Aerosol nucleation and growth, SOA formation, upcoming NorESM simulations at University of Helsinki

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NorESM WS, Stockholm, 24.10.2014

Evaluation of aerosol number concentrations in NorESM with improved nucleation parameterization

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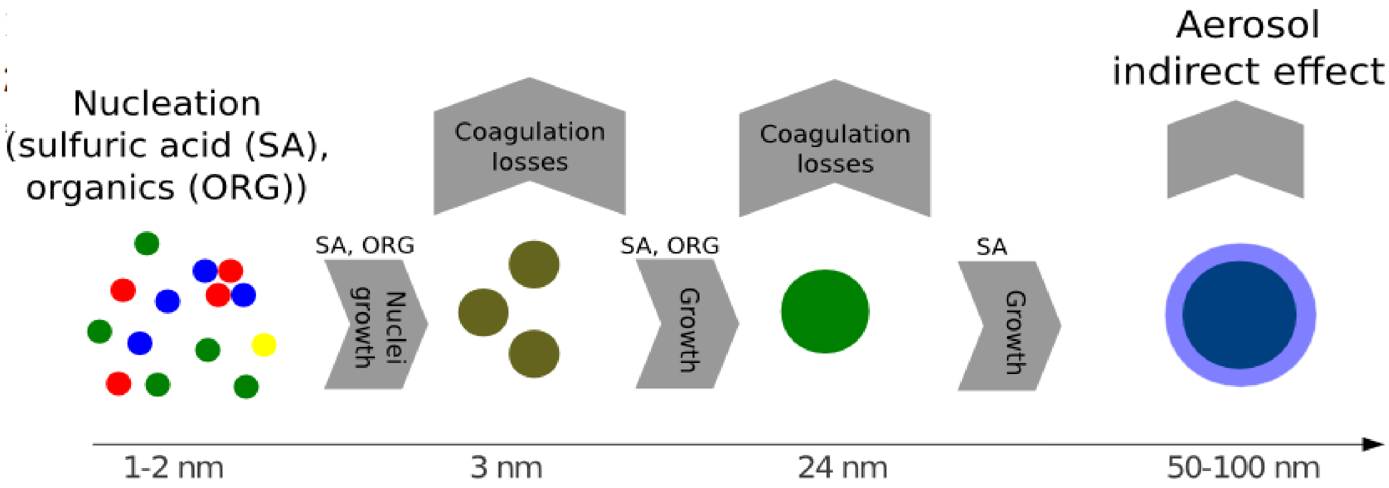
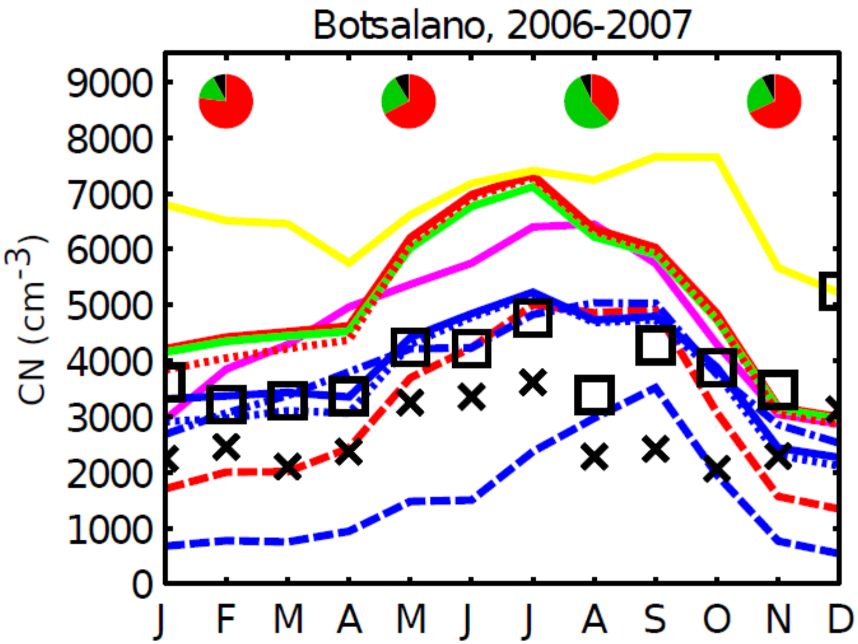


Table 1. Simulated sensitivity experiments. The simulated climate is identical in all experiments except ActNuc_BC24_Online, where aerosol–climate interactions are switched on.

Short name	Nucleation	BSOA	BC_{FF} radii	Additional information
NorESM1-M	On*	On	11.8 nm	As in Kirkevåg et al. (2013)
NoNuc_BC12	Off	On	11.8 nm	
NoNuc_BC24	Off	On	23.6 nm	
ActNuc_BC12	Eq. (1)	On	11.8 nm	
ActNuc_BC24	Eq. (1)	On	23.6 nm	
OrgNuc_BC12	Eq. (4)	On	11.8 nm	
ActNuc_BC12_NoSOA	Eq. (1)	Off	11.8 nm	
ActNuc_BC24_NoSOA	Eq. (1)	Off	23.6 nm	
ActNuc_BC24_Online	Eq. (1)	On	23.6 nm	Aerosols affect model meteorology
ActNuc_BC24_Nuc10	Eq. (1)	On	23.6 nm	SO4 nucleation-mode diameter set to 10 nm

*Original NorESM1-M assumed that after condensation, all excess sulfuric acid nucleates as new particles.



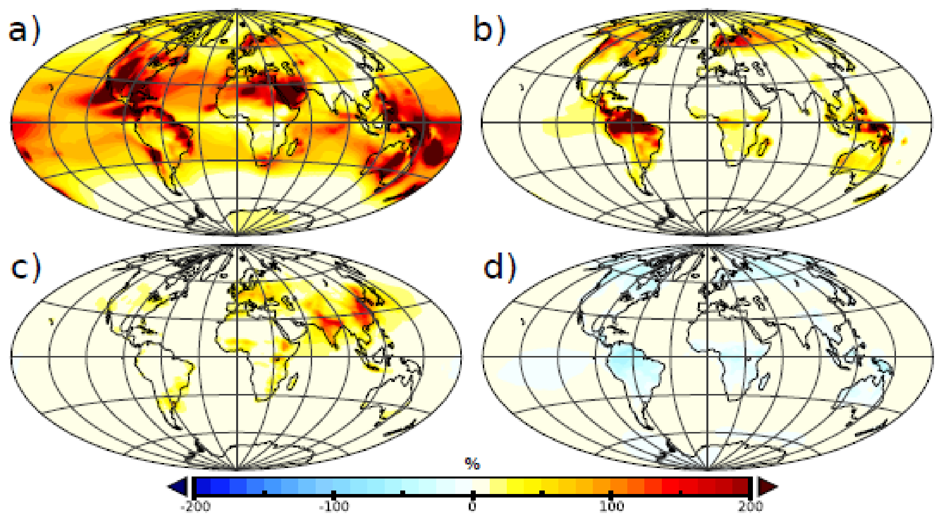
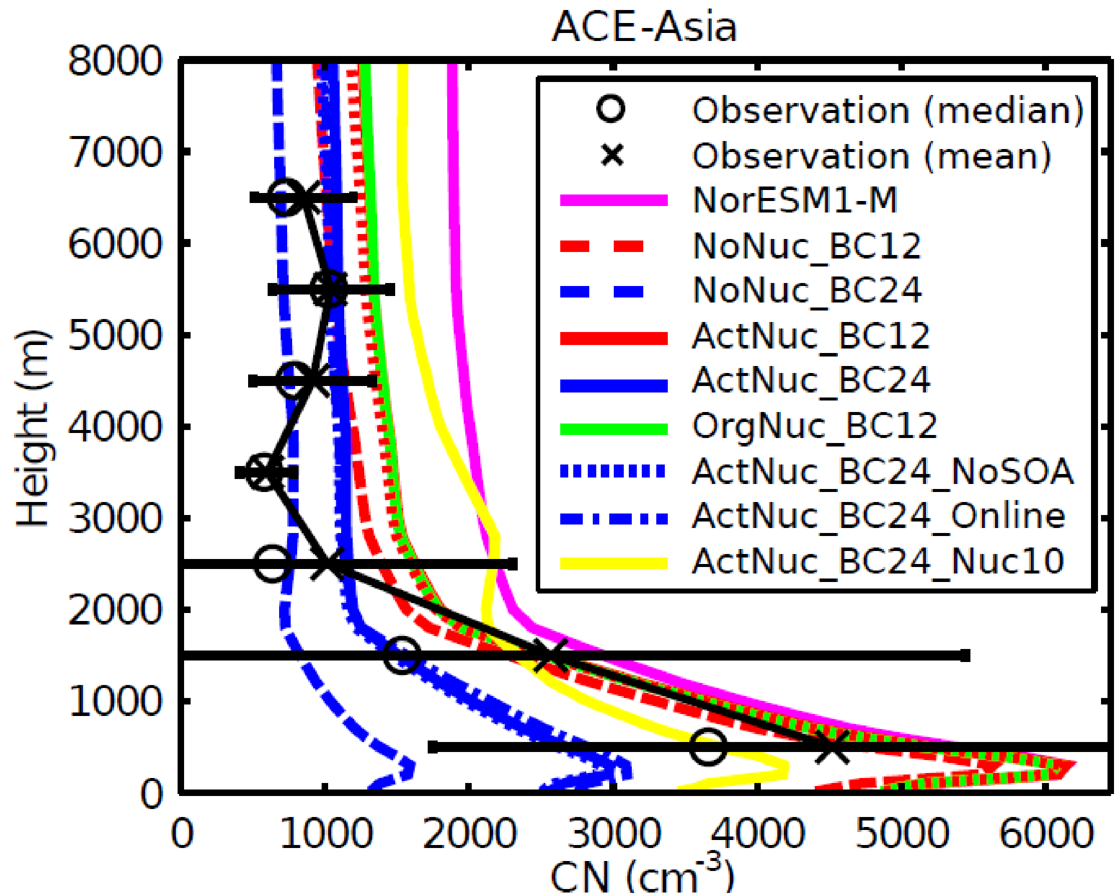


Fig. 2. Surface-level aerosol number concentration difference fields (%) from sensitivity simulations, due to **(a)** nucleation (ActNuc_BC12-NoNuc_BC12), **(b)** SOA formation (ActNuc_BC12-ActNuc_BC12_NoSOA), **(c)** BC emission size (ActNuc_BC12-ActNuc_BC24) and **(d)** nucleation parameterization (ActNuc_BC12-OrgNuc_BC12). Differences are calculated against ActNuc_BC12 simulation (Fig. 1).

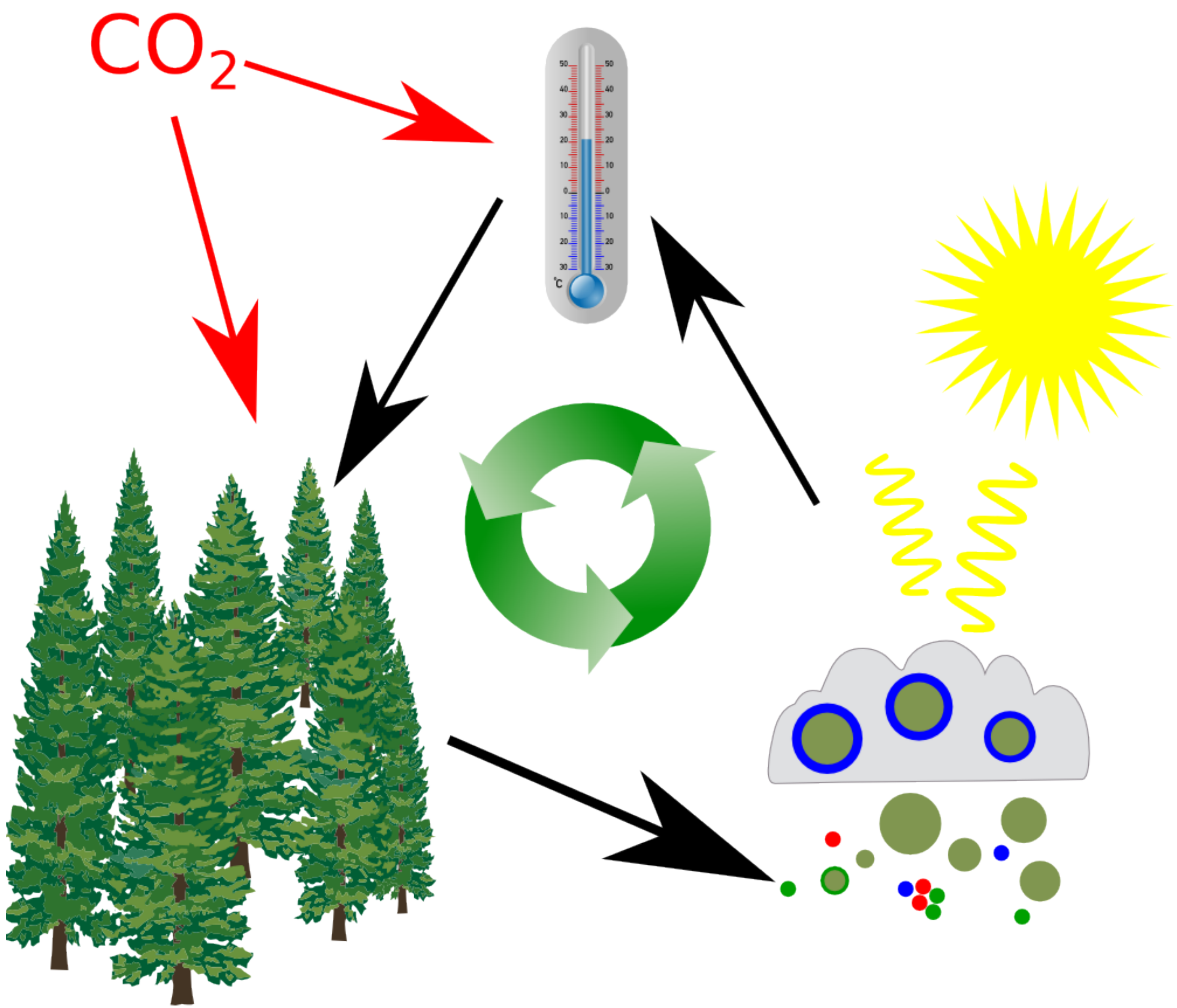


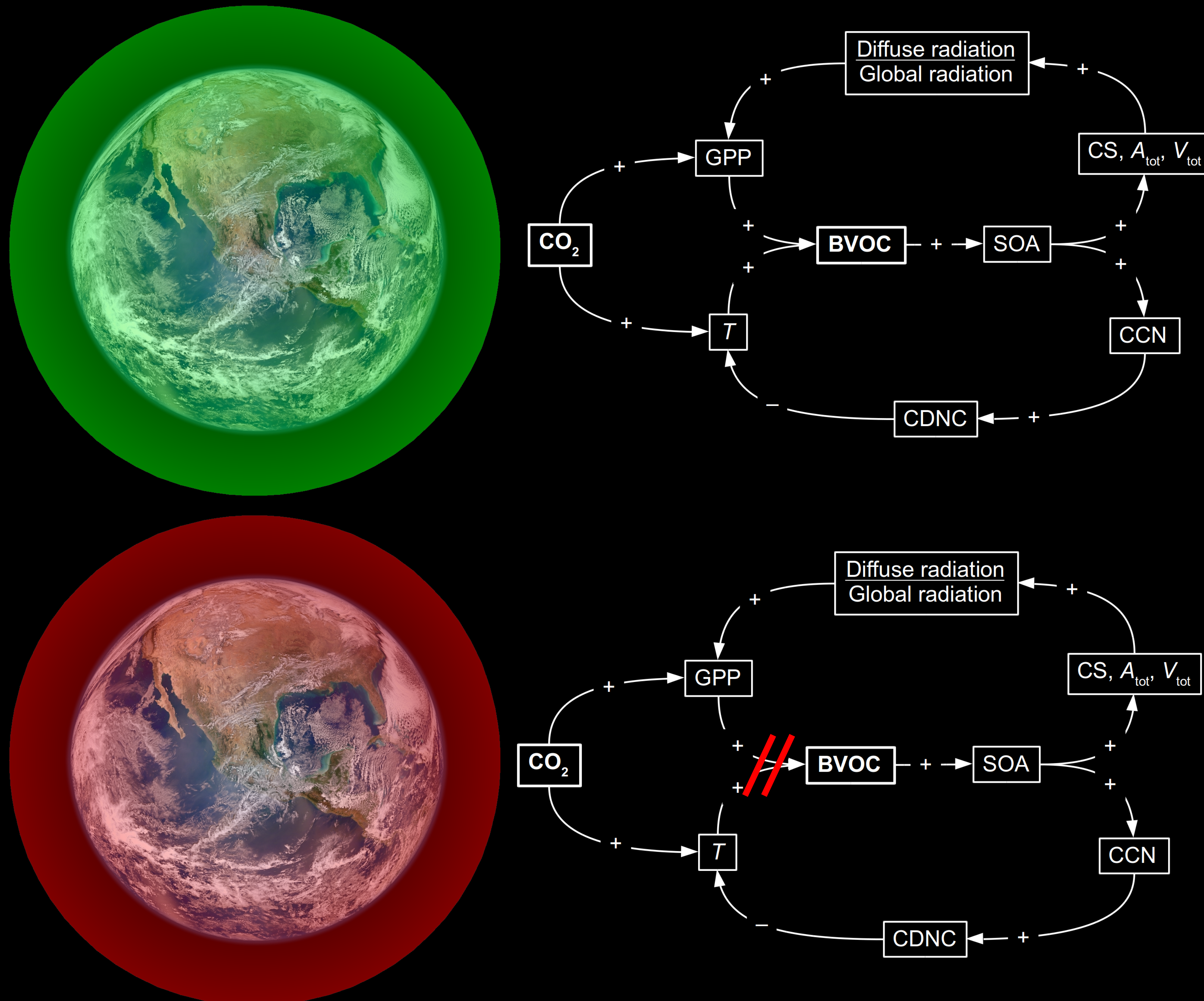
	All	
	BIAS (%)	R^2
NorESM1-M	33	0.38
NoNuc_BC12	−27	0.30
NoNuc_BC24	−64	0.35
ActNuc_BC12	20	0.40
ActNuc_BC24	−5	0.41
OrgNuc_BC12	20	0.39
ActNuc_BC12_NoSOA	2	0.38
ActNuc_BC24_NoSOA	−25	0.42
ActNuc_BC24_Online	−8	0.43
ActNuc_BC24_Nuc10	81	0.38

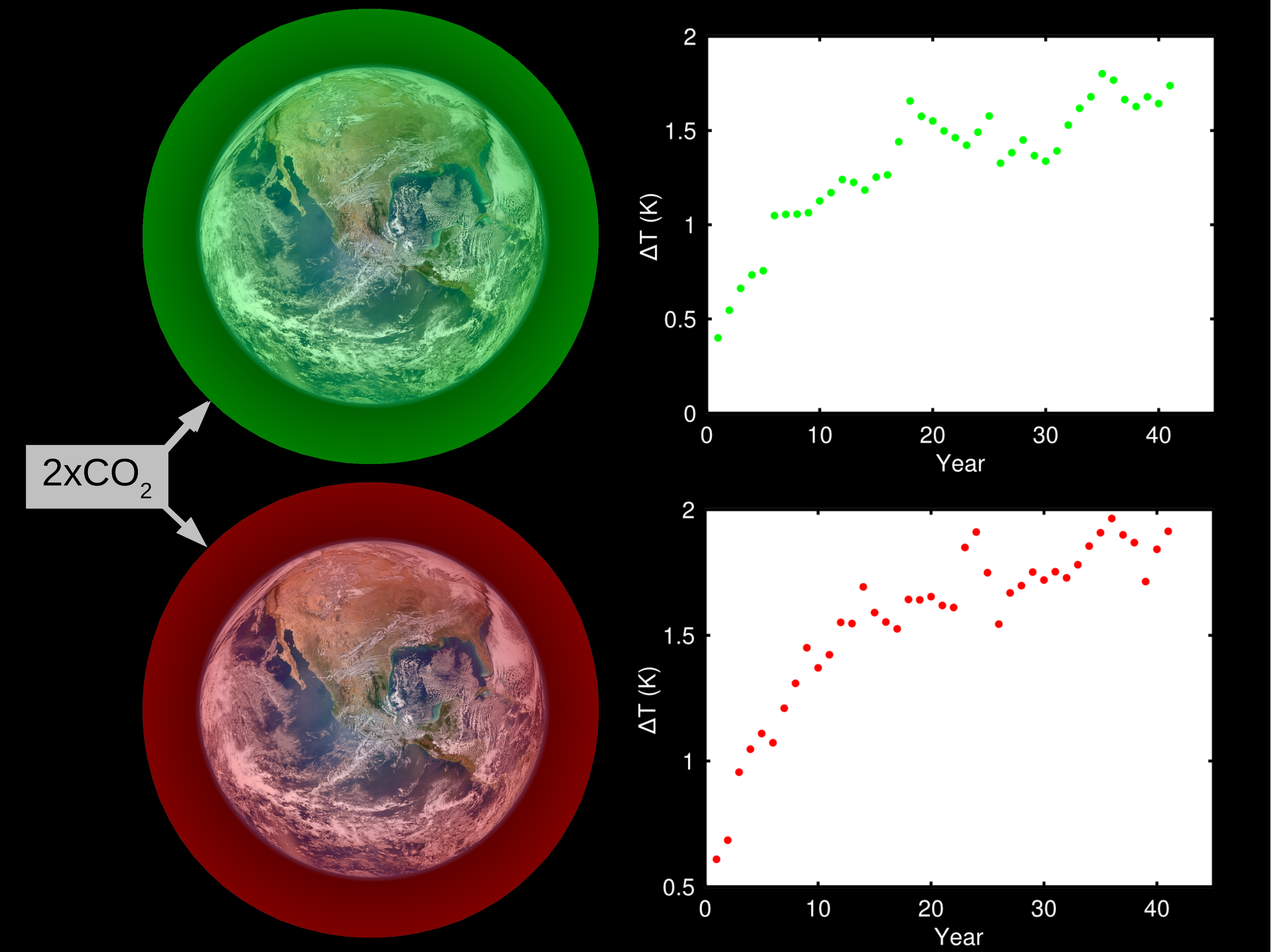
Aerosol-Climate Feedbacks in Earth System Simulations

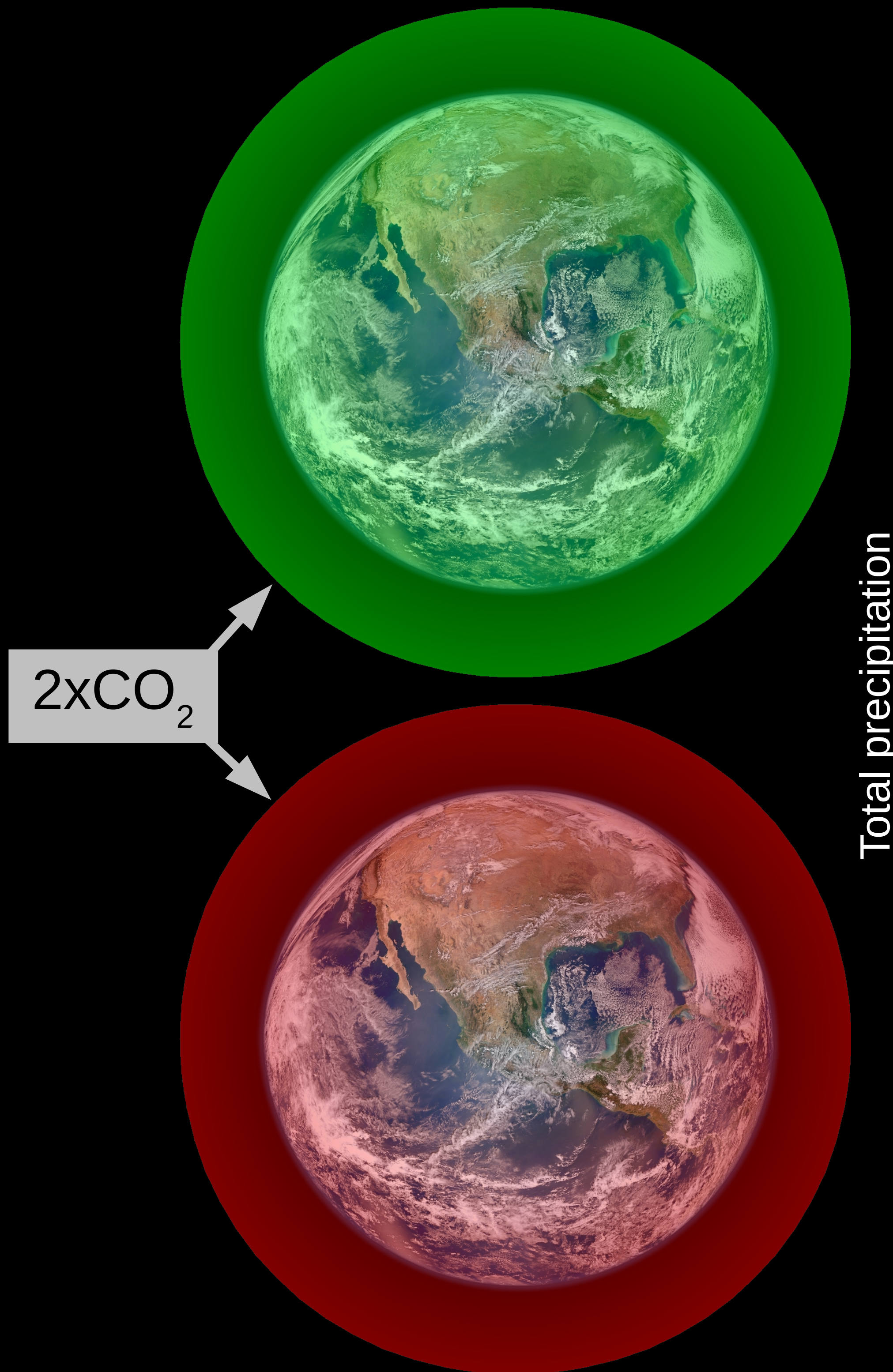
- CRAICC WP8: synthesis
- BACCHUS task 4.4: Biosphere-atmosphere-cloud-climate interactions and feedbacks
- CSC Grand Challenge ACFESS: 6 million CPU hours

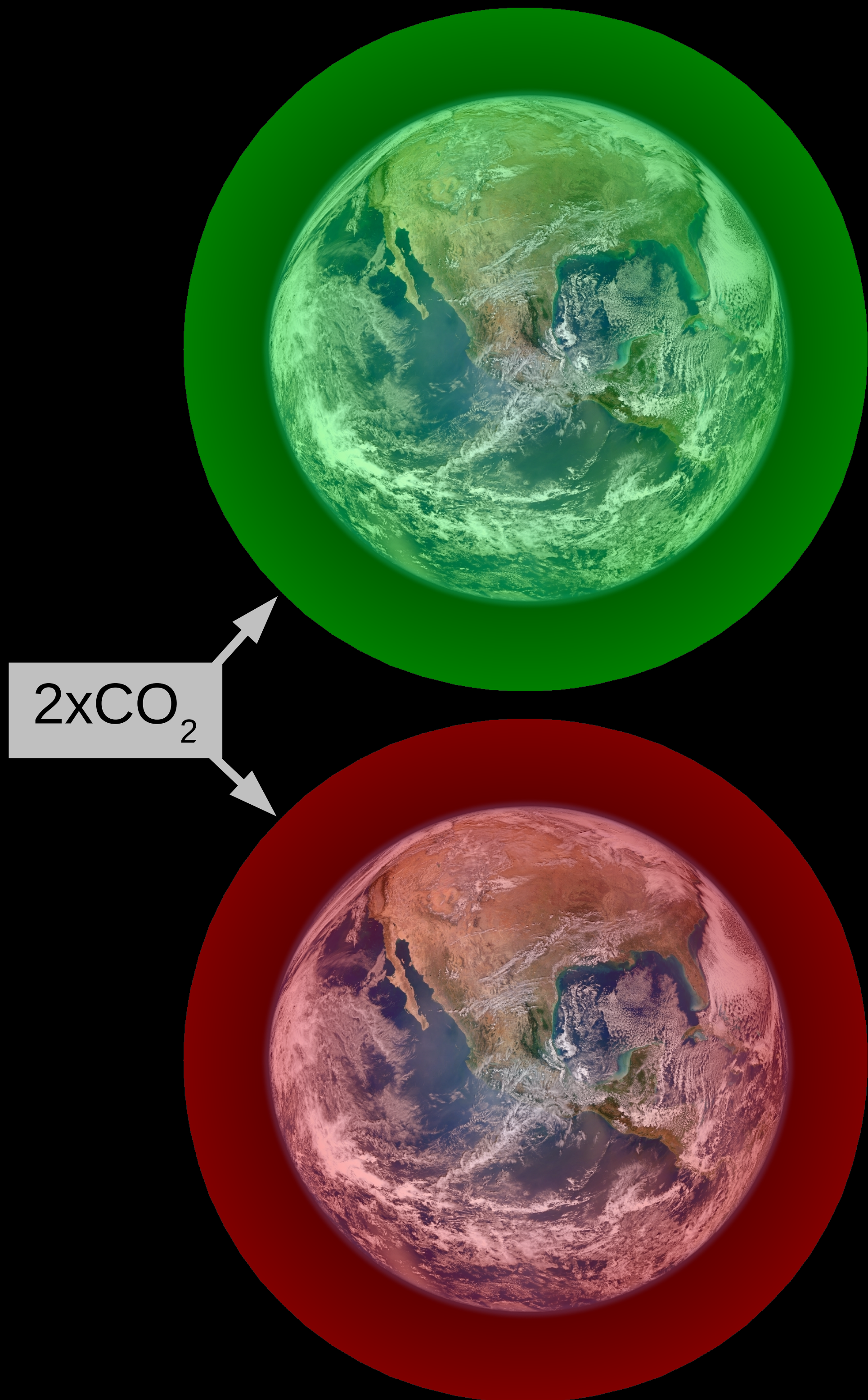
BVOC-aerosol-climate feedback



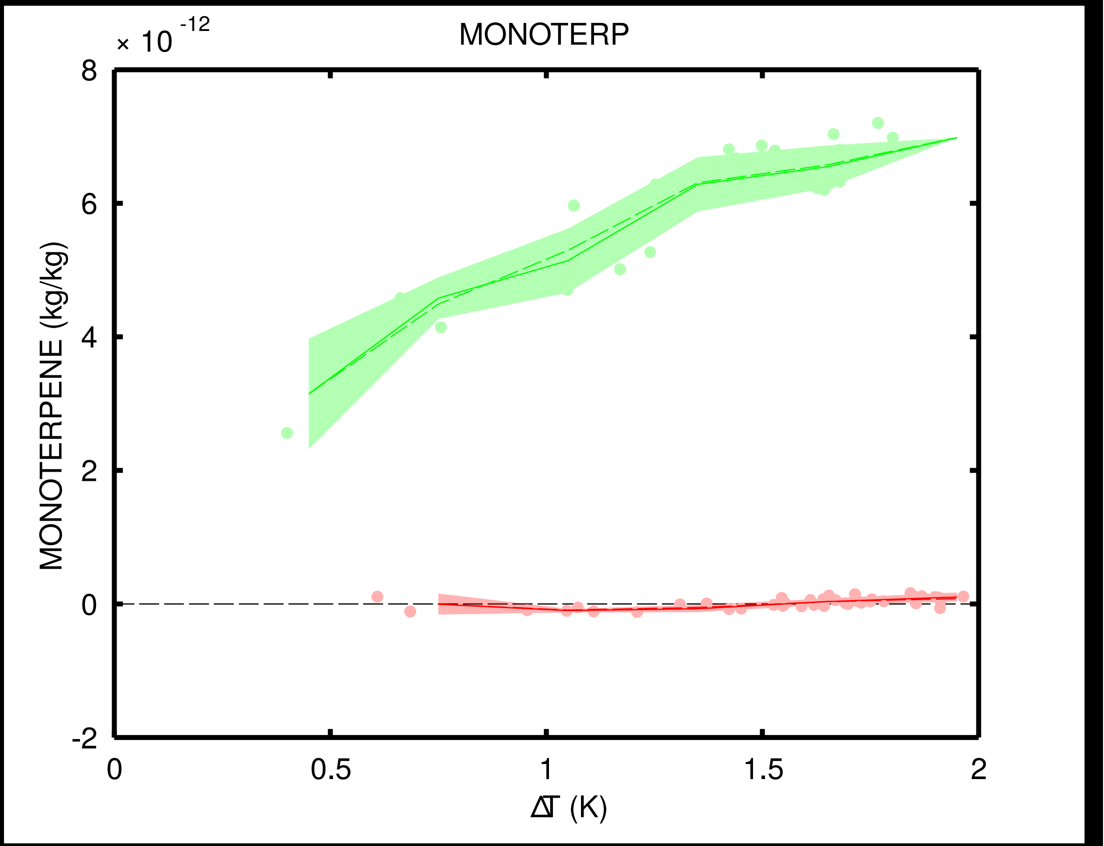

Diffuse radiation
Global radiation
GPP
CS, A_{tot}, V_{tot}
CO_2
BVOC
SOA
T
CCN
CDNC
Diffuse radiation
Global radiation
GPP
CS, A_{tot}, V_{tot}
CO_2
BVOC
SOA
T
CCN
CDNC

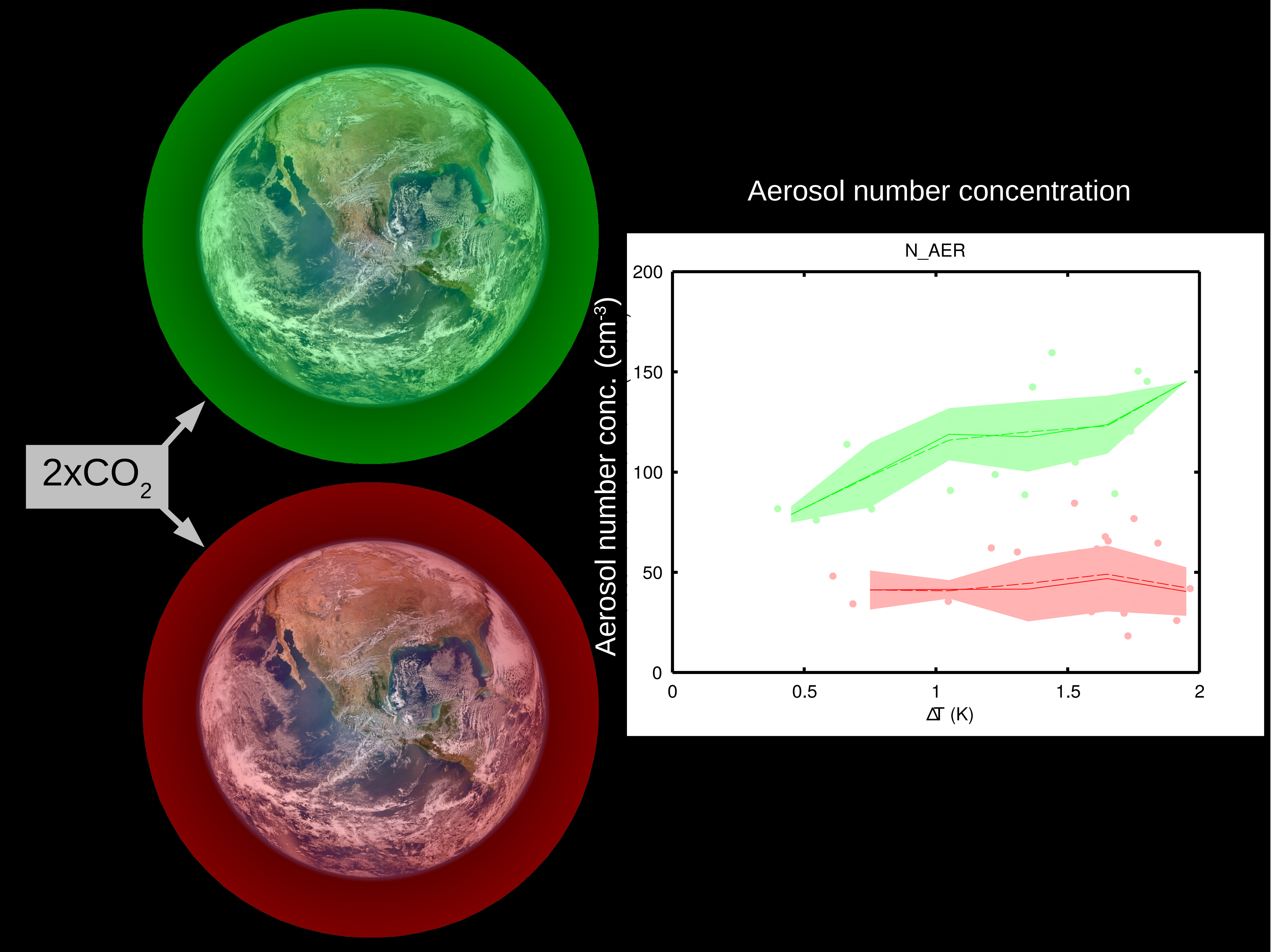

2xCO2
ΔT (K)
Year
ΔT (K)
Year

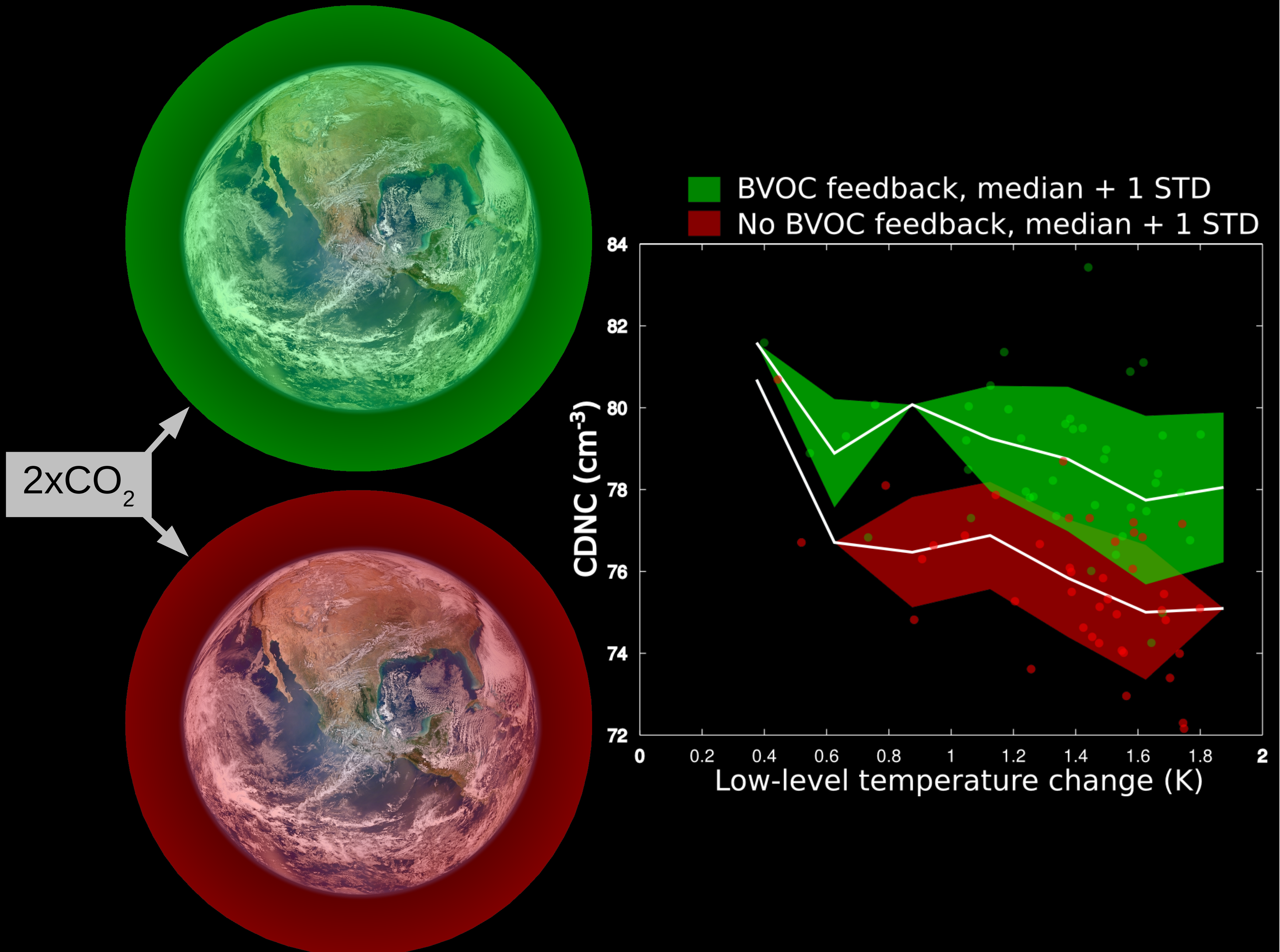

2xCO2
Total precipitation



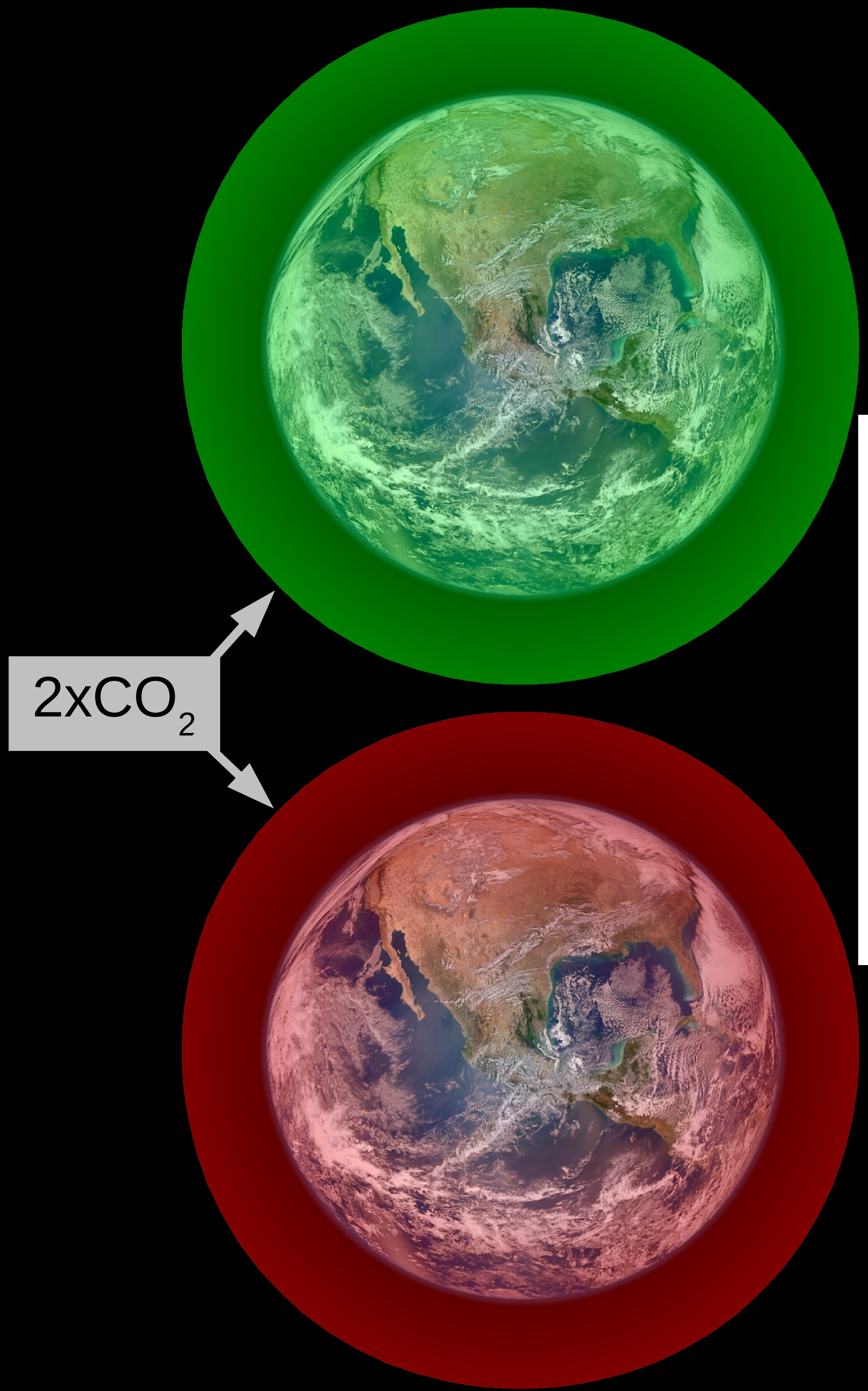
Monoterpene concentration



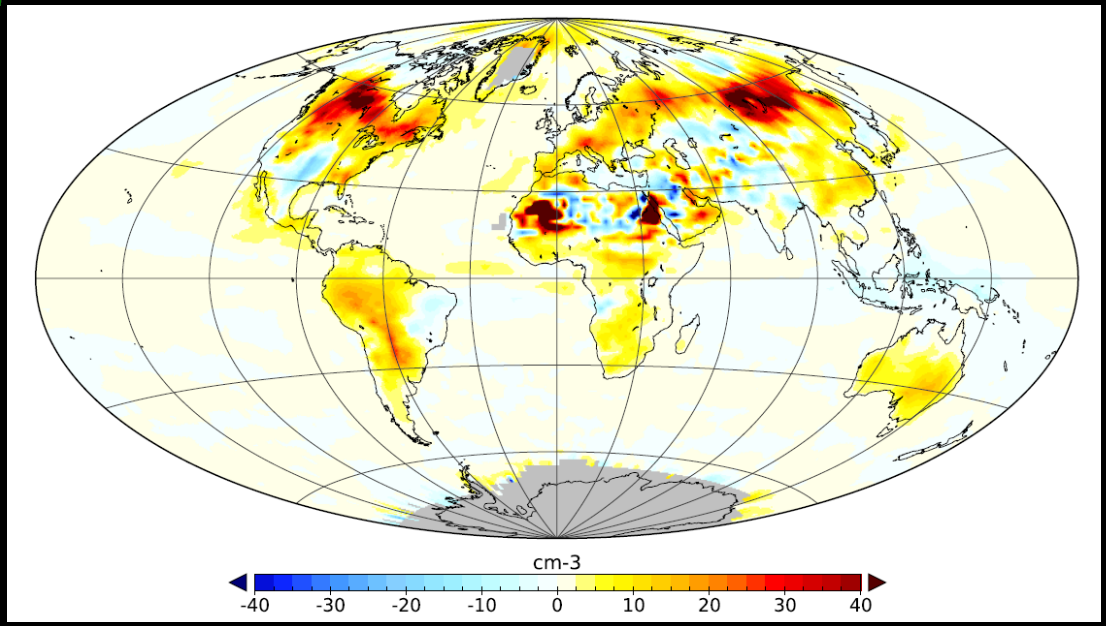

2xCO2
Aerosol number concentration
N_AER
Aerosol number conc. (cm-3)
200
150
100
50
0
0
0.5
1
1.5
2
ΔT (K)

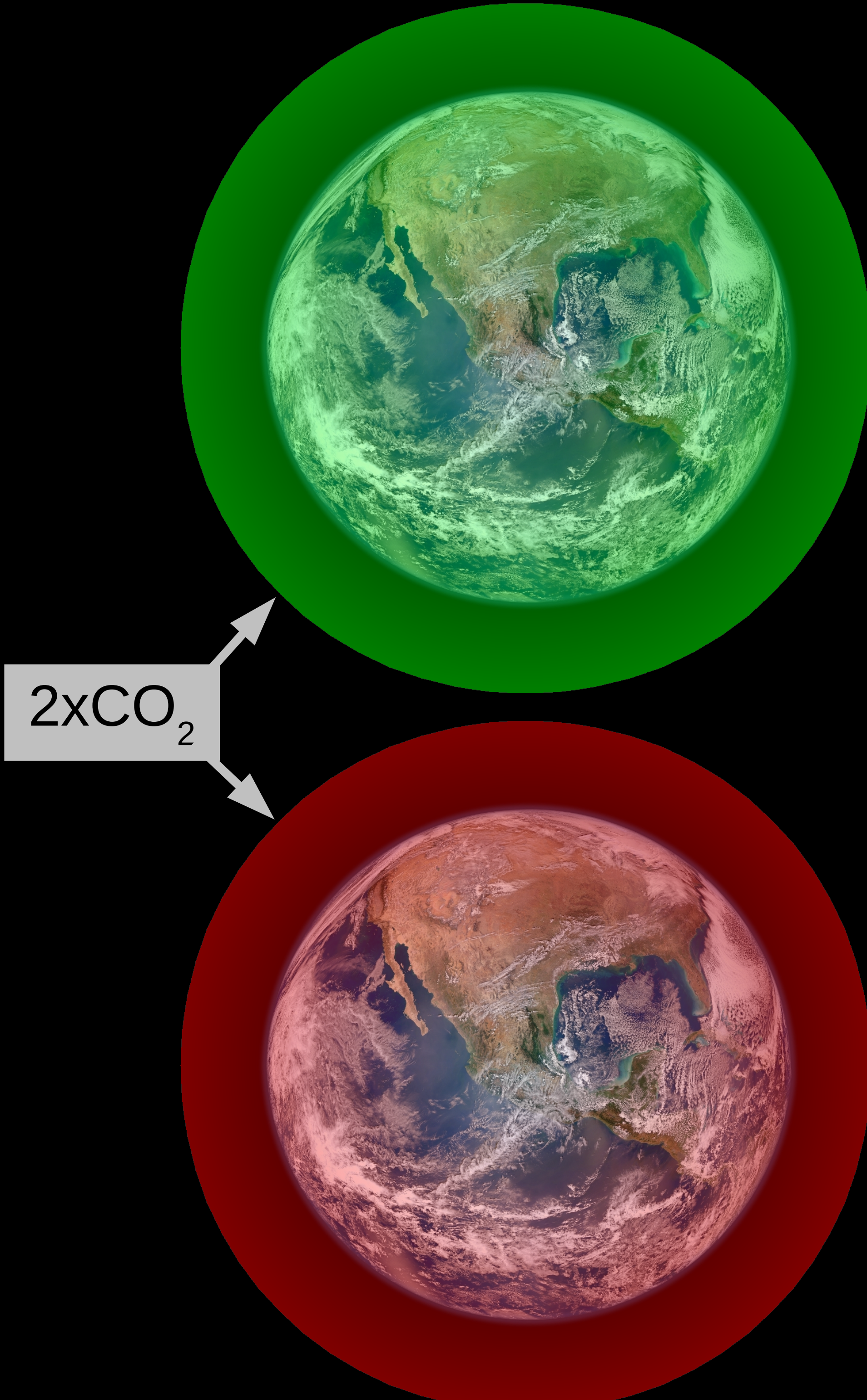


2xCO2
BVOC feedback, median + 1 STD
No BVOC feedback, median + 1 STD
CDNC (cm-3)
84
82
80
78
76
74
72
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Low-level temperature change (K)

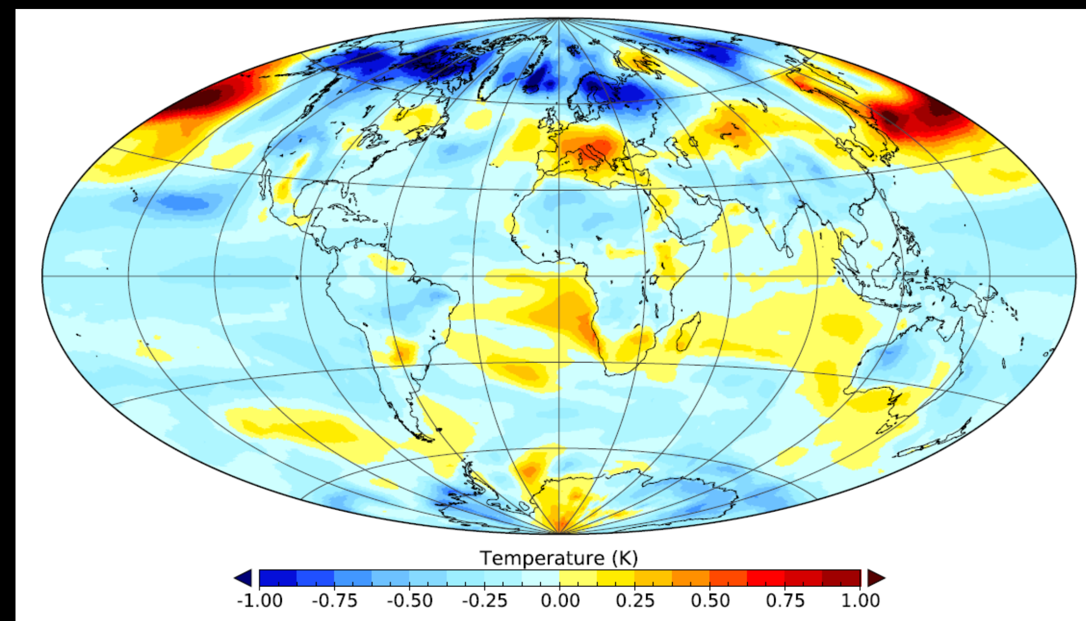


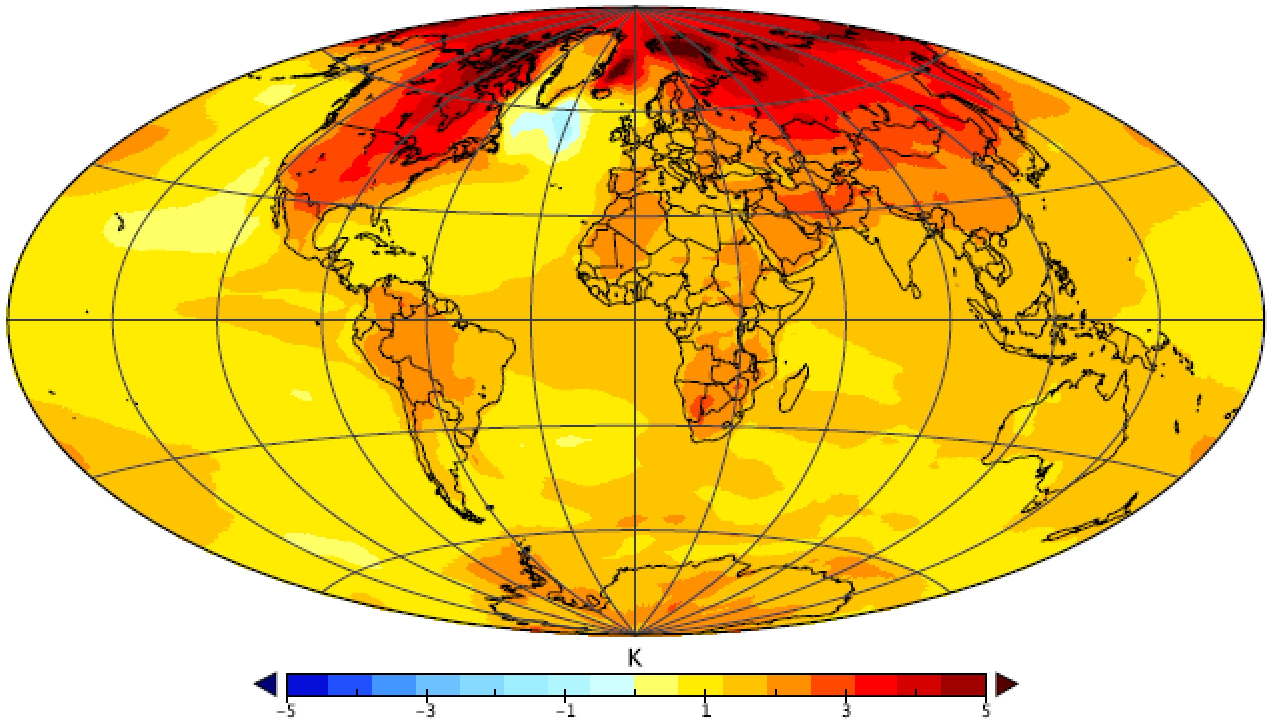
CDNC: FEEDBACK – NO FEEDBACK





Temperature:
FEEDBACK – NO FEEDBACK

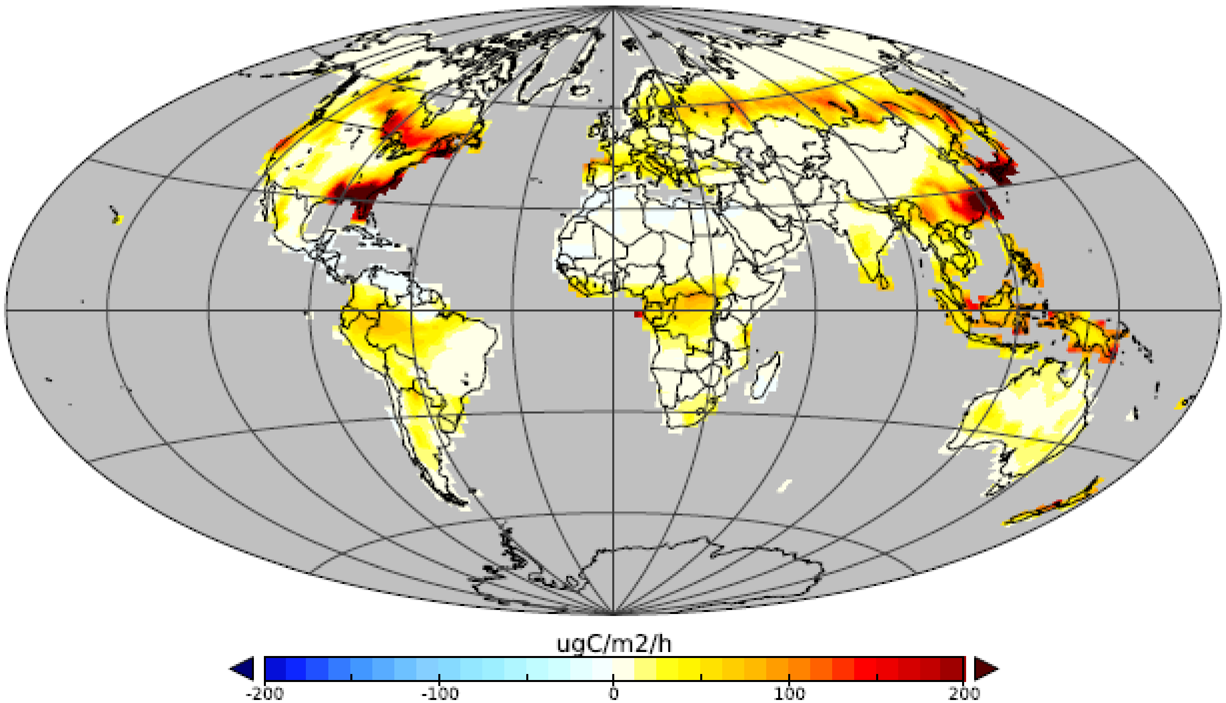




Climate change from doubled CO2

($NoFB\_2xCO_2$ - $NoFB\_1xCO_2$)

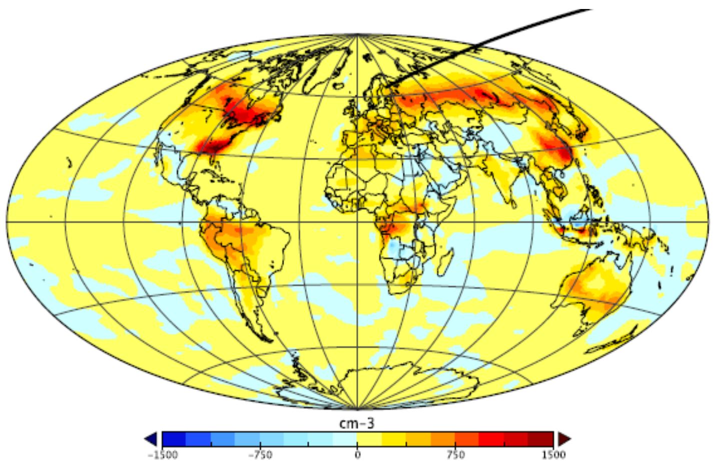
The above figure show the response of the model to doubled CO_2 concentration, with BVOC feedback switched off. Global average atmospheric temperatures increase by ~3.5 K, and the change is most pronounced in the Northern Hemisphere and the Arctic.



Increase of monoterpene emission in warmer climate

(FB_2xCO_2 - CTRL)

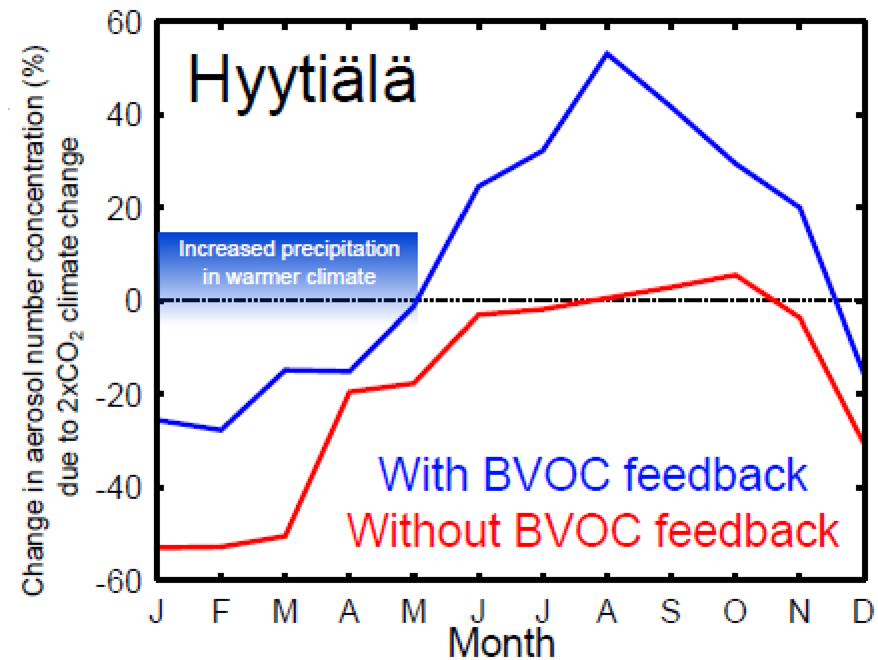
The increase in temperature and CO_2 lead to an increase in biogenic VOC emissions. Monoterpene emissions are increased globally by ~20%.



Increase in aerosol number concentration

(FB_2xCO_2 - CTRL)

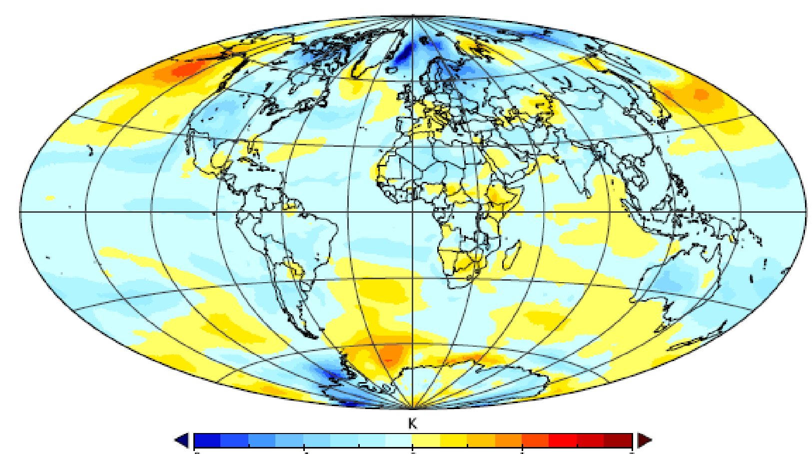
The increase in VOC emission results in increased SOA formation, which both increases aerosol mass and growth of nucleated particles.



The signal from increased BVOC emission is modulated by changes in simulated climate. In Hyytiälä, for example, particle number is increasing in summer due to increased BVOCs, but decreasing in winter due to increased precipitation.

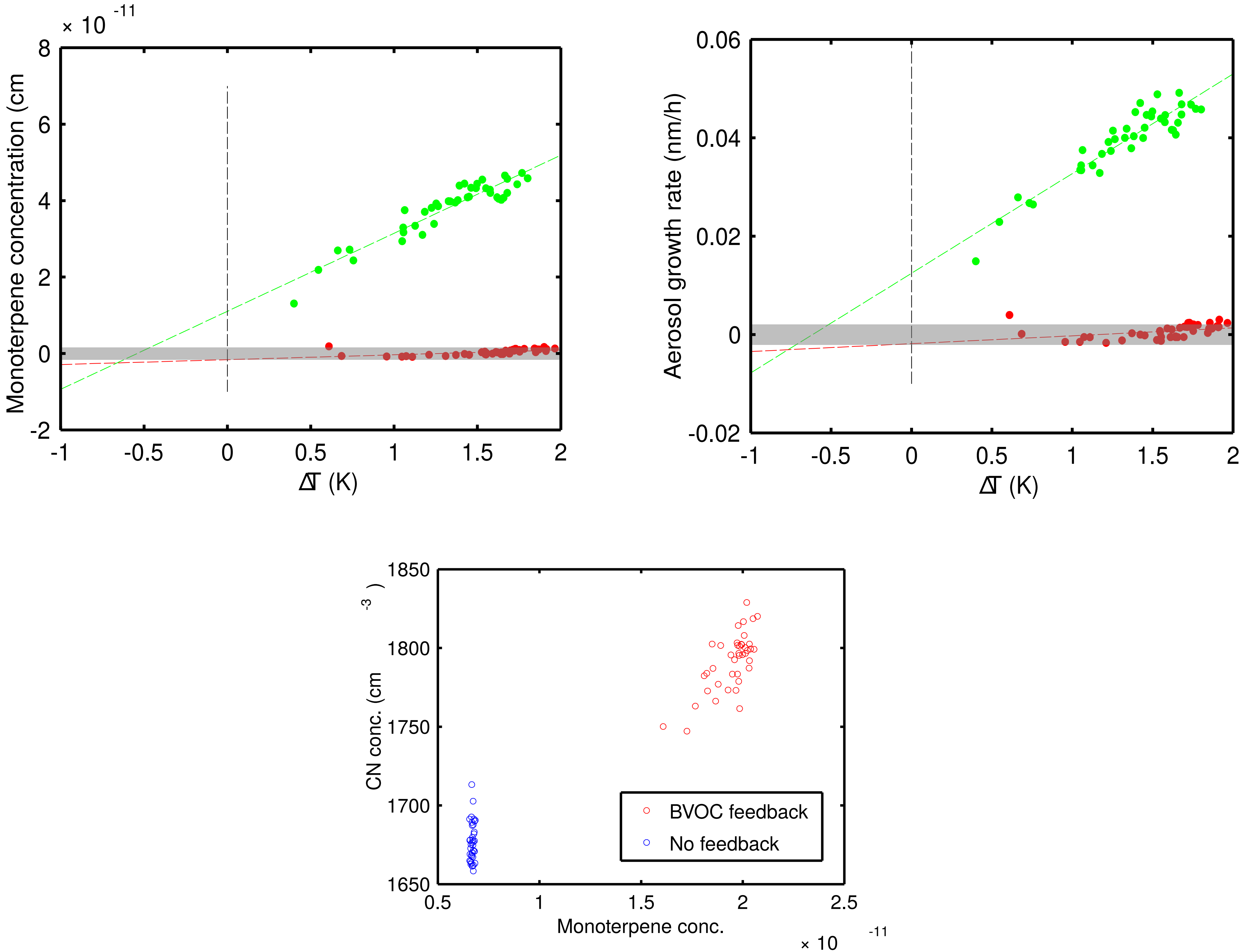
Cooling effect of increased BVOC

Increase in aerosol formation, aerosol optical depth and cloud droplet number concentrations in the $2xCO_2$ climate lead to increased aerosol forcing. The cooling effect of this additional forcing can be seen by comparing the equilibrium temperatures of the experiments (figure on the right). According to the simulations, BVOC-aerosol-climate feedback can act to reduce the climate warming.

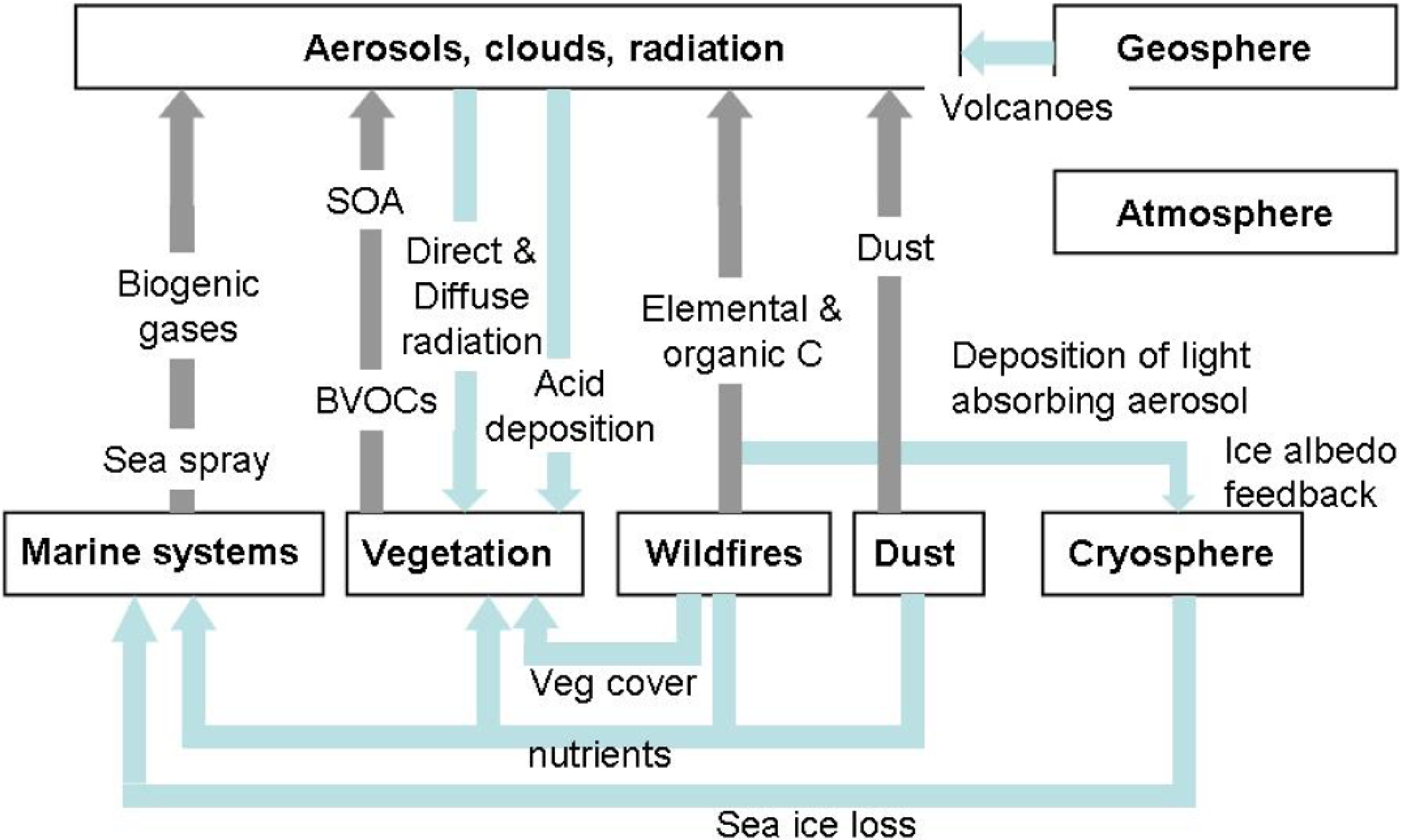


Temperature difference

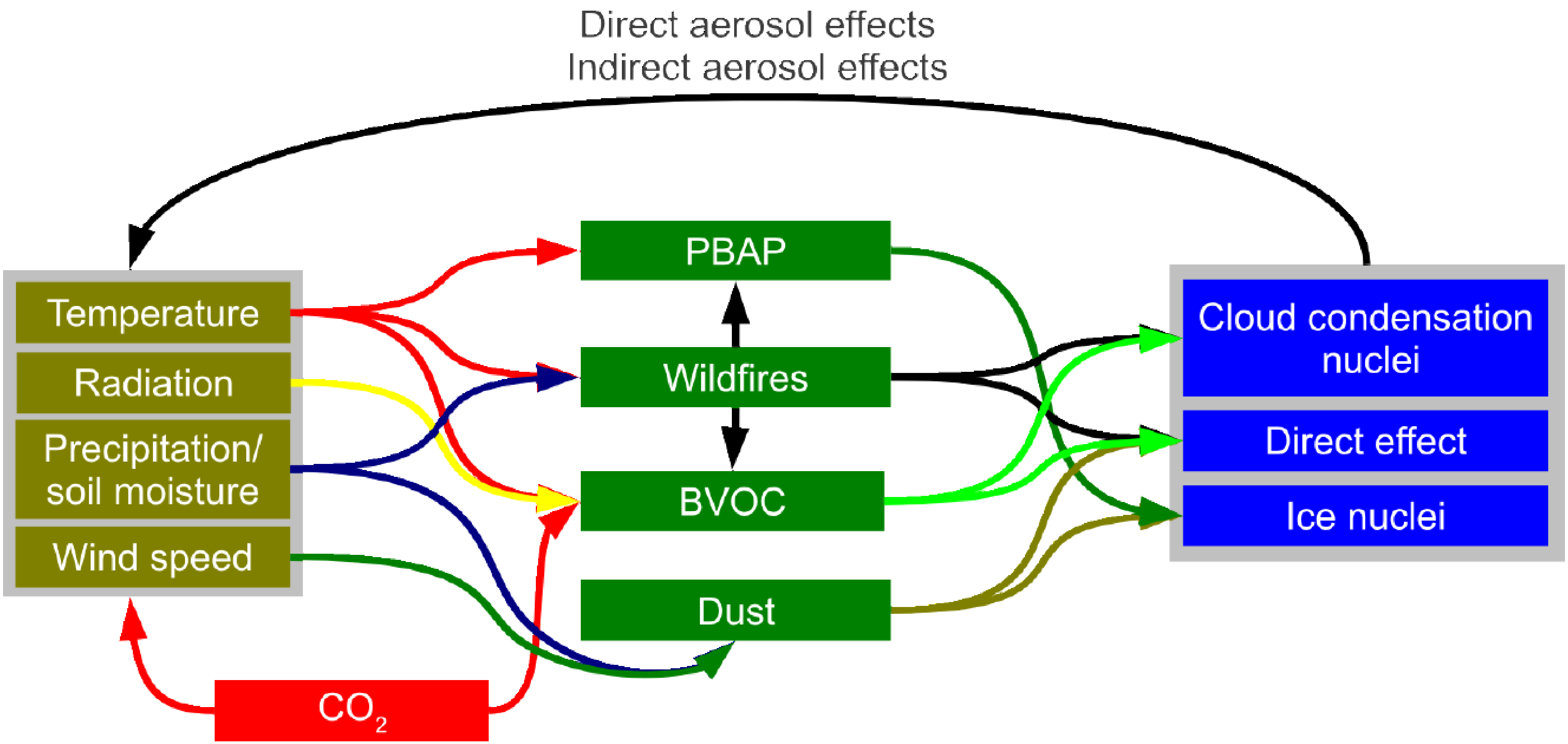
FB_2xCO2 - NoFB_2xCO2



× 10^-11
Monoterpene concentration (cm
ΔT (K)
Aerosol growth rate (nm/h)
ΔT (K)
CN conc. (cm^-3)
Monoterpene conc.
× 10^-11
BVOC feedback
No feedback

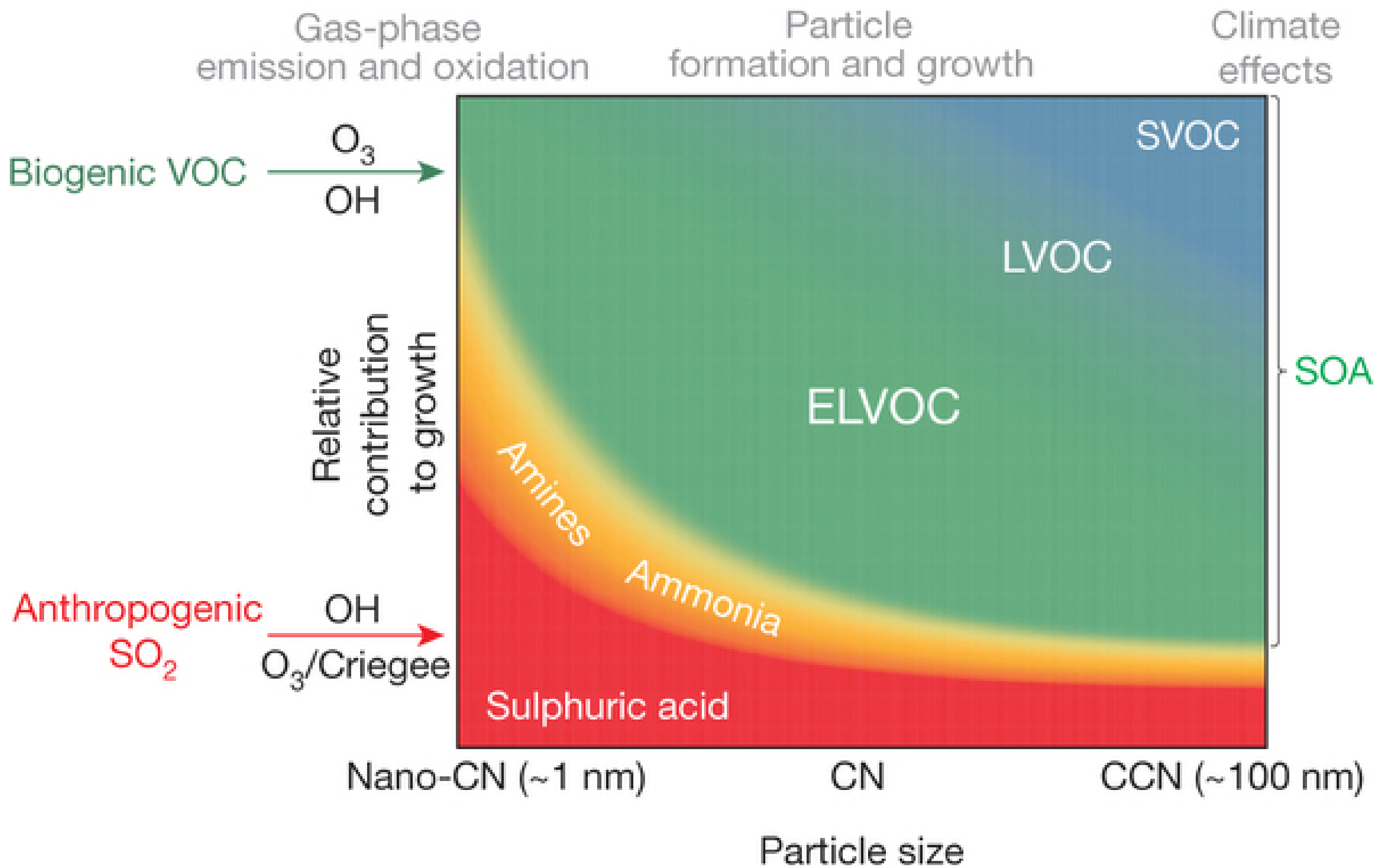


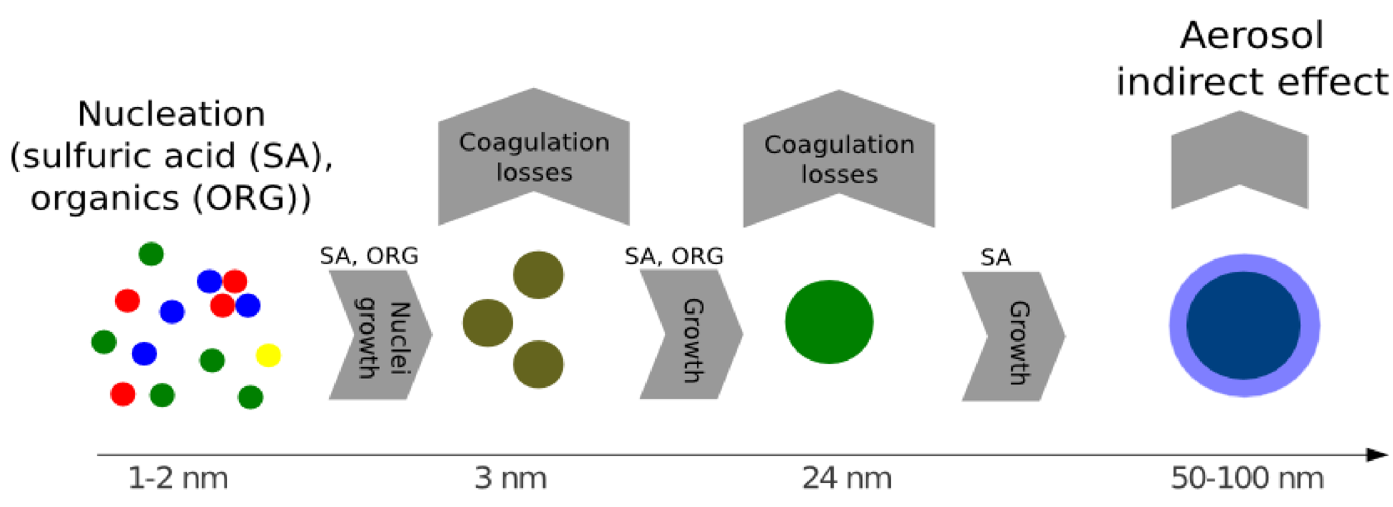
Carslaw et al., 2010



Direct aerosol effects
Indirect aerosol effects
Temperature
Radiation
Precipitation/
soil moisture
Wind speed
PBAP
Wildfires
BVOC
Dust
Cloud condensation
nuclei
Direct effect
Ice nuclei
CO2

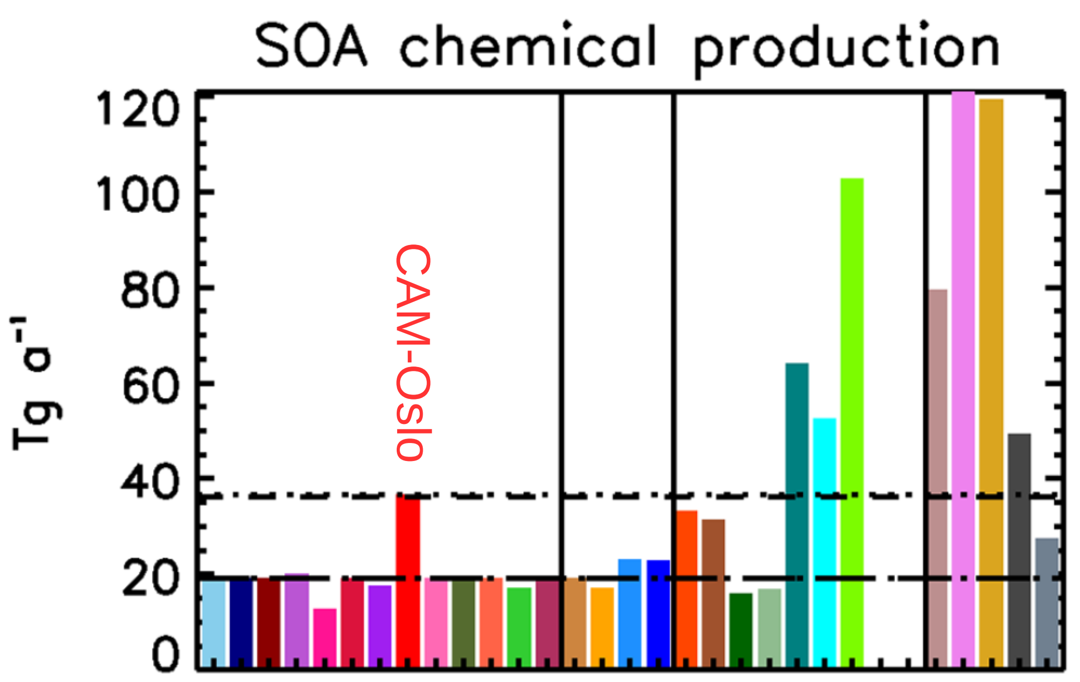
Extremely Low-volatility organic compounds (ELVOCs)





Near-future work

- (Aerosol-)climate feedback simulations for CRAICC
- Evaluation of Arctic aerosols in CRAICC/PEEX/eSTICC
- Implement new nucleation mechanisms (e.g. ion-induced)
- Implementing/improving ELVOC-chemistry in NorESM-NPF, working towards "missing SOA"



Tsigaridis et al., 2014

Spracklen et al., 2011: 50-380 Tg/a (140 Tg/a best estimate)