

**Volcano Eruptions, Earth- & Seaquakes, Dry Fogs vs.  
Aristotle's *Meteorologica* and the Bible in the Framework of  
the Eighteenth Century Science History\***

by

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There will be famines and earthquakes in various places.  
(Matthew 24: 7)

Un jour tout sera bien. Voilà notre espérance.  
Tout est bien aujourd'hui. Voilà l'illusion.  
(Voltaire, Poème sur le désastre de Lisbonne)

KEYWORDS. — Volcano Eruption; Earthquake; Seaquake; Dry Fog; Lisbon 1755; Aristotle; *Meteorologica*; Bible.

SUMMARY. — The earthquake, or better said the seaquake, of All Saints' Day of 1 November 1755 at Lisbon was felt in three different continents, namely Europe, Africa and America. The ensuing tsunami was observed in Europe, in Africa, on the Azores and Madeira, and even in the Antilles and the eastern coast of America. Later observations showed in the whole of Europe the presence of "seiches", *i.e.* fluctuations of the water surface due to the seism.

The authors have considered the meteorological conditions at the moment of the earthquake and suggest here a new interpretation of the appearance of a yellow fog or smoke and the foul smell of sulphur namely as a consequence of the eruption of Katla volcano in Iceland a fortnight before. This interpretation is confronted with the then dominating theory of Aristotle's *Meteorologica* or with prognostications from the Bible. Nevertheless, other accounts testify the emerging new vision of scientific ideas in the spirit of the Enlightenment.

TREFWOORDEN. — Vulkaanuitbarsting; Aardbeving; Zeebeving; Droge Mist; Lissabon 1755; Aristoteles; *Meteorologica*; Bijbel.

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\* Paper presented at the meeting of the Section of Technical Sciences held on 25 January 2007. Text received on 7 March 2007.

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SAMENVATTING. — *Vulkaanuitbarstingen, aard- en zeebevingen, droge mist vs. Aristoteles' Meteorologica en de Bijbel in het licht van de 18de eeuwse wetenschaps-geschiedenis.* — De aardbeving, of beter de zeebeving, van Lissabon van Allerheiligen 1755 was voelbaar in drie verschillende continenten, namelijk Europa, Afrika en Amerika. De daaropvolgende tsunami werd waargenomen in Europa, in Afrika, op de Azoren en Madeira en zelfs tot op de Antillen en aan de oostkust van Amerika. Verder waren er in heel Europa waarnemingen van „seiches” of van het fluctueren van de wateroppervlakken door de beving.

De auteurs buigen zich over de meteorologische toestand op het ogenblik van de aardbeving en komen met een nieuwe interpretatie van de waargenomen feiten aan, namelijk de observatie van een zwavelachtig riekende mist als gevolg van de Katla vulkaanuitbarsting in IJsland een veertiental dagen voordien. Deze interpretatie wordt geconfronteerd met de toen heersende wetenschapstheorie van de *Meteorologica* van Aristoteles en met prognosticaties uit de Bijbel. Andere teksten getuigen van de nieuwe filosofische ideeën gegeneerd door de Verlichting.

MOTS-CLES. — Eruption volcanique; Tremblement de terre; Tremblement de mer; Lisbonne 1755; Brouillard sec; Aristote; «Les Météorologiques»; La Bible.

RESUME. — *Eruptions volcaniques, séismes terrestres et sous-marins, brouillard sec par comparaison à la Meteorologica d'Aristote et la Bible à la lumière de l'histoire des sciences au XVIII<sup>e</sup> siècle.* — Le séisme terrestre, ou plutôt sous-marin, qui frappa Lisbonne le jour de la Toussaint 1755 fut ressenti sur trois continents différents, à savoir l'Europe, l'Afrique et l'Amérique. Le tsunami qui s'ensuivit fut enregistré en Europe, en Afrique, aux Açores et à Madère, et même jusqu'aux Antilles et la côte est de l'Amérique. Des observations ultérieures révélèrent dans toute l'Europe la présence de «seiches» ou oscillations de la surface de l'eau dues au séisme.

Les auteurs se sont penchés sur la situation météorologique au moment du séisme et proposent une nouvelle interprétation des faits établis, à savoir l'observation d'une brume sulfureuse nauséabonde provoquée par l'éruption du volcan Katla en Islande une quinzaine de jours auparavant. Cette interprétation est confrontée à la théorie scientifique, autrefois dominante, de la *Meteorologica* d'Aristote et des prophéties de la Bible. D'autres textes, néanmoins, servent d'exemple aux nouvelles idées philosophiques générées par les Lumières.

## 1. Introduction and Setting of the Paper

Ever since an immense seaquake devastated the shores of Southeast Asia on December 26, 2004, caused a toll of several hundred thousand lives and left at least one million homeless, the word *tsunami* [1]\* has entered our daily vocabulary. Note that the word *maremoto* has been used for centuries in the Hispanic and Lusitanian contexts. The fact that this catastrophe occurred in Christmas time

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\* Numbers in brackets [ ] refer to the notes, p. 356.

and made its victims among the poor and needy humanity of Third-World countries, shook the foundations of our worldview. World media immediately connected the tragic event to other global issues such as global climate change, ecological policy, North-South contrasts and weather-related disasters. The “biblical dimensions” were noticed and even the meaning of the disaster was sought as if it carried a divine message (NORDLIE 2006).

Very similar considerations were held on the occasion of the famous Lisbon sea- and earthquake of November 1, 1755, occurring also on the holy day of All Saints. To name only one, Voltaire who made “Candide” witness the destruction of the town of Lisbon and asked the famous philosophical question of the goodness of our world. A “seismic crisis” took place in the period 1755-62 as earthquakes did occur frequently in North-West Europe (ALEXANDRE & VOGT 1994).

The authors will mainly consider the meteorological descriptions of the Lisbon earthquake. Those can be divided into two groups, the first one which tells that the weather for the weeks preceding the sea- & earthquake was very fine and clear, and that the quake occurred with a clear sky (point 3.1.). In terms of literature these nice weather conditions help provide a strong contrast with the catastrophic events of the town destruction.

However, it was rather striking that several authors who were direct witnesses of the events augmented their weather accounts with descriptions of dark, coloured, bad smelling fogs observed before the fatal earthquake. Although these descriptions (point 3.2.) are fully in line with the ongoing scientific theory of that time, namely Aristotle’s *Meteorologica* (point 7), the descriptions are so detailed and numerous from independent sources that the authors of the present paper made a daring hypothesis. They interpreted these descriptions as dry fogs from the Icelandic Katla volcanic eruption a fortnight before. Similar phenomenon was witnessed in Lisbon in the summer of 1783 but due this time to the Icelandic Lakígígar volcanic eruption (point 5). In point 8 the traditional religious view of the earthquake is confronted with the emerging Enlightenment views while point 9 contains the conclusions.

## **2. The Overseas Effects of the Seaquake: Tsunami and Seiches [2]**

The effects of the Lisbon 1755 earthquake (fig. 1) were felt in North Africa and in a larger part of Europe but mainly on the Iberian Peninsula. However, light tremors were also witnessed in France, Switzerland, Italy and even in the Low Countries.

Compilation works — but without referring to contemporary sources — describe the effects of the Lisbon 1755 earthquake in the Low Countries as follows: “It was heard about some tremors at Spa and in other sites of the country of Liege but without the sad effects that occurred in Spain, and in Portugal” (Anonymous 1756b, p. 34). “In the Rhenish provinces and in the Principality of



Fig. 1. — Representation of the Lisbon 1755 sea/earthquake (HALLER 1756).

Liege, the vibration of soil persisted several days; many buildings were cracked there or even ruined entirely, and several inhabitants were there victims, some of these accidents, others of their fright. In Belgium, the Marlagne, the Ardennes and the vicinity of Namur felt the effects of this crisis, without suffering however considerable damages” (TORFS 1862, pp. 158-159; LANCASTER 1901, p. 208).

Jan de Boer noted in his “Vervolg der Chronologische Historie van a° 1753, 1754, en 1755” the following about the earthquake in Amsterdam: “On land little was perceived here of the earthquake. [...] But in the White Friar’s church, as it was All-Saints, the chandelier hanging in the middle of the church, was seen moving vigorously, without being touched, and also without somebody knew the cause of the movement” (in de Boer, *Vervolg der Chronologische historie...*, pp. 437-438).

The Lisbon 1755 tsunami affected three continents: Europe, Africa and America. A brief selection of contemporaneous sources dealing with the effects of the tsunami in Africa, the Atlantic Ocean and America is given to illustrate the large geographical covering of the phenomenon.

At first, a few examples dealing with the Low Countries show the possible effects in our region. Few people knew the word before Christmas 2004 and even less were aware of its potential danger on our coast, our rivers and harbours.

WILLEMS *et al.* (2004) asked the question if tsunamis are possible in the North Sea.

At the time of the big earthquake in Lisbon, November 1, 1755, toward the ten hours in the morning, one has observed in Nieuport [Flanders], by a very quiet time, an unusual movement and an extreme agitation in the waters of the sea: the tide was extraordinarily high, to the point to arrive until the gates of the city; what gives 5 or 6 feet more than the highest tides of the high waters unaffected by the wind. Everybody ran to the port, astonished of this phenomenon of which one could not then guess the reason (MANN 1783, pp. 140-141).

The tsunami in the Mediterranean Sea was probably damped; however, its effects were felt in Cagliari (Sardinia) and in Corsica (*Amsterdamse Dingsdaegse Courant*, 9 December 1755). It is more difficult to provide information from more remote areas due to the limited available historical sources in the 18th century. However, it is known that the tsunami struck Morocco, Madeira, the Azores, the Antilles and even Newfoundland. A mention dealing with the eastern coast of the U.S.A. seems to relate to the Cape Ann, November 18, 1755, earthquake in New England. Since effects were observed in Newfoundland and in the Caribbean, it is most likely that the eastern coast of the U.S.A. and the coast of Brazil were also affected by the Lisbon 1755 tsunami.

A letter of General Fowke, Governor of Gibraltar, describes the effects of the tsunami in Barbary [3] that were received at Gibraltar on 1st January 1756.

In Tanger, the sea came up to the very walls, a thing never seen before, and went down directly with the same rapidity as it came up, as far as the place where the large vessels anchor in the bay, leaving upon the mole a great quantity of sand and fish. These commotions of the sea were reported eighteen times, and continued till six in the evening, though not with such violence as at the first time. [...] At Arzilah, at the coming up of the sea seven Moors, who were out of the town walls, were drowned; and the waters came in through one of the city gates very far. The water came up with such an impetuosity, that it lifted up a vessel in the bay, which, at the water's falling down to its center again, fell down with such a force on the land, that it was broken to pieces; and a boat was found at the distance of two musket-shots within land from the sea. [...] At Salé, the waters came up with such a rapidity, that they came into the city, and at their falling down, great quantities of fish were found in the streets, and many persons were drowned: two ferry-boats overset in the river [Bou Regreg], and all the people on board were drowned; and a large number of camels that were just then going for Morocco, were carried away by the waters. [...] At Safi, the sea came up as far as the great mosque, which is within the city, and at great distance from the sea (*Philosophical Transactions*, 1756, Letter XVI, pp. 428-432).

Thomas Heberden described the effects of the tsunami at Funchal, Madeira:

About an hour and half after the shock had ceased, the sea, which was quite calm (it being a fine day and no wind stirring) was observed to retire suddenly some paces, and, arising with a great swell, without the least noise, as suddenly advancing, overflowed the shore, and entered the city. It arose full fifteen feet perpendicular

above high water mark, although the tide, which ebbs and flows here seven feet, was then at half ebb. The water immediately receded again, and, after having fluctuated four or five times between high water and low water mark, the undulations continually decreasing (not unlike the vibrations of a pendulum) it subsided, and the sea remained calm as before the phenomenon had appeared. [...] In the northern part of this island the inundation has been more violent, the sea there retiring at first above a hundred paces, and suddenly returning, overflowed the shore, destroying or damaging several houses and cottages, forcing open doors, and breaking down the walls of several stores or magazines, and carrying away in its recess a considerable quantity of grain, etc. [...] as the fluctuation and swell was much greater here in Funchal than it had been further to the westward where in some places it has been hardly, if at all, perceptible (*Philosophical Transactions*, 1756, Letter XVII, pp. 432-434).

Mr Charles Chambers, also at Madeira, wrote to his father in similar words on the tsunami effects in Madeira (*Philosophical Transactions*, 1756, Letter XVII, pp. 435-436).

Mr Mathias Pires wrote on 9th November 1755 from Angra [do Heroísmo], capital of the island of Terceira, Azores: “The day of the last Judgment approaches, I believe, for these Isles. There were felt here since three weeks three earthquakes stronger than any of those that ever arrived. As I never felt any in my life, I believed to touch my last hour, and I was almost persuaded the day of All Saints’ Day of it, where the sea overflowed itself, although it was not agitated by any bad weather, and that it was even though calm, than it seemed like a river, it took away boats and houses of this town [...]” (*Journal Économique*, 1756).

Captain AFFLECK (1757) of the Advice Man of War wrote on the tsunami in the Antilles: “The tide rose here twelve feet perpendicular several times, and returned almost immediately: the same at Barbados. At Martinique, and most of the French islands, it overflowed the low land, and returned quickly to its former boundaries. In Martinique, in that remarkable flux and reflux of the sea, it was in some places dry for a mile; and in others, flowed into the upper rooms of the houses, and destroyed much coffee: At the island of Saba, it flowed twenty-one feet; at St. Martin’s a sloop that rode at anchor in fifteen feet water, was laid dry on her broadside”.

At Bonavista, one of the few places in Newfoundland with a fishing presence during the time of the year, the local settlers watched in shock as the tidal wave was approaching their area. Rev. Philip Tocque, in “Wandering Thoughts”, wrote about the event: “The sea retired and left the bed of the harbour dry for a space of ten minutes, when it again flowed in and rose to an unusual height, overflowing several meadows for about the same space of time as it had retired [...] the waters on each side of the cape were greatly agitated” (WHIFFEN 1998).

In his manuscript, Jan de Boer described the movement of the water in the harbour of Amsterdam as follows: “This morning, a quarter to eleven, we have had here an earthquake which was felt more in the water than on the land. In the Singel, the movement of the water was so great and strong that the ropes with

which the ships were moored up were torn off. The same ropes, no matter how strong they were, broke off as if they were thin silk treads and the ships were thrown by the wild water against the banks or embankments so that in the middle of the canal the bottom was shown. It happened so in several other canals and waters in and around this town”.

### 3. The Weather Conditions at Lisbon

In this section, in line with the 18th century’s natural scientists, the weather conditions extracted from contemporaneous writings before and on the day of the earthquake are given. At first, descriptions of clear and nice weather are given.

#### 3.1. “UNDER A CLEAR SKY AND SERENE WEATHER”

The general weather conditions at the moment of the fatal earthquake were given by MOREIRA DE MENDONCA (1758): “Saturday, first of November, and the twenty-eighth lunar day, at dawn it was a calm day, [...] a little after nine hours and a half of the morning, the barometer being at 27 inches and seven lines, and the thermometer of Réaumur at 14 degrees above zero, blowing a light wind of the Northeast, the earth began to tremble with a pulsation from the centre to the surface, and increasing the impulse, it continued to shake forming a swinging move from North to South”.

Richard Wollfall, a surgeon in Lisbon, wrote: “Since the beginning of the year 1750, we have had much less rain than has ever been known in the memory of man, excepting the last spring, which gave such a supply of rain, as has produced very plentiful crops: the summer has been cooler than usual, and for the last forty days, fine weather, without being remarkably so” (*Philosophical Transactions*, 1756, Letter II, pp. 402-407).

João Mendes Sacchetti, a Portuguese physician, wrote from the fields of Lisbon: “This year has been with us very rainy and wet, the three preceding ones excessively dry, insomuch that some springs, formerly plentiful of water, were dried, and totally lost; at the same time the predominant winds were east and north-east, accompanied with various, though very small, motions or tremblings of the earth, and, in the year 1750, we had a very sensible one” (*Philosophical Transactions*, 1756, Letter IV, pp. 409-411).

Most letters from Lisbon or from other places in Portugal and Spain report only the beautiful weather conditions the day of the fatal earthquake. Mr Plummer, a merchant in London, reported from Oporto that: “during the time of the earthquake, and indeed preceding it, was heard a hollow dreadful noise, but I did not observe any disagreeable smell, or alteration in the air, the sky being serene as usual, and the after-part of the day without a breath of air” (*Philosophical Transactions*, 1756, pp. 419-420).

Another author wrote similarly: “The day broke with a clear sky over this immense town ... on the 1st of November” (Anonymous 1756). Rev. Charles Davy (1722-1797) witnessed the earthquake as follows: “There was never a finer morning than the 1st of November; the sun shone out in its full luster; the whole face of the sky was perfectly serene and clear; and not the least signal of warning of the approaching event ...” (TAPPAN 1914).

Judith Nozes (1987) published ten or so British eye-witness accounts, mostly by merchants, of the Lisbon earthquake. The calm weather just before the fatal earthquake is mentioned on several occasions. “There I was sitting on the first Day of the present Month, about Ten of the Clock in the Morning, (the Weather being serene, and the Sky without a cloud in it), when I felt the House begin gently to shake, ...”

“About Ten O’Clock, after Breakfast, the 1st of November, All-Saint’s Day, [...] A calm fine Morning; suddenly we found the House shake, and a great Noise like a Coach and Six driving by ...”

Thomas Heberden (1703-1769), an English physician, wrote from Funchal in Madeira: “The season of the year has been more than ordinarily dry; the rains, which generally begin to fall the beginning of October, not having set in as yet (Nov. 10). The weather for some weeks preceding the earthquake has been very fine and clear, but the day previous thereto (October 31), was very remarkably fair and serene, as was the former part of the day on which it happened: but the afternoon was very dull and dark, the sky being entirely overcast with heavy black clouds: the subsequent day was very fair” (*Philosophical Transactions*, 1756, Letter XVII, pp. 432-434).

Mr Benjamin Bewich, merchant at Cadiz, reported: “The day of the earthquake the weather was clear and serene as the finest summer-day in England” (*Philosophical Transactions*, 1756, Letter XIV, pp. 425-427). Don Antonio d’Ulloa wrote from Cadiz: “The earthquake happened in very fine weather ...” (*Philosophical Transactions*, 1756, Letter XV, pp. 427-428).

At Cadiz, the weather conditions were as follows: “In the morning of the 1st November 1755, the horizon was clear and the sky without clouds. The wind not much considerable was at northwest, and remained there, not without one noticed anything else than a heat that wasn’t exactly of the season. But as it wasn’t very sensitive, one didn’t pay too much attention” (Recueil Fontanieu, pp. 366-371).

RAPIN (1757) continued his description by the account of Gaudin, academician and mathematician at Cadiz, of what had happened in that town: “On the 1st November at sunrise, the weather was clear and calm, with a moderate north-west wind. One noticed small clouds in the north. The atmosphere was in a good equilibrium though the height of the mercury in the barometer was at 28 ‘degrees’ and 3 inches, and of an irregular behaviour, what could be observed by the 11 ½ degrees of a thermometer exposed outside while another one inside and well regulated showed 15 degrees at the same time”. Rapin explained in a

footnote that these clouds at Cadiz denote the fog that prevailed at Lisbon (at a distance of several hundreds kilometers!).

### 3.2. DESCRIPTIONS OF THE FOG AND OTHER LUMINOUS AND OPTICAL PHENOMENA

João Mendes Saccheti continued his description as follows: “The day before the fatal earthquake the atmosphere, and light of the sun, had the appearance of clouds and notable offuscation, and more strong and visible at the actual time of the great shock, which was by undulation, and lasted from six to eight minutes. The weather was rather warmer than commonly we have it at this time of the year, and had continued so for several days before. In all this time were predominant the east and north-east winds. [...] The earth opened in fissures in several parts, but neither fire nor visible smoke came out of it” (*Philosophical Transactions*, 1756, Letter IV, pp. 409-411).

Stoqueler, Consul of Hamburg, made the following observations at Colares, a town about twenty miles from Lisbon:

The 31st of October the weather was clear, and uncommonly warm for the season; the wind north, from which quarter about four o'clock in the afternoon, there arose a fog, which came from the sea, and covered the valleys; a thing very common in the summer, but rare in this season of the year. Soon after the wind changing to the east, the fog returned to the sea, collecting itself, and becoming the thickest I ever saw. As the fog retired, the sea rose with a prodigious roaring.

The 1st of November, the day broke with a serene sky, the wind continuing at east; but about nine o'clock the sun began to grow dim, and about half an hour after we began to hear a rumbling noise, like that of carriages, which increased to such a degree as to equal the noise of the loudest canon, [...] I observed from one of the hills called the Fojo, near the beach of Adraga, that there issued a great quantity of smoke, very thick, but not very black; which still increased with the fourth shock, and after continued to issue in a greater or lesser degree. Just as we heard the subterraneous rumblings, we observed it would burst forth at the Fojo; for the quantity of smoke was always proportioned to the subterraneous noise. This I saw continue till the noon of the 2nd of November, when I retired from the place where I had observed it. It continued to smoke some days longer, more or less, according to the subterraneous rumblings. [...]

The 20th in the afternoon, being on the former spot, I saw a small fog coming from the sea (from the same quarter whence the smoke appeared), which smelt of sulphur; and the wind returning to the east, the fog retired to the sea; and in the morning of the 21st, about nine o'clock, we felt two shocks of an earthquake sufficiently violent, but no more smoke was seen. [...] I went to examine the place, from whence I saw the smoke arise, but I did not discover from whence it could have issued; nor did I find any signs of fire near the place: from whence I infer, either that the smoke exhaled from some eruption or volcano in the sea, which the waters covered, or that, if it issued from some chasm in the land, it closed afterwards (*Philosophical Transactions*, 1756, Letter VI, pp. 413-418).

Stoqueler rather inclined to the former opinion because of the movements of the waters. He observed the same prognostic in the afternoon of the 24th November but the fog was not so thick and no earthquake occurred in the following days.

A letter, dated 19 November 1755, from a merchant of Lisbon to his correspondent at Paris states that: “The air there had seemed heavy with a reddish and unhealthy fog at sunrise and at sunset in the last days of October. At the eve of All-Saints, one noticed some light tremors that were forerunners of the shock that was felt the day afterwards at 10 o’clock in the morning” (Recueil Fontanieu, pp. 341-348).

A series of thirty-three letters from members of the German merchant community at Lisbon dealing with their experiences and doings on the fatal day of the earthquake and afterwards were collected and printed in the *Hannoverisches Magazin* between August 9 and September 27, 1779. This late publication shows the deep impact that the earthquake still had more than twenty years after the event. One of the letters dated “In Campo, 1st November 1755” tells the story of the earthquake and explicitly mentions the stinking fog earlier in the morning: “[...] it was a quite clear day which I didn’t expect this morning by 6 and 7 o’clock as by that time there was a really thick stinking fog, and I was already worried, as I got up, that we would have cold and wet weather during our agreed ride, but around 8 o’clock it cleared up and it became a real pleasant weather, and the sun shined so hot as she can only shine in the summer”.

RAPIN (1757) witnessed the calamities at Lisbon. He published a book in Liège, capital of the Prince-Bishopric of Liège, expressing his ideas on the nature of the earthquakes, his personal account of the event and also a relation on what occurred in Cadiz. The weather on the fatal day is described as follows: “On the 1st November, All Saints Day, at sunrise a thick fog dominated over the whole town, and apparently over all surroundings, but as the very scorching rays of the sun dispersed it, the air seemed to evaporate, and a great many persons complained and one could only breathe with great difficulty, of a kind of exhaustion in which they were dozing despite themselves. The sea seemed itself moved by the great calm that reigned at that moment what seemed all the more so extraordinary to the sailors as they were used to see, especially at daybreak, a land wind that usually favoured the entry or exit of the harbour to the vessels”.

Thomas Jacomb, a merchant, mentioned that: “On the 11th November 1755, several accounts of Eruptions in the Earth especially at Sintra near the Rock where much Flames and Sulphur were seen to evaporate” (MACAULAY 1946). LOPEZ DE AMEZUA (1756) described the weather at Madrid as follows: “The first of November, at daybreak, the same [north-west] wind still reigned, although with less violence. The sky was enough clear; the sun was only disturbed by a few clouds which, not covering it entirely, made its light from time to time a little bit pale”.

Fiery red sunrises and sunsets were reported in various parts of Europe and over the Atlantic from November 1755 to January or February 1756. In Cornwall,

England, on 1 November 1755 the sky full of fiery red clouds, in the afternoon becoming “a very odd coppery colour in places”. Flame-coloured glow was noticed till 2 ½ hours after sunset in western Ireland on 1st November 1755 (LAMB 1970). Several optical phenomena indicative of large volcanic eruptions were seen in the Iberian Peninsula (MONTBEILLARD 1761).

MOREIRA DE MENDONCA (1758, p. 237) wrote in his famous memoir on earthquakes: “In several areas was seen a vapor, like thick smoke, that rose out of the ground and caused a great shortness in the light of the Sun, and the Moon. On the eve of the day of the earthquake around five o’clock in the afternoon, I saw, with great fright from under the portal of the Church of Our Lady of Graces, this town covered by a kind of dark yellow fog that caused me some surprise for its thickness and colour”.

The *Gazeta de Lisboa* of February 5th, 1756, wrote: “Alaquero [Portugal] 11th February. On the first day of last year’s month of November, by nine and a half o’clock in the morning, blowing an almost insensitive wind from North-east, and the horizon of this Village being clear from clouds, the atmosphere was suddenly occupied by a tenuous and futile vapour, that made the Sun appear pale, and it was perceived an uncommon heat, in the present season”.

MOREIRA *et al.* (1993) mentioned further “unusual gas exhalations (a kind of fog)” at Alcalá, Spain, several days before the earthquake (WOERLE 1900). In the inquiry ordered by the Marquis de Pombal after the catastrophe sulphur or sulphurous gases were mentioned in the district of Aveiro (COSTA 1956, RUNA & MORAIS FREIRE 1987, MOREIRA *et al.* 1993):

[...] although some that were warned by the first revolution of the trembling say that they felt a sulphurous respiration, or mineral but as there is no greater evidence that justifies the news, nothing more is added to the story (*Freguesia de Nossa Senhora da Apresentação*).

This memorable day showed up in the serenity of time that for sure did not allow to anticipate the unfortunate events that happened, since this very same quietness has deceived almost everybody; all of a sudden, from 9 to 10 o’clock in the morning the air thickened with a color never seen as it did neither imitate at all shadow, nor by being morbid, it was heard from the North... (*Freguesia de S. Miguel*).

[...] the Lamps were in a continuous movement and all was making such formidable spectacle that each one was thinking about the end of his life: it was felt a fetidness of sulphur; however by the infinite goodness of the Lord none of our houses fell, ... (*Concelho de Vagos, Freguesia de Covão do Lobo*).

Similarly, in the aftermath of the 1755 earthquake, King Fernando VI of Spain ordered an enquiry to know the damages due to that earthquake. A large part of the information in Galicia came from the southern part of the region, this is the area adjacent to Portugal. In the Provincial Archive of Orense, Galicia, the information from the jurisdiction of Celanova (Orense) contains the following (fig. 2): “During and after the trembling it was perceived the Atmosphere be covered by a dense vapour as a thick smoke, that obscured — the sky being clear and without

clouds — as if it was an almost total eclipse, the Light from the sun leaving its rays well scarce, and its Light pale. Those vapours still remain today as a smoky fog that at a certain distance hide or obscure the objects even if they are big enough, certain signal that the earth vomits by its pores and mouths the malign smells of the subterranean exhalations that cause so many movements in its fetid body, as after the big earthquake it were observed ten or twelve momentaneous...” (11-XI-1755).

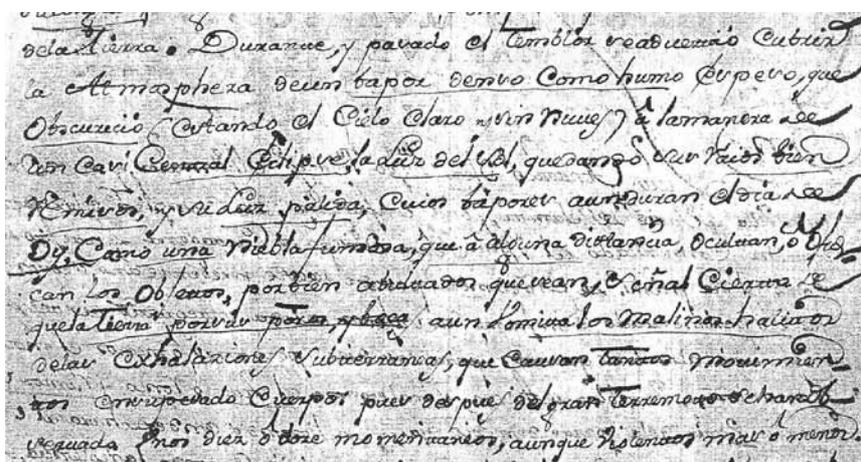


Fig. 2. — Detail of the text from the Provincial historical Archive of Orense, Galicia, mentioning the thick fog that obscured the light of the sun.

More difficult to be related to the Katla volcanic eruption is the snowfall that was mentioned in the same enquiry in three villages of the Orense Province (South of Galicia): “... the night of the day (18th October 1755) with the occasion of falling a copious snow...” (*Jurisdicción de Viana do Bolo*, 11-XII-1755), “Only if, more or less fifteen days before the mentioned earthquake it fell so much snow in this Valley and its surroundings, that ruined the most part of trees, ...” (*Jurisdicción de Conso y sus cotos*, 12-XII-1755), “... Sunday (20th of October) in which the most part of the fructiferous and no fructiferous trees awoke without branches in the whole of this country, of which resulted a very considerable ruin with little snow that was seen on that day of twenty October” (*Villa de Orrios y su Jurisdicción y Partido de Souto Vermud*, 5-XII-1755). It is questioned if this snowfall late October is an exceptional phenomenon or related to disturbances in the atmospheric circulation patterns due to the large amount of tephra in the atmosphere. Is it comparable to the remarkable frost observed in England (CULLUM 1784) on June 23, 1783, a few days after the Lakagígur eruption?

#### 4. Earthquakes, Volcano Eruption in Iceland and Tephra Fallout in October 1755

Katla volcano, located near the southern end of Iceland's eastern volcanic zone, is hidden beneath the 200-700 m thick Mýrdalsjökull ice cap that fills a caldera of about 70 km<sup>3</sup>. It erupted in historical times, on average, twice a century producing damaging glacier-outburst floods, or jökullhlaups, whose peak volumes can be compared with the River Amazon.

On September 10, 1755, heavy earthquakes started to occur in northern Iceland, but most violently near Húsavík and on the island Flatey (THORODDSEN 1925). What follows is taken from the account of several natural scientists who witnessed the earthquakes at the farm Höfði in Skágafjarðarsýsla in northern Iceland (Anonymous 1758). The first shock was noticed at 8 o'clock in the morning as a relatively strong movement of the ground. It was moving five or six times at either side, but without damage. At 9 o'clock another movement occurred much more intense than the previous one and also all later ones. Much noise was also heard. The earthquakes lasted for six days. Before the beginning of these earthquakes there were about fourteen days of fair weather without much wind, which is very unusual at that time of the year. This may in a certain way agree with what the old people in Iceland unanimously tell and take for truth, that earthquakes always have brought "thick" air and mild and fair weather.

The earthquake had its largest effect on the uttermost headlands rather than on the mountains that are situated inland of Iceland. From this the natural scientists concluded that the earthquake's epicentre was situated at sea. They further believed that the earthquakes were connected to the Katla volcanic eruption that was to come.

Katla erupted on 17 October 1755. It started with incessant earthquakes before noon. An enormous *jökullhlaup* started in the evening and lasted all night. The southeastern part of the Mýrdalssandur outwash plain was flooded. This time, the *jökullhlaup* seemed to be more devastating than previous ones in 1625, 1660 and 1721. The *Annals of the Katla eruptions* mention that farms were destroyed due to flooding, tephra fallout, sand and pumice stones. Both grass and bush disappeared under ash which led to the abandonment of about fifty farms, and all farms in the western Skaftafellssýsla County were heavily damaged. In the vicinity of the volcano the thickness was four to six feet deep in cavities in the gardens whereas in the farthest areas from the volcano it varied from one or two feet on flat surfaces.

On October 18, 1755, the earth was like stunned and the sky full of clouds and fog so that one could not see the mountains but lightnings flashing through darkness accompanied by frequent roaring, bangs and earthquakes but not as strong as on the first day. The eruption produced much ash that was brought over most of the country, and brought also over a long distance at sea. The lack of visibility was vividly described as follows: "Smoke, sand and ash that

the mountain throws out fill the air in such a way that the sun's rays and the daylight could not penetrate. Three Danish miles away from the mountain, when there was no wind on the 22nd and 23rd October, it was never more than half illuminated, and on the 24th one had to light the houses from 2 o'clock in the afternoon. Where it was windy, the ash and the sand fell down in streams like the most intense rain, and caused such a darkness that people who went together in the fields were not able to see each other, and had to take hands of each other for not getting separated. [...] At some places the darkness was told to have been lasting for 8 days. The strong wind in the mountains had already spread a layer of as far as Mùlasýsla, 50 Danish miles away, so that travellers could not find the road and had to wait, and in the houses at midday they could not see the smallest daylight".

A letter, dated Edinburgh, 10 Feb. 1756, mentioning black dust came from a passenger on board of the ship belonging to Mr David Loch, merchant in Leich, and bound for Charlestown in South Carolina: "We are informed, that upon the night of the 23rd or 24th of October last, when the weather was quite calm, a shower of dust fell upon the decks, tops and sails of the ship, so that next morning they were covered thick with it. The ship at this time was betwixt Shetland and Iceland, about 25 leagues distant from the former, and which was the nearest land. The shower was probably owing to the great eruption, which happened to the mountain Hecla in Iceland, in October" (WHYTT 1757).

Tephra fallout was noticed on the Shetland Islands as was reported by a letter dated Pall-Mall, June 9th, 1757: "[...]; only on Monday the 20th October last, betwixt the hours three and four in the afternoon, the sky being very hazy, as it uses to be before a storm of thunder and lightning, there fell a black dust over all the country, tho' in greater quantities in some places than in others. It was very much like lampblack; but smelled strongly of sulpher. People in the fields had their faces, hands, and linen, blackened by it. It was followed by rain. Some people assign the cause of it to some extraordinary eruption of Hecla. Several other persons of credit and reputation had seen and observed the same phænomenon in different parts of the country at the time above-mentioned" (MITCHELL 1758). The wind direction at the time of the black dust was from the SW.

Another source of tephra fallout came from the captain of a ship travelling in the second half of October 1755 from Husavik in northern Iceland to Europe (most probably Copenhagen): "After reliable reports, one has not perceived anything of this earthquake on the southerly coast of Iceland. However, a sailor whom with a Company ship, has arrived here from the above-mentioned Husewig district, has brought a kind of earth dust or sand that on his inward travel on the 26th October, fell on his ship in quiet weather, in the area of the Faeroes. One believes therefore, that maybe the fire-breaching mountain Hekla, on the island Iceland, got a new outbreak" (J.H.R. 1756, p. 47).

## 5. Historical Black Clouds and Dry Fogs

During historic times European and Icelandic volcanoes erupted large volumes of ash, some of its appearances were noticed all over Europe and are known as “Dry Fogs”. Dry fogs could have the appearance of dark black clouds providing a most dreadful impression (VON HOFF 1840-41). It was quite evident that the appearance of such a cloud was interpreted as an omen of the worst.

An example is the Etna eruption of 44 BC known from the classical authors and contemporaneous to the murdering of Julius Caesar. Mestrius Plutarchus (c. 46-127), better known in English as Plutarch, wrote in his “Life of Julius Caesar”, 69, 3-4: “[...] and the dimness of the sun, whose orb continued pale and dull for the whole of that year, never showing its ordinary radiance at its rising, and giving but a weak and feeble heat”.

The best-known example of a dry fog episode is given by the Lakagígar eruption of the year 1783 (GRATTAN & BRAYSHAY 1995, STOTHERS 1996, DEMAREE *et al.* 1998, DEMAREE & OGILVIE 2001, PISEK & BRAZDIL 2006). Around Midmorn on Whitsun, June 8th of 1783, in clear and calm weather, a black haze of sand appeared in the Sida area of southern Iceland. The Lakagígar, the Laki fissure or also named the *Skaftáreldar* or Skaftá Fires, volcano eruption had begun. Soon after, a haze was spun out like a veil over much of the Northern Hemisphere, persisting for periods up to three months and more. This phenomenon was also witnessed at Lisbon as it is shown in the following lines.

Jacob Crisóstomo PRETORIUS (1785), an early Portuguese meteorologist, reported: “But what makes this year [1783] more remarkable among many passed, was the misty summer weather. Since 22 June till 6 July it occurred during 14 days a permanent fog, day and night, and for a short time after since 12 July till 20 it happened all the same for an 8 days interval: and what is still more to retain, the same foggy weather reigned in the most part of our Boreal Hemisphere. Despite this continuous mist, and some fogs, the whole Summer was very dry: it can be said extraordinary that for a period of 70 days, since 19 June till 27 August it did not rain, apart that small humidity of the mentioned fogs: although this lack of rain was afterwards compensated, ...”. However, Pretorius did not make any relation to similar occurrences on the occasion of the Lisbon earthquake of November 1755.

As the Lisbon earthquake occurred soon after the large Katla volcanic eruption in Iceland on October 17, 1755, and tephra fallout was demonstrated on the Shetlands and over the Atlantic Ocean, it was suggestive to search for descriptions similar to Pretorius’ observations.

## 6. Earlier Tremors, Tsunami and Seiches

Apparently, several contemporaneous authors mentioned earlier tremors the day before the fatal earthquake. Similar conclusions might be drawn from the

unusual state of the River Tagus in the early morning of All Saint's Day. It might be hypothesized that this unusual state of the river is due to seiches caused by these tremors that were hardly felt by the Lisbon people.

He also said that the Tagus has had a considerable rise in the water level that had preceded the earthquake, ... (Recueil Fontanieu, p. 351).

Yesterday, first day of November, at about nine o'clock in the morning, one came to tell me that the Tagus, prodigiously swollen, attracted the attention of a great number of people. The one that brought me this news, didn't have the time to speak, when I felt the wooden floor of my room tremble under my feet (Anonymous, s.l.n.d.).

LOPEZ DE AMEZUA (1756) noted at Madrid: "In the night of the last day of October, a horrible wind blew from the north-west. Religious figures and some individuals [...] assured that they felt some tremors at midnight".

MOREIRA DE MENDONCA (1758, p. 237) wrote: "In the same night, the sea was heard in extreme anger, because the weather was very calm. It was felt a hot air with a heat that the season didn't allow. In this short time the signals of great fermentation that was occurring in the interior of the earth, were multiplied".

## 7. Earthquakes, Exhalations and Volcanoes

Until the late 18th century Aristotle's *Meteorologica* still remained the principal source of meteorology (or what was being considered as meteorology by that time). Indeed all sub-lunar manifestations such as winds, earthquakes, thunder, lightning, exhalations, and even falling stars are considered as "meteors". This term is used in that way here. Vapours, named "exhalations", occur in the lower stratum of the atmosphere which is the region where meteors defined by the action of the air including winds, earthquakes, thunder, lightning, etc. are taking place. Under the earth, subterranean caverns full of inflammable gasses, loaded with sulphurous mixtures, nitrous and bitumous matters, etc. strongly interact and explode causing tremors and quakes. Exhalations venture through the cracks. These exhalations are sometimes witnessed as sulphurous vapours and are described to condense as falling stars in the higher regions (ORTIZ GALLARDO DE VILLARROEL [s.d.], JANKOVIC 2000).

By the beginning of the 18th century, several physicists started to make observations and asked the question "whether there follow not great winds, rains, thunder and lightning after the earthquake is over". For centuries, generations of physicists and meteorologists took this sentence as a working programme. The atmospheric conditions preceding an earthquake could be disputed as it turned out quite naturally, but the question was never abandoned. The latter consequently provided plentiful of weather descriptions (VON HOFF 1840-41), data now treasured by the historical climatologists. It was believed that earthquakes generally

begin with calm weather, and a black cloud. And when the air is clear, just before an earthquake, yet there are often signs of plenty of inflammable sulphurous matter in the air (JANKOVIC 2000).

BONI (1756) dealing with historical and philosophical account of the doleful events of the year 1755 stated that: “The air then cleared from dimness and fogs, and also anticipates earlier the tremblings many times, and we have the example of this in the earthquake fatal to Lisbon and to the rest of Portugal, and so widely spread over Spain, and over a so large part of Europe; ...” All these “meteoric” actors were noted at the Lisbon earthquake, true or not true.

RAPIN (1757) saw the subterranean fires as the origin of the outbreak of the fires in the destroyed town after the shocks. “One wasn’t able to witness, because of the clearness of the day, that by its openings the earth vomited fires which set afire the combustibles of several houses, [...] from where a thick smoke, that could be seen in other places, announced together with the impetuous winds which suddenly arose, the general fire of the whole town”. However, most probably, the falling of burning candles or kitchen fires under the churches and houses caused these fires. Indeed, a large part of the population was in the churches and monasteries to celebrate the religious festivities of All Saints’ Day. RAPIN (1757) following the scientific theories of his time wrote: “The Earth that had opened itself under the foundations of the houses of the town, vomited at the same time bituminous and sulphurous matters, which catching fire by syncope, in the openings or otherwise the cracks, exhalations evaporated that weakened the strongest hearts”.

MOREIRA DE MENDONCA (1758, p. 260) wrote: “Fiery raging winds developed from the many dry exhalations that carried the earth, these are produced by the fire that is in movement indicating sufficiently the proximity of one or the other tremor of the earth”. The last words of this treatise are the following: “This signal has ambiguity. It is true that the last earthquake was preceded by strong winds in the previous summer. But what concerns these winds, it is true that since more than one year they were observed as stormy over the whole Kingdom of Portugal and its coasts. These are the signals that were noted by various authors. I have exposed the causes according to my own system”.

In Spain, in the neighbourhood of Córdoba, the Spanish correspondant of the *Journal Etranger* noted: “The earth melted in a mountain by Luque, a small neighboring town, and it comes out of this crack a stinking exhalation that makes die the animals” (*Journal Etranger*, 1756).

## 8. The Traditional Religious Views vs. the Enlightenment

The occurrence of minor earthquakes that struck London in February and March 1750 left a terrorizing effect on the English population that was by that time considering earthquakes rather as rare and abnormal events (KENDRICK

1957). These earthquakes raised their attention and when, five years later, the Lisbon earthquake took place, it immediately had an immense response in England, the traditional ally of Portugal.

The hypothesis of the wrath of God for the sinful way of living of people was one of the features in the literature that was occasioned by the dreadful Lisbon earthquake. Of course emphasis and views were different according to the authors whether they were Roman Catholics, Anglicans, Lutherans (in the Netherlands). In non-Roman Catholic media the brutal and bloody actions of the Inquisition in Portugal were denounced as one of the factors of the wrath of God.

One of the key players in the debate was without doubt Voltaire (François-Marie Arouet, 1694-1778) who, shortly after the earthquake, wrote his famous poem in which he expressed his deist vision of the world and where God is not seen as much as an actor but rather as a spectator of what happens on this earthy floor. One of the interesting voices was the French Jansenist Laurent-Etienne Rondet (1717-1785) who claimed a justification of the Lisbon earthquake as Portugal being one of the countries where the Jesuits were very welcome. As a matter of fact, the Marquis de Pombal, the dictator who emerged from the earthquake, shut down the Jesuit order in Portugal in 1762. Rondet wrote a two-volume treatise in which he tried to prove with biblical texts that all meteoric appearances could be seen as prognostications.

Rondet dedicated his work with the quotation “He (= The Lord) looks at the earth, and it trembles (Psalm 104: 32)”. The movements of the waters were explained as signs that redemption was near: “On the earth, nations will be in anguish and perplexity at the roaring and tossing of the sea (Luke, 21: 25)”. According to the Bible, the waters represent the people: “The waters you saw are peoples, multitudes, nations and languages (Revelation 17: 15)”, “He turned rivers into a desert, flowing springs into thirsty ground, and fruitful land into a salt waste, because of the wickedness of those who lived there (Psalm 107: 33-34)“.

It is clear that the traditional views on the causes of the Lisbon earthquake collided directly with those of the Enlightenment. The Enlightenment scientists were putting more stress on “observation”, “scientific evidence” and “change”. However, the debate was still influenced by the Aristotelian view on earthquakes and one had to wait until new theories emerged. As a matter of fact, the Lisbon earthquake served as a laboratory for new seismological concepts. Authors like Emmanuel Kant, Elie Bertrand, John Bevis, John Mitchell, and others, soon published on the subject.

## 9. Conclusions

The Lisbon earthquake of November 1, 1755, is without doubt one of the most important landmarks of the 18th century. Not only was it one of the earthquakes

that has left a very deep impression on the general public in Western Europe by the size of its destructions but also by the blow that the catastrophe caused to the optimism of the Enlightenment philosophy. Immediately, a large number of letters, papers, pamphlets, books dealing with scientific, religious, political, philosophical aspects, or merely of an informative character, were published.

The authors have put together a number of quotations out of these contemporaneous publications of the earthquake related to the “meteoric” observations of the Lisbon earthquake. In these quotations, there is several times mention of the appearance of a dark cloud, smell of sulphur and even of a yellow fog or smoke.

In many cases, these mentions are in line with Aristotle’s *Meteorologica* that was still largely the surviving scientific theory at that time. Another interpretation came from the religious point of view where the appearances dealing with sulphurous events were related to prognostications from the Bible. In this view, the earthquake was often seen as the wrath of God.

All these mentions are rather difficult to interpret and much caution should be given. It is not always clear if the authors write what was consistent with the dominant scientific and philosophical theory of their times or if it corresponds to factual information. However, the authors of the present paper are inclined to accept that part of the information does correspond to facts. As Aristotle’s *Meteorologica* belongs itself completely to the reign of the History of Science, another explanation had to be sought. It is suggested that these observations are related to the Katla volcanic eruption in Iceland of mid-October 1755. Black dust fallout has been reported in the Shetlands and over the Atlantic Ocean by late October 1755. Indeed, the timescale of the process of the injection of large amounts of SO<sub>2</sub> gases into the atmosphere, its conversion into sulphate aerosols and the transport of tropospheric aerosols (having a lifetime of one to three weeks) by the atmospheric circulation patterns is largely consistent with the observations on the Iberian Peninsula.

Furthermore, the quotations are widely consistent with the descriptions of the “Great Dry Fog of 1783” corresponding to the Lakagígar eruption in Iceland (DEMAREE & OGILVIE 2001). Of course, the synoptic weather patterns in the second part of October 1755 could provide valuable additional information to strengthen this hypothesis. Unfortunately, the State-of-the Art Sea Level Pressure field reconstructions for the mid-18th century remain monthly (LUTERBACHER *et al.* 2002) and therefore it is not yet possible to demonstrate the full picture of the daily circulation patterns.

#### ACKNOWLEDGEMENTS

The authors express their sincere gratitude to Maria Justina Correia, Instituto de Meteorologia e Geofísica at Lisbon, Maria de Fátima Nunes Ferreira, Universidade de Evora, Ana-Maria Spanoghe, Ghent University, Franca Maria Vacante, Ghent, Magnus Stefansson, Bergen University, Mariano Barriendos Vallvé, Universitat de Barcelona,

Juerg Luterbacher, NCCR Climate, University of Bern, Lina Nordlie, Oslo, Rui Alexandre Pita Perdigão, Royal Meteorological Institute of Belgium, and Thierry Camelbeeck, Royal Observatory of Belgium, for their valuable and precious help in the archival search, translation, editing and reviewing. Thanks are also due to the Historische Drucke at the Staatsbibliothek, Berlin, Biblioteca de la Universidad de Sevilla, Biblioteca nacional de España, Madrid, Universitäts- und Stadtbibliothek Köln, for having provided scans of old printed books.

#### NOTES

- [1] A tsunami is a large wave on the ocean usually caused by a seaquake, a volcanic eruption, or a coastal landslide. It can travel hundreds of miles at large speeds and cause extensive damage when it encounters land.
- [2] A seiche is a standing wave caused by seismic or atmospheric disturbances in an enclosed or partially enclosed body of water.
- [3] A medieval term for the Maghreb after its Berber inhabitants.

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