An early comment on the sunspot-climate connection

S. Galindo
Departamento de Física, Instituto Nacional de Investigaciones Nucleares, Km 36.5, carretera México-Toluca

A. Saladino
Facultad de Humanidades, Universidad Autónoma del Estado de México, Ciudad Universitaria, Cerro de Coatepec, Toluca México.

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In 1784, a remark on the possible relationship between sunspots and climate was published by the Mexican astronomer and meteorologist José Antonio Alzate. In this paper we wish to note that Alzate was perhaps the first 18th century scientist to suggest the possible relation between sunspots and the Earth's weather, thus preceding William Herschel's 1801 scientifically reasoned statement on this matter, the latter widely regarded as the earliest ever made.

Keywords: Alzate; History of Science; Sunspots

En 1784 un comentario sobre la posible relación entre las manchas solares y el clima fue publicado por José Antonio Alzate, astrónomo y meteorólogo mexicano. En este trabajo queremos notar que Alzate fue quizás el primer científico del siglo XVIII en sugerir la posible relación entre manchas solares y el clima terrestre, de manera que precedió la afirmación hecha en 1801 por William Herschel sobre este mismo tema, citándose ampliamente la de Herschel como la primera afirmación científicamente razonada sobre el tópico.

Descriptores: Alzate; historia de la ciencia; manchas solares.

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1. Introduction

With the ongoing concern over the present global warming, it is generally accepted that "greenhouse gases" are the main cause of this heating effect. However, climate has fluctuated abruptly in the past.

Historical research has shown short-term climatic changes in times when anthropogenic carbon dioxide and aerosols emissions were negligible. As a result, the possibility is now being discussed that there might be other sources of climatic alteration, among them the possible role of our Sun's output variability as an additional factor that may be affecting the earth's changing climate [1].

The Sun is not a stable star. It experiences nearly periodic variations in its activity, known as solar cycles. The most notorious is the "eleven-year" cycle, but other longer cycles have being identified as well. When all cycles are combined, a complicated, convoluted pattern is established. At the height of a solar cycle, dark spots on the solar disk are more numerous and the sun shines with greater intensity. In contrast, at a solar minimum hardly any sunspots can be observed on the sun. Today the mechanisms of how the Sun influences the earth's climate are not well understood, but past and present studies have hinted at a correlation between climatic transients and the occurrence of sunspots. For example, in the late 17^{th} century, during an inactive period of the Sun, there were virtually no sunspots at all. This coincided with the so-called "Little Ice Age" when glaciers expanded, the river Thames froze over, and temperatures dropped significantly [2].

Reputedly the first serious attempt to establish a correlation of the sunspots' effect on climate change was made by Sir William Herschel in 1801 [3,4]. During that year, Herschel published two papers in the *Philosophical Transactions of the Royal Society*, where he pointed out that the absence of sunspots coincided with "severe seasons". In order to test his speculation Herschel turned to records of the price of wheat in England as a proxy for climate. He argued that costly wheat would result from "severe seasons", while the "mild seasons" would produce low-priced wheat. It is important to mention that Herschel did not turn to meteorological records, because in those days these were lacking. Herschel read his papers on this matter before the Royal Society, but his inference met the customary skepticism and even led to laughter [5]. Nevertheless Herschel refined his assertion to some extent in 1807 in a letter to Bode on the variation of solar heat by noting that the Sun's radiant heat does not have an instantaneous, but a delayed effect on wheat prices. Therefore he reckoned that "*the whole theory of the symptomatic disposition of the Sun is only proposed as an experiment to be made*" [6].

However in 1784, a few years before Herschel's 1801 paper, a remark on the possible relation of sunspots and climate was published by the Mexican astronomer and meteorologist Antonio Alzate [7]. His comment stands out because Alzate was, as we shall see, a thorough recorder of meteorological data and at the same time an important sunspot observer.

In this paper we wish to note that Alzate was perhaps the first 18th century scientist to suggest the possible relation be-

tween sunspots and the Earth's weather [8]. In order to place our commentary in a historical perspective, in what follows we shall make a short account of past attempts to correlate weather with variations in solar activity, highlighting only what we consider relevant to this work. Then we will make a brief appraisal of Alzate's noteworthy accomplishments, and finally we shall concentrate on his early comment and its context.

2. Attempts to correlate sunspots with climate

In spite of the skepticism that Herschel's 1801 comments generated, a small number of astronomers maintained an interest in the solar disk. By 1843, after years of careful observations, Heinrich Schwabe stated that the number of spots observed on the Sun rose and fell in a regular 11-year cycle [9]. There followed some speculation regarding the solar influence on climate. However, by the end of the century, a small community of scientists was pursuing the question of how solar variability might relate to short-term weather cycles, as well as long-term climate changes. Understandably, attempts to correlate weather patterns with the sunspot cycle were hampered by a lack of both meteorological data and an adequate statistical analysis.

In the early decades of the 20^{th} century, most meteorologists held the view that the global climate was generally stable, except for a few researchers who continued to gather evidence of a connection linking solar variations with climate cycles. Among them were Annie and E. Walter Maunder, whose studies on past records indicated the scarcity of sunspots from about 1645 to 1715. [10] They associated the "Little Ice Age" to this fact. However, by the mid 20^{th} century, many researchers gave up the quest for solar cycles and their relationships with the weather due again to a widespread atmosphere of skepticism.

By the 1970s, scientists were beginning to understand that the planet's climate could go through self-sustaining oscillations, driven by feedbacks between ocean temperatures and wind patterns. These cycles range from a timescale of a few years (such as *El Niño* in the South Pacific) to oscillations lasting several decades. This renewed interest in weather cycles prompted scientists to scrutinize solar activity and climate connections. In 1976, John Eddy decided to review historical naked-eye sunspot records, with the intention of definitively confirming the long-standing belief that the sunspot cycle was stable over the centuries. Instead, Eddy found evidence that the Sun was by no means as constant as some scientists supposed. Moreover, he looked through meteorological records and tied all the threads together, claiming a solar-climate connection. Eddy stressed the case of "Little Ice Age", which he called the "Maunder Minimum" in honor of Annie and E. Walter Maunder, whose work had been overlooked [11]. But perhaps Eddy's finest contribution was finding a new variable associated with solar activity, namely, an inverse relation between the concentrations of ^{14}C and sunspots. This is based on the fact that ^{14}C is produced by cosmic rays which are modulated by the solar activity [12].

Recently, Hoyt and Schatten (1998) undertook a considerable attempt to gather past information on solar activity since the early 17th century [13]. This feat was carried out to improve the statistical analysis, based primarily on recovering a large quantity of historical records on sunspot observations. As a result, these records hinted once again at a correlation between climatic transients and sunspot occurrence.

At present, additional research has continued work on past records in an attempt to recover supplementary sunspot observations that might improve the Hoyt and Schatten 1998 database, and thus to better understand the solar activity fluctuation and its connection with our environment. Among these additional past records, the observations made by the Mexican Jose Antonio Alzate in the late 18^{th} century have been recently reviewed by solar physicists [14,15]. However we must point out that the mechanism and extent of the Sun's activity regarding its role in the climate transients is not yet well established [16].

3. José Antonio Alzate

José Antonio Alzate y Ramírez (21 November 1737 - 2 February 1799) was born in Ozumba Mexico [17]. He attended the *Colegio de San Ildefonso* in Mexico City, taking his Baccalaureate in Theology (equivalent to the first professional degree) in 1756. In 1768 he started a weekly journal "*Diario Literario de Méjico*" (1768). Under his guidance, this journal was devoted to the promotion and diffusion of all aspects of science. However, in New Spain there were no paper mills during that time, and consequently paper was scarce and costly. In addition, his journal was censored by local authorities and forced to close [18]. His publication lasted only three months. Some years later, he used an inheritance to start a new publication "*Asuntos Varios sobre Ciencias y Artes*" (1772-1773) and for a second time it was closed down by the government. Years later, he established again a journal with the same scientific aims. The title of this new journal was "*Observaciones sobre la Fisica, Historia Natural y Artes Utiles"* (1787-1788) [19]. Afterwards he renamed this journal *"Gaceta de Literatura"* (1788) which continued to appear until 1795, (115 issues). He was also a frequent contributor to the "*Diario de Mexico*". The natural sciences, physics, astronomy and meteorology were for him subjects that deserved great attention. He conducted several scientific experiments, and wrote more than thirty treatises on various scientific subjects. He attained a high reputation as a zoologist and botanist, and for his researches he was named member of the Royal Botanical Garden of Madrid. However, in New Spain he was frequently opposed, even reviled, to the point that his journal, *"Gaceta de Literatura"* was censored and forced to close by the Spanish colonial authorities four years before he died in Mexico City in 1799 [20]. In

his honor, the *Sociedad Científica Antonio Alzate* [Antonio Alzate Scientific Society] was created in 1884. In 1935, this society became the *Mexican National Academy of Sciences*.

José Antonio Alzate was one of the earliest trustworthy observers of Mexican meteorology. He realized that accurate observations might some day be vital for weather forecasting. He wrote [21]:

> *"The precise observation to (for) which our atmospheric air is under scrutiny, in its weight or lightness, as in its dryness, humidity, heat and cold, represents a diversion for those who perform it as well as useful activity for mankind; these observations instruct us to predict with some veracity the coming weather and the good or bad health effects that we ourselves can test... The present instruments known today to perform this observation are: the barometer, thermometer, hygrometer and a pennant or wind vane"*

His activity in the observing of meteorological phenomena, according to his own writings, lasted for a period of more than two decades [22]. During this time he reported a large variety of weather events such as: rainstorms, frost, thunderstorms, cloud formations, rainbows, and hot, humid, and cold weather conditions, etc., backed by his wide knowledge of related instruments and the use of field-mode observation equipment as barometers, thermometers, wind vanes or pennants and hygrometers.

Among his meteorological works, he wrote "*Observaciones meteorológicas"* [Weather observations][23], *"Utilidad de las observaciones meteorológicas*" [Value of meteorological observations][24],"*Observaciones físicas ejecutadas en la Sierra Nevada..."*[Physical observations performed in the Sierra Nevada...][25], "*Sobre escarchas"* [On rime][26], "*Sobre heladas*"[On frosts][27], "*Fidelidad del barometro*" [Reliability of the barometer][28]. In addition to the papers mentioned, there is one publication that is relevant to our discussion, as will become clear, namely: *"Medios de que se pueden valer los hombres para prevenir calamidades*" [Means by which mankind can prevent calamities] [29] published in the *Gaceta de Literatura*, June 17, 1795.

In the last work of the list, Alzate proposes the use of records of seed prices to investigate the state of the weather in past periods [29]. The paper begins with Alzate trying to encourage his generation to gather past weather records. He urges them: *"let us re-examine what has happened in past times to achieve a close forecast of what we expect in the future"*. Moreover, Alzate in the same paper describes that he has scrutinized available archives, pointing out that *" ...I have searched public registers in order to see if they could show me some reliable data..."* and regrets *"...there is no sign of data that could show me the way out of this spiny labyrinth...For that reason I beg lovers of humankind to inform me if, in some corner, there is a register, encompassing some lengthy period, for the price of seeds that have been sold: This will be a reliable compass needle to point us, more or less, toward the time interval in which our atmosphere exhibits the same effects"*[29].

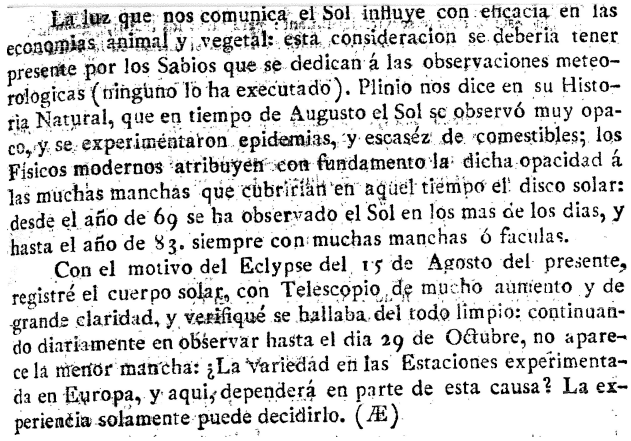
We have already mentioned that Herschel presented the same idea, but in 1801, *i.e.*, to relate weather conditions to the price of wheat.

Alzate's activity as an astronomer is outstanding. During his lifetime, two of his astronomy related works were published by The French Academy of Sciences. This institution named him Foreign Associate Member of the Academy, the only person to receive that honor in New Spain. His systematic and careful observation of the heavens is reflected in various publications such as: *"Eclypse de luna del doce de diciembre de mil setecientos setenta y nueve años observado en la Imperial Ciudad de México y dedicada al Rey nuestro Señor"* [Lunar Eclipse of December 12, 1769 observed in the Imperial City of Mexico and dedicated to our Lord the King] [30], "*Observacion del paso de mercurio por el disco del Sol (9 de noviembre 1769)*" [Observation of the passage of Mercury by the Solar disc][31], and a note on the observation of the passage of Venus by the disc of the Sun, June 3, (1769)[32], etc.

In the path towards reaching his understanding of meteorological phenomena, Alzate's expertise on Astronomy and Meteorology made him propose the following hypothesis, which is the focal point of our present manuscript and which we shall analyze next.

4. The Hypothesis of Alzate on the Sunspot-Climate Connection.

The important statement that Alzate made appeared in the "*Gazeta de México*", N° 23, dated on Wednesday, November 17, 1784, on page 191, with no heading or title (see facsimile in Fig. 1). The same note was reprinted almost fifty years later with the added heading "*Observacian* –sic- *sobre la luz*" [7]. Alzate's remark reads as follows:


La luz que nos comunica el Sol influye con eficacia en las economias animal y vegetal: esta consideracion se deberia tener presente por los Sabios que se dedican á las observaciones meteorologicas (ninguno lo ha executado). Plinio nos dice en su Historia Natural, que en tiempo de Augusto el Sol se observó muy opaco, y se experimentaron epidemias, y escasez de comestibles; los Físicos modernos atribuyen con fundamento la dicha opacidad á las muchas manchas que cubririan en aquel tiempo el disco solar: desde el año de 69 se ha observado el Sol en los mas de los dias, y hasta el año de 83. siempre con muchas manchas ó faculas.

Con el motivo del Eclypse del 15 de Agosto del presente, registré el cuerpo solar, con Telescopio de mucho aumento y de grande claridad, y verifiqué se hallaba del todo limpio: continuando diariamente en observar hasta el dia 29 de Octubre, no aparece la menor mancha: ¿La variedad en las Estaciones experimentada en Europa, y aqui, dependerá en parte de esta causa? La experiencia solamente puede decidirlo. (Æ)

FIGURE 1. Facsimile of the original remark by Alzate.

> *"The light conveyed by the Sun, efficiently influences vegetables and livestock markets: this assertion should be present in the minds of those savants dealing with meteorological observations (none has implemented it). Pliny tells us in his "Natural History" that, in times of Augustus, the Sun was dim and epidemics and food scarcity struck; modern physicists ascribe the mentioned dimness to the numerous sunspots that masked the solar disc at that time; from the year [17]69 I have been observing the Sun most days till the year [17]83, always with numerous sunspots.*
>
> *In relation to the Eclipse of August 15, [17]84, I surveyed the Solar body using a telescope with much magnification and great clarity and confirmed that it was completely spotless. I continued observing daily up to 29 October, and no single spot appeared. Would the seasonal alterations experienced in Europe, and here, depend partly on that cause? Only experience will tell."*

In order to analyze Alzate's remarks, we are going to divide it into four statements and a conclusion as follows:

"*The light conveyed by the Sun, efficiently influences vegetables and livestock markets: this assertion should be present in the minds of those savants dealing with meteorological observations (none has implemented it)*". With this sentence Alzate comments on the financial importance of weather and regrets the lack of recorded data.

"Pliny tells us in his "Natural History" that, in times of Augustus, the Sun was dim and epidemics and food scarcity struck; modern physicists ascribe the mentioned dimness to the numerous sunspots that masked the solar disc at that time." Here there are two ground-breaking ideas: initially, Alzate makes the connection between sunspots and climate, and then Alzate initiates the examination of historical accounts [33] long before their use by Annie and Walter Maunder in the 19th century [2], and before the studies on past records by John Eddy in the 70's [11] and the 1998 analysis of Hoyt and Schatten [13].

"...from the year [17]69 I have been observing the Sun most days till the year [17]83, always with numerous sunspots." He states that he has been a conscientious observer of the solar disc for 14 years in a row. He notes the incidence of copious sunspots in that period. We must stress that his papers show that Alzate also determined weather parameters during his observations [30].

In relation to the Eclipse of August 15, [17]84, I surveyed the Solar body using a telescope with much magnification and great clarity and confirmed that it was completely spotless. I continued observing daily up to 29 October, and no single spot appeared. At this point he reports a change in the solar disc to a spotless state that, with his hypothesis in mind, is promptly associated with the current state of the weather at that time. This brings him to question the connection between climate and sunspots in his last statement:

> *Would the seasonal alterations experienced in Europe, and here, depend partly on that cause? Only experience will tell."*

5. Conclusions

Old publications indicate that José Antonio Alzate was perhaps the first 18th century scientist to plausibly infer the possible relation between sunspots and the Earth's weather, thus preceding William Herschel's 1801 statement on this matter. Nevertheless, there is a similarity between Herschel and Alzate's thoughts in that both realize that future research remained to be performed. In the first case, Herschel proposed the climate-sunspot connection only as "*an experiment to be made*". In the other case, Alzate realized that *"only experience will tell"*. However, there is a clear difference in the origin of their conjectures, namely: Alzate was a meteorologist and based his speculation arguably on his own meteorological data and on Pliny's historical records, whereas Herschel used the wheat proxy to reach his conclusion. Nevertheless, Alzate was first to propose the use of seed prices to estimate weather conditions. Curiously enough, this idea is still being used by present day scientists [34].

We must add some final observations. The process of global warming from anthropogenic carbon dioxide and aerosol emissions cannot and should not be ignored. But the fear of climate change by the unknown is also great. Historical records have proven throughout the ages that climate change has occurred. The available evidence hints at a correlation between climatic transients and the occurrence of sunspots. However, the search for "correlations" should be taken "*cum grano salis*" and much scientific research remains to be done in this matter [16].

It has been said that History gives us a frame of reference to consider the possible causes of the future ahead of us. Alzate knew this.

Acknowledgments

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1. D.V. Hoyt & K.H. Schatten, "*The Role of the Sun in Climate Change"* (Oxford University Press New York, 1997).
2. W. Wei-Hock Soon & S.H. Yaskell, "*The Maunder Minimum and the Variable Sun-Earth Connection"* (World Scientific Publishing Co. Singapore, 2007) p. 206.
3. William Herschel, *Phil. Trans. Royal Soc. London* **91** (1801) 265.
4. William Herschel, *Phil. Trans. Royal Soc. London* **91** (1801) 354.
5. When Herschel presented his papers to the Royal Society, Lord Brougham scoffed and called it "a grand absurdity" and went on to say that "[s]ince the publication of Gulliver's voyage to Laputa, nothing so ridiculous has ever been offered to the world". Henry Brougham, [Lord Brougham and Vaux]. "*Critique"* in The Edinburgh Review, January 1803. Francis Jeffrey editor. Edinburgh, Scotland. In this "critique", Brougham refers to the episode in "Gulliver's Travels" where Gulliver takes notice of the anxiety of the Laputian "learned men", who see that "*The face of the sun will by degrees be encrusted with its own effluvia, and give no more light to the world*". Gulliver's Travels was published anonymously in October, 1726 by Jonathan Swift. The excerpt was taken from J. Swift "Gulliver's Travels" Riverside Press 1960, p. 132.
6. W. Herschel (1805) Letter from William Herschel, Esq., F.R.S. to Johann E. Bode. Published as "Aus einem Schereiben des Herrn Doctor Herschel, datiert Slough bei Windsor der May 1804". *Berliner Astronomisches Jahrbuch*, p. 242, Berlin. As quoted in reference 1 p. 49. Reference 1 makes a mistake in its main text by asserting that the letter was published in the *Philosophical Transactions*. The erratum is corrected later on, in its bibliography in p. 247 of the same book.
7. J.A. Alzate (1784) *(without heading) Gazeta de México* N ° 23 (1784) 191. Also reprinted with an added heading "Observancian -sic- sobre la luz" [Comment on Light] in a recompilation of his Works under the title "*Gacetas de Literatura de México*", edited in 1831. Oficina del Hospital de San Pedro, Miguel Buen Abad editor, Puebla, México, Vol. IV p. 349. The spelling "gazeta" and "gaceta" was used indistinctly at that time.
8. The book by Hoyt and Schatten (see reference 1 page 107) mentions a comment made in 1729 by J.B. Wiedenburg of Helmstadt on the influence of sunspots on climate. No supplementary indication of the scientific motive or context of Wiedenburg's commentary is given there, nor is the original reference specified.
9. Heinrich Schwabe, *Astronomische Nachrichten* **21**(1844) 233. See also Helen Sawyer Hogg, *Journal of the Royal Astronomical Society of Canada* **42** (1948) 42, http://adsabs.harvard.edu/abs/1948JRASC..42...42S
10. See Chaps. 3 and 4 in Ref. 2.
11. J.A. Eddy,*Science* **192** (1976) 1189.
12. Juerg Beer, *Proc. XXVIII ICRC* **8** (2003) 373.
13. D.V. Hoyt & K.H. Schatten, *Solar Phys.* **181** (1998) 14.
14. J.M. Vaquero, *Solar Phys.* **219** (2004) 379.
15. J.M. Vaquero, R.M. Trigo, M.C. Gallego, and M.A. Moreno Corral *Solar Phys* **240** (2007) 165.
16. See for example Kerry Emanuel, "What we Know about Climate Change" *Boston Review Books* (The MIT Press, Boston, USA 2007).
17. For a biography of Alzate see for example: A. Saladino *El Sabio José Antonio Alzate y Ramírez de Santillana* (in Spanish) UAEM, México, 2001).
18. According to R. Moreno, the journal was suppressed by the authorities based on the claim that the newspaper "*contained offensive and indecorous propositions to law and nation"*. In Roberto Moreno (1980) *José Antonio Alzate, Obras* in the "*Introducción*" Vol. 1 p. xii, UNAM, México (in Spanish).
19. The title of this Journal "*Observaciones sobre Física, Historia Natural y Artes útiles*" reproduces the title of the French Journal "*Observations sur la Physique, sur L'Histoire Naturelle et sur les Arts*" published and distributed in the same epoch by its editor, J.F. Rozier. Note by R. Moreno (1980) *José Antonio Alzate, Obras* Vol. 1 p. 27, UNAM, México.
20. For details on journal censorship in the Spanish Colonies see for example A. Saladino (1996) *Ciencia y Prensa durante la Ilustración Latinoamericana* UAEM, México.
21. J.A. Alzate (1773) *(without heading)* "Asuntos varios sobre ciencias y Artes" Jan 4 issue, Also reprinted with an added heading "Utilidad de las observaciones meteorológicas′′ ["Value of Meteorological Observations"] in a recompilation of his Works under the title "*Gacetas de Literatura de México*", (1831) Vol. IV p. 191. Oficina del Hospital de San Pedro, Miguel Buen Abad editor, Puebla, México. The original text in Spanish is: " *La observación esacta á* -sic- *que está sujeto el aire de nuestra atmósfera, asi* –sic- *en su gravedad y ligereza, como el la sequedad, humedad, calor y frio* -sic-, *es una ocupacion* -sic- *muy divertida para el que la ejecuta, y utilísima para todos los hombres: estas observaciones nos instruyen para poder predecir con alguna verosimilitud el tiempo que se prepara, y los buenos ó* –sic- *malos efectos que pueden experimentarse respecto de la salud. Los instrumentos hasta el dia* –sic- *conocidos para esta observacion* –sic-, *son el barómetro, termómetro, hidrómetro y una grimpola ó veleta.*"
22. J.A. Alzate (1784.) *(without heading) Gazeta de México*, in the Afterword N ° 48, p. 58. Also reprinted in a recompilation of his Works under the title "*Gacetas de Literatura de México*", edited in 1831. Oficina del Hospital de San Pedro, Miguel Buen Abad editor, Puebla, México, Vol. I p. 421. The original text in Spanish is: "*Observaciones meteorológicas continuadas por* [mi por] *más de veinte años*" [Meteorological observations performed [by me] for more than twenty years].
23. J.A. Alzate (1769) *(without heading) Gazeta de México*, p. 54. Also reprinted with the added heading "Observacion -sic- meteorological",in a recompilation of his Works under the title "*Gacetas de Literatura de México*", edited in 1831. Oficina del Hospital de San Pedro, Miguel Buen Abad editor, Puebla, México, Vol. IV p. 419.
24. J.A. Alzate (1773) *Op. cit.* in Ref. 20.
25. J.A. Alzate (1789) "Observaciones Físicas Ejecutadas por D. José de Alzate en la Sierra Nevada, situada al Estsudeste –sic- respecto de Mégico –sic-, á –sic- la distancia de quince leguas" [Physical observations performed by José de Alzate in the Sierra Nevada, situated East-by-South-East of Mexico, at a distance of five leagues] *Gaceta de Literatura*. No. 14, Feb. 28.

Reprinted in *Gacetas de Literatura de México*, edited in 1831 Oficina del Hospital de San Pedro, Miguel Buen Abad editor, Puebla, México, Vol. I pp. 99

26. J.A. Alzate (undated) *Gazeta de México*. Reprinted in *Gacetas de Literatura de México*, edited in 1831 Oficina del Hospital de San Pedro, Miguel Buen Abad editor, Puebla, México, Vol. IV p. 398

27. J.A. Alzate (undated) *Gazeta de México*. Reprinted in *Gacetas de Literatura de México*, edited in 1831 Oficina del Hospital de San Pedro, Miguel Buen Abad editor, Puebla, México, Vol. IV p. 414.

28. J.A. Alzate (undated) *Gazeta de México*. Reprinted in *Gacetas de Literatura de México*, edited in 1831 Oficina del Hospital de San Pedro, Miguel Buen Abad editor, Puebla, México, Vol. IV p. 434.

29. J.A. Alzate (1795) "Medios de que se pueden valer los hombres para prevenir calamidades" *Gaceta de Literatura*, June 17. Reprinted in *Gacetas de Literatura de México*, edited in 1831 Oficina del Hospital de San Pedro, Miguel Buen Abad editor, Puebla, México, Vol. III p. 463. The original text in Spanish is: *"...ocurramos, pues á* –sic- *lo experimentado en los tiempos anteriores para logar una casi inferencia de lo que debamos experimentar en lo sucesivo...tengo registrados los archivos públicos para ver si me mostraban algunos datos seguros... no hay alguna constancia de datos que dirijan en este espinoso laberinto...Por lo que suplico á* –sic- *los amantes á* –sic- *la humanidad me informen si en algun* –sic- *rincon* -sic- *se halla la serie de valores a que se ha vendido las semillas en un dilatado tiempo: este será la brújula segura por donde se venga á* –sic- *conocer á* –sic- *poco mas o menos el periodo en que nuestra atmosfera nos presenta los mismos efectos.*

30. J.A. Alzate (1770) "Eclypse de luna del doce de diciembre de mil setecientos sesenta y nueve años observado en la Imperial Ciudad de México y dedicada al Rey nuestro Señor" [Lunar Eclipse of December 12 1769 observed in the Imperial City of Mexico and dedicated to the King our Lord] Joshep Jáuregui, Calle de San Bernardo, México. Reprinted under the title "Eclipse de luna del doce de diciembre de mil setecientos sesenta y nueve, observado en la capital de México" in *Gacetas de Literatura de México*, edited in 1831 Oficina del Hospital de San Pedro, Miguel Buen Abad editor, Puebla, México, Vol. IV p.62. This document reveals the concern that Alzate had in the measurement of parameters such as barometric pressure and atmospheric temperature during his astronomical observations. In this work he reports that during the eclipse "*el barómetro y el termómetro no tuvieron alteración especial"*. [The barometer and thermometer did not have a particular change at all].

31. J.A. Alzate (1769) "Sobre el paso de Mercurio por el disco del Sol" [On the passage of Mercury by the Solar disc] *Gazeta de México*, November 9. Reprinted in *Gacetas de Literatura de México*, edited in 1831 Oficina del Hospital de San Pedro, Miguel Buen Abad editor, Puebla, México, Vol. IV p. 426.

32. The observation of the Transit of Venus is mentioned in several manuscripts, among them: "Elogio Histórico del Dr. D. José Ignacio Bartolache" [Historical Elegy for Dr. D. José Ignacio Bartolache] *Gaceta de Literatura*, August, 3, 1790. Also an allusion appears in "Estado de la geografía de la Nueva España y modo de perfeccionarla" [Situation of the Geography in New Spain and a way to improve it] "*Asuntos varios sobre ciencias y artes*" December 7, 1772. Both documents reprinted in *Gacetas de Literatura de México*, edited in 1831 Oficina del Hospital de San Pedro, Miguel Buen Abad editor, Puebla, México, Vol. 1 P. 409 and Vol. IV, p 123 respectively.

33. Alzate is referring to two separate passages in the book by Pliny the Elder (Caius Plinius Secundus), entitled *"Naturalis Historia"* (Latin for "Natural History") written circa 77 A.D. The first extract appears in Book II, Chapter 30 *"Eclipses of the sun also take place which are portentous and unusually long, such as occurred when Cæsar the Dictator was slain, and in the war against Antony, the sun remained dim for almost a whole year"*. Here Pliny clearly refers to events different from an eclipse, due possibly to an abundance of sunspots. The second passage turns to be an episode from book VII chapter XLVI: *"The misfortunes of Augustus...the pestilence in Rome Citie, the famine and drought universally through Italie"*. The remarkable insight of Alzate, is that he correlates both episodes in Pliny's books. Quotations taken from "*The Natural History*" Pliny the Elder. John Bostock, M.D., F.R.S. H.T. Riley, Esq., B.A. London. Taylor and Francis, Red Lion Court, Fleet Street (1855).

34. L.A. Pustilnik and G. Yom Din (2004) "Space Climate Manifestation in Earth Prices – from Medieval England up to Modern U.S.A." *Solar Phys.* Vol. 224 pp. 473-481. In this paper the authors claim that the wheat prices revealed "a maximum/minimum price asymmetry consistent with the phases of the sunspot cycle".