# The AeroCom multi-model perturbed physics ensemble (MMPPE)

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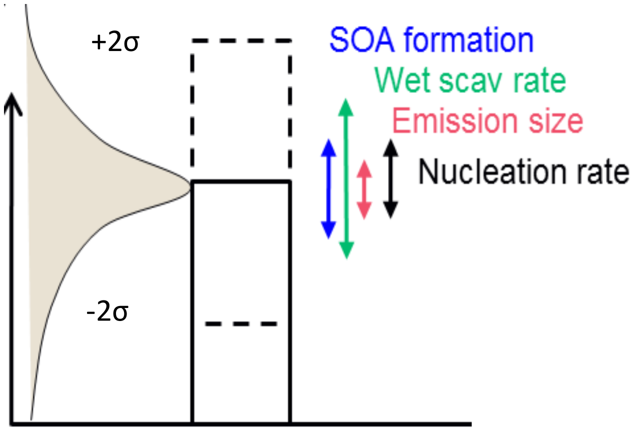
N8 Research Partnership | High Performance Computing

# Identifying causes of uncertainty





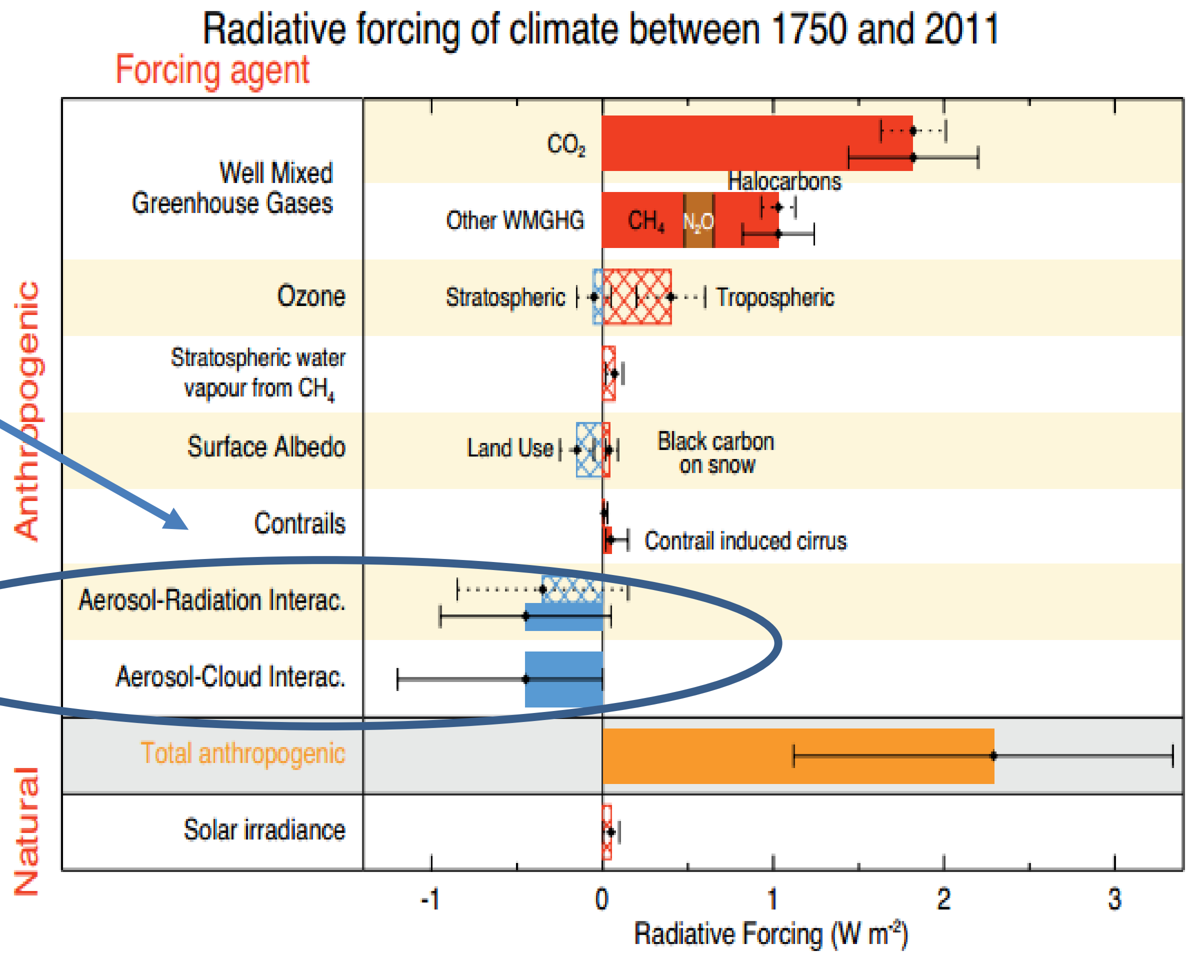




**Figure 8.15** | Bar chart for RF (hatched) and ERF (solid) for the period 1750–2011, where the total ERF is derived from Figure 8.16. Uncertainties (5 to 95% confidence range) are given for RF (dotted lines) and ERF (solid lines).

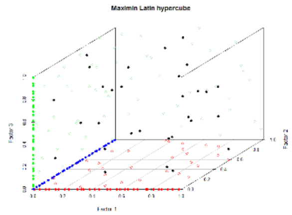
# The approach, following ACP 2011



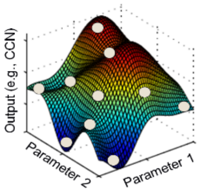
Define key model outputs

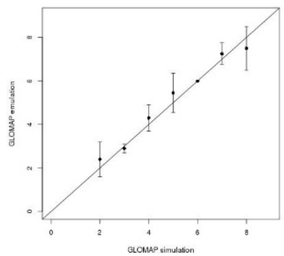
Expert elicitation of parameter uncertainties

Design sample of parametric combinations for emulation




Run global aerosol model




Build and validate emulators of the key model outputs

Sample from emulator for variance-based sensitivity analysis

Observationally constrain the key model outputs

# Variance-based sensitivity analysis



Main Effect: $$S_i = \frac{V_i}{Var(Y)}$$

The expected reduction in variance when a parameter is learnt precisely

Require extensive sampling of the parametric uncertainty space

# GLOMAP PPE



Mass emission rates

| Parameter | Lower | Upper |
|---|---|---|
| BCOC mass emission rate (fossil fuel) | 0.5 | 2.0 |
| BCOC mass emission rate (biomass burning) | 0.25 | 4.0 |
| BCOC mass emission rate (biofuel) | 0.25 | 4.0 |
| Sea spray mass flux (coarse/acc) | 0.2x | 5.0x |
| SO2 emission flux (anthropogenic) | 0.6x | 1.5x |
| SO2 emission flux (volcanic) | 0.5x | 2.0x |
| Biogenic monoterpene production of SOA | 5 Tg/a | 360Tg/a |
| Anthropogenic VOC production of SOA | 3Tg/a | 160Tg/a |
| DMS mass flux | 0.5x | |
| BCOC mode diameter (fossil fuel) | 30 nm | |
| BCOC mode diameter (biomass burning) | 50 nm | |
| BCOC mode diameter (biofuel) | 50 nm | |
| Subgrid conversion of SO2 to SO4 ("primary SO4") | 0% | |
| Mode diameter of "primary SO4" | 20 nm | |

Microphysics / Model properties

| Parameter | Lower | Upper |
|---|---|---|
| BL nucleation rate k[H2SO4] | 1E-10 | 2E-04 |
| FT nucleation rate (BHN) | x0.01 | X10 |
| Ageing "rate" from insol to sol (monolayer) | 0.3 | 5 |
| Modal width (accumulation) | 1.2 | 1.8 |
| Modal width (Aitken) | 1.2 | 1.8 |
| Mode separation diameter (nucleation/Aitken) | 9nm | 20nm |
| Mode separation diameter (Aitken/accumulation) | x1.5 | x3 |

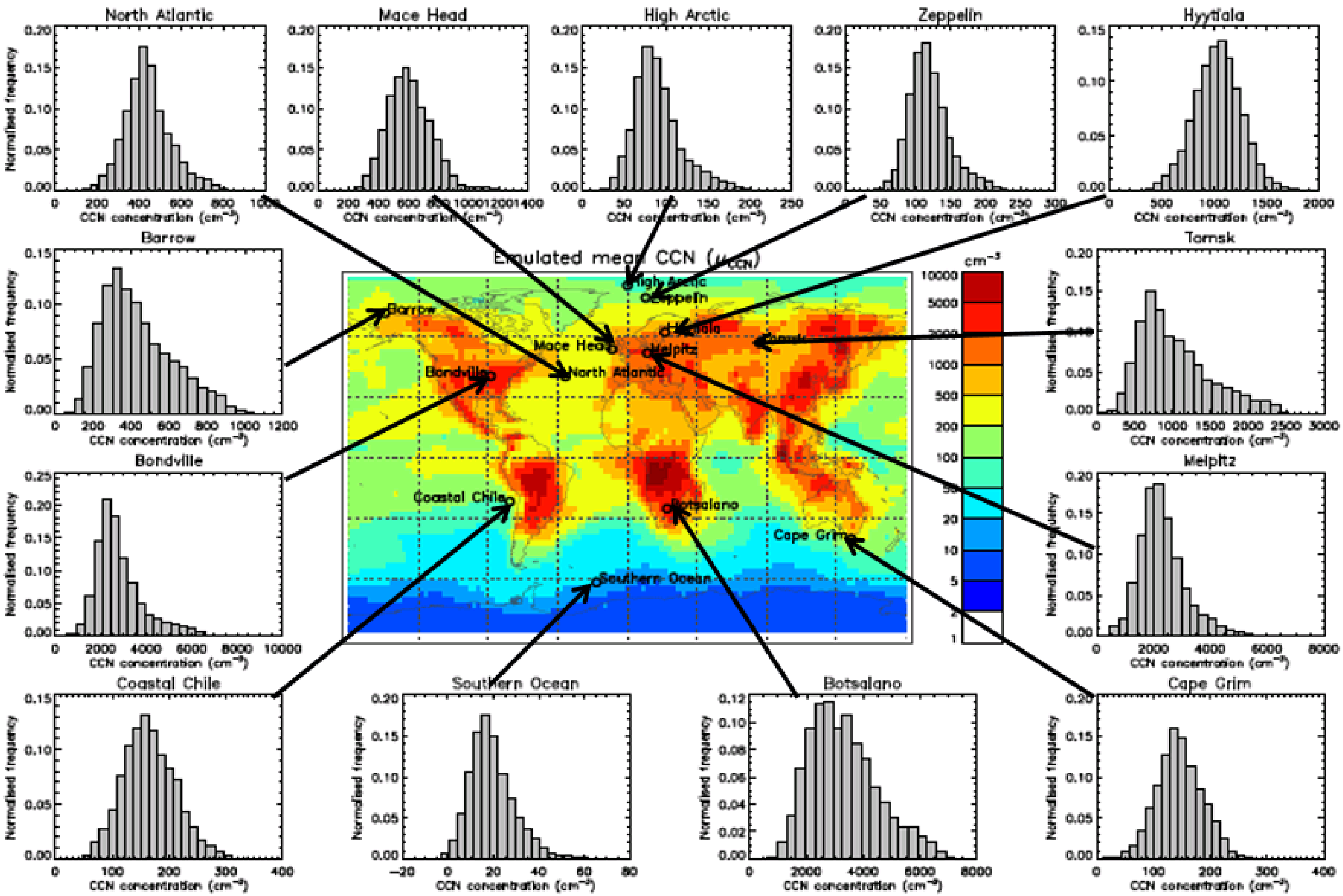
Cloud processing

| Parameter | Lower | Upper |
|---|---|---|
| Cloud drop activation dry diameter | 30 | 100 |
| Reaction SO2 + O3 in cloud water (clean) | pH=4 | pH=6.5 |
| Reaction SO2 + O3 in cloud water (polluted) | pH=3.5 | pH=5 |

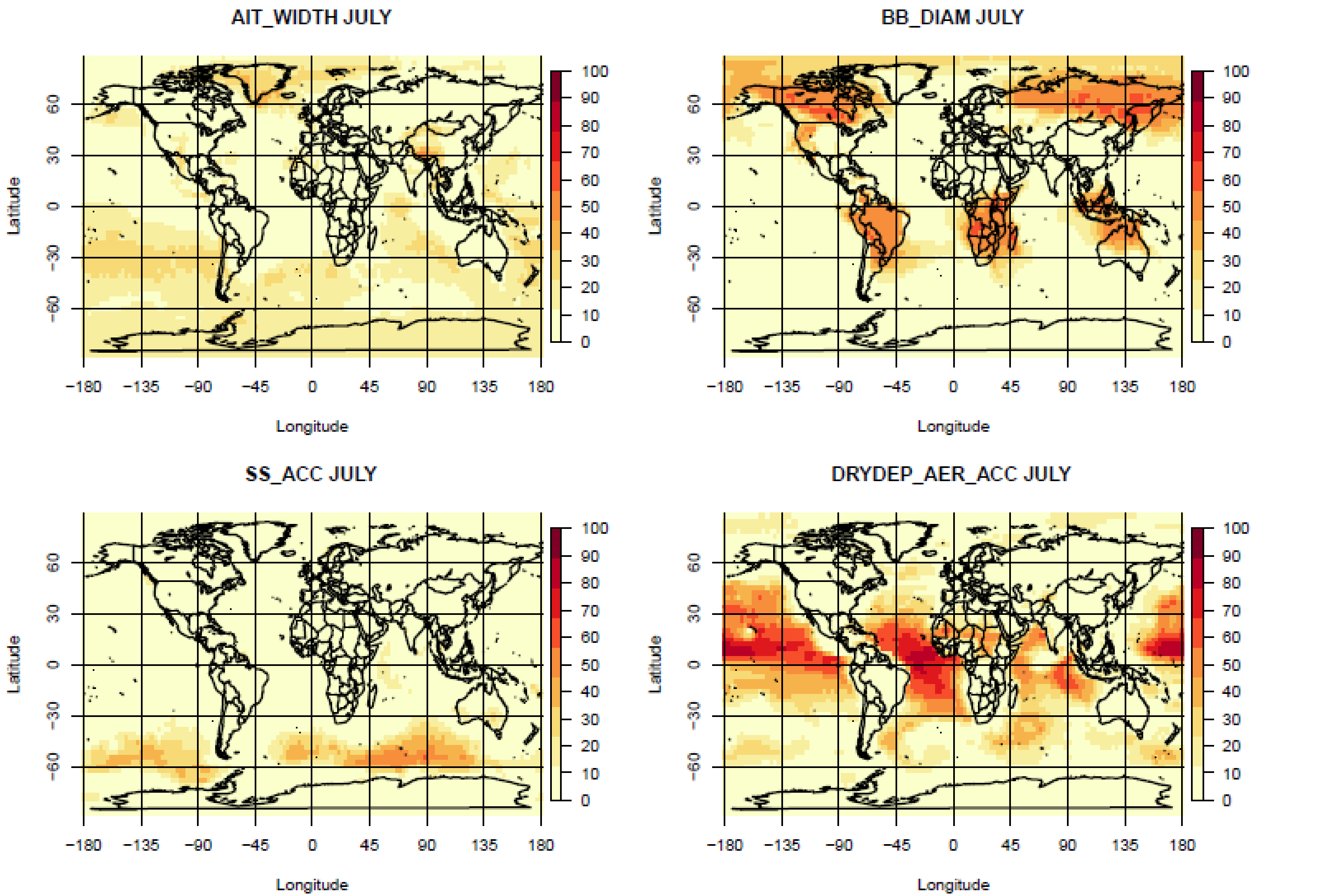
Dry and wet deposition

| Parameter | Lower | Upper |
|---|---|---|
| Nucleation scavenging dry D (above activation) | 0 | 100 |
| Nucleation scavenging fraction (T< -15C) | 0.05 | 0.75 |
| Dry deposition velocity (Aitken) | x0.5 | X2.0 |
| Dry deposition velocity (accumulation) | X0.1 | X10.0 |
| Dry deposition velocity (SO2) | X0.5 | X2.0 |

# PPE uncertainty in cloud condensation nuclei (CCN)



# PPE main effect sensitivity maps



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# PPE main effect sensitivity time series

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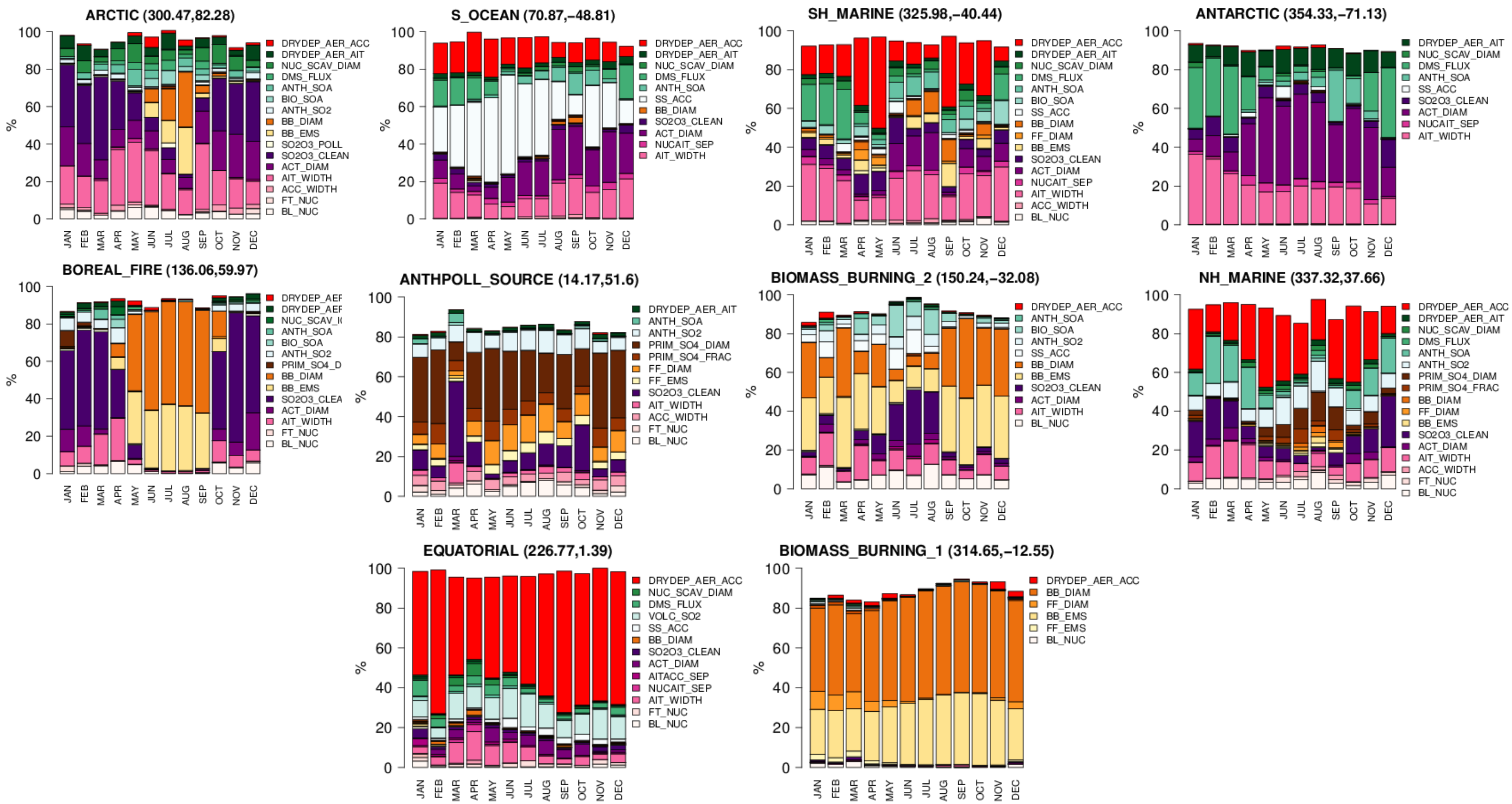

# Extending to MMPPE



- Require consistency in perturbations
  - Without consistency in process representation

Begin with two 3-parameter MMPPEs:

Direct radiative effect
*and*
Aerosol-cloud interaction

# Multi-model experiments



- Time period
  - 2008 and some pre-industrial year
- Simulations
  - 39 simulations + AeroCom baseline

To be consistent between models

- Emissions
  - Current emissions
- Nudging
  - Nudging such that radiation effects can be determined
- Chemistry
  - Offline but not CTM

Model dependent

# The black carbon experiment

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Direct radiative forcing
+0.71 [+0.08,+1.27]

**Atmospheric BC burden**

1. Aerosol number

Scale BC number flux, at emission, with fixed radius

[X*0.5, X*2]

2. Wet deposition

Scale removal tendencies

[X*0.1, X*10]

**Radiative properties**

3. Radiative properties

Scale imaginary part of refractive index

[X*0.5, X*2]

# The cloud experiment

Aerosol-cloud interaction
- the largest historical forcing

| Atmospheric aerosol → CCN | Aerosol → droplets | Loss via precipitation |
|---|---|---|
| 1. CCN | 2. Activation | 3. Autoconversion |
| Scale DMS number flux (?) | Scale updraft velocities in participating scheme | Change exponent in autoconversion scheme |
| [X*0.5, X*2] | [X*0.2, X*5] | KK: [-2, -1] |

# Diagnostics

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## 6. Diagnostics

**Global, 3d field, monthly**
N50, N3, PM2.5, BC
**Global, 2d field, monthly**
AOD (550nm), TOA fluxes, BC dry deposition flux, BC wet deposition flux, Emission fluxes, BC burden
**3hr Station**
BC, AOD (440 and 870nm), AAOD
**To be defined**
Aerosol mass, Aerosol number, Size distribution, Drop size, CDNC, CCN, LWP, Cloud mass, Cloud fraction, Surface fluxes, Rain and snow fluxes, others...

- Compare model to observations
- Compare models to each other

# Selected references




**Lee LA**; Reddington CL; Carslaw KS (2016) On the relationship between aerosol model uncertainty and radiative forcing uncertainty, *Proceedings of the National Academy of Sciences of the United States of America*, **113**, pp.5820-5827. doi: 10.1073/pnas.1507050113

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