The impact of downslope winds and the urban heat island on fog formation over the Zagreb area

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Motivation & Aim

- According to the climatological data, haze and fog occur frequently over the Zagreb-Airport (Fig.1) area and cause severely low visibility that can last for several days.
- Comparison of the number of days with fog at airport is more than double compared with the urban station Zagreb-Grič.
- During the fog events, the most common wind direction is in the range of 230°–260° (Koračin, 1978). As wind speed increases, the winds are more often from N – NE directions.
- Although Zagreb stations show a reduction in the number of days with reduced visibility in the last 40 years, it is the smallest at Zagreb-Airport (~15% on an annual basis) without changes in the winter months (Brzoja, 2012).
- Considering this reduction, the anthropogenic (urban) impact and effects of the nearby topography and the Sava River are still unclear.

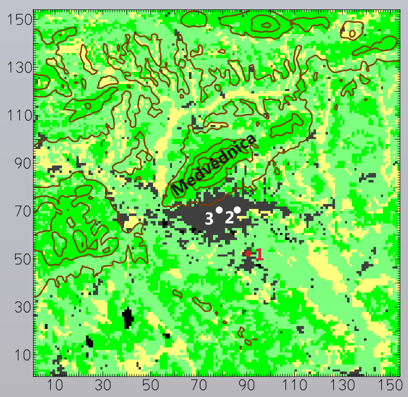

Fig. 1: The area of interest (wider Zagreb area) and measuring sites as circles: Zagreb-airport (1), Zagreb-Maksimir-radiosounding site (2) and urban site Zagreb-Grič (3). Zagreb airport is located in a flat terrain south of Zagreb near the Sava river at a height of 108 m above sea level (asl). To the north, the city of Zagreb (~120 m asl) is a main source of urban pollution including condensation nuclei. There are heavy traffic roads around the airport which also generate pollutants. North of Zagreb, the Medvednica mountain rises up to 1000 m asl in a relatively short distance of about 10 km, with a very well defined downslope forest area.

Model WRF-ARW, V3

- 3.5-day period: 5-9/November/2013
- initial and boundary conditions (every 6 h) ECMWF analysis;
- vegetation and land-use: USGS & CORINE databases;
- 4 domains (dx=13.5 km, 4.5 km, 1.5 km, 0.5 km) & 2-way nesting on a Lambert conformal projection;
- top of the atmosphere = 50 hPa & 97 sigma levels with 25 levels in the first 1 km.

Several physical options:

- RRTM for the longwave radiation;
- Dudhia scheme for the shortwave radiation;
- a five-layer thermal diffusion scheme for the soil temp.;
- the Betts-Miller-Janjić cumulus parameterization in 2 outer domain
- PBL schemes: MYJ and MYNN
- Microphysics schemes: Lin, Morrison
- Included urban surface scheme (single-layer UCM) and gravitational settling of fog/cloud droplet.

Fog detection

- Detection of fog from measurements: horizontal visibility < 1000 m (METAR reports) & satellite MSG data
- Detection of fog from model: cloud water content & algorithms:

$$vis\,(km)=60\cdot\exp[-2.5\cdot(rh(\%)-15)/80] \quad (1)$$

$$vis\,(mile)=6000\cdot[(T(°C)-Td(°C))/(rh(\%))^{1.75}] \quad (2)$$

(1) Adopted from Rapid Update Cycle (RUC) method
(2) Developed by NOAA/Forecast Systems Laboratory (FSL) method.

3-day fog event->6-8/November 2013

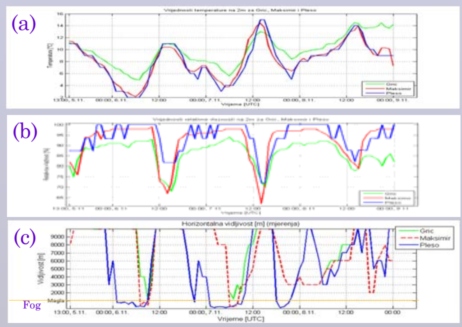

Fig. 2: Time-series of temperature [°C], relative humidity [%] and horizontal visibility [m] at three measuring sites: Zagreb-Airport (blue; station 1 in Fig. 1), Zagreb-Maksimir (red) and Zagreb-Grič (green). Opposite to the urban site 3 where the haze was just observed at the airport three episodes of fog were detected within the period of 8 h, 9 h and 3 h, respectively.

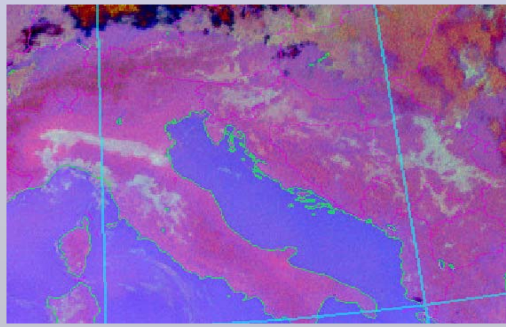

Fig. 3: MSG satellite images on 7 Nov 2013, at 05 UTC the combined NM-RGB channel. Fog is in greenish color on the RGB products covering wider Zagreb area.

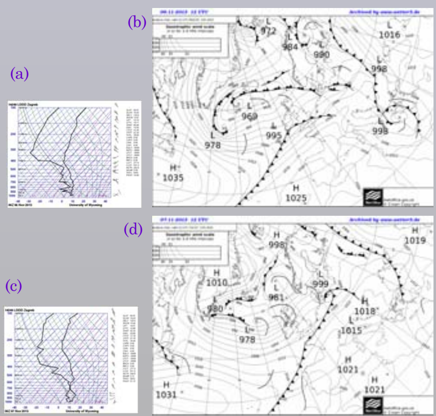

Fig. 4: Radiosounding profiles plotted on a skew T-log p diagram in Zagreb-Maksimir (station 2) and surface pressure distribution on (a) 6 Nov 2013 at 00 UTC, (b) 6 Nov 2013 at 12 UTC, (c) 7 Nov 2013 at 00 UTC and (d) 7 Nov 2013 at 12 UTC. After the passage of cyclone, the wider Zagreb area was influenced by the pressure increase and by the absence of pressure disturbances which allowed large local influence on the fog lifespan. Radiosoundig profiles showed temperature inversions in the lowermost 200 m (on 6 Nov) – 400 m (on 7 Nov).

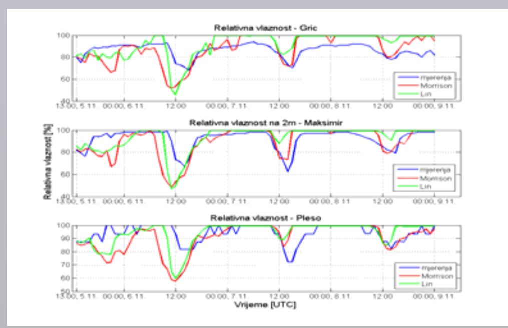

Fig. 5: Near-surface measurements (blue) for all three stations versus modeled values of the 2 model setup (MYJ&Lin; green and MYNN&Morrison; red). The data shows the 84-h evaluation of a relative humidity, rh [%] for whole period 12 UTC 05 Nov until midnight 7 Nov 2013. The position of the locations (1-3) is shown in Fig. 1.

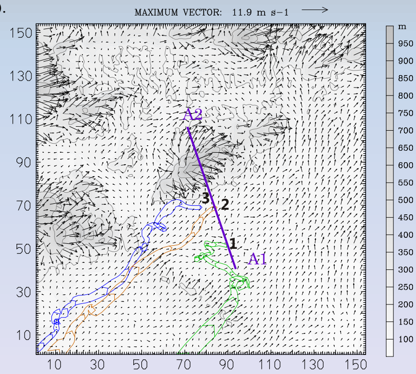

Fig. 6: 24 h 3-D backward trajectories arriving at the three points (dots 1-3 in Fig. 1) and 10-m wind at 03 UTC (=04 CET) on 7 Nov 2013. The trajectories were calculated at 0.5 km horizontal resolution within the largest model domain at 10 m level and arrows represent parcel positions for every ½ hour.

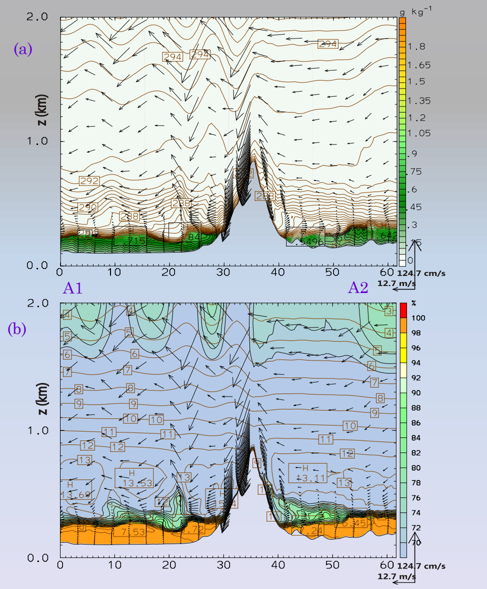

Fig. 7: Vertical cross-sections (see violet line in Fig. 6) of (a) the potential temperature (°C, brown lines), cloud water mixing ratio (g/kg, filled areas) and wind vectors (m/s) and (b) air temperature (°C, brown lines) and rh (%, filled areas) at 03 UTC (=04 CET) on 7 Nov 2013.

Summary

- The influence of the downslope wind on the Zagreb fog formation is weak and limited.
- Urban areas contribute to the decrease of fog occurrence and duration.

References

Koračin D (1978): Glavni uzroci magle na zagrebačkom aerodromu Pleso. Diplomski rad. PMF Zagreb, str. 69.
Brzoja D (2012): Analiza pojave magle na širem području Zagreba. Diplomski rad. PMF Zagreb, str. 74.

Acknowledgements

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