WATERSPOUT OUTBREAKS OVER EUROPE AND NORTH AMERICA: ENVIRONMENT AND PREDICTABILITY

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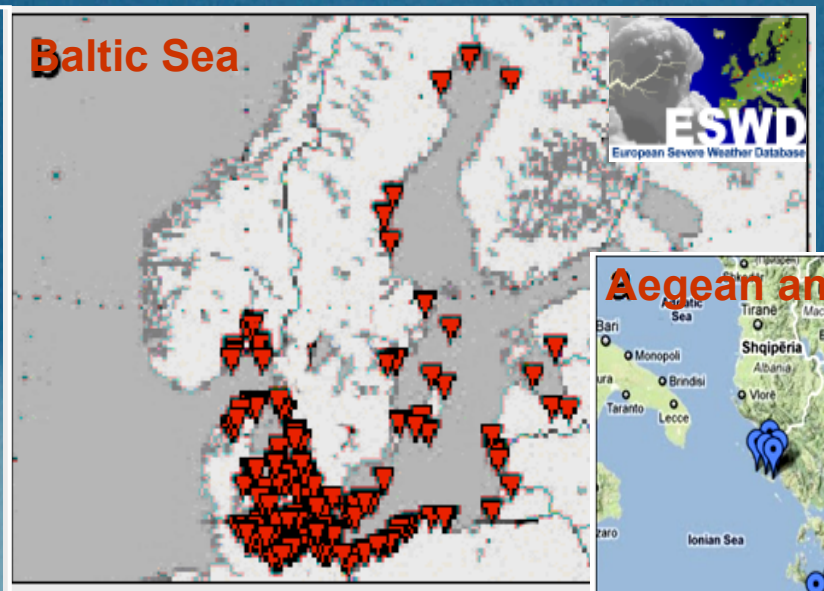
Waterspout outbreak definition

- Waterspouts are tornadoes over a water surface of a sea or lake.
- Waterspout outbreaks, are referred to as multiple simultaneously or successively waterspout forming.
- As Galway (1977) stated, “a waterspout outbreak can mean many things to many people”.
- In *Glossary of Meteorology* (Glickman, 2000) a tornado outbreak is defined as a “multiple tornado occurrences within a single synoptic system”.
- In this study a **waterspout outbreak** is considered as a multiple waterspout event over a region and for a given period of time, generally produced by the same synoptic system.
- Waterspout outbreaks are classified as either **Small-SO** (2-9 waterspouts), **Moderate-MO** (10-19 waterspouts) **and Large-LO** (20 or more waterspouts), occurring on a single calendar day (12:00 through 11:59 UTC).

Areas of research and data

- 48 outbreak days with 167 waterspouts in the Aegean and Ionian Sea (2000-11).
  - 46 Small (2-9 WS)
  - 1 Moderate(10-19 WS)
  - 1 Large (20+ WS)
- 27 outbreak days with 176 waterspouts over the Baltic Sea (2000-10).
  - 25 Small
  - 2 Moderate
- 158 outbreak days with 731 waterspouts over the Great Lakes (1994-2010).
  - 149 Small
  - 7 Moderate
  - 2 Large

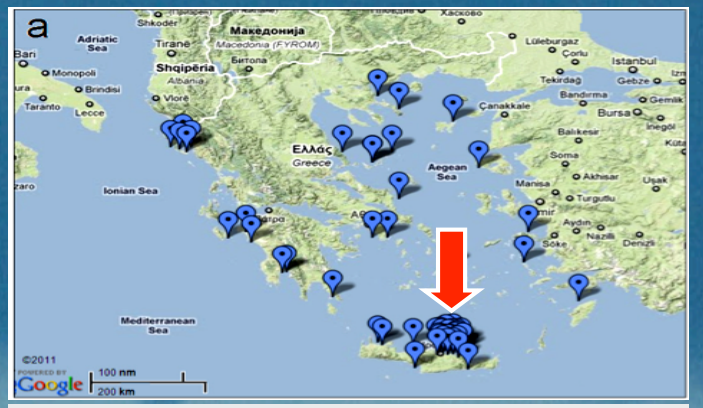


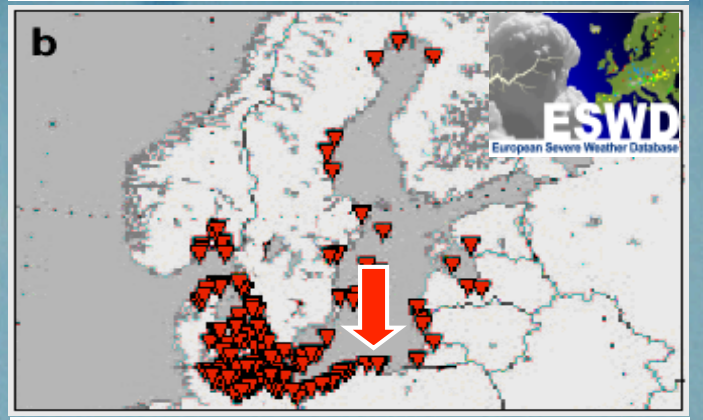
Considerable waterspout outbreaks

- About 30 waterspouts, occurred North off shore, Iraklio, Crete, Aegean Sea, on September 21, 2006, 06:00-08:00 a.m. local time (03:00-05:00 UTC).

- 10 waterspouts, Sassnitz, Germany, Baltic Sea, on August 11, 2006 at 9:15 am local time (08:15 UTC).

- The largest waterspout outbreak over the Great Lakes (Lake Ontario) was September 27 to October 3, 2003, with over 66 waterspouts totally recorded and over 20 waterspouts in a single day.






6 August 2009, Lake Erie, Canada


21 Sept. 2009, Crete Isl., Greece


27 January 2003, Limassol, Cyprus


9 September 1999, Lake Huron, Great Lakes

Spatial distribution

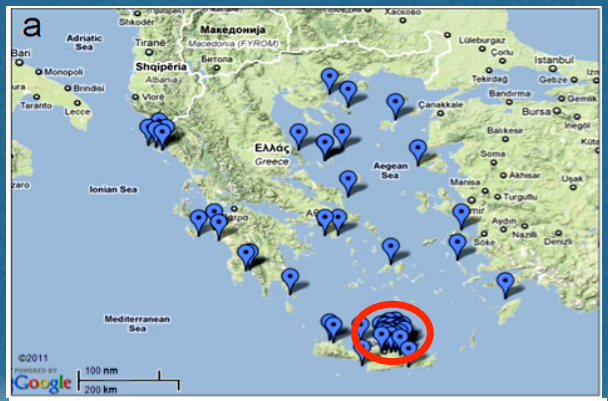
- The spatial maximum of waterspout outbreak days for the Aegean and Ionian Sea, is located north off shore of Crete Isl. This area exhibits the majority of outbreaks recorded, 21 out of 47 WSO days for the 11 year data.

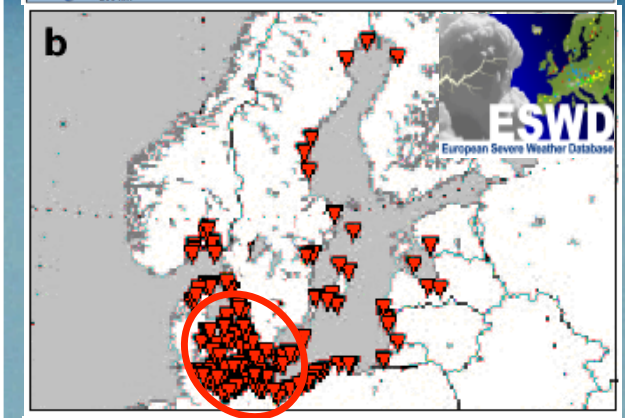
- Waterspout favour conditions in the southern Aegean Sea seem create the dominant Aegean northern flow interacted with land breeze.

- In the Baltic Sea both most waterspout events and most events associated with outbreaks are located in the southwest area between Germany, Denmark and Sweden.

- For the Great Lakes, Lake Erie exhibits the highest frequency of waterspout outbreaks.

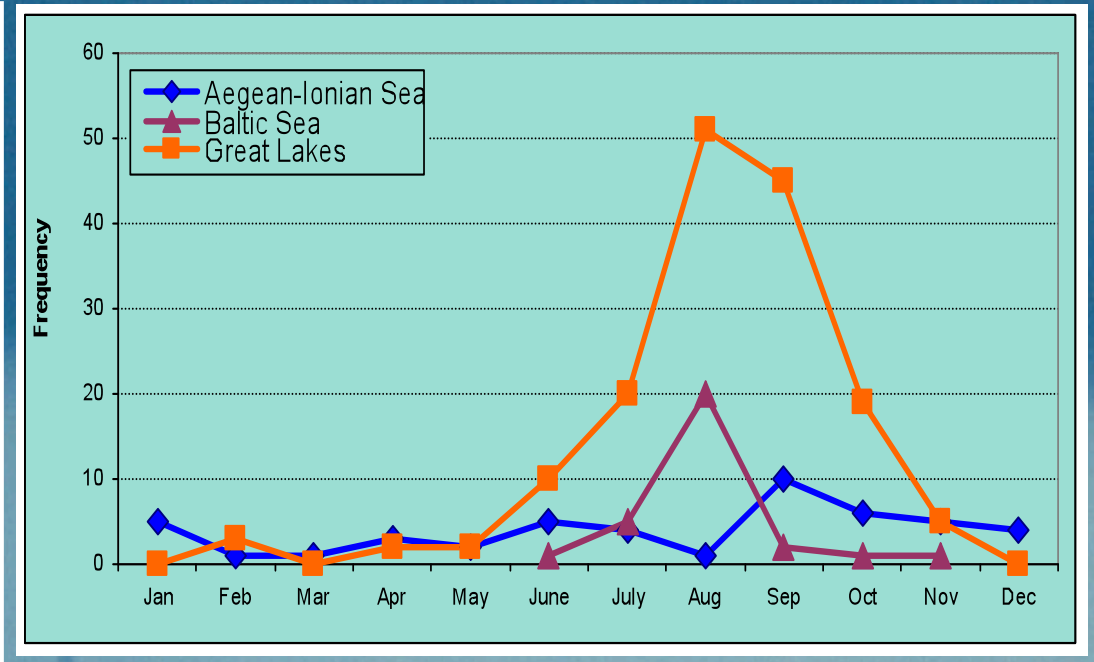
- Lake Erie is the shallowest and warmest of the Great Lakes, resulting in the greatest instability and, hence, largest waterspout activity.

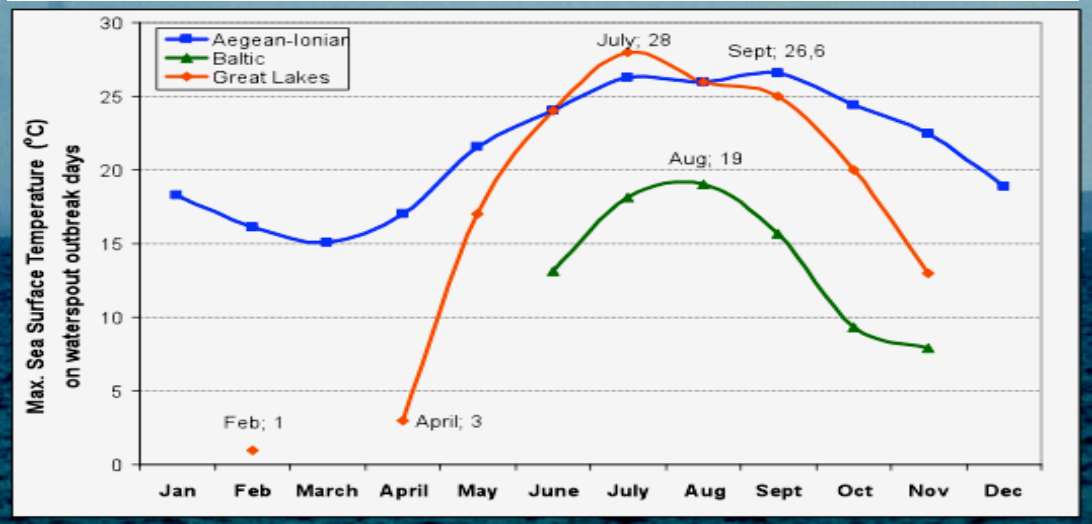




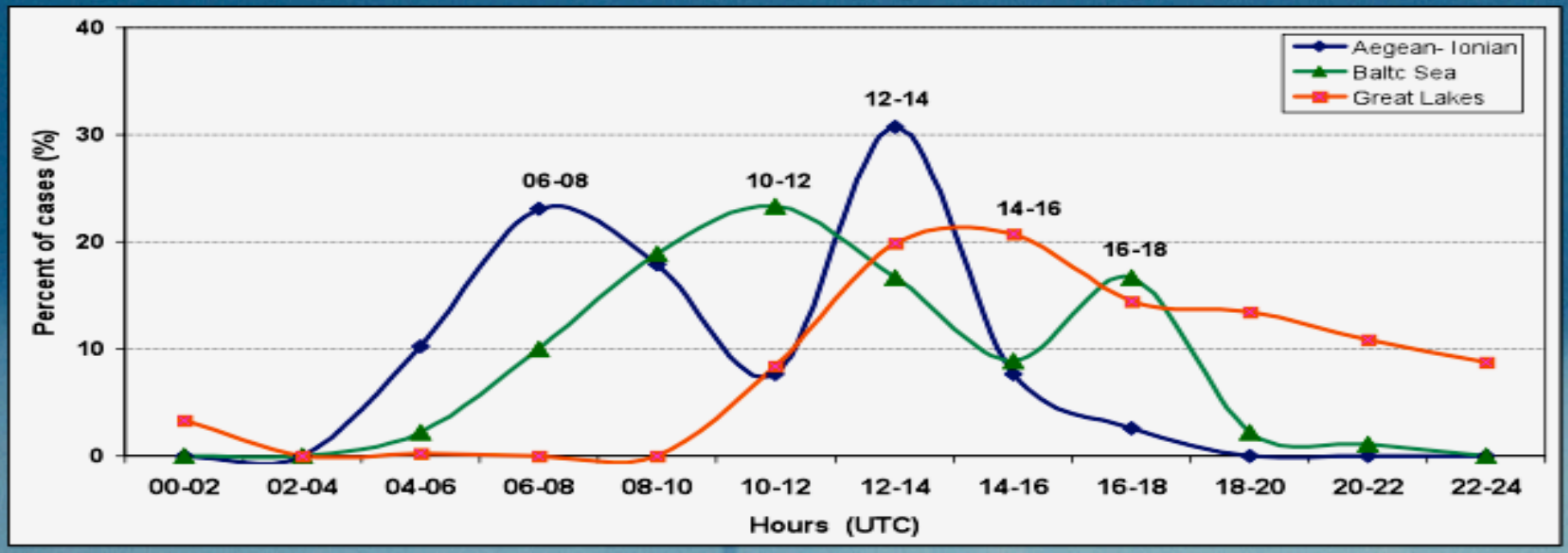
Monthly distribution

- In the Aegean and Ionian Sea, most outbreaks occur in September, a month with warmest sea waters.
- Maximum frequency of the Baltic Sea outbreaks occurs in August. No Baltic outbreaks in December and from January to May.
- For the Great Lakes, August exhibits the highest frequency of outbreak followed by September.
- August and September is the time of year when convergent line land breezes reach at their maximum. Land breezes are highly conducive to waterspout outbreaks.





Diurnal frequency



- The Aegean-Ionian waterspout outbreaks mostly occur in the afternoon hours 14:00-16:00 UTC **(5-7 p.m. local time)**, with a secondary maximum during the morning hours 06:00-08:00 UTC **(9-11 a.m. local time).**

- The Baltic waterspout outbreaks occur most frequently in 10:00-12:00 UTC **(11-13 a.m. local time),** with a secondary maximum in the afternoon hours 16:00-18:00 UTC **(17-19 p.m. local time).**

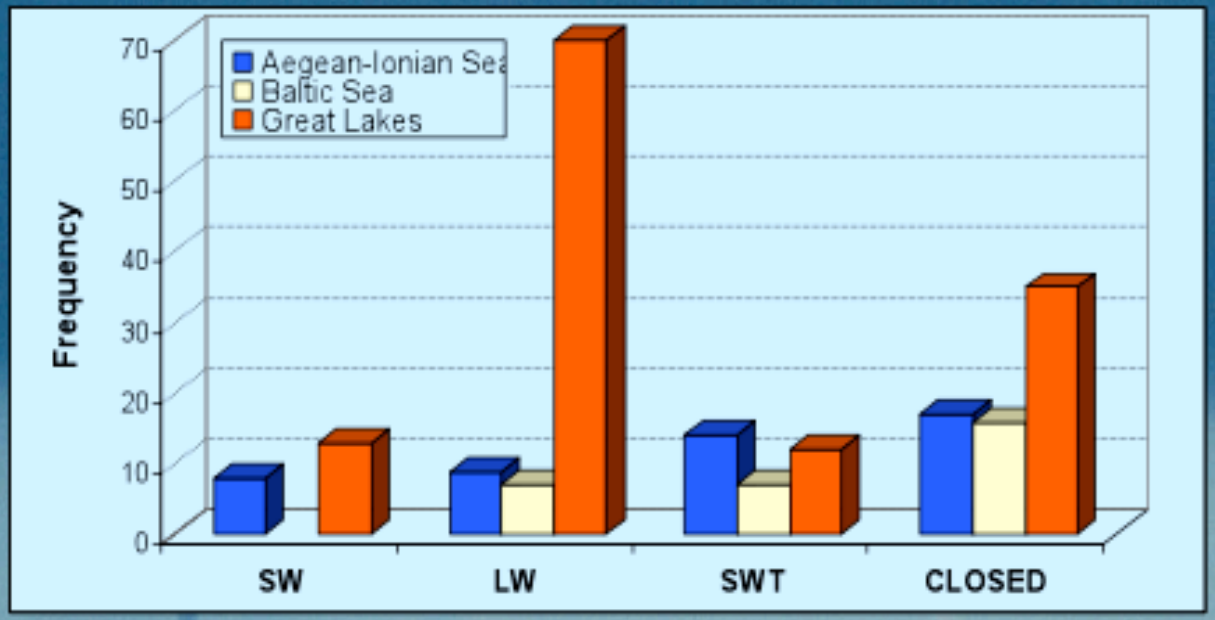
- The Great Lakes waterspout outbreak maximum occurs during the morning hours 14:00-16:00 UTC **(8-10 a.m. local time).**

Synoptic conditions

- Synoptic conditions during waterspout outbreaks were examined based on a four basic synoptic types were identified as most related to waterspout outbreaks.

- CLOSED type prevailed for the Aegean-Ionian and Baltic Sea waterspout outbreaks, followed by SWT type.

- For the Great Lakes, the LW type pattern was most related to waterspout outbreaks. LW form quite frequently over North America to the lee of the Rocky Mountains.



Thermodynamic environment

- Mean values and standard deviations of thermodynamic parameters, conventional instability indices, wind and moist parameters.
- Generally higher values indicative of a more unstable environment represent the Aegean and Ionian Sea data compared to the Baltic Sea.
- The mid and upper atmospheric role seems more significant in the Aegean and Ionian waterspout outbreaks than in the Baltic Sea.

Thermo-dynamic parameters, indices, wind and moist parameters	Aegean-Ionian Sea WSO days		Baltic Sea WSO days	
	MEAN	STDV	MEAN	STDV
KI	27.8	3.9	18.0	12.8
TT	48.4	5.5	46.0	5.9
LI	0.3	2.3	2.5	3.2
SW	2.6	2.7	4.7	3.1
CAPE (J/kg)	264.2	329.9	154.3	109.6
BRN	31.2	65.4	27.7	26.1
SWEAT	136.2	55	103.7	42.2
MLMR aver. mix ratio low 500 m (g/kg)	9.4	2.2	7.5	1.9
THCK 1000-500 hPa (m)	5543.1	100.1	5360.0	83.4
PW (mm)	24.9	6.3	20.4	7.0

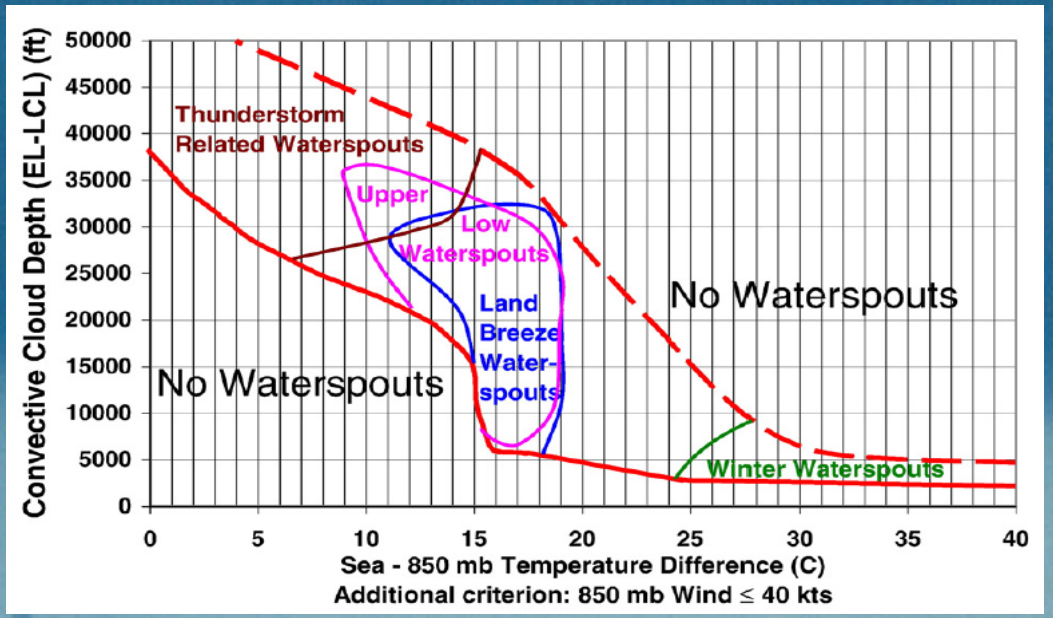
Waterspout predictability - SWI

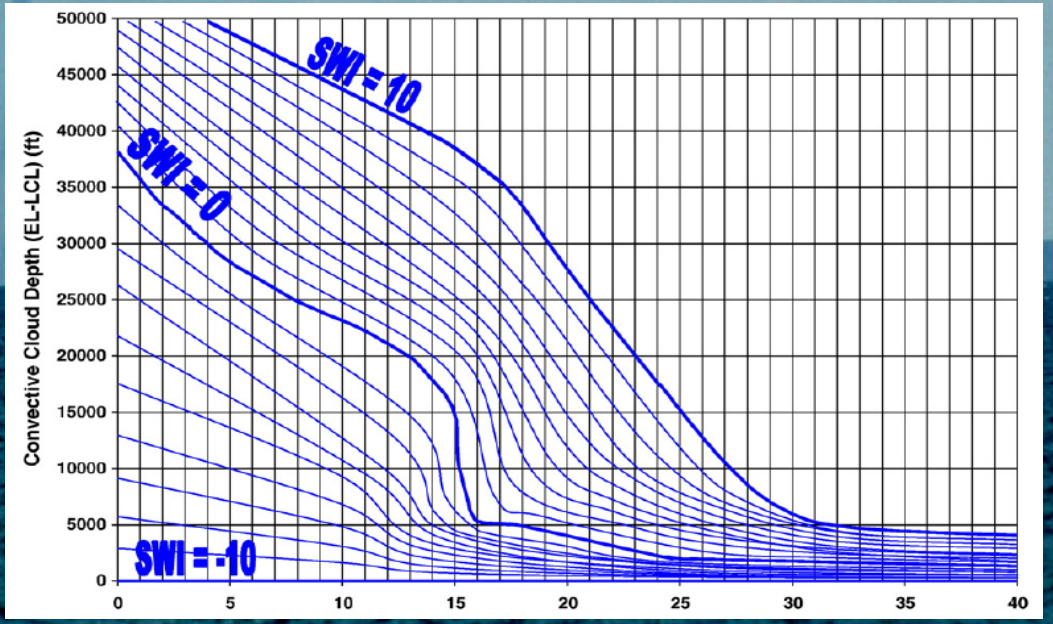
- The SWI index is used to evaluate the potential for waterspout development. The SWI is derived from the waterspout nomogram and it is based on 3 parameters:
  - SST-T_{850} hPa difference
  - Convective cloud depth (EL-LCL)
  - 850 hPa wind speed.

- The values of SWI range from -10 to +10. Waterspouts are likely to occur when the SWI≥0.

- The larger the positive value of SWI, the higher the potential for waterspout development.

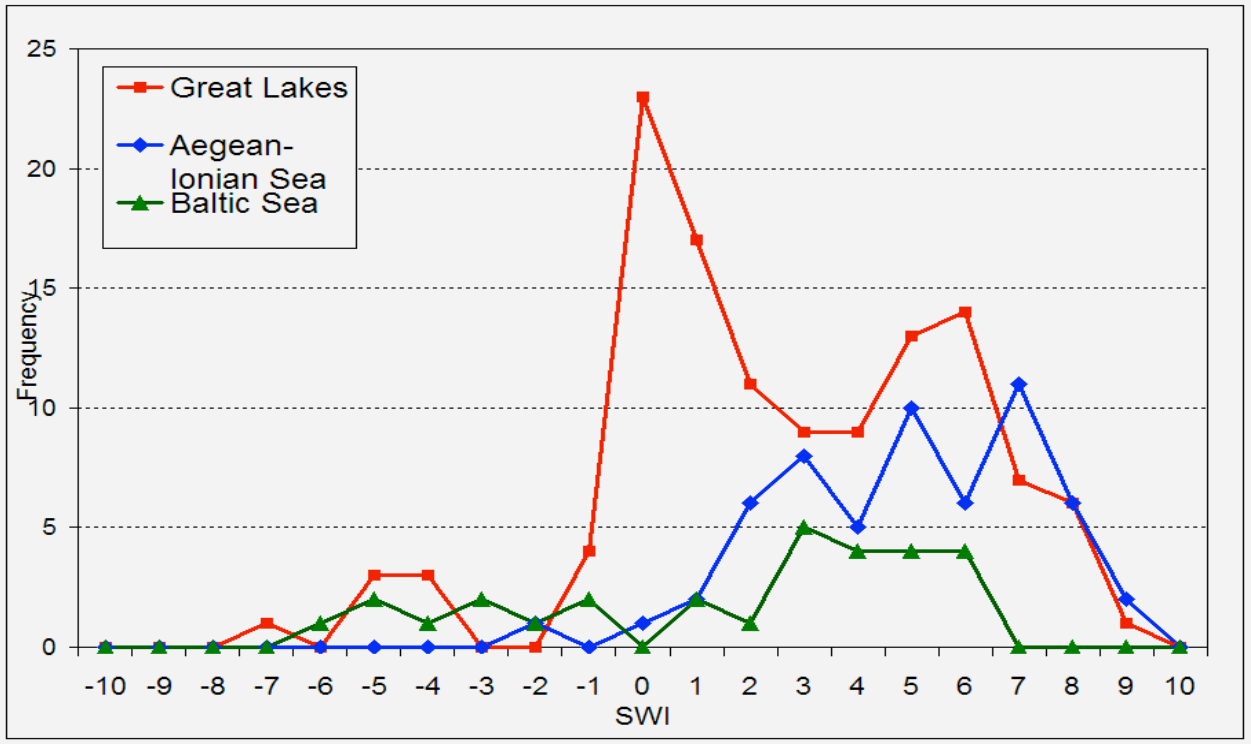
- For all 3 examined areas, the larger the SWI the larger the outbreak potential.





SWI

- Waterspout outbreaks for all 3 examined areas are strongly correlated with SWI values ≥ 0, peaking at:
  - SWI = 0 for the Great Lakes
  - SWI = 3 for the Baltic Sea, and
  - SWI = 7 for the Aegean-Ionian Sea.



Waterspout outbreak area	Nomogram pass (%)	Mean SWI
Aegean – Ionian Sea	98	4.9
Baltic Sea	69	1.7
Great Lakes	91	2.5

Conclusions

- Waterspout outbreaks showed strong correlation with certain synoptic environments and also showed some similarity between the different areas of the study.
- For both Europe and North America, outbreaks peaked in the late summer months of August or September when water temperatures are at their highest and outbreaks of cooler air began. Concerning diurnal frequency, morning hours seem most favoured for waterspout outbreak formation, a feature primary attributed to land breeze interacted with mesoscale circulations and leading to local convergence.
- Both dynamic and thermal process seems contribute to the formation of the Aegean-Ionian and the Baltic waterspout outbreaks, mostly associated large ΔZ values (EL-LCL>8000 m), and relatively high ΔT values (SST-T_{850}<16 C). Concerning the Great Lakes, ΔZ values are smaller but ΔT values are higher as compared to the European cases, indicating a stronger thermal mechanism.
- Outbreaks were associated with all four synoptic types, however, favoured synoptic types differed between Europe (CLOSED) and North America (LW). These differences primary are attributed to the different geography and climatic backgrounds.
- Thermodynamic data showed a more unstable environment for the Aegean and Ionian Sea data compared to the Baltic Sea during waterspout outbreaks.
- Waterspout outbreaks were strongly correlated with the SWI for both Europe and North America. The great majority of outbreaks occurred with SWI values of ≥ 0, and peaking at SWI=0 for Great Lakes, 3 for the Baltic Sea and 7 for the Aegean and Ionian Sea.

Thanks and credits

- Waterspout observers – meteorologists, officials, sailors, amateurs
- The ESTOFEX and internet databases ESWD (http://essl.org/ESWD).
- Atmospheric soundings http:/weather.uwyo.edu/upperair/sounding.html
- http://itouchmap.com/latlong.html
- http://poet.jpl.nasa.gov