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Integrated Hydro-Ecological Modelling (IHEM) Project

Interim Report

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Introduction & Objective

The main objective of the project remains as originally stated, to develop an efficient integrated model, capturing the essential elements of plant growth and surface-atmosphere gas exchange, including atmospheric and soil feedbacks.

Changes from work plan

There have been changes in the personnel involved in the project at CEH Edinburgh: Andrew Friend and Andrew White have been replaced by Peter Levy and Marcel van Oijen. There are also some changes in the models being used in the project. Principally, the model of Levy *et al.* (2000) has replaced the original vegetation growth model "Hybrid". However, the basic approach is still the same as originally proposed: to couple an Atmospheric Boundary Layer (ABL) model with a dynamic vegetation model, and to compare results with uncoupled "off-line" forms (Figure 1).

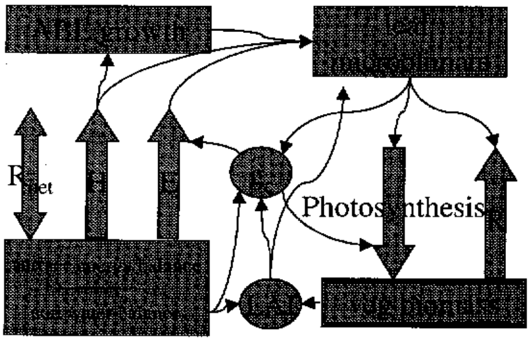

Figure 1. Diagram of model linkages

Progress

Peter Levy has provided massive input into this project, having worked at CEH Wallingford for periods in January, April, June and October 2000. Peter Levy modified Chris Huntingford's ABL model to run using measured surface fluxes as input data. Field data for Howbery (a grassland site next to CEH Wallingford) were used to test the model's ability to simulate surface temperature and humidity, given surface fluxes of heat and water vapour. Radiosonde data from Herstmonceux were used to verify model predictions.

The vegetation light interception sub-model was altered to represent multiple layers. The carbon balance of each layer, based on cumulative photosynthesis minus respiration, is used to allow self-regulation of LAI. Leaf death occurs in layers where the carbon balance is negative for a (variable) number of days. The performance of this sub-model was evaluated by examining predictions of LAI in different climates: along a rainfall gradient in Africa, along an altitudinal gradient in Oregon, and globally by comparison with the satellite NDVI-based estimates of Sellers et al. (1994) (Figure 2).

The coupled model was run at the UK Howbery site, where simultaneous and extensive surface meteorological data, flux measurements & radiosonde profiles were available. The coupled model was used to examine the magnitude of ABL-vegetation feedback effects when the system is perturbed by either a doubling of atmospheric CO_2 concentration ($2xCO_2$) or a 3°C rise in temperature (T+3). The uncoupled models were run for comparison and *feedback amplification* was calculated as:

$$\frac{\text{Coupled } (X_{\text{pertubed}} - X_{\text{unpertubed}})}{\text{Uncoupled } (X_{\text{pertubed}} - X_{\text{unpertubed}})}$$

where X is the output variable of interest predicted in either the perturbed scenario (either $2xCO_2$ or T+3) or unperturbed (current climate) scenario. Preliminary results suggest that the ABL feedbacks are not critical when CO_2 is perturbed (though the effects on LAI and LE are large), as existing negative feedbacks dominate. However, when temperature is perturbed, the ABL feedbacks are much larger and positive feedback loops can be induced. Within the context of just diurnal variability, this project has led to definitions and discussion of feedback amplifications in Huntingford (2000).

Table 1. *Feedback amplification* effects on evapotranspiration and LAI when either a doubling of atmospheric CO2 concentration (2xCO2) perturbs the system or a 3°C rise in temperature (T+3). Note that when absolute values are greater than unity, the ABL is acting as a positive feedback.

	E	LAI
CO_2 x 2	+0.91	+1.02
T + 3°	-1.4	+1.02

Scientific issues and further work.

One of the main difficulties in modelling the ABL is in quantifying the role of advection. We plan to compare sites in regions where we expect advective influences to differ eg. Howbery (UK), Sweden and the Sahel. Collaboration will also take place with Chris Taylor (CEH-W) during the next two months to build advective "fields" from the ECMWF re-analysis project. In the remaining period of the project, we will focus on refining and finalising the simulations and producing publications based on the work. The work started between Chris Huntingford and Mark Smith (CEH-W) on analysing stomatal response will finish very shortly (Huntingford and Smith, 2000).

Project difficulties

Collaboration is now working well between CEH-W and CEH-E. There are no problems to report.

Outputs

Huntingford, C and Smith, M. (2000) A reinterpretation of stomatal behaviour based upon a theoretical analysis of existing descriptions. To be submitted shortly to Plant, Cell and Environ.

Huntingford, C. (2000) Convective boundary-layer feedbacks on surface energy fluxes due to changes in land surface prescription. Boundary-layer Meteorol. (Submitted)

Levy, P.E. and Huntingford, C. (2000) Feedbacks between the atmospheric boundary layer and terrestrial ecosystems: implications for global-scale modelling. Extended abstract published in AMS conference book

Peter Levy has given two talks (AMS, ESA) on this work. Chris Huntingford has given on talk at the EGS. Peter Levy has maintained the IHEM web site at http://www.nbu.ac.uk/ihem

Other references

Levy, P.E., Lucas, M.E., McKay, H.M., Escobar-Gutierrez, A.J. and Rey, A. (2000) Testing a process-based model of tree seedling growth by manipulating CO_2 and nutrient uptake. Tree Physiology, 20, 993-1005.

Sellers, P.J., S.O. Los, C.J. Tucker, C.O. Justice, D.A. Dazlich, G.J. Collatz, and D.A. Randall (1994). A global 1 deg. x 1 deg. NDVI data set for climate studies. Part 2: The generation of global fields of terrestrial biophysical parameters from the NDVI. I. J. Remote Sensing. 15:7:3519-3545.

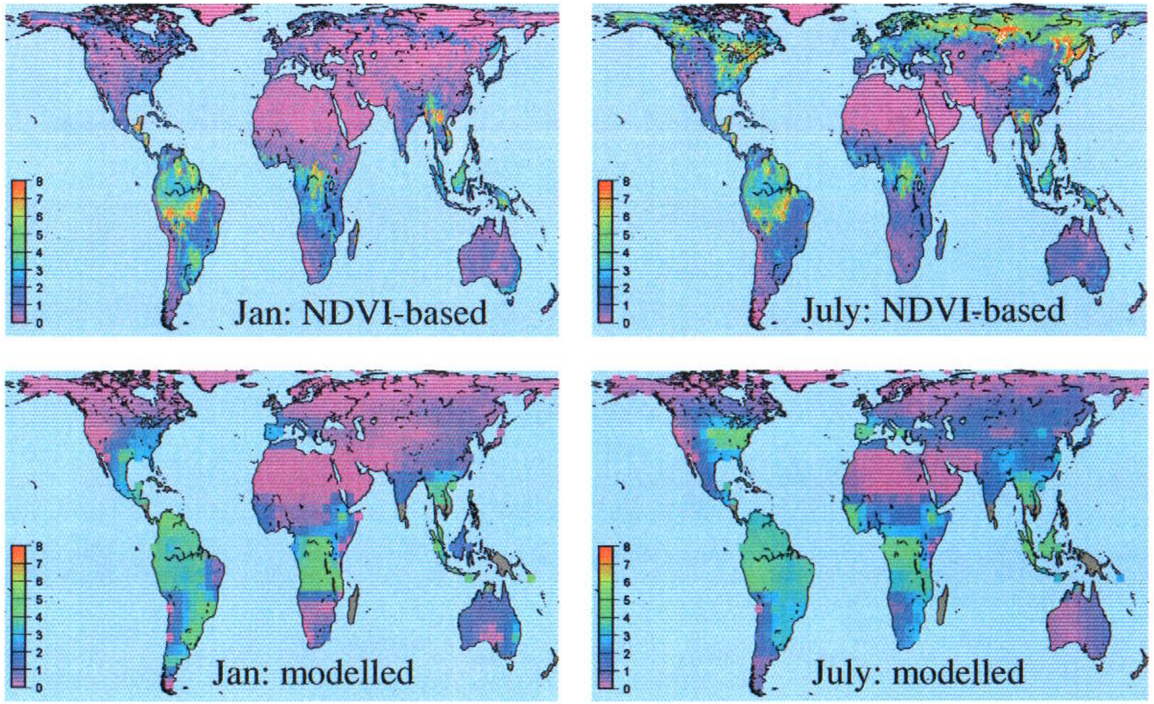

Figure 2. Comparison of modelled LAI values with those derived by Sellers et al. (1994) using satellite NDVI measurements spanning 1987-1988. Note that there is a considerable difference in spatial resolution, as the satellite measurements are on a 1 x 1 degree grid, whereas the model was run on a 10 degree grid, using the CEH WGEN weather generator as input. The model results are in at least broad agreement with NDVI observations, with the latitudinal and temporal patterns approximately correct, with the exception of the northern evergreen forests in summer.