SYNOPTIC AND MESOSCALE ANALYSIS OF WATERSPOUTS IN THE ADRIATIC (2001 – 2011 PRELIMINARY CLIMATOLOGY)

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I. INTRODUCTION

A comprehensive analysis of waterspout events observed and recorded in the Eastern Adriatic Basin in 2010 was carried out. The synoptic and mesoscale environment was discussed and the corresponding Szilagyi Waterspout Nomogram (SWN) and Szilagyi Waterspout Index (SWI) (Szilagyi, 2005; Keul et al. 2009) values were calculated with the help of ALADIN model (Renko et al, 2012). Since official observations are rare and occasional information from different media unreliable, an effort was made to establish continuous data collection, in order to ensure better understanding of all possible factors and environmental conditions for waterspout formation, and to provide a preliminary climatology of waterspouts in this region. For that purpose a survey: "You saw a waterspout/tornado? Report to us! " was launched in spring 2011 on the official web site of Croatian Meteorological and Hydrological Service (DHMZ), http://meteo.hr. This survey resulted in a more complete database, covering 220 waterspout events from 2001 to 2011 which are analyzed and discussed in this work.

FIG. 1: Waterspout near Dubrovnik, photo by Daniel Pavlinovic.

II. DATA AND METHOD

Information on waterspout events has been obtained from various sources. Data were collected from SYNOP reports as well as from climatological weather stations which are parts of or run by DHMZ. Since spring 2011 the majority of reports have reached the authors via the survey that was launched on DHMZ web page. The others were gathered with the help of various media (newspaper, internet, facebook etc.). Reports collected via the survey and through the media usually lacked some necessary details and were therefore supplemented with the help of SYNOP data, satellite images and LINET lightning data (Betz et al., 2009). For the period 2001-2011 a total of 220 waterspout events have been collected and synoptic, mesoscale and thermodynamic weather conditions have been analyzed.

III. WATERSPOUT CASES AND PRELIMINARY CLIMATOLOGY

The Croatian/Eastern part of the Adriatic Sea is characterized by a very complex topography. Differential heating of a large number of islands and peninsulas favors the development of convection and therefore, even without any big atmospheric disturbances conditions for waterspout development can be satisfied.

In Fig. 2 approximate locations of waterspout events, recorded in 11 year period, are shown. The events are mostly evenly distributed along the coast.

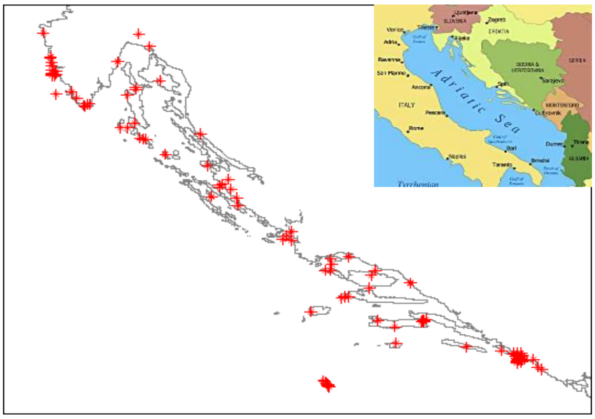

FIG. 2: Approximate locations of waterspout events recorded along the Croatian coast (2001-2011).

In the given period (2001-2011), 101 days with waterspout activity and total number of 220 waterspouts were registered.

Despite the inter-annual variability in the waterspout activity in Fig. 3, one can see a clear trend in number of recorded waterspouts in the past few years. The highest number (65) was recorded in 2010, followed by 50 cases recorded in 2011.

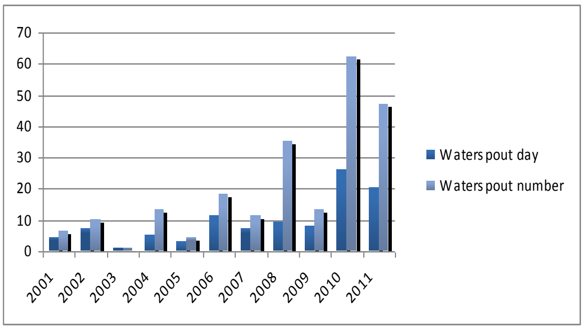

FIG. 3: Annual number of waterspout events and waterspout days along the Croatian Adriatic coast (2001-2011).

Seasonal distribution in Fig. 4 shows that waterspouts can develop in all seasons in the Adriatic Sea. The occurrence frequency reaches its maximum in summer months, due to the high convective activity and high sea-surface temperature (SST) (104 waterspouts in 40 days), followed by autumn when cold advections are more frequent and the SST is still quite high, especially in the southern part of the Adriatic (52 waterspouts in 28 days).

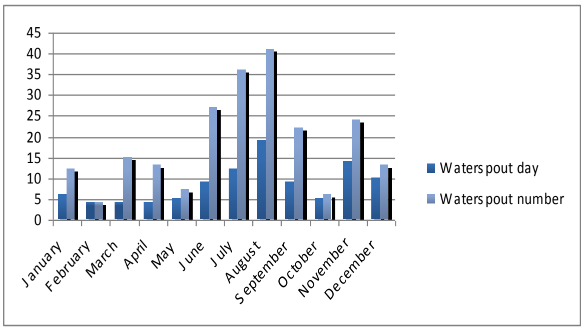

FIG. 4: Monthly distribution of number of waterspout events and waterspout days along the Croatian Adriatic coast (2001-2011).

The most active month in 2001-2011 period was August, with 41 events in 19 days. By the number of waterspout days follow November (14) and July (12), but by the number of waterspouts July (36) and June (27).

The least active month is February. In as much as 30% of the cases the time of observation during the day is unknown, but most often the known occurrences are between 8 and 10 am (Fig. 5).

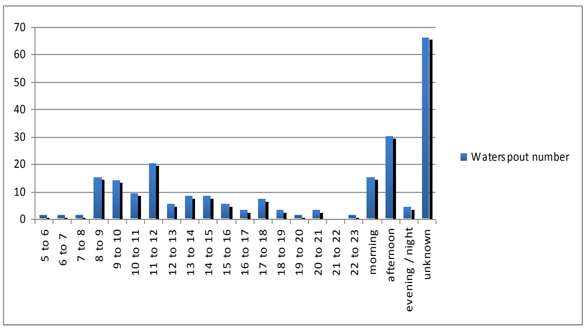

FIG. 5: Diurnal distribution of waterspout events along the Croatian Adriatic coast (2001-2011).

Prevailing synoptic conditions were examined for 220 waterspout events that were observed in 101 days. The circulation flow at 500 hPa level and the position and orientation of trough and ridge axis in conjunction with surface features were analyzed (Sioutas and Keul, 2007). One more circulation type was included, pressure field without gradients (WG), that is quite usual during the summer and favors the development of convection.

As can be seen in Fig. 6, it appears that waterspouts occur most frequently when the south-westerly flow (SW) is present. Next is the CLOSED low with 29,1 %, long wave trough (LW) with 16,8 %, short wave trough (SWT) with 13,2 % , whereas 6,8 % of total number of events occurred during the presence of pressure field without gradients (WG).

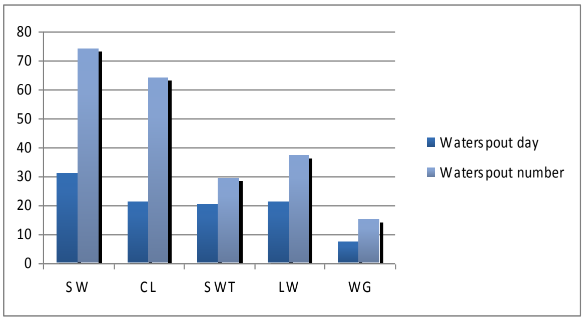

FIG. 6: Synoptic circulation type distribution of number of waterspout events and waterspout days long the Croatian Adriatic coast (2001-2011).

Thermodynamic conditions in which the waterspouts occurred were determined with the help of radiosounding data. Four instability indices were monitored (KI, TT, SWEAT, CAPE), data mostly taken from the pages of the University of Wyoming (http://weather.uwyo.edu) for Zadar, Croatia and Udine, Italy stations.

The presence of lightning activity was determined from the LINET lightning detection network (Betz et al, 2009) and waterspouts were divided into thunderstorm related and fair weather ones. The majority of observed waterspouts (69%) are related to thunderstorms. The calculated means, medians, minimums, maximums, upper quartiles and lower quartiles for the two samples are shown in box plots in Fig. 7 (Upper and lower part of the box show 75th and 25th percentiles while horizontal line inside the box shows the median value. fair – fair weather waterspouts, thunder – thunderstorm related waterspouts).

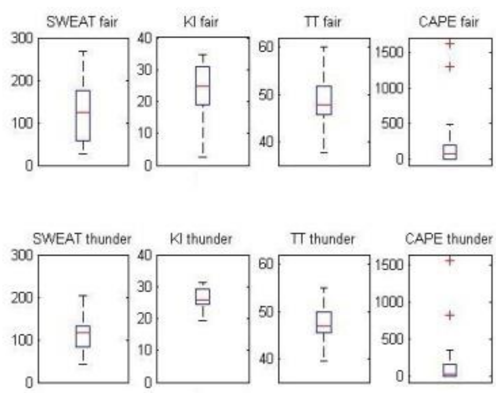

FIG. 7: Representation of instability indices SWEAT, KI, TT, CAPE on radiousounding stations Zadar and Udine.

Median values for KI and TT agree with the values already obtained in the previous studies of waterspouts in the Adriatic Sea (KI=26, TT=47) (Sioutas and Keul, 2007), while CAPE and SWEAT values show large deviations from the theoretical ones. Also, dispersion of values is smaller for thunderstorm related waterspouts, as it was expected.

IV. SUMMARY/CONCLUSION

In this paper we have presented the preliminary climatology of waterspouts phenomena in the Adriatic Sea based on data for the eleven-year period 2001-2011. In 101 days 220 waterspouts were recorded. Waterspouts were evenly distributed along the coast, but some parts stand out by the number of observed events due to the denser population that could take part in monitoring.

In the Eastern part of the Adriatic Sea the waterspouts mostly develop in summer months and this can be explained by the high SST as well as the stronger convective activity. Then follows the autumn period when the sea is still warm and the cold air masses come from the north into the Adriatic area. The majority of waterspouts (69 %) are thunderstorm related and the KI and TT instability indices proved to be the most representative.

It appears that waterspouts occur most frequently when the SW flow is present, with 34 % of the total waterspout events, followed by the CLOSED low conditions, with 29 %.

IV. ACKNOWLEDGMENTS

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V. REFERENCES

Betz, H.-D., Schmidt, K., Laroche, P., Blanchet, P., Oettinger, W.P., Defer, E.,Dziewit, Z., Konarski, J., 2009. LINET — an international lightning detection network in Europe. *Atmos. Res.* 91, 564–573.

Keul A.G.,Sioutas, M.V. and Szilagyi W., 2009. Prognosis of Central – Eastern Mediterranean waterspouts, Atmos. Res. 93,426-436.

Sioutas, M. V., Keul, A. G., 2007. Waterspouts of the Adriatic, Ionian and Aegean Sea and their meteorological environment. *Atmos. Res*. 83, 542-557.

Szilagyi, W., 2005. Waterspout Nomogram Instruction, Internal manuscript. Meteorological Service of Canada, Toronto

Renko, T., Kozarić, T., Tudor, M., 2012. An assessment of waterspout occurrence in the Eastern Adriatic basin in 2010: Synoptic and mesoscale environment and forecasting method. *Atmos. Res*., doi:10.1016/j.atmosres.2012.06.018