How Does Stratospheric Aerosol Injection Improve Harmattan Conditions?

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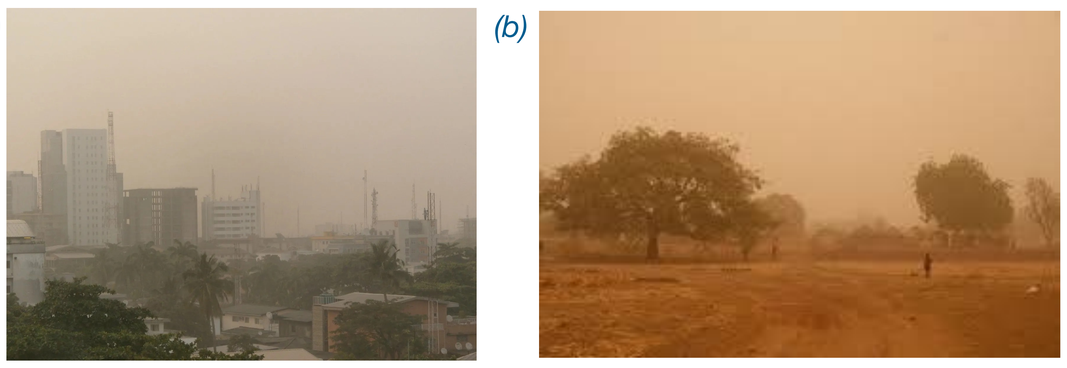
Background

- The Harmattan is characterized by dry and dusty northeasterly trade winds that blow from the Sahara Desert over West Africa into the Gulf of Guinea.
- Typically occurs around December to February, marked by a significant drop in humidity, cooler temperatures during the day and cold temperatures at night.
- Impact on Health – the dense dust in the air during this period can lead to serious health problems, specifically, respiratory issues, skin irritations and eye infections.
- Impact on Air Quality – the dust has profound impact on air quality across the region.
- Impact on Daily Life – reduced visibility also disrupt air travel and increase the risk of road accidents. Moreover, dry conditions may exacerbate water scarcity.
- Impact on Agriculture – reduced rainfall and lower humidity makes the region rife for droughts.
- **This work examines the impact of Stratospheric Aerosol Injection (SAI), a proposed Climate Intervention, on Harmattan season using the ARISE-SAI simulations.**

(a) (b)



Typical Harmattan conditions in West Africa; (a) Ghana and (b) Nigeria
(source: Ghana & Nigeria Meteorological Agencies)

Data and Methods

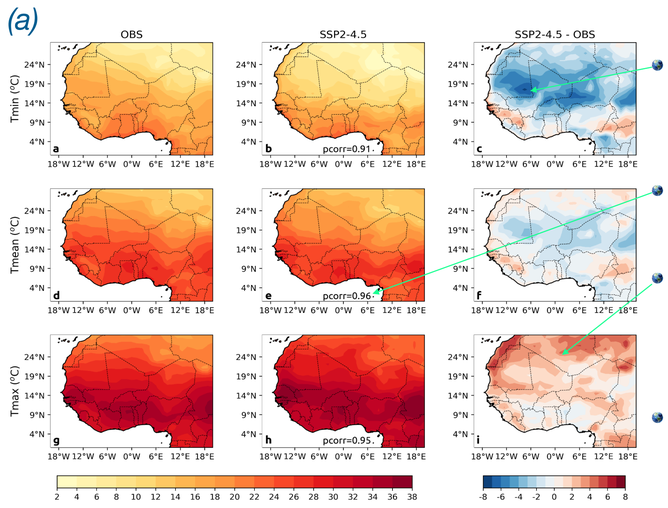
Dataset	Variables	Period
Climatic Research Unit, v4.07 (0.5 x 0.5 res)	Maximum Temperature (Tmax), Mean Temperature (Tmean) and Minimum Temperature (Tmin)	1980-2014
European Center for Midrange Weather Forecast (ECMWF) fifth generation atmospheric reanalysis, ERA5	Maximum Temperature (Tmax), Mean Temperature (Tmean) and Minimum Temperature (Tmin), Near-surface Specific humidity (q)	1980-2014
Community Earth System Model, v2 (CESM2) with the Whole Atmosphere Community Climate Model, v6 (WACCM6)] *(both historical and projections under Shared Socioeconomic Pathway (SSP2-4.5))*	Maximum Temperature (Tmax), Mean Temperature (Tmean) and Minimum Temperature (Tmin), Near-surface Specific humidity (q), Wind speed at 950 hPa	1980-2069
Assessing Responses and Impacts of Solar Climate Intervention on the Earth system with Stratospheric Aerosol Injection (ARISE-SAI), *[based on CESM2 with the Whole Atmosphere Community Climate Model, v6 (WACCM6)]*	Maximum Temperature (Tmax), Mean Temperature (Tmean) and Minimum Temperature (Tmin), Near-surface Specific humidity (q), Wind speed at 950 hPa, Dust concentration	2035-2069

List of datasets used in the study

- The CRU dataset is used to assess the ability of CESM2 (WACCM6) to reproduce observed climate conditions for baseline (BSL; present-day climate) period (1980-2014).
- For control period (CTL) we use 2015-2034.
- We examine the projected changes in temperature, dust concentration, wind speed and specific humidity (not shown) under a future with and without SAI.
- The domain for West Africa used here is 20°W-20°E & 0°N-30°N.

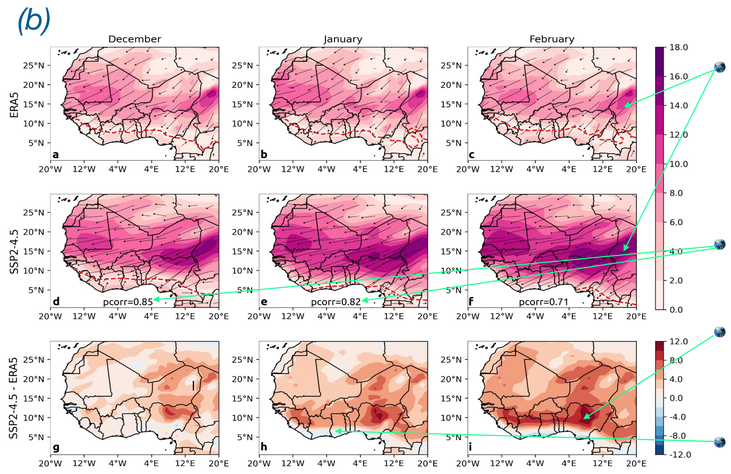
Results

(a)



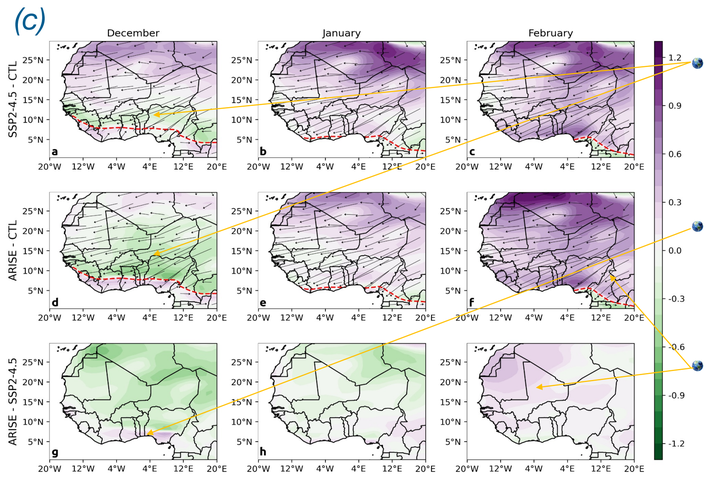
- CESM2 (WACCM6) exhibits a cool bias in minimum temperature (Tmin).
- High Pattern correlation coefficient.
- CESM2 (WACCM6) exhibits large warm bias in maximum Temperature (Tmax).
- Overall, temperature is captured fairly well by the model.

(b)



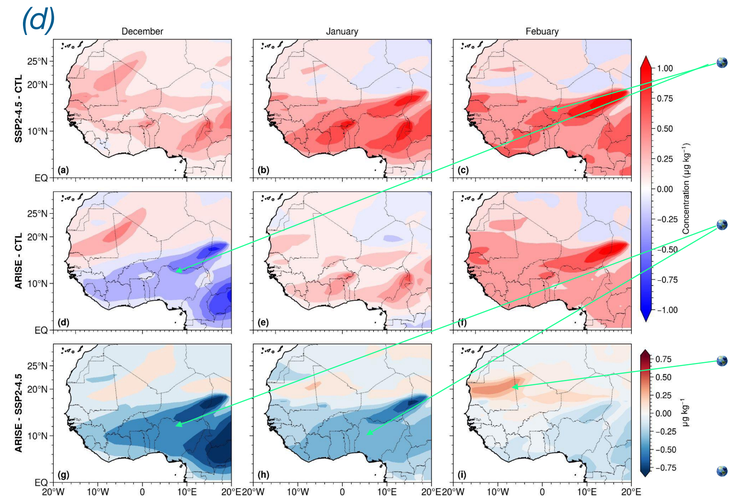
- Wind speeds are well represented by CESM2 (WACCM6) & strong wind speeds at Bodélé Depression (dust source).
- High Pattern correlation coefficient.
- CESM2 (WACCM6) exhibits bias over majority of region, especially over the Jos Plateau.
- Model underestimates along the Guinea Coast.

(c)



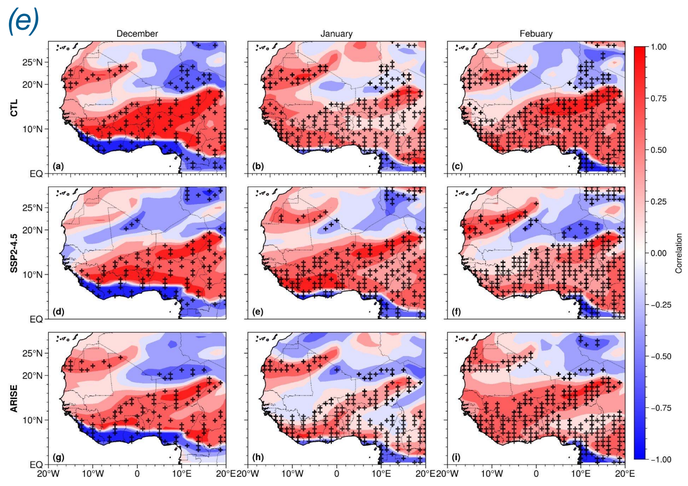
- Projected decrease in wind speed over Sudanian region behaviour is magnified in ARISE-SAI spreading towards Sahara.
- Increase in wind speed just below the tropical rain-belt at the onset (month of December) of Harmattan.
- Increase in wind speed in the cessation (month of February) of Harmattan.

(d)



- Projected increase in dust concentration however, ARISE-SAI weakens the strength in January and February while reversing this behaviour particularly in the onset of Harmattan
- ARISE-SAI significantly reduces dust concentration during Harmattan with high reductions in December and January.
- ARISE-SAI introduces a slight increase in dust concentrations in the cessation month of Harmattan
- General decrease in dust concentration across the Guinea Coast.

(e)



- Strong positive correlations between dust core (Bodélé Depression) and wind speed at 925 hPa.
- Wind speed is closely linked to dust concentrations.

Summary

- For the validation of the CESM2 (WACCM6) model with CRU and ERA5 datasets, we find that the model represents temperature, wind patterns and specific humidity (not shown) fairly well with some biases.
- Our findings show SAI reduces wind speeds over large parts of West Africa consequently reducing dust concentration during the Harmattan as they are strongly correlated.
- Large dust concentration reductions are recorded in December and January months under SAI. This may have a positive effect on livelihoods as this implies improved air quality leading to fewer health issues and better visibility enhancing transportation.
- SAI does not affect the position of the tropical rain-belt as its position remains unperturbed.

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