Can biomass burning aerosol induced surface cooling be amplified through sea surface temperature-cloud feedback over the Southeast Atlantic?

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Motivation – Background



- Biomass burning aerosols (BBA)
- More extreme fires in the future.
- BBA-radiation-cloud interactions

Motivation – SE Atlantic (SEA)



- Stratocumulus clouds of SEA under strong influence of biomass burning aerosols (BBA) emitted from southern Africa.
- Aerosol semi-direct effect vs. aerosol indirect effect [Sakaeda et al. 2011; Gordon et al. 2018; Mallet et al. 2020, Lu et al., 2018, etc.]
- SST-low cloud feedback [e.g. Schneider et al., 2019]: cooling effect ⇒ colder SST
 ⇒ stable boundary layer ⇒ more Sc cloud?

Method

- NCAR CESM 2.1 with 1.9°× 2.5° resolution
- Fully coupled vs. Atmospheric component only
- Turn on or off BBA emissions (BC and POM) in southern Africa
- PI condition (1850) to eliminate other aerosols' effect.

	Component set	BBA emission	Simulation years	Years for analysis
FC_OF	"B1850" – fully coupled	On	200 years	80 years
FC_XF	"B1850" – fully coupled	Off	200 years	80 years
AO_OF	"F1850" – atmos. only	On	12 years	10 years
AO_XF	"F1850" – atmos. only	Off	12 years	10 years

Results

Time series of difference between two <u>FC</u> cases over
SEA (5 years running mean)
► : mean diff. between FC
> : mean diff. between AO



- 20- to 30-year oscillation cycles
- CRE: Δ FC < Δ AO (-3 W m⁻² vs. -4.8 W m⁻²). Why?

Positive feedback
 between T_s and cloud.
 Reversed direction?

Results: why weaker cooling effect?

Cross section of BBA mixing ratio (unit: μg/kg) and cloud fraction (%) differences between <u>FC_OF</u> and <u>AO_OF</u>



• Lower BC in FC_OF over SEA

 Stronger sea breeze because cooler SST in FC_OF (fixed SST in AO_OF)

 Weaker ASE and/or AIE, lower cloud fraction in FC_OF

Results: why weaker cooling effect?



Results: evidence of sea breeze effect



 Effect of sea breeze on BBA field

 21 years of observation of sea-land AOD contrast and Ts contrast

• R = 0.48 (significant > 95%)

NASA MODIS aerosol optical depth (AOD) vs. ERA5 reanalysis surface T data

Results



Results: Direction of positive feedback



- Cooler SST ⇒ high surface pressure system ⇒ anti-cyclonic winds
- Anti-clockwise rotation of ocean currents ⇒ warm sea water of equator to SEA

Conclusion

- Counterintuitively the cloud radiative effect (CRE) caused by the BBA is weaker if SST-low cloud feedback is considered compared to fixed-SST simulation
- This is caused by 1) stronger sea breeze due to larger sea-land temperature contrast causing less smoke transport over SEA and 2) less moisture supply from surface due to colder SST.
- Changes in SST also lead to changes in ocean circulation.
 Consequently, the excess heat transport from the equator reverses the direction of SST- cloud feedback in this region.