Palaeogeography, Palaeoclimatology, Palaeoecology 304 (2011) 359–378

Contents lists available at ScienceDirect

Palaeogeography, Palaeoclimatology, Palaeoecology

journal homepage: www.elsevier.com/locate/palaeo

# Modelling Late Miocene vegetation in Europe: Results of the CARAIB model and comparison with palaeovegetation data

L. François [a,*], T. Utescher [b], E. Favre [a], A.-J. Henrot [c], P. Warnant [a], A. Micheels [d], B. Erdei [e], J.-P. Suc [f], R. Cheddadi [g], V. Mosbrugger [d]

[a] Unité de Modélisation du Climat et des Cycles Biogéochimiques (UMCCB), Université de Liège, Bât. B5c, Allée du Six Août 17, B-4000 Liège, Belgium
[b] Steinmann Institute, University of Bonn, Nussallee 8, D-53115 Bonn, Germany
[c] Laboratoire de Physique Atmosphérique et Planétaire (LPAP), Université de Liège, Bât. B5c, Allée du Six Août 17, B-4000 Liège, Belgium
[d] Senckenberg Research Institute und Nature Museum, LOEWE - Biodiversity and Climate Research Centre (LOEWE BiK-F), Senckenberganlage 25 D-60325 Frankfurt am Main, Germany
[e] Botanical Department, Hungarian Natural History Museum, H-1476, POB222, Hungary
[f] Institut des Sciences de la Terre de Paris (UMR 7193 CNRS), Université Pierre et Marie Curie, 4 place Jussieu, case 117, 75252 Paris Cedex 05, France
[g] Institut des Sciences de l'Evolution, CNRS UMR 5554, Université de Montpellier II, Case Postale 061, Place Eugène Bataillon, F-34095 Montpellier, France

ARTICLE INFO

*Article history:*
Received 1 March 2010
Received in revised form 9 January 2011
Accepted 16 January 2011
Available online 21 January 2011

*Keywords:*
Miocene
Europe
Vegetation
Model
Palaeovegetation data
Plant functional types
Biomes

ABSTRACT

The CARAIB (CARbon Assimilation In the Biosphere) model is used to study the vegetation distribution during the Late Miocene (Tortonian). In this version, the plant classification is specifically adapted to best represent Miocene European vegetation. Compared to other plant classifications used in global models, this adapted classification is more refined, since it is specifically developed for European vegetation and it includes various thermophylous tree types, which were present in Europe during the Miocene. The corresponding climatic tolerance parameters are based on the study of Laurent et al. (Journal of Vegetation Science, 15, 739-746, 2004) for the tree types currently present in Europe and on the distribution of analogue species in southeastern Asia and North/Central America for the thermophylous (sub-tropical) trees. The same classification is used to characterize the palaeoflora at the available Late Miocene localities, allowing a model–data comparison at the plant functional type level, rather than at the biome level. The climatic inputs to CARAIB are obtained from the COSMOS atmosphere–ocean general circulation model. The climatic anomalies (Tortonian minus Present) derived from COSMOS are interpolated to a higher spatial resolution before being used in the vegetation model. These anomalies are combined with a modern climatology to produce climatic fields with high spatial resolution ($10' \times 10'$). This procedure has the advantage of making apparent relief features smaller than the grid cells of the climate model and, hence, makes easier the comparison with local vegetation data, although it does not really improve the quality of the Tortonian climate reconstruction. The new version of CARAIB was run over Europe at this higher spatial resolution. It calculates the potential distribution of 13 different classes of trees (including cold/cool/warm-temperate, sub-tropical and tropical types), together with their cover fractions, net primary productivities and biomasses. The resulting model vegetation distribution reconstructed for the Tortonian is compared to available palaeovegetation and pollen data. Before performing this comparison, the tree taxa present at the various data sites are assigned to one or several model classes, depending on the identification level of the taxa. If several classes are possible for a taxon, only those that can co-exist with the other tree classes identified at the site are retained. This methodology is similar to the co-existence approach used in palaeoclimatic reconstructions based on vegetation data. It narrows the range of tree types present at the various sites, by suppressing in the data the extreme types, such as the cold boreal/temperate and tropical trees. The method allows a comparison with the model simulation on a presence/absence basis. This comparison provides an overall agreement of 53% between the model and the data, when all sites and tree types are considered. The agreement is high (>85%) for needle-leaved summergreen boreal/temperate cold trees (*Larix* sp.) and for tropical trees, intermediate (>40%) for other boreal/temperate cold trees and for needle-leaved evergreen temperate cool trees, broadleaved summergreen temperate cool trees and broadleaved evergreen warm-temperate trees, and poor (<40%) for most temperate perhumid warm trees. In many cases, the model is shown to be better at predicting the absence than the presence, as observed for tropical trees. The modelled distributions of cold boreal/temperate trees tend to extend too much towards the south compared to the data. By contrast, model sub-tropical trees (temperate perhumid warm and needle-leaf summergreen temperate warm trees) appear to be restricted to some limited areas in southern Europe, while they are present in the

* Corresponding author. Tel.: +32 4 3669776; fax: +32 4 3669711.
*E-mail address:* louis.francois@ulg.ac.be (L. François).

0031-0182/$ – see front matter © 2011 Elsevier B.V. All rights reserved.
doi:10.1016/j.palaeo.2011.01.012

data from central Europe up to at least 50°N. Consequently, modelled Late Miocene climate appears to remain too cold to produce assemblages of trees consistent with the data. The predicted modelled trends from the past to the present are in the right direction, but the amplitude remains too small. For the simulations to be in a better agreement with the data, higher $CO_2$ levels may be necessary in the climate simulations, or possibly other oceanic boundary conditions may be required, such as different bathymetry in the Panama seaway.

© 2011 Elsevier B.V. All rights reserved.

## 1. Introduction

The CARAIB model is used to study the vegetation in Europe simulated for the Tortonian (11.61–7.25 Ma). Although the time-span studied coincides with the Late Miocene cooling (Zachos et al., 2001) and the first presence of sea ice in the Northern High Latitudes (e.g., Darby, 2008), there is evidence from various proxy data that climate still was all over warmer and more humid than today, especially in the mid- and the higher latitudes. Also latitudinal and longitudinal climate gradients were shallower than at present (e.g., Bruch et al, 2007; Fauquette et al., 2007). In the continental realm, various proxy data such as plant and mammal fossil records, and systematics-based climate reconstructions, allow quantification of continental climates and provide an insight into spatial patterns and amplitudes of change in time series all over Europe (e.g., Bruch et al., 2007, 2011; Utescher et al., 2009, 2011; Akkiraz et al., 2011–this volume; Böhme et al., 2011). Using proxy data it is inferred that in Central Europe mean annual temperatures were higher by ca. 5 °C than today (e.g., Mosbrugger et al., 2005); the study of Utescher et al. (2011) shows strong positive temperature anomalies for both the cold and the warm seasons for the mid-latitudes of Central and Eastern Europe of 5 °C at a minimum. According to palaeobotanical proxies temperature was only slightly raised in the lower latitudes of Europe when compared to present (e.g., Utescher et al., 2011) but conditions were all over more humid; a Mediterranean type climate did not yet exist (e.g., Bertini, 2003). Consistently Tortonian phytocoenoses should display a distinctly warmer and/or more humid aspect, depending on its geographical position, when compared to modern potential vegetation.

There exist numerous qualitative descriptions of the vegetation types recorded in the European Tortonian (e.g., Mai, 1995; Eder-Kovar et al., 1996). In more recent times, semi-quantitative and quantitative studies have been carried out on well dated Late Miocene floras focussing on diversity patterns of plant functional types (Utescher et al., 2007a; Eder-Kovar et al., 2008). According to these studies, deciduous forest was the dominant zonal vegetation type all over Central Europe, extending over the former Western Paratethys (Molasse Basin, Styrian Basin, and Vienna Basin) along the north coast of Lake Pannon to the Transcarpathian realm and Ukraine. Depending on the region this vegetation may have contained a minor proportion of broadleaved evergreen elements (e.g., Erdei et al., 2007; Utescher et al., 2007a; Ivanov et al., 2011). Towards the lower latitudes, all over Spain, in the southern Pannonian realm, and in the Eastern Paratethys, Mixed Mesophytic Forests existed. This forest type is characterized by a high proportion of broadleaved evergreen trees; partly thermophilous conifers are important as well. In the southwest of the study area and along the south coast of the Eastern Paratethys, the presence of sclerophyllous broadleaved trees points to the presence of a drier season (Utescher et al., 2007a,b). In the east and the southeast, partly open woodlands existed in the earlier part of the time-span studied (e.g., Ivanov et al., 2011).

The Tortonian was characterized by all over warmer climate conditions with respect to the present and is thus an example of a warmer world that may help understand future climate, although it cannot be considered as a direct analogue for the future. Indeed, atmospheric $CO_2$ contents and palaeogeography differed from the present-day situation and prognosticated future change, as did the rate of warming. In the Tortonian mainly the southern part of the study area did undergo considerable palaeogeographic shifts, such as orogenic uplift (e.g., Carpathians), subsidence (e.g., Pannonian basin), and volcanism. A large brackish water body, the Lake Pannon, formed as a result of plate reorganisation in the Central Paratethys and was filled in by sediment discharge of huge river delta systems (e.g., Magyar et al., 1999). In the Tethyan realm the Western Mediterranean Basin was opened, except for the Tyrrhenian Sea. Our palaeogeographic maps show the classical connection between the Mediterranean and the Eastern Paratethys through the Bosphorus area (Popov et al., 2004, 2006), a concept which has been recently severely questioned (Melinte-Dobrinescu et al., 2009) in favour of a long and narrow marine gateway through the Balkans, particularly through the areas of Skopje and Niš where the connection between the Pannonian and Dacic basins also took place (Popescu et al., 2009). It is clear that these specific settings had an impact on regional climate and vegetation hampering a direct comparison with modern or near future conditions. There is, however, no doubt that on a continent-wide scale, the Tortonian example is useful for assessment of future scenarios.

Palaeoclimatic and palaeovegetation simulations have also been performed for this period (François et al., 2006; Steppuhn et al., 2006, 2007; Gladstone et al., 2007; Micheels et al., 2007; Micheels et al., 2009). New climatic simulations have been performed for the Tortonian with COSMOS (Eronen et al., 2009; Micheels et al., 2011), i.e., the coupled atmosphere–ocean general circulation model (AOGCM) ECHAM5-MPIOM which allows better integration of the oceanic contributions (e.g., opening of oceanic pathways) in the climatic simulation. These simulations will produce here the inputs for the CARAIB dynamic vegetation model.

The aim of this study is to develop a methodology to validate climate and vegetation model runs for some Neogene time slices on the basis of available palaeoflora. We will apply this method to the validation of the CARAIB dynamic vegetation model forced with ECHAM5-MPIOM Tortonian climatology in Europe. The simulation results will be compared to available palaeovegetation data of several localities in Europe. This is the reason why the classification of the CARAIB vegetation model is specially adapted to the vegetation which was present in Europe during the Miocene, with many warm-temperate taxa recorded in the available palaeobotanical records. For the vegetation simulation, 15 plant functional types (PFTs) are defined and 13 among them are allocated to different classes of trees from arctic to tropical conditions. More precisely, the tree types used in the classification can be subdivided into three groups with broadleaved or needle-leaved characteristic: temperate cold/cool, temperate warm and tropical PFTs.

## 2. The CARAIB model

### 2.1. General description

The CARAIB model (Warnant, 1999; Otto et al., 2002; Laurent et al., 2008) is a global vegetation model, originally designed to study the role of vegetation in the global carbon cycle at present (Warnant et al., 1994; Nemry et al., 1996; Gérard et al., 1999) or in the past (François et al., 1998, 1999, 2006; Galy et al., 2008). It is composed of five modules describing respectively (1) the hydrological budget,

Download English Version:

https://daneshyari.com/en/article/4467284

Download Persian Version:

https://daneshyari.com/article/4467284

Daneshyari.com