An online reporting system for tornadoes, waterspouts and funnel clouds over Greece: http://tornado.geol.uoa.gr

Matsangouras I.T.[1,2] and Nastos P.T.[1]

[1]*Laboratory of Climatology and Atmospheric Environment, Faculty of Geology and Geoenvironment, University of Athens, Panepistimioupolis, 15784, Athens, Greece, john_matsa@geol.uoa.gr, nastos@geol.uoa.gr*

[2]*Hellenic National Meteorological Service, Hellinikon, 16777, Athens, Greece*

Abstract. A systematic effort started in 2007, by the Laboratory of Climatology and Atmospheric Environment (LACAE) at the University of Athens (UoA), in recording tornado activity in Greece. In the fall of 2009, LACAE launched the first online tornado report system, which since then has been settled fully operational. This paper illustrates the methodology of reporting and quality-control procedure of the Greek online Tornado Report System (GTRS).
The main goal of the GTRS is to collect, verify and provide detailed and quality controlled information regarding tornado activity in Greece, using a web based geographical user interface application and homogeneous data reports. The GTRS consists of three individual user friendly steps, encompassing detailed information regarding the type, the exact location, the impact and date of the event. The reported tornado event is subject to plausibility check by a quality control procedure based on cross check with other sources.
The GTRS is an innovative online system for reporting tornado, waterspout and funnel cloud activity over Greece, using a web GIS framework. More than 170 reports (by April 2014) have been submitted to LACAE since 2009, revealing unreported tornado events and contributing to the research of tornado climatology.

Keywords: tornado, waterspouts, funnel clouds, Greece, GIS,

1. Introduction

Tornadoes, waterspouts and funnel clouds could be characterized as some of the most violent small-scale natural phenomena having sufficient intensity to cause loss of life, injuries, significant property damage, and/or disruption to commerce. These phenomena have always been fascinating to mankind and always capture the interest of the media and academic community. In the United States of America, the National Climatic Data Center of National Oceanic and Atmospheric Administration started recording tornadoes in the early 1950s, in order to establish a coherent and homogeneous database of tornadoes, supporting climatological studies in mitigating the tornado impact.
In Europe, the interest in recording tornadoes systematically started in 1974 by Dr. Terence Meaden, who set up the Tornado and Storm Research Organization (TORRO, http://www.torro.org.uk/site/index.php), in his effort to determine with acceptable accuracy the extent to which Britain suffers from tornado damage every year (Meaden, 1976). Similar to TORRO organization another organization was initiated in northern Europe in 1977. The TorDACH (http://www.tordach.org/) was founded by a network of more than 30 scientists from different fields and laymen who collected information mainly on tornado, waterspout and downburst events in the three countries Germany (D), Austria (A), and Switzerland (CH). Hail, flash floods, gustnadoes, funnel clouds, and lightning were also events of interest. The

main objective was to obtain reliable and complete climatological records for these severe local storm phenomena in each of the three countries.

Later in 2000, the vision of European Severe Storms Laboratory (ESSL, http://www.essl.org/) was first presented by Dr. Nikolai Dotzek at the Conference on European Tornadoes and Severe Storms in Toulouse and in 2006 a pan-European database of severe thunderstorm reports in a homogeneous data format, named European Severe Weather Database (ESWD), was launched. The main goal of the ESWD database is to collect and provide detailed and quality-controlled information on severe convective storm events in Europe using a homogeneous data format and web-based, multi-lingual user-interfaces where both the collaborating National Meteorological and Hydrological Services and the public can contribute and retrieve observations (Dotzek et al., 2009). The following categories of severe weather are included in the ESWD at this time: dust devil, funnel cloud, gustnado, heavy rain, large hail, tornado, severe wind, heavy snowfall/snowstorm, ice accumulation, avalanche, and damaging lightning.

Severe weather events hold a special place in the scientific literature, since they might cause fatalities, injuries and damage over Greece. Pytharoulis et al., (2016) studied a flood event in Thessaloniki, Katsafados et al., (2011) presented a numerical simulation of tropical like cyclone that took place over the Aegean Sea in 2004, Nastos and Matangouras (2014) showed the daily composite synoptic conditions for tornadoes and waterspout activity over the western Greece. Regarding tornado activity in Greece, significant publications by individual researchers and academic institutes have addressed the spatial and temporal distribution of tornadoes and waterspouts events during the last years (e.g. Nastos and Matsangouras, 2010; Sioutas, 2011; Nastos and Matsangouras 2014; Matsangouras et al., 2014a). More specifically, Matsangouras et al. (2014a) presented a tornado climatology based on historical data sets (1709–1999) and recent data sets (2000–2012), thus more than 612 Greek tornadic events have been recorded: 171 tornadoes, 374 waterspouts and 67 funnel clouds, within the period 1709–2012. Because a tornado is part of a severe convective storm, and these storms occur all over the earth, tornadoes are not limited to any specific geographic location. The complex topography of the Greek mainland surrounded by the Aegean and the Ionian Sea, are likely to play an important role in creating regionally favorable conditions for severe thunderstorms and convective weather phenomena. Matsangouras et al., (2014b), based on numerical simulations presented that the complex topography constituted an important factor during tornado events of 17 November 2007 (Thebes, Boeotia) and 12 February 2010 (Vrastema, Chalkidiki), based on EHI, SRH, BRN, and MCAPE analyses. However, the study of the tornado event over NW Peloponnese on 25 March 2009, revealed that the topography did not constitute an important factor during the tornado event on March 25, 2009, based on EHI, SRH, BRN, and MCAPE analyses (Matsangouras et al., 2016a).

The Laboratory of Climatology and Atmospheric Environment (LACAE, http://lacae.geol.uoa.gr) at University of Athens has undertaken a systematic effort in recording tornadoes, waterspouts, and funnel clouds in Greece since 2007. LACAE in 2009 launched the first Greek online Tornado Report System (GTRS; http://tornado.geol.uoa.gr), contributing to the compilation of a climatology of these extreme weather events. Since then, LACAE has been actively collecting information on tornadic events (tornadoes, waterspouts and funnel cloud) in Greece. The current tornado reporting system is designed based on Greek language but an updated version is under progress and it will support multilingual users (e.g. English, French, Italian and German). Before GTRS, the recording of tornado and waterspout activity in Greece was conducted by an individual researcher (Sioutas, 2011).

The GTRS consists of three individual steps, encompassing detailed information regarding the type, the exact location, the impact and the date/time of the event. At this time, the following categories of severe weather are included in GTRS: tornado, waterspout, funnel cloud, other event. The submitted tornado report is subject to plausibility check by a quality control procedure, which is currently one of the most important tasks of LACAE. Moreover, LACAE is in close collaboration with ESSL and contributes to the ESWD database with several reports from Greece. Moreover, LACAE has been actively collecting also lightning impacts with a similar approach (Matsangouras et al., 2016b).
The goal of this article is to present in details the GTRS dedicated to record tornado, waterspout and funnel cloud activity over Greece. The outline of the paper is as follows. Section 2 presents the methodology of the reporting practice, while in Section 3 the quality-control procedure is presented. Finally, Section 4 summarizes LACAE's online tornado report system.

2. The Greek online tornado report system (GTRS; http://tornado.geol.uoa.gr/)

A systematic effort was started in 2007, by LACAE at UoA, in recording tornadic activity (TE) over Greece. Moreover, in the fall 2009, LACAE launched the first GTRS, which has been settled fully operational, since then (Fig. 1). The main goal of the GTRS is to collect, verify and provide detailed and quality controlled information regarding tornado activity in Greece, using a web based geographical user interface application and homogeneous data reports. GTRS constitutes an online research tool where researchers and the public contribute and retrieve TE that occurred over Greece.

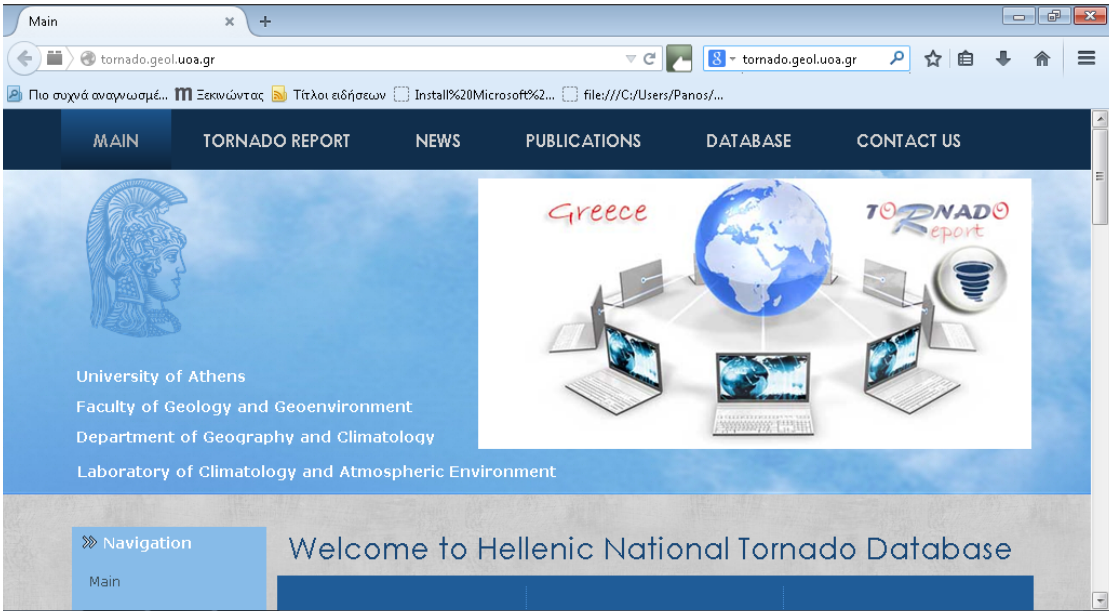

Figure 1. Screenshot of the main home page of LACAE's online tornado report system (http://tornado.geol.uoa.gr).

The GTRS consists of three individual steps, encompassing detailed information regarding the type, location, date, time and impact of tornadic occurrence. In addition, the system provides to the user the ability to: attach media files (e.g. photos, videos), describe in details the phenomenon, add details regarding damage on crops and structures and finally submit his/her contact information for additional clarification during the verification process of every TE.

At the first step of GTRS (Fig. 2a), the simplicity of a Google Map interface is adopted, as the majority of internet users have been familiarized with the use of it. Thus, the user can easily suggest the exact location of TE that took place with a very high accuracy, as he/her can depict the specific area with a detailed zoom. Fig. 2a, illustrates a screenshot (in Greek) of the first step of GTRS. On the left panel of Fig.2a, the geographical location of the event (X sign with red label) is depicted with the usage of the Google map interface and on the right panel the temporal information of the event is illustrated.

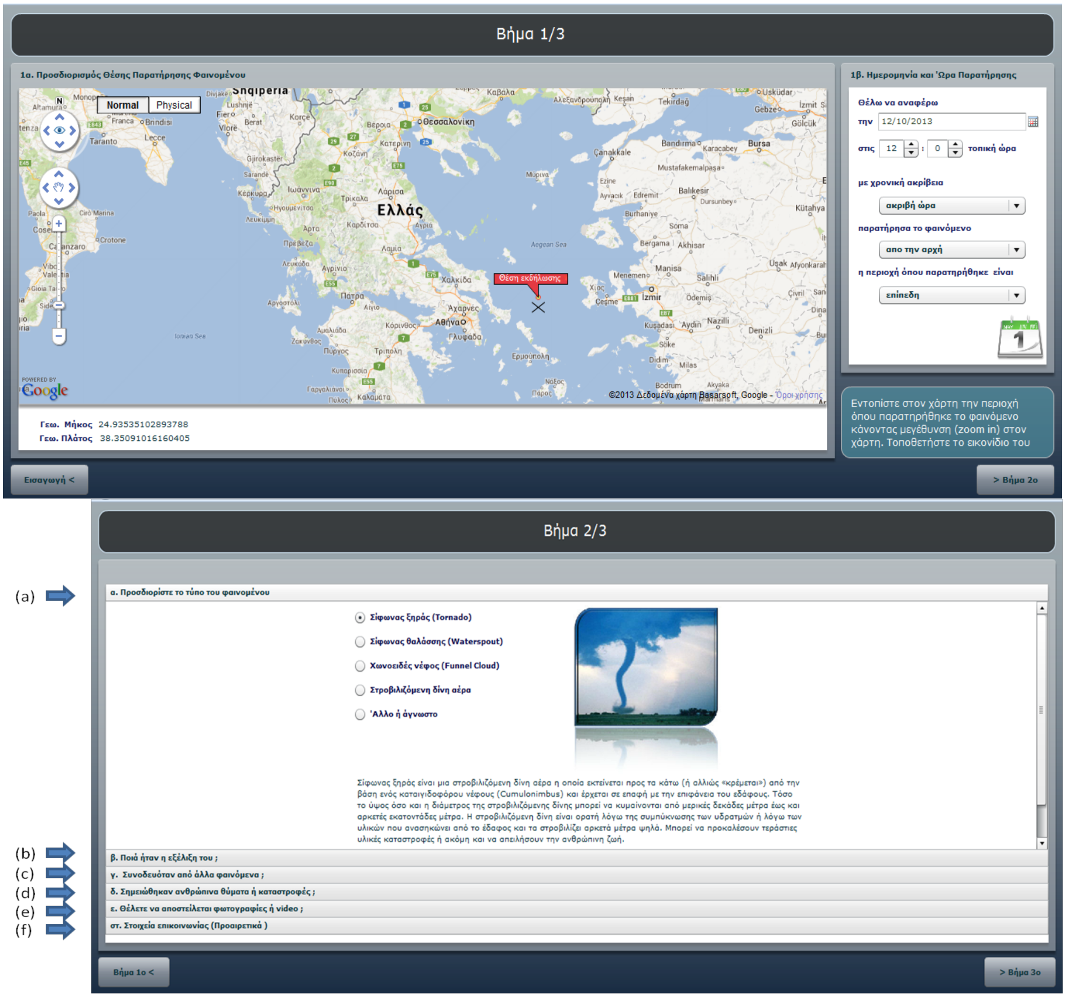

Figure 2. Screenshots (in Greek) of the first step (upper) and second step (bottom) of LACAE's online tornado report system (http://tornado.geol.uoa.gr). The first step illustrates the geographical location of the event with the usage of the Google map interface (left panel) and the temporal information of the event (right panel). The second step illustrates the six subcategories (blue arrows) that can be easily accessed by the user (with one click) in order to: report the type (a), evolution (b), accompanied phenomena (c), fatalities or injuries, (d) to attach media files (e) and submit user's contact details (f).The grey buttons at the bottom of each image navigate user to next and previous step.

Longitude and latitude coordinates, with the accuracy of 12 decimal digits, of the World Geodetic System (WGS 1984) coordinate system, are automatically stored in LACAE's database by clicking the location of the event. Moreover, the user can submit the following information:

- the date of the event
- the time of the event

- the time precision (e.g. ± 15 min, ± 30 min) of the event
- the duration of observation (e.g. if the user noticed the event from the beginning or at the end) and
- topography characteristics (e.g. flat terrain, hilly or mountainous areas) of the terrain.

The second step is characterized as the most important step during tornado reporting procedure, as the user should submit detailed information regarding the type of event, the impact, and can also attach files verifying his/her report. Thus, the second step was designed to be divided into six subcategories, so that each of them can be easily accessed by the user (Fig. 2b) with one click. The user can easily access any subcategory or can be navigated to the first or to the last step within GTRS. The system was designed to have the above-mentioned flexibility, so as for the user to easily review or amend any incorrect information before the final submission without refreshing or moving backward the page.

At the first subcategory of the second step, the user should define the type of the event (e.g. tornado, waterspout, etc), while a detailed definition of the phenomenon is also presented, providing additional help to the user. To eliminate user's uncertainty about the selection of the correct type that he/her had observed, the GTRS supports a submission of unknown type event, which could be categorized later, during the verification process by the administrators.

Fig. 3a and 3b, illustrates screenshots of the second step of GTRS depicting the second, third and forth subcategory, regarding the evolution of the event, the accompanied phenomena, the number of fatalities/injuries and the impact on crops/structures, respectively. At the second subcategory of the second step (Fig. 3a), the user can describe the evolution of the phenomenon and report any similar activity that took place close to that area in the past. At the third subcategory of the second step (Fig. 3b) the user reports the existence of other accompanied weather phenomena like: hail, gale winds, lightning and rain. Significant information regarding the impact and damage can also be reported at the forth sub step of the second step (Fig. 3c). The user reports the number of fatalities and/or injuries caused by the tornadic event accompanied by descriptions of damage on farms, forests, croplands and structures (e.g. roofs, signs, cars, and buildings).

The fifth and sixth subcategories of second step in GTRS are used in the verification procedure that will be described in detail in the following section (Section 3). Fig. 4a and 4b illustrates screenshots of the second step regarding the fifth and sixth subcategory, where the user can upload files, that will verify the reported tornadic activity (Fig. 4a), and his/her contact information (e.g. name, e-mail address) and optionally any additional comments regarding the reported event (Fig. 4b). GTRS supports all format types that illustrate or enclose the reported tornado activity (e.g. pdf, JPEG). A significant amount of images has been collected since 2009, illustrating waterspouts and funnel cloud activity over Greece. Finally, at the last step in GTRS (Fig. 4c) the system provides a review of all inserted information and asks the user to verify that all submitted data are not violating any copyrights of third parties and can be used by LACAE. By accepting LACAE terms of use, an automated report is saved to LACAE's database and a notification email is submitted to administrators. In addition, the attached files (e.g. photos, videos) are stored in a specific folder on LACAE's server that can be easily accessed by a network File Transfer Protocol (FTP).

Figure 3. Screenshot (in Greek) of the second step of LACAE’s online tornado report system (http://tornado.geol.uoa.gr) illustrating the second, third and forth subcategories regarding the evolution of the event (a), the accompanied phenomena (b), the number of fatalities/injuries and the damage impact on crops and structures (c).

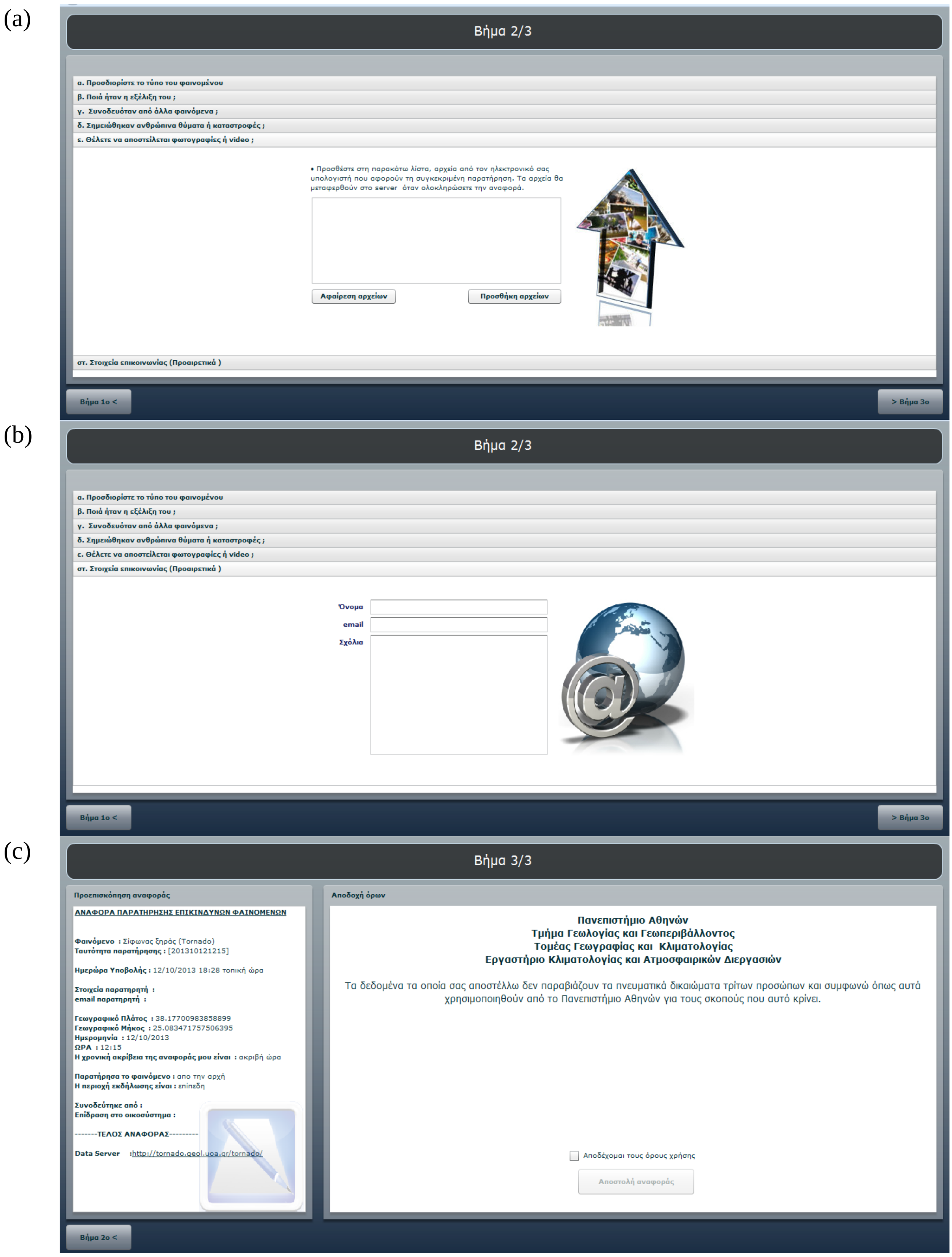

Figure 4. Screenshots (in Greek) of the second step (a, b) and the third step (c) of LACAE's online tornado report system (http://tornado.geol.uoa.gr). The upper image illustrates the fifth subcategory of attaching files, while the middle image illustrates the last subcategory regarding the submission of user's contact information (b). The lower image illustrates a review of the report (left panel) and LACAE's terms of use, highlighting that the submitted data do not violate any intellectual property and can be used by the LACAE (right panel). corner.

3. Quality control of submitted tornado reports

All submitted tornado reports are subject to plausibility check by a quality control procedure, which is currently one of the most important tasks of LACAE. The quality control process is based on cross checks with:

- other individual submitted tornado reports to GTRS
- sources from media (e.g. newspaper, TV, radio)
- the attached files (e.g. images, videos)
- the liability of the user and
- the verified unstable weather conditions.

In addition, quality control process also includes merging multiple submitted tornado reports into one report. Matsangouras et al., (2014a) presented a synoptic flow chart of LACAE's quality control procedure (Fig. 5). More than 181 reports have been submitted to GTRS, but only 168 reports passed the plausibility check. The 13 unconfirmed tornado reports have been remained stored in LACAE's server for future cross check with other sources (e.g. ESWD).

Based on the submitted reports, it is clear that the contributors to this system are forecasters and observers of the Hellenic National Meteorological Service (HNMS), members of the Hellenic Meteorological Society (EMTE), researchers from the Greek academic community and mostly members of weather fun groups.

Using geographical information system (GIS) software, a geo-database has been developed to encompass the stored tornadic reports. The application of GIS software provides not only the ability to add significant information such as disasters, fatalities, dates and other information, but also the ability to produce several thematic layers that could assist the research in specific regions.

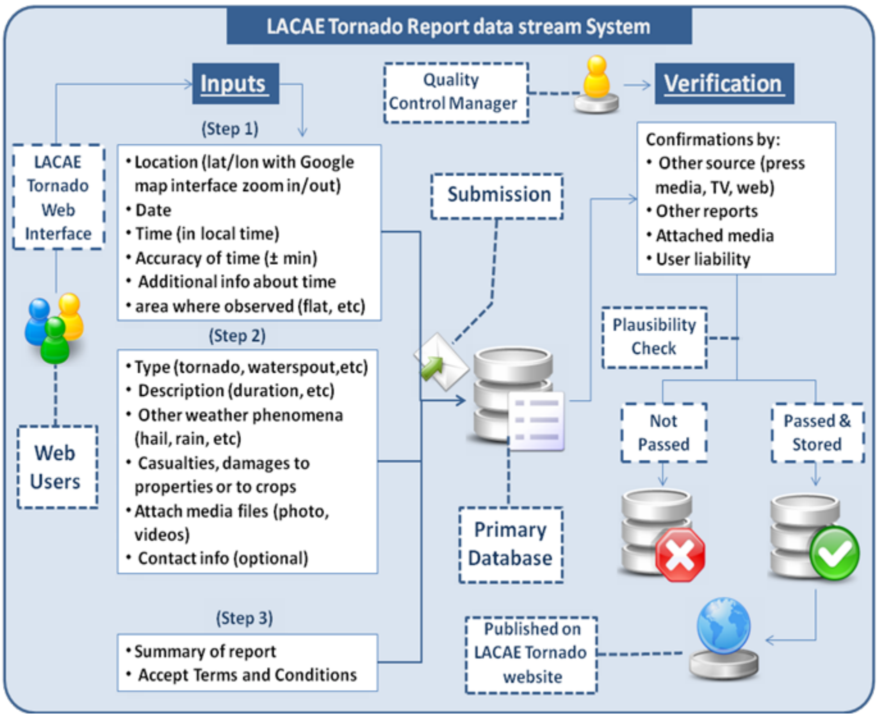

Figure 5. LACAE's flowchart presenting tornado report system and quality control procedure from Matsangouras et al., (2014).

4. Summary

LACAE launched in 2009 an online tornado report system (http://tornado.geol.uoa.gr) in order to support the research on tornadic activity over Greece. The GTRS is the first online reporting system designed for Greek internet users, providing the ability to report any tornadic activity in Greece based on the friendly Google map application.

The GTRS consists of three individual steps, encompassing detailed information regarding the type, the location, the impact and temporal information. The reported tornadic event is subject to plausibility check by a quality control procedure based on cross check with multiple sources (media, ESWD). Moreover, LACAE is in close collaboration with ESSL and constantly contributes ESWD database with numerous verified tornadoes and waterspouts that occurred in Greece.

More than 181 reports have been submitted to LACAE's online tornado report system, but only 168 passed the plausibility check. The 13 unconfirmed tornado reports have been remained stored in LACAE's server for future cross check with other sources (e.g. ESWD).

Future plans concern the development of the second (updated) version of GTRS that will be available to multilingual users and expand the categories of reporting severe weather events introducing, hail, severe precipitation, gusty winds and lightning impact. To this direction, the updated version will be able to illustrate online thematic maps and all events will be easily accessed by individual researchers or public in a compatible format to GIS software or Google earth application.

5. Acknowledgement

The authors thank the Hellenic National Meteorological Service (HNMS), state authorities, media (blogs, news site, TV and radio stations), all Greek weather fun groups and all anonymous people, who contributed to LACAE's online tornado report system.

6. References

Dotzek N., Groenemeijer P., Feuerstein B., Holzer AM., 2009. Overview of ESSL's severe convective storms research using the European Severe Weather Database ESWD (2009) *Atmos. Res.*, 93, 575-586.

Katsafados P., Mavromatidis E., Papadopoulos A., Pytharoulis I., 2011. Numerical simulation of a deep Mediterranean storm and its sensitivity on sea surface temperature. *Nat. Hazards Earth Syst. Sci*., 11, 1233-1246. doi:10.5194/nhess-11-1233-2011

Matsangouras IT., Nastos PT., Bluestein HB., Sioutas MV., 2014a. A climatology of tornadic activity over Greece based on historical records, *Int. J. Climatol.*, 34, 2538–2555, doi:10.1002/joc.3857.

Matsangouras IT., Pytharoulis I., Nastos PT., 2014b. Numerical modeling and analysis of the effect of complex Greek topography on tornadogenesis, *Nat. Hazards and Earth Syst. Sci.*, 14 (7), 1905-1919.

Matsangouras IT., Nastos PT., Pytharoulis I., 2016a. Study of the tornado event in Greece on March 25, 2009: Synoptic analysis and numerical modeling using modified topography, *Atmos. Res.*, 169, 566-583, http://dx.doi.org/10.1016/j.atmosres.2015.08.010.

Matsangouras IT., Nastos PT., Kapsomenakis J., 2016b. Cloud-to-ground lightning activity over Greece: Spatio-temporal analysis and impacts, Atmos. Res., 169, 485-496, http://dx.doi.org/10.1016/j.atmosres.2015.08.004

Meaden GT., 1976. Tornadoes in Britain: their intensities and distribution in space and time. *J. Meteorol.* 1(8): 242–251.

Nastos PT, Matsangouras IT., 2010. Tornado activity in Greece within the 20th Century. Adv. Geosci., 26, 49–51.

Nastos PT, Matsangouras IT., 2014. Analysis of synoptic conditions for tornadic days over western Greece, *Nat. Hazards Earth Syst. Sci.*, 14, 2409-2421.

Pytharoulis I., Kotsopoulos S., Tegoulias I., Kartsios S., Bampzelis D., Karacostas T., 2016. Numerical modelling of an intense precipitation event and its associated lightning activity over northern Greece. *Atmos. Res.*, 169, 523-538. doi:10.1016/j.atmosres.2015.06.019

Sioutas MV., 2011. A tornado and waterspout climatology for Greece. *Atmos. Res.*, 100, 344–356.