Investigation of global aerosol regimes from pre-industrial times to future

based global aerosol simulations and machine learning techniques

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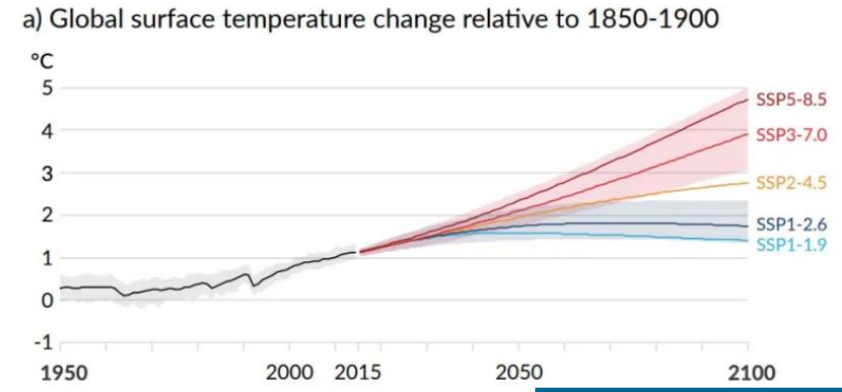
Road map

- Motivation
- Methods
  - Global aerosol simulations
  - Machine learning techniques
- Results: lower tropospheric case (surface – ~700 hPa)
  - Aerosol regime characteristics (primary scale)
  - Regime developments through time (primary scale)
  - Clean cluster sub-classification (secondary scale)
- Summary

Motivation: Understanding changes of aerosol large scale pattern

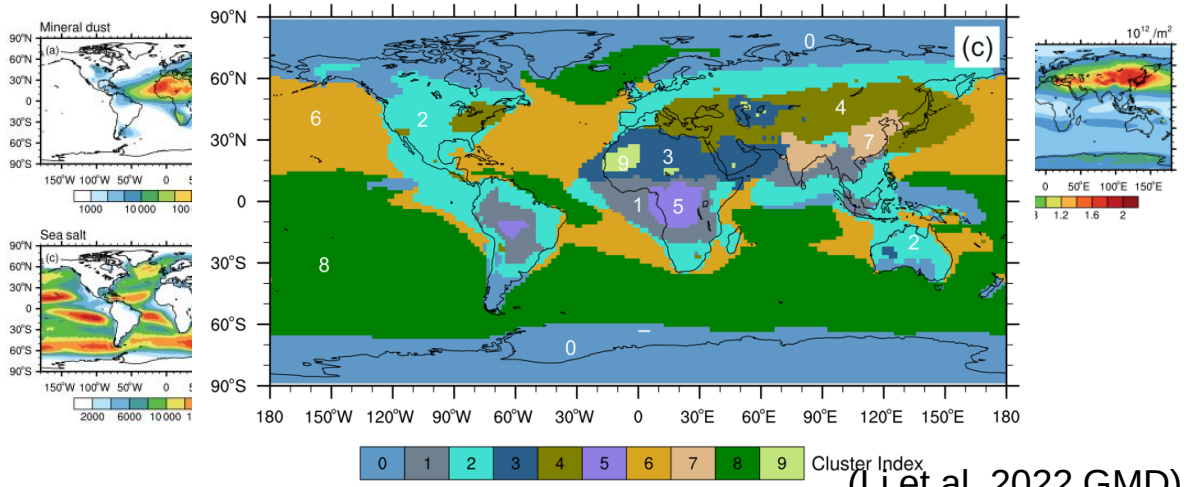


IPCC Sixth Assessment Report)

PI-1750 → PI-1850 → REF-2015 → 2050 - SSP3-7.0, 2050 - SSP2-4.5, 2050 - SSP1-1.9

Scientific questions

- How to derive aerosol regimes based on different aerosol properties?
- How aerosol clusters develop through times?
- How emissions drive the evolution in clusters?

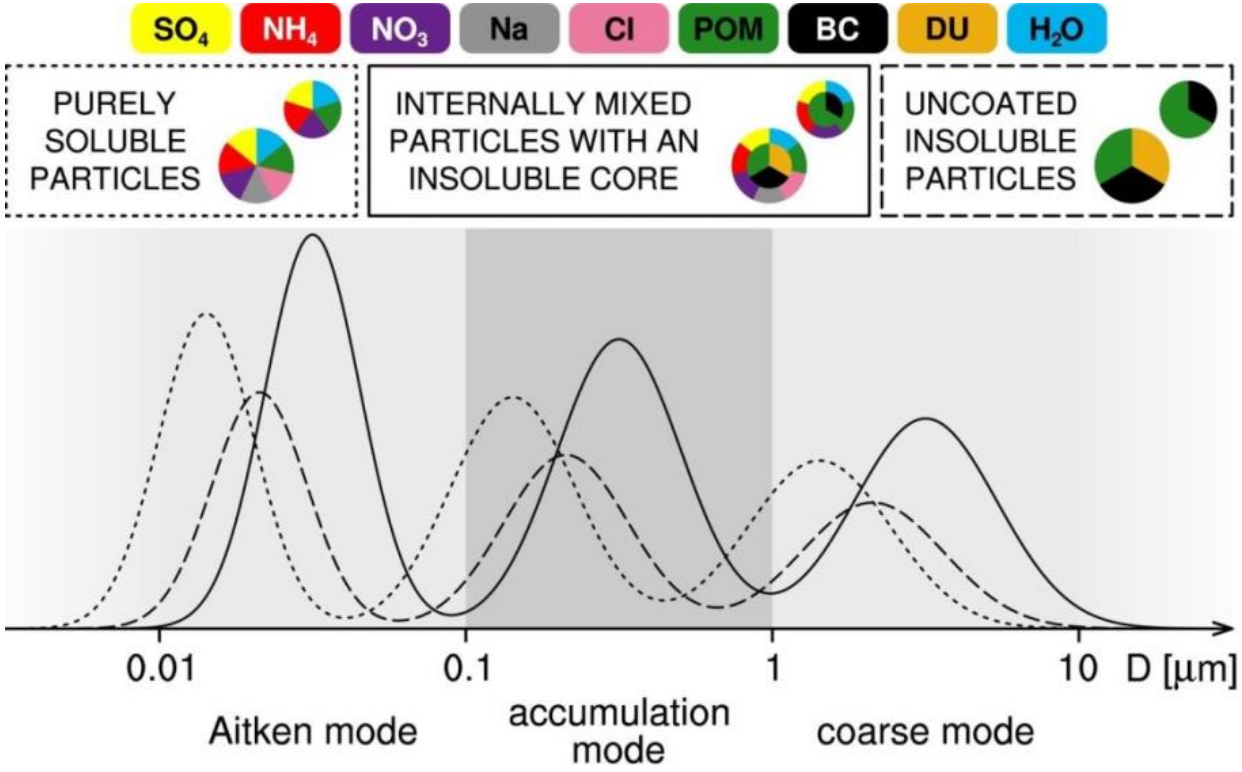


(Li et al. 2022 GMD)

Methods: Global aerosol simulations

Model : EMAC-MADE3

- ECHAM/MESSy (Jöckel et al., 2010, 2016)
- Equipped with the aerosol microphysical sub- module MADE3 (Kaiser et al., 2014, 2019)



Considered aerosol properties

Climatological (Multi-year mean)

Mass concentration (5 species):

BC, Mineral dust, POM, sea salt,

and SAN (sum of sulfate, nitrate and ammonium)

Number concentration (2 modes):

Aitken mode and accumulation mode

Model setups (Righi et al. 2023)

- Resolution: T42L41
- Emission data: CMIP6 for different time slices
- Nudging data: ERA-Interim
- Simulation period: 15 years

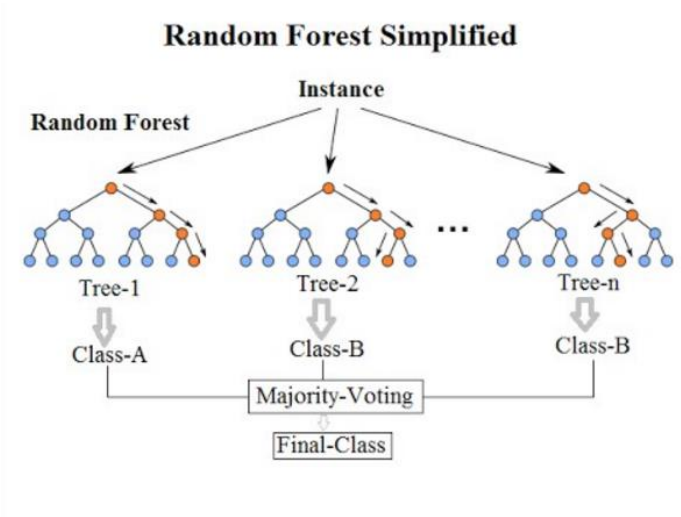
Methods: Machine learning technics

K-means (MacQueen 1967):

- **an unsupervised** machine learning clustering algorithm
- **partitions** a sample set ***X*** into a predefined number of clusters (***k***) using **minimization within cluster variances**.

Random Forest (Ho, 1995):

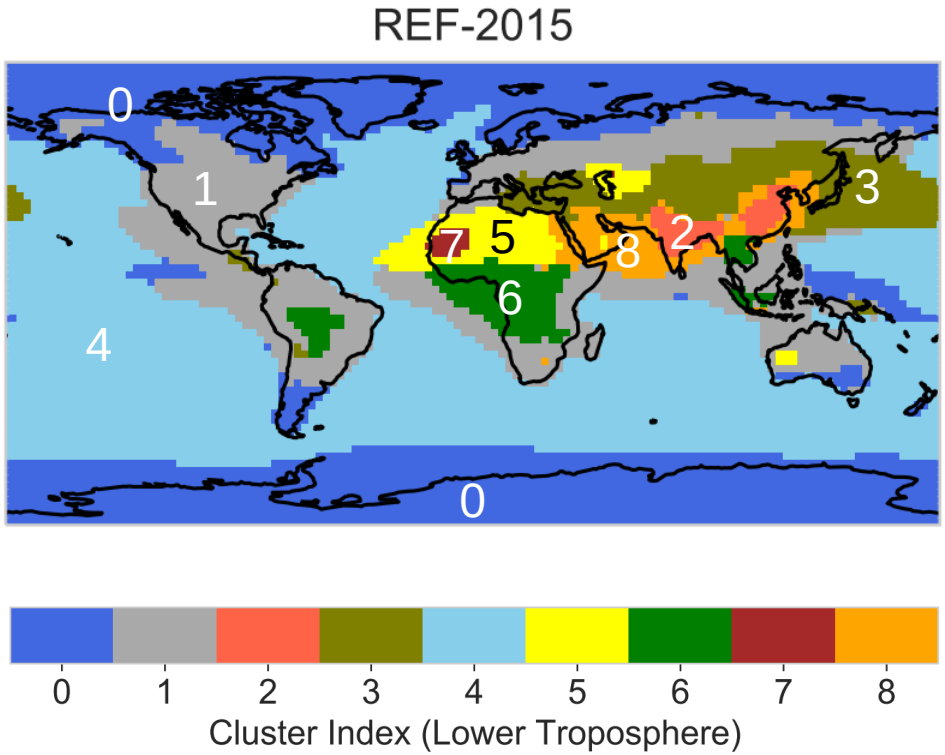
- **a supervised** machine learning clustering algorithm
- is an **ensemble learning method** for classification. It builds decision trees on different samples and takes their majority vote for classification.



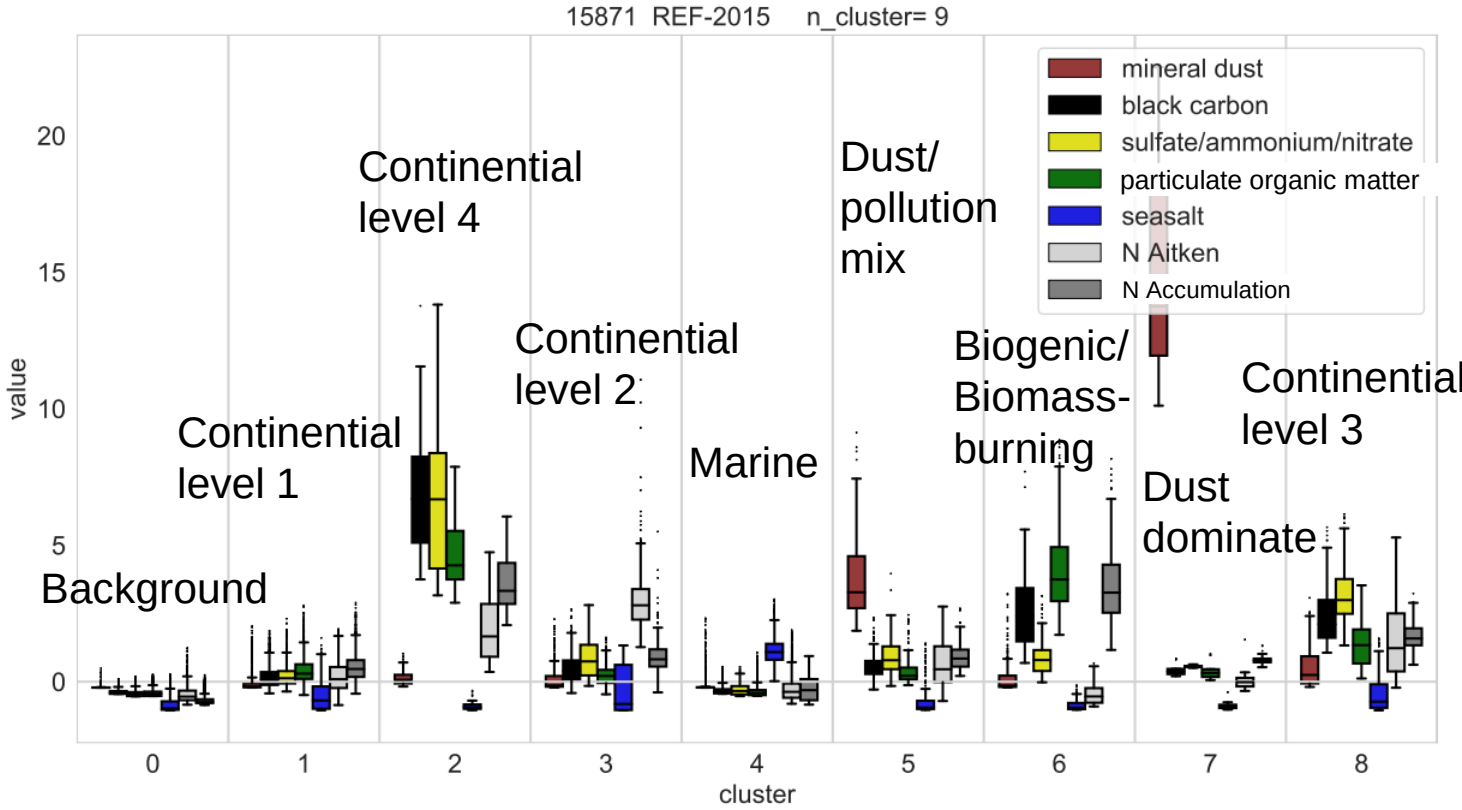
Analyses procedures:

REF-2015 Aerosol properties → K-means → REF-2015 Aerosol regimes Aerosol properties → Random Forest → REF-2015 Classification Criterion → Random Forest → Other time slices aerosol regimes

Results: Aerosol regime characteristics (primary scale)

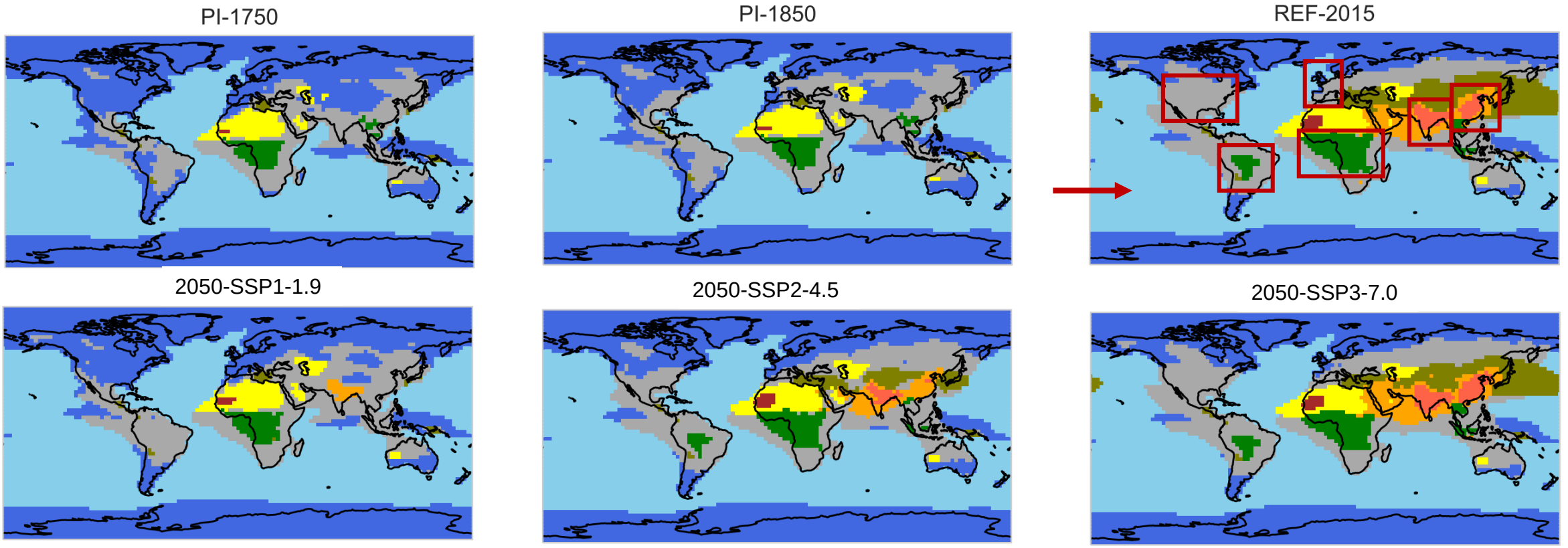


The distribution of low tropospheric aerosol regimes. Each color/index represents one cluster.



The characteristics of identified aerosol regimes, represented by the data distributions of the seven considered aerosol properties (legend) for each regime (x-axis)

Results: Regime developments through time (primary scale)



Regions in focus

- Biogenic/Biomass burning cluster: Cluster 6
- Most polluted continental cluster: Cluster 2
- Most clean continental cluster: Cluster 1
- Marine cluster: Cluster 4

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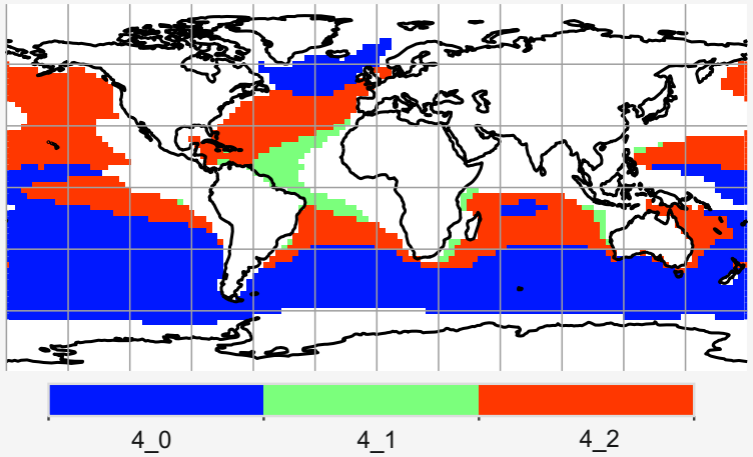
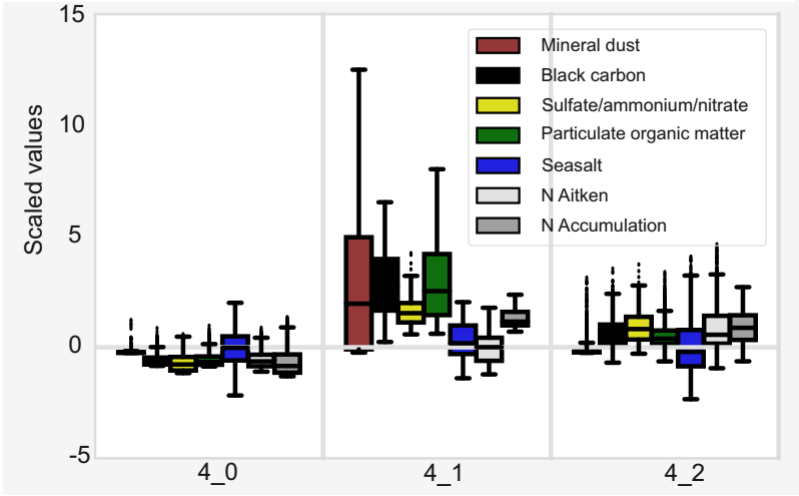
Results: Clean cluster sub-classification (secondary scale)

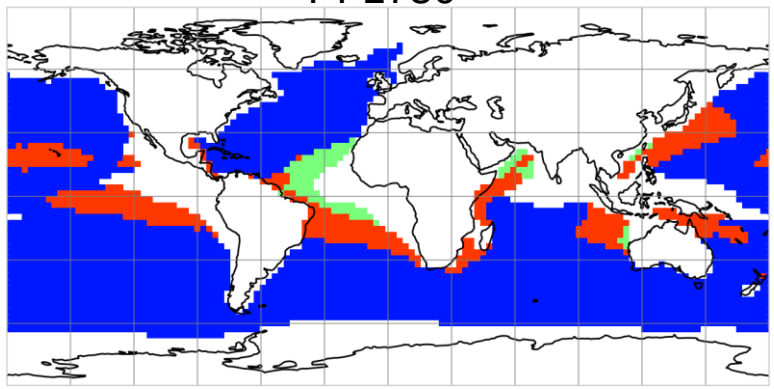
Marine cluster case
REF-2015



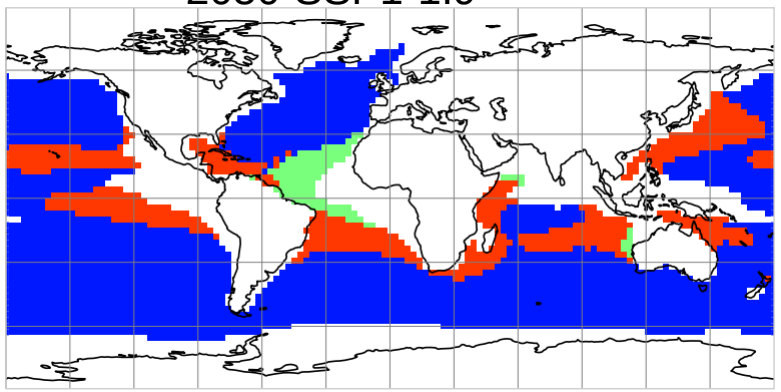
Marine cluster case
Sub classes characteristics



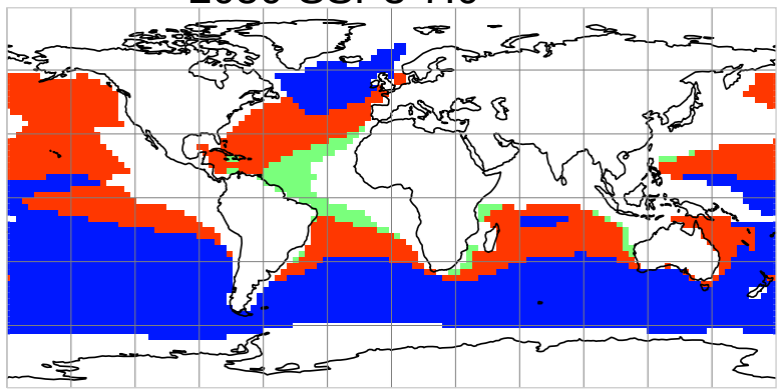
PI-1750



2050-SSP1-1.9



2050-SSP3-7.0



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- REF-2015 show difference between Northern and Southern Hemisphere.
- Pre-industrial marine clusters include mostly low aerosols loads typical of present-day pristine marine regions of the Southern Hemisphere.

Summary

- The **investigation** of **aerosol regime developments** through time are realized by using a combination of **K-means** classification and **Random Forest**, and based on global aerosol simulations using **EMAC-MADE3**.

- Aerosol classifications are conducted on **two scales**: a **primary classification** which captures the large scale pattern of global aerosol distributions, and a **secondary classification** (sub-classification) which identifies fine cluster structures within the primary clusters.

- Lower tropospheric primary aerosol regimes during **pre-industrial** times are dominated by **clean clusters** (background, marine and the cleanest continental cluster).

- The lower tropospheric aerosol regimes in **2050 differ from** the **present-day** case mainly in **the extent of the clusters representing polluted regions**

- The secondary classification demonstrates that **pre-industrial marine clusters** show **no clear difference** between **Northern and Southern Hemisphere**, as it is the case in the present-day.

- These **results** are further **supported** by direct **comparisons of aerosol emissions** from different time slices and scenarios for selected regions, and additional information of the respective contributions of the emissions from different sectors.

THANK YOU FOR YOUR ATTENTION!

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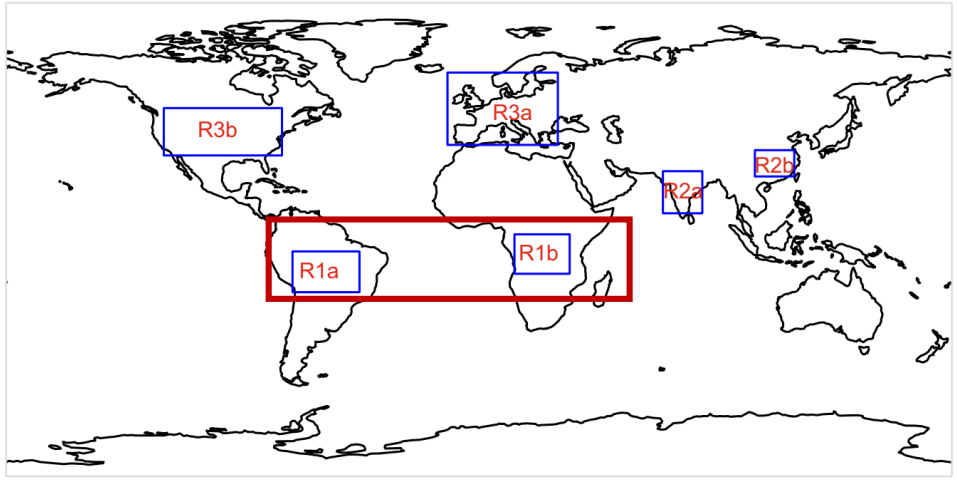
Results: Discussion on specific regions: Emissions changes through time



Example Regions: **R1a** and **R1b**

- Both identified biogenic cluster in the present day case
- They undergo different developing path through time

Emissions comparison

- Among time slices and scenarios (**legend**)
- For aerosol species: NOx,SO2, BC and NH3 (**y-axis**)
- Contribution from different emission sectors: Open burning, Antropogenic non-traffic, Road, Ship, Air and Total (**x-axis**)