# Brown Carbon (BrC) in EC-Earth 3

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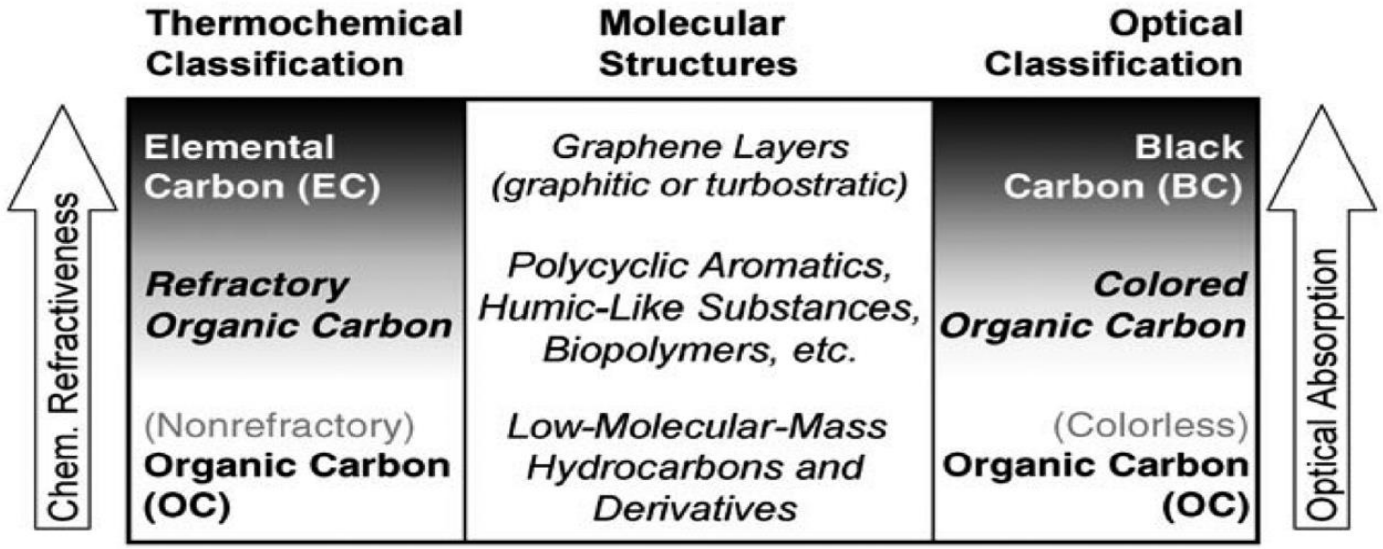
# What is Brown Carbon (BrC)

- Most known absorbing carbonaceous aerosol →BC
- Organic Aerosols (OA) scatter visible radiation
- Fraction of the OA that absorbs radiation → BrC




*Laskin et al., Chemical Reviews, 2015*

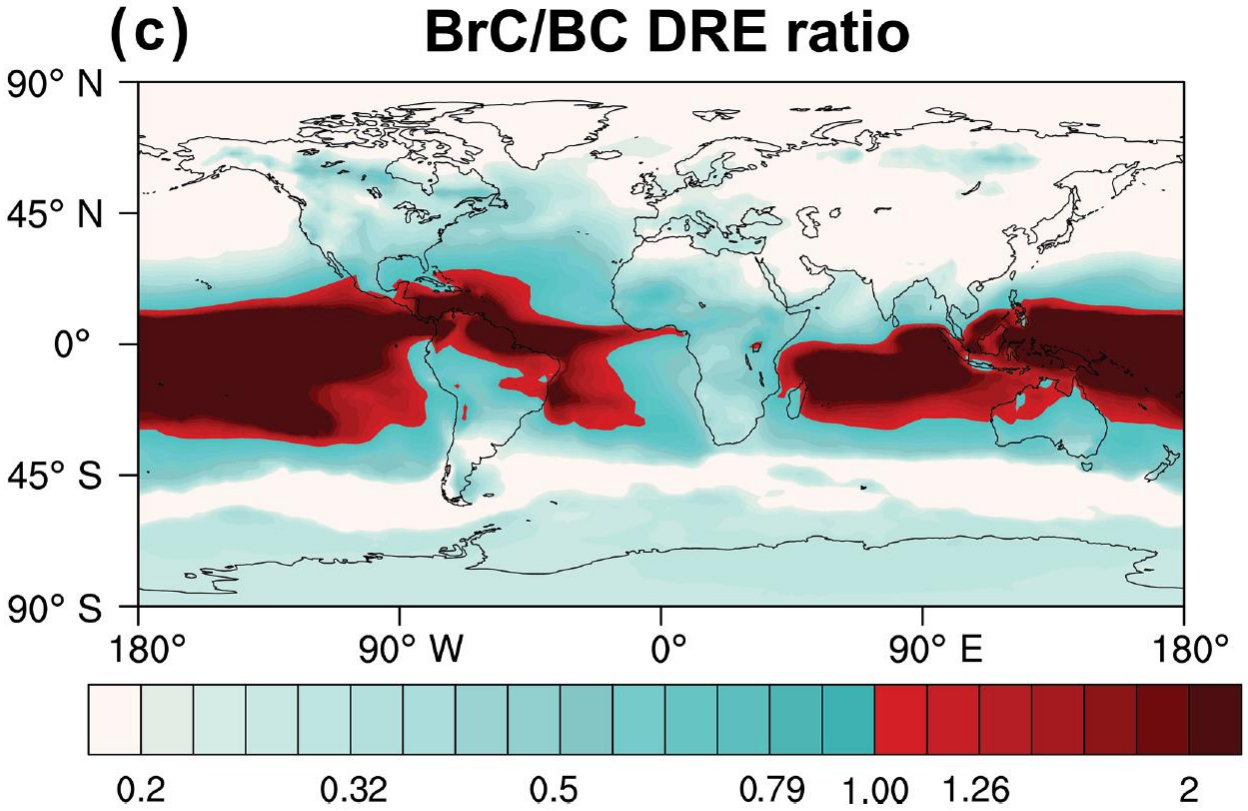
# Why do we care?


- Primary sources – Biomass Burning, Fossil Fuel, Biofuel
- Secondary sources – Aromatics, ELVOCS

*Wu et al., Advances in Climate Change Research, 2016*

# Motivation & Aim

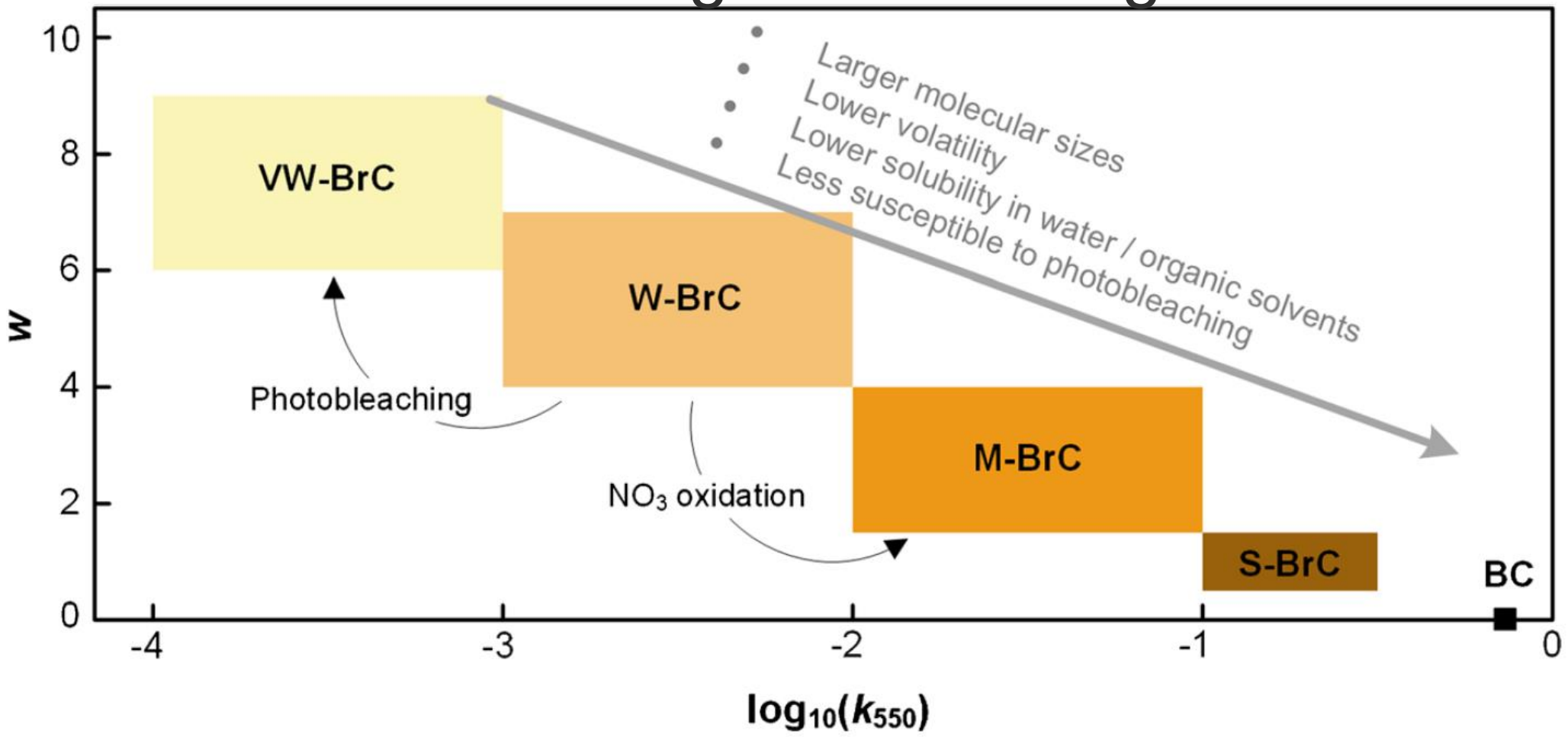
- First estimate of BrC impact on DRE
→ BrC is potentially very important




*Zhang et al., Atmospheric Chemistry and Physics, 2020*

- Improve the representation of absorbing aerosols in ESMs
- Explicitly account for BrC in ESMs
- Better understand the contribution of BrC in radiative forcing

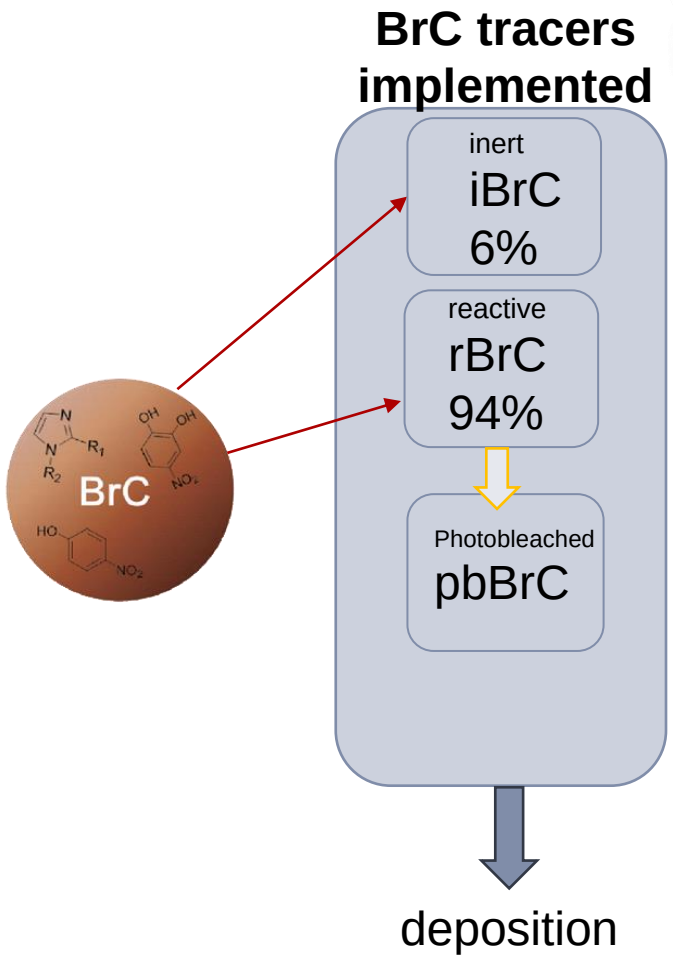
# BrC types & transformations in the atmosphere
## Bleaching and browning




*Saleh, Current Pollution Reports, 2020*

# An ESM modeling approach

- Chemistry (mCB05) (*Williams et al. 2017*)
- M7 aerosol microphysics (*Vignati et al. 2004*)
- Aerosol Optical Properties based on Mie Theory (*van Noije et al. 2014*)
- Emissions
  - Anthropogenic – Biomass Burning CMIP6 (*Eyring et al. 2016*)




*Photobleaching*
rbrc → pbbrc
$k = 4.8 \cdot 10^{-11}\ [OH] s^{-1}$
based on 0.24d by
*Fang et al., npj Climate and Atmospheric Science (2023)*

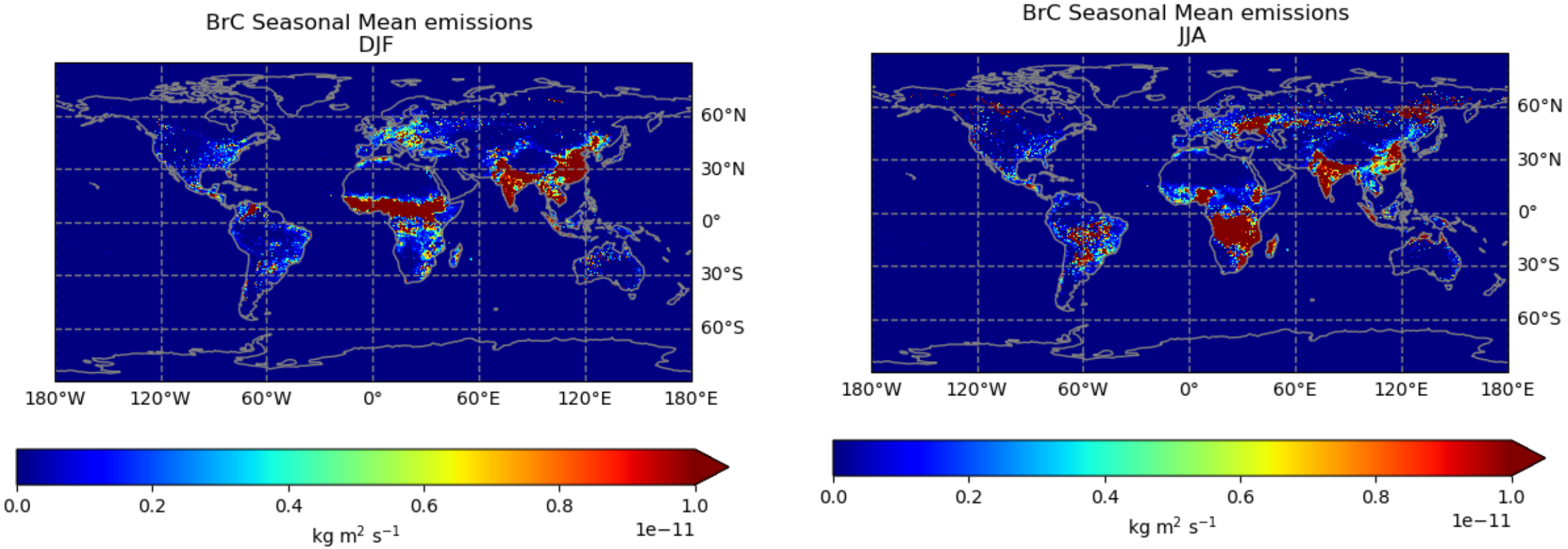
All species in accumulation soluble mode
Not included in M7

# BrC emissions

- Parameterization used by Zhang et al. 2020 based on parameterizations by Saleh et al., 2014 and Liu et al., 2013
- Emissions in equivalent to absorption mass

$$K_{OA,550} = 0.016 log_{10}\left(\frac{E_{BC}}{E_{OA}}\right) + 0.03925$$

$$E_{BrC} = \left(\frac{4\pi \mathrm{K_{OA,550}}}{\rho\ 550nm\ MAE_{BrC}(550nm)}\right) \mathrm{E_{OA}}$$



# Optical properties

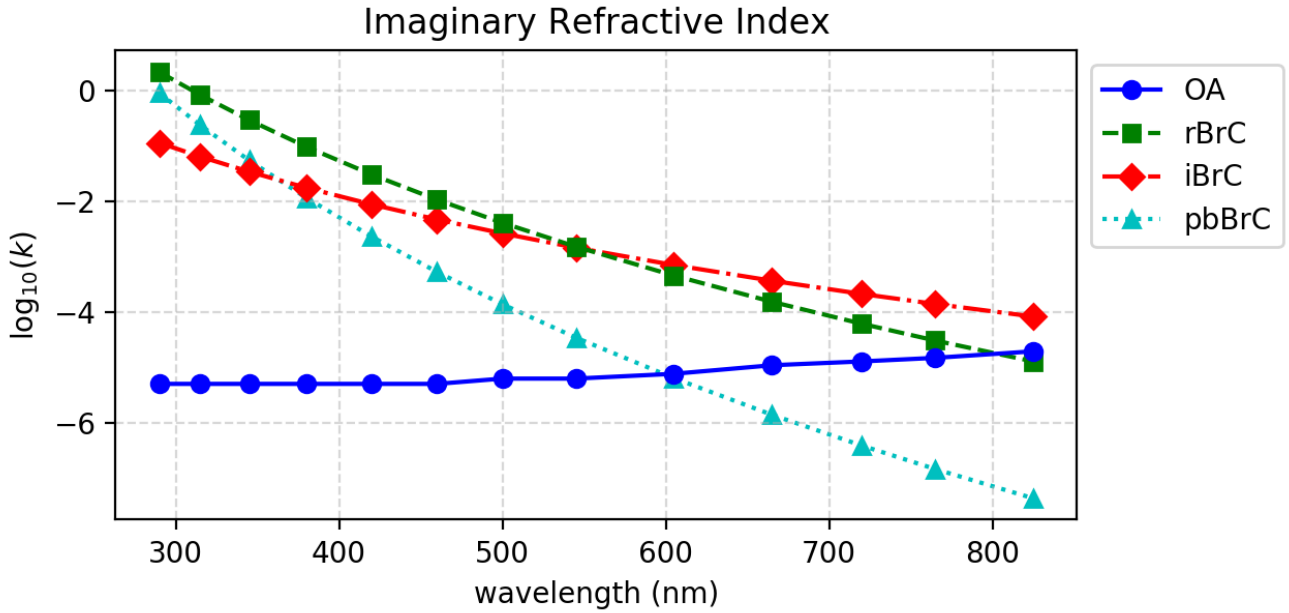
Calculation of the imaginary part of the refractive index for BrC based on the work by Zhang et al. 2020

$$k_{BrC,\lambda} = \frac{\rho\ \lambda\ \mathrm{MAE}(\lambda)}{4\pi}$$

Calculation of k at 550nm

$$k_{BrC,\lambda} = k_{BrC,550}\left(\frac{550}{\lambda}\right)^{w}$$

For all the other wavelengths




$MAE_{BrC}$ = 1 $m^2\ g^{-1}$ at 550nm for rbrc and ibrc
$MAE_{BrC}$ = 0.19 $m^2\ g^{-1}$ at 550nm for pbbrc

OA are considered only scattering k = 0.0
BrC is considered only absorbing n = 1.0

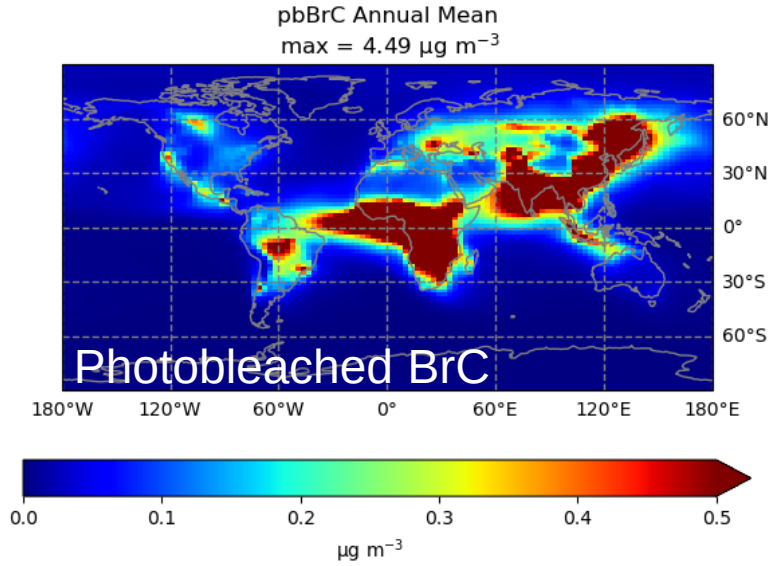
w = 3 for iBrC
w = 5 for rBrC
w = 7 for pbBrC

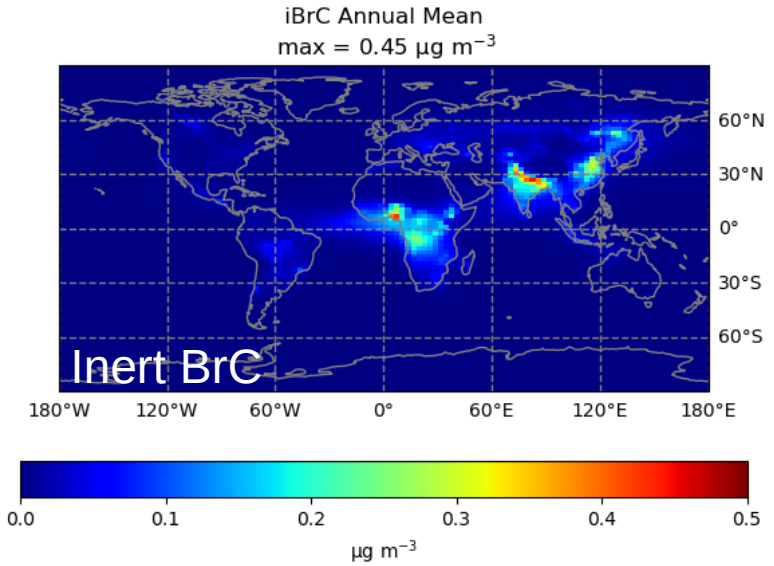
Based on Saleh 2020

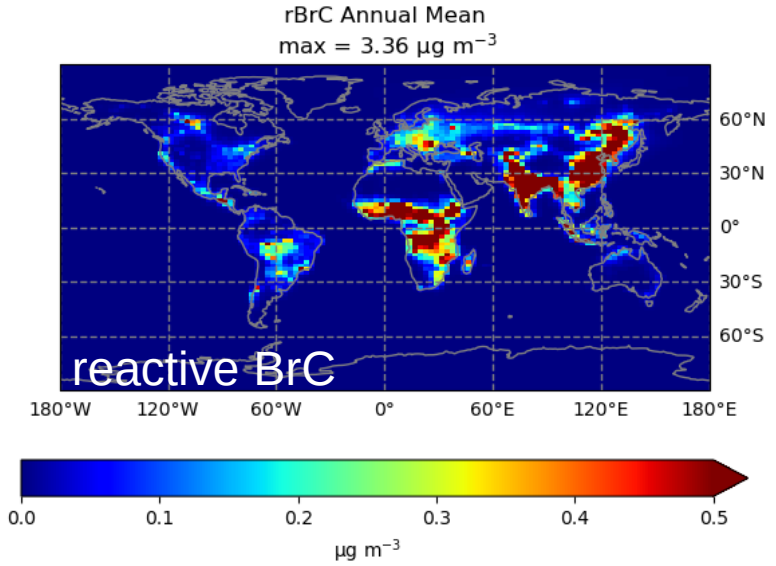
Aerosols Internally mixed

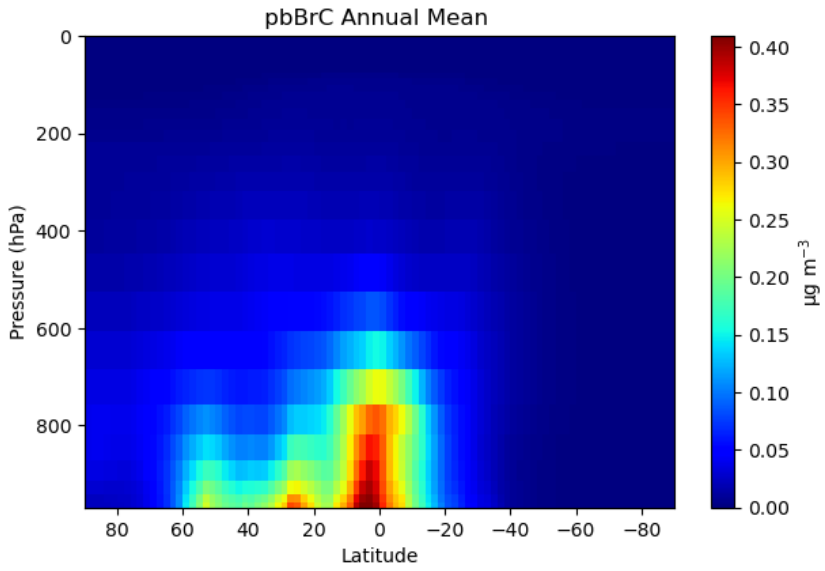
Refractive indices and component contribution volume weighted

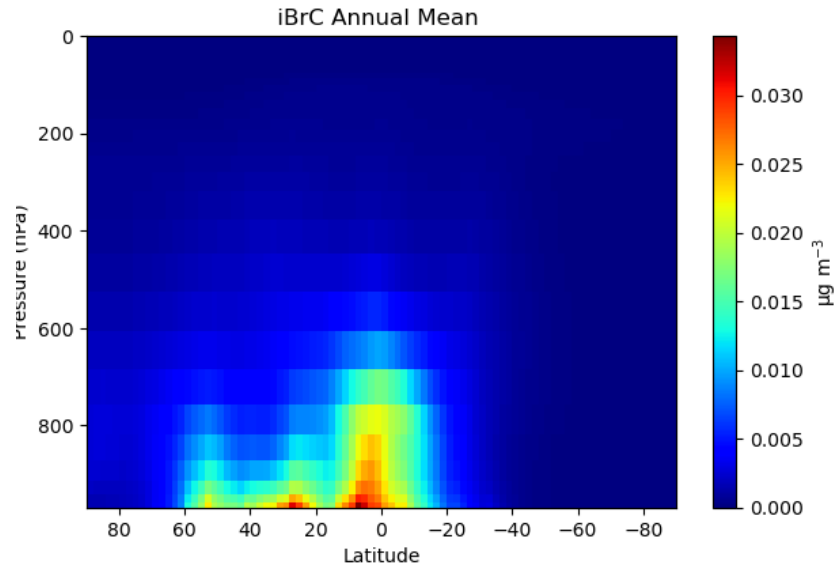
# BrC Distribution

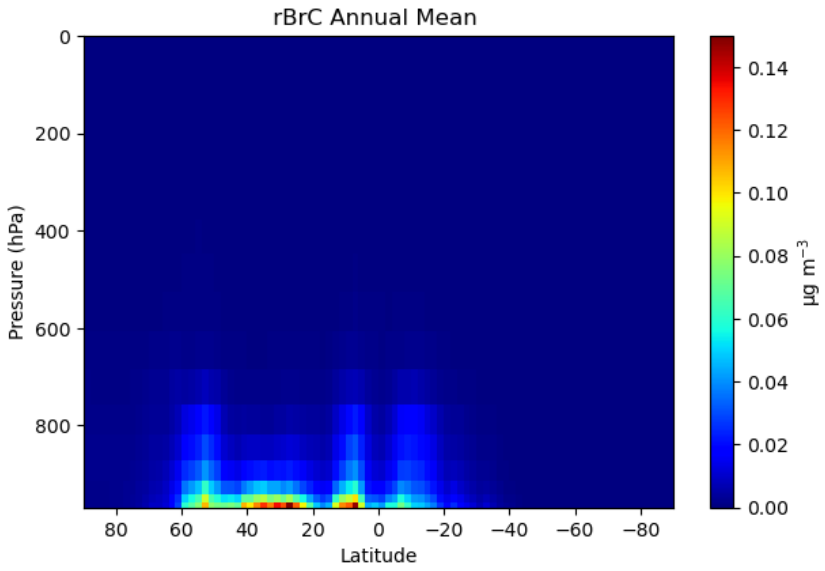


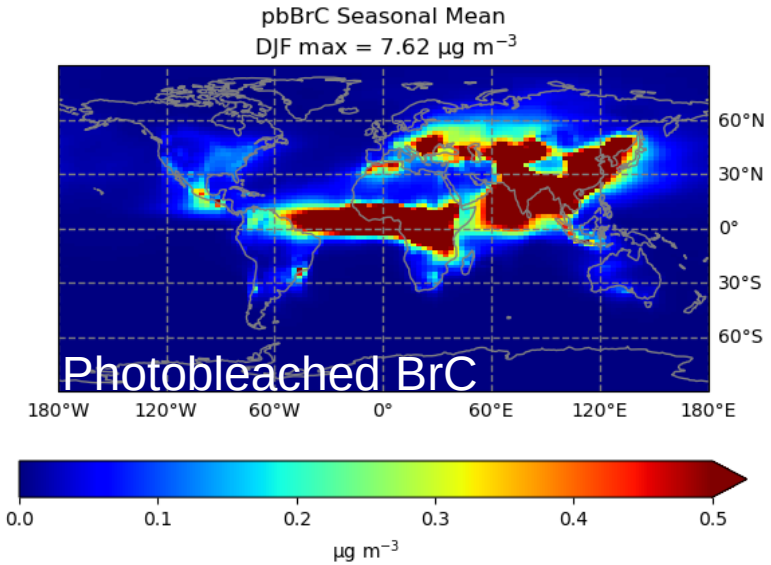



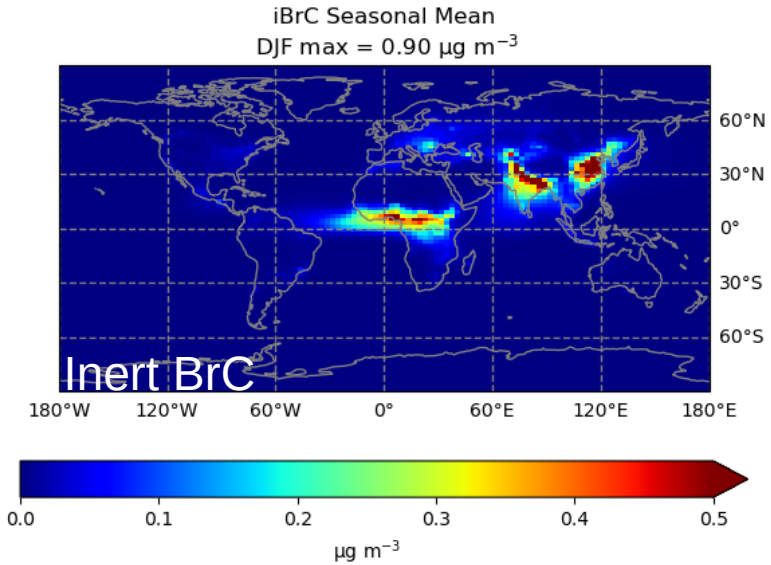



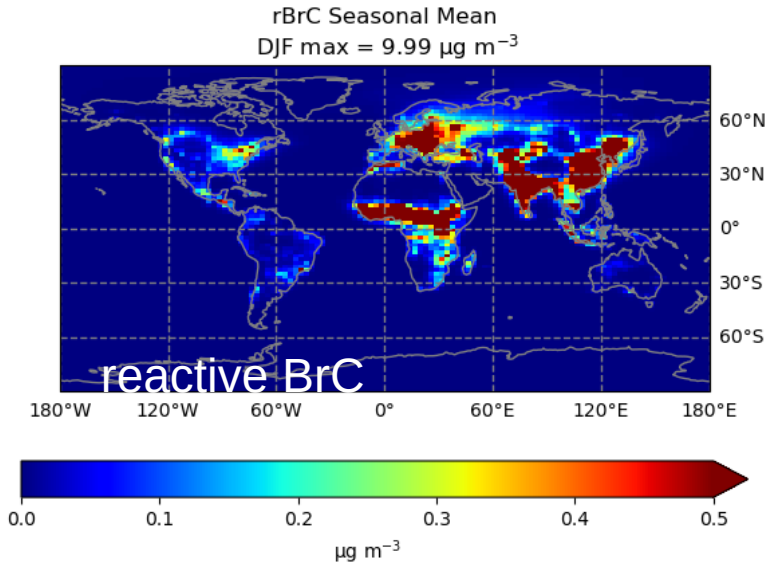



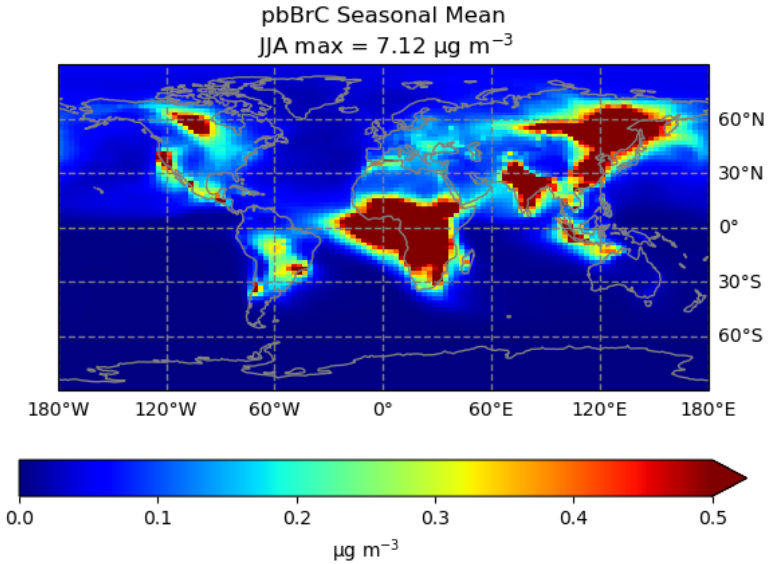



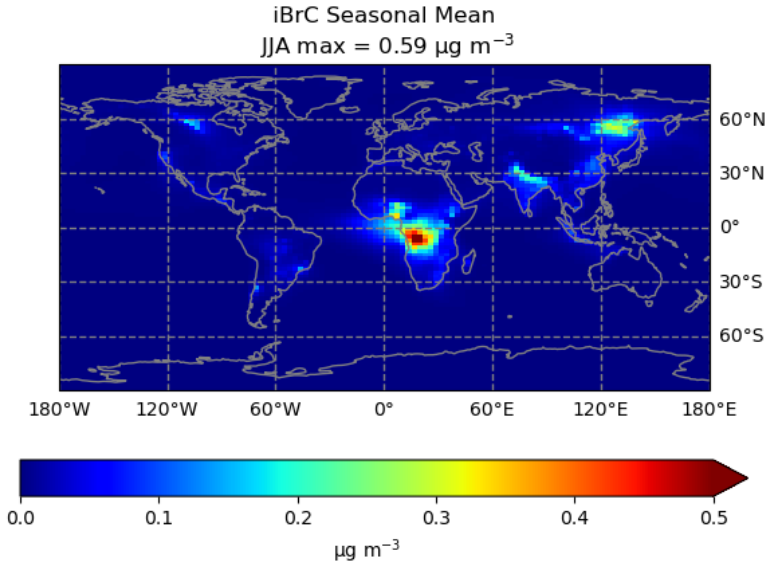
# BrC Distribution

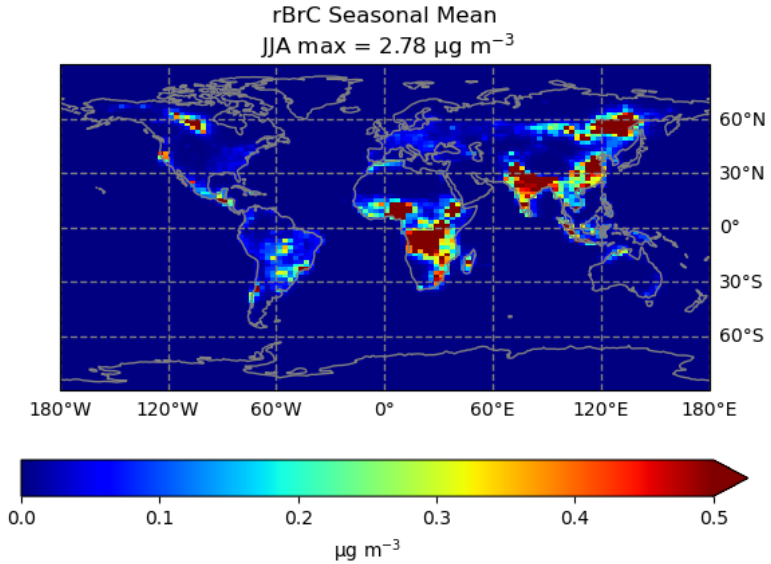


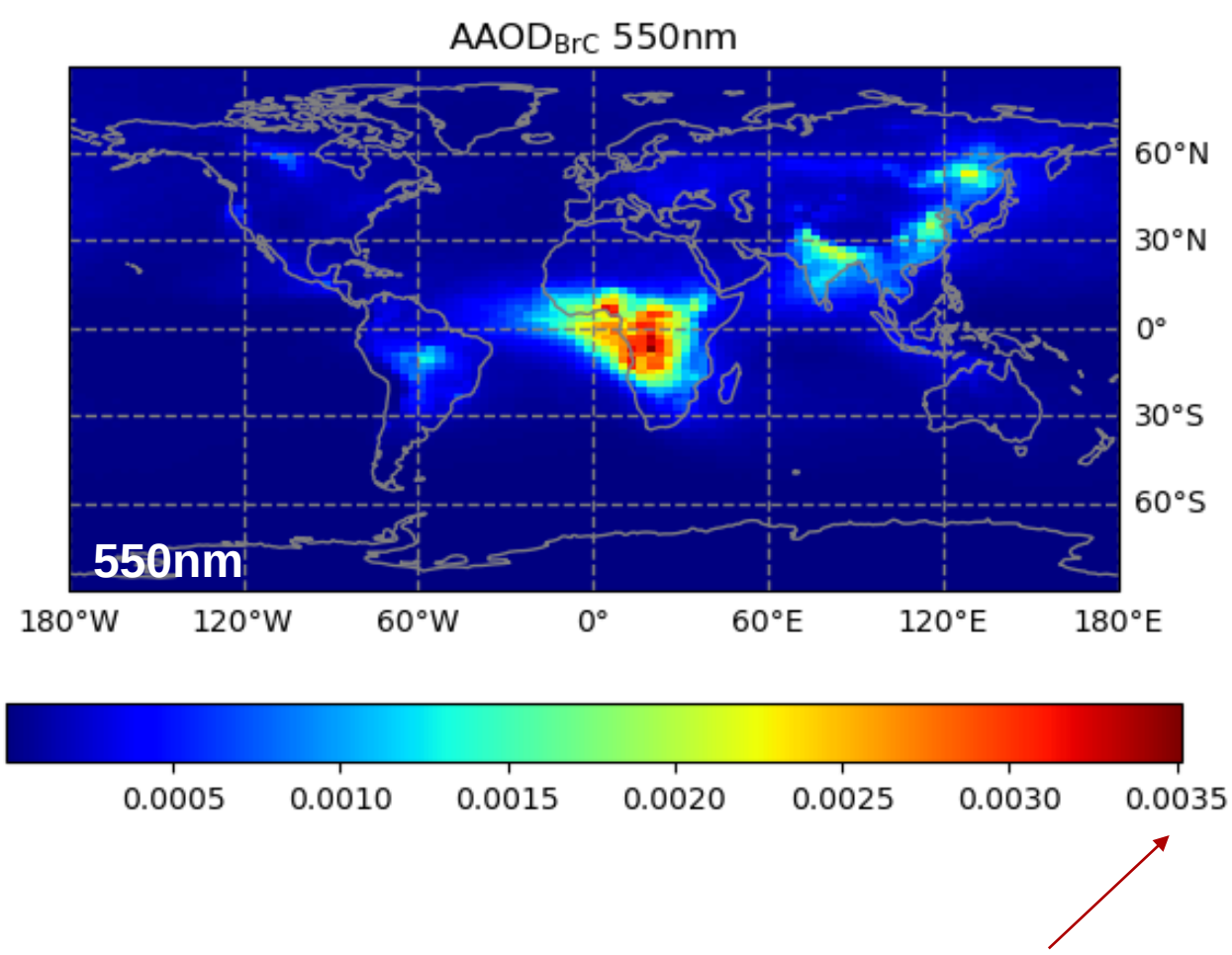



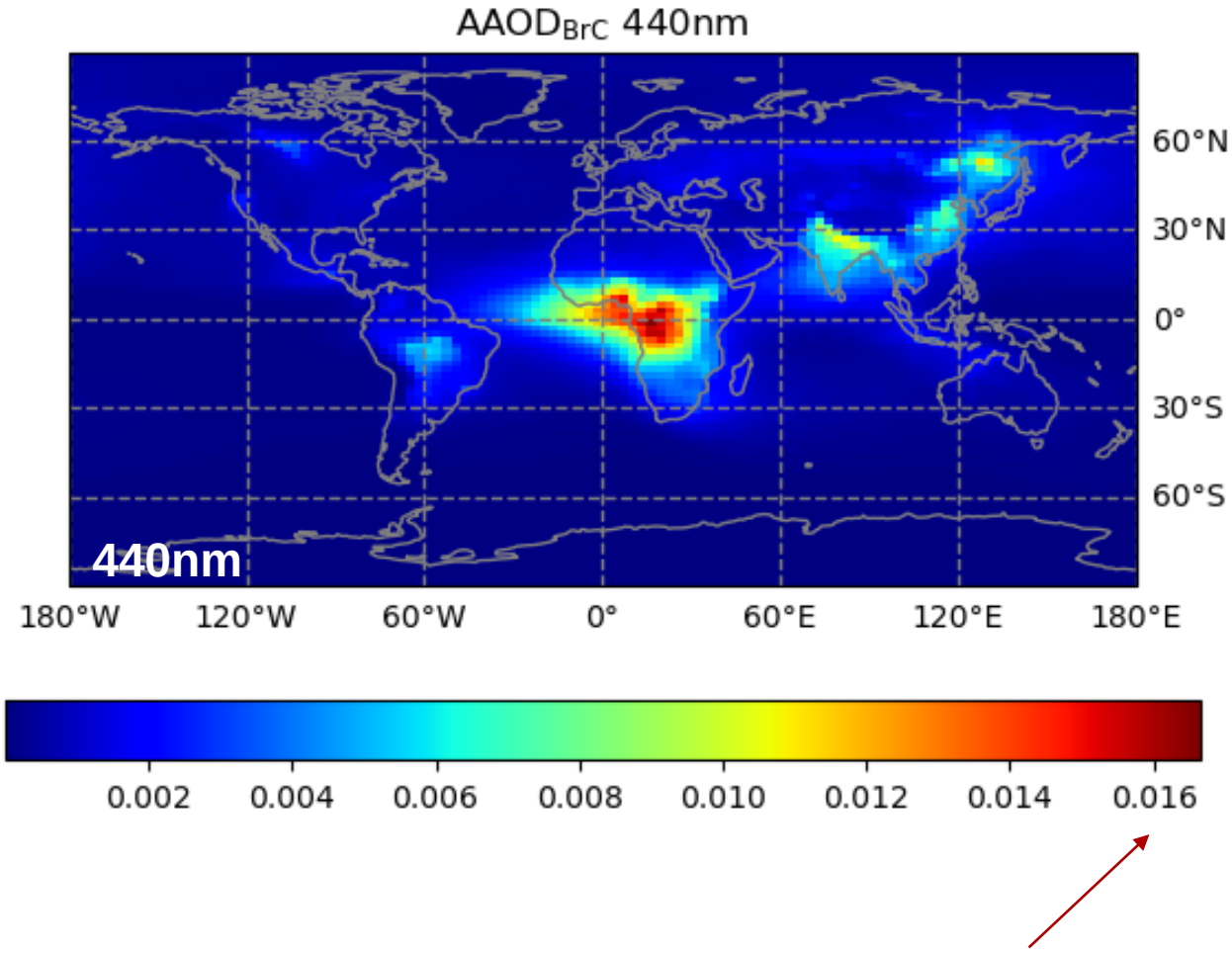



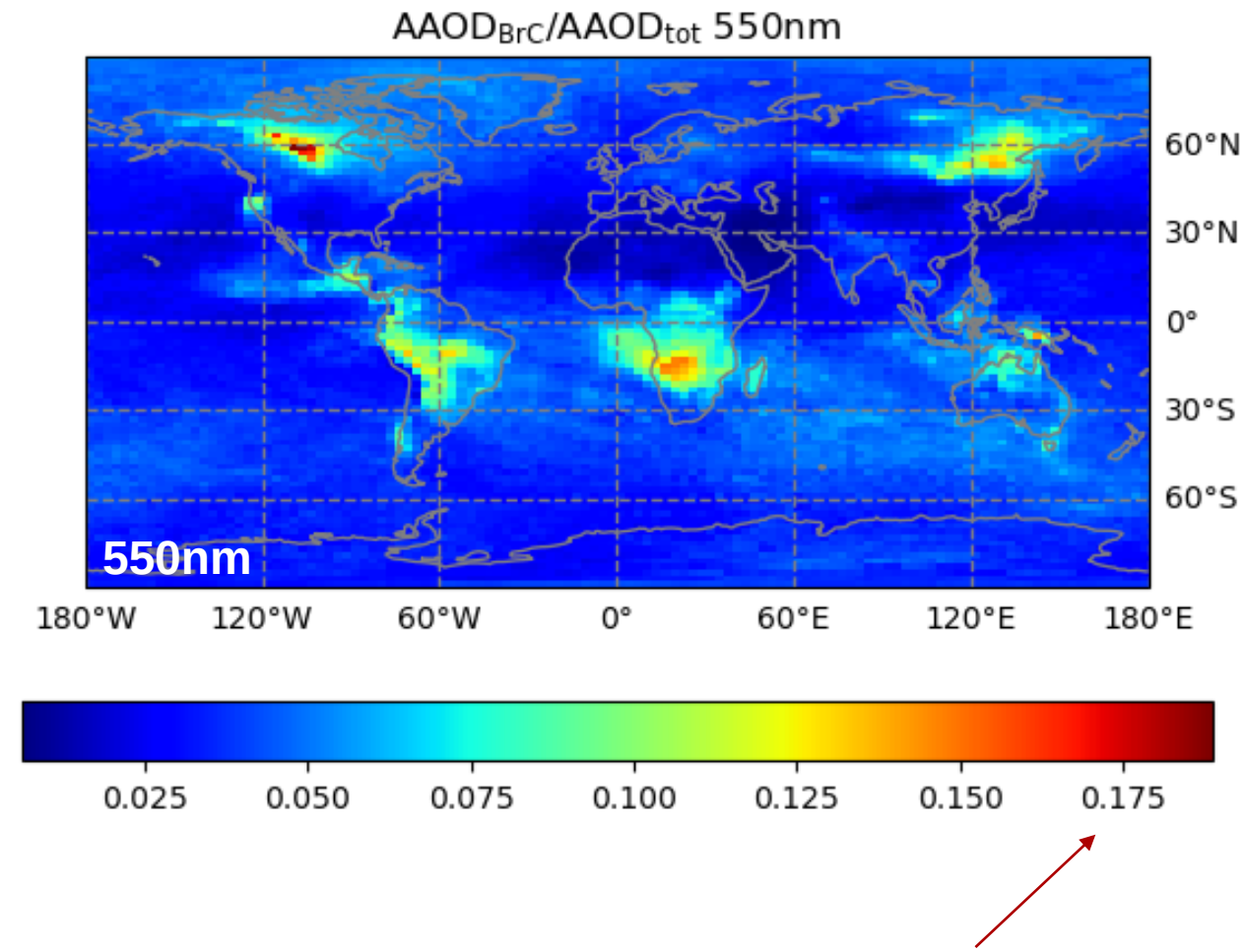
# BrC Absorption

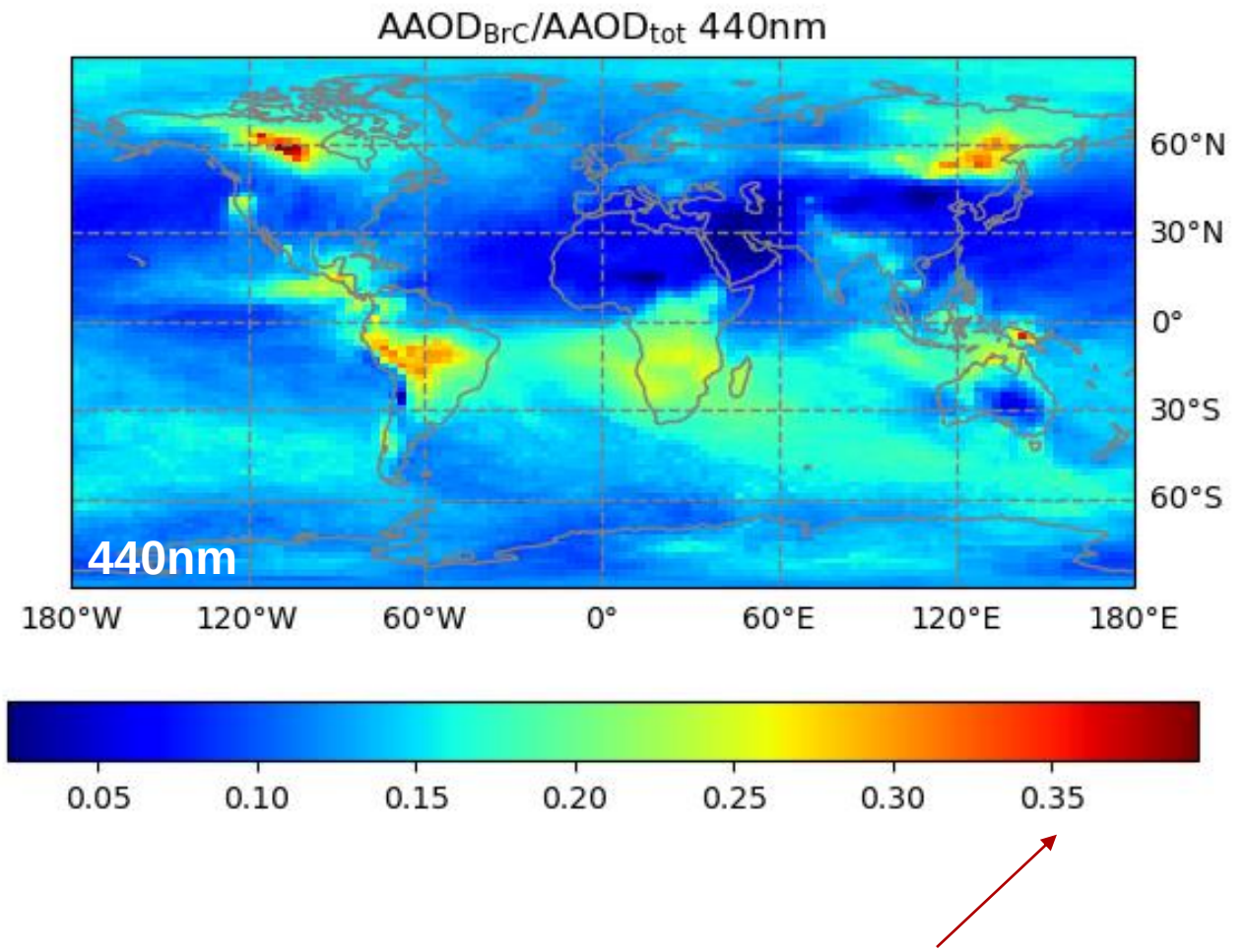



$$AAOD_{BrC} = AAOD_{tot} - AAOD_{(tot\text{-}BrC)}$$

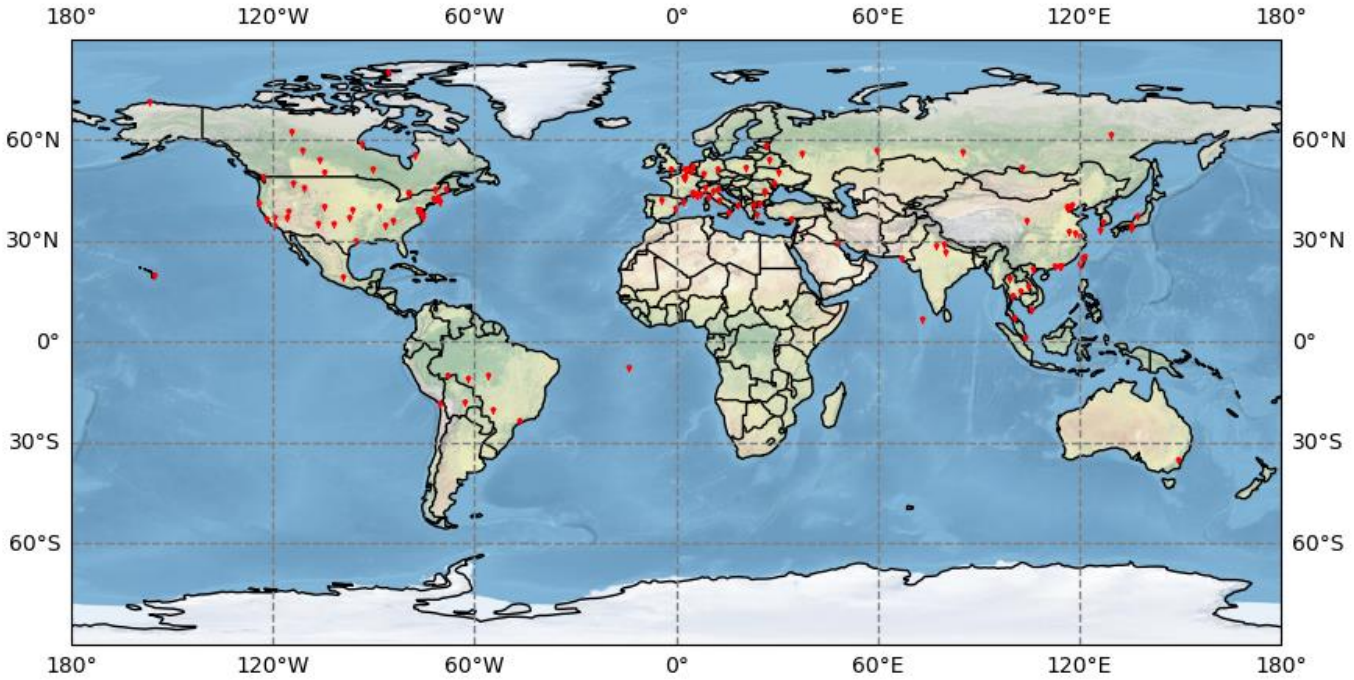
# BrC Absorption



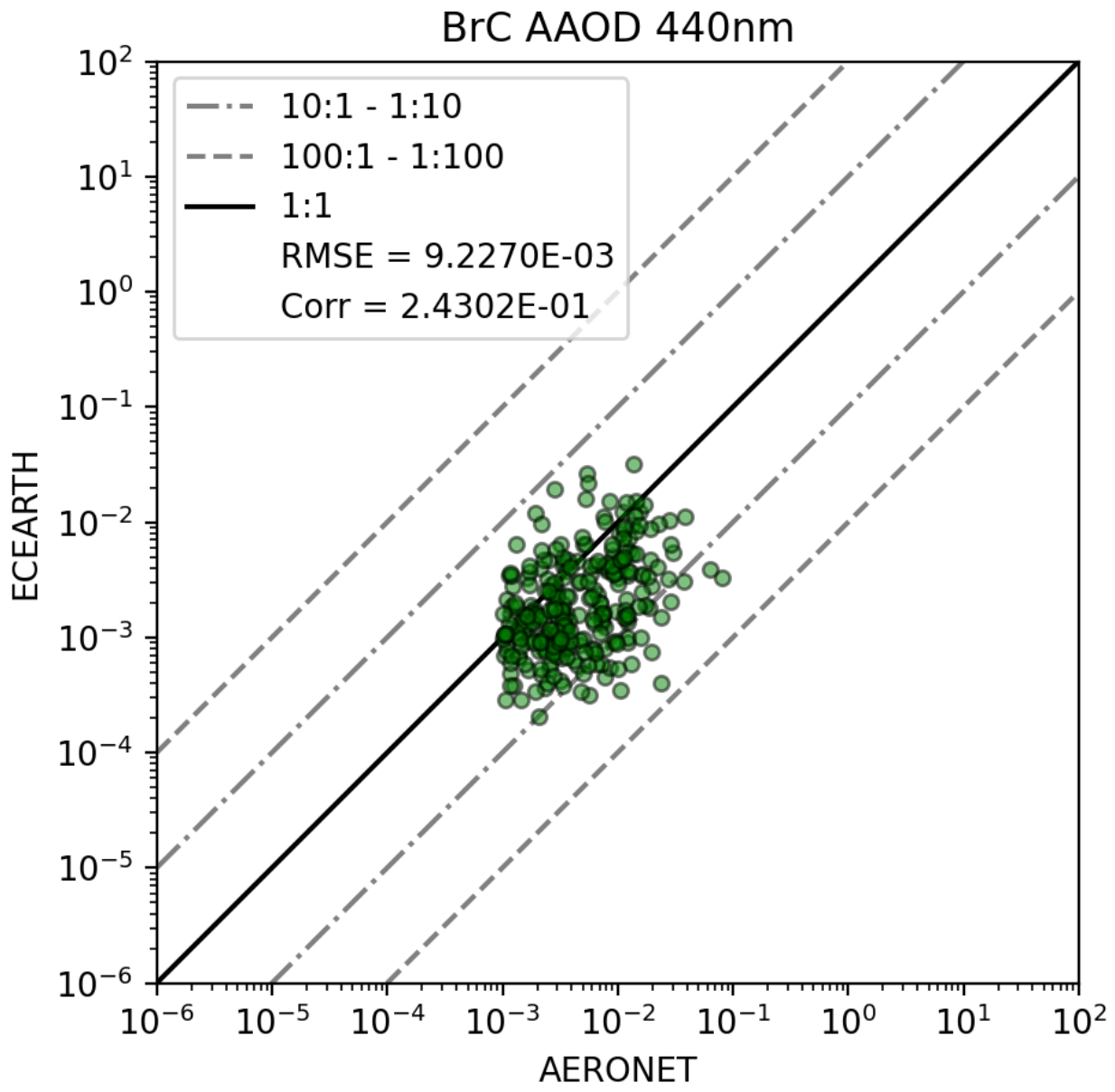
# AERONET Data for model evaluation

- Filters applied (methodology by Bahadur et al. 2012 & Wang et al. 2018)
  - Remove coarse mode AOD at 440nm (coarse mode AOD contribution to total AOD > 10%
  - Remove values with $EAE_{440/675} < 1$
  - Remove values with $SAE_{440/675} > 1.2$ and $AAE_{675/870} / AAE_{440/675} < 0.8$




126 stations

# Model evaluation



# Summary

- Three different species have been successfully implemented in the model
- The model underestimates the BrC AAOD against AERONET measurements
- Tests ongoing (optical properties, photobleaching)

# Further steps

- 10 year simulation 2010-2020 with climatological SST and Sea Ice for BrC ERF
- Collaboration with FMI (Harri Kokkola, Tero Mielonen) for the implementation of BrC in EC-Earth 4 (OpenIFS)