https://doi.org/10.5194/angeo-2020-1
Preprint. Discussion started: 13 February 2020

Annales Geophysicae Discussions

An Early Low Latitude Aurora Observed by Rozier (Beziers, 1780)

Chiara Bertolin[1], Fernando Domínguez-Castro[2,3], Lavinia de Ferri[1]

[1]Department of Mechanical and Industrial Engineering, Norwegian University of Science and Technology, Trondeim, 7491, Norway
[2] ARAID Foundation, 50018, Zaragoza, SPAIN
[3] Departamento de Geografía y Ordenación del Territorio, Universidad de Zaragoza, 50009, Zaragoza, SPAIN

Correspondence to: Chiara Bertolin (chiara.bertolin@ntnu.no)

Abstract. Aurorae Observations are an uncommon phenomenon at low latitudes that, at the end of the 18th century was not well known and understood. Low latitude Aurorae observations provide information about episodes of intense solar storms associated with flares and outstanding coronal mass ejection (CME) and on the variation of the geomagnetic field. However, for many observers at low latitude, the features of a northern light were unknown, so he could easily report it as a phenomenon without explanation. In this work, we found that an earlier low latitude aurora was observed in Beausejour, close to Beziers (43º 53′ N, 3º 35′ E), France, by the abbot Francois Rozier. He was a meticulous botanist, doctor and agronomist with special interest in atmospheric phenomena. On 15 August 1780, from 20:05 to 20:17 (Universal Time), Francois Rozier observed a "phosphoric cloud". A careful analysis of the report points out that he was reporting an auroral event. The recovery of auroral events at low latitude during the 1780's is very useful to shed light to the solar activity during this period because there are few records of sunspot observations.

1 Background and Introduction

Incursions of high-energy particles from space, mainly solar wind, strongly interact with the Earth's magnetosphere, causing ionization and excitation of atmospheric gases and auroral emissions (Vazquez et al. 2014). These interactions cause disturbs on the magnetosphere as disruption of the earth's magnetic field or the generation of electric fields strong enough to damage electronic devices. The aurora borealis is a spectacular phenomenon that have been recorded from the Babylonians (Stephenson et al., 2004) to nowadays. However, it is not until 1733 when Mairan (1733) suggest that the aurora can be caused by the solar atmosphere (Krivsky, 1984).

Low latitude auroras (LLAs) are associated with strong geomagnetic storms (Green and Boardsen, 2006; Green et al., 2014; Humble 2006), and have been considered a proxy of solar activity. The observation of LLAs is rare and although there are observers familiarized with the phenomena who recorded auroras systematically in Europe during the 18th century e.g. Francisco Salvà (Barcelona, Spain) (Vaquero et al., 2010), Giuseppe Toaldo (Padova, Italy) (Domínguez-Castro et al., 2016). There are many sporadic observers that record LLAs as strange and inexplicable phenomena. These sporadic reports are important to generate LLAs catalogues but require an accurate analysis to avoid possible misinterpretations. Here, we analyzed

https://doi.org/10.5194/angeo-2020-1
Preprint. Discussion started: 13 February 2020

Annales Geophysicae Discussions

an observation made by the Abbot Francois Rozier in 1780 with enough details and quantifiable information to know if he observed an LLA or a different phenomenon.

2 Methodology

2.1. The Observer

Jean-Baptiste François Rozier, (Lione, 23 January 1734 - Lione, 29 September 1793) (Fig. 1) (http://dictionnaire-journalistes.gazettes18e.fr/journaliste/720-jean-baptiste-francois-rozier; https://www.afes.fr/portfolio-item/rozier-abbe-jean-baptiste-francois-1734-1793/; https://fr.wikisource.org/wiki/Cours_d%E2%80%99agriculture_(Rozier)/Notice_sur_la_vie_et_les_%C3%A9crits_de_l%E2%80%99abb%C3%A9_Rozier) was a professor of Botanic and Medicine at the University of Lione. After studying at the Jesuit college at Villefranche-sur-Saône entered the the Saint-Irénée seminary in Lyon, never entering in a major seminar decided to dedicate his life to science. In 1771 Rozier moved to Paris to edit the Journal de Physique et d' Histoire Naturelle founded by Jacques Gautier d' Agoty; successively, he become the journal owner re-titling it Journal d' Observations sur la Physique, l' Histoire Naturelle et sur les Arts et Métiers. Later it becomes the Journal de Physique where the original versions of many fundamental memoirs, such as Lavoisier's early studies on combustion and Coulomb's researches on the law of electrical attraction, appeared (McKie, 1957). Rozier maintained the journal up to 1779 when he devoted himself to the writing of the Cours d' agriculture (see below) and the periodical was edited by his nephew, the mineralogist and priest Jean-André Mongez (21 November 1750 – May 1788). In 1779 he became prior of the abbey at Nanteuil-le-Haudouin (between Paris and Reims), while in July 1780 Rozier bought an estate close to Béziers (Beauséjour), Southern France (domaine de Beauséjour) to install his own model farm (1781). Here he could edit his Cours Complet d' Agriculture Théorique et Pratiqueou Dictionnaire Reisonné et Universel d' Agriculture (twelve volumes in form of a dictionary, of which nine were by Rozier himself, 1781–1800, and the last two were published after his death). Finally, he sold the property and in 1786 moved to Lyon where he accepted a position as director of the school of agriculture. Furthermore, he became director of the Pépinière (plant nursery) de la Province in 1788, enriching them with useful plantations and carrying out changes improving safety.

From the beginning of the French Revolution (5 May 1789) he sided with the new regime, asking to the first two assemblies to create a national agriculture school. He became constitutional curate of Sainte-Polycarpe parish in Lyon and was killed in his bed by a bomb during the siege of the town the night between the 28th and 29th of September 1793.

Rozier was recognized by contemporary scientists he was a member of the Académie de Lyon and thanks to be editor of scientific journals was in contact and corresponded with the most famous scientists and intellectuals of his times. Rozier devoted his life to the observation of botanical or agricultural (e.g. observations on different types of crops), biological, chemical (e.g. observations on flora and fauna species, on mineralogical elements or results from the experiments), physical and meteorological phenomena (e.g. temperature, atmospheric pressure observations with barometers of different diameters or state of the sky as thunders` observations) with diligence and accuracy that enabled him to apply scientific principles to agriculture registering the smallest peculiarities.

https://doi.org/10.5194/angeo-2020-1
Preprint. Discussion started: 13 February 2020

Annales Geophysicae Discussions
Open Access
EGU

2.2. The Documentary Source and the Observation description

The observation was described in the "Observations sur la physique, sur l` Histoire naturelle er sur les arts, avec des planches en taille-douce" tome XVIII under the title "Sur une Nuée rendue phosphorique par une surabondance de l' electricitè, vuede Beausejour près de Beziers, le 15 Août" [About a cloud rendered phosphoric by an overabundance of electricity observed at Beziers the 15th of August][1] (Fig. 1). The most important fragments of the observation are reported below in English, while the complete original French version is reported in the Supplementary Materials.

"The closer the night approached, the more the clouds were pushed and accumulated towards the great chain of mountains of the third order that cross the low-Languedoc from east to west.

…At 20:05 it was completely night. It was at this moment that, examining the direction and the effects of the flashes, I noticed behind the slope of the hill, which on one side blocks the view from my house, a bright spot. This light did not look like that of a candle seen from afar, nor that which spreads from a forest or grass when they are set on fire. It seemed to me to have the whitish color of phosphorus burning in the open air, or rather of that of mercury stirred in a tube without air.

This bright spot gradually acquired volume and intensity. It imperceptibly formed an area, a phosphoric band that appeared to my eyes at a height of 3 feets: and starting from the top of the hill almost to Beziers, this area seemed to form the base of a 60 ° angle, whose summit responded to my eye.

On this first luminous area, a second one of the same height formed and it had only 30 ° of extension [width], or half of that of the lower area. Between them remained a void whose height equaled that of one of the two areas considered separately.

Even if these two zones followed a horizontal direction, it is not to believed that their line of demarcation followed exactly a straight line. We noticed on both some irregularities, roughly as on the edges of that big white cloud, before it was orange-colored, and these edges were not all equally bright even if the center of the zones showed a uniform light.

During the period of time when these areas were moving eastward, the lightning and thunder noise were more rapid; finally, at three different times, a flash started from the end of the lower area. But an object worthy of note is that the noise following these flashes, if there was one, was weak and I would dare to say almost null because I could not distinguish it from the noise of the thunder that was starting from the upper region and from a greater distance. Every flash, launched by the general mass,

[1]Rozier Sur une Nuée rendue phosphorique par une surabondance de l'electricitè, vuede Beausejour près de Beziers, le 15 Août. Observations sur la physique, sur l`Histoire naturelle er sur les arts, avec des planches en taille-douce" tome XVIII under the title " (1781)

https://doi.org/10.5194/angeo-2020-1
Preprint. Discussion started: 13 February 2020


Annales Geophysicae Discussions

made me clearly appreciate the vines, the crops, the top and the sinuosity of the small mountains located in front of the big chain.

That light helped me to understand that the areas were closer to me and did not belong to the mass of clouds pushed by the winds towards the mountain.

This phenomenon was shown from 20.05 until 20.17. In this instant a blow of wind from the south changed the direction of the clouds, bringing them closer to the big mountain chain, and the orange moved away from Beziers.

It would seem that these areas were a simple mass of vapors, only charged by electricity, which made them transparent and phosphoric. It is proved by the fact that three times the flash disappeared and the trail of light left by the flash appeared to be more than twice the diameter of normal flashes. The [apparent] proximity of the objects could, it is true, be due to these optical effects.

I am led to believe that these areas were detached entities [bodies] and that they did not belong to the mass of the other clouds because the mountains were visible behind them when the flash departed from the big mass; finally, when the flash started from these areas, there was no explosion.

I don't know if such a phenomenon has been observed elsewhere; but I never read anything that can be compared to it."

3 Analysis of the Observation

Hour of Observation and sun depression angle: Rozier describes the starting (20:05) and ending (20:17) hour of his observation as local solar time (LST) i.e. the measure of time of the French Hours that lasted until the French Revolution in 1789. These times correspond to 20:05 and 20:18 in Universal Time. At these times the solar depression angle was 13° and 14.9° respectively. Although the observation was recorded during the nautical twilight Rozier consider that was "completely night".

Shape: Related to the shape description, Rozier was very accurate. He described shape peculiarities as: two zones [i.e. luminous areas approximately of the same height – separated by a void – with the lower area wider (60 ° width) than the upper one (30 ° width)] following (through irregularities) a horizontal direction, the edges of which in turns were not all equally bright respect to the uniform light observed in center of these zones. Rozier described a mostly quite aurora with a main structure of two bands oriented east to west but some motion is recorded as rays oriented with the earth magnetic fields "a flash started from the end of the lower area…". This is a frequent structure of the aurorae (Vaquero & Vasquez, 2009).

Color: He carefully mentioned the colors: "whitish color of phosphorus burning in the open air" and again "big white cloud, before it was orange-colored". At this latitude, northern lights have generally specific colors e.g. red and white and diffuse due to the enhancement of the 630,0 nm [OI] emission caused by soft electrons (<100 eV) precipitating from the plasmasphere (Tinsley et al., 1986). This has been confirmed by Abbott and Juhl in 2016 (Abbott & Juhl, 2016) which have examined the distribution of colors of 279 records of LLAs and attempted to evaluate how auroral colors vary as a function of their relative energy. They found that low-latitude auroras are predominantly red (66%, 835 events) with lesser proportions of white (20%, 253 events) and black auroras (6%, 67 events). Rozier observed a white aurora, this made the phenomena more unusual and

https://doi.org/10.5194/angeo-2020-1
Preprint. Discussion started: 13 February 2020

Annales Geophysicae Discussions

increase the possibility of misinterpretation of the phenomenon by Rozier. This color suggests a high production of ^{14}C at this time (Abbott & Juhl, 2016).

Noise: He concluded saying that finally, at three different times, a flash, with almost null noise, started from the end of the lower area.

Moon: Rozier does not report any information about the moon. But the moon was in the sky that day. The moon, on 15 August 1780 was full moon and rose at 19:36 (UT) at an azimuth angle of 112° ESE direction, i.e. opposite respect the direction of observation of Rozier and close to the horizon. This fact suggests that the aurora was highly bright because Rozier could record it with full moon in the sky. Probably the short time of observation was related with the light conditions due to the moon rise. However tropospheric clouds could also decrease the visibility of the phenomenon.

Geomagnetic latitude: We have calculated the temporal evolution of the geomagnetic latitude in Beziers for the night of the observation using the geomagnetic model gufm1 (Jakson et al., 2000). The geomagnetic latitude, φ equals to 50,18°N is obtained by equation (2) in the hypothesis of a dipolar configuration for the geomagnetic field.

$$\boldsymbol{\varphi} = \frac{\tan \boldsymbol{I}}{\mathbf{2}} \quad (2)$$

where I is the magnetic inclination obtained from the gufm1 model for the year 1780. This implies that the aurora is in the upper limit of the low latitude.

In summary it is clear that Rozier observed a white and bright LLA with a two bands structure.

4 Discussion

In the previous section we have verified that Rozier observed an aurora the night of the 15th august 1780. According with the Angot catalogue (Angot, 1896) this night the aurora was also observed at Ratisbon (Germany, 49º N), 5.5° further north than Beziers. The Angot catalogue has been extensively used on the reconstruction of auroral nights and as a proxy of the long-term geomagnetic variability. But it is important to note that Angot (1896) is a secondary source (the author was no witness of the described facts) and does not provide information of the primary sources consulted for the elaboration of the catalogue. The secondary sources must be used carefully because can include errors due to the transcription or interpretation of the primary sources. For this reason, is important to found primary sources that corroborate the information provided by Angot, specially during the nights that Angot record an event at only one location, as the night of 15th august 1780.

Magnetic indexes are not available in 1780 e.i. Ak index is available since 1844 (Nevalinna & Kataja, 1993), aa index is only available from 1868 (Mayaud, 1980) and geomagnetic IDV index (Svalgaard & Cliver, 2010), is available from 1835. For this reason, we have used LLAs catalogues and sunspot number as proxies of the geomagnetic activity at Rozier's times.

We have analyzed the aurorae catalogue at comparable latitudes, we have compared it with two existing coeval series of auroras homogeneously recorded at low latitude i.e Toaldo (1766-1797) (Padova, 45º 24' N) (Domínguez-Castro e tal., 2016) and Salvà (1780-1825) (Barcelona 41º 23') (Vaquero et al, 2010). For differentiation, the additional series of auroras observed

https://doi.org/10.5194/angeo-2020-1
Preprint. Discussion started: 13 February 2020

by Thomas Hughes from Stroud (mid-latitude, 51,75°N, 2,22°W) (Giles, 2005) has been analyzed. Figure 2 shows the Toaldo, Salva and Hughes yearly total observations of auroras and the geomagnetic latitude for Padua, Barcelona, Stroud and Beziers over the common 1766-1800 period. The Rozier's observation was close to the maximum LLA observed by Toaldo at Padova (1779). Nevertheless, no aurora was recorded by Salvà at Barcelona during 1780. At higher latitudes (Stroud) Hughes recorded a mean to low activity of auroras for this year. At a global scale Rozier's observation is close to a secular maximum of the auroral activity (Silverman, 1992).

Figure 3 show the sunspot number during the period 1766-1800. Rozier´s observation was in the decrease phase of the solar cycle 3, 2-years delayed respect the peak of the highest solar activity. It is a good moment to see LAA because long-lived coronal holes, source of high ionized particles in the solar wind, occur more frequently in the declining phase of the sunspot cycle (Verbanac et al., 2011). It is important to note that the Rozier's observation occurred in a period with few solar observations. As we can see in Figure 4 the solar observations during the 1780`s are low, frequently below the 30 observations per year. For this reason, any contribution to the knowledge of the geomagnetic activity in this period is very welcomed.

Figure 4 show at monthly scale the solar activity and the auroras recorded in Padova from august 1779 to august 1781. We can see that no aurora was observed during August and only one solar observation was recorded in this month. This solar observation was the 30th of august when J.C. Staudach report 4 groups in the solar disk. The previous observation was done by P. Zeno at 12th of July recording one group (Vaquero et al., 2016). This is 48 days without sunspot information.

Conclusions

We have found a record of an atmospheric phenomenon observed on 15th August 1780. It was observed by Abbot Francois Rozier and described as a "big white cloud … whitish color of phosphorus burning in the open air". Thanks to the accuracy of his report, we have been able to analyze quantitative information and facts that contribute to confirm that Francois Rozier observed a low latitude aurora that night in Beziers, France. The aurora was white shows the two bands and some rays. The geomagnetic and the solar activity during this period has high uncertainties because there are few solar and LLA observations. This event contributes to enlarge the geomagnetic knowledge of this period.

Funding

The research reported in this publication was not supported by any external funding.

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Authors contributions

https://doi.org/10.5194/angeo-2020-1
Preprint. Discussion started: 13 February 2020

Annales Geophysicae Discussions

C.Bertolin conceived the study, performed the analysis and drafted the manuscript with F. Dominguez-Castro, who wrote the final manuscript. L. de Ferri translated the original data and conducted the historical research used in the study as well as contributed to scientific discussion of the article together with C. Bertolin and F. Dominguez-Castro.

ORCID iD

Chiara Bertolin https://orcid.org/0000-0002-0684-8980
Fernando Dominguez-Castro https://orcid.org/0000-0003-3085-7040
Lavinia de Ferri https://orcid.org/0000-0001-8904-4779

References

Abbott D. and Juhl R., New historical records and relationship among ^{14}C production rates, abundance and color of low latitude auroras and sunspot abundance, Adv. Space Res. 58 2181-2246, doi.org/10.1016/j.asr.2016.07.015, 2016.

Angot A., The Aurora Borealis, (D. Appleton & Co) 326 pp, 1897.

De Mairan J. J. D., Traité physique et historique de l'aurore boréale, Academie Royale des Sciences, Paris, 1731.

Domínguez-Castro F., Vaquero J.M., Bertolin C., M. C. Gallego, De la Guia C. and Camuffo D., Aurorae observed by Giuseppe Toaldo in Padua (1766-1797), J. Space Weather Spac., 6, A21, doi.org/10.1051/swsc/2016016, 2016.

Green J. L. and Boardsen S.A., Duration and extent of the great auroral storm of 1859, Adv. Space Res. 38, 130–135, 10.1016/j.asr.2005.08.054, 2006.

Green J.L., Boardsen S. A, Odenwald S., Humble J. and Pazamickas K.A., Eyewitness reports of the great auroral storm of 1859, Adv.Space Res. 38-2, 145-154, doi.org/10.1016/j.asr.2005.12.021, 2014.

Harrison G., Aurora diaries, Astron. Geophys., 46, 4.31-4.34, doi.org/10.1111/j.1468-4004.2005.46431.x, 2005.

Humble J., The solar events of August/September 1859 – Surviving Australian observations, Adv. Space Res. 38, 155–158, 10.1016/j.asr.2005.08.053, 2006.

https://www.afes.fr/portfolio-item/rozier-abbe-jean-baptiste-francois-1734-1793/ (accessed 06/01/ 2020)

http://dictionnaire-journalistes.gazettes18e.fr/journaliste/720-jean-baptiste-francois-rozier (accessed 06/01/ 2020)

https://fr.wikisource.org/wiki/Cours_d%E2%80%99agriculture_(Rozier)/Notice_sur_la_vie_et_les_%C3%A9crits_de_l%E2%80%99abb%C3%A9_Rozier (accessed 06/01/ 2020)

http://loc.gov/pictures/resource/ppmsca.02227/ (accessed 06/01/ 2020)

Jakson A., Jonkers A. R. T. and Walker M. R., Four centuries of geomagnetic secular variation from historical records, Philosophy Transaction of the Royal Society of London, A358, 957-990, doi.org/10.1098/rsta.2000.0569, 2000.

Krivsky L., Long-term fluctuations of solar activity during the last thousand years, Sol. Phys. 93, 189–194, doi.org/10.1007/BF00156664, 1984.

https://doi.org/10.5194/angeo-2020-1
Preprint. Discussion started: 13 February 2020

Library of Congress Prints and Photographs Division Washington, D.C. 20540 USA DIGITAL ID: (digital file from original print) ppmsca 02227

McKie D., D.Sc. Ph.D. F.R.I.C. F.R.S.E., "The "Observations" of the Abbé François Rozier (1734–93)", Annals of Science 13, 73-89, doi.org/10.1080/00033795700200071, 1957.

Mayaud P. N., A Historical Review of Past Indices, Derivation, Meaning, and Use of Geomagnetic Indices, Mayaud P. N. (ed), American Geophysical Union, 4-16, 1980.

Nevanlinna H. and Kataja E., An extension of the geomagnetic activity index series aa for two solar cycles (1844–1868), Geophys. Res. Lett. 20, 2703-2706, doi.org/10.1029/93GL03001, 1993.

Stephenson F. R., Willis D. M. and Hallinan T. J., The earliest datable observation of the aurora borealis, Astron. Geophys. 45, 15-17, doi.org/10.1046/j.1468-4004.2003.45615.x, 2004.

Silverman S.M., Secular variation of the aurora for the past 500 years, Review of Geophysics, 30, 333-351, doi.org/10.1029/92RG01571, 1992.

Svalgaard L. and Cliver E. W., Heliospheric magnetic field 1835–2009, J. Geophys. Res., 115, A0911, doi.org/10.1029/2009JA015069, 2016.

Tinsley B. A., Rohrbaugh R.P., Rassoul H. K., Sahai Y. and Texeira N. R., Low-Latitude Aurorae and Storm Time Current Systems, J. Geophys. Res., 91, 11257-11269, doi.org/10.1029/JA091iA10p11257, 1986.

Vazquez M., Vaquero J.M. and Gallego M.C., Long-term Spatial and Temporal Variations of Aurora Borealis Events in the Period 1700-1905, Sol. Phys. 289, 1843-1861, doi.org/10.1007/s11207-013-0413-6, 2014.

Vaquero J. M., Gallego M. C., Barriendos M., Rama E. and Sanchez-Lorenzo A., Francisco Salva`s auroral observations from Barcelona during 1780-1825, Adv. Space Res., 45, 1388-1392, 10.1016/j.asr.2010.02.009, 2010.

Vaquero J. M. and Vazquez M., The Sun Recorded Through History, Springer, 2009.

Vaquero J.M., Svalgaard L., Carrasco V.M.S., Clette F., Lefèvre L., Gallego M.C., Arlt R., Aparicio A.J.P., Richard J-G. and Howe R., A revised collection of sunspot group numbers. Sol. Phys. 291, 3061-3074, 10.1007/s11207-016-0982-2, 2016.

Verbanac G., Vrsnak B., Veronig A. M. and Temmer M. B., Equatorial coronal holes, solar wind high speed strams, and their geoeffectiveness, Astron. Astrophys., 526, A20, doi.org/10.1051/0004-6361/201014617, 2011.

WDC-SILSO, Version No. 2.0, Royal Observatory of Belgium, Brussels

https://doi.org/10.5194/angeo-2020-1
Preprint. Discussion started: 13 February 2020

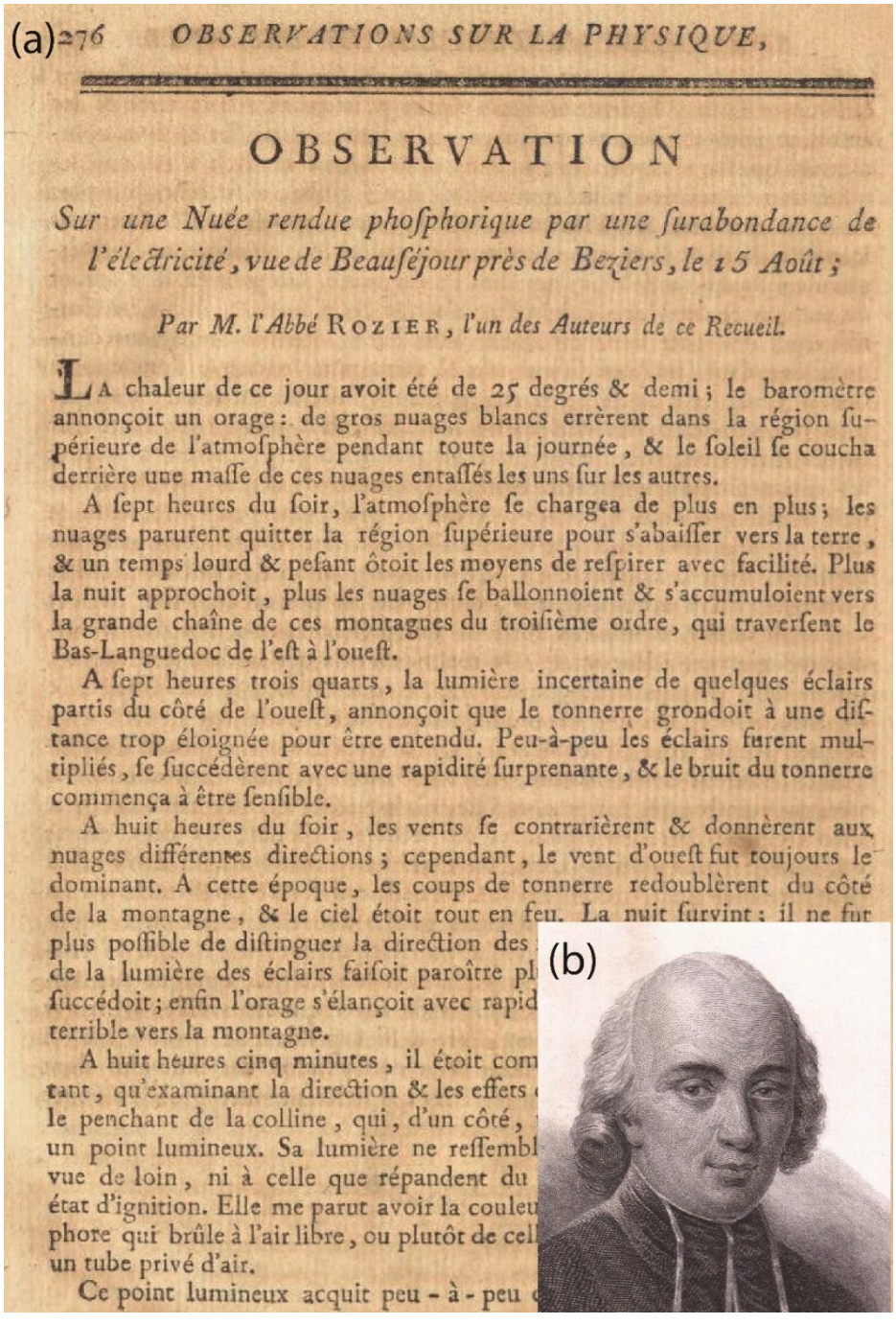

Figure 1: (a) first page of the manuscript reporting the NLC observation made by Abbot Francois Rozier, on 15 August 1780 in Beziers, France (courtesy of the Physics department library of the University of Florence). (b) Photographic portrait of Abbot Francois Rozier (photo in public domain) (Library of Congress Prints and Photographs Division Washington; http://loc.gov/pictures/resource/ppmsca.02227/).

https://doi.org/10.5194/angeo-2020-1
Preprint. Discussion started: 13 February 2020

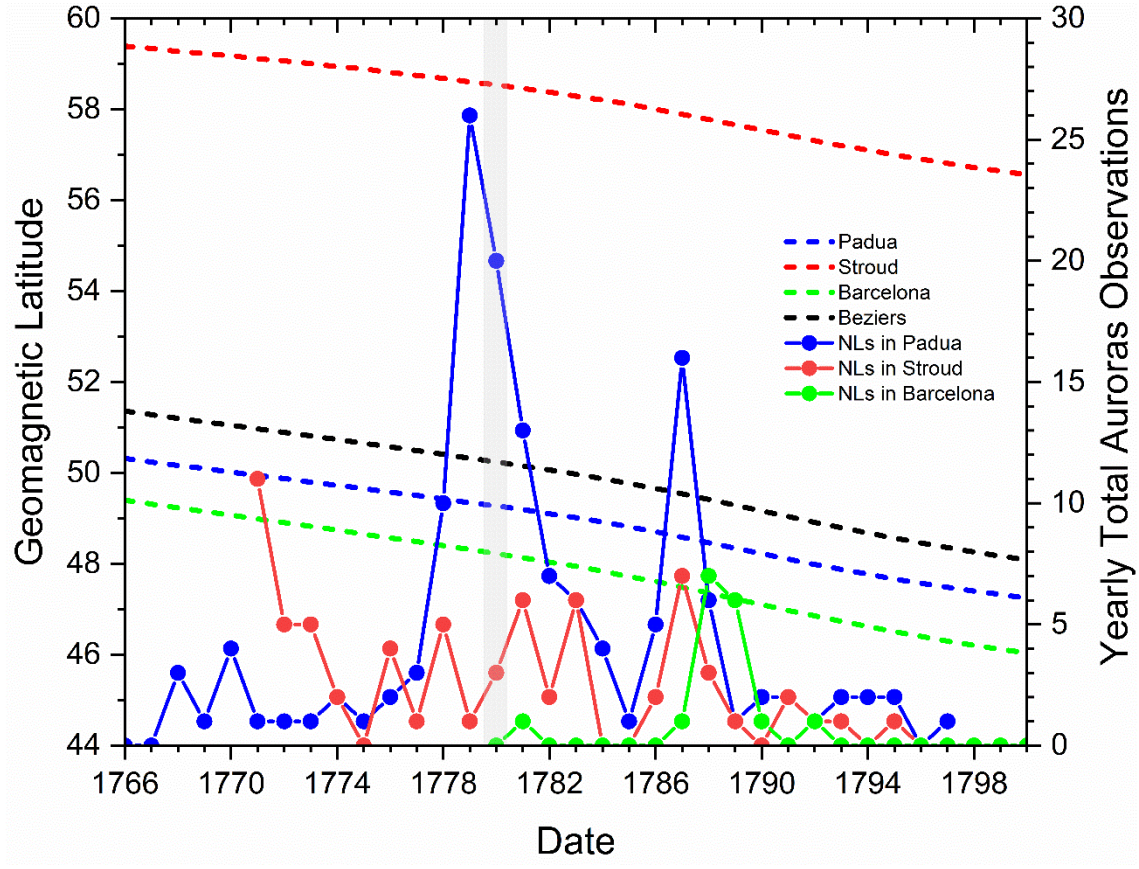

Figure 2: Geomagnetic Latitude variations for Padua, Barcelona Stroud and Beziers and yearly total auroras recorded in these places by Toaldo, Salva and Hughes. The grey column remarks the year of the Rozier's auroral observation 1780.

https://doi.org/10.5194/angeo-2020-1
Preprint. Discussion started: 13 February 2020

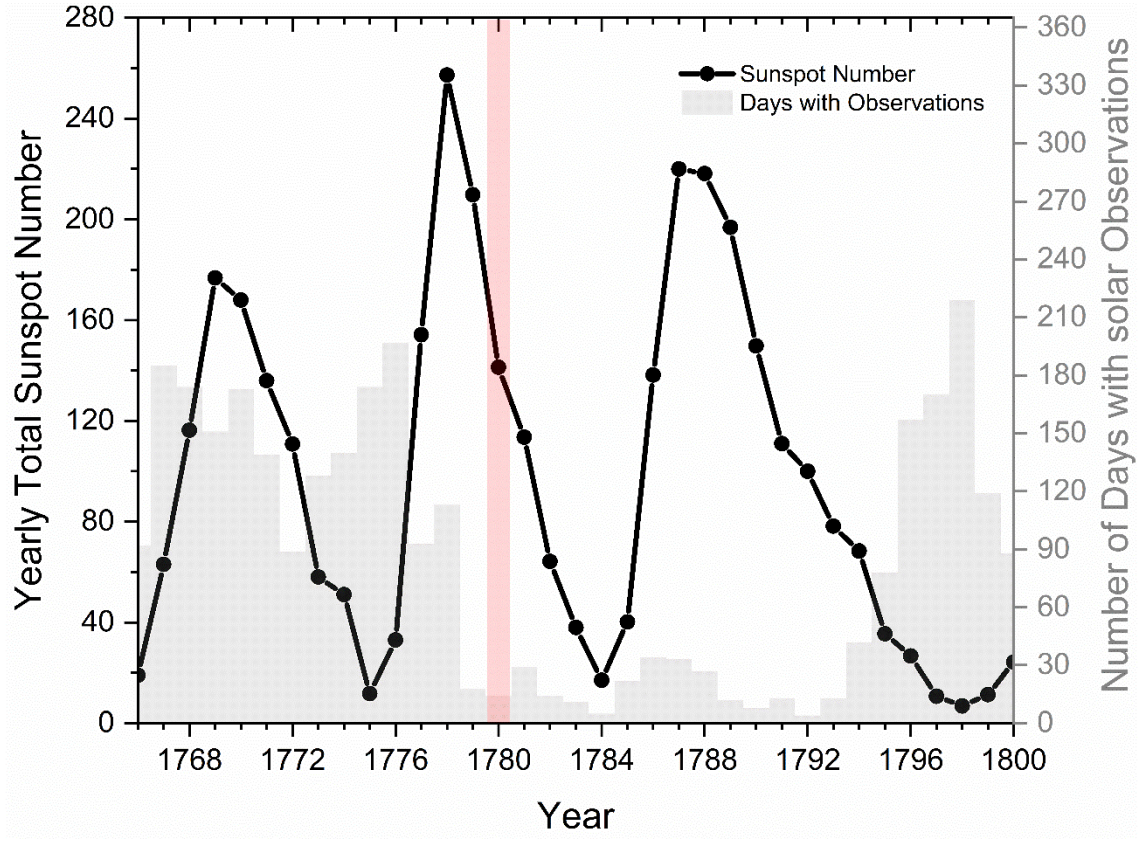

Figure 3: Annual sunspot numbers and number of days with solar observation (WDC-SILSO).

https://doi.org/10.5194/angeo-2020-1
Preprint. Discussion started: 13 February 2020

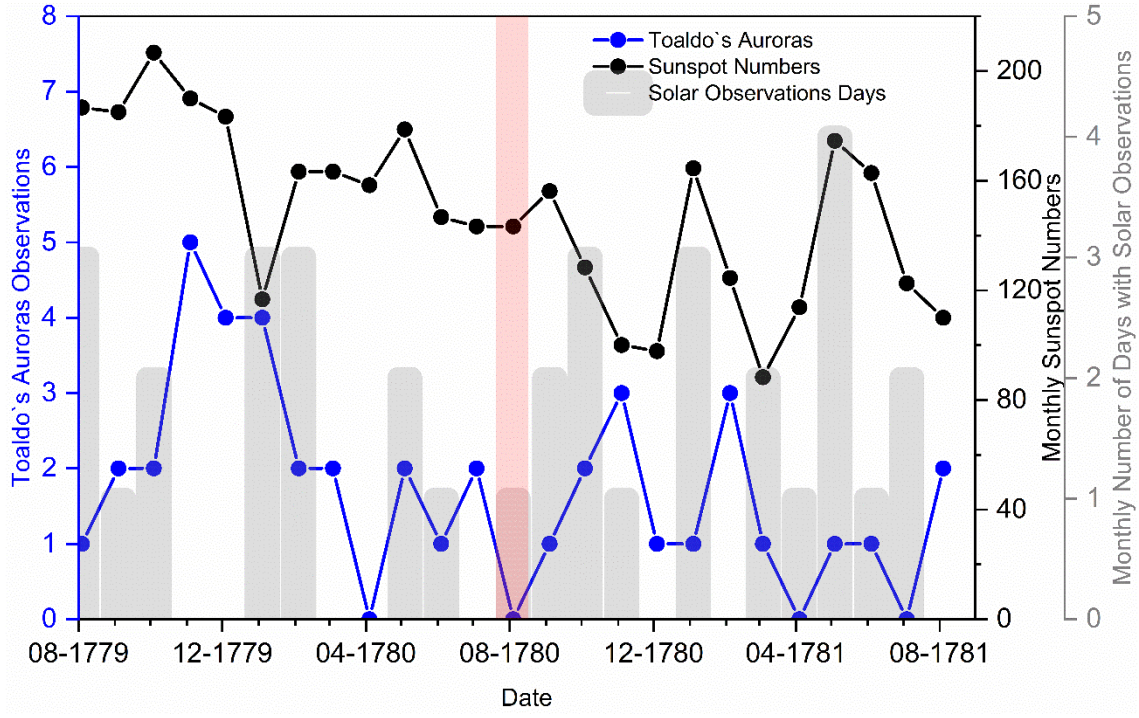

Figure 4: Monthly sunspot numbers, days with solar observations and auroras from Toaldo catalogue from august 1779 to august 1781.