Recent rainfall decline in West Africa due to enhanced biomass burning and dust emission

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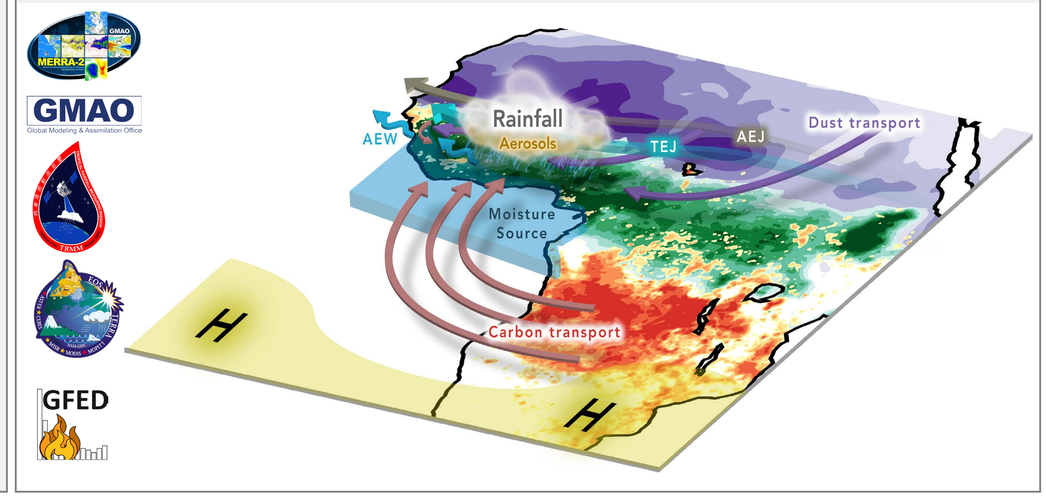
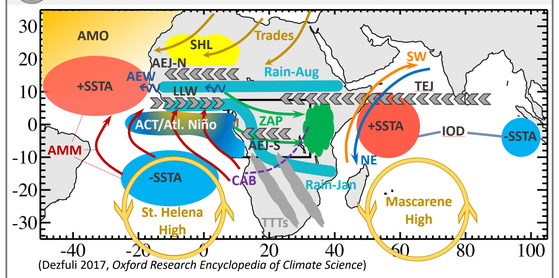
Overview:

- West African monsoon (WAM), the dominant climatic feature in Africa, is most active over Southern West Africa in June.
- Livelihoods of more than 200 millions of people in SWA are affected by rainfall as they rely on rainfed agriculture, fishing, hydropower, and inland waterway systems.
- Rainfall characteristics have also health implications, for example:
  - Dry & dusty conditions → high risk of meningitis
  - Extreme precipitation → cholera outbreaks
- Unlike dynamical features of WAM, the role of aerosols on SWA rainfall variability is not well-understood.
- We found a two-decade negative trend in SWA's rainfall that is inversely related to the combined loadings of black carbon (BC) and dust. A possible mechanism is provided.
- Improvements in seasonal predictions, using a hybrid dynamical-statistical approach.
- The results are crucial because land use change, deforestation, and rapid urbanization growth are projected to increase aerosols in the region. Therefore, SWA could experience an increase in drought intensity and frequency in future.

Graphical Abstract: Dynamical Features & Aerosols Affecting SWA's Rainfall in June



1 Climatic Features Affecting Africa

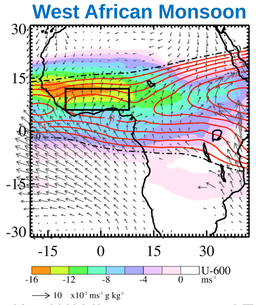


(Dezfuli 2017, *Oxford Research Encyclopedia of Climate Science*)

- African Easterly Jet/North (AEJ-N), Tropical Easterly Jet (TEJ), Low-Level Westerly (LLW), African Easterly Wave (AEW), Saharan Heat Low (SHL): *Jun-Sep*
- AEJ-S: *Sep-Nov*
- Zonal Asymmetric Pattern of Precipitation (ZAP): *Dec-Mar*
- Atlantic Meridional Mode: *Mar-May*
- Atlantic Cold Tongue/Atlantic Niño: *Jun-Aug*
- Summer (*Jun-Sep*) & *Winter (Dec-Mar)* Indian Monsoon
- Indian Ocean Dipole (IOD) Mode: *Sep-Oct*

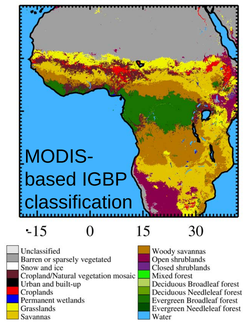
2 Climatic Characteristics of Southern West Africa in June

West African Monsoon

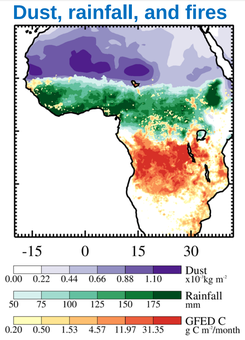


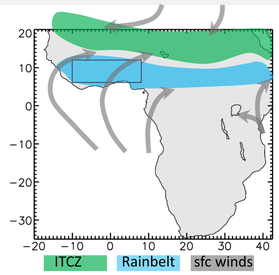
- Key WAM's components: AEJ, TEJ, and low-level monsoon flow.

Land cover/ land Use



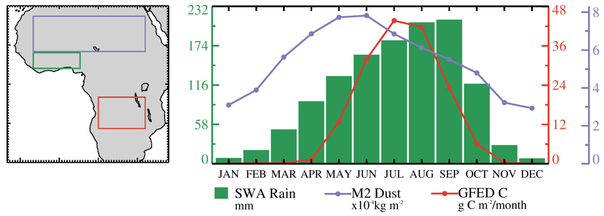
Dust, rainfall, and fires





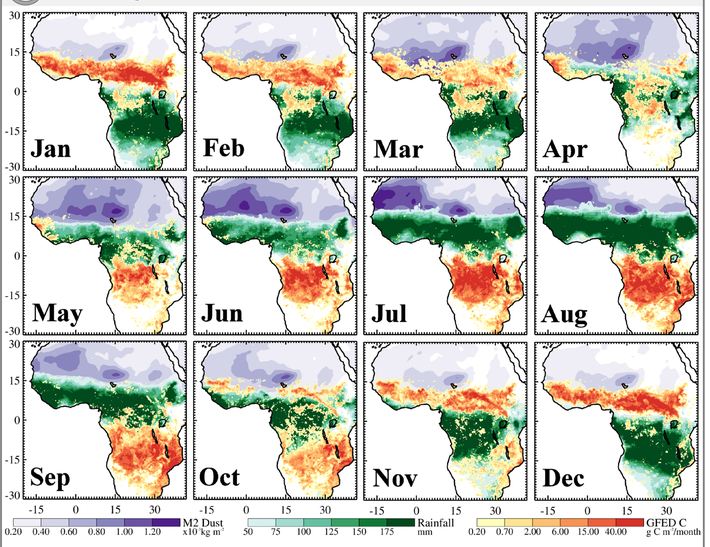
- Intertropical Convergence Zone (ITCZ) and tropical rainbelt can be decoupled over land!

3 Annual Cycle: Rainfall, M2 Dust, C Emissions



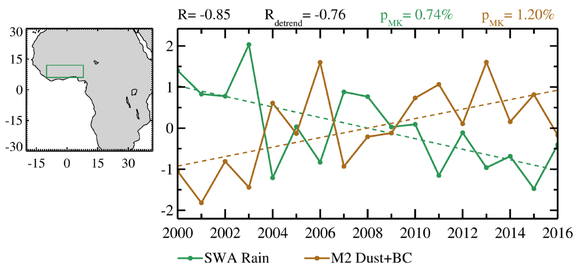
- Dust production reaches its annual peak in June and southern African biomass burning presents a sharp shift to begin its most-active season.
- June is also the onset of WAM, when the tropical rainbelt covers SWA.

4 Monthly Mean Patterns of Dust, Rainfall & C Emission

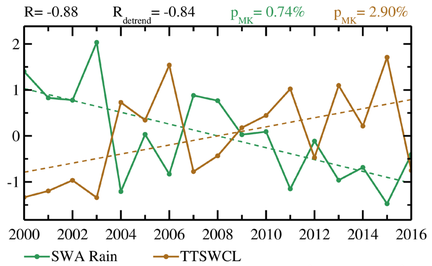


Dust is from MERRA-2, rainfall from TMPA, and C from Global Fire Emissions Database (GFED). The tropical rainbelt and region of maximum biomass burning have both a meridional excursion but in opposite directions. Dust has an annual cycle, but is geographically confined to the Sahara-Sahel zone.

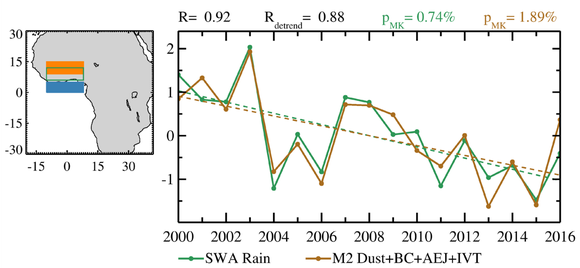
5 Role of Aerosols vs. Traditionally-Known Dynamical Features in Rainfall Variability and Trend



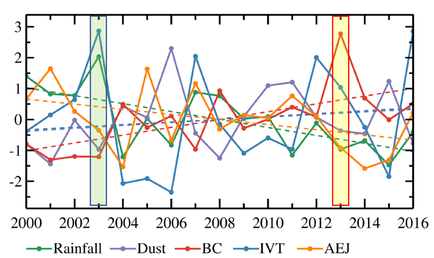
- Combined loadings of dust and BC is inversely related with rainfall for both interannual variability and particularly trend.



- Aerosols ↑ Solar radiation absorption ↑ Heating ↑ Rainfall ↓



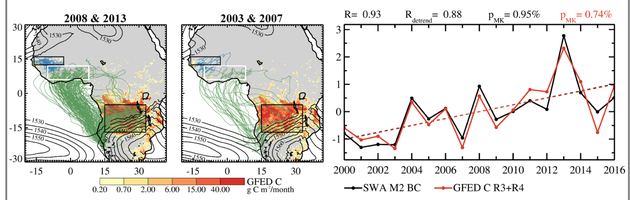
- Both interannual variability and trend are well-captured.
- Including aerosols adds 40 and 24% improvement in capturing the trend and interannual variability.



- **2003 (wet)**: strong moist monsoon, low BC & dust transport.
- **2013 (dry)**: strong moist monsoon, but also extreme BC.

6 Source of Aerosols: Local or Remote?

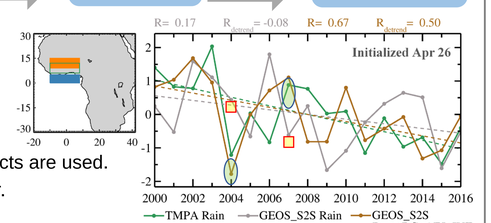
- Using NOAA's HYSPLIT model driven by MERRA-2 data
- Back-trajectory mode initiated from SWA at 300 m
- Calculating trajectory counts from SWA to hotspots of aerosols
- Identify regions with largest contribution to the loadings of dust and BC in SWA



- BC in SWA can be reproduced with linear combination of C emission due to fires over southern savannas of Africa and Western Sahel and the corresponding transport.
- Significant trend and interannual variability exist.
- Composites of high (2008 & 2013) and low (2003 & 2007) C transport are shown.
- Similarly, dust in SWA can also be reproduced by dust transport from two different regions over the Sahara (not shown).

7 Potential Seasonal Prediction Skill

GEOS-5 initialized in April → Dynamical prediction → Dust, BC, IVT, ... in June → Empirical relation → Model Variables & Obs. Rain in June



- Monthly hindcast products are used.
- One ensemble member.
- AEJ at 500 hPa!
- Uq & Vq at 850 and 500 hPa.
- R_critical for 5% Sig. Lev= .48

○ Skillful Hybrid Forecast
□ GEOS-5 Forecast

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