

Waterspout forecasting indices over the Adriatic Sea computed from operational ALADIN model data

Martina Tudor, Tanja Renko and Tomislav Kozarić
 Meteorological and Hydrological Service of Croatia

Introduction

Waterspouts occur over the Adriatic throughout the year. They are a hazard to navigation and produce damage in a case of landfall. The possibility to forecast waterspouts using several empirical indexes computed from the Aladin forecast data will be described.

Most of the waterspouts reported in the media are missed by the official meteorological network over the Adriatic so there is a lack of measured meteorological data representative for the conditions in the immediate vicinity of the waterspout formation.

Waterspouts are tornadoes over bodies of water. They are connected to thunderstorms but fair weather cumuli or cumulus congestus clouds can also initiate waterspouts. Tornado and waterspout formation depends on

- high moisture in the boundary layer
- capped by a stable layer
- and dry and cold air mass above boundary layer
- with strong vertical wind shear
- pre-existing boundary layer vertical vorticity
- and near-surface horizontal convergence as a source of lift.

Kuipers and van der Haven waterspout index

In the Netherlands, many waterspouts are reported every summer when the warm weather supports their formation in combination with cyclonic circulation. Kuipers and van der Haven (2007) describe an index that estimates the risk of the waterspout formation, and name it KHS-index (after Kuipers and van der Haven waterSpout index). The KHS-index is based on the meteorological conditions that coincide with the occurrence of waterspouts and funnel clouds over the North Sea coast of the Netherlands, especially over the warm shallow coastal waters. The index describes the four circumstances in the meteorological environment that were found favourable for the waterspout and funnel cloud development.

$A = \max(2, 5/[V_{850} - V_{10m}])$ is for the wind shear

$B = 9.81(T_{surf} - T_{925})/\phi_{925}$ is set to 0 if the temperature lapse rate is less than 8K/km

$C = 100 \text{ave}(\text{RH}_{1000}^{900})$ is set to 0 if the average relative humidity is less than 50%.

$D = \max(2, 5/V_{10m})$ is for the 10m wind.

The KHS index is designed to use the operational HIRLAM model data as input. The results for the Adriatic using ALADIN operational data are presented below. There are several possible reasons for the forecast failure. The model sea surface temperature (SST) as well as threshold retuning according to local climatology and forecast model will be investigated first.

Methods

Current operational weather forecast models do not resolve the horizontal scales required to model the waterspout directly. Instead, model and measured data are used to detect the meteorological conditions that have been related to the waterspout occurrence in the past. Various indexes and procedures have been described so far. The indexes are developed on local climatology of the observed and reported waterspouts and using the index on another geographical area may require revisiting the thresholds used in the index computation.

The Szilagyi waterspout nomogram and index

Szilagyi presents an empirical method developed to forecast waterspouts over the Great Lakes of North America. It is based on a large data set of meteorological parameters measured during the observed waterspout events and depends on three meteorological parameters:

- the temperature difference between the water surface and 850 hPa level,
- the depth of the convective clouds is computed as the difference in the height of equilibrium level (EL) and liquid condensation level (LCL) and
- the wind speed at 850 hPa.

If these conditions fall within a certain area in the Szilagyi waterspout nomogram (SWN), the waterspouts are likely to occur. Values that fall outside this area are not favourable for the waterspout development.

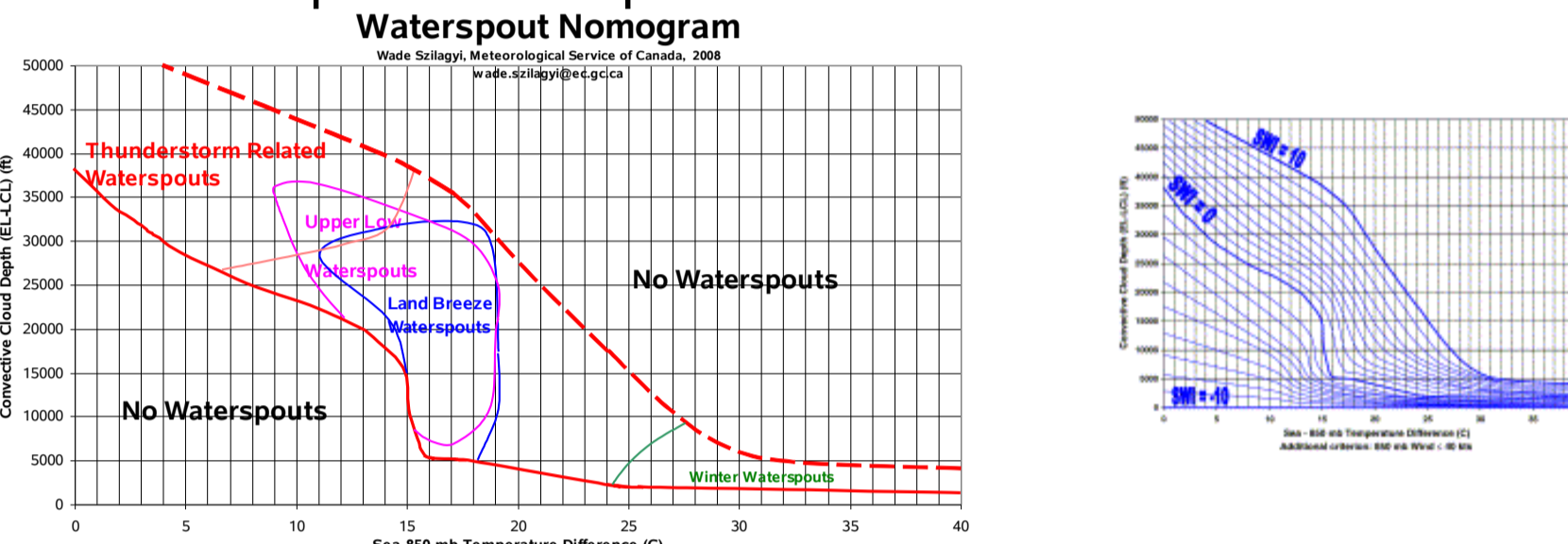


Figure: Szilagyi waterspout nomogram and the Szilagyi waterspout index (SWI) values (embedded graphics). There is no formula for SWI but an empirical table is constructed.

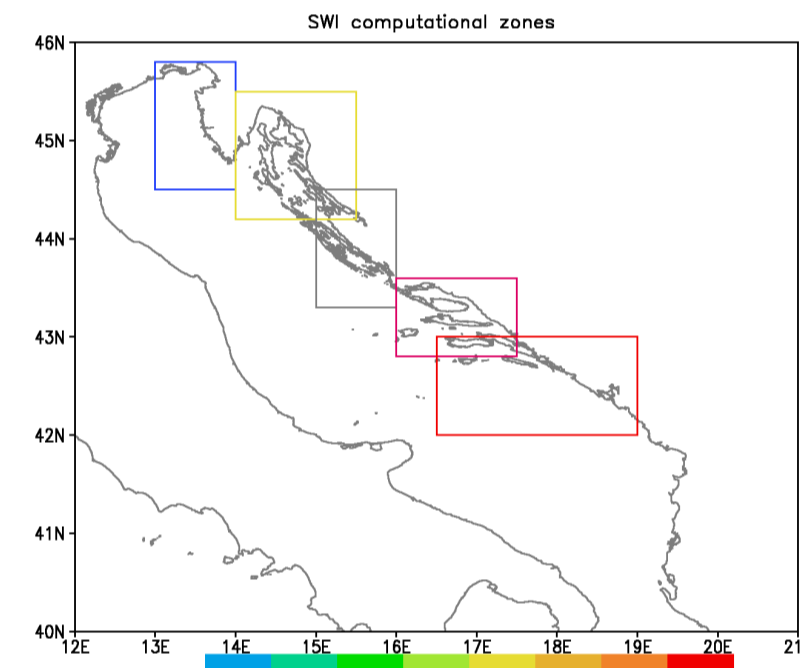


Figure: The Adriatic area close to Croatian coast was divided into 5 zones limited by rectangular frames. The convective cloud depths, 850 hPa wind and the difference between sea surface and 850 hPa temperature were computed from the model output data for each model grid point in each frame. Then, this data for each point is plotted on a nomogram with SWI in the background. All points for a particular area are plotted on a graph with a different colour.

Results

Two indexes designed to forecast waterspouts are applied to waterspouts observed over eastern Adriatic coast. They are computed using ALADIN operational NWP model data for each day in 2010 when waterspouts were observed. The forecasters (second and third author) then evaluated the forecast indexes. A yes/no value for both indices is evaluated for all 19 cases. The KHS successfully forecasts the occurrence of waterspouts in 13 cases (hit rate of 68,4%) and the SWN in 14 cases (73,7%).

no.	date	time (UTC)	duration	location	lon	lat	lightning	weather type	SW	KH
1	1.1.2010.	12:40	unknown	Makarska	17.02	43.28	yes	SW	yes	no
2	2.1.2010.	16:25	unknown	Vela Luka	16.72	42.97	yes	SWT	yes	yes
3	9.2.2010.	15:07	3 min	Sibenik	15.92	43.73	no	SW	yes	yes
4	5.4.2010.	9:53	5 min	Makarska	17.02	43.28	yes	LW	yes	no
5	6.5.2010.	22:15	unknown	Primosten	19.92	43.59	yes	LW	yes	yes
6	15.5.2010.	10:30	unknown	Funtana	13.60	45.15	no	CLOSED	no	no
7	30.5.2010.	9:00	2 h 20 min	Poreč	13.60	45.22	yes	SWT	yes	yes
8	21.6.2010.	11:55	17 min	Dubrovnik airport	18.08	42.65	yes	CLOSED	yes	yes
9	26.7.2010.	12:30	unknown	Zadar	15.22	44.13	no	LW	no	no
10	6.8.2010.	5:25	5 min	Dubrovnik airport	18.08	42.65	yes	CLOSED	yes	no
11	7.8.2010.	before noon	unknown	Sibenik	15.92	43.73	no	CLOSED	yes	yes
12	8.9.2010.	11:30	unknown	Poreč	13.60	45.22	yes	SW	no	no
13	26.9.2010.	8:40	unknown	Pula	13.85	44.87	no	CLOSED	yes	yes
14	27.9.2010.	8:45	unknown	Rovinj	13.65	45.10	no	CLOSED	yes	yes
15	17.10.2010.	8:40	1 min	Makarska	17.02	43.28	yes	SW	yes	yes
16	11.11.2010.	sunset	unknown	Dubrovnik	18.08	42.65	no	LW	yes	yes
17	18.11.2010.	12:15	unknown	Makarska	17.02	43.28	no	SW	no	yes
18	23.11.2010.	before noon	unknown	Krk	14.60	45.03	no	LW	yes	yes
19	12.12.2010.	before noon	unknown	Dubrovnik	18.08	42.65	no	SWT	no	yes

Table: List of the waterspout events in Croatia reported in meteorological station reports, media and severe weather database for 2010.

Conclusions

The results below show the waterspout forecast indexes for several cases. The contributions of different factors in the KHS index are also plotted. The contribution of the terms B and C is shown together since they are several orders of magnitude smaller or larger than the KHS index itself. Term C that describes the PBL moisture is always contributing. There had been no evaluation of the false alarm rate so far, however one can expect a high value. The results below show an alarm for various parts of Adriatic where no waterspouts were reported. This suggests a need for re-tuning the thresholds and perhaps introducing other criteria available from the model output, as wind convergence, vertical vorticity and variations of static stability in the vertical. One should bear in mind that these are merely forecast indexes. They provide an indication that some conditions favourable for waterspout formations are met. This does not mean that waterspouts will develop. On another hand, no waterspouts reported does not mean there were not any, just that no one has observed and reported it.

The research shows that most of the waterspout events were thunderstorm related. Several fair-weather waterspouts require more than the common thermodynamic instability indexes. This study shows that SWN and KHS indexes improve the waterspout forecast and can provide guidance in issuing warnings for severe weather phenomena.

