Application of the ACASA model for urban development studies

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OBJECTIVE

Since urban population is growing fast and urban areas are recognized as the major source of CO_2 emissions, more attention has being dedicated to the topic of urban sustainability and its connection with the climate. The main goal of this study is the development of a software framework to estimate the carbon exchanges accounting for alternative scenarios which can influence urban development. The modeling system is based on four main components: (i) a Cellular Automata model for the simulation of the urban land-use dynamics; (ii) a transportation model, able to estimate the variation of the transportation network load and (iii) the ACASA (Advanced Canopy-Atmosphere-Soil Algorithm) model which was tightly coupled with the (iv) mesoscale weather model WRF for the estimation of the relevant urban metabolism components (Fig. 1).

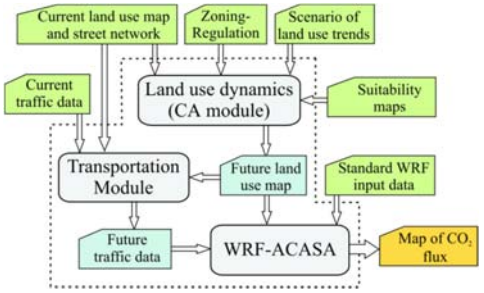

Fig. 1. Outline of the modeling framework highlighting the most relevant data exchange between the involved components.

METHODOLOGY

1) The land-use dynamics simulation module (CA) takes as main input the current map of land uses, the constraints related to the zoning regulation, the cells suitability (Fig. 2a) to produce a future land use map.

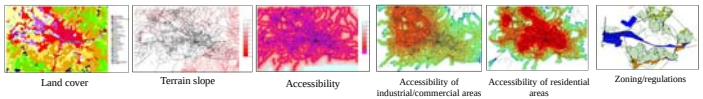

Fig. 2a. Cellula Automata ingredients to provide future maps of land use in Florence.

2) Such future land use map, together with the street network including the current traffic data, are used by the transportation module for estimating future traffic data coherent with the assumed land uses trends (Fig. 2b).

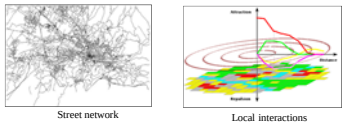

Fig. 2b. Transportation module ingredients to estimate future traffic data.

3) The future land use scenario and traffic data, are then used by the coupled model WRF-ACASA for estimating future maps of CO_2 fluxes in the urban area (Fig. 3).

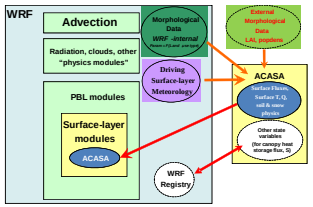

Fig. 3. Scheme of the WRF and ACASA models coupling.

CELLULA AUTOMATA

A Cellular Automata (CA) model provides spatial scenarios of the land use allocation, considering changing in demography, transportation road, socio-economic activities, and urban legislation (Fig. 4). Future land use scenarios are then used by models to asses the impact of future planning alternatives on urban metabolism (Blecic et al., 2011).

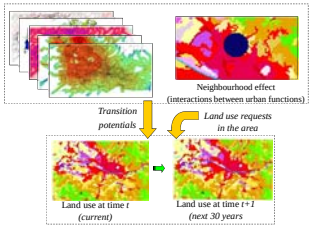

Fig. 4. Current (time t) and future (time t+1) land use in Florence used for WRF-ACASA simulations.

The transportation model provides an estimate of the load variation related to the future land uses scenarios. It uses an origin-destination (OD) trip matrix, expressing the distribution of trip demand, which is computed on the basis of relevant land uses considered as trips sources and attractors

ACASA MODEL

The multilayer model ACASA (Fig. 5) (Pyles et al., 2000; Marras et al., 2010) has been first applied at local scale (Fig. 6) to estimate the urban metabolism components in Florence (Italy). Urban fluxes are parameterized as proportional to population density: the more people there are in an area, the more building surfaces there are that can be flux sources and sinks.

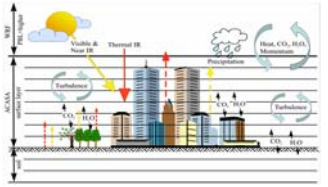

Fig. 5. Schematic representation of the multi-layer scheme.

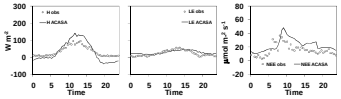

Fig. 6. Comparison between measured and simulated urban fluxes in April 2008. H=sensible heat flux; LE=latent heat flux; NEE=net ecosystem exchange. Data are sorted by time and averaged over 30 days.

WRF-ACASA MODEL

ACASA was recently coupled with the mesoscale Weather Research and Forecasting model (WRF). ACASA substituted the existing surface-layer scheme available in WRF due to a more realistic representations of the surface-layer physics and physiology in ACASA. A sequence of 6 nested domains with feedback for WRF-ACASA (48.6, 16.4, 5.2, 1.8, 0.6 and 0.2 km) was used to simulate urban fluxes (Fig. 7).

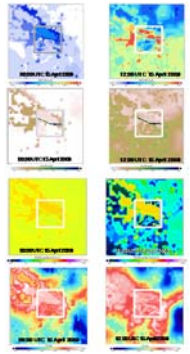

Fig. 7 WRF-ACASA simulated fluxes. Inner domain(d06): 7x7 km, dx = 200m; outer domain (d05): 18.6x18.6 km, dx = 600m.

RESULTS AND CONCLUSIONS

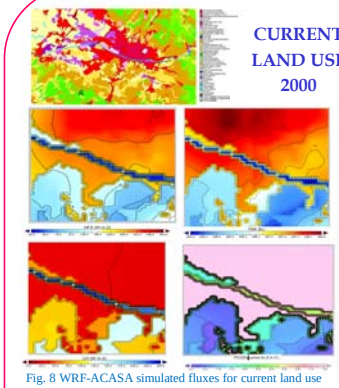

Fig. 8 WRF-ACASA simulated fluxes for current land use (Corine map at year 2000), at 118 m spatial resolution.

Urban fluxes for 1st April (10.00 UCT) are showed for 2008, by using the current land use map (Corine 2000) (Fig. 8), and for 2010 by using future land use map (Fig. 9). The increased urbanization level is highlighted by the blue circle in the future land map. For future, WRF-ACASA simulations show a clear increase in the urban heat island (higher HFX and air temp.), less evapotranspiration (LH) and an increase in CO_2 emission level.

Results show the usefulness of the developed framework system in supporting urban planners to achieve a more sustainable metabolism in the urban environment.

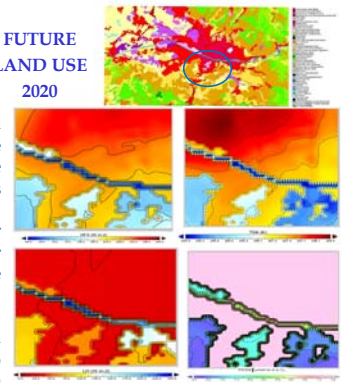

Fig. 9 WRF-ACASA simulated fluxes for future land use, at 118 m spatial resolution.

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