Geophysical Research Abstracts, Vol. 8, 00786, 2006
SRef-ID: 1607-7962/gra/EGU06-A-00786

Sensitivity of wind-induced shallow lake circulation patterns on changes in lakeshore land use

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In most shallow lakes hydrodynamics is driven by the wind. In the absence of large scale upwind topographic features and for lakes with horizontal extension small compared to typical cyclonic scales the input wind speed field over the lake is often considered spatially constant. Efforts are usually put then on determining the wind speed dependent lake surface roughness, only. In reality, however, an internal boundary layer (IBL) develops over the lake due to the abrupt change in roughness conditions at the shoreline, resulting in significant modification of the near surface wind profile along the fetch. It has been confirmed by long term wind speed measurements carried out at multiple locations over the lake surface, and could be reproduced even by simple semi-empirical formulae available in the literature. At the air-water interface this all creates fetch dependent surface shear stress distribution with occasionally significant curl in it, which can then largely determine lake circulation patterns.

In nearly neutral near surface conditions one of the key parameters in the IBL development is the characteristic aerodynamic roughness of the upwind lakeshore region, scaled primarily by the actual land use there. Forests, farmlands, cottage areas, tall or short grass all result in different roughness height and near surface equilibrium wind profile. Once running onto the lake surface, this profile will be restructured according to the IBL development principles, resulting in the growth of surface shear stress along the fetch. Consequently, land roughness and its spatial distribution around the lake proves a necessary additional parameter in realistic numerical modelling of circulation patterns. In fact, topographic gyres due to relative bottom slopes can be sig-

nificantly modified, counterbalanced or even reversed by the curl of the wind shear stress field.

First the approach, its mathematical analysis and numerical implementation in existing lake flow models will be presented, along with its validation by simultaneous wind and lake flow measurement data. A number of sample applications will be then given showing the often striking modification of the topographic gyres especially in mild bottom slope conditions. Besides evaluating the sensitivity of the circulation patterns on the upwind land roughness conditions, the effect of long term significant changes in the water level on the above mentioned mechanisms will be also outlined.