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Variational methods application for retrieving past climates and paleo vegetation maps

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A system for retrieval of paleo climate and past vegetation maps based on a dynamic vegetation model, variational data assimilation system and a variational interpolating system is set up. The retrieved paleo climate is an upgrade of paleo climatological model simulation to climate resulting from assimilation of vegetation observation derived from fossil floras taxa. And the vegetation maps are simulated with the vegetation model using the retrieved climate as forcing. The system components are:

- The ***Caraib*** model: a mechanistic model of the land biosphere. It describes soil hydrology, carbon cycle in plants and soils, as well as vegetation properties, structure and distribution over the continents, in equilibrium or transient modes. The model is mainly applied to Holocene or Pleistocene time slices (Francois et al., 1998, 1999; Otto et al., 2002; Cheddadi et al., 2006), as well as for vegetation reconstructions for various time intervals of the Neogene, as for instance for the Tortonian (Francois et al., 2006).
- The variational data assimilation system is based on the ***Caraib*** model, its adjoint model and an iterative minimisation procedure. It is designed to compute the ***Caraib*** model input climate parameters which minimise the misfit vegetation parameters simulation and their observation.
- Data-Interpolating Variational Analysis (***Diva***) software based on a method designed to perform data-gridding (or analysis) tasks, with the assets of taking into account the intrinsic nature of data, i.e., the uncertainty on the in situ measurements and the anisotropy due to advection and irregular topography. The Variational Inverse Method (VIM, Brasseur et al., 1996) implemented in ***Diva*** consists in minimizing a variational principle which accounts for the differences between the observations and the reconstructed field, the influence of the gradients and variability of the reconstructed field. ***Diva*** analyses anomalies calculated with respect to a background field defined a priori (e.g. climatological average).

To retrieve past climate and paleo vegetation maps a three-step methode is applied:

- 1. Application of variational data assimilation for each observation fossil floras site derivation. The assimilated observation is the floras cover fraction parameter. First the floras presence/abscence is established and the cover fractions are determined using a methodology which provide cover fraction at each site to which model outputs can directly be compared (Francois et al. 2011). The a prior knowlege of climate parameters is also derived from the observation using the ***Coexistence Approach*** method (Mosbrugger and Utescher 1997, Mosbrugger et al. 2005). The minimisation procedure uses climatological model simulation of climate parameters for the observation site as first guess.
- 2. Application of variational interpolation (using ***Diva***) of the resulting optimal climatic parameters for a set of observation sites. The climatological model simulation (on the domain defined by the observation sites) is used as background (reference field) for (***Diva***) computations. The resulting climatic parameters fields constitute the optimal climate in agreement with the vegetation observation.
- 3. Simulation of vegetation maps using the interpolated optimal climatic parameters as the input to the ***Caraib*** model.

The system for retrieval of paleo climate and past vegetation maps is presented, as well as an application on the Tortonian time interval. European Climate parameters maps of Tortonian and paleo vegetation maps are retrieved using observation on 40 tortonian site distributed over Europe.