Climate-Vegetation-Feedbacks as a Mechanism for Accelerated Climate Change: The ONSET of the African Humid Period

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Introduction:
Paleo-environmental records and models indicate that the African Humid Period (AHP) abruptly ended about 5000-4000 years before present (BP). Some proxies indicate also an abrupt onset of the AHP between 14,000 and 11,000 BP. How important are local orbital forcing, ice-sheet forcing, greenhouse gas forcing, and the reorganization of the Atlantic Meridional Overturning Circulation (AMOC) for changes in the African Monsoon/vegetation system? Here we use transient simulations with climate-vegetation models of different complexity to identify the factors that control the onset of the North African Monsoon/vegetation. We test the following hypothesis:

1) Insolation-thresholds exist for the onset/termination of the AHP.
2) The climate-vegetation feedback accelerates the onset of the AHP.
3) CO₂ fertilization has a significant influence on the vegetation changes over North Africa.
4) A shutdown of the AMOC is as important as orbital insolation for the African Monsoon.

Fig. 1: Simulated Temperature, Rainfall, and Vegetation in North Africa

Fig. 2: Vegetation Changes 9000-8000 BP

Fig. 3: Vegetation-Atmosphere feedback dynamics

Fig. 4: Climate-vegetation feedback induces a 'hysteresis' in the vegetation over North Africa

Fig. 5: CO₂ fertilization contributes to the bimodal vegetation states

Fig. 6: Forcing factors for the climate 21,000-0 BP

Fig. 7: Proxy records of the African (Asian) Monsoon 21,000BP-0BP

Fig. 8: Waterhosing experiments: North African climate during AMOC shutdown

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Transient model simulations from LGM to present (21,000BP – 0 BP):
- Dynamical vegetation model LPJ forced with 2m air temperatures, precipitation, and cloud cover from time slice experiments with the HadSM3 model and a transient simulation with ECBilt-CLIO.
- Earth System model of intermediate complexity, LOVECLIM in two versions: ECBilt-CLIO with VECODE active/inactive vegetation-albedo feedback.
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Summary and conclusion:
1) Role of the local insolation for the rapid onset of the AHP:
   - The insolation threshold is unlikely to exist for the North African Monsoon/vegetation, based on the proxy/model evidence.
2) The importance of the vegetation-feedback:
   - The vegetation feedback leads to a 'rapid' onset of the African Humid Period.
   - The feedback induces a 'hysteresis' effect in the North African vegetation.
3) Atmospheric CO₂ changes directly affect the vegetation growth over North Africa through the CO₂ fertilization effect. The CO₂ fertilization effect is associated with a (weak) negative climate-vegetation feedback.
4) A shutdown of the Atlantic meridional overturning circulation is as important as the local orbital forcing. The AMOC shutdown during the YD event masks insolation-driven Monsoon signals in the paleoclimatic proxies.

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