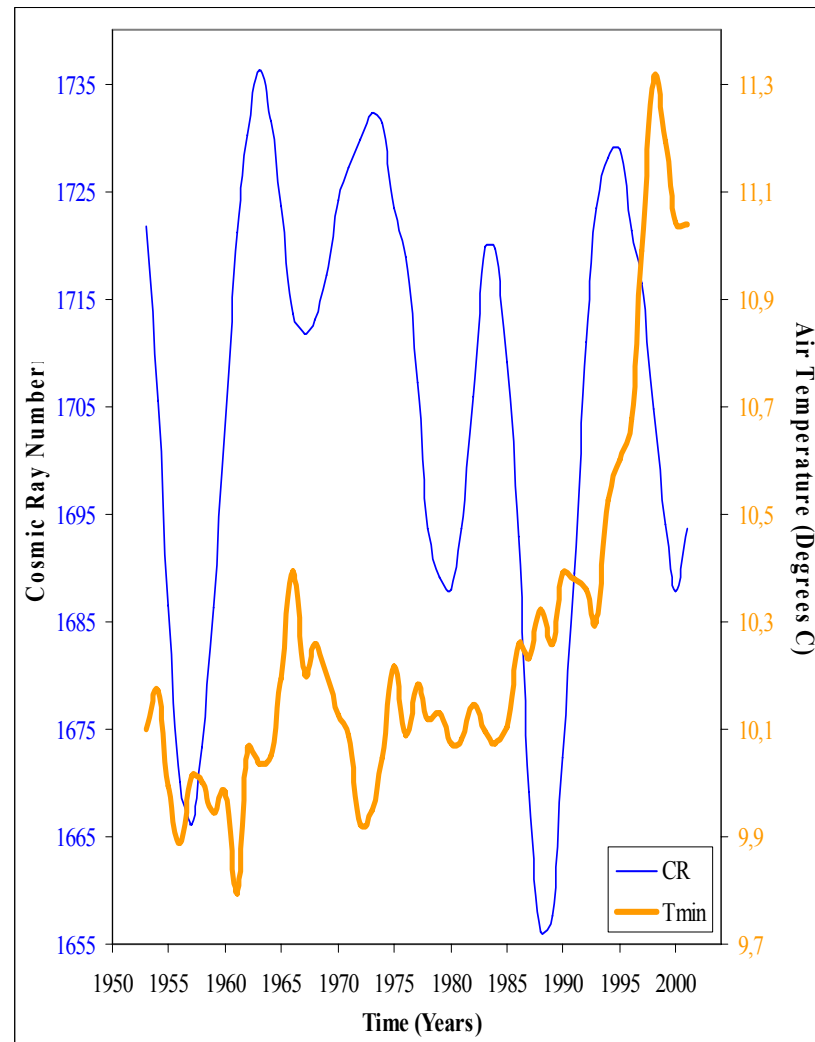
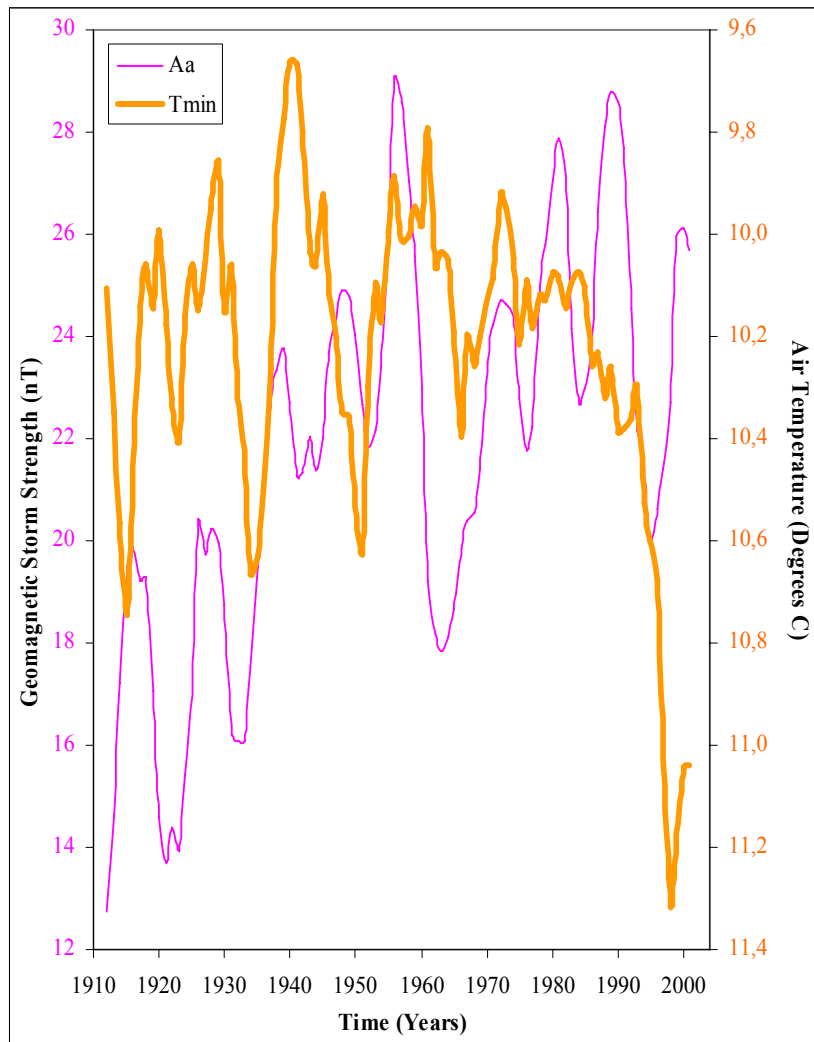


Figure A.4. Istanbul's five-year running mean minimum air temperature and a) geomagnetic activity b) cosmic rays

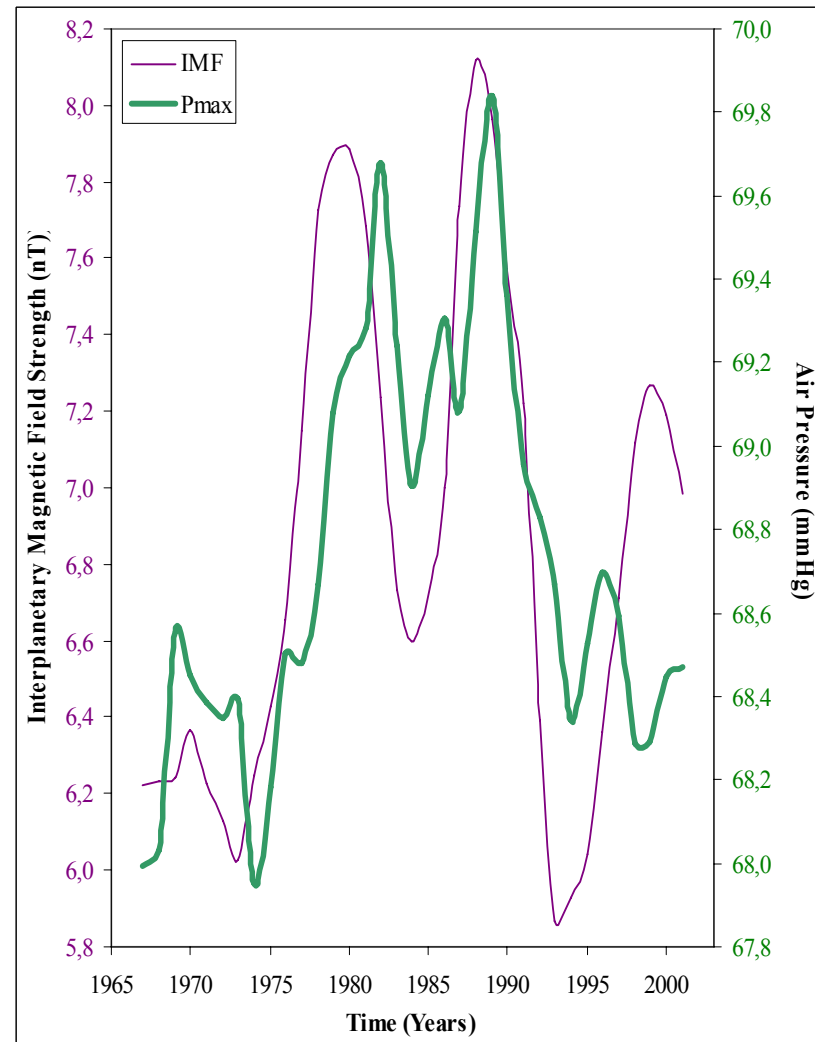
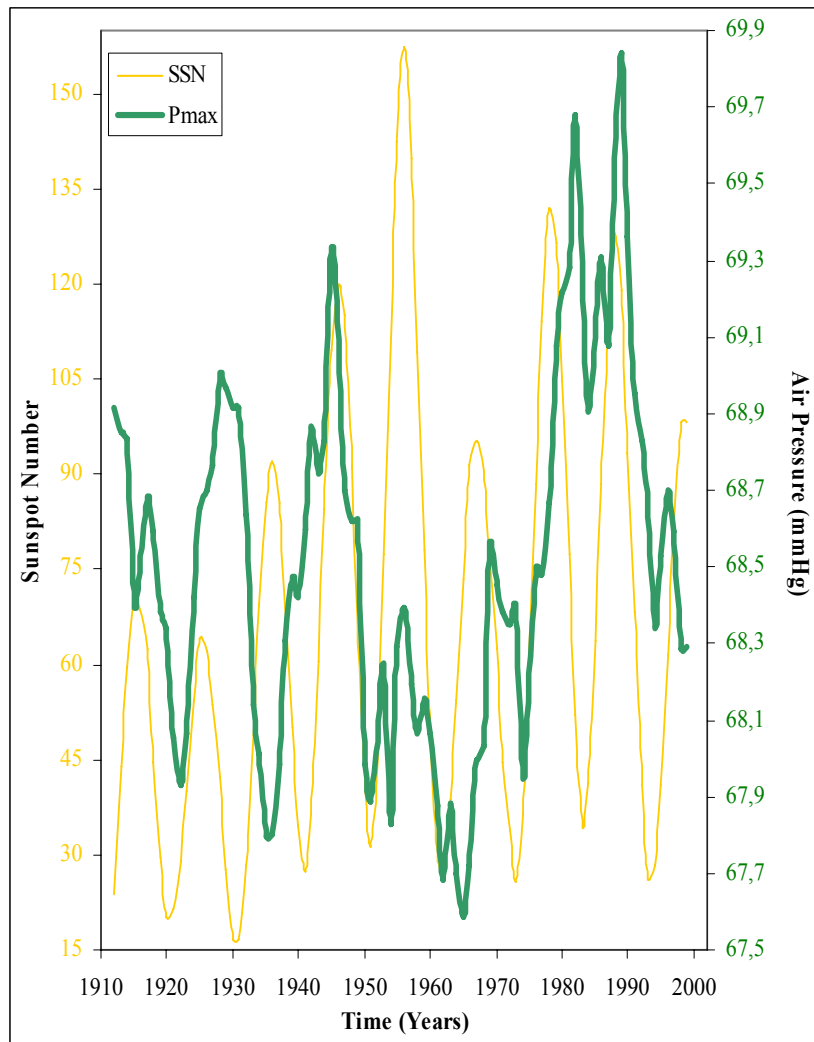


Figure A.5. Istanbul's five-year running mean maximum air pressure and a) solar activity b) interplanetary magnetic field

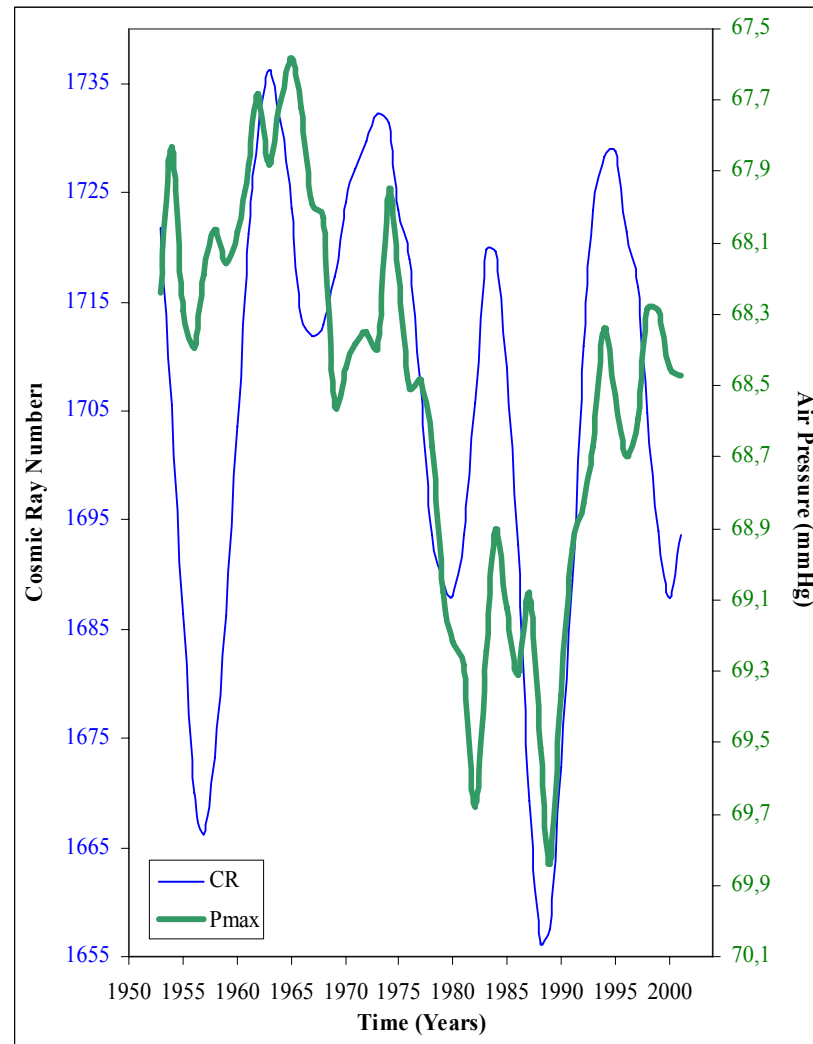
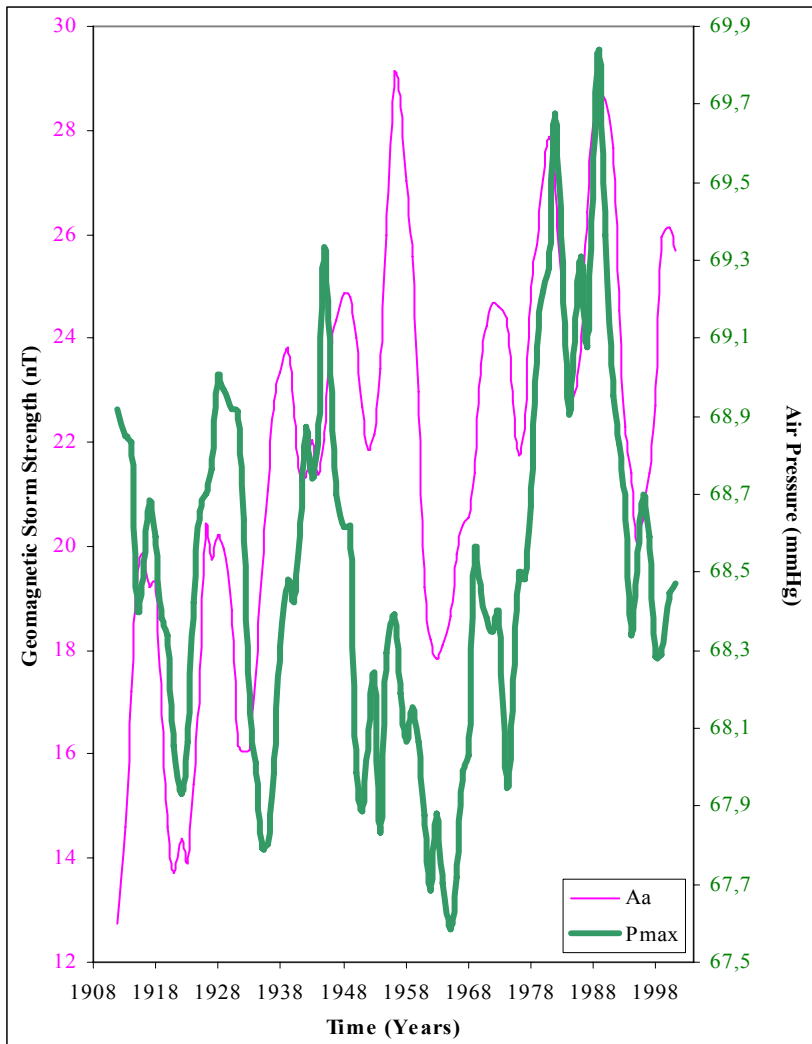


Figure A.6. Istanbul's five-year running mean maximum air pressure and a) geomagnetic activity b) cosmic rays

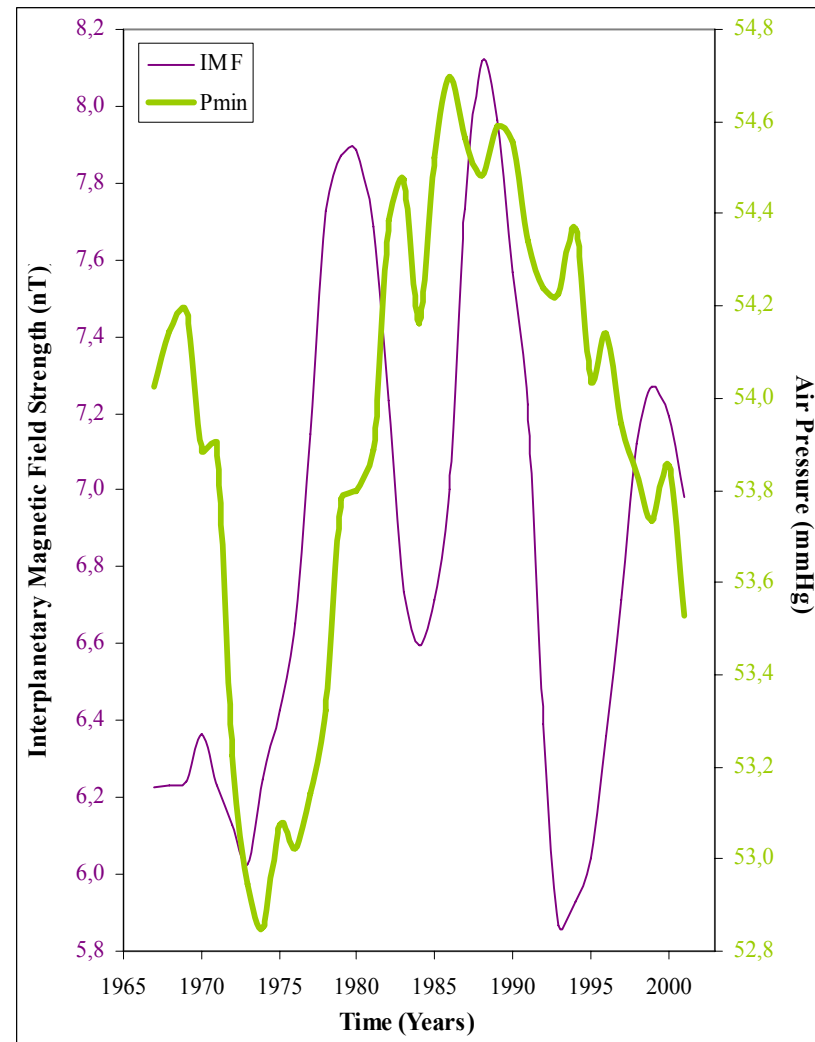
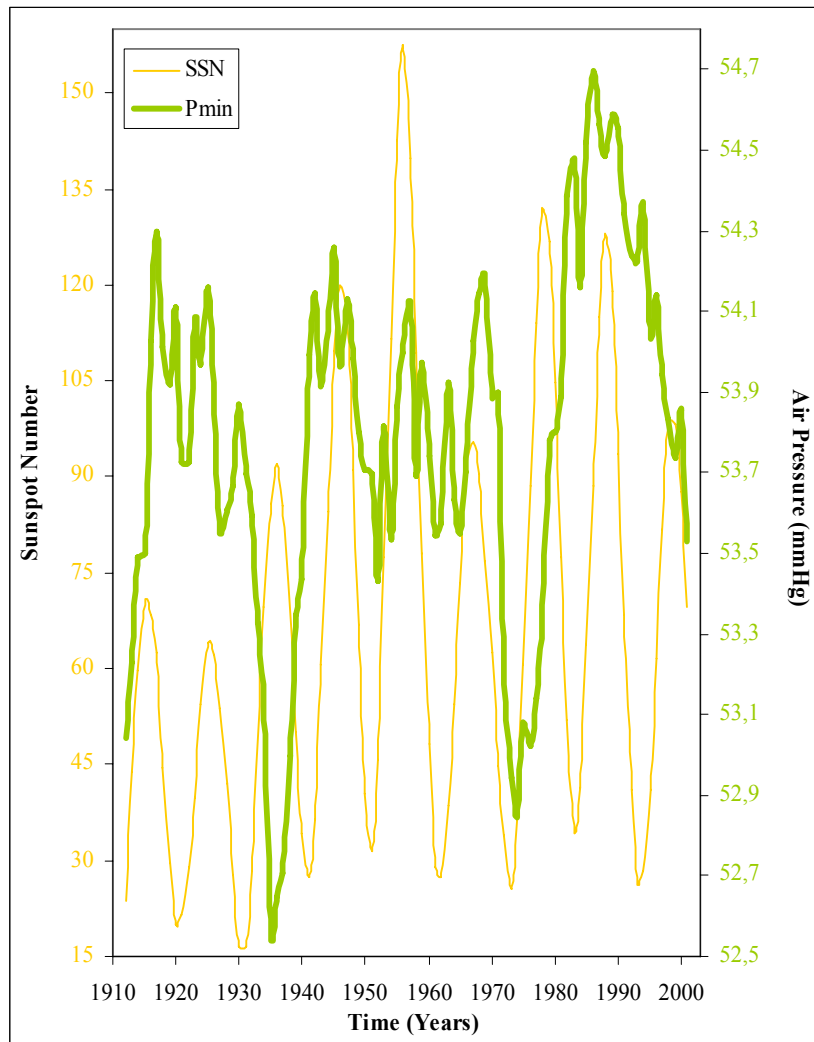


Figure A.7. Istanbul's five-year running mean minimum air pressure and a) solar activity b) interplanetary magnetic field

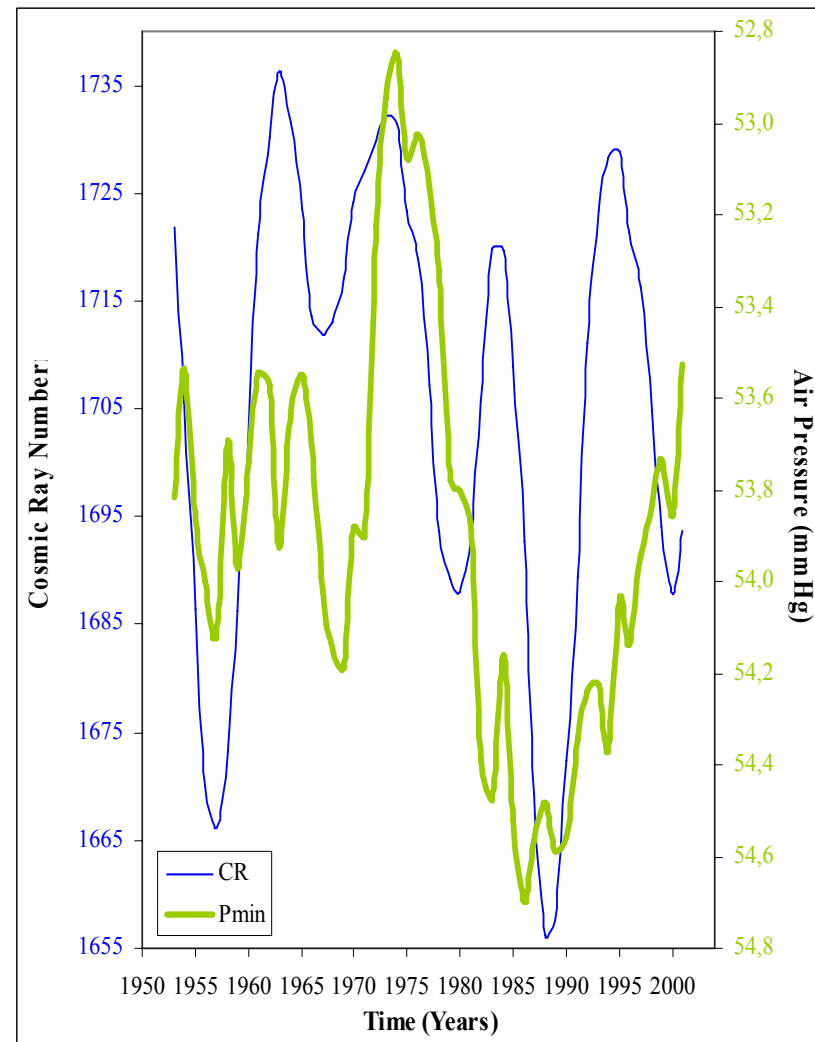
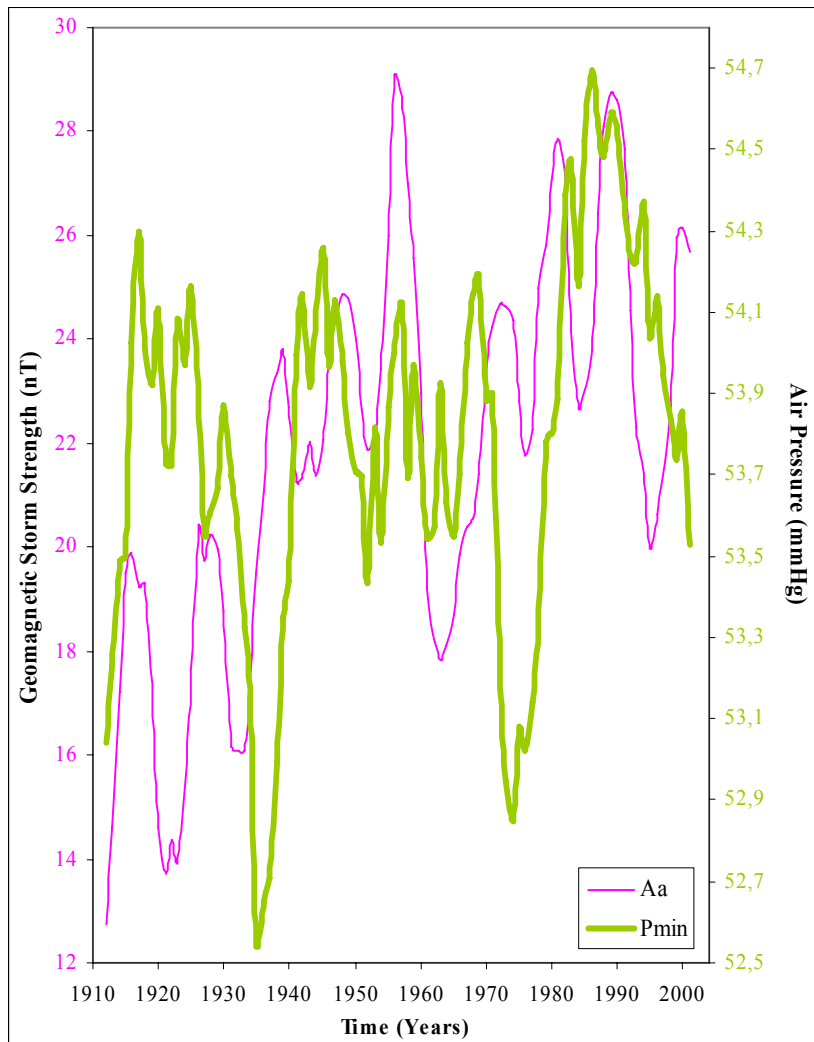


Figure A.8. Istanbul's five-year running mean minimum air pressure and a) geomagnetic activity b) cosmic rays