SENSITIVITY OF PLANETARY BOUNDARY LAYER HEIGHT TO CROP TYPE AND FERTILIZATION LEVEL IN AN ANTICYCLONIC WEATHER

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Abstract: Hungary has relatively large flat areas enabling strong land-surface/atmosphere interactions in convective weather situations. The role of land-surface in governing exchange processes is unarguable, only the role and the relative strength of impact of different land-surface components is somewhat different. The treatment of agricultural areas in earth sciences becomes more and more important. Since in Hungary dominantly agricultural lands are frequent, the representation of agricultural areas can be especially important.

The first simulation considering land-surface/atmosphere interactions appeared in 2007. In that and the following simulations, the land-surface heterogeneities are represented by USGS (United State Geological Survey) method, in which agricultural areas are categorized as “Dryland Cropland and Pasture”. This categorization considers agricultural land as homogeneous, which means that spatial inhomogeneities caused by crop rotation, irrigation, fertilization or other activities are not taken into account at all.

In this work, an earth science application related to agricultural land use we present. More precisely, the sensitivity of planetary boundary layer height to cropland types and fertilization intensity is analyzed. The simulation region is the Carpathian Basin, the chosen day is a typical summer day when the shallow convection is prevailing in an anticyclonic weather. The research tool used is the WRF (Weather Research and Forecasting) model system; the results are evaluated visually.

The first results suggest that planetary boundary layer height is as sensitive to cropland type as to the fertilization level. The results obtained could be useful in both the environmental and agricultural sciences.

Keywords: anticyclonic weather, planetary boundary layer height, agricultural areas, maize, fertilization

Introduction

Environment is impacted by humans via land use, fossil-fuel burning and fertilization activity. The most ancient phenomenon is the plant production induced land use change resulting in birth of first civilizations. Fossil-fuel burning activity is started at the time of industrial revolution. Production of chemical fertilizers enabled the enormous large human population growth and led to the host of environmental pollutions.

Hungary, similarly to Europe, shows a strongly human landscape; wild, unmanaged areas can hardly be found. Hungary’s landscape is determined by agriculture and urbanization; the former one is more important. In the meteorological models, agricultural areas are represented as spatially homogeneous vegetation areas having uniform plant morphological (e.g. leaf area index) and physiological (e.g. minimal stomatal resistance or maximal photosynthetic capacity) characteristics, which are changing in time per month. Information needed for describing time dynamic is based on satellite observations. In the WRF model, there are options to use different land cover type categorization systems (SiB (Simple Biosphere Model), USGS (United State Geological Survey) etc.). The USGS is one of the most frequently used. In this land use categorization agricultural areas are characterized by category “Dryland Cropland and
Pasture” without making differences between, for instance, winter wheat, corn, sunflower, rape, potato, apple, vine or others. The categorization mentioned doesn’t contain any information related to cropping practice (e.g. irrigation or fertilization), which could also have propound impact on both the morphological and physiological characteristics of the plant canopy.

To get an inside into the potential impact of crop-specific land use and the cropping practice on mixing of the near-surface air, we replaced category “Dryland Cropland and Pasture” by non-fertilized and fertilized corn characteristics and analyzed the caused differences in the planetary boundary layer (PBL) height and Bowen ratio (ratio between the sensible and latent heat flux). The WRF (Weather Research Forecast) model system is applied. The simulations performed above Carpathian Basin refer to 5th July, 2012 when the prevailing process was shallow convection because of the influence of a dominant anticyclone.

Materials and methods

Model: The WRF-ARW v3.1 model is used as research tool. It is applied with Noah land-surface and YSU planetary boundary layer schemes in Carpathian Basin (Ács et al., 2013) using horizontal resolution of 10x10 km². The number of vertical levels in the atmosphere was 28, most of them prescribed in the lower levels within PBL.

Data: Investigation is performed for 5th July, 2012. On this day, the weather was dominated by anti-cyclonic influence in the eastern part of Carpathian Basin.

Atmospheric data: Initial and boundary conditions for the simulation domain were generated from the global model data by the preprocessor of the WRF system. Global weather data were available every 3 hours in a horizontal resolution of half degree.

Land-surface data: Land cover type data are taken from both the USGS categorization and the literature. USGS distinguishes 21 land cover types, among them only a few (e.g. dryland cropland and pasture, grass, forest, bare ground, water, urban) are used in Hungary (Ács et al., 2013). Since corn fields are quite frequent in Hungary, we introduced corn as a separate land cover type. It is characterized by the crop height and leaf area index for both non-fertilized and fertilized case. Corn parameter values used in tests are taken from domestic literature (Micskei et al., 2012; Micskei et al., 2009) and are presented in Table 1 together with parameters referring to land cover type “Dryland Cropland and Pasture”.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Dryland Cropland and Pasture</th>
<th>non-fertilized corn</th>
<th>Fertilized corn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height [m]</td>
<td>0.5 – 1.4</td>
<td>1.5</td>
<td>1.9</td>
</tr>
<tr>
<td>Leaf area index [m²/m²]</td>
<td>2.3 – 4.3</td>
<td>2.1</td>
<td>3.4</td>
</tr>
<tr>
<td>Minimum stomatal resistance [smt]</td>
<td>40</td>
<td>40</td>
<td>40</td>
</tr>
</tbody>
</table>

Table 1. Vegetation parameter values for different land cover types as used in the WRF simulations
Soil texture categorization is given after USDA (United State Department of Agriculture). There are only 7 classes applicable in Hungary. The area distribution of classes is specified according to FAO (Food and Agriculture Organization). For the soil texture categories the soil hydraulic parameter values derived for the Hungarian soil physical database are used.

**Experimental design:** Three runs are performed for sensitivity tests (Table 2). The runs differ only in land cover types. Run 1, denoted as run 05-00-HU (column 1 is for land cover type, column 2 for soil texture and column 3 for soil parameter values), uses land cover type 5, categorization “Dryland Cropland and Pasture”. Run 2, denoted as 51-00-HU, is performed for land cover type “non-fertilized corn”. Analogously, run 3 as run type 52-00-HU is made by land cover type “fertilized corn”.

<table>
<thead>
<tr>
<th>Run number</th>
<th>Run type</th>
<th>Main land-surface conditions as used in Hungary</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Land cover type</td>
</tr>
<tr>
<td>1</td>
<td>05-00-HU</td>
<td>Dryland Cropland and Pasture</td>
</tr>
<tr>
<td>2</td>
<td>51-00-HU</td>
<td>Non-fertilized corn</td>
</tr>
<tr>
<td>3</td>
<td>52-00-HU</td>
<td>Fertilized corn</td>
</tr>
</tbody>
</table>

Land cover type effects are analyzed via different comparisons. Comparing the results of run 1 and run 2 we can analyze the effect when land cover type “Dryland Cropland and Pasture” is replaced by land cover type “non-fertilized corn”. Comparing the results of run 2 and run 3 we can get an insight into how the fertilization affects the weather. Lastly, comparing the results of run 1 and run 3 we can analyze the effects caused by replacing land cover type “Dryland Cropland and Pasture” by land cover type “fertilized corn”.

**Results and discussion**

Area-averaged daily courses of Bowen ratio and PBL height for different run types obtained in a sub-region (19–21°E, 45.5–47°N), where the sky was completely cloud-free, are presented in Figs. 1 and 2. Fig. 1 refers to agricultural land cover type effect while Fig. 2 to the fertilization effect. Each plot contains information on mean differences and standard deviations. “D” denotes the space/time averaged Bowen ratio or PBL height difference between the 1st and the 2nd run, denoted at the top of the figures, in the sub-region and in the time period 11-15 UTC. “STD” denotes the time averaged standard deviation of the Bowen ratio or PBL height in the time period 11-15 UTC for the same sub-region. The curves are presented with their standard deviations. Note that “D” values in Fig. 1 (-0.17 and -113 m) are comparable with “D” values in Fig. 2 (0.13 and 91 m). Of course, PBL height above fertilized corn is lower than above the non-fertilized corn since it has higher leaf area index and therefore lower Bowen ratio.
Figure 1. Area-averaged daily courses of Bowen ratio (left) and PBL height (right) for land cover types “Dryland Cropland and Pasture” and “non-fertilized corn” in the sub-region within the Great Hungarian Plain. The run type specification is given in figures. D = space/time averaged Bowen ratio and PBL height difference between the reference and the actual run in the sub-region and in the time period 11-15 UTC. STD = time averaged standard deviation of Bowen ratio and PBL height obtained for actual run in the time period 11-15 UTC.

Figure 2. Area-averaged daily courses of Bowen ratio (left) and PBL height (right) for land cover types “non-fertilized corn” and “fertilized corn” in the sub-region within the Great Hungarian Plain. The run type specification is given in figures. D and STD is as in Figure 1.

Conclusions
This study demonstrated that fertilization could have about the same mixing effect on the near surface air in an anticyclonic weather as the differences in cropland types.

Acknowledgements
The work was supported by OTKA (Hungarian Scientific Research Foundation) under contract number K81432. We thank Nándor Fodor the help.

References