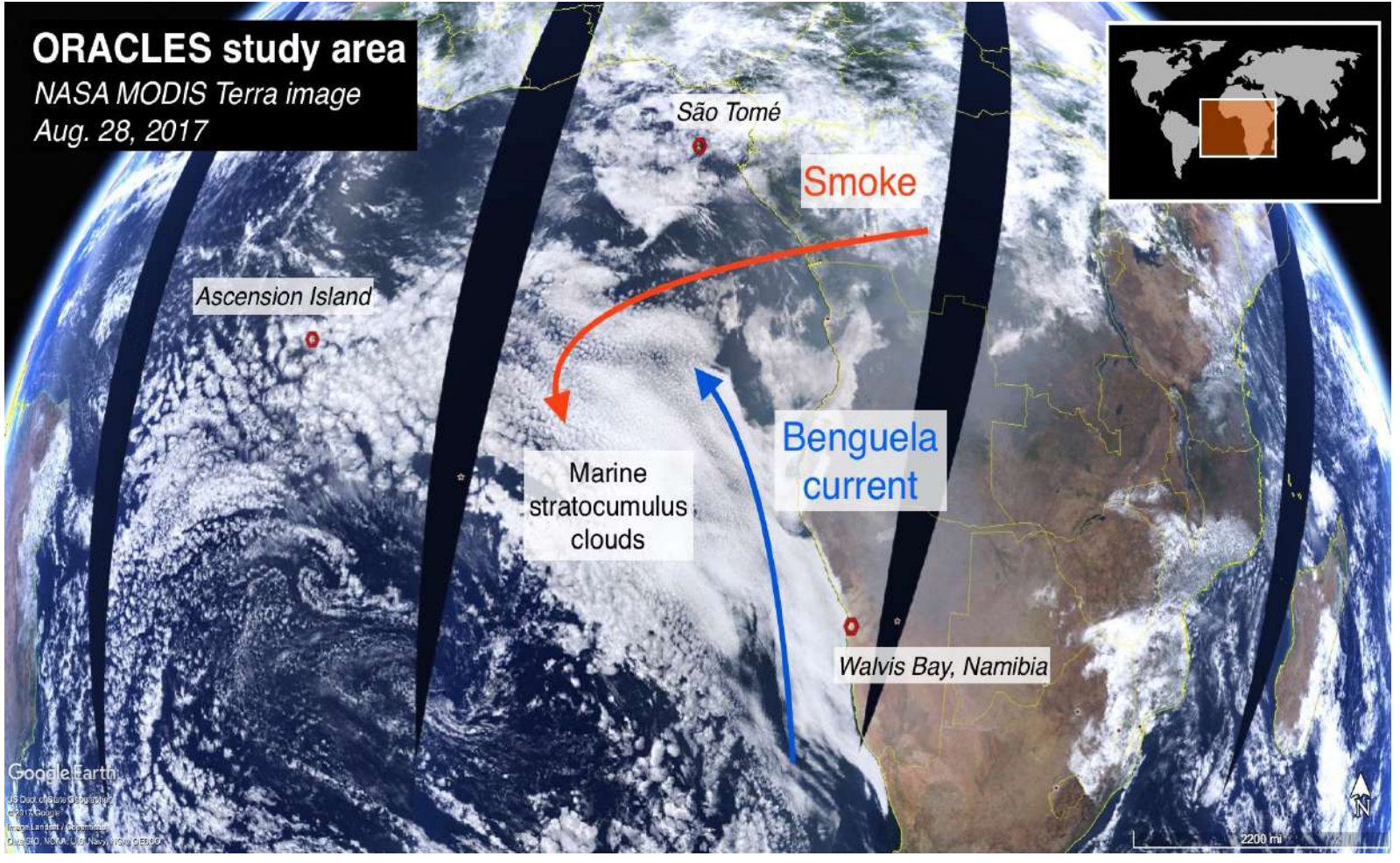
Impact of BBA on the radiative budget, cloud properties and climate over the tropical Africa.

M. Mallet, P. Nabat, A. Voldoire, F. Solmon, T. Druge, R. Roehrig, D. Bouniol, B. Johnson, P. Formenti, C. Flamant, J. Haywood, P. Zuidema, S. Doherty, H. Wu, J. Taylor, S. Burton, S. Leblanc, A. Dobracki & J. Redemann

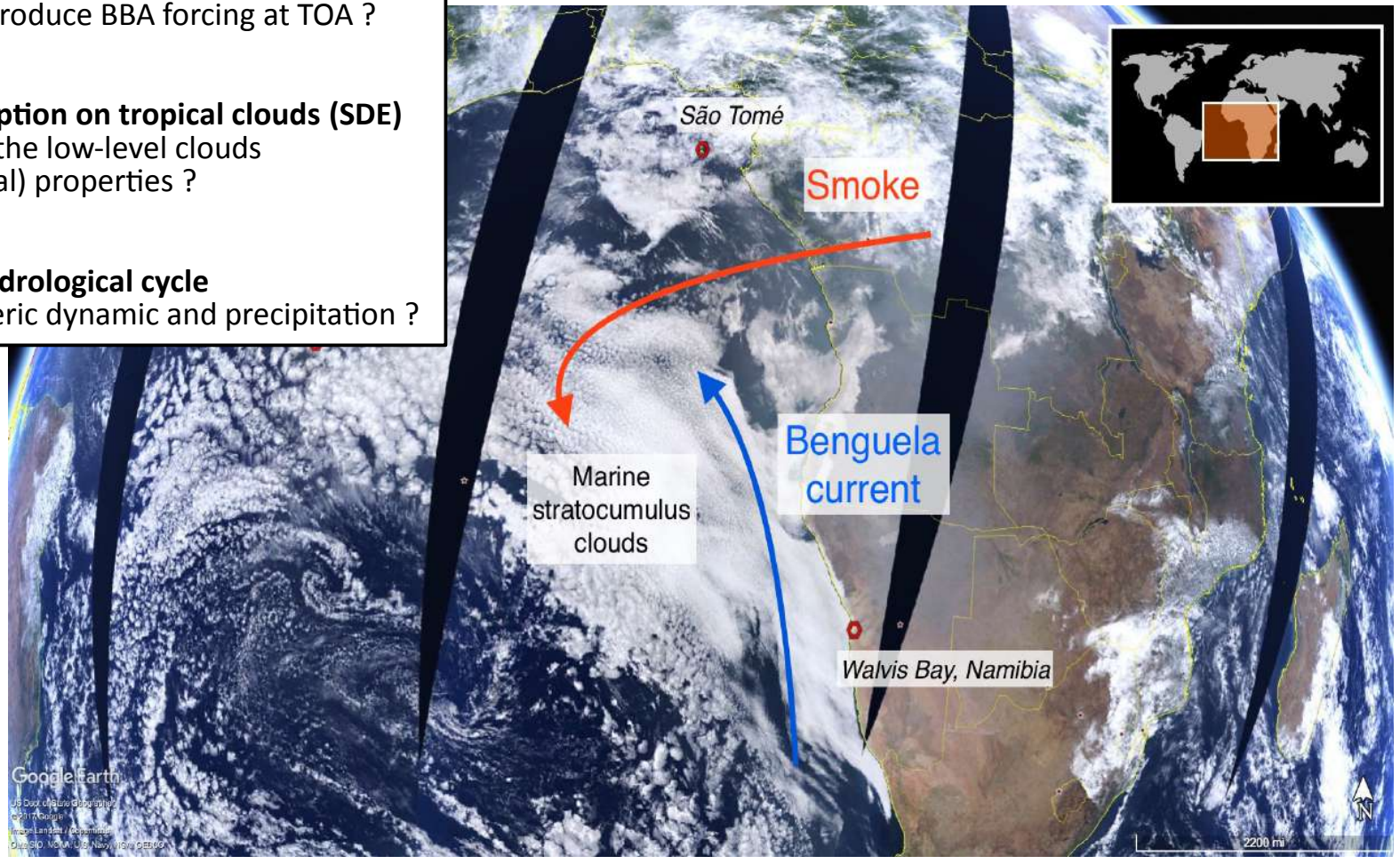


Impact of BBA on the radiative budget, cloud properties and climate over the tropical Africa

1) BBA direct radiative forcing over Southeast Atlantic (SEA)
→ Do BBA heat or cool at the regional scale ?
→ Are CMIP6 models able to reproduce BBA forcing at TOA ?

2) Impact of BBA-induced absorption on tropical clouds (SDE)
→ what are the BBA impacts on the low-level clouds (macrophys., microphys. & optical) properties ?

3) Feedback's on the Tropical hydrological cycle
→ how do BBA modify atmospheric dynamic and precipitation ?

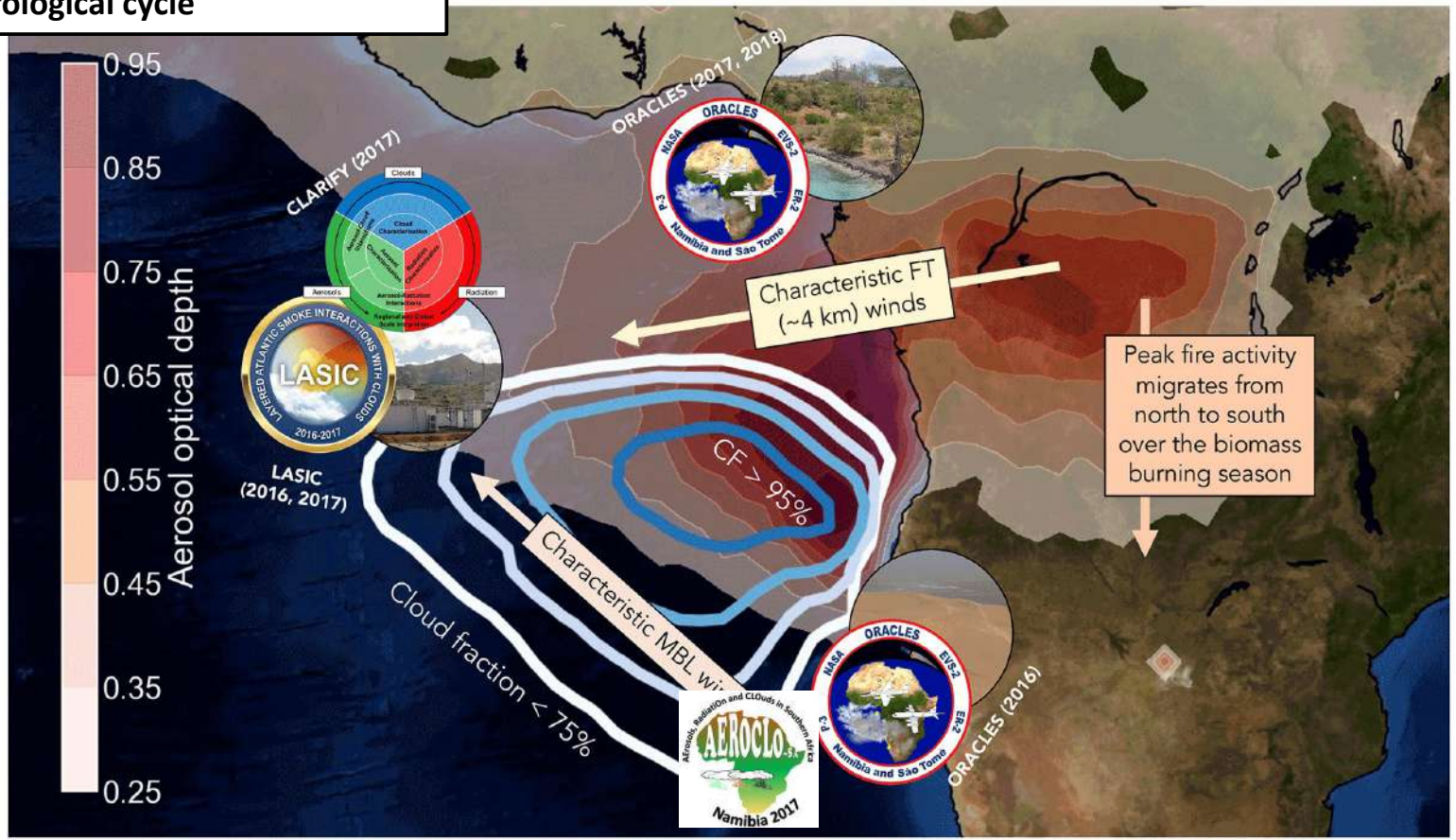


- International context -

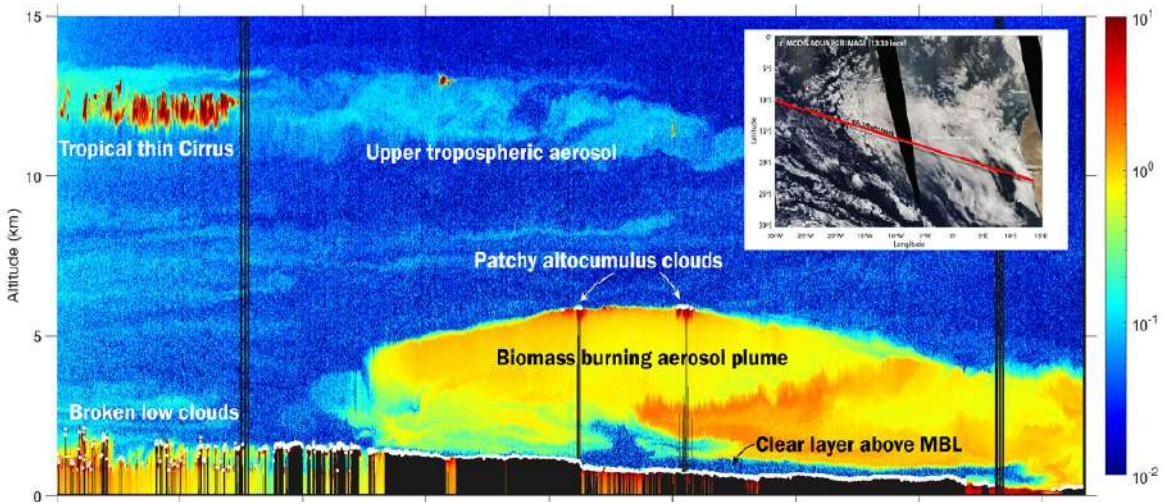
1) BBA direct radiative forcing over Southeast Atlantic (SEA)

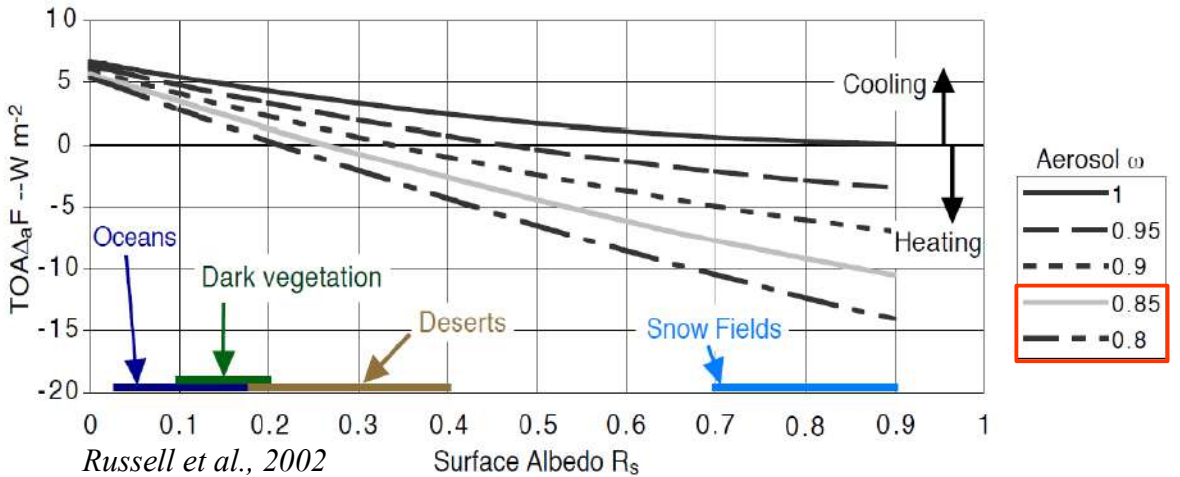
2) Impact of BBA-induced absorption on tropical clouds (SDE)

3) Feedback's on the Tropical hydrological cycle



BBA Direct Radiative Forcing (DRF) at TOA





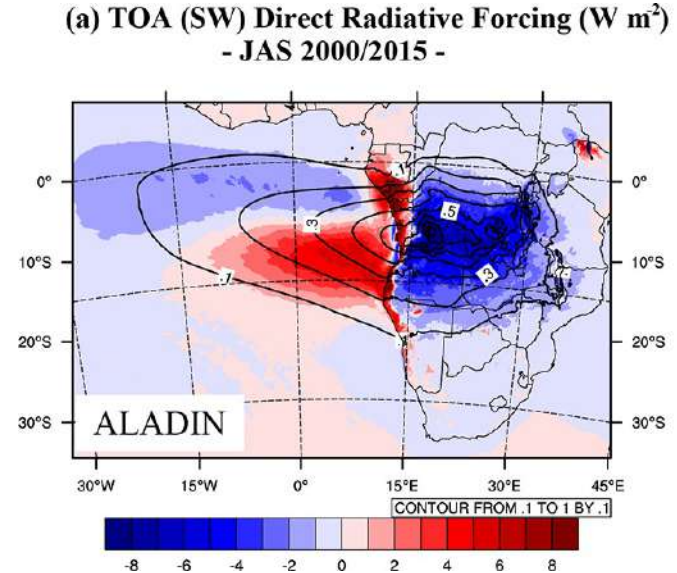
BBA

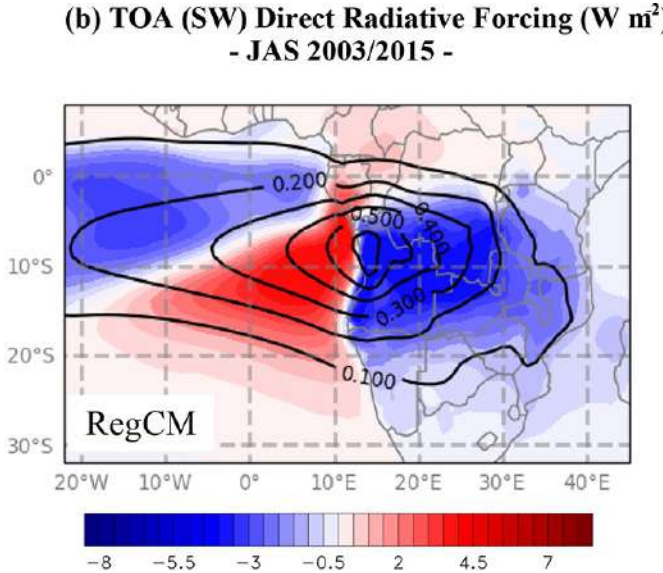
Large amount of highly absorbing smoke transported above Sc clouds

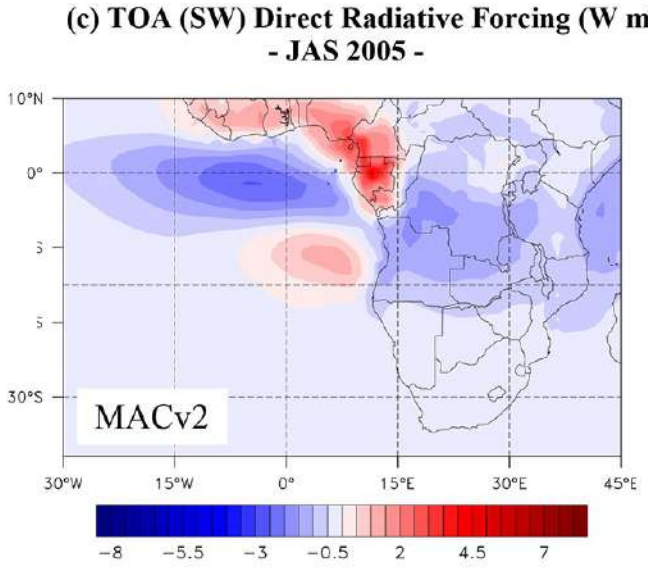
→ BBA could create positive TOA DRF over SEA

ORACLES (Pistone et al., 2019)
AEROCLO (Chauvigne et al., 2021)
LASIC (Zuidema et al., 2018)
CLARIFY (Wu et al., 2021)
DACCIWA (Denjean et al., 2020)

BBA Direct Radiative Forcing at TOA - Regional Climate Models (RCM) -



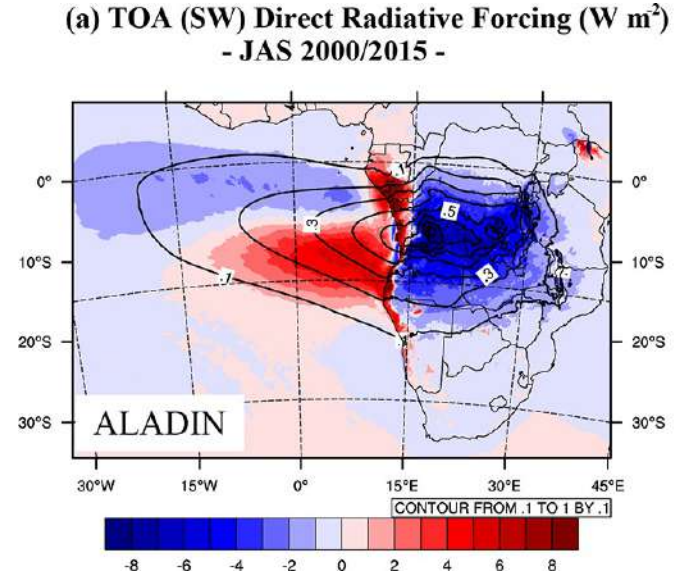


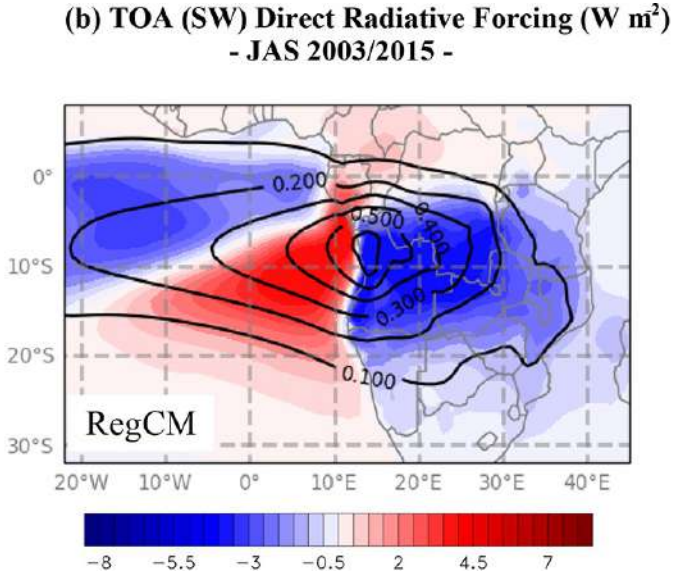


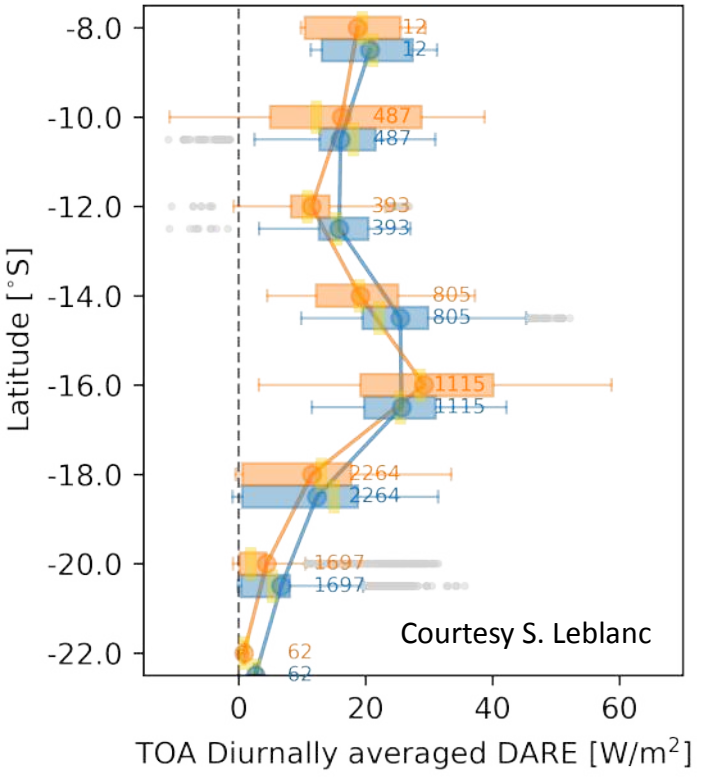
- strong regional heterogeneity with positive DRF over the Sc
- positive DRF over Gabon (Sc)
- cooling over the Gulf of guinea
- north/south DRF gradient over the ocean consistent with MACv2

Mallet et al. (2020)

BBA Direct Radiative Forcing at TOA - Regional Climate Models (RCM) -



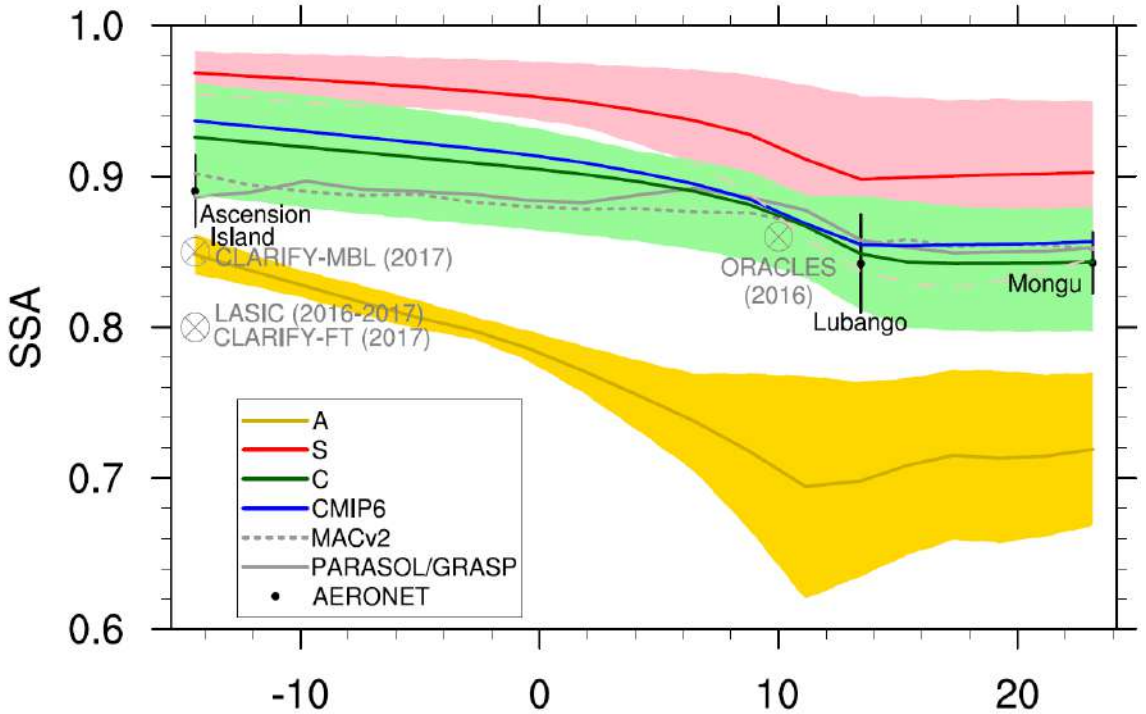




- strong regional heterogeneity with positive DRF over the Sc
- positive DRF over Gabon (Sc)
- cooling over the Gulf of guinea
- north/south DRF gradient over the ocean consistent with MACv2
- positive DRF over SEA consistent with ORACLES observations

Are CMIP6 models able to reproduce positive BBA Direct Forcing at TOA ?

- CMIP6 models evaluation using satellites & reanalyses



Climate models generally underrepresent the warming by Central Africa biomass-burning aerosols over the Southeast Atlantic

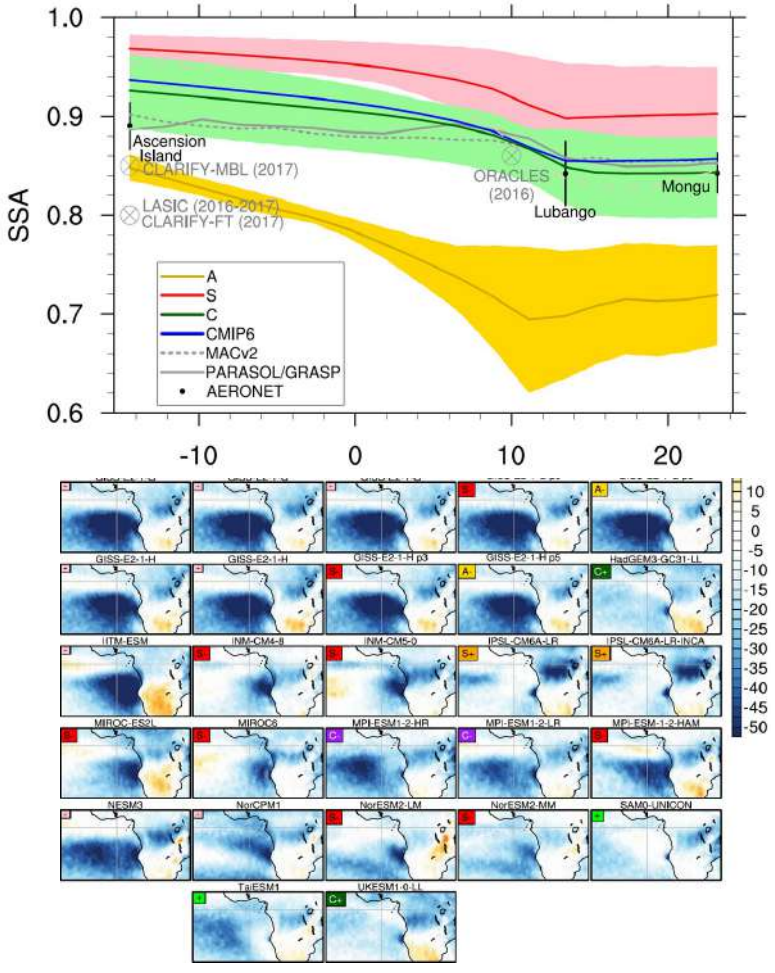
Marc Mallet[1]*, Pierre Nabat[1], Ben Johnson[2], Martine Michou[1], Jim M. Haywood[2,3], Cheng Chen[4,5], Oleg Dubovik[5]

- CMIP6 SSA over SEA ~ 0.92-94
- PARASOL/GRASP & MACv2 ~ 0.90
- in-situ ~ 0.80-0.85
- AERONET ~ 0.89

→ CMIP6 models generally underestimate SSA over SEA

Mallet et al., Science Advances, 2021

Are CMIP6 models able to reproduce positive BBA Direct Forcing at TOA ?

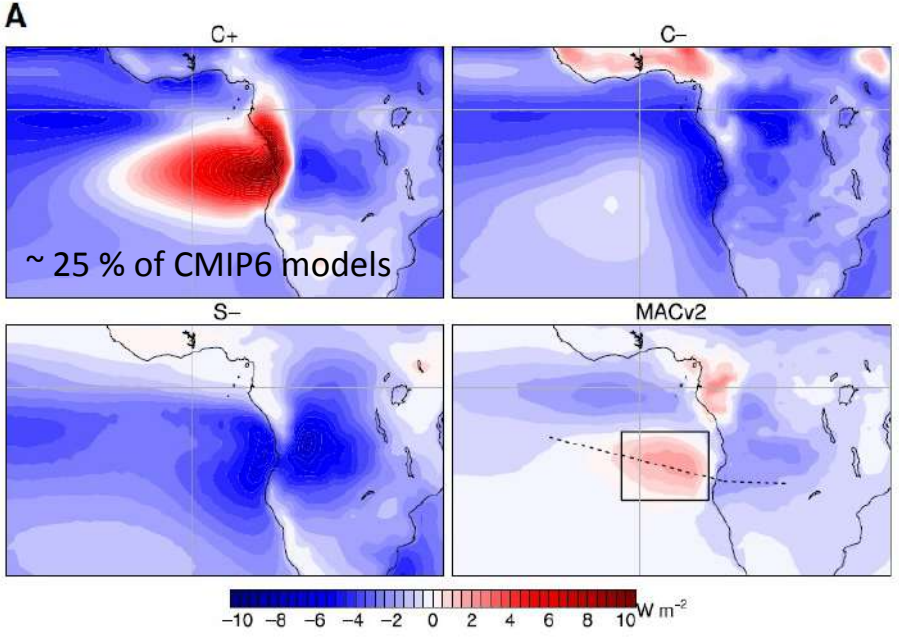


Cloud Fraction (CMIP6 historical, compared to CALIPSO)

→ overestimate SSA

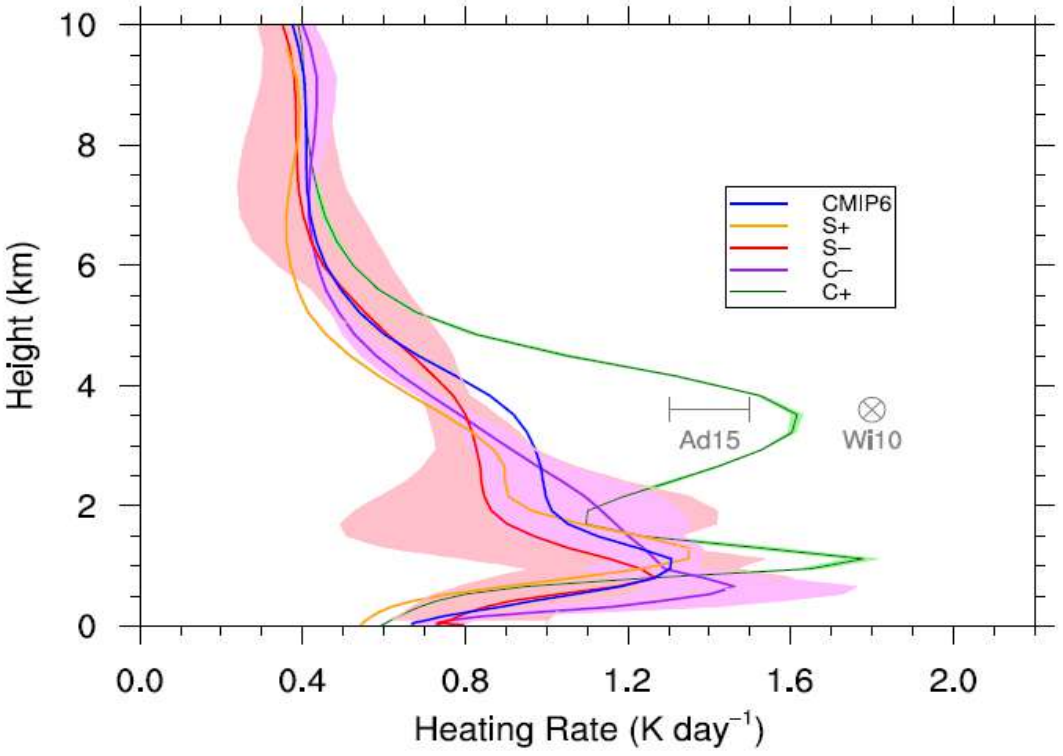
&

→ underestimate LCF



→ ~ 75 % of CMIP6 models simulate cooling over SEA

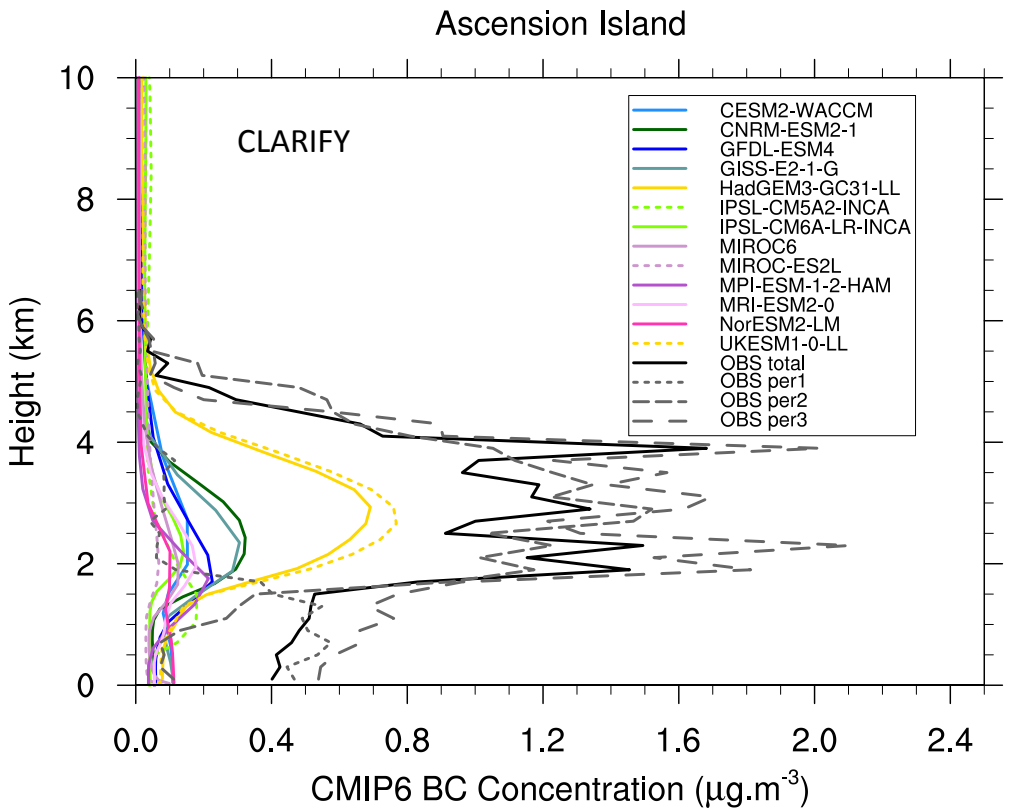
Are CMIP6 models able to reproduce positive BBA Direct Forcing at TOA ?



- BBA SW heating is underestimated in CMIP6 models

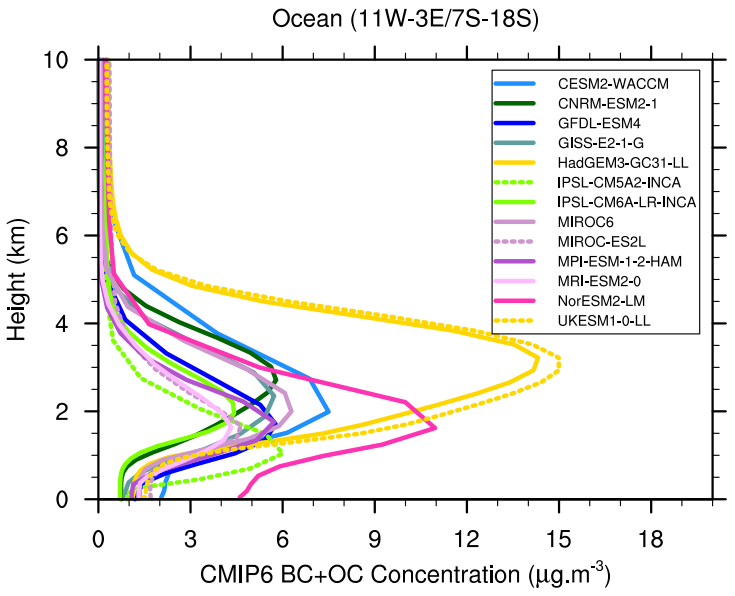
- Are they able to represent BBA SDE on tropical clouds ?

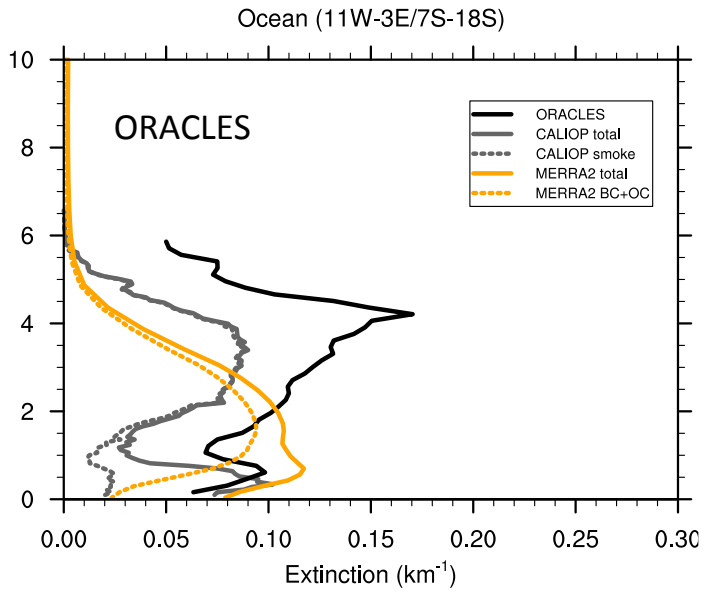
Why do models underestimate the SSA - in-situ observations -



- BC concentration underestimated in CMIP6 models

Mallet et al., in prep.



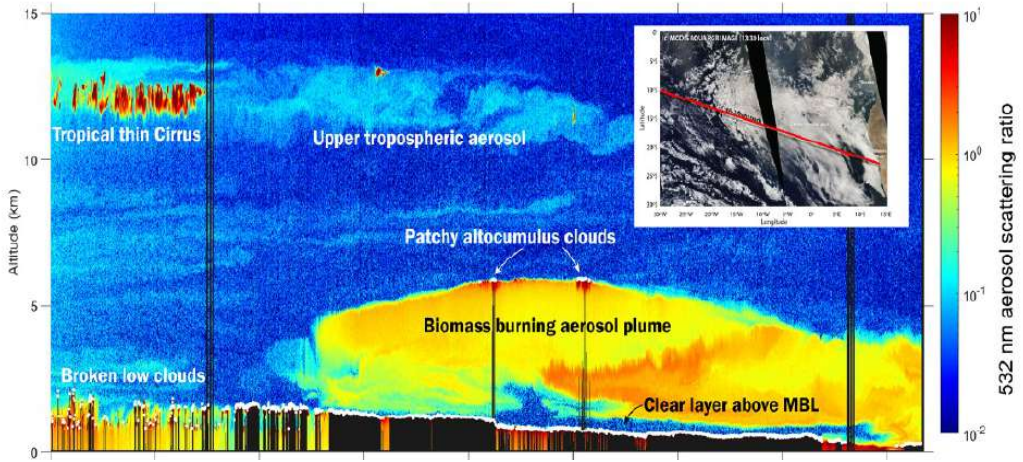


- bias in the altitude of transport :

→ too much intrusion in MBL

→ scavenging effect ?

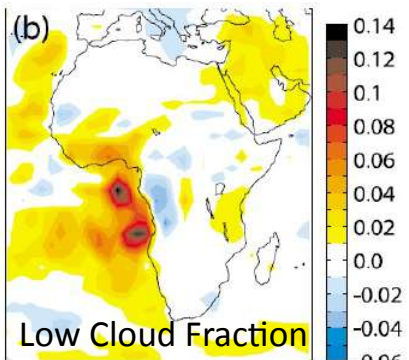
BBA Semi Direct Effect (SDE)



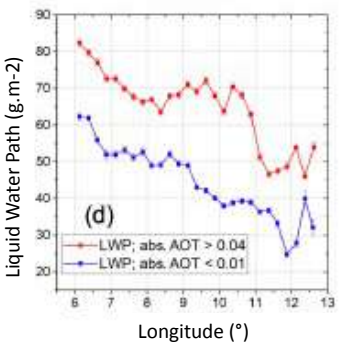
SDE is controled by :

- BBA-induced heating in the lower tropos.
- altitude of transport
- **SST responses**
- Lower Tropos. Stability (LTS)

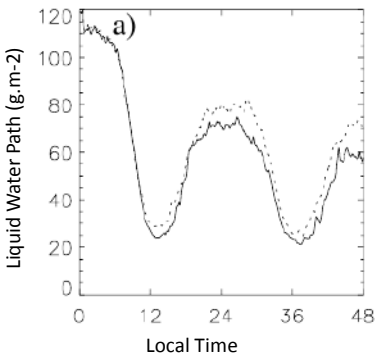
→ strong LTS favors the inversion that inhibits entrainment, favoring shallower & well-mixed boundary layer [Wood and Hartmann, 2006]



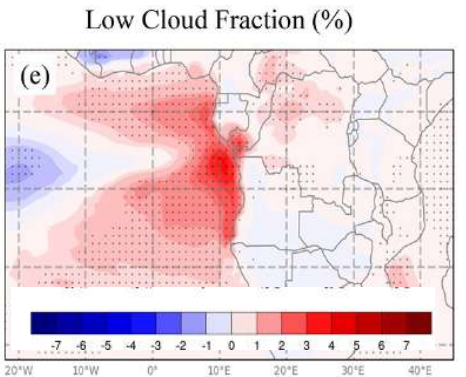
GCM-SOM
Sakaeda et al. (2011)



Satellite obs.
Wilcox (2010)
Deaconu et al. (2019)

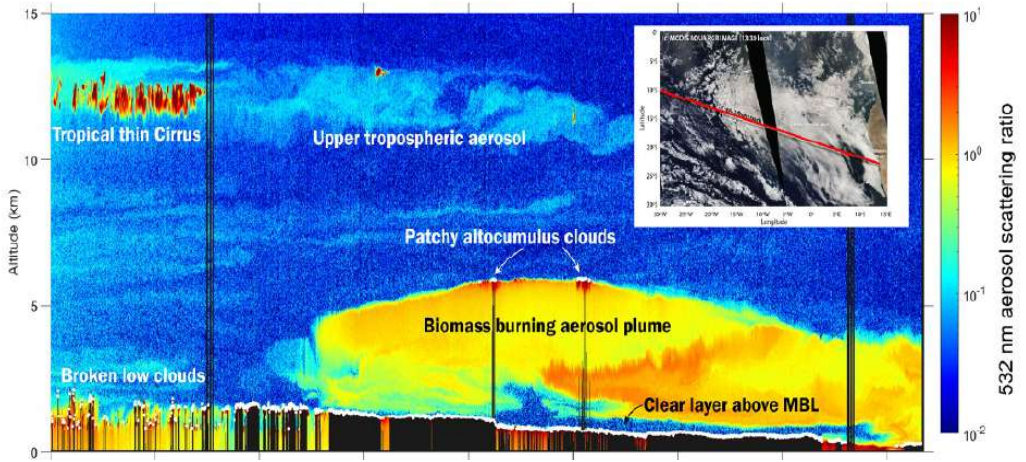


LES
Johnson et al. (2004)
Herbert et al. (2021)

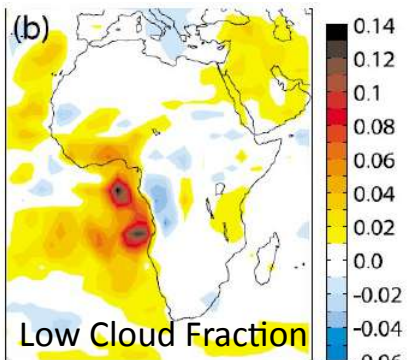


RCM
Mallet et al. (2021)

BBA Semi Direct Effect (SDE)



Complete GCM-SOM, LES, satellite & RCM-SOM studies with new O-A GCM simulations



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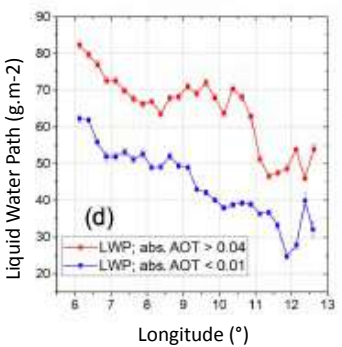

Satellite obs.
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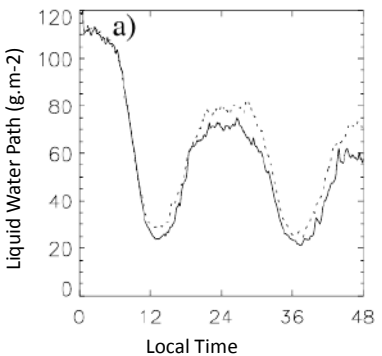

LES
Johnson et al. (2004)
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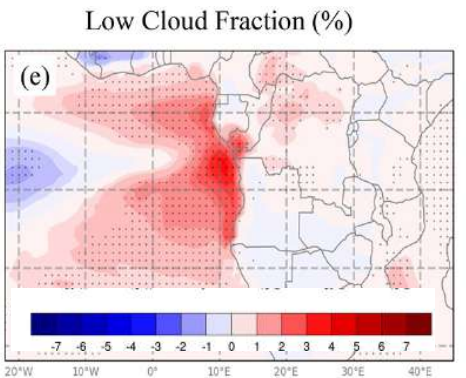
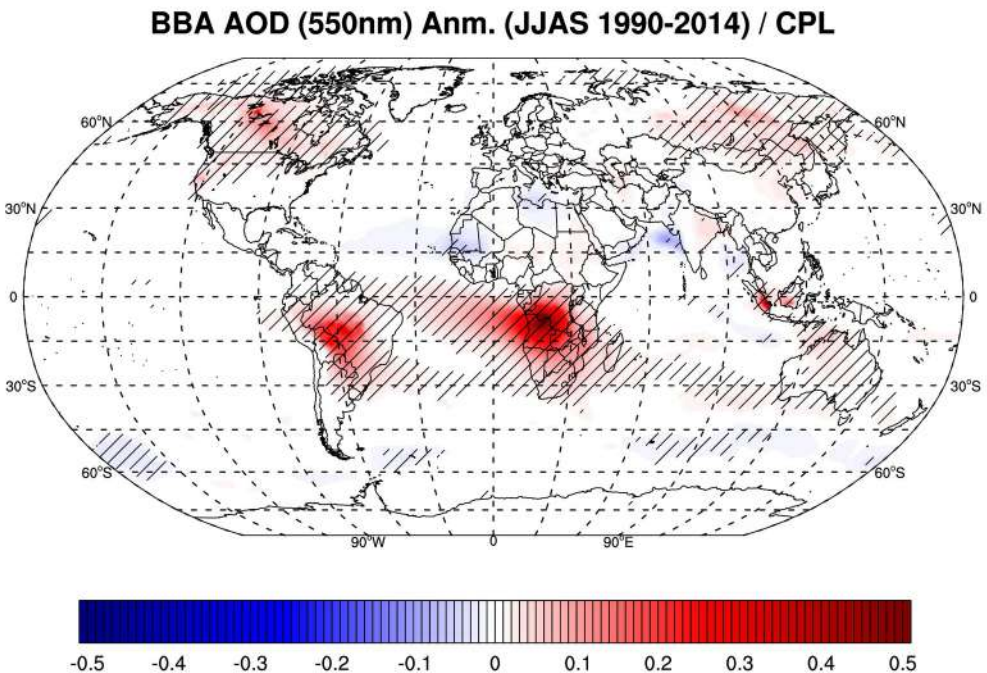
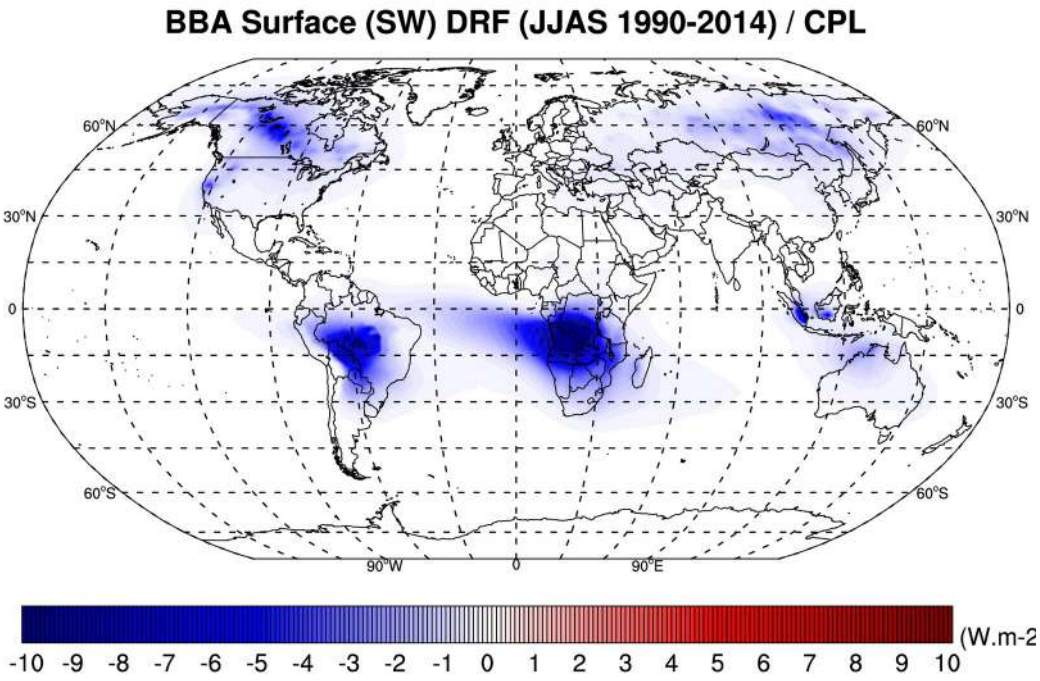


RCM
Mallet et al. (2021)

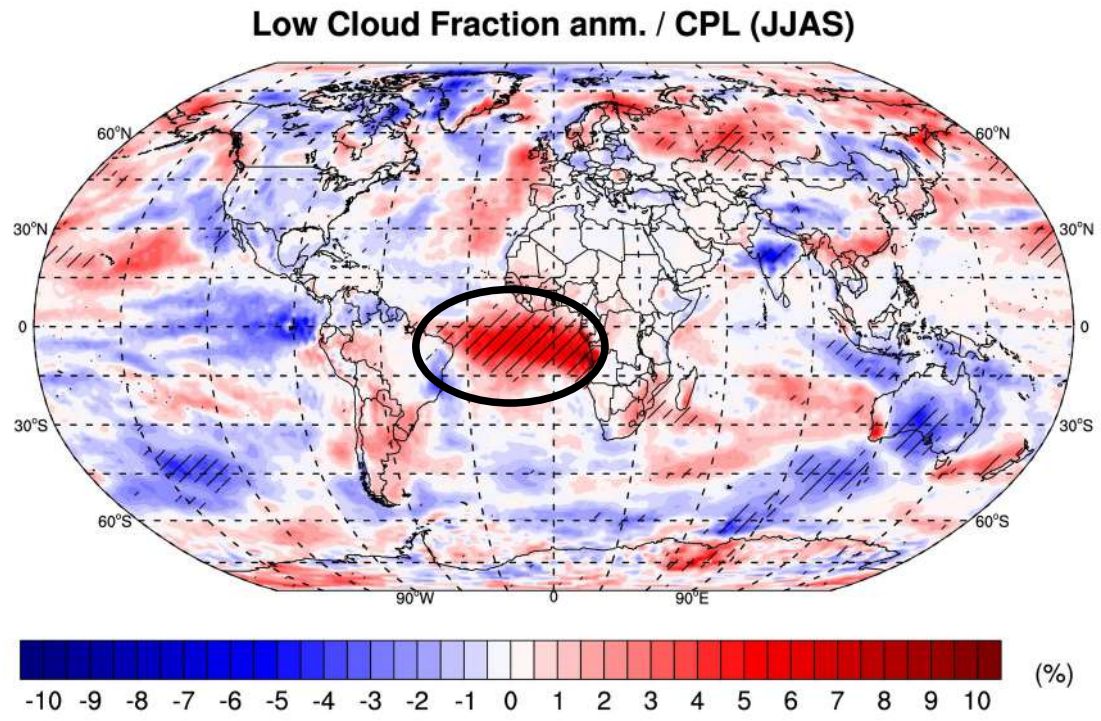
BBA Semi Direct Effect (SDE) - GCM -

- O-A GCM approach (CNRM-CM model)
- atmospheric component : ARPEGE-Climat
- oceanic component : NEMO
- improved BBA optical properties (Druge et al., ACP, 2022)





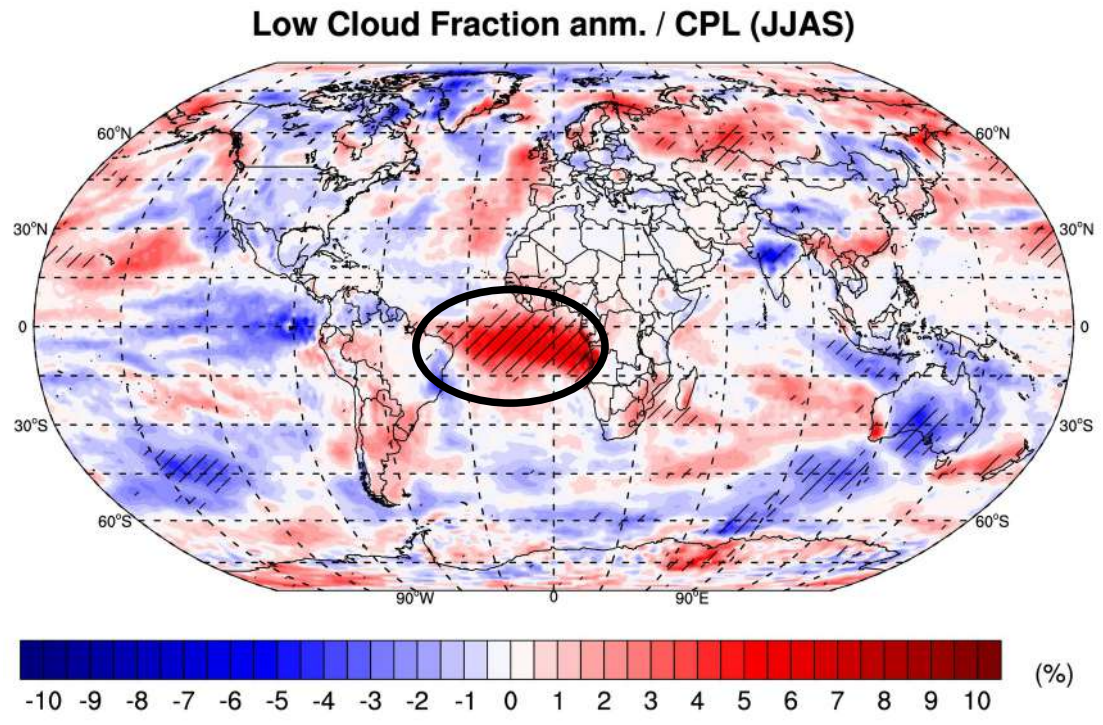
BBA Semi Direct Effect (SDE) - GCM -



- consistent LCF responses

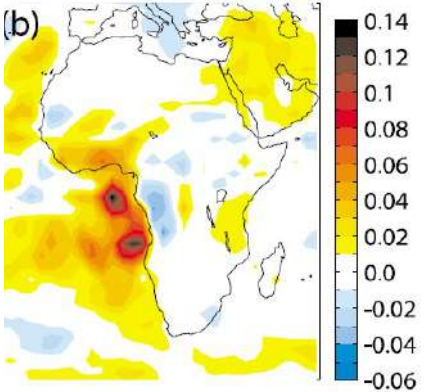
Mallet et al. (in prep.)

BBA Semi Direct Effect (SDE) - GCM -

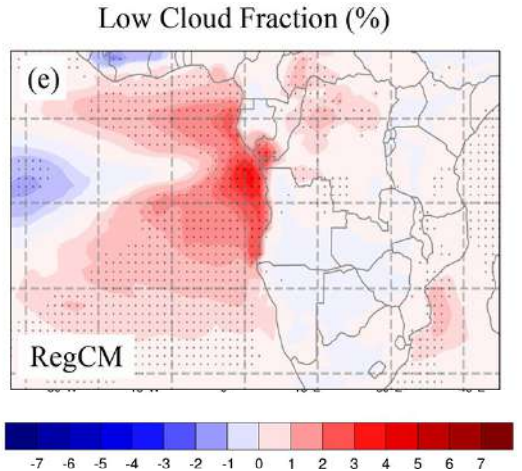


- consistent LCF responses

- SDE simulated over the Tropical ocean [0-20°S]

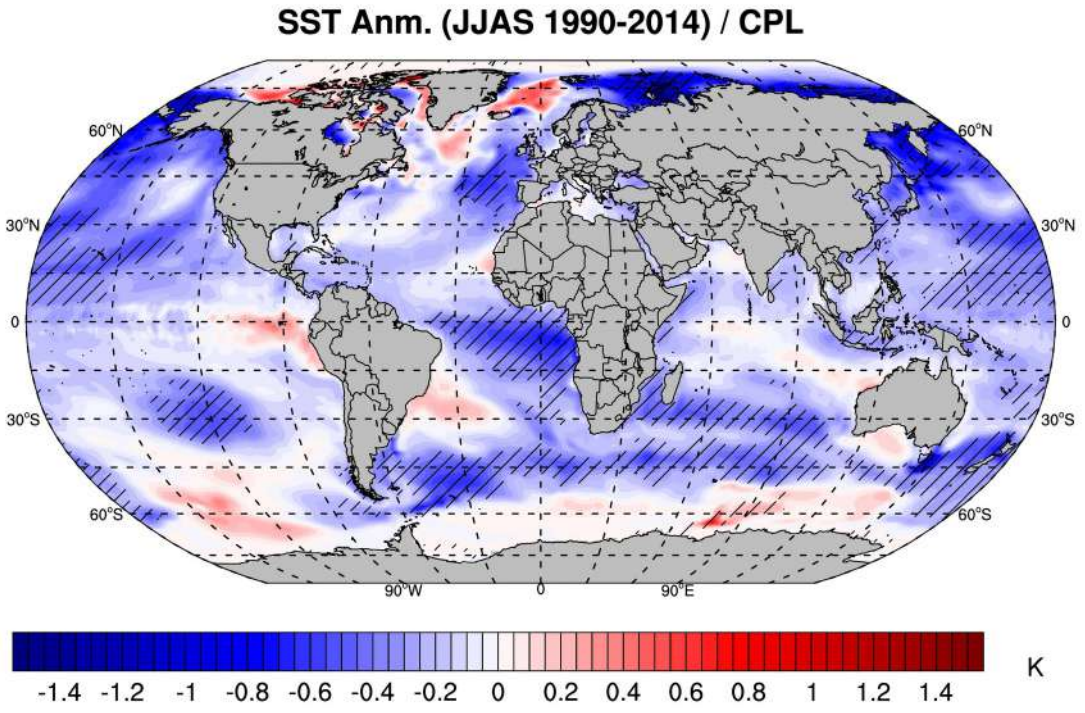


GCM-SOM
(Sakaeda and Wood, 2001)



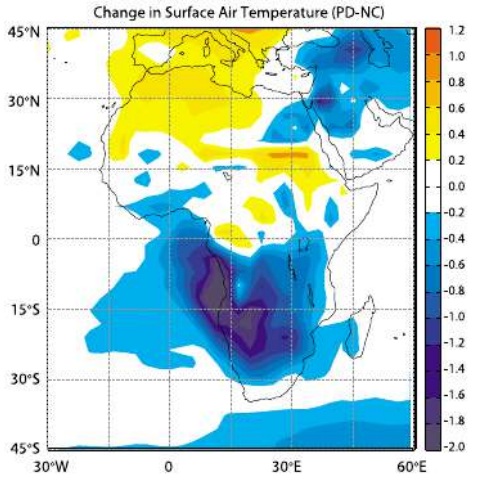
RegCM-SOM
(Mallet et al., 2021)

BBA Semi Direct Effect (SDE) - GCM -

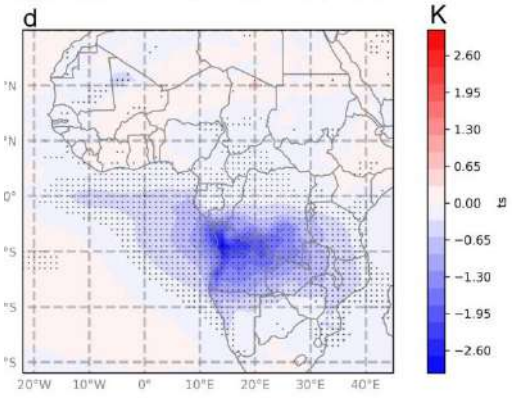


- consistent SST anomaly (~ -1/1,5°K) over SEA

- larger regional extend of the « SST anomaly »



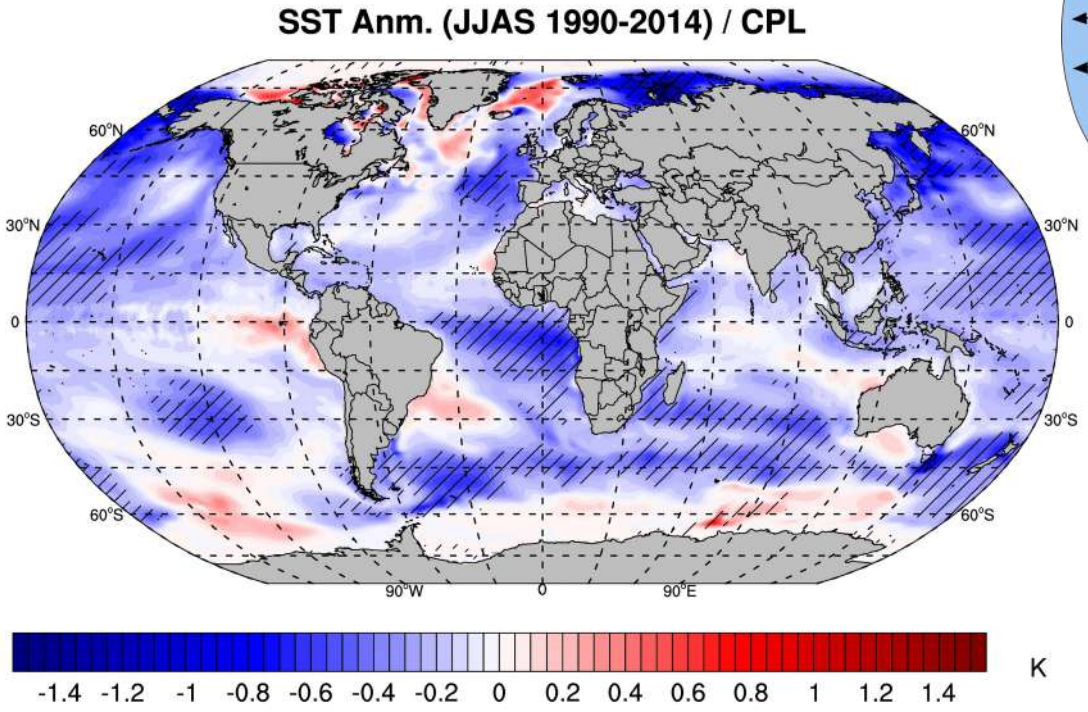
GCM-SOM
(Sakaeda and Wood, 2001)

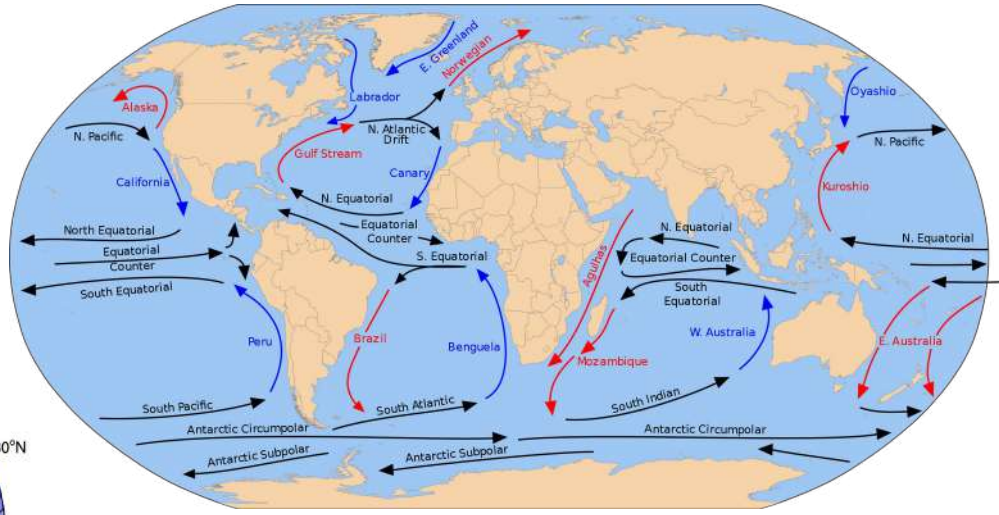


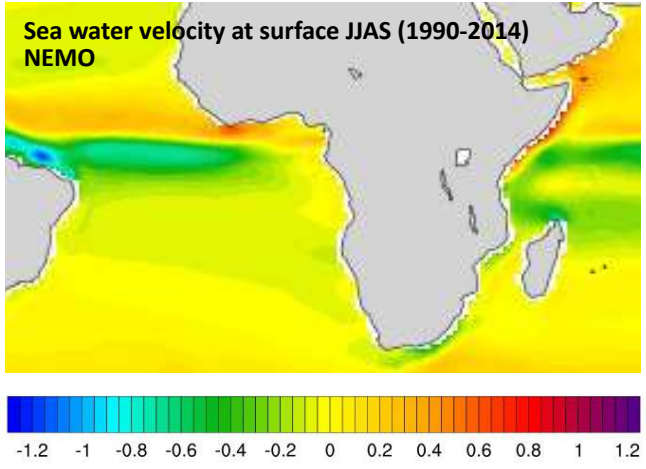
RegCM-SOM
(Mallet et al., 2021)

BBA Semi Direct Effect (SDE) - GCM -

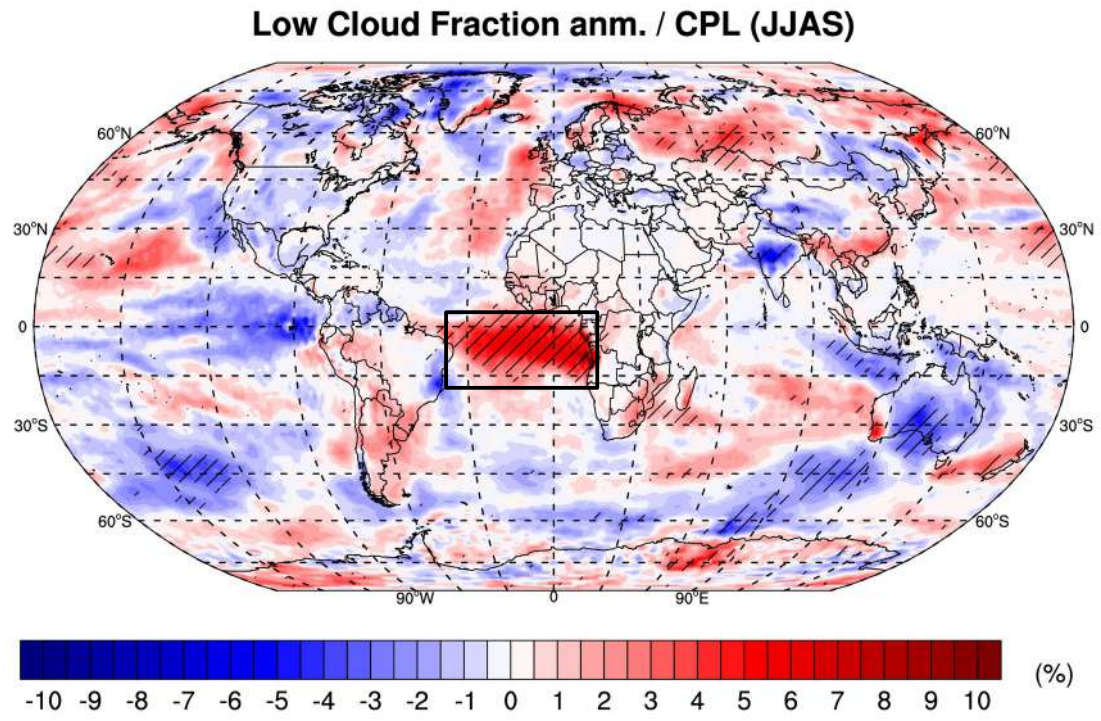
- advection of SST anomaly to the open ocean (not represented in SOM)







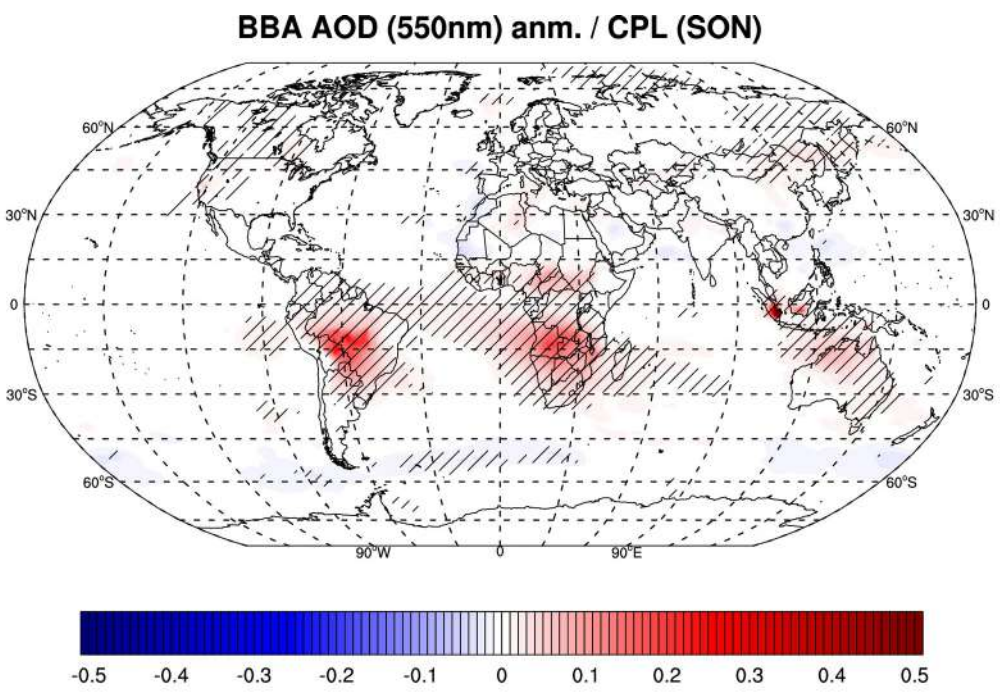
BBA Semi Direct Effect (SDE) - GCM -

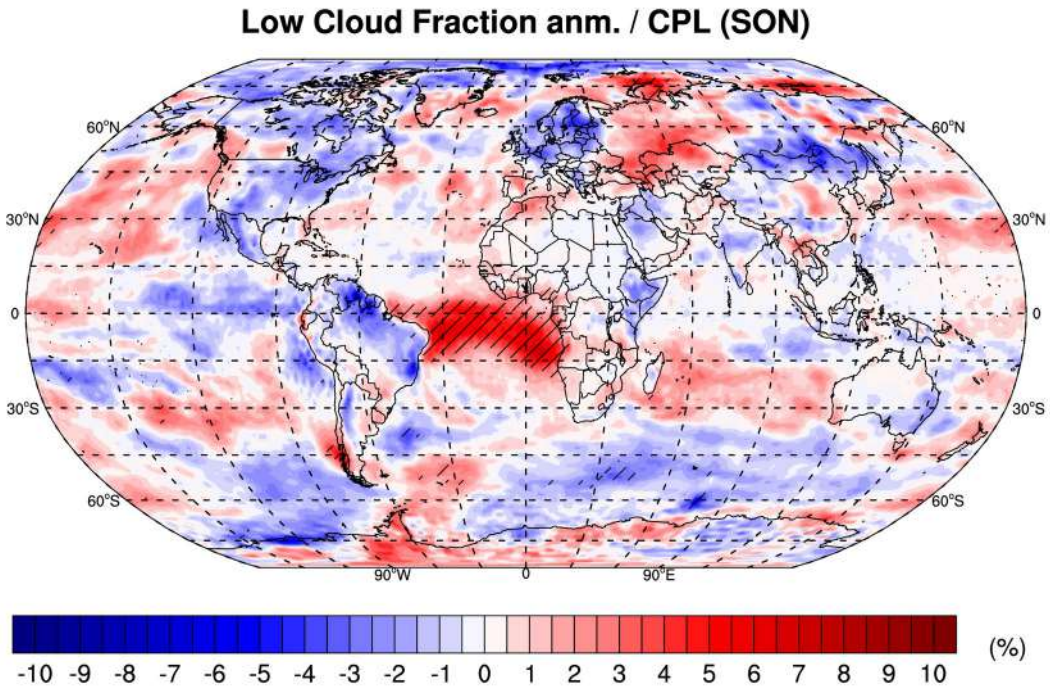


- BBA SDE could be amplified in A-O GCM vs. GCM or RCM-SOM

- need to be quantified using the advection terms

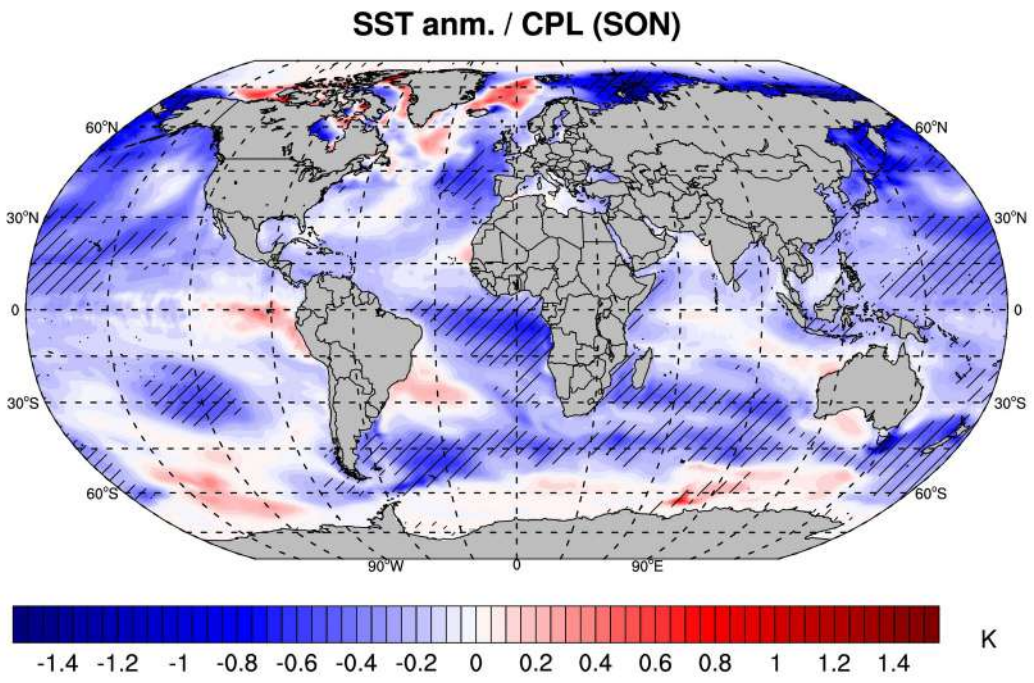
BBA Semi Direct Effect (SDE) - GCM -

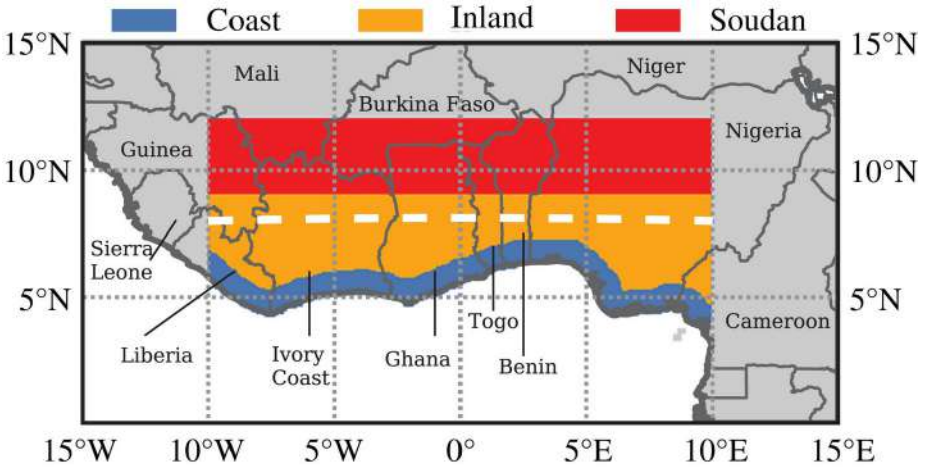


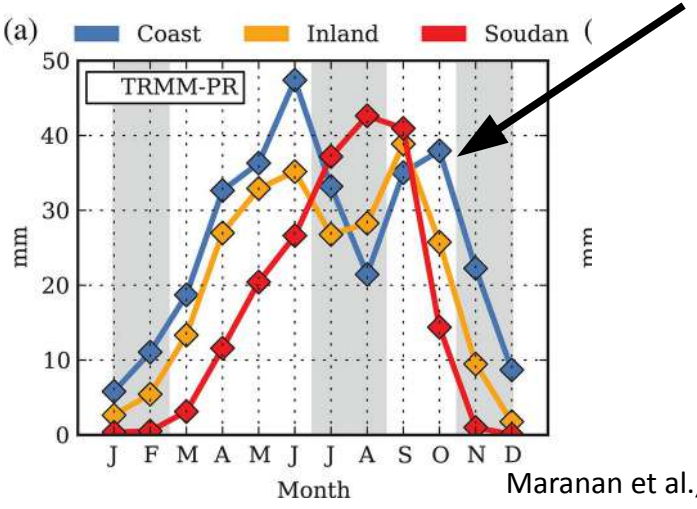


- BBA SDE could be propagated to SON season due to the inertia of the « slow response » (SST)

BBA Semi Direct Effect (SDE) - GCM -







- influence on precipitation during the secondary rainy season (SON) over **coastal** southern West Africa ?

Maranan et al., 2018