Regional modelling of aerosol impact on the West African Monsoon system

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DAAD Deutscher Akademischer Austauschdienst German Academic Exchange Service

WASCAL West African Science Service Centre on Climate Change and Adapted Land Use

SASSCAL Southern African Science Service Centre for Climate Change and Adaptive Land Management

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Introduction

- The West African Monsoon (WAM) is an integral and important component of the West African climate system.
- More than 75% of the summer-time rainfall is related to WAM (Hagos and Cook, 2007).
- There is a strong intra-seasonal to decadal variability, determined by the strength of the low-level monsoonal flow, which modulates weather (rainfall) and climate of W-Africa.
- The seasonality is characterized by the warm, moist SW monsoon inflow during May–Sept. and the hot, dry NE Harmattan wind in Nov.–Feb. (Fig. 1).

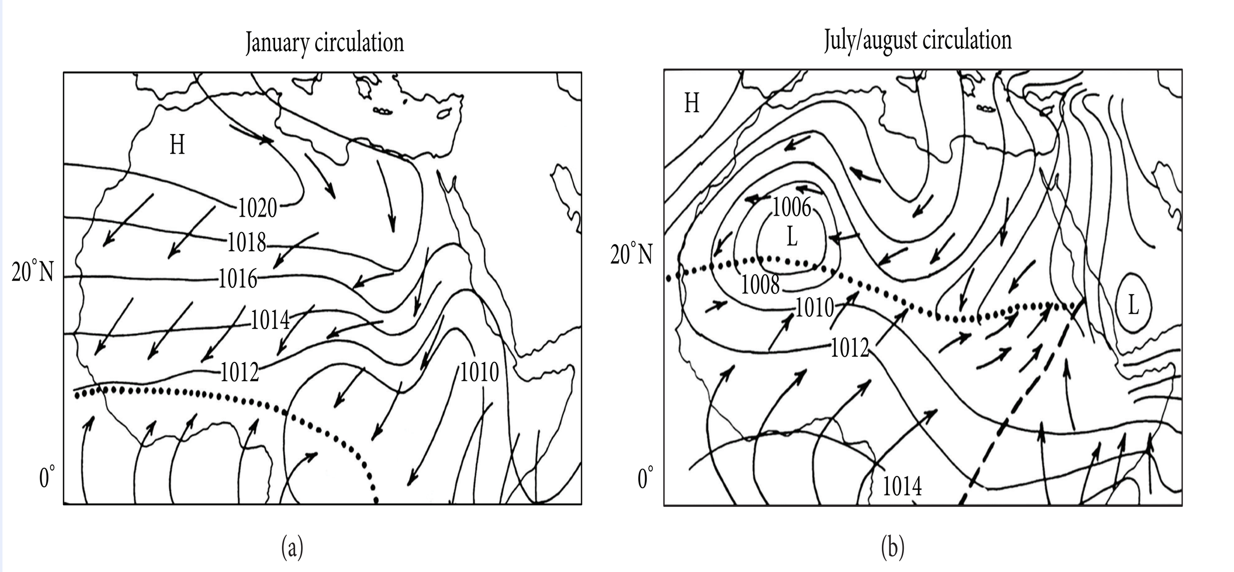


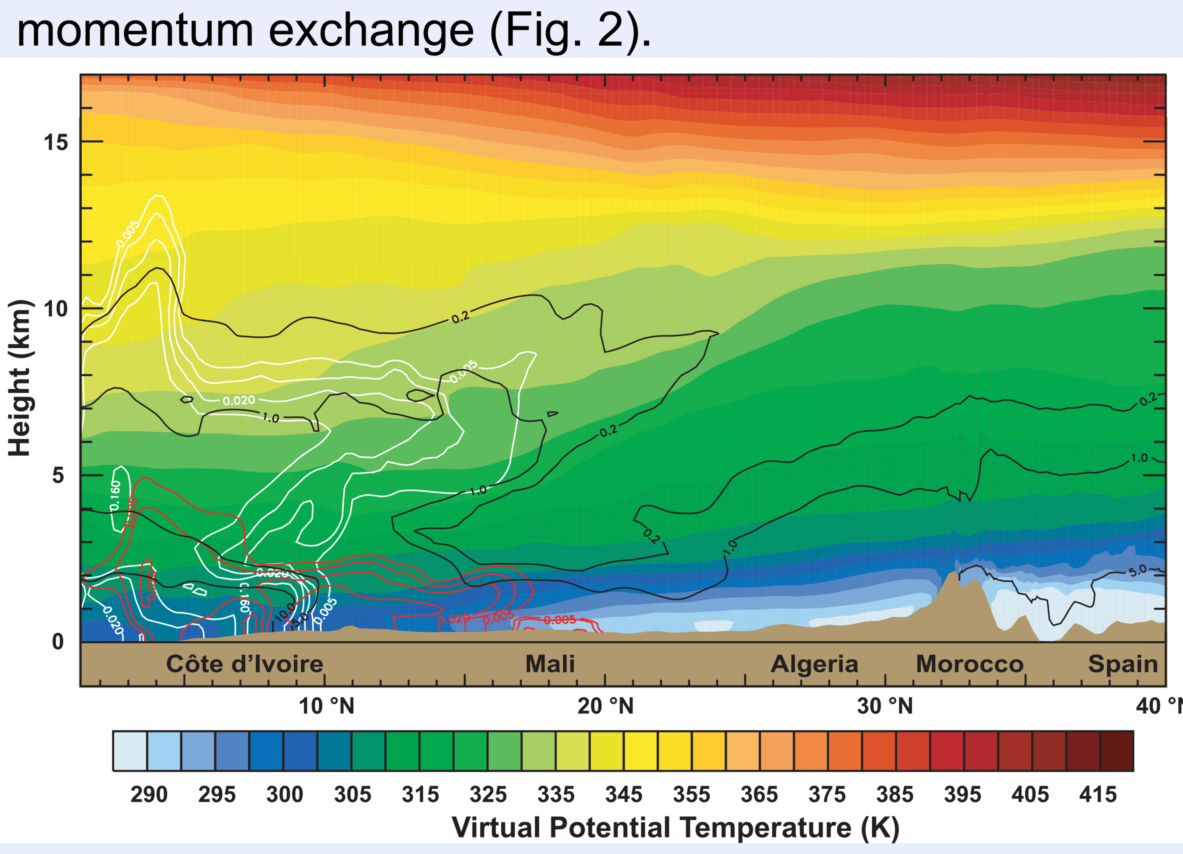
Fig. 1: *Illustration of surface wind (arrows) and pressure (mb) over West Africa during (a) the winter and (b) the peak of the summer monsoon (Nicholson, 2013).*

- The WAM affects the production, transport and removal of natural and anthropogenic aerosol (e.g. Saharan dust) while aerosol feeds back upon WAM through direct and indirect aerosol radiative effects.
- The DAAD climapAfrica project 'Aerosol-radiation and aerosol-cloud effects on the West African Monsoon system in a changing climate (ACCLIMATE)' aims to study the yet poorly quantified impact of aerosol on WAM.

State of the art

- Aerosol directly modify the shortwave radiation reaching the earth surface by scattering and absorbing solar radiation (Boucher et al., 2013).
- This direct effect can be measured by the aerosol optical depth (AOD), which indicates how much direct sunlight is prevented from reaching the ground by these aerosol particles.
- Aerosol can indirectly interact with cloud and thus modify its properties (e.g. Rosenfeld et al., 2014)
- A semi-direct interaction occur when absorbing aerosol above and below warm clouds lead to the evaporation of such clouds.
- Radiative and cloud processes can therefore interact with each other to produce complex aerosol effects on clouds, precipitation, and extreme precipitation, in response to local and remote emission regions (e.g. Wilcox et al., 2018).
- Aerosol particles can influence the WAM system via aerosol-radiation and aerosol-cloud interactions (Knippertz et al., 2015a).
- Dynamic response of monsoon precipitation to mineral dust radiative forcing shows that doubling the mineral dust lead to changes in seasonal precipitation in the West African region (Akinyoola et al., 2019)
- In West Africa, massive economic and population growth and urbanisation are expected to lead to a tripling of anthropogenic emissions by 2030 (Knippertz et al., 2015b), the question on how these changes will impacts human health, ecosystems, food security and regional climate is yet unanswered
- COMSO-MUSCAT model is a useful tool that can be used to investigate the interactions of aerosol and its transport as well as its role on atmospheric heat, moisture and momentum exchange (Fig. 2).

Fig. 2: *COSMO-MUSCAT simulation of meridional-vertical cross-section along 5ºW at 1200 UTC on 17 January 2008 depicting contours of virtual potential temperature (K, filled), specific humidity (g kg−1 , black), and extinction coefficients at 550 nm (km−1) due to dust (red) and biomass-burning aerosol (white) (Knippertz et al., 2011).*



The project ACCLIMATE

Research aim

- Investigation of the impact of the mixture of natural and anthropogenic aerosol on the WAM system.

Approach

- Interactive simulations with the regional chemistry-transport model COSMO-MUSCAT over the North Africa Middle East region (Fig. 3).
- Thorough model evaluation using recent field observations, incl. DACCIWA experiment, and satellite and AERONET sun photometer observations.
- Sensitivity runs with regard to changes in emissions, climate and land use.

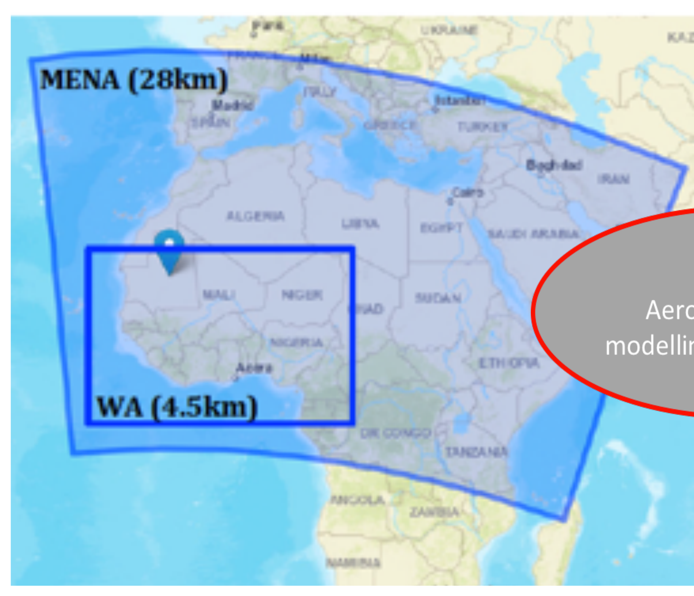


Fig. 3: *COSMO-MUSCAT model domains.*

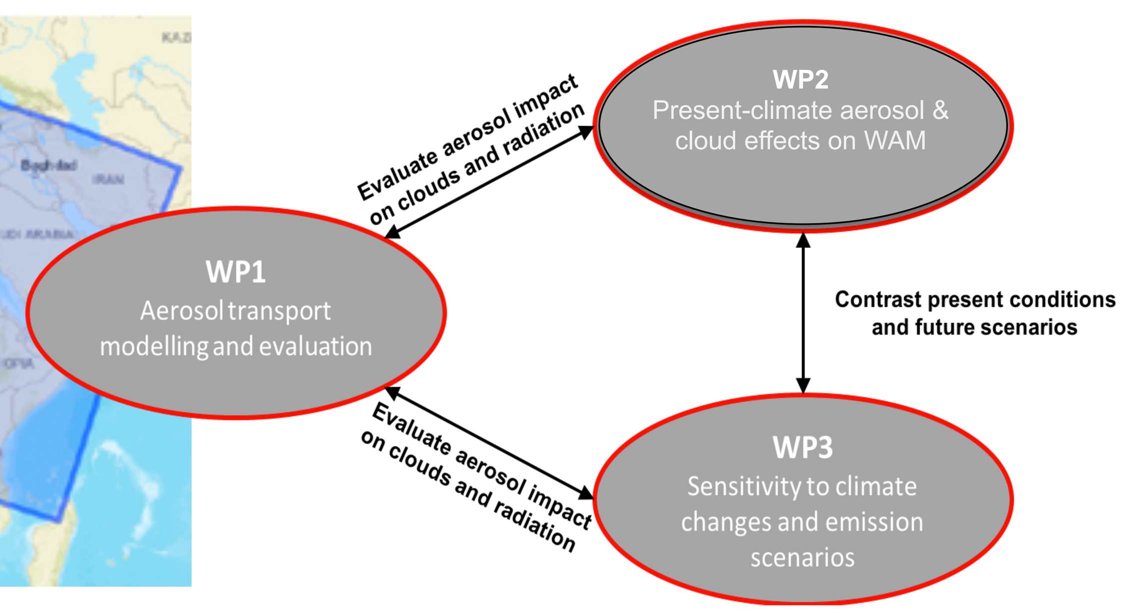


Fig. 4: *Project work packages.*

Expected outcomes

- An evaluated and improved representation of West African aerosol.
- Detailed model-based assessment of sources and transport pathways of natural and anthropogenic aerosol over West Africa (WP1; Fig 4).
- A state-of-the-art quantification of aerosol-radiation and aerosol-cloud effects on atmospheric dynamics and the WAM system.
- An improved understanding of how the different aerosol compounds modify atmospheric processes in present climate (WP2; Fig 4).
- Evaluation of the sensitivity of aerosol effects on WAM to changing climate conditions and anthropogenic emissions (WP3; Fig 4).
- Information relevant to guide decision and policy makers in making decisions that will ensure a sustainable economic development and planning.

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