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Aerosol emission estimation using "perfect" satellite observation capabilities and Observing System Simulation Experiments (OSSEs)

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OSSE and the case of a "Perfect" Satellite...

In an OSSE we use a simulation as Nature (a.k.a Nature Run)
This Nature has altered emissions (e.g. Sea Salt Emissions x 0.5)

Data assimilation estimates these emissions using
- Aerosol Optical Depth (AOD)
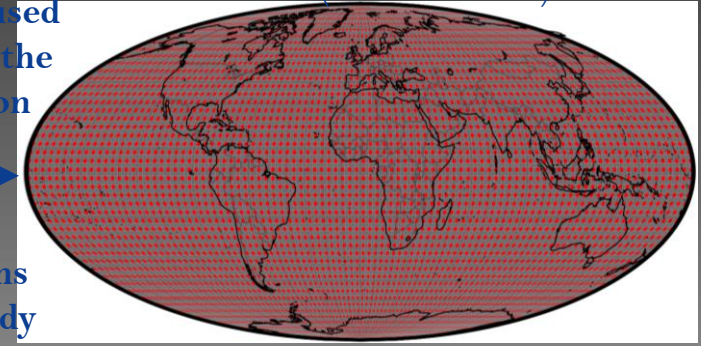- Angstrom Exponent (AE)
- Single Scattering Albedo (SSA)

Benefits

1. Ground Truth is known $\Rightarrow$ Complete Evaluation
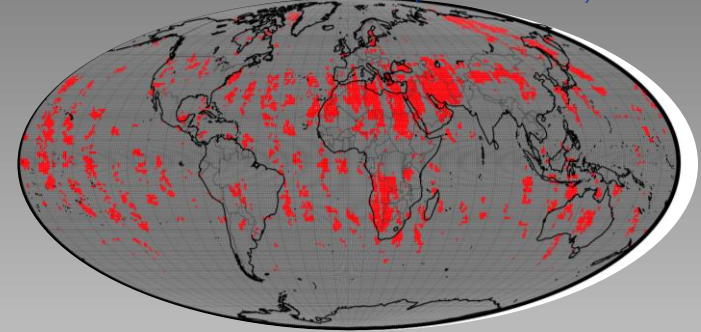2. Can replicate any satellite observation capabilities.

This one is used throughout the presentation

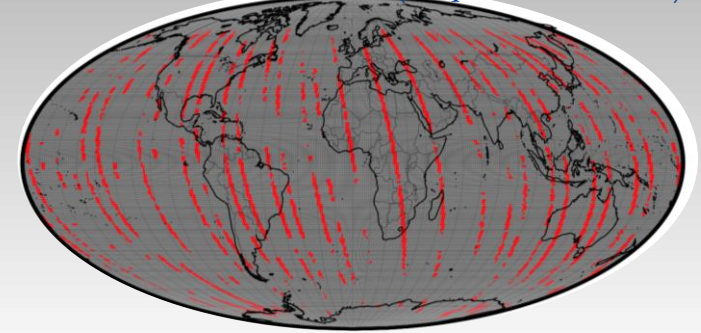Observations even in cloudy conditions

Satellite Coverage in two days
"Perfect" (Ideal Satellite)
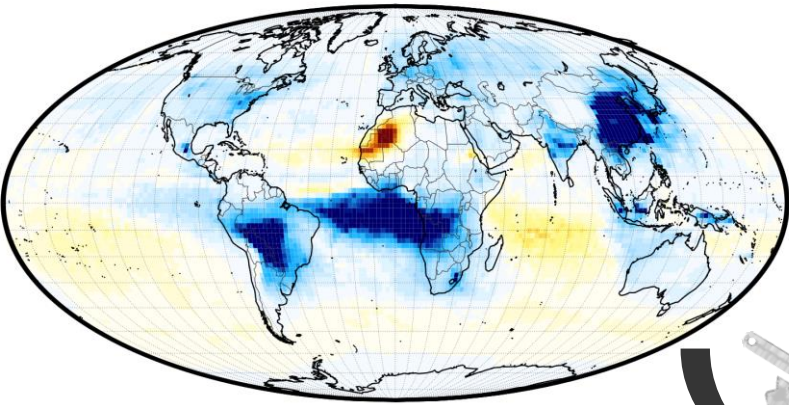

As reference **POLDER** (2006-2013)
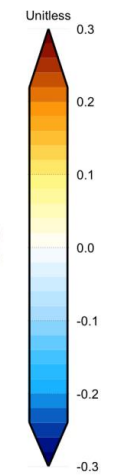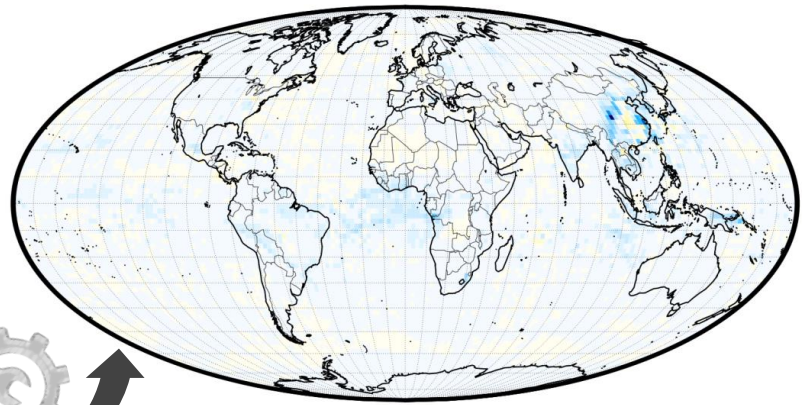

As reference **SPEXone** (Expected at 2022)

Differences of AOD_{550} between
Control − Nature

Differences of AOD_{550} between
Assimilation − Nature

Data assimilation

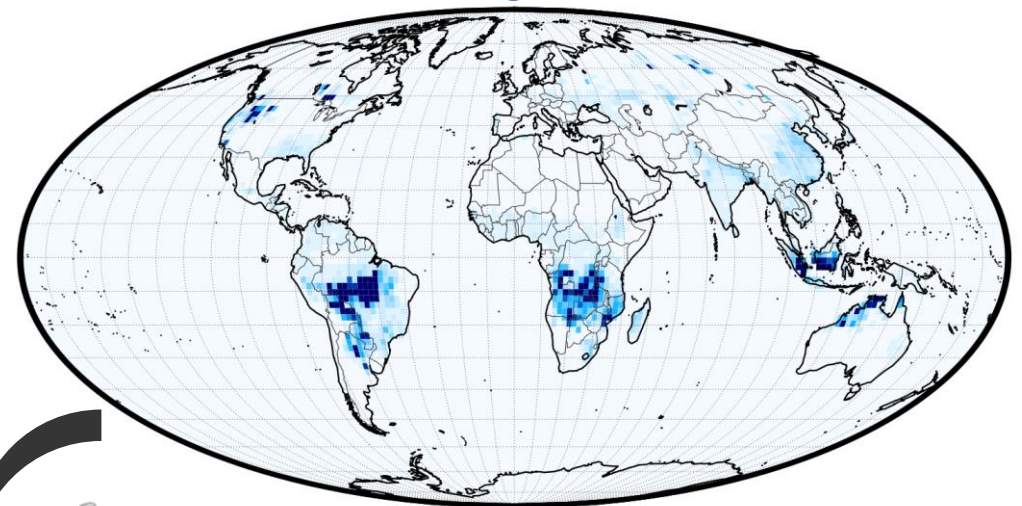Unitless
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3

■ Observations   ■ No Observations

SRON

Emission Estimation under an OSSE…

Differences of Sea Salt Fluxes

Differences of Organic Carbon Fluxes
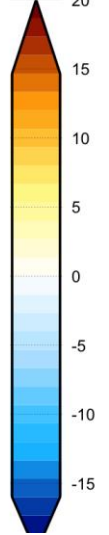
Control − Nature
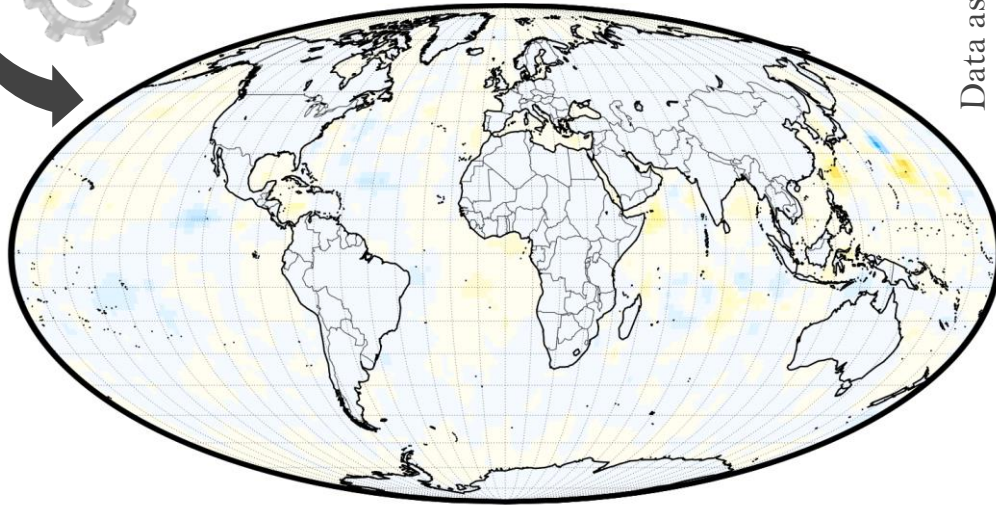
Assimilation − Nature

Data assimilation

Data assimilation

(kg km^2 day^-1)

The role of **Meteorology**…

All experiments (Nature, Control, Assimilation) are nudged to ERA5 reanalysis meteorology.
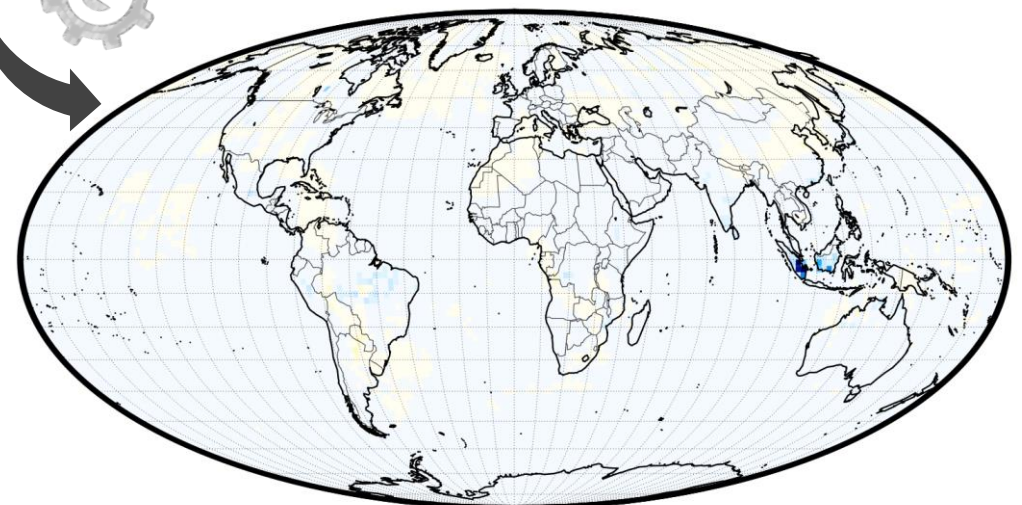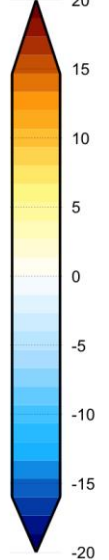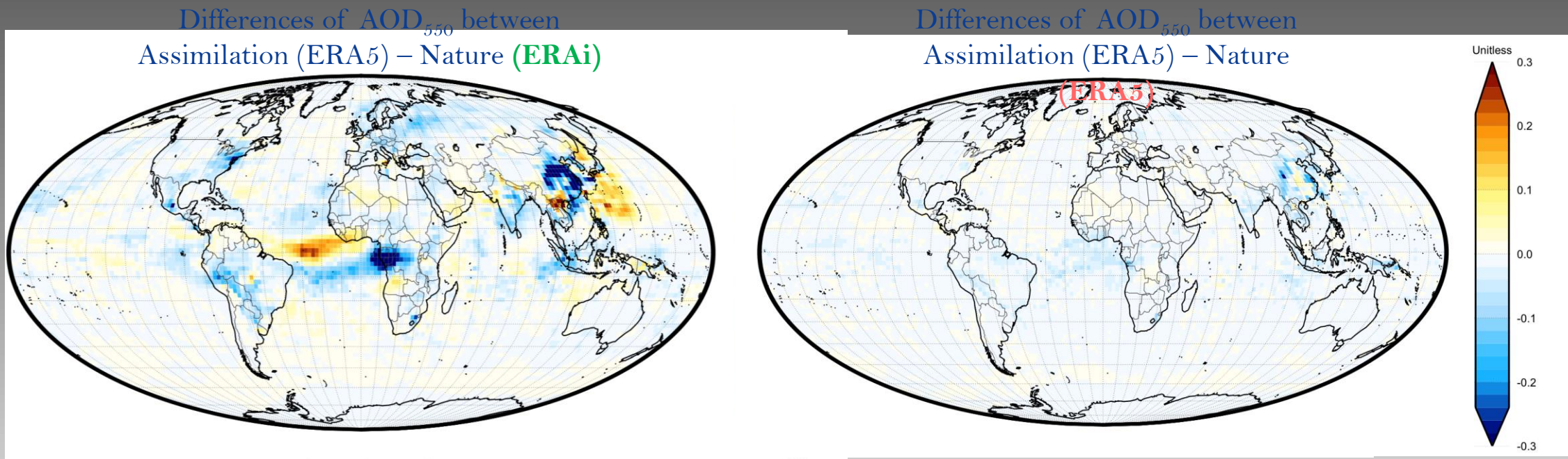But what if Nature was nudged to ERA_i while Control & Assimilation to ERA_5 ?

Differences of AOD_{550} between
Assimilation (ERA5) − Nature **(ERAi)**

Differences of AOD_{550} between
Assimilation (ERA5) − Nature
(ERA5)

Data assimilation is able to correct biases originating from emissions.
Although, as expected, it is not able to correct biases originating from other factors, in this case meteorology.

Outside of an OSSE framework these biases cannot be quantified and we have to be aware that are there!

The role of **Prior Correction**…

Prior (first guess) of emissions can significantly affect the performance of a data assimilation experiment.

Prior Correction is just a method to improve data assimilation results.
Instead of setting prior emissions equal to Control,
we adjust them based on the emissions estimated (analysis) the previous day.

Differences of $AE_{550-865}$ between
Control – Reality

Data assimilation
Prior Correction OFF

Data assimilation
Prior Correction ON

For example, with prior correction we get a slight improvement in our already quite low bias in AE as well as in AOD and SSA (not shown)

Unitless
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
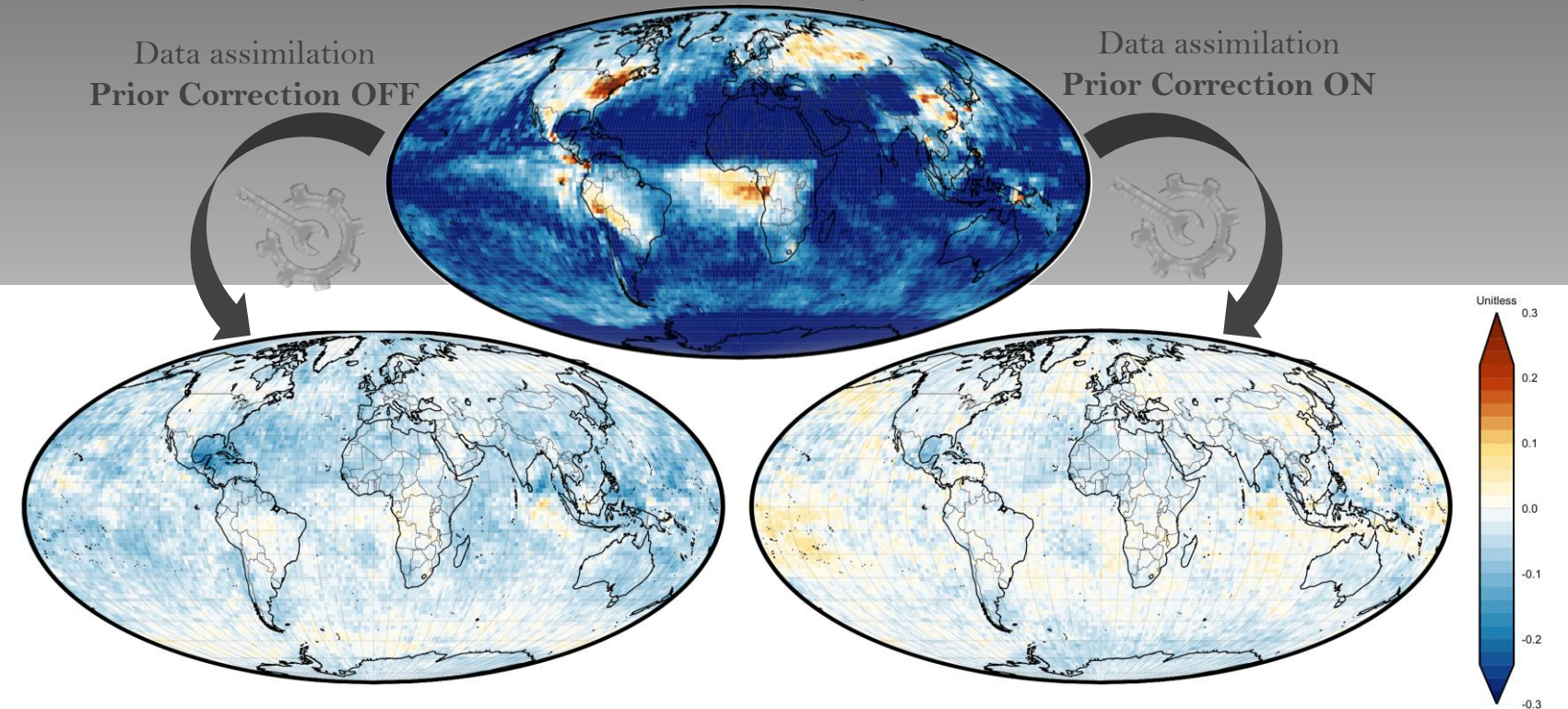
Conclusions

Developed the first data assimilation system
for **aerosol emission estimation** on ECHAM-HAM.

Using OSSEs:

- Successfully estimated emission with observations (AOD, AE, SSA) utilizing a "Perfect" satellite setting.
- Addressed the important role of meteorology in aerosol data assimilation (1st test on Nature Run complexity).
- Developed a prior correction method which improves data assimilation emission estimation.

Future Work

- Emission estimation using past (POLDER) and future (SPEXone, HARP-2 & OCI) observation capabilities.
- Sensitivity studies on Nature Run complexity (e.g. different emission inventories and schemes)
- Sensitivity studies on data assimilation temporal cycles.