Radiation parametrization for sloping surfaces

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Introduction

Usually, the solar radiation in forecasting models is calculated for the flat surface. But the radiation fluxes will be different for the sloping surface. In this research we try to parameterize this flux dependence on surface slopes.

Let's consider the radiation fluxes in the mountains. The amount of solar radiation coming on the surface depends on angle of solar illumination i. This angle is equal to zenith angle of the Sun in the case of flat surface, but for sloping surface this angle will be different.

The angle i can be less then zenith angle and then the surface will receive more solar radiation. Wherever i more then 90^0 the surface is self-shadows, that is the Sun is below the local horizon. Some surfaces can be shaded by neighboring mountains blocking the Sun, this is the cast shadow. For example, a flat area may be in shadow of mountains at low solar angles.

Some part of solar radiation is scattered by atmosphere and clouds, and comes on the surface as diffuse radiation. Diffuse radiation does not directly depend on surface slope. But the amount of diffuse radiation received by sloping surface depends on sky obstruction by the slope itself, clouds and by the nearby terrain.

The angle i can be defined by trigonometric formulas, if we know the zenith angle and azimuth of the Sun and angle of sloping and direction of sloping which is named aspect of given surface (Kondratiev et al, 1978):

$$cos(i) = cos(a_s)cos(\xi) + sin(a_s)sin(\xi)cos(\psi - \psi_s) \quad (1)$$

Where a_s is the slope angle of surface; ξ is the zenith angle; ψ is the azimuth of the Sun; ψ_s is the slope aspect. Then the flux on the sloping surface is described as:

$$S_{surf} = S_{\perp} \cdot cos(i) \quad (2)$$

Where $S_{\perp}$ is a flux on surface which is perpendicular to sun rays.

The single-column calculations were made (Senkova and Rontu, 2003). The differences of radiation fluxes for sloping surfaces of different direction can be more then 10 %. This difference should take into account in detailed mesoscale models.

The needed information about sloping surface angles and directions for experiment area

To make a full three dimensional model experiments we need the information about slope and aspect of Earth surface over the experiment area. This information is available in the Hydro1k data base (Hydro1k, 2003), but with resolution 1x1 km. For using one in HIRLAM experiments, we should convert the sloping data to the HIRLAM experiment resolution. We can use the different averaging methods. Since there can be several different sloping or flat surfaces in one HIRLAM grid cell it was decided to use the fractional method for more accuracy.

This method is to divide the all sloping surfaces inside a HIRLAM grid cell into four types according their aspect: Northern, Eastern, Southern and Western. We calculate the fractions, that is the percentage of area of each type related to full cell area. Then we define the average slope angle for each fraction. Radiation fluxes for each surface fraction are calculated separately and then are summarized.

Description of HIRLAM 3-dimensional experiments

For a HIRLAM experiment an anticyclonic situation over the Carpathian Mountains was chosen.
The resolution was about **3.3 km**,
including **256x201** grid points at **40** levels.
We used the hydrostatic **reference HIRLAM 6.0.0** but with updated in radiation scheme (close to the version 6.2.4) and alternative basic orography (Rontu, 2003).
Two experiments at 3.6.2000 00UTC+36h were run:
RR3 - reference experiment,
SR3 - includes calculation of radiation fluxes on the sloping surfaces.
Horizontal boundary data were obtained from a 33 km/40 level HIRLAM reanalysis experiment.

Fig. 2 shows information about sloping surface prepared for HIRLAM experiment. In the mountains there are slopes of all types, and the slope angles are not more then 22 degree. The fraction value can change from 0 to 1. Usually in one grid cell there a are few surfaces with different direction but there are some areas having only one slope direction (fraction equal 1).

The difference of shortwave surface fluxes between SR3 and RR3 experiments is local and has a maximum value of about 10 W/m2. Fig. 1 shows the example of difference of two-metre temperature averaged in the morning, evening and during 24 hours. The difference of temperature SR3-RR3 is quite small, local and does not achieve values more then 1^0C.

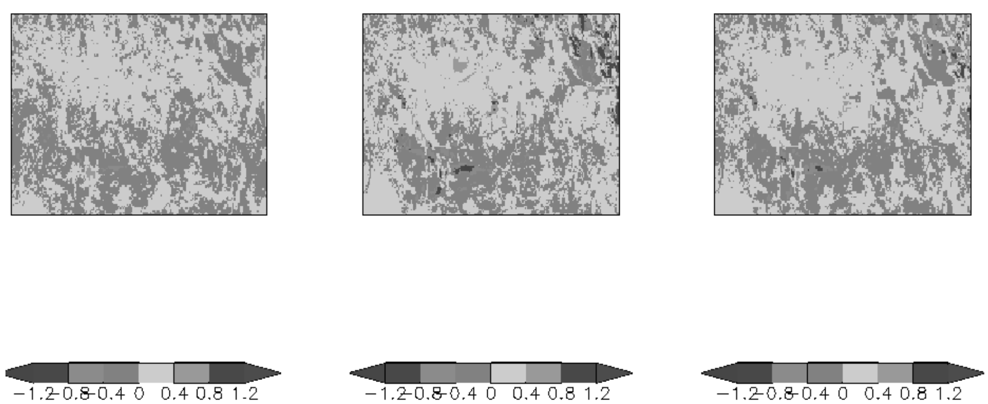

Figure 1: *The differences (SR3-RR3) of 2m forecasting temperature average for* **morning (3-9 UTS)***; * **evening (15-21 UTS)** *and* **daily (24 hours)**

The forecasted wind at 3 June was weak, but there are some clouds. Unfortunately, the maximum difference in radiation fluxes between the experiments coincide with cloudy areas. In reality, no significant clouds were observed in this case. It turned out that (unrealistic) soil moisture values originating from a cold start of the experiment at 1 June, strongly influenced cloud generation. In subsequent studies, the influence of soil moisture could be excluded by using a small constant value or values resulting of long assimilation.

Conclusion

This was the first attempt to carry out a full model experiment, which accounts the sloping surfaces in radiation scheme. Based on the results we can conclude:

The changes of scheme produce a small local effect on surface shortwave radiation fluxes and surface temperature. The changes of temperature are about 0.5^oC, of the radiation fluxes about 10 W/m2.

There is some interaction with clouds. The radiation scheme is very sensitive to clouds and the appearance of small changes of clouds result in large changes of radiation fluxes.

To correctly describe the sloping surface effect it is necessary to more accurately account for the diffuse radiation and mountain shading. More studies are needed.

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References

Kondratiev K.Ja., Z.I. Pivovarova, M. P. Fedorova, 1978: The radiation regime of sloping surfaces. *L., Hydrometeoizdat*, 216 p.

Rontu L., 2003. Derivation of orography-related climate variables for a fine resolution HIRLAM. HIRLAM Newsletter, 44, 83–96.

Senkova A., Rontu L., 2003. A study of the radiation parameterization for sloping surfaces. Baltic HIRLAM Workshop, *St.Peterburg, 17-20 November*, 79-82.

Hydro1k Team, 2003. Web page of Hydro1k data base of surface elevation, slope and aspect. Available at http://edcdaac.usgs.gov/gtopo30/hydro/

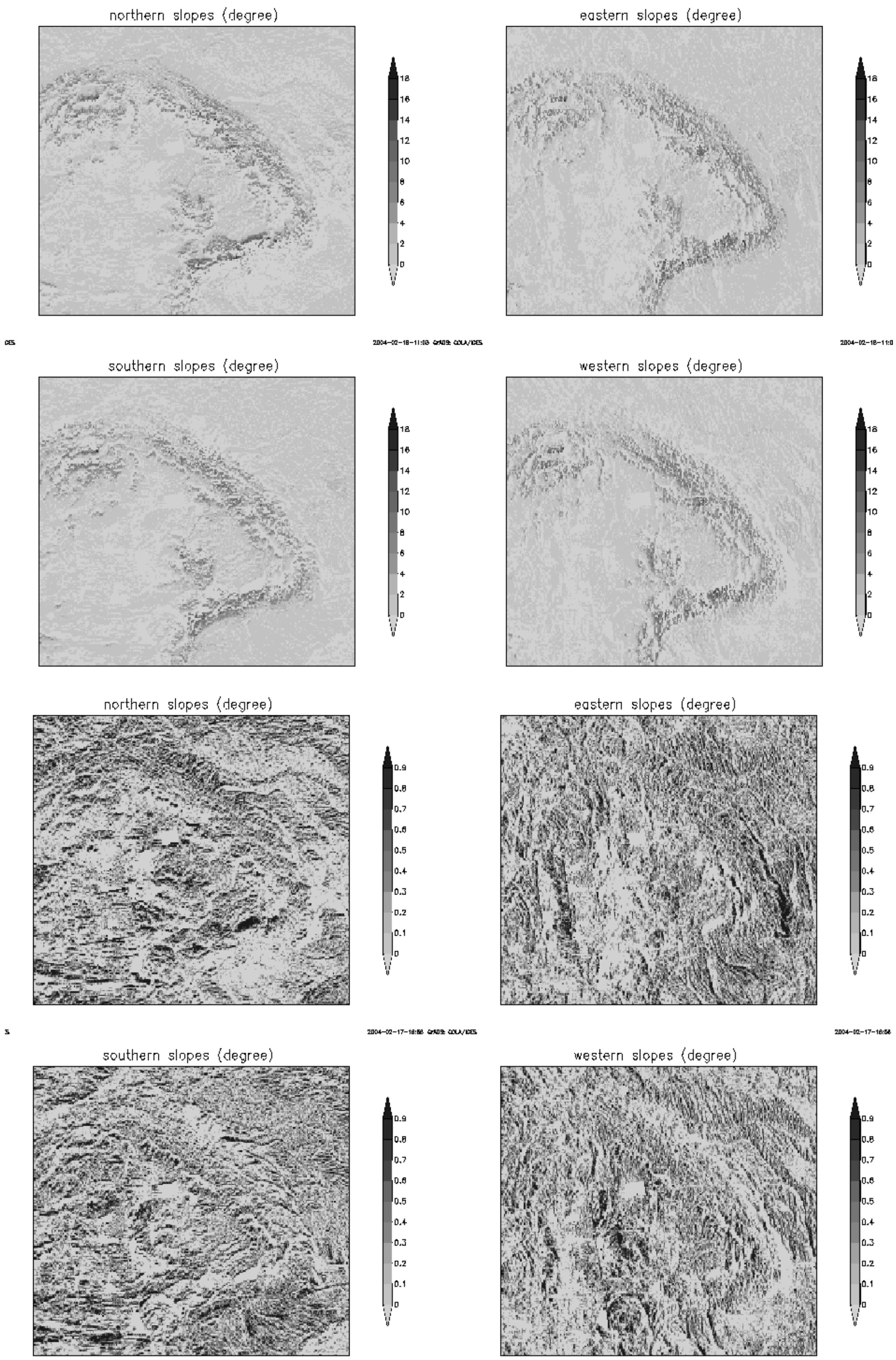

Figure 2: *The initial fields of* **slope angle** *and* **fraction of area** *for four types of surface directions over Carpathian mountains.*