Dynamic Hydrological Discharge Modelling for CoupledPaleoclimate Runs of the Last Glacial Cycle

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Motivation

• The continually evolving large ice sheets present in the Northern Hemisphere during the last glacial cycle caused significant changes to river pathways both through direct blocking of rivers and through glacial isostatic adjustment. These river pathway changes are believed to have had a significant impact on the evolution of ocean circulation through changing the pattern of fresh water discharge into the ocean.
• A fully coupled ESM simulation of the last glacial cycle thus requires a hydrological discharge model that uses a set of river pathways that evolve with the earth’s changing orography.

1. Aims

• Develop a sufficiently accurate method for periodically updating the river directions and flow parameters.
• Develop a model for both periglacial lakes and also African paleolakes during the African Humid Period.

2. Challenges

• The natural scale determining the path of rivers and lake basins is far smaller than the scale of simulated paleo- orographies.
• Narrow valleys are not resolved in coarse orographies and thus false inland sink points can be produced.
• Need to use an existing hydrological discharge model embedded in JSBACH that runs on a half degree scale.
• New model must fit within a wider coupled earth system modelling framework for transient paleoclimate runs. Must be fully automatic and computational costs must be kept to a minimum.

3. Method

1. For Rivers Only

   One-Time Generation of New Height Corrections

   - Develop orography correction to present day river directions
   - Subtract present day DEM to convert to relative corrections

   River Direction and Flow Parameter Generation

   - Apply Relative Corrections
   - Generate River Directions
   - Up scaling Algorithm
   - Parameter Generation

   Need to be done ‘guided’ by hand, once only

   Every 10 years (with VULMA and land-sea mask calculations)

   Every model day

2. For Rivers and Lakes Together (under development)

   One-Time Generation of New Height Corrections

   - Existing Relative Correction Set
   - Fill present day lakes
   - Burn Carved Exit Valleys to Produce Sink-less DEM
   - Re-apply present day lakes
   - Subtract present day DEM to convert to relative corrections

   River Direction and Flow Parameter Generation

   - Apply Relative Corrections
   - Generate River Directions
   - Up scaling Algorithm
   - Lake Basin Parameter Generation
   - Lake Parameter Generation

   Fill lake basins to give three back to back HD model runs (orography, river directions, and flow models)

   Need to be done ‘guided’ by hand, once only

   Every 10 years (with VULMA and land-sea mask calculations)

   Every model day

4. Results

• The river catchments derived from a 10 minute present day orography match the manually corrected river directions used in the current non-dynamic JSBACH setup to within 5% in most cases. All significant disagreements are due to minor deficiencies in the current non-dynamic JSBACH setup’s manually corrected river directions.
• The upsizing algorithm up-scales catchments to within a accuracy of 1 - 2% or less in almost all cases.
• Trial runs with and without this method show it has a significant effect on ocean circulation at the LGM.

Conclusions

The proposed method proves an effective method for the generation of dynamic river directions and flow parameters for paleoclimate simulations which can be run on the existing modelling framework within JSBACH (the land surface model of MPI-ESM1). This method will be used in fully coupled paleoclimate runs made using MPI-ESM1. Tests show this procedure reproduces the known present-day river network to a sufficient degree of accuracy and also produces flow parameters that give satisfactory response characteristics. Work is ongoing to add the possibility of modelling paleolakes to this setup.