ROLE OF BROWN CARBON IN THE AEROSOL ABSORPTION OVER THE SOUTH-EAST ATLANTIC REGION

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I. Problematic

The solar absorption by particles plays a major role in the sign and the intensity of the aerosol radiative forcing and its possible feedbacks on climate. Current studies indicate that some aerosol organic compounds, called **"brown carbon (BrOC)"** (emitted mainly by biomass burning), have a significant solar absorption efficiency, particularly in the ultraviolet spectrum. However, global climate models including organic carbon generally do not take into account this potential absorption by brown carbon, considering organic compounds as mainly scattering. The absorption properties of particles are key parameters in the estimation of their climate impact, especially in cloudy scenes. For example, the radiative heating induced by absorbing aerosols over stratocumulus can modify convection processes and alter the vertical development of the cloud. This process, known as the semi-direct effect, can be important in the South-East Atlantic region, where biomass burning plumes are frequently transported above one of the 3 most persistent stratocumulus layer on the planet. However, this aerosol feedback on clouds is difficult to apprehend by climate models because of the complexity in accurately representing the aerosol absorption.

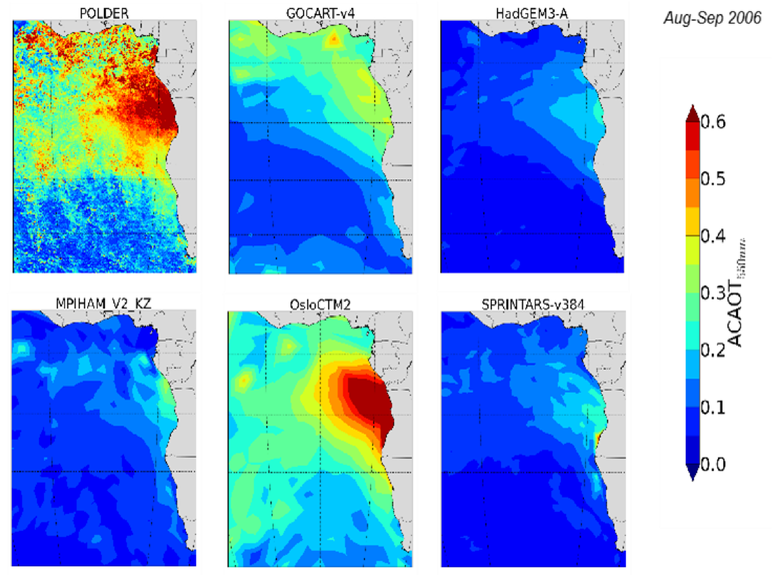

FIG. 1: Above Cloud Aerosol Optical Depth (ACAOD) at 550nm retrieved by the POLDER-3 space sensor in the South Atlantic region and modeled by 5 climatic models. Average on the August-September 2006 period. Peers et al., 2016.

The biases of climatic models, both on the aerosol load and on their absorption properties, may explain the current difficulties in obtaining accurate estimates of the radiative effects of aerosols, in particular in the South-East Atlantic region.

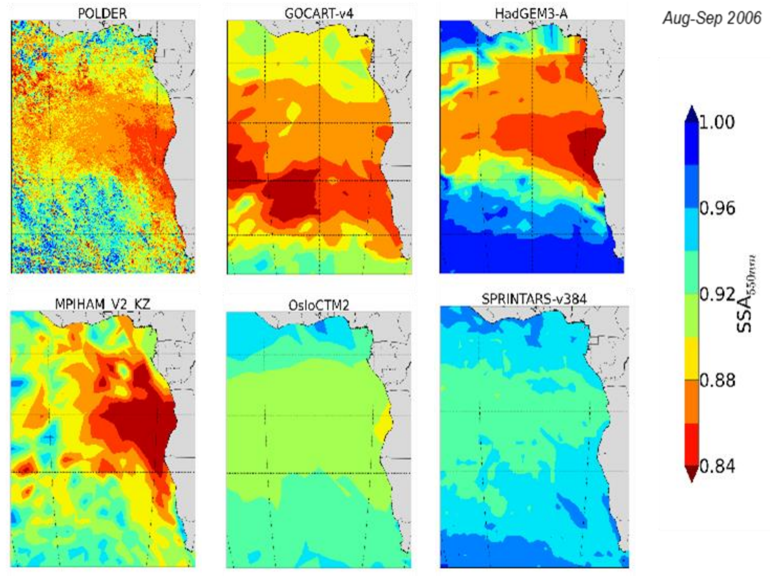

FIG. 2: Above Cloud Single Scattering Albedo (ACSSA) at 550nm retrieved by the POLDER-3 space sensor in the South Atlantic region and modeled by 5 climatic models. Average on the August-September 2006 period. Peers et al., 2016.

The main objective of this thesis is to estimate the contribution of brown carbon in the aerosol absorption properties, with a focus on biomass burning particles transported above clouds and to study its associated climate impact.

II. Methodology

Emission inventories

- **Biomass burning emissions (BC, OC, …): global inventory at 1x1km² resolution - Turquety et al., 2014**
- Anthropogenic emissions: REanalysis of the TROpospheric (RETRO) chemical composition for the years 1960-2000 at 0.5°x0.5° spatial resolution
- Biogenic emissions: Model of Emissions of Gases and Aerosols from Nature (MEGAN v.2.1) at 1x1km² spatial resolution - Guenther et al., 2012

Meteorological fields

Reanalysis made by the National Centers for Environmental Prediction (NCEP) from the Global Forecast System (GFS)

Data are updated every 6 hours at 1° spatial resolution

Mesoscale model WRF-CHEM

Simulates atmosphere chemistry and its interaction with meteorology (including direct and semi-direct radiative effects)

Large diversity of aerosols: NO3, NH4, SO4, POA, SOA, …, GOCART emission scheme for dust & sea salt

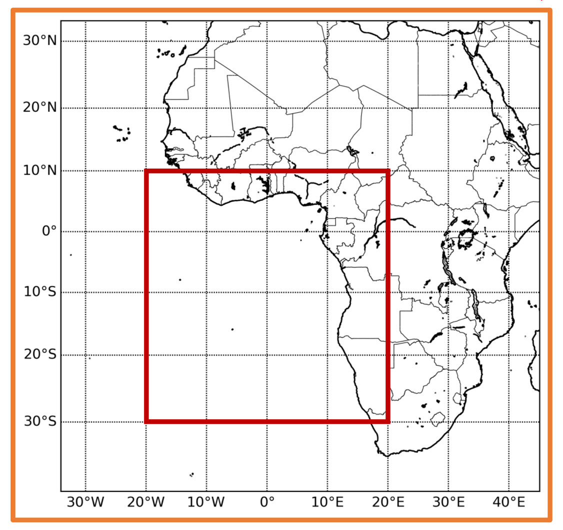

FIG. 3: Field of study in WRF-CHEM with a focus on the South-East Atlantic region framed in red

Zone of interest

- Horizontal: 30x30km² resolution
- Vertical: 30 levels up to 50 Pa
- Period of interest: June to October 2008 (AEROCLO campaign in summer 2017)

Output

- Meteorological parameters
- Clouds and aerosols properties

Satellite data

Comparisons with innovative aerosol retrievals from recent algorithm applied to POLDER-3 observations in clear sky conditions (GRASP - Dubovik et al. – 2014), and above cloud scenes (Waquet et al. - 2013)

III. Results

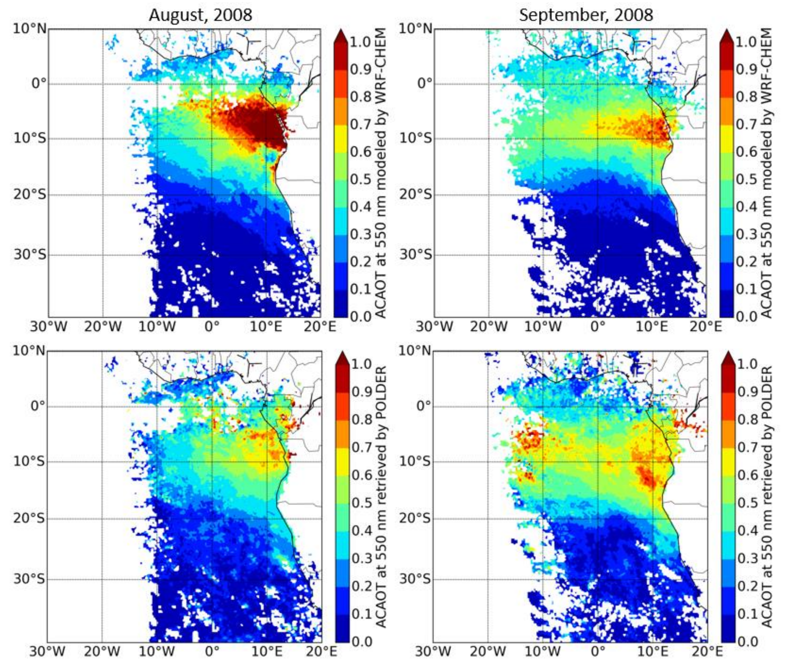

FIG. 4: ACAOD at 550nm modeled by WRF-CHEM (top) and retrieved by the POLDER-3 space sensor (bottom) in the South-East Atlantic region. Monthly average between 1 and 2 pm to match the PARASOL satellite pass (about 1.30 pm).

WRF-CHEM

POLDER

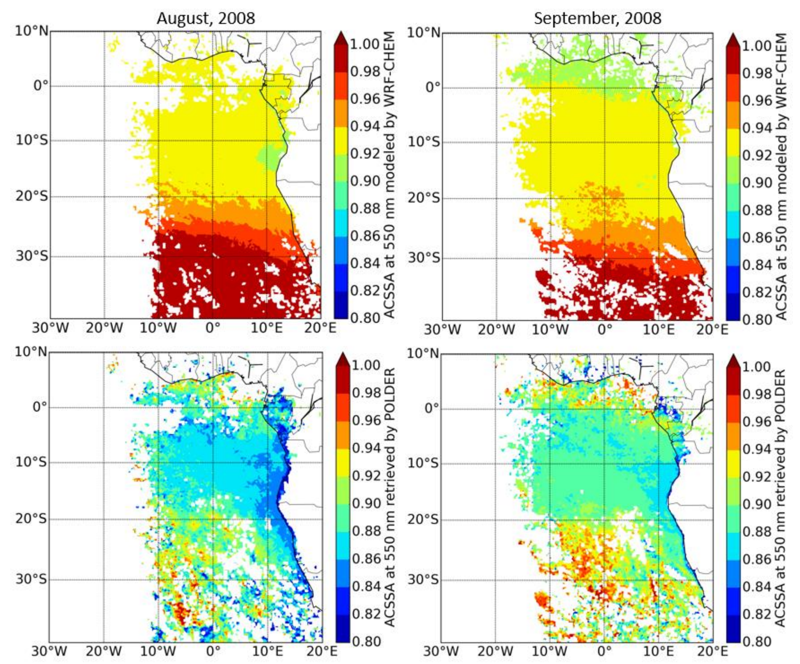

FIG. 6: ACSSA at 550nm modeled by WRF-CHEM (top) and retrieved by the POLDER-3 space sensor (bottom) in the South-East Atlantic region. Monthly average between 1 and 2 pm to match the PARASOL satellite pass (about 1.30 pm).

→ Slightly overestimation of the AOD values may be explained by an underestimation of the calculated cloud top height (not shown here)

→ Modeled particles are not enough absorbing

→ Is there enough absorbing black carbon in the model ?

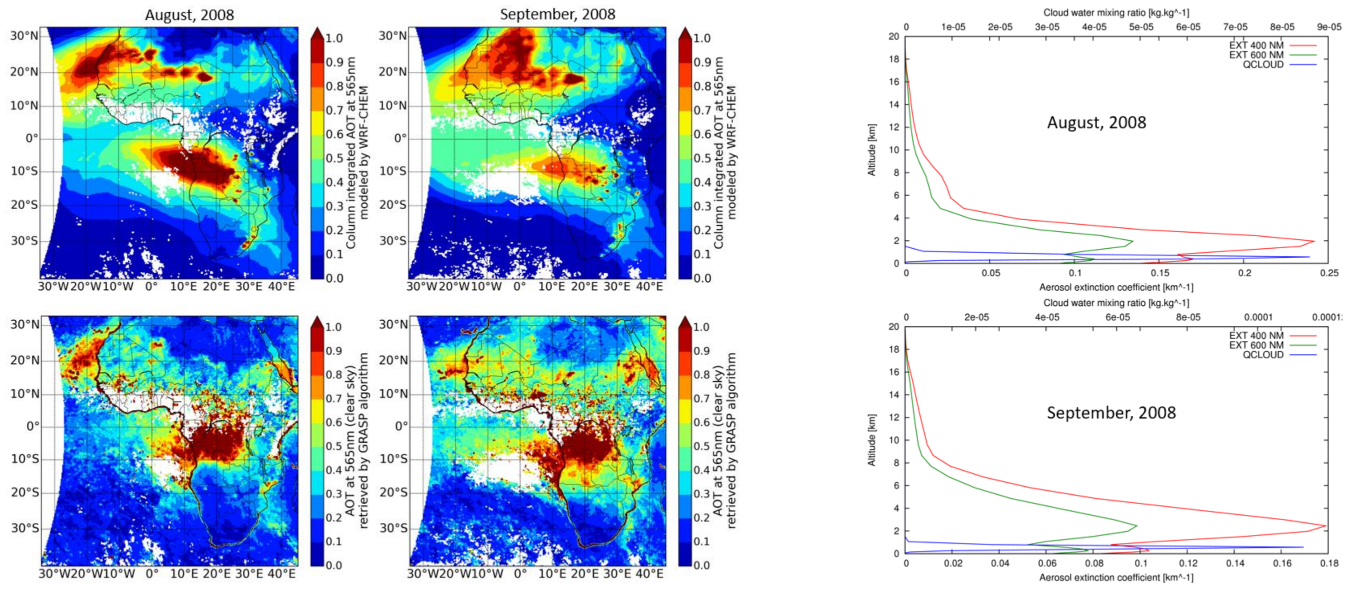

FIG. 5: Column integrated AOD at 565 nm from WRF-CHEM (left, top) compared to Grasp retrieval (left, bottom). Aerosol extinction profiles above ocean (right).

→ Power of biomass burning emissions sources is rather well reproduced by the model

→ Transport of aerosols from the sources region over the South-East Atlantic stratocumulus layer is well reproduced

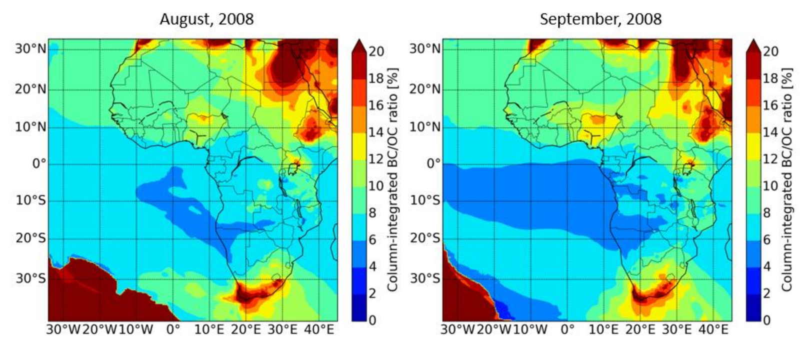

FIG. 7: Column integrated black carbon (BC)/organic carbon (OC) ratio modeled by WRF-CHEM. Monthly average.

→ Proportion of BC/OC, about 6.0% in mean between the South-East Atlantic region and the sources of biomass burning emissions is in good agreement with other global climatic models (Peers et al. - 2016)

- **Underestimation of aerosol absorption properties**
- **The non-inclusion of brown carbon in this test simulation may explain the underestimation of aerosol absorption**

IV. Future work

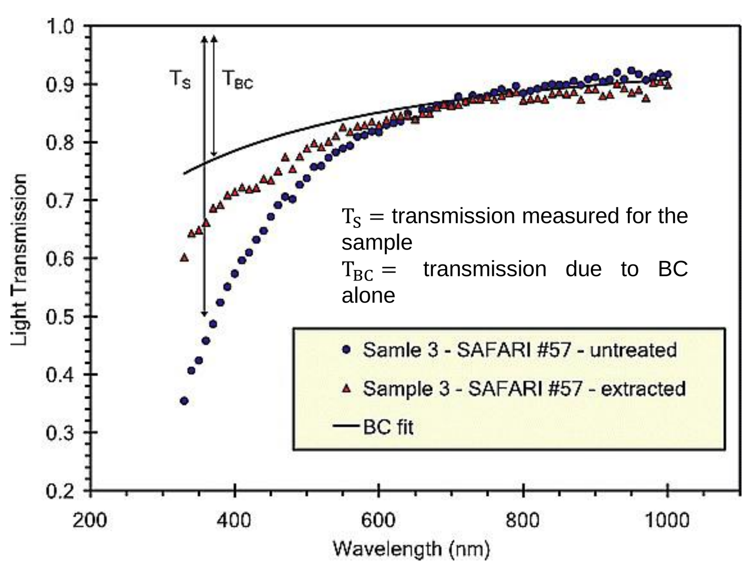

FIG. 8: Apportionment of light absorption to black carbon (BC) and organic carbon (OC) in a biomass smoke sample. Kirchstetter et al. – 2004.

→ Brown carbon absorbs more efficiently UV-blue radiation than pure soot

→ Refractive indices of brown carbon (Hoffer et al. - 2016, 2017) to be implemented in the model:

Wavelength (nm)	300	400	600	1,000
Refractive index	1.85 – 0.5i	1.85 – 0.3i	1.82 – 0.2i	1.60 – 0.08i

→ We will use the difference of the spectral dependence between BC & BrOC **to estimate the amount of BrOC** for different proportions of BrOC and BC in the aerosol plume

→ Resulting aerosol absorption will be compared with that retrieved from remote sensing measurements in the 340-870 nm spectral range

→ Studying the climate impact due to the brown carbon contribution

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Acknowledgments

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