

## ***Interactive comment on “Effects on the Czech Lands of the 1815 eruption of Mount Tambora: responses, impacts and comparison with the Lakagíggar eruption of 1783” by R. Brázdil et al.***

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We would like to thank Ricardo Trigo for very valuable comments contributing to the improvement of the paper.

1. Major comments 1.1. (Novelty of datasets used and results obtained) It is not entirely clear to readers the level of novelty of the various datasets presented in section 2.2. If I understood correctly all datasets have been described/used in the past, with the exceptions of the documents related to Reverend Simon Hausner and the teacher Noviny pod Ralskem. This is important to understand if the authors have simply used datasets compiled previously (even if often by themselves) or if new datasets were explored within the scope of this particular work. Please clarify. RE: The sections 2.1 and

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2.2 related to data was newly re-elaborated. Using of all data available for the analysis of the Tambora eruption is new because we did not yet worked with this topic. Some of these datasets were already reported or elaborated in some other publications (i.e. in referee's understanding "dataset compiled previously"), but with other aims than in this topic. Other data were not yet published, but were extracted during the systematic historical-climatological research running for couple of years in our institute. The new paragraphs 2.1 and 2.2 were changed as follows: "2.1 Instrumental data The climatological analysis herein is based on the following monthly, seasonal and annual temperature and precipitation series for the Czech Lands (Fig. 1): (i) Prague-Klementinum (central Bohemia): homogenised series of temperatures (1775–2010) and precipitation (1804–2010), starting in a block of buildings that were once the Jesuit college of St. Clement, and located on the same site until quite recently (for data see Brázdil et al., 2012a) (ii) Brno (south-eastern Moravia): homogenised series of temperatures (1800–2010) and precipitation (1803–2010) compiled from a number of places in the Brno area and homogenised to the recent Brno airport station (for data see Brázdil et al., 2012a) (iii) Czech Lands: series of mean areal temperatures (1800–2010) and mean areal precipitation (1804–2010) calculated from ten homogenised temperature series and 14 homogenised precipitation series over the Czech Lands (for data and details of calculation, see Brázdil et al., 2012a, 2012b) (iv) Žitenice (north-western Bohemia): homogenised series of temperatures (1801–1829) measured by parish priest František Jindřich Jakub Kreybich at Žitenice (measurements started in 1787 but incomplete before 1801), worked up by Brázdil et al. (2007) (v) Central Europe: reconstructed temperature series (AD 1500–2007), consisting of temperatures derived from documentary-based temperature indices for Germany, Switzerland and the Czech Lands up to 1759 and homogenised temperature series of 11 secular meteorological stations located in these three countries and Austria from 1760 onwards (Dobrovolný et al., 2010).

2.2 Documentary data The pre-instrumental and early-instrumental period of meteorological observations in the Czech Lands is well covered by documentary evidence that

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contains information about weather and related phenomena. It occurs in a number of data sources (e.g. annals, chronicles, memoirs, diaries, newspapers, financial records, songs, letters, epigraphic records, and others), which provide the basis for research in historical climatology (Brázdil et al., 2005b, 2010b). As well as a wealth of chronicles and personal histories reporting various climatic and weather anomalies, their impacts and consequences (for those used in this study see Section 4.2), the following sources have proved particularly valuable: (i) Annual summaries of the weather and the general economic situation that accompany the daily weather observations kept by František Jindřich Jakub Kreybich in Žitenice for the years 1815, 1816 and 1817 (S1–S3) (ii) Qualitative daily weather observations and their monthly and annual summaries kept by Reverend Šimon Hausner of Buchlovice (south-eastern Moravia), spanning the 1803–1831 period (S4) (iii) The detailed weather records kept by Anton Lehmann, a teacher in Noviny pod Ralskem, over the 1756–1818 period, which were copied into the local “book of memory” by Joseph Meissner in 1842 (S6) (iv) Notes extracted from meteorological observations kept by Antonín Strnad and Alois David, the third and fourth directors of the Prague-Klementinum observatory (Poznámky, 1977). Moreover, the editions of newspapers published in Prague (Prager Zeitung), Brno (Brünner Zeitung) and Vienna (Wiener Zeitung) covering the post-Tambora years were also systematically scrutinised for 1815–1817. Although weather information appears relatively rarely in their pages with respect to descriptions of events in the Czech Lands or Austria, related stories from other parts of Europe or North America clearly prevail there.”

Moreover, to ensure reproducibility and homogenization of derived datasets it is common for authors to provide all methodological steps on the information and time series derived from documentary sources. Here no such information is provided in section 3 (Methods), underlining perhaps that these are not new datasets (?). Please clarify. RE: Accepted, the new paragraph related to the use of documentary data was added as follows: “In this paper, descriptions of weather and related phenomena in the Czech Lands post-Tambora, i.e. May 1815–December 1817 are derived from documentary data. All such the data extracted were critically evaluated, including analysis

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of source credibility, place and time attribution of records, content analysis, interpretation of records with respect to recent meteorological terminology and cross-checking of records against various different places in the Czech Lands. The creation of a database was the next step, in which information about place, time and event, characterised by key-words, full reports and data sources, has been recorded to provide a basis for further use (see Section 4.2). Kreybich’s records from Žitenice (S1–S3) and Hausner’s observations from Buchlovice (S4) were then further employed for calculation of monthly numbers of precipitation days in 1815–1817 (see Fig. 6).”

It is clear that the authors have a large experience in past-climate analysis, particularly over Czech Republic. Thus, it is expected that all relevant literature for the main topic of this work (i.e. impacts of major eruptions in Czech lands) is provided at the introduction, allowing to stress the novelties that will be investigated here. Thus it is rather strange that the first time a key reference evaluating the impact of major eruptions in the mean Czech temperature region is mentioned only at the end (Page 11), and not in the introduction (Mikšovská et al, 2014). Please clarify. RE: The new paragraph related to effects of volcanic eruption in the Czech Lands was added in Introduction part as follows: “There are only a few studies that address the effects of volcanic activity on the Czech Lands (central Europe). For example, Kyncl et al. (1990) analysed climatic reactions and tree-ring responses to the Katmai eruption (Alaska) in 1912, largely on a central European scale. Brůžek (1992) studied the impacts of large 19th–20th-century volcanic eruptions upon temperature series at the Prague-Klementinum station. Brázdil et al. (2003) described a number of extreme climatic anomalies following the 1783 Lakagígar eruption (Iceland) in the course of an analysis of daily weather records covering 1780–1789, kept by Karel Bernard Hein in Hodonice, south-west Moravia. Písek and Brázdil (2006) used temperature records from Prague-Klementinum, together with other central European series (Kremsmünster, Vienna-Hohe Warte and Germany), to address the temperature effects of seven large tropical eruptions and nine eruptions in Iceland and the Mediterranean, complemented by short descriptions of the Lakagígar 1783 and Tambora 1815 events based on documentary data. This paper also

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included the effects of three tropical eruptions on series of sums of global radiation for the Hradec Králové station (together with Potsdam in Germany and Skalnaté Pleso in Slovakia). Brázdil et al. (2010) analysed climate and floods in the first post-Lakagígar winter (1783/1784) with particular reference to central Europe. Volcanic forcing was also taken into account as part of an attribution analysis of Czech temperature and precipitation series by Mikšovská et al. (2014) and in Czech series of spring and summer droughts by Brázdil et al. (2015b).”

1.2. (Lack of statistical significance inference of several results). There are a number of interesting results describing weather/climate extremes that may be associated to the effects of both eruptions in the climate of the Czech Lands. However, many times the descriptions are not accompanied by a more robust statement on the statistical significance (or uniqueness) of the so called-extreme event. A few examples of that are highlighted here: RE: Looking on the character of documentary evidence, when, in many cases, we are not able to create any series of quantitative values, it is very difficult to say, how the event was unique or what is his statistical significance. We are able only to say, that it was sure any extreme event (looking also on experience of contemporaries) which was worthy of interest and from this reason it was recorded, i.e. for memory of people for the future.

a) (Page 4, lines 33-36): “A message from Litoměřice dated 9 August reports a flood lasting eight days on the River Elbe after five weeks of rainy periods. The water rose to a level of two feet [c. 65 cm] under the bridge, so the structure survived, but grain, vegetable and other field crops were damaged (Katzerosky, 1895).” How exceptional is this situation? How many time has it occurred in the last 300 years? RE: The problem is that documentary data usually give for some particular place incomplete data with emphasis on really extreme events. From this point of view we are sure that it was severe flood when water went more than half a meter above the bridge. But to say, for example, how many times it occurred during the past 300 years (it is to calculate any N-year re-occurrence period) is practically impossible. Moreover, systematic water-level

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measurements started at Litoměřice since 1851, it is any more exact comparison is not available.

b) (Page 5, lines 8-10): “The ice was definitely gone by 8–9 March (S2). Lehmann reports a 3/4-ell [c. 58-cm]-thick crust of ice on some fields in Noviny pod Ralskem (S6). Frosty weather prevailed in March with blizzards from 26 to 31 March. April was cold and dry, with no heavy rain (S4).” Again, to what extent are these descriptions unique in the longer term context? RE: We are just describing weather course or interesting weather (climate) anomalies/events which occurred after the Tambora eruption and which we know from instrumental records and documentary evidence. This means that we are not reporting if every such message is unique in the long-term context or not. Where it is possible, we are trying to explain it (see e.g. your point c) below) what is, for example, question of temperature and precipitation anomalies (see Section 5.1).

c) (Page 6, lines 5-8): Kreybich, the Žitenice cleric, reports four landslides in spring, the result of extremely wet conditions in north-western Bohemia: the first on Křížová hora Mt. north of Žitenice, the second on Trojhora Hill between Chudoslavice and Třebušín, the third at Vitín near Malé Březno (community now defunct) and the fourth east of Jílové (S3). Are landslides very rare in the area? How often do these occur? RE: Following text, characterising landslides described, was added: “ Five landslides in 1817 in north-western Bohemia, which are not included in the historical catalogue of landslides by Špůrek (1972), are the three most important events of this kind to appear in documentary evidence before 1900. Other recorded documented landslides in this area took place only in 1770, as a result of the very wet and rainy year of 1769, and in winter 1769/1770 (see e.g. Raška et al., 2016) and in 1897–1900, due to persistent wet and rainy patterns (Rybář and Suchá, 2000).”

1.3. (The choice of Tambora vs Lakagígar is not clear). It is not clear to readers the choice of these two eruptions that are so different in their characteristics, location, impacts, etc. A more straightforward approach would be to consider several major tropical explosive eruptions (as those listed in Fischer et al. 2007) or, alternatively, major erup-

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tions in high latitudes (particularly in Iceland). Besides taking place roughly with 30 years apart, it is not entirely clear the rationale for the combined assessment. Please clarify. RE: The paper is reduced only on Tambora eruption and its consequences. Parts related to Lakagígur were deleted.

Please notice that the differences between the two types of eruptions are so large that they have implications in the literature cited (that can be quite different) and even way their impact is evaluated. In particular the definition of month 0 (and in fact year 0, 1 and 2) is quite unclear to me in the case of the eruption of Lakagígur that took place between (1783 and early 1784). Please clarify

RE: Part of the manuscript related to Lakagígur was deleted.

2. Minor suggestions/comments 2.1. (Page 3, sections methods) Please provide 1 or 2 references to support the various options explained, particularly the 5+5 years used before and after the eruption. RE: Accepted, we add following sentence with some quotations: “The climatic effects of the volcanic eruption based on instrumental observations are expressed in the short-term and long-term contexts. In the short-term, the approach followed is that taken by several other papers addressing the effects of eruptions on temperature series (e.g. Sear et al., 1987; Robock and Mao, 1995; Kelly et al., 1996; Písek and Brázdil, 2006; Fischer et al., 2007).”

2.2. (Page 3, end of section 4.1) I think that this section would gain with a sentence explaining that major tropical eruptions (e.g. Tambora-1815, Krakatoa-1883, Pinatubo 1991) have the capacity to alter the radiative balance for the entire world, impinging widespread cooling at the surface level of the globe, but often inducing large-scale changes in the atmospheric circulation that can warm the continental areas in winter (see carefully Robock 2002, Science). RE: Accepted. Because of the comment of the referee 1, we had to move small Section 4.1 to Introduction. In the first paragraph of Introduction we included two sentences, following your request: “The effects of large tropical volcanic eruptions on radiative balance manifest themselves not only

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in widespread cooling, but also contribute to large-scale changes in atmospheric circulation, leading to one or two post-volcanic mild winters in the Northern Hemisphere (Robock, 2000). Fischer et al. (2007) associated volcanic activity with a positive phase in the North Atlantic Oscillation (NAO), causing stronger westerlies in Europe and wetter patterns in Northern Europe.”

2.3. (Page 3, sections 4.1) The term VEI has not been described before. Please provide its meaning here when it appears for the first time (Volcanic Explosivity Index, VEI). It would be also useful to give a range of its scale between 1 and 8 (and a glimpse of the logarithmic nature of its scale, thus emphasizing the much larger volume of lava associated to a VEI-7 when compared to a VEI-6). RE: Corrected. Explaining text related to VEI was added as follows: “The volcanic eruption of Tambora (Lesser Sunda Islands, Indonesia) in April 1815, is among the most powerful of its kind recorded, classified at an intensity of 7 in terms of Volcanic Explosivity Index (VEI) (a relative measure of volcanic explosiveness, VEI is an open-ended scale that ranges from 0 to 8, where 8 represents the most colossal events in history. It is based on the amount of volcanic material ejected and the altitude it reaches – see Newhall and Senf, 1982).”

2.4. (Page 4, lines 1-2, Fig. 2) The 5 lines used in Fig.2 are very similar and it is not clear the exception mentioned for Brno as being particularly milder than the others for the winter 1816/1817 (?) RE: Accepted. Because it is not clearly visible in Fig. 2, the formulation were modified to make this point more clear: “After a very mild winter of 1816/1817 (the mildest in the 1811–1820 period in four series; only winter in Brno 1814/1815 was slightly warmer), negative anomalies occurred, especially in spring with the strongest negative anomaly (stronger than in summer 1816).”

2.5. (Page 4, Section “The year 1815”) Are the author implying that the “cold May 1815 with more frequent rain and frosts on 29–30 May” are related to the Tambora eruption? And the same doubt applies to the reference to the fruit trees eaten by caterpillar. RE: We are not implying, that any events described are direct effect of Tambora eruption. We are just describing weather or interesting weather (climate) anomalies/events which

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occurred after the Tambora eruption and which we know from instrumental records and documentary evidence. Sentence about “eaten fruit trees by caterpillar” is included because it had influence on bad harvest of fruits which were important part of nutrition for people.

2.6. (Page 4, Section “The year 1815”) Are the authors implying that the “cold May 1815 with more frequent rain and frosts on 29–30 May” are related to the Tambora eruption? RE: See response to the previous point 2.5.

2.7. (Page 6, line 17) Please provide a reference to Fig.6 earlier at the end of the sentence: “. . .driving prices up from 1813 onwards, culminating in 1817 (Fig. 6)”. RE: Corrected as requested.

2.8. (Page 7, lines 33-38) Several specific extreme weather events are mentioned here (e.g. March 1784; April 1785). A number of works for other sectors of Europe have been developed for the years post-Lakagigar, please provide some links to these works in terms of compatibility (or not) of the atmospheric circulation anomalies. RE: Parts of the manuscript related to Lakagigar eruption were completely deleted.

2.9. (Page 8, section 5.2) The contents of this section are not particularly well incorporated into the overall flow of the text. First, this discussion is not structured with Tambora being analysed after Lakagigar (that should be probably the most natural order, but the authors have preferred the reverse from the beginning). Secondly the temporal and spatial link between these various theories (earthquake in Messina 1783, Comet in 1811, Number of sunspots in 1814, etc) is not provided in a meaningful way. RE: Corrected as requested. A part related to Lakagigar was deleted and a part related to Tambora was changed accordingly.

Figures Fig1 Please provide different symbols for stations with different information. For example Prague and Brno should have a distinct symbol. The same apply for those locations with just documentary sources. RE: Corrected as requested.

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Fig3. I believe the figure caption should read: “Difference between mean summer and winter. . .” RE: Corrected as requested.

Fig. 6 It seems that the contents of this figure is repeated in Fig 10 (?) RE: Figure 10 was deleted.

Fig. 7 I believe that the time delimitation of Lakagigar eruption should extend until February 1784. RE: This figure was deleted.

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