STRONG TORNADO AND WATERSPOUT CLIMATOLOGY OF GREECE

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SCOPE AND OBJECTIVES OF THE STUDY

- Strong tornadoes are defined those of an F2/EF2 of the Fujita/Enhanced Fujita tornado intensity scale or T4 of the TORRO scale or greater. Strong waterspouts are considered those associated with severe thunderstorms occasionally moving to land becoming damaging tornadoes equivalent of an EF1 or T2 intensity level or greater.
- Analysis of climatological features of strong tornadoes and waterspouts of Greece, in term of spatiotemporal patterns of frequency of occurrence and intensity levels.
- Probability cluster analysis using the Optimized Hot Spot Analysis tool in ArcGIS and the local spatial autocorrelation statistic Gi*.
- Meteorological conditions associated to strong tornado and waterspout occurrences examined based on synoptic flow patterns and thermodynamic environment parameters.

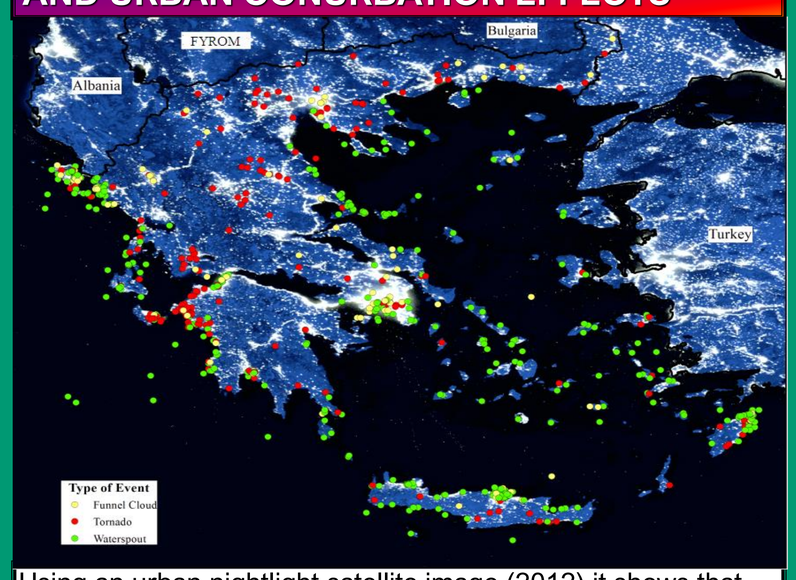
THE GREECE TORNADO DATABASE

- Tornado, waterspouts and funnel cloud occurrence in Greece has been actively recorded for the last 20 years.
- The database includes **date** of event, **location** in latitude and longitude, **time**, **damage** path length and mean **width**, **direction** of movement, **duration** and the **intensity** classification. **Damage description**, eyewitness and sources of information, accompanying phenomena, synoptic data and reliability of the event are also included where available.
- This ongoing initiative, incorporating technological advancements such as time-lapse and smart phone cameras, has resulted in improved observational and reporting opportunities along with quantitative and qualitative improvement in the database.

TORNADO 20-year CLIMATOLOGY

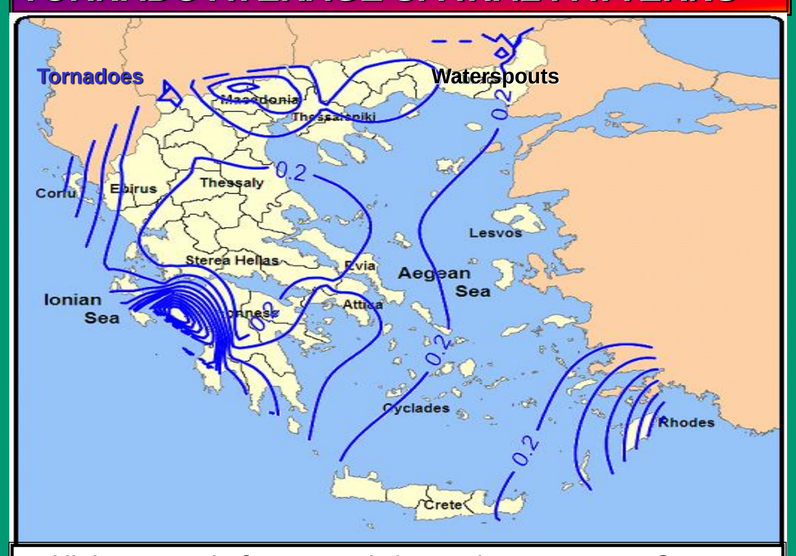
- A total of about **1700 tornado events** were reported **in 1150 days** during the 20-year period 2000–19 (November).
- **Tornadoes** in **302 days** with **317 events**. *Maximum tornado activity was reported the year 2016 with 26 events*.
- **Waterspouts** in **690 days** with **1160 events**. *Maximum waterspout activity in the year 2014 with 144 events.*
- **Funnel clouds** in **167 days** with **235 events**. *Maximum funnel activity was reported the year 2014 with 55 events.*

OBSERVER NETWORKING, POPULATION AND URBAN CONURBATION EFFECTS



Using an urban nightlight satellite image (2012) it shows that western Greece exhibits the greatest tornado occurrence, with maximum over Kerkyra Isl. and northwest Peloponnese. North offshore of Crete, appears the highest waterspout occurrence.

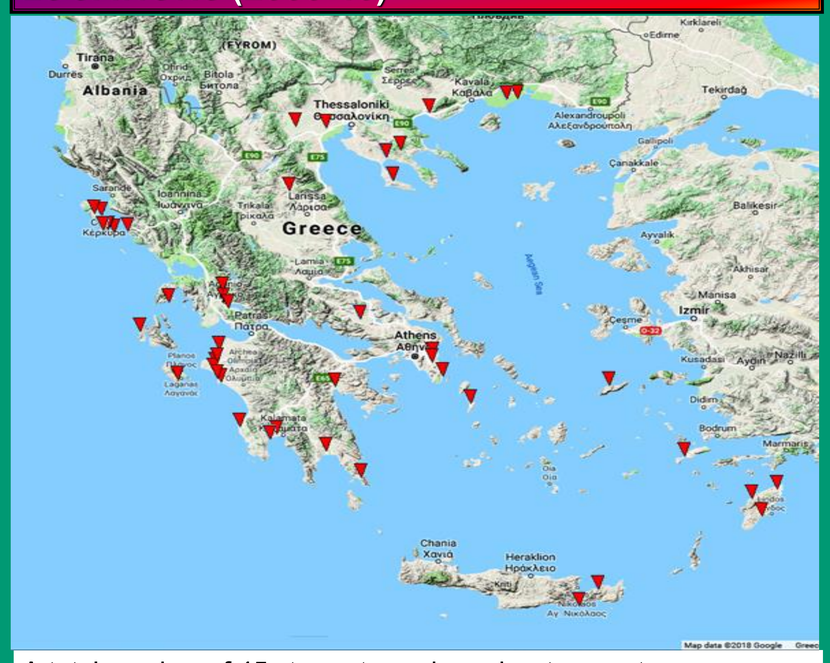
TORNADO AVERAGE SPATIAL PATTERNS



- Higher tornado frequency is located over western Greece.
- Coastal and low elevation areas generally exhibit an increased tornado frequency.
- A tornado local maximum is located over northwest Peloponnese, with a yearly average of 2.5 tornado days.

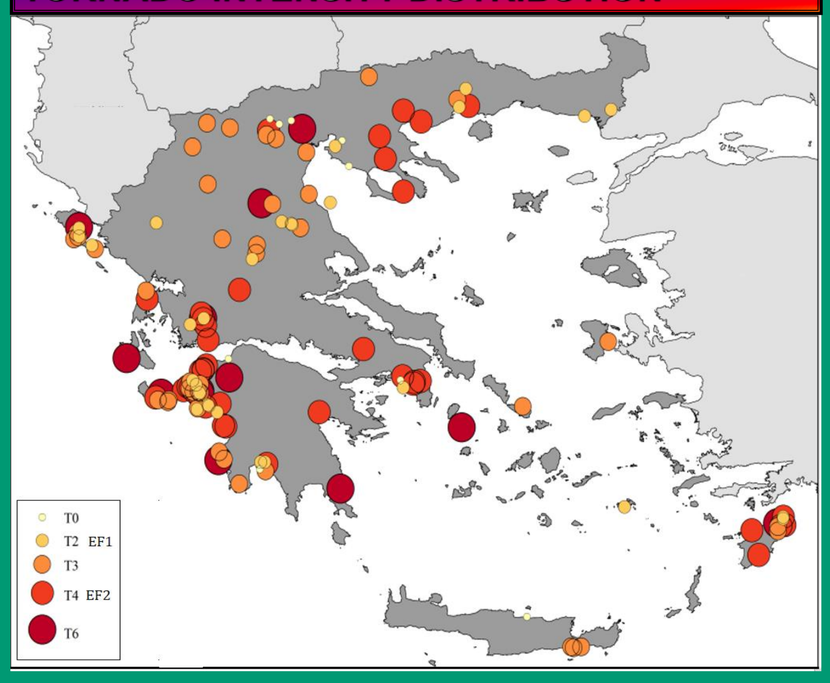
STRONG TORNADO AND WATERSPOUT DAMAGE IN GREECE

STRONG TORNADO AND WATERPOUT LOCATIONS (2000-19)

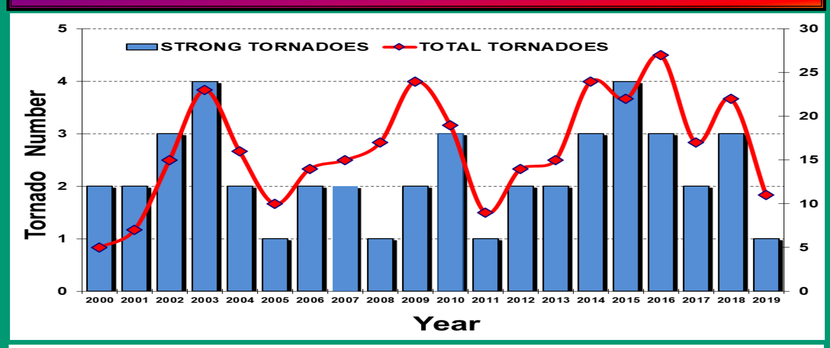


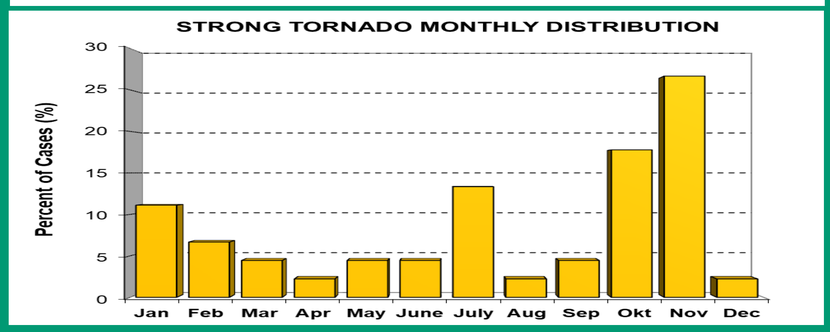
A total number of 45 strong tornado and waterspout occurrences have identified in the 20-year systematic recording Greek tornado data base (2000-19). They are distributed in various areas, with most frequent those of western Greece. Coastal and low elevation areas are generally prone to strong tornado development.

TORNADO INTENSITY DISTRIBUTION

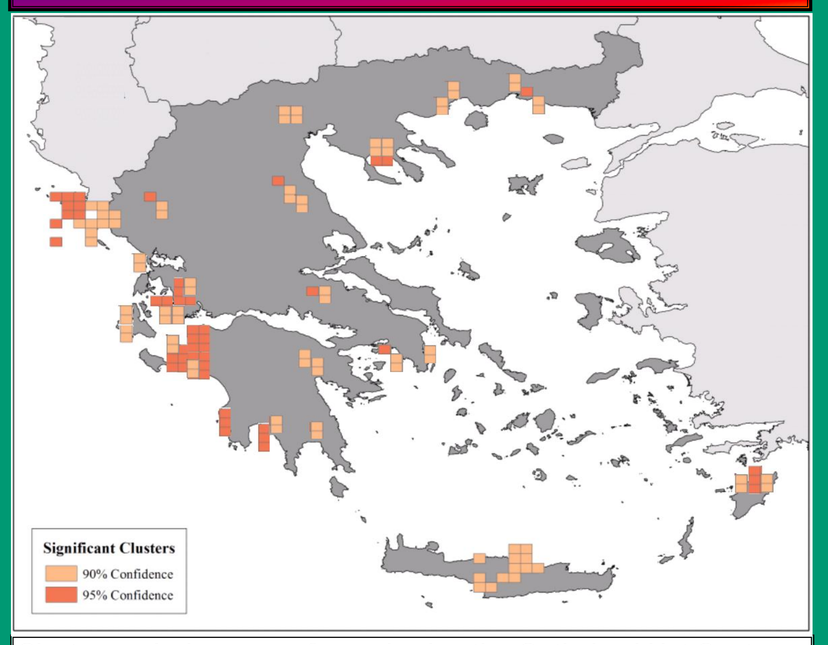


YEARLY AND MONTHLY DISTRIBUTION





PROBABILITY CLUSTER ANALYSIS

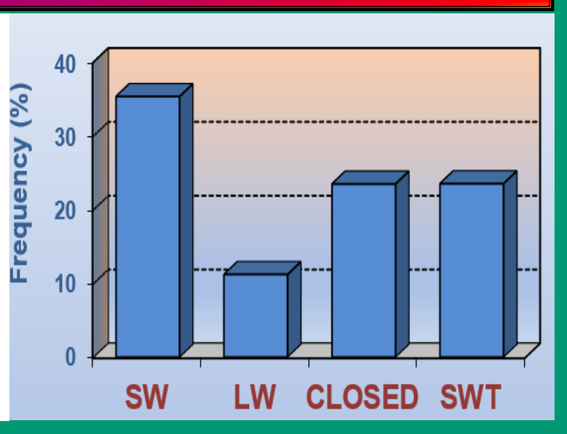


Cluster analysis was performed using the Optimized Hot Spot Analysis tool in ArcGIS. This helps identify clusters of events in a point dataset using the local spatial autocorrelation statistic Gi*. It shows, with two levels of confidence, locations most likely to experience a tornado event.

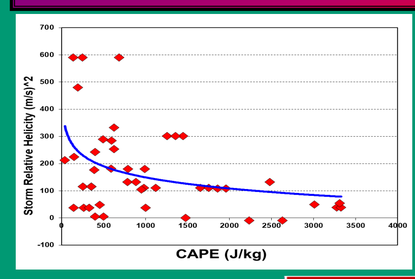
SYNOPTIC TYPES AND STRONG TORNADOES

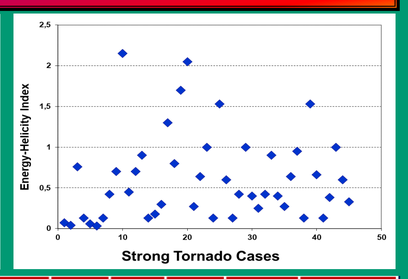
A four synoptic typing scheme was identified in strong tornado days.

Southwest flow (SW) was the dominant synoptic type with a percentage of 35.3% of the strong tornado days, followed by short wave trough (SWT) with 29.4%, closed low (CLOSED) with 23.5% and long wave trough (LWT) with 11.2%.



THERMODYNAMIC PARAMETERS IN STRONG TORNADO ENVIRONMENTS





- S-R helicity vs CAPE represent contribution of both low level shear and buoyancy.
- Energy-Helicity Index, represents a dimensionless parameter combining CAPE with 0-3 km SRH.

Parameters/Indices	Mean	Min	Max	St. Dev.	Threshold
CAPE (J/kg)	1070.2	41	3326	995,8	> 2000
CIN (J/kg))	24.2	5	95	21.9	< 22
LCL (m)	925.5	230	1767	437.8	< 800
0-2 km wind Shear (10^{-3} s^{-1})	8.8	1.6	20	8.8	--
0-6 km wind Shear (10^{-3} s^{-1})	6.8	2	12.3	2.7	--
BRN Shear ($m^2 s^{-2}$)	60.7	4	178	41.5	> 40
BRN	81.4	0	532	147.2	< 50
0-2 km SRH ($m^2 s^{-2}$)	131.8	-13	484	154.9	> 200
0-3 km SRH ($m^2 s^{-2}$)	165.8	-9	591	154.9	> 200
EHI	0.6	0.03	2.2	0.6	> 1
KI	31.5	23	40	3.8	--
LI	-3.9	-10	2	3.7	--
SI	-0.5	-8	4	2.9	--
TT	53.1	47	61	3.8	--

RESULTS & FUTURE

- Tornado occurrence in Greece based on the 20-year period 2000-19 database, stands at: 19% tornadoes, 67% waterspouts and 14% funnel clouds.
- Strong tornadoes in Greece are rather rare, with a yearly frequency of about to 2-3 cases, with western parts of Greece appeared hit most frequently.
- Climatological studies indicated most strong tornado and waterspout prone areas in term of spatiotemporal patterns, frequencies and distributions.
- The last years tornado data set is influenced by an increased tornado reporting, including extensive use of cameras and internet social media. This results to further improvements to both quality and quantity of the GTD.
- Further analysis of the Greek tornado database will include topography and other geographical features, mapping and statistical analysis of the data, tornado and waterspout predictability, regional climate and climate change influence.

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