Investigation of the Vegetation Effects on Convection by Using COSMO-CLM

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Abstract

Convection is affected by vegetation cover considering variation of water and heat retention of different soil surfaces. Vegetated areas also change the amount of incoming and outgoing components of the surface energy budget, therefore the areas affect the atmospheric convection. In this study, vegetation effects on convection were investigated using a non-hydrostatic, limited-area, atmospheric prediction model (COSMO-CLM) with different land cover maps that use different vegetation fractions and normalized difference vegetation index (NDVI) values. The model domain covered especially forested regions from the northeastern part of Turkey and Black Sea to the eastern coasts of Caspian Sea. In this context, changes of atmospheric parameters considered as indicators of convection obtained by model simulations were investigated.

Introduction

Vegetation covered area promotes convection both by extraction of soil moisture and by shading the soil so that conduction of heat into the soil was reduced (thereby increasing the available energy) [1]. Considering surface energy budget, vegetated area change the amount of incoming or outgoing components of the budget. Fig. 1 shows the schematic illustration of the surface heat budget over different types of covers [2]. In order to better understand the effects of vegetation on convection, fluxes over the surfaces should be examined.

There are several studies about varying of surface fluxes and precipitation by vegetation covered area. Some examples of these studies can be found following:

Lyons et al. found a reduction of sensible heat flux in southwestern Australia as a result of the conversion of land to agriculture [3]. In other studies it is found that the leafing out of vegetation in the spring has a dramatic effect on a reduction in sensible heat flux [4, 5]. Machado et al. investigate the variability of convection over different vegetation types. It is shown that the main differences between rainforest and savanna or deforested sites occur in the dry season, whereas the magnitude and diurnal cycle of convection as well as amount of rainfall [6].

In this study, vegetation effects on convection has been investigated by COSMO-CLM simulations using different land cover maps covering especially forested regions.

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Data and Method

Vegetation effects were simulated by using COSMO-CLM. The COSMO model is the non-hydrostatic operational weather prediction model applied and further developed by the national weather services joined in the COnsortium for SMall scale MOdeling (COSMO). COSMO was developed from the Local Model (LM) of the German Meteorological Service by CLM-Community which is an open international network of scientists (`http://www.cosmo-model.org`). In 2005, the CLM-Community improved the COSMO-Model to be capable of long-term simulations so it is called COSMO model in CLimate Mode (COSMO-CLM or CCLM), then CCLM became the regional Community-Model for the German climate research. This model version has been applied on time scales up to centuries and spatial resolutions between 1 and 50 km in different regions of the world (`http://www.clm-community.eu`). The COSMO model is based on primitive thermo-hydrodynamical equations that define compressible flow in a moist atmosphere without using any scale approximations. The general aim is to be used for both operational numerical weather prediction (NWP) and research applications on meso-scale. COSMO model flowchart is shown in Fig. 2.

In order to obtain the simulations, ERA-Interim data set with six hour interval belonging to the year 2012 was used as input data for COSMO-CLM. ERA-Interim by European Centre for Medium-Range Weather Forecasts (ECMWF) is a global atmospheric reanalysis from 1979, continuously updated in real time. The ERA-Interim reanalysis is produced with the ECMWF Integrated Forecasting System (IFS), which incorporates a forecast model with three fully coupled components for the atmosphere, land surface, and ocean waves [7]. Fig. 3 shows the ERA-Interim variables used as the initial values (`http://rda.ucar.edu/datasets/ds627.0`).

Study area locates from the northeastern part of Turkey and Black Sea to the eastern coasts of Caspian Sea. Fig. 4 shows the study area used as base map for the model. The model runs with one hour temporal and 30km spatial resolutions. GLC2000 and GLOBCOVER were used as land use cover maps for the simulations. They differ from each other according to the satellites and sensors that they use. GLC2000 land cover map uses SPOT 4 satellite and has 1km spatial resolution. GLOBCOVER land cover uses 300m MERIT sensor of ENVISAT satellite.

Results

Model results were obtained as six hourly data and then converted to the daily values. The figures of model outputs shows the monthly averages for temperature, sensible heat flux, latent heat flux and total cloud cover and the monthly total values for precipitation data. Analyses illustrates on both GLC2000 and GLOBCOVER land use maps. Land use maps shows different vegetation fractions and normalized difference vegetation index (NDVI) values. For GLC2000 land use, plant cover and leaf area index for the COSMO-Model and for a special day are produced by using only the data set for vegetation and an averaged NDVI ratio by NDVI type choosing. For GLOBCOVER land use plant cover, leaf area index and roughness length for the COSMO-Model and for a special day are produced by using 12 monthly climatological mean values for plant cover, leaf area index and roughness length. The difference for the vegetation area fractions for GCL2000 and GLOBCOVER are shown in Fig. 5.

Different land use maps caused different results although the initial data and boundary conditions are the same. Distribution of simulated temperature (Fig. 6) and precipitation (Fig. 7) show similar distribution to the vegetation fractions. Especially precipitation values are highest where the vegetation fractions are also high. This situation may be caused by the forest area due to gas exchanges by photosynthesis and also respiration. Because GLC2000 land use map has higher values of vegetation fraction, maximum precipitation amounts are also higher than GLOBCOVER land use.

Sensible heat flux (Fig. 8) and latent heat flux (Fig. 9) have not much difference for different land use maps but where vegetation fraction is high for GLOBCOVER, values are higher than GLC2000. Especially in summer times, over the Caspian Sea and the western part of the sea, lower negative values can be seen. Sensible heat flux values are lowest in the western part and also in the southeast part of the Black Sea. Heat fluxes cannot be linked to only vegetation cover of the surface. Sea-land distribution and topographic effects should also be considered. However, in winter times, heat fluxes have highest values where vegetation fractions also high.

Total cloud cover mainly affected by moisture sources. In this study, existence of sea trigger in convection by evaporation and air masses pass over the Black Sea. However, vegetation cover is also a source for connectivity by the gas exchange between plants and atmosphere. Total cloud cover distribution is illustrated in Fig. 10.

Conclusions

The impacts of vegetation on convection occur as affecting surface fluxes of gases (CO_2, O_2, H_2O etc.) and wind speed over the plant canopies and extraction of soil moisture. Surface fluxes over canopies have different behavior from bare soil. Because vegetation processes and change directly affect the surface energy and moisture fluxes into the atmosphere. Of course convection in the atmosphere depends on many other factors and causes the change of many other parameters. Thus, for the future studies, changes of other parameters like wind shear and wind shift need to be examined. Beside monthly variations, daily and hourly variations need also to be considered in the examinations. It is hard to examine only vegetation effects, so atmosphere-ocean-cloud-agriculture coupled models need to be applied in future studies.

References

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Figures

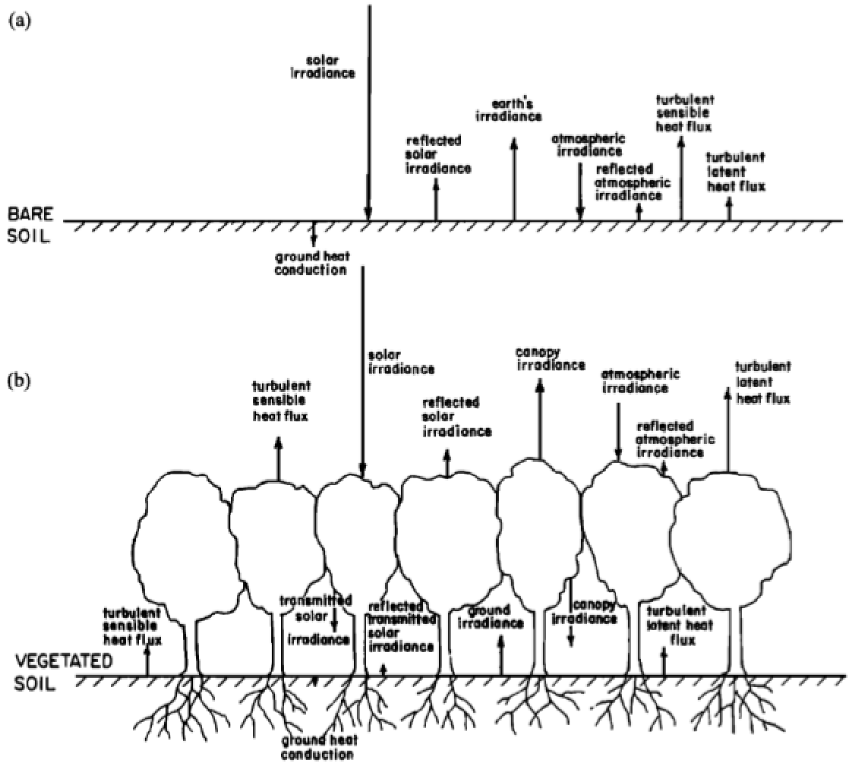

Fig. 1: Schematic illustration of the surface heat budget over (a) bare soil and (b) vegetated land [2].

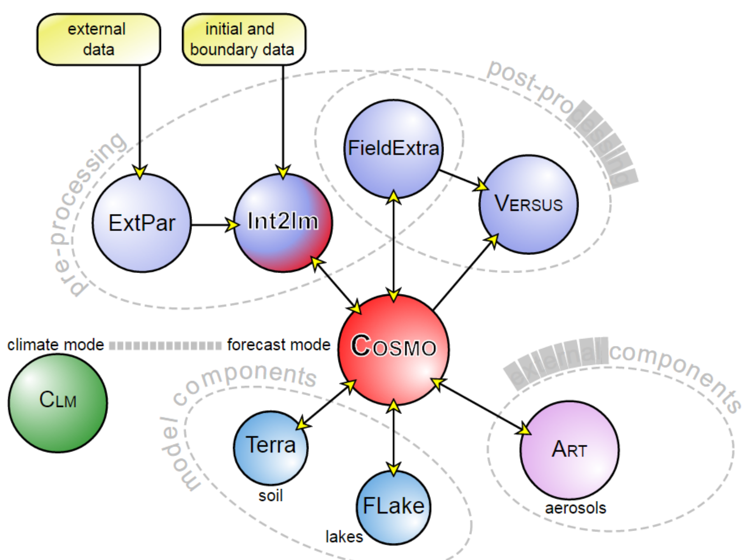

Fig. 2: COSMO-CLM flow chart [7].

Air Temperature	Albedo	Cloud Amount/Frequency	Cloud Liquid Water/Ice
Convection	Convergence/Divergence	Dew Point Temperature	Evaporation
Geopotential Height	Gravity Wave	Heat Flux	Humidity
Hydrostatic Pressure	Ice Extent	Incoming Solar Radiation	Longwave Radiation
Maximum/Minimum Temperature	Outgoing Longwave Radiation	Planetary Boundary Layer Height	Potential Temperature
Precipitable Water	Precipitation Amount	Runoff	Sea Level Pressure
Sea Surface Temperature	Shortwave Radiation	Skin Temperature	Snow
Snow Density	Snow Depth	Snow Melt	Snow/Ice Temperature
Soil Moisture/Water Content	Soil Temperature	Streamfunctions	Sunshine
Surface Air Temperature	Surface Pressure	Surface Roughness	Surface Winds
Terrain Elevation	Tropospheric Ozone	Upper Level Winds	Vegetation Cover
Vegetation Species	Vertical Wind Motion	Vorticity	Water Vapor
Wind Stress			

Fig. 3: ERA-Interim variables.

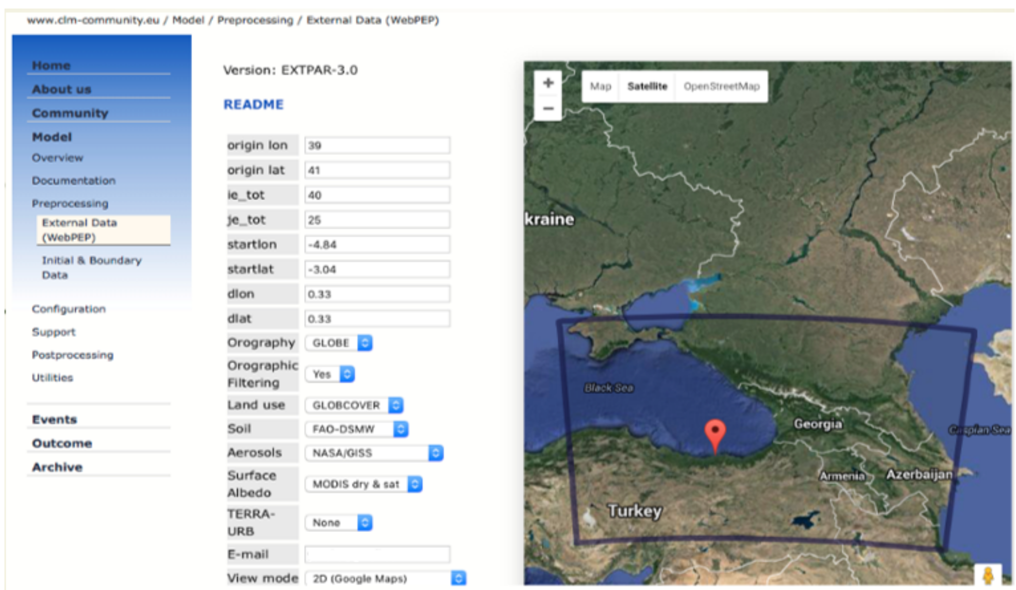

Fig. 4: Study Area.

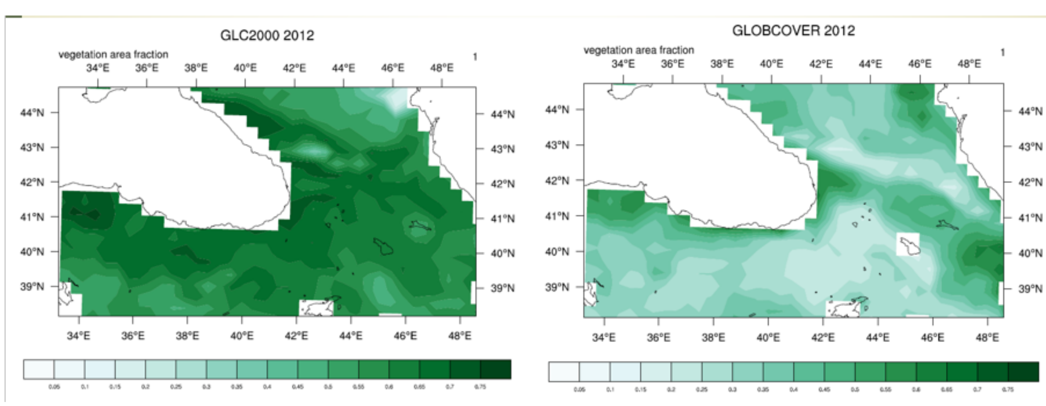

Fig. 5: Vegetation area fractions for GLC2000 and GLOBCOVER land use maps.

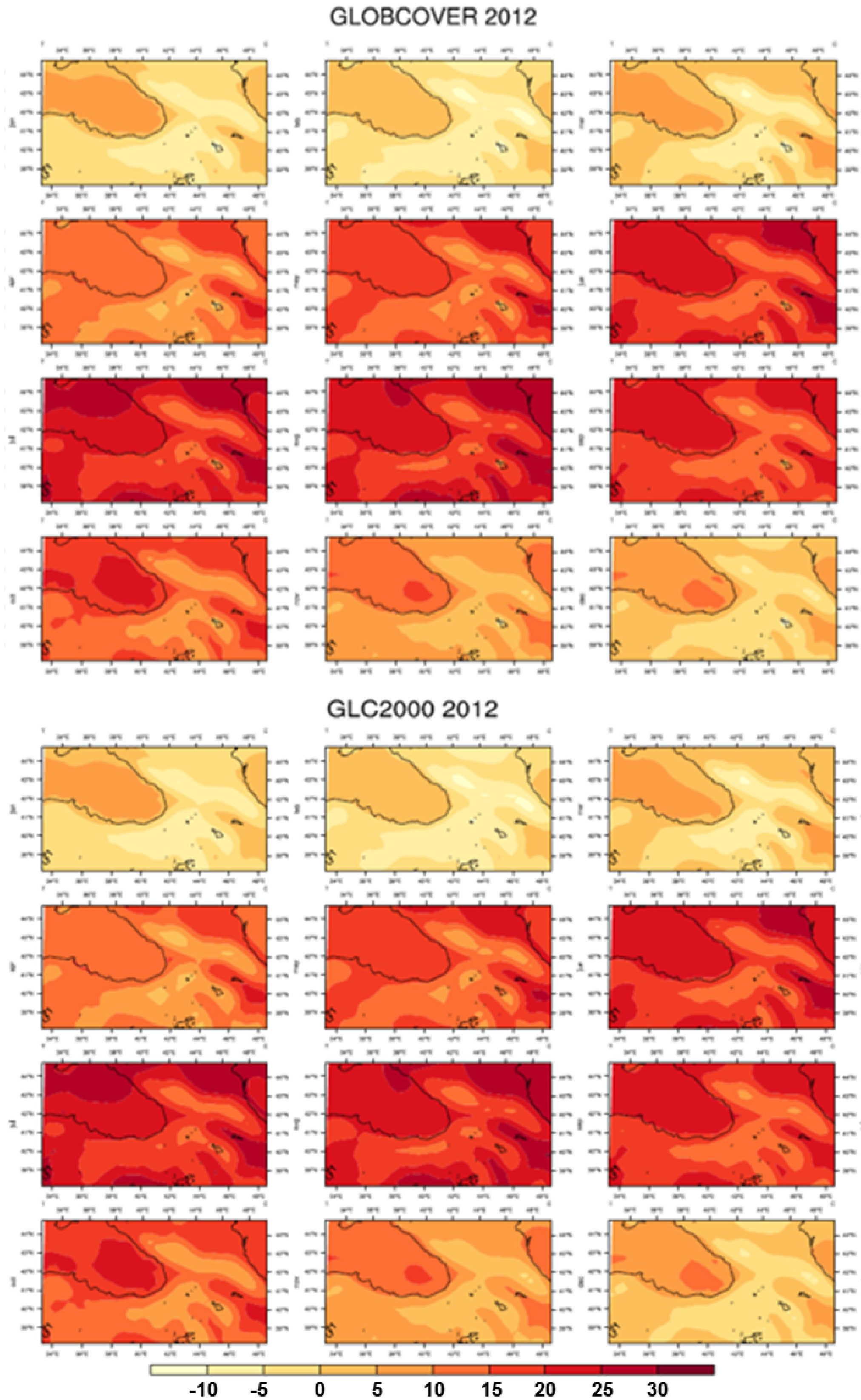

Fig. 6: Monthly mean temperature for GLC2000 and GLOBCOVER land use maps.

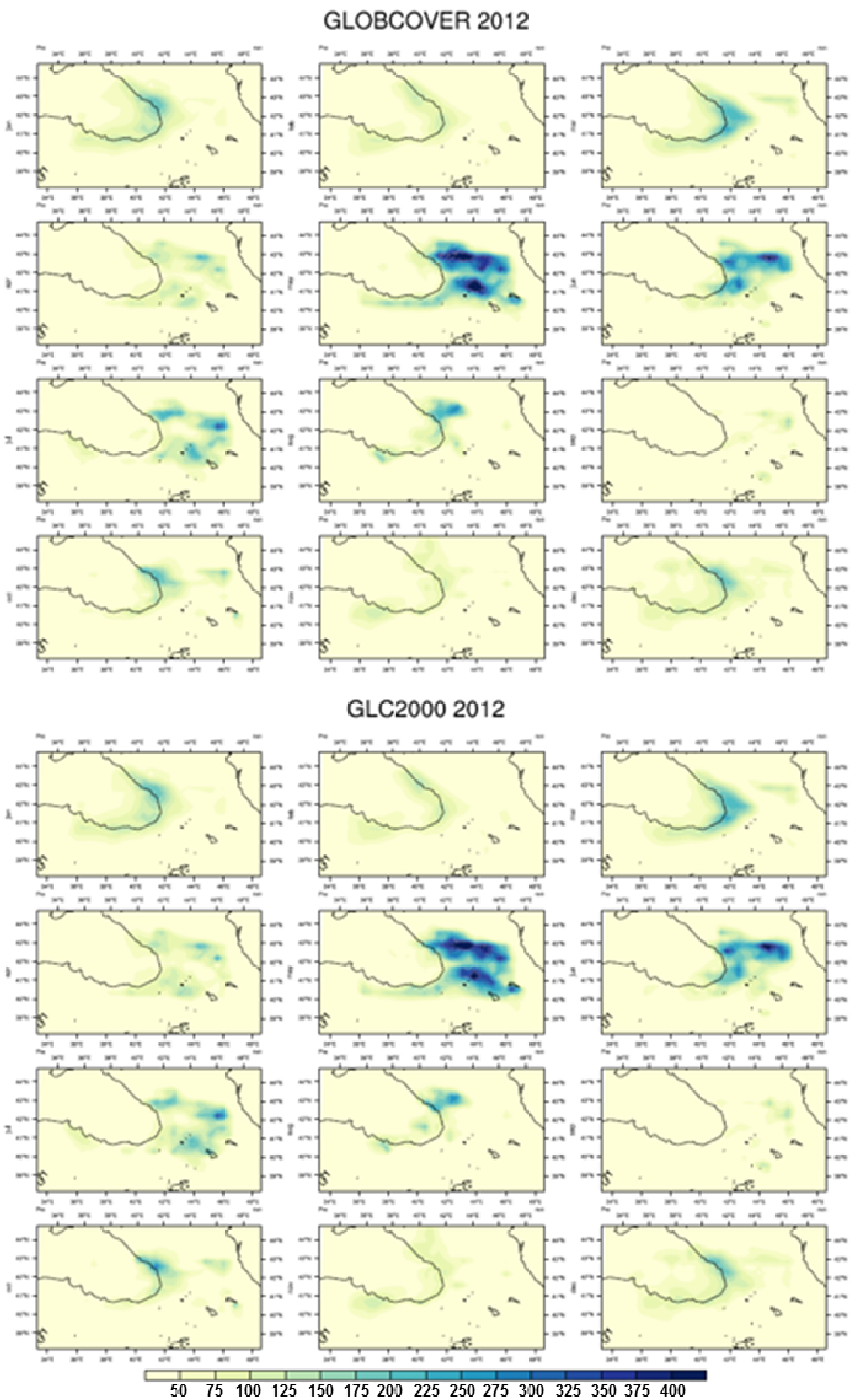

Fig. 7: Monthly total precipitation for GLC2000 and GLOBCOVER land use maps.

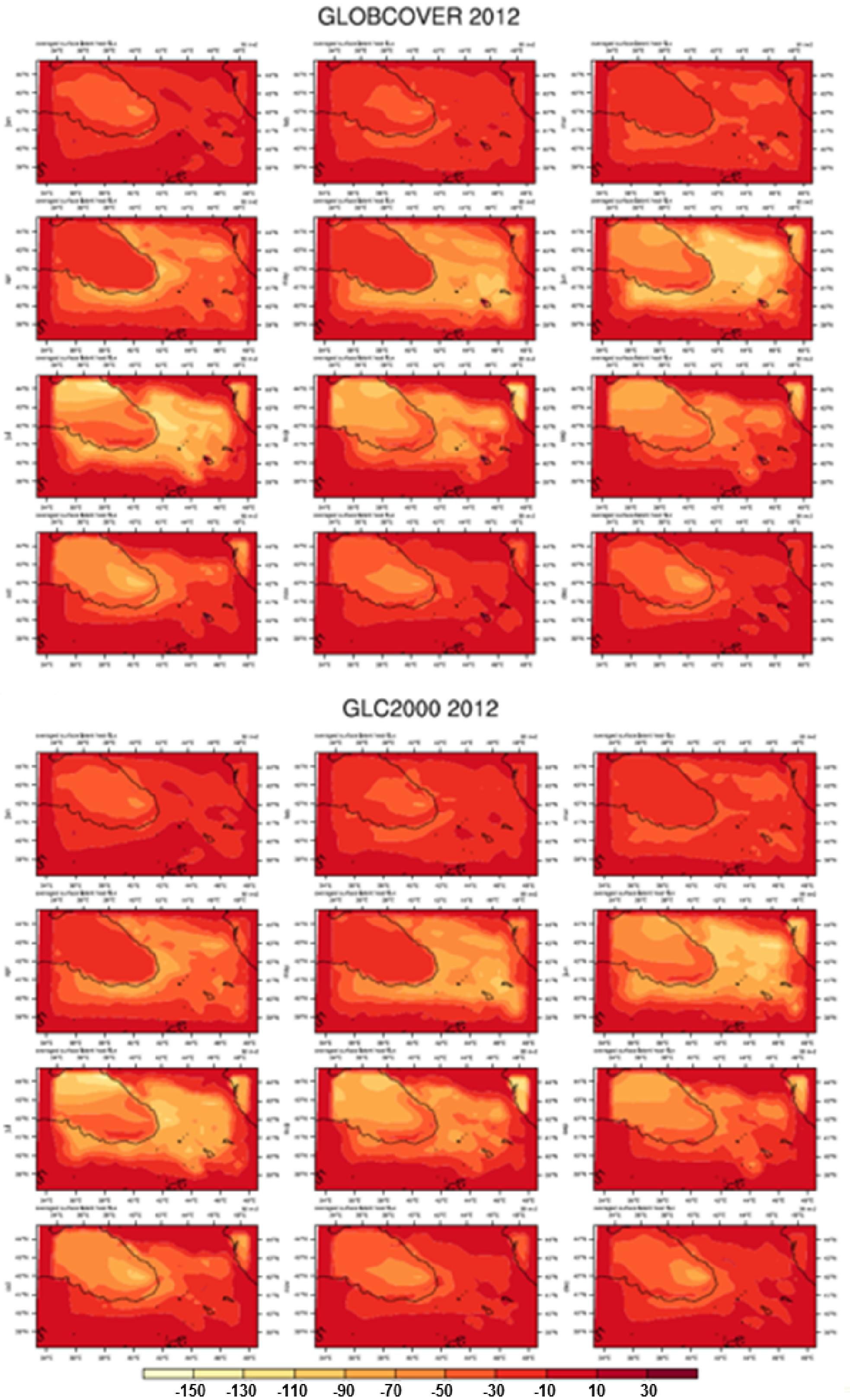

Fig. 8: Monthly mean latent heat flux for GLC2000 and GLOBCOVER land use maps.

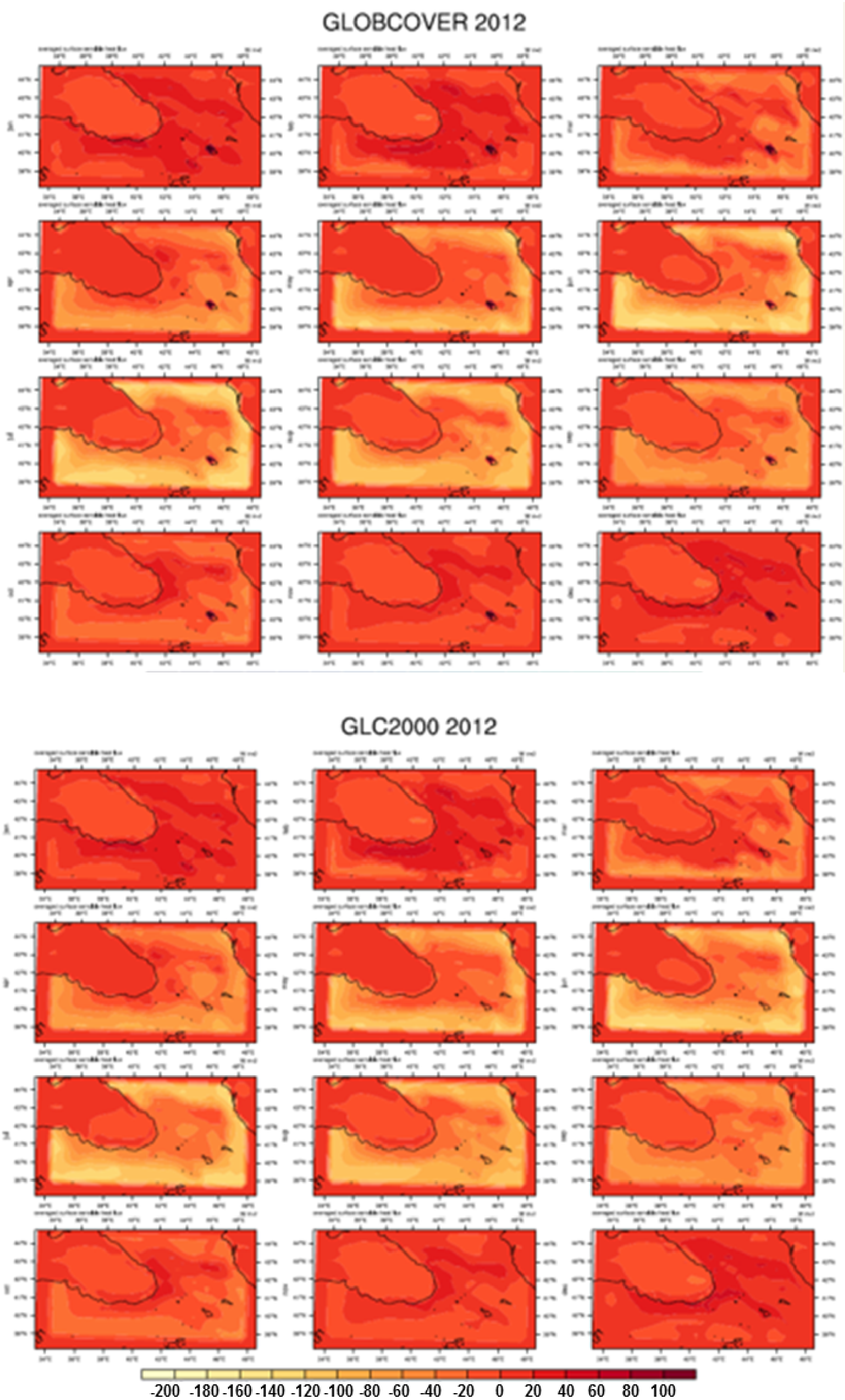

Fig. 9: Monthly mean sensible heat flux for GLC2000 and GLOBCOVER land use maps.

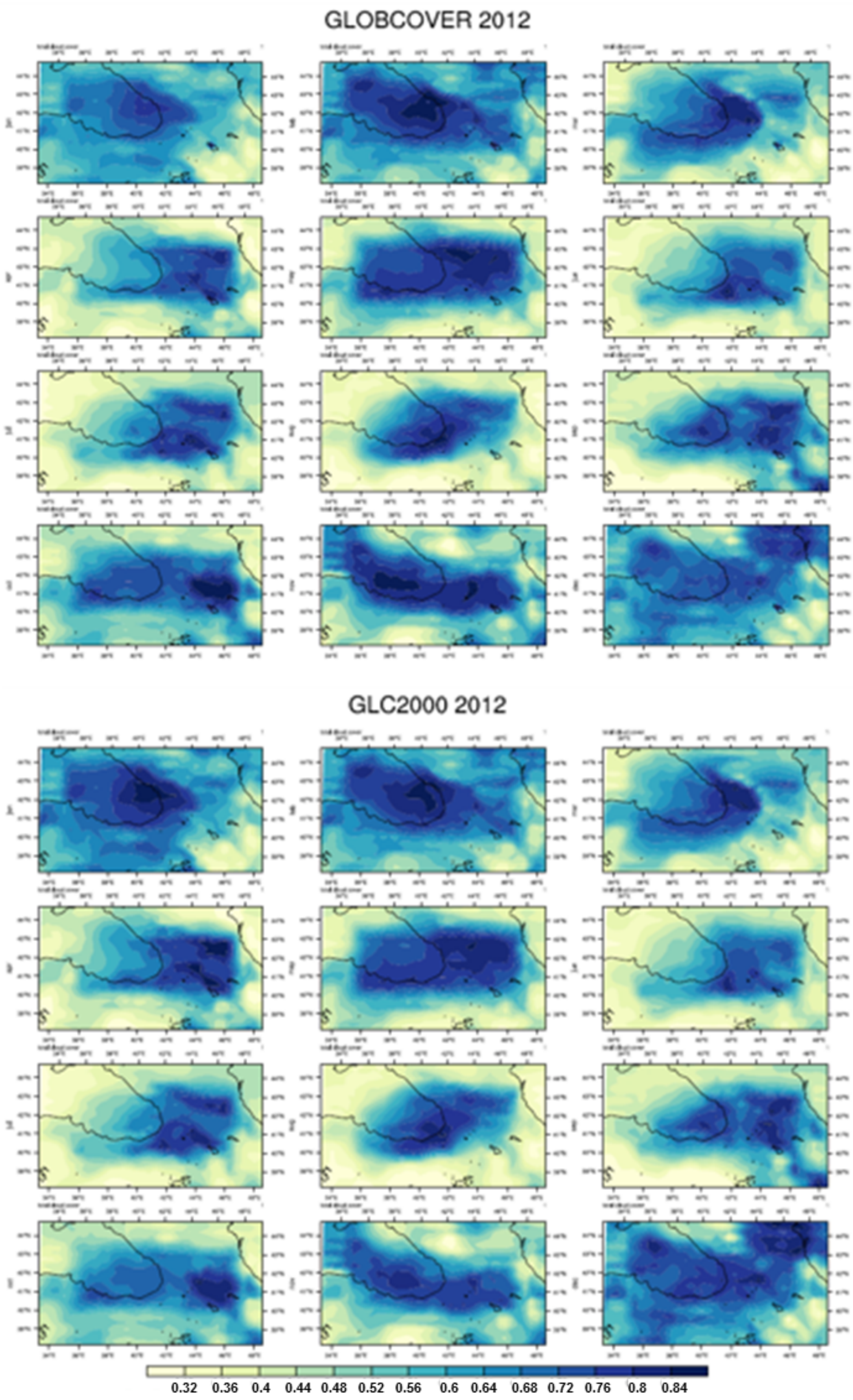

Fig. 10: Monthly mean total cloud cover for GLC2000 and GLOBCOVER land use maps.