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Development of user-friendly didactic climate models for teaching and learning purposes

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Abstract— ***This study reports on the development and application of two e-learning tools dedicated to climate science: these are Energy Balance Models, or EBMs. Such physically-based models form the ideal framework for studying fundamental energy processes at the basis of global climate and climate changes. The main assumption behind this development is that learning strategy would enhance the student's conceptual understanding from improved pedagogical technologies by allowing a greater interactivity and faster turn around, thus allowing a large number of experiments per unit time where all features are interfaced to appealing graphic displays. Consequently, these tools would contribute to learning efficiency. An analysis of the sort of reception such tools obtained in the student community in terms of their structural design, ergonomy and overall learning performances was carried out. The results show that their understanding of basic climate concepts may improve due to the interactivity and the graphic interfaces, allowing a visual display of the basic climate processes driving the energy balance of the Earth.***

Index Terms—*climate models, computer simulations, higher education, learning tools, Fortran, Java, JSP*

1. Introduction

The theoretical concepts fundamental to climate and climate change are taught at the bachelor level in a number of science departments (e.g., Geography) around the world. As is often the case, undergraduates do not have a profound knowledge of energy flow in the global climate system, and many of them are still having problems understanding the Earth's greenhouse effect, its anthropogenic disruption and the potential links to climatic change. Moreover, lecturers are expected to deal with a broad spectrum of student ability and background [1]. Courses and teaching methods require constant improvement and must also be adjusted to deal with classes having wider objectives. Recently, a growing interest in computer-based e-learning tools has prompted the development of innovative learning strategies [e.g., 2]. One of them is provided by web-based applications for climate processes. Nowadays, only a few, scattered and more-or-less user-friendly options with graphic interfaces exist to facilitate learning and better understanding of the complexity of the climate system. For example, in Java [3,4,5,6]; others present the many steps needed to achieve a climate model by means of Matlab [7,8] or with the Stella environment [9]. More complex software, allowing students to learn and experience the full climate system are available on the web [EdGCM; 10]; their use is, as yet, restricted to graduate students and people having the necessary scientific background, and form excellent methods for those who need to have a comprehensive knowledge of the climate system. Learning with increasingly innovative pedagogic methods may turn out to be more beneficial for learners than plugging numbers into memorized equations for which no connection to the real world exists, such as is the case in a classical teaching environment. Nowadays, computer simulations and virtual labs are becoming efficient tools for learning [11,12]. Traditional pedagogical supports such as blackboards, textbooks, transparencies and videos have been complemented by computer-based e-learning tools, allowing teaching to take place in a more polyvalent, ordered and appealing educational environment. Such new technologies are not intended to replace lecturers, however. The latter, rather than having to change their roles, may be less focused on teaching theoretical aspects of climate science and should concentrate more on the learning strategies to be adopted by the students, who would feel more involved in their training.

The goal of this study is to develop and apply a number of simple climate model interfaces aiming to improve teaching of climate and climate change concepts. In addition, these would help learning of climate processes by interacting with an easy-to-use interface, thus allowing fast turn-around experiments. One main advantage is that these interfaces can be used remotely, outside the lecture theatre, thus helping to optimise the

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climate science in an appropriate manner so that they gain a useful understanding needed later for research in other activities. E-learning resources provide a quantity of innovative methods, and in this study we have demonstrated to some extent their potential to develop efficient and useful tools having an indisputable added pedagogical value.

APPENDIX

Table 1. Definitions and ranges of the values of the adjustable parameters of EBM 0D and EBM 1D. Below, NP stands for North Pole and EQ for Equator.

0D EBM Parameters	Definitions	Ranges	Default values
T_o	Initial temperature	150 – 350 K	200 K
α_p	Planetary albedo	0 - 1	0.3
τ_a	Atmospheric transmissivity	0 - 1	0.62
F_s	Rheostat	0.5 – 1	1.0
D_m	Mixed/layer	1 – 200 m	20
1D EBM			
α_{clouds}	Cloud albedo	0 - 1	0.5
α_{ice}	Ice albedo	0 - 1	0.62
α_{sfc}	Surface albedo	0 - 1	.5 (NP), .3, .1, .08, .08, .2, .2, .05, .05 (EQ)
T_{crit}	Critical temperature	-15 – +5°C	-10.0°C
K	Heat transport coefficient	0 – 50 W m^{-2} °C^{-1}	3.81 W m^{-2} °C^{-1}
A	Infrared parameter	150 – 310 W m^{-2}	204 W m^{-2}
B	Infrared parameter	0 – 20 W m^{-2}°C^{-1}	2.17 W m^{-2}°C^{-1}
F_s	Rheostat	0.5 – 1	1.0
Ci	Cloud amount	0 - 1	.52 (NP), .58, .62, .63, .57, .46, .4, .42, .5 (EQ)

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