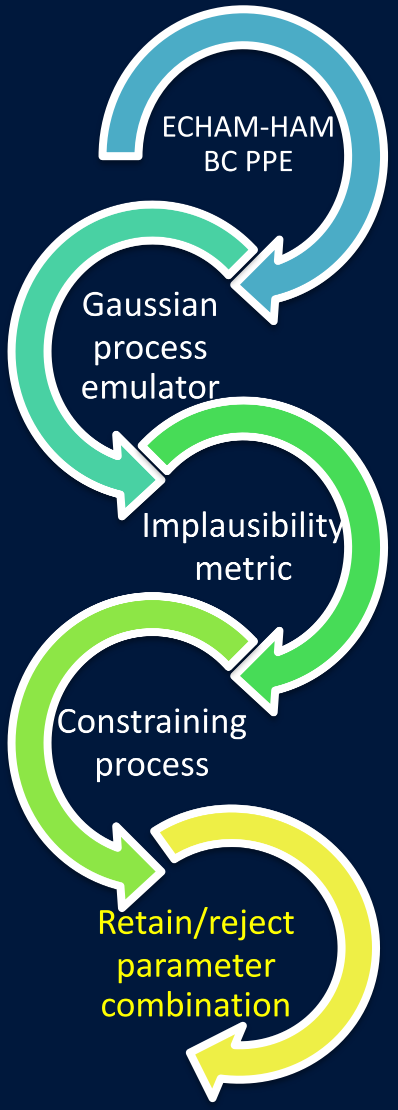

Constraining direct aerosol radiative forcing using remote sensing and in-situ constraints

Lucia Deaconu[1], Duncan Watson-Parris[1], Philip Stier[1], Lindsay Lee[2]

Motivation: the present day lack of good constraints on aerosol absorption can significantly affect the estimates of aerosol climate impact.

Objective: Comprehensively sample uncertainty within a single model and challenge that uncertainty with multiple observation types.

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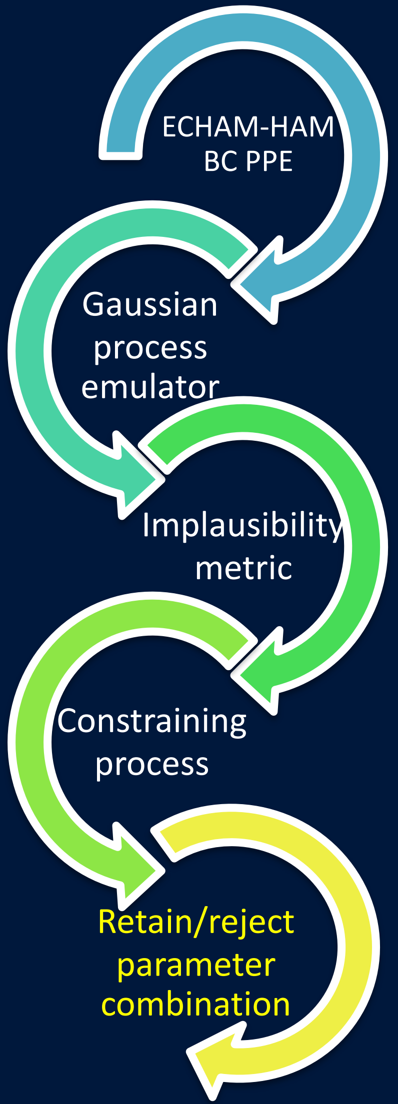
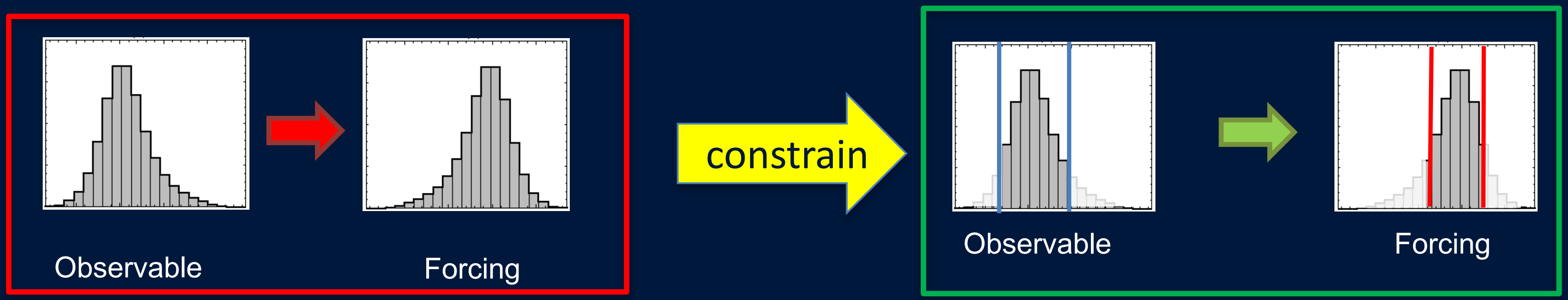


Initial model variant and aerosol forcing

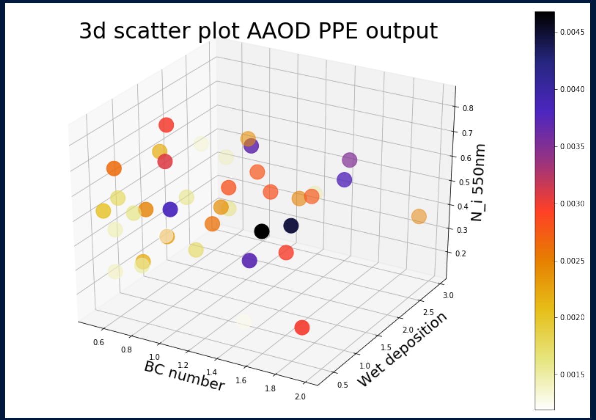
Constrained model variant and aerosol forcing



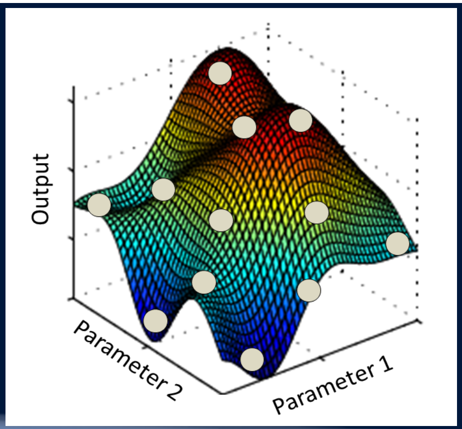
Methodology

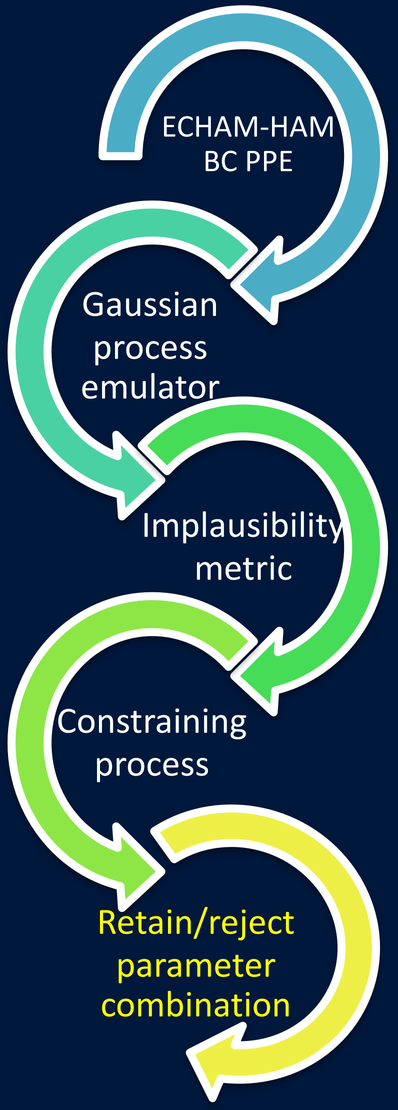
1. Build the Perturbed Parameter Ensemble (PPE):
Latin Hypercube sampling => parameter combination design

- 3 perturbed parameters: Black carbon emissions, Black carbon imaginary part of RI and Wet Deposition
- 39 year-long model runs: 26 training, 13 validation (years 2017 and 1850) + spin-up



2. Gaussian process emulator - Emulate 1 million points
Map the relationship between a set of uncertain inputs (3 parameters) and a model output of interest





3. Implausibility metric
* Calculated for each set of observations

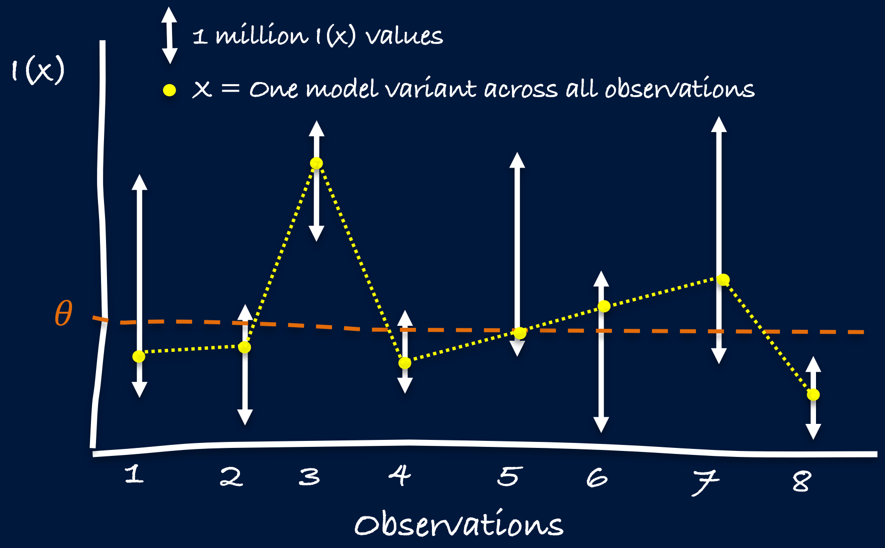
$$I(\boldsymbol{x}) = \frac{|z - E[\eta(\boldsymbol{x})]|}{\sqrt{[Var(\phi(\boldsymbol{x})) + Var(\epsilon) + Var(\delta)]}}$$

Observation
Model output
[Prediction from emulator]
Emulator prediction uncertainty
Observational uncertainty
Structural uncertainty

(Johnson et al., 2019 ACPD)

4. Calculate tolerance and threshold

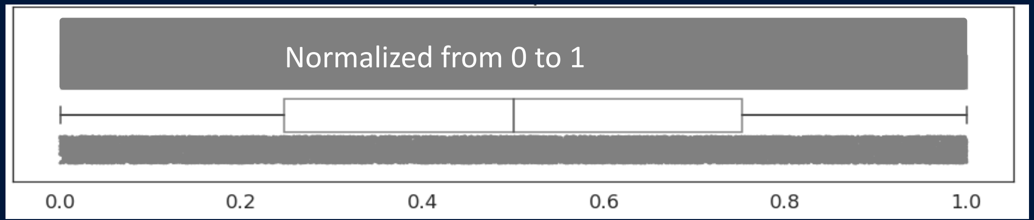
- **Threshold (T)** = the limit value of *I(x)* allowed
- **Tolerance (θ)** = the % of observations allowed over the threshold (usually max 10%)



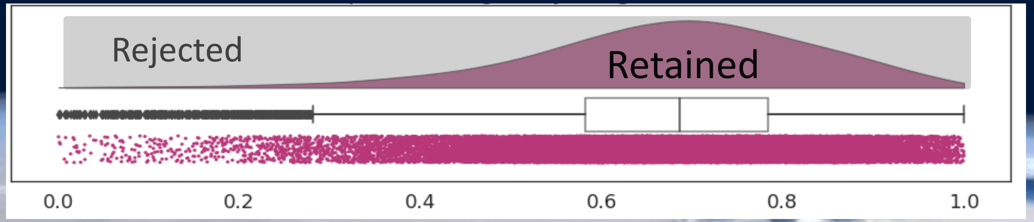
From the combination of **T** and **θ** build a **density functions** of each constrained parameter, normalized from 0 to 1 for the entire observation sample (global or regional constraint)

5. Constrain the parameter space

Unconstrained parameter PDF



Constrained parameter PDF



(Watson-Parris et al., in preparation)

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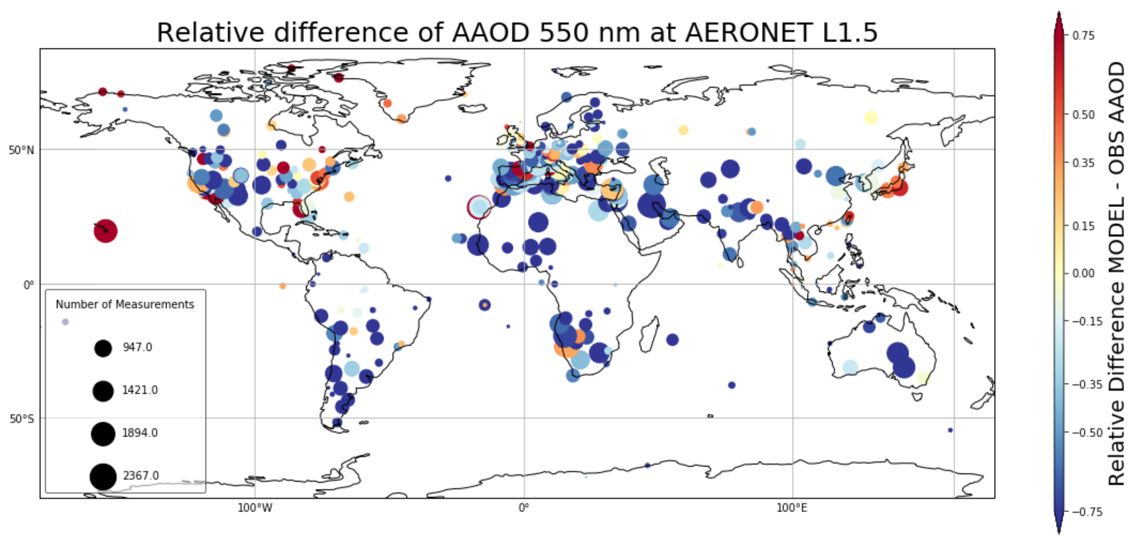
AERONET AAOD constraints

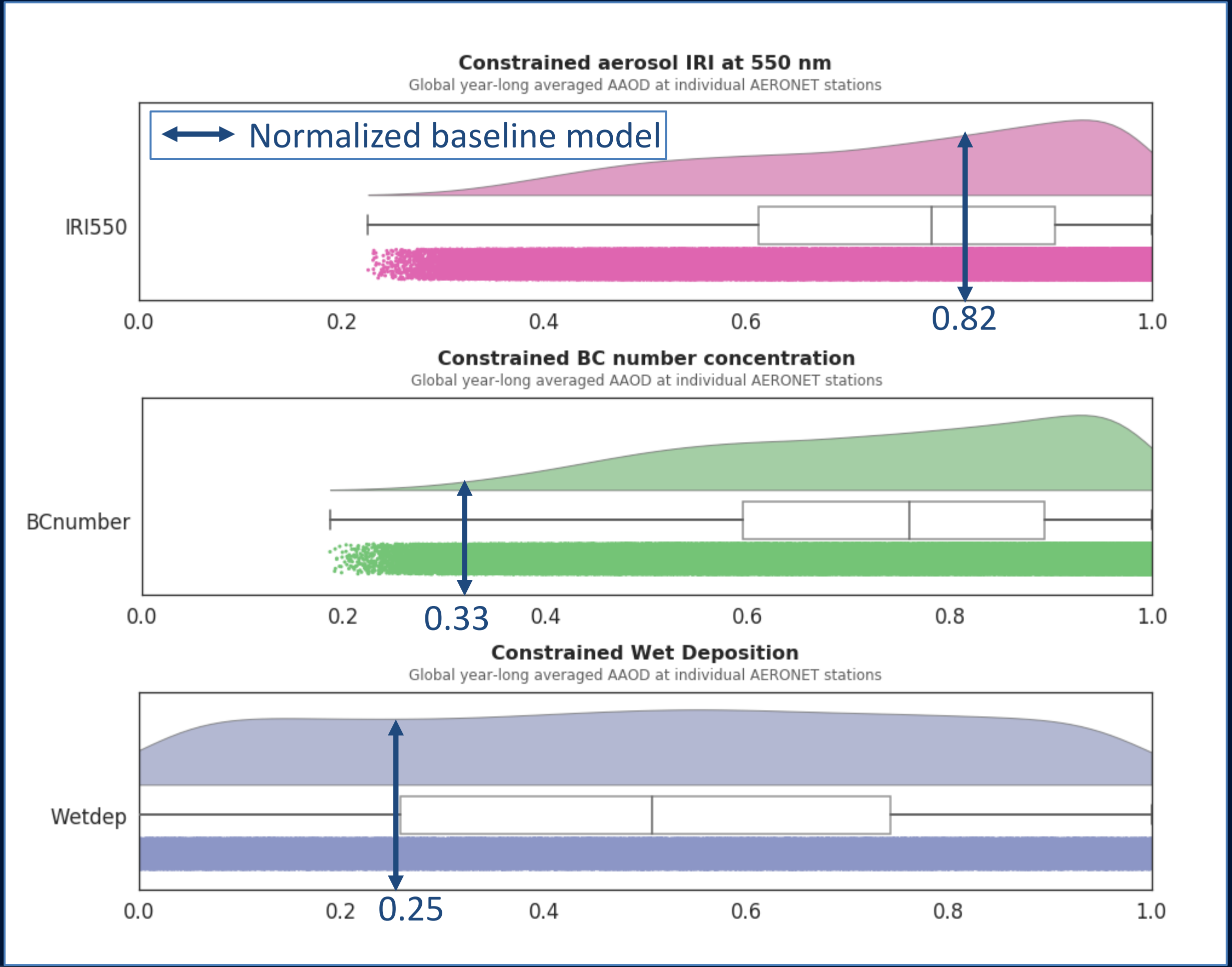
Year-long averaged relative difference between collocated 3 hourly PPE AAOD and observations at individual AERONET stations



There is large variability between the BC PPE averaged AAOD and the AERONET measured AAOD

AAOD – absorbing aerosol optical depth

Applying the AERONET AAOD as global constraint on collocated 3 hourly BC PPE AAOD leads to constrained BC emissions and BC imaginary part of RI. The wet deposition parameter space remains unconstrained.



(Deaconu et al., in preparation)

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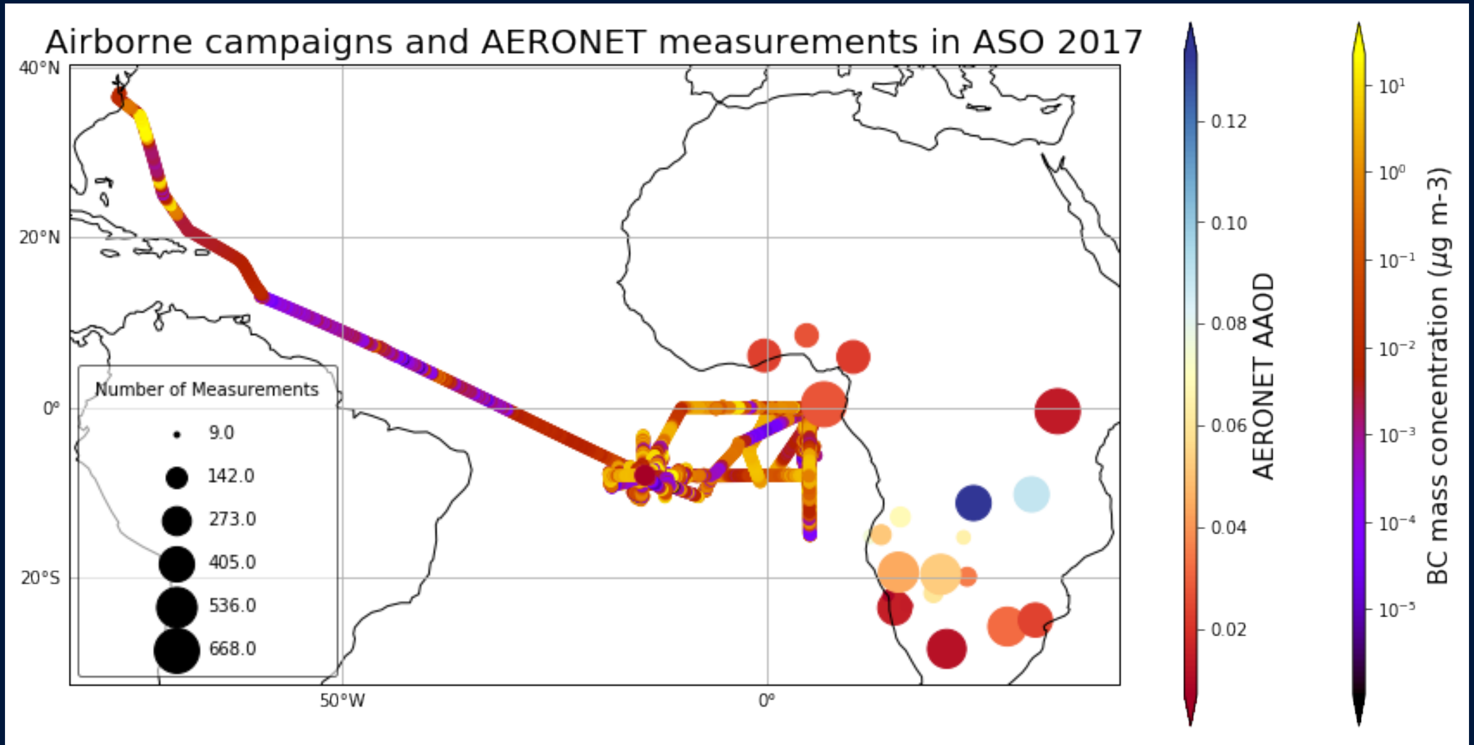
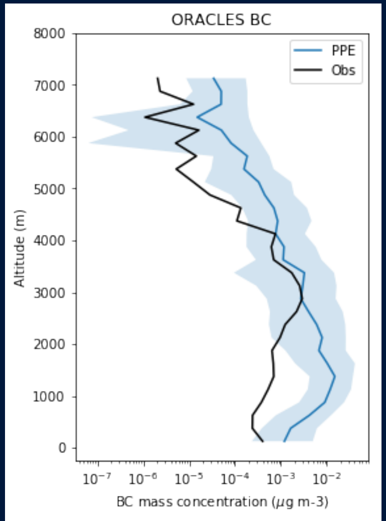
Flight track BC mass concentration and AERONET AAOD measurements in 2017

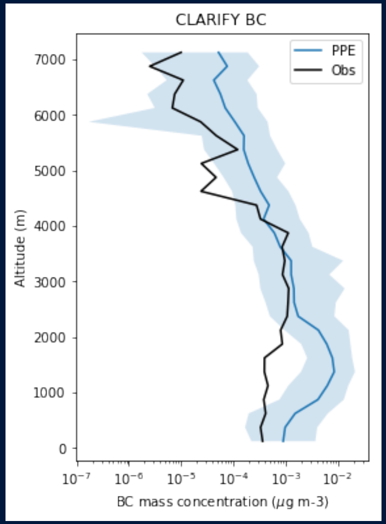
(August-October)

Lines –Airborne campaigns in 2017: ORACLES, CLARIFY-2017 in South Atlantic
Bubbles - AERONET measurements in South Africa



Spread in the PPE BC mass concentration vs. BC measurements



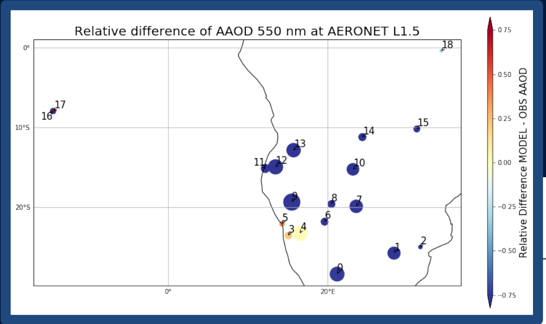


Ground-based measurements are expected to constrain the BC emissions and optical properties, while airborne BC measurements and satellite remote sensing could be useful in constraining the removal processes

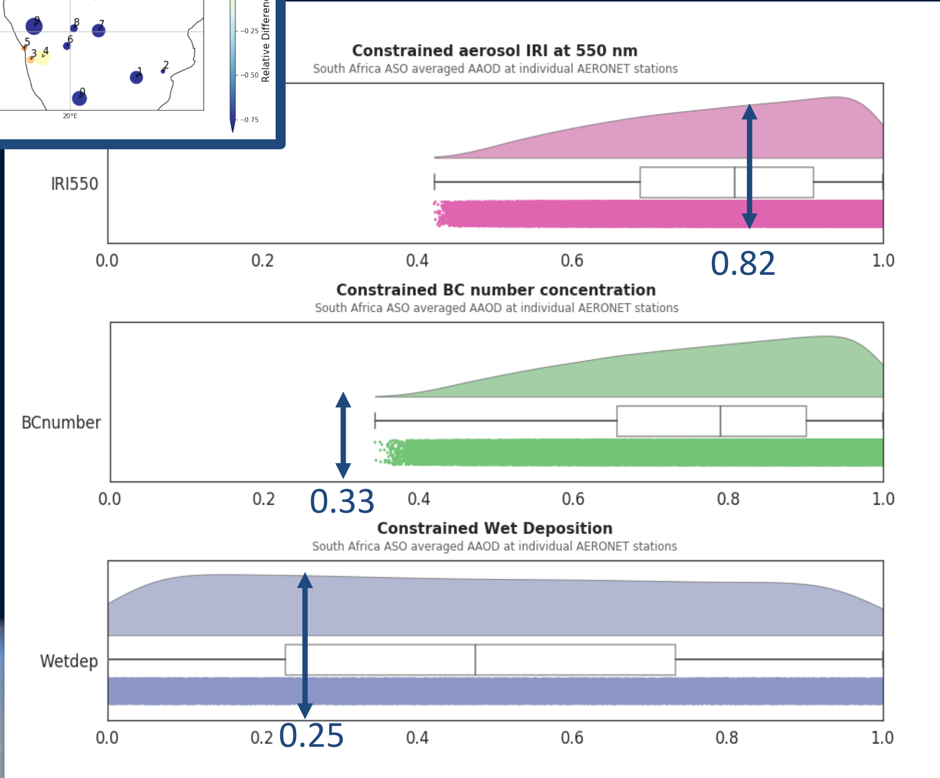
(Deaconu et al., in preparation)

AERONET AAOD constraints

Applying the AERONET AAOD as regional constraint on collocated 3 hourly BC PPE AAOD leads to strongly constrained BC emissions and BC imaginary part of RI towards larger values. The wet deposition parameter space remains unconstrained.



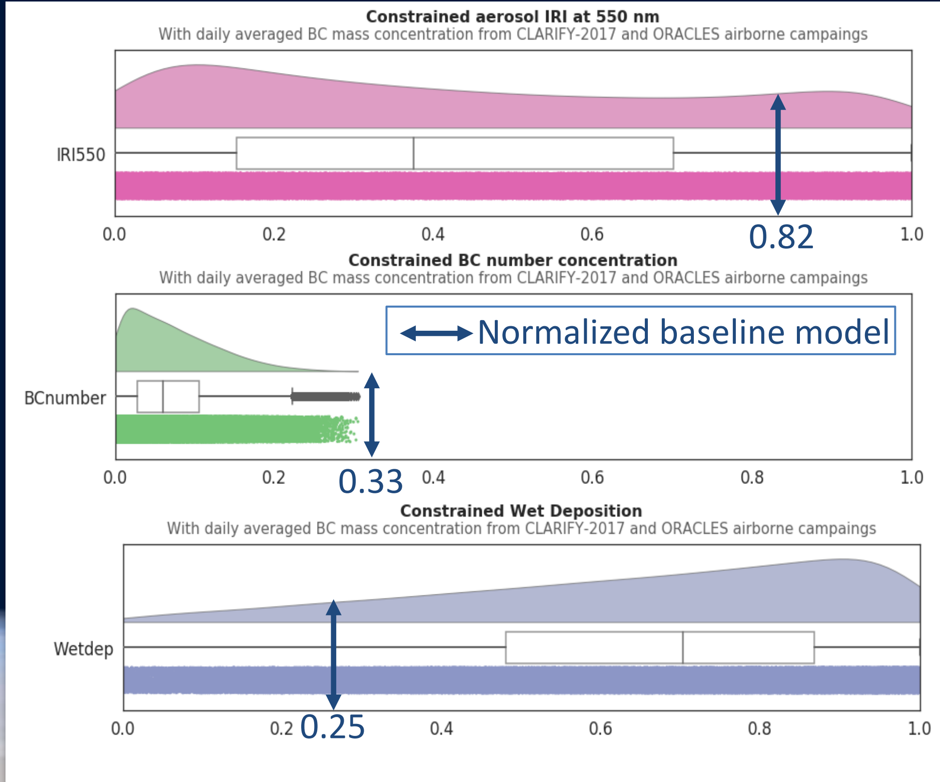
Seasonal (August-October 2017) averaged relative difference between 3 hourly PPE AAOD and observations at individual AERONET stations



Flight track BC mass conc. constraints

The BC mass concentration measured during CLARIFY and ORACLES campaigns constrains strongly the BC emissions – however on the lower end of the parameter space (towards small values). It remains something we need to understand.

The Wet Deposition is also quite well constrained (which was expected).



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Discussions & conclusions

- We use a PPE and a gaussian process emulator to constrain 3 uncertain parameters (BC emission, BC imaginary part of RI – BC IRI, and Wet Deposition) with ground-based observations (AERONET AAOD) and in-situ measurements from airborne campaigns (ORACLES and CLARIFY-2017)
- We present the constrain methodology and preliminary results:
  - The year-long global collocated AERONET AAOD and model output AAOD constrains the BC emissions and BC IRI.
  - The seasonal (ASO) and regional constrains over South Atlantic and South Africa show differences, depending on the measurement used. The ground-based AAOD constrains the BC emissions and BC IRI towards large values (suggesting an underestimation of the emissions at source in the PPE), while the BC mass concentration measured in-situ constrains the BC number to lower values and the Wet Deposition to larger removal scales.
  - These differences could be linked to the particle size and BC lifetime, something that we still need to study.
- Outlook:
  - Use more airborne campaigns to constrain the long-distance transported BC (aged) as well as satellite retrievals of AAOD and aerosol burden.
  - Constrain the direct radiative forcing of BC