A Large Forcing Attributed to the Variability of Biomass Burning Emissions in CESM2

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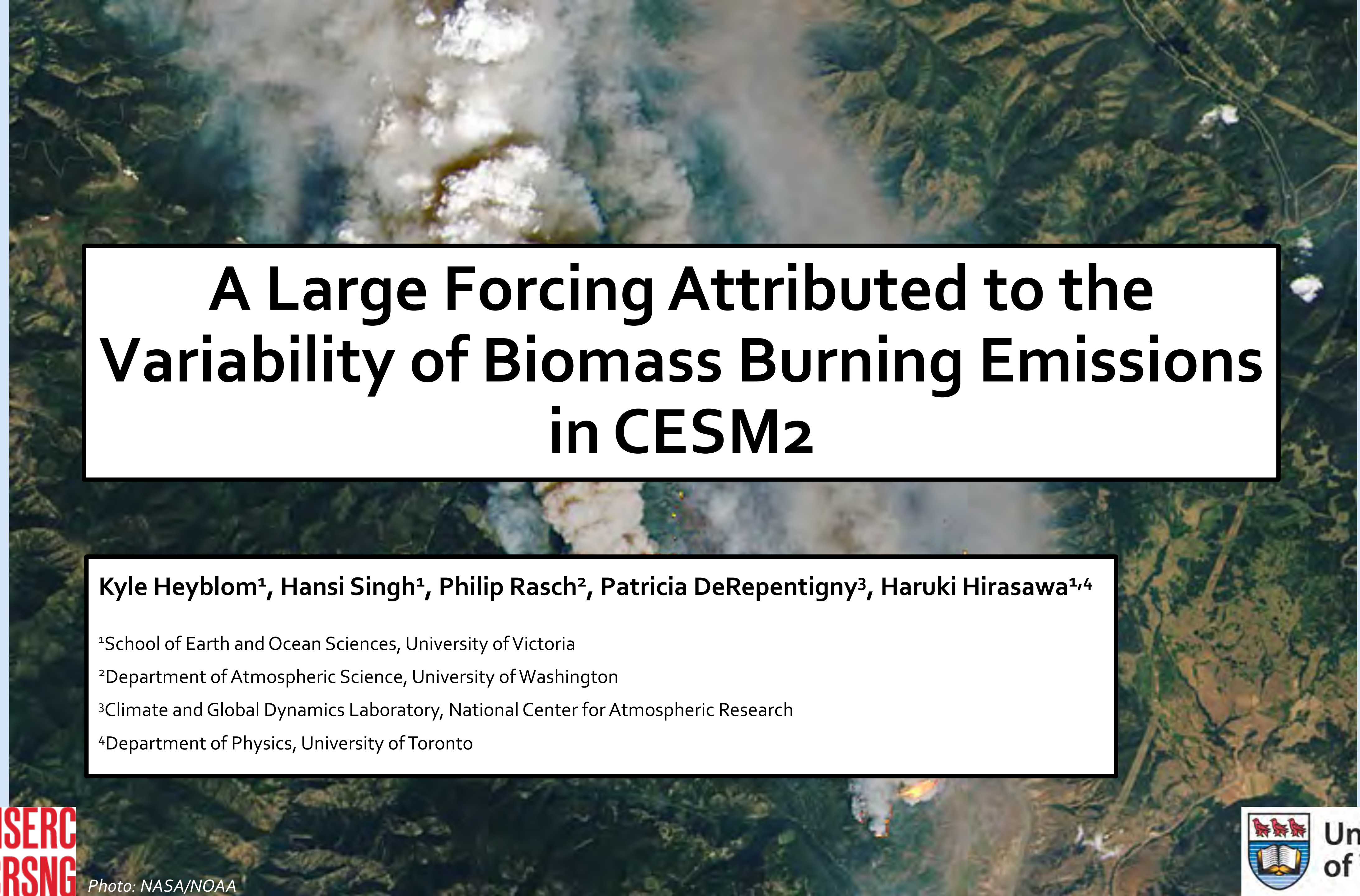


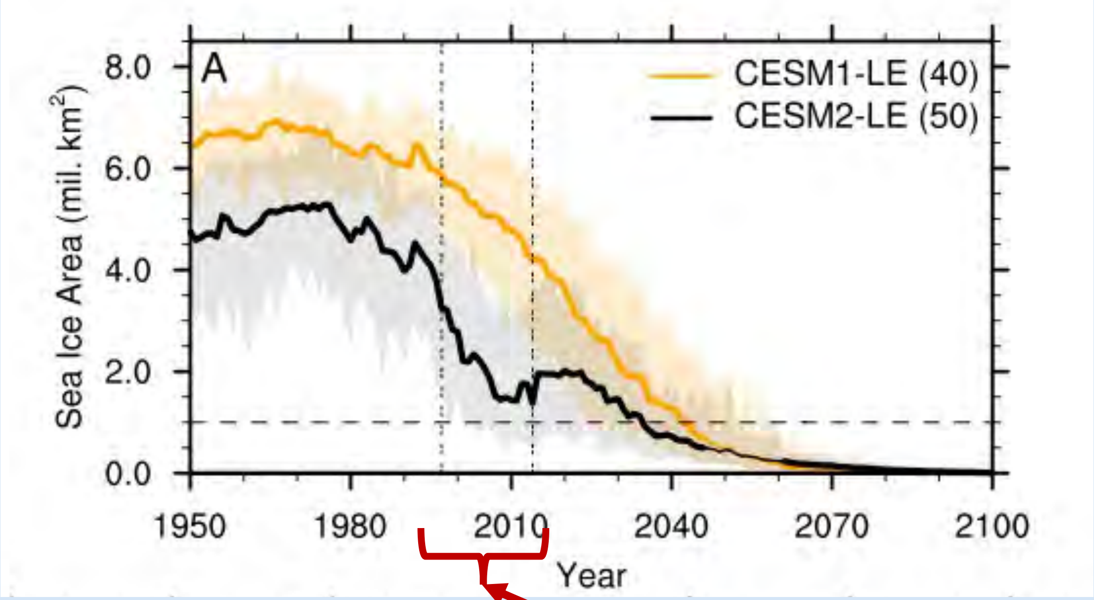
Photo: NASA/NOAA

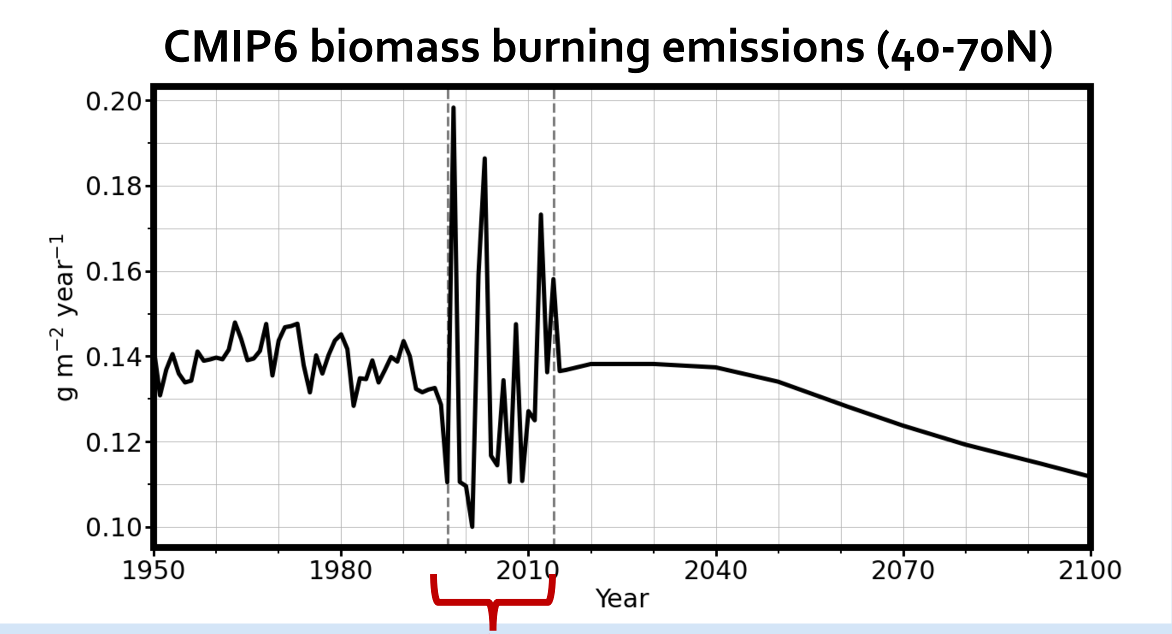
NSERC CRSNG

University of Victoria

CESM2 shows rapid decline in Arctic sea ice in CMIP6 historical runs

Simulated variability the result of satellite observations



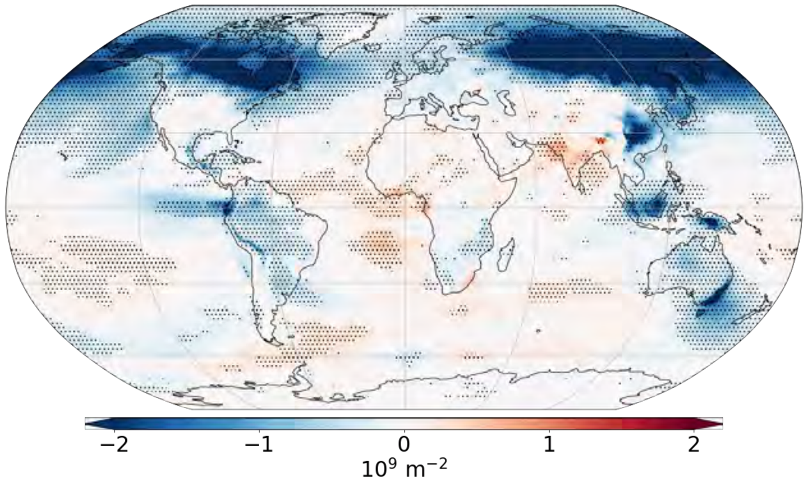


Enhanced SIA loss due to emissions variability

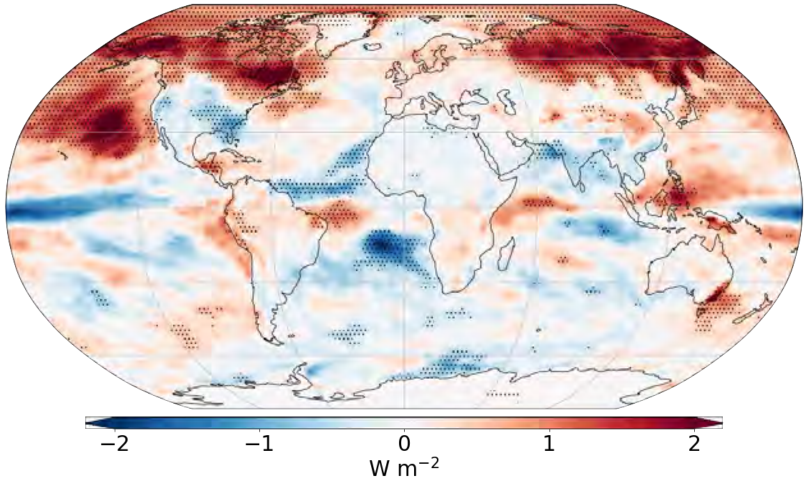
(DeRepentigny et al., in-review at Science Advances)

Sudden increase in biomass burning (BB) emissions variability leads to surface warming in CESM2

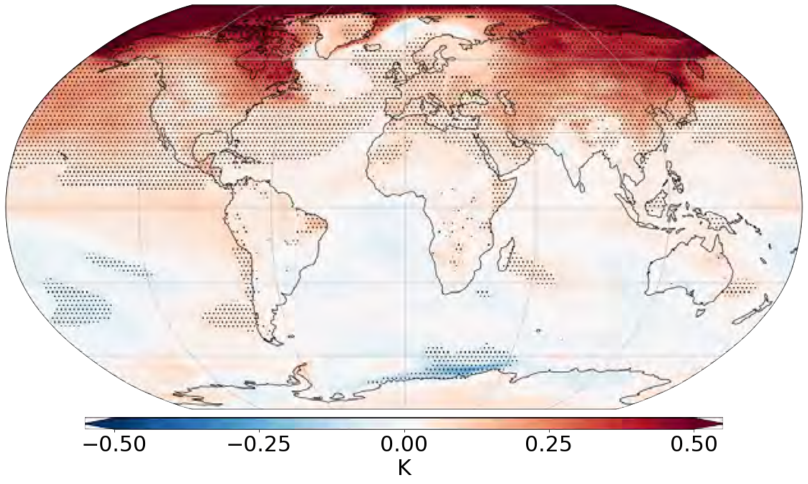
Cloud droplet number concentration:



Net Surface SW:



Surface temperature:

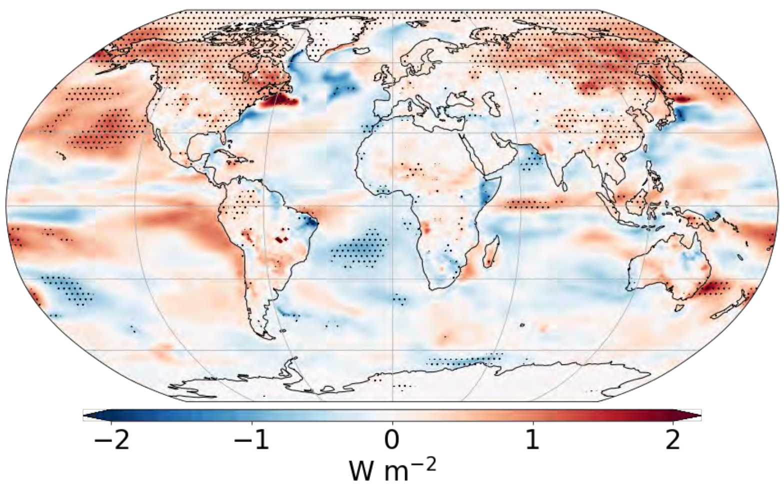


Due to increase in BB emissions variability

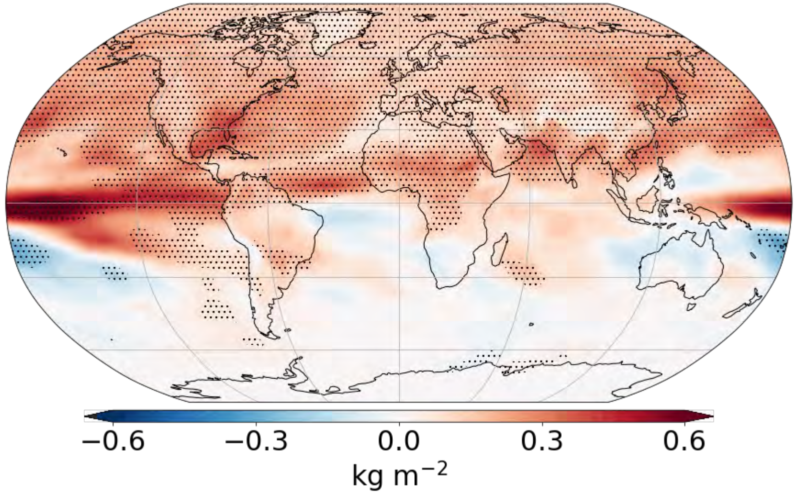
(Fasullo et al., 2022; DeRepentigny et al., in-review; Heyblom et al. 2022)

Increase in BB emissions variability leads to amplified hydrologic cycle in CESM2-LE

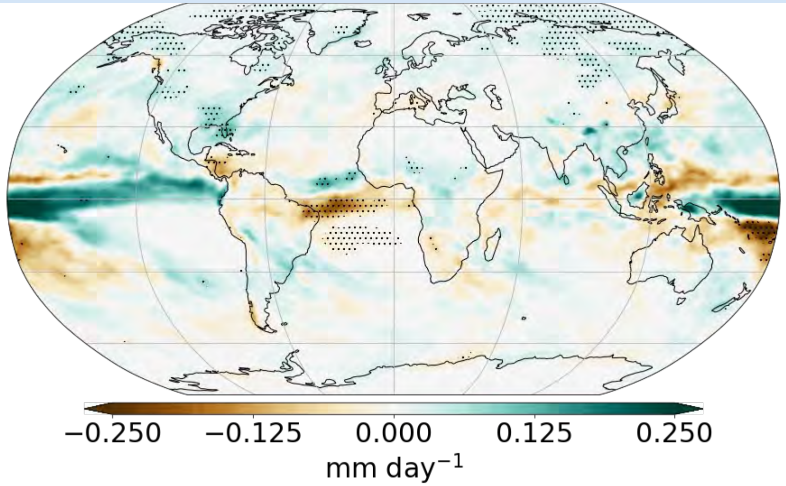
Evaporation:



Precipitable water:



Precipitation:



40-90° N:
0.3 W m^{-2}
(0.8% increase)

40-90° N:
0.2 kg m^{-2}
(1.4% increase)

40-90° N:
0.01 mm day^{-1}
(0.5% increase)

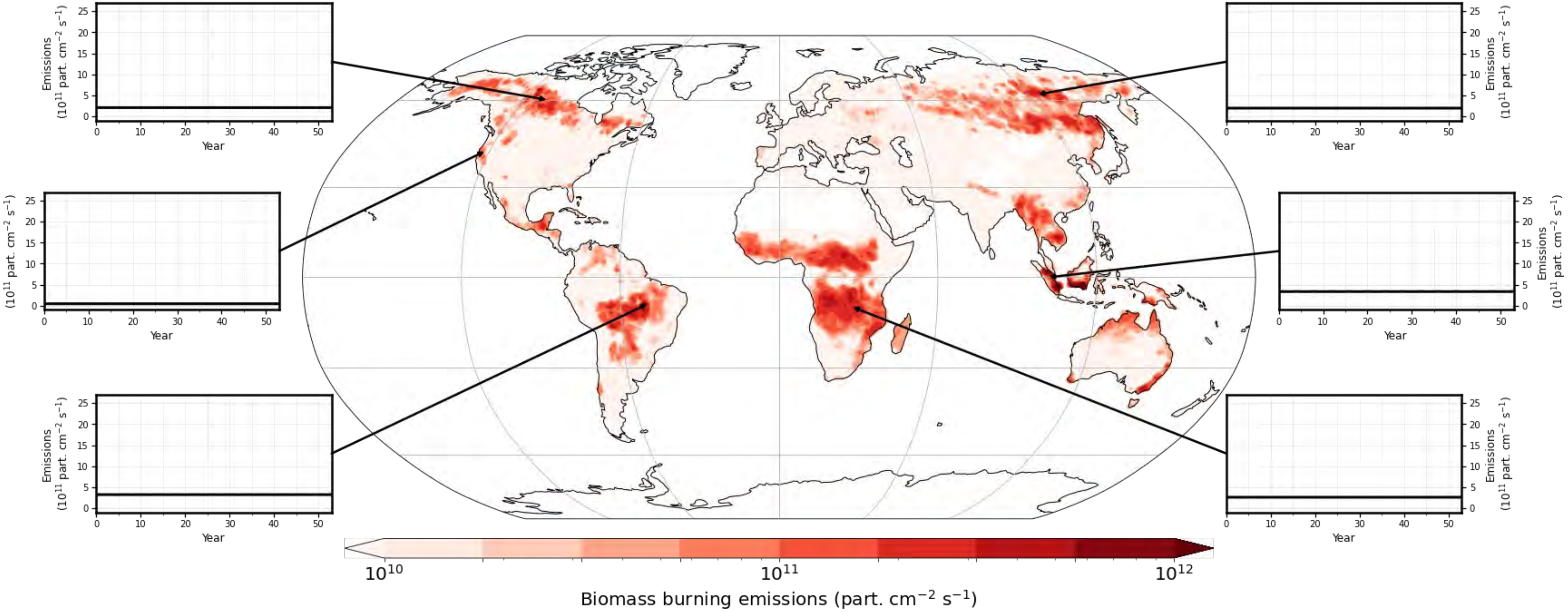
***~6% of signal** from 1950-1980 to 2070-2100*

(Heyblom et al. 2022, GRL)

How does considering variability in BB emissions affect the radiative forcing?

Idealized simulations →

- CESM2
- Fixed SSTs
- Fixed sea ice concentrations
- Constant 2000's climatology



Fixed emissions (baseline)

Idealized simulations →

- CESM2
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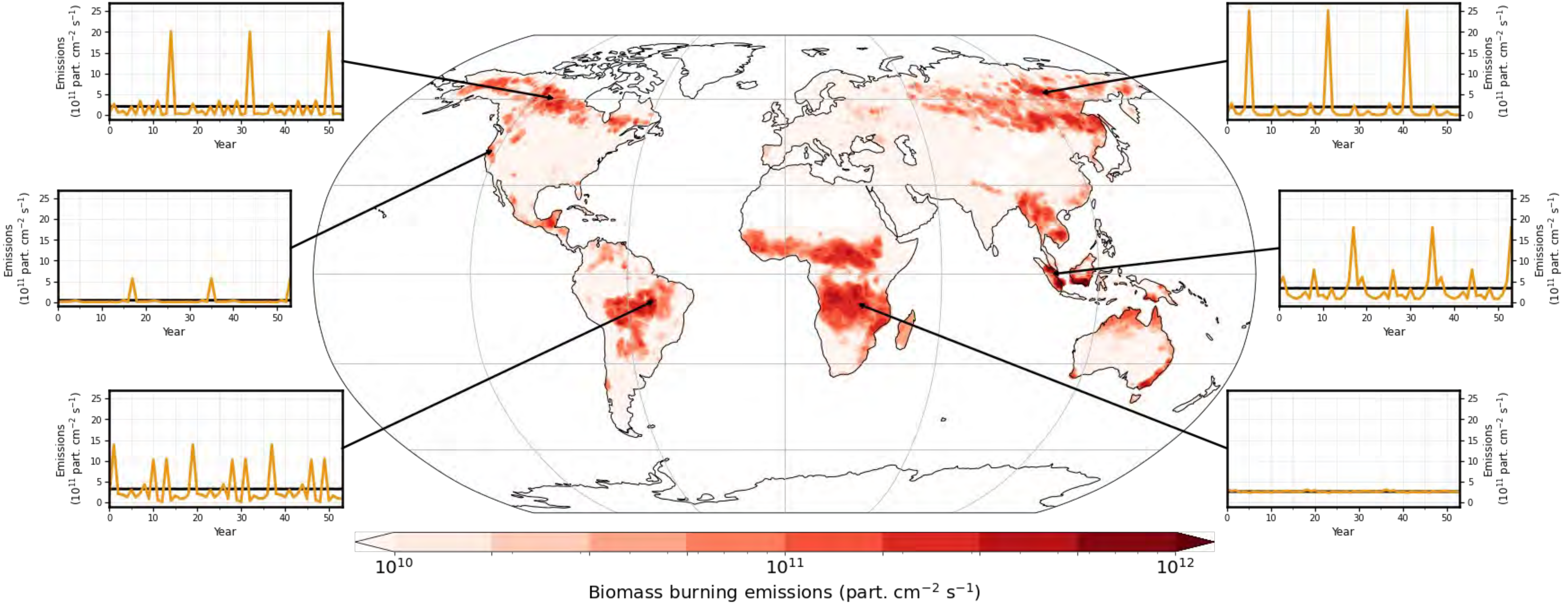
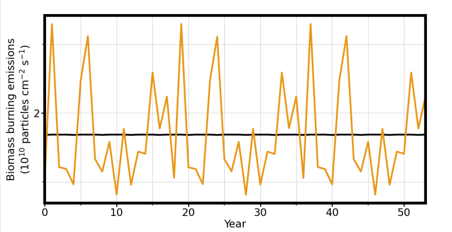


Fixed emissions (baseline) **CMIP6 high variability emissions**

Variability in BB emissions leads to a large increase in forcing over Boreal land regions

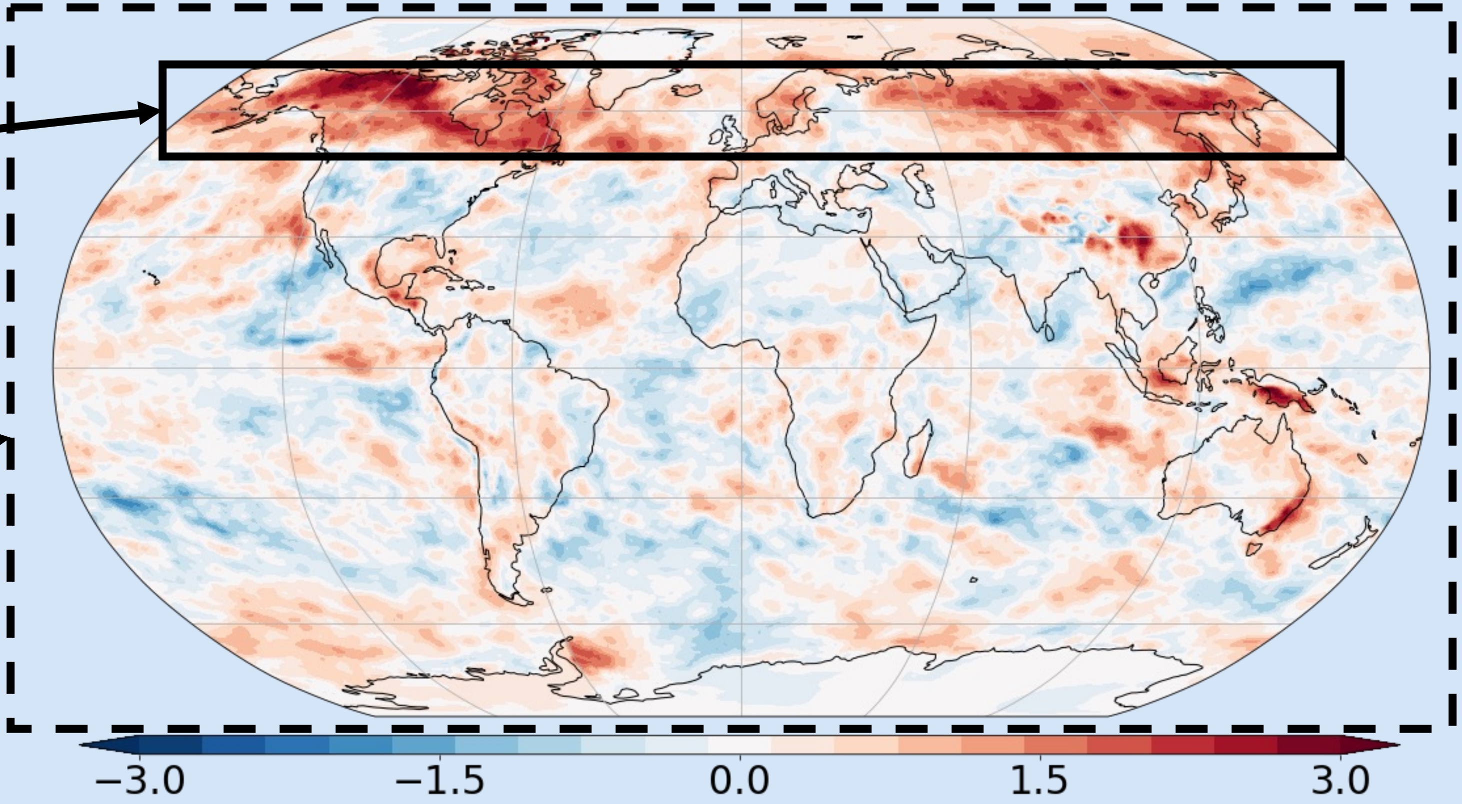
***Forcing due to CMIP6 emissions variability**



Radiative Forcing Change (W m^{-2}):

50-70N:
1.0 W m^{-2} annual mean increase

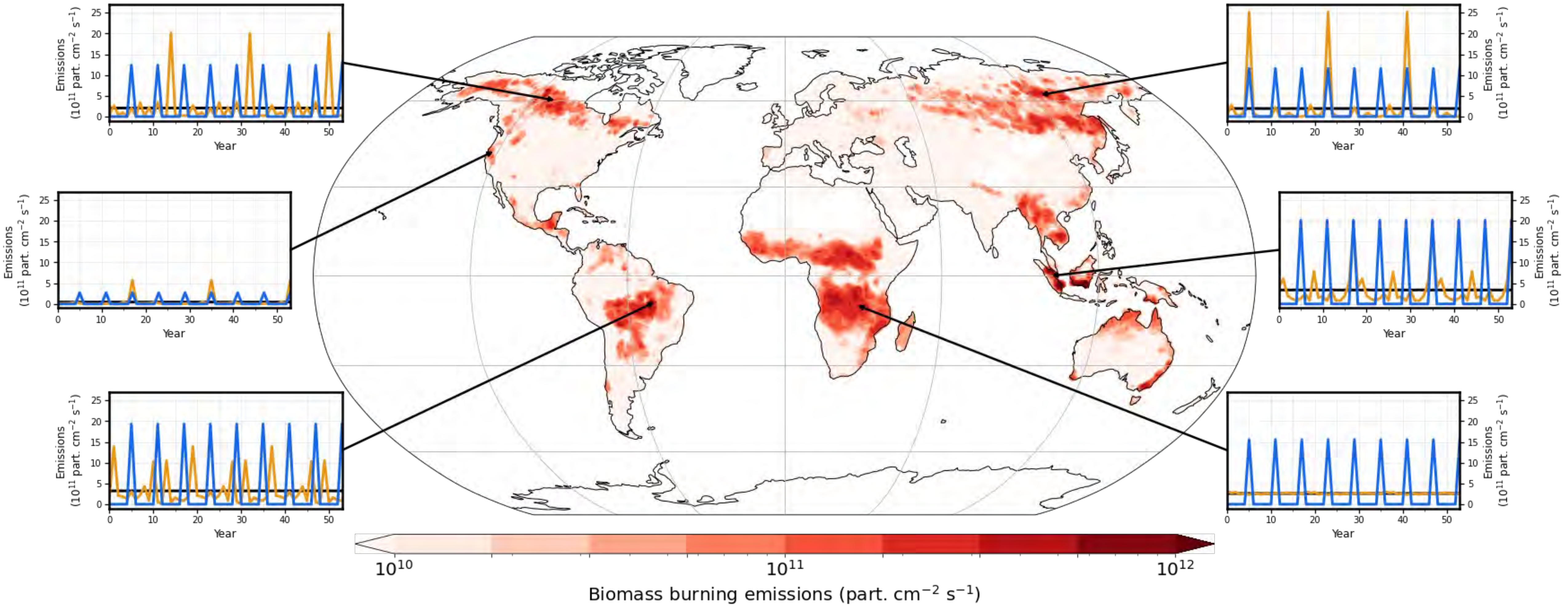
Globally:
0.1 W m^{-2} annual mean increase



Why do we see a change in radiative forcing?

Idealized simulations →

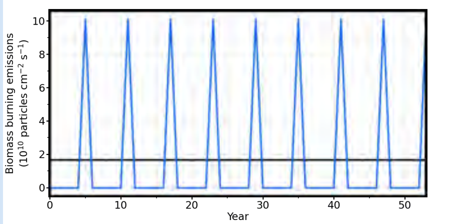
- CESM2
- Fixed SSTs
- Fixed sea ice concentrations
- Constant 2000's climatology



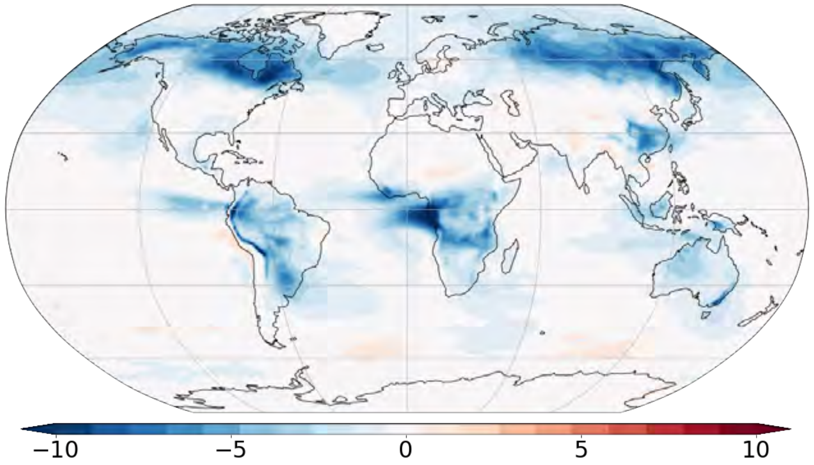
Fixed emissions (baseline) **CMIP6 high variability emissions** **Idealized variability**

Cloud effect results in time-integrated forcing

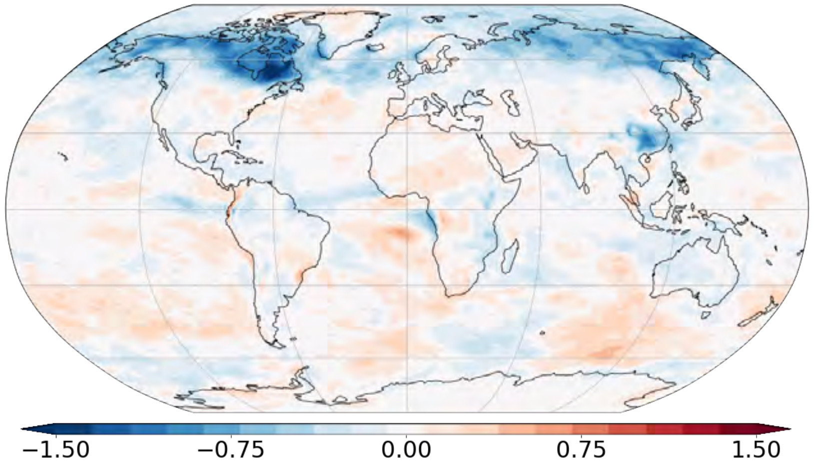
*Using idealized emissions variability



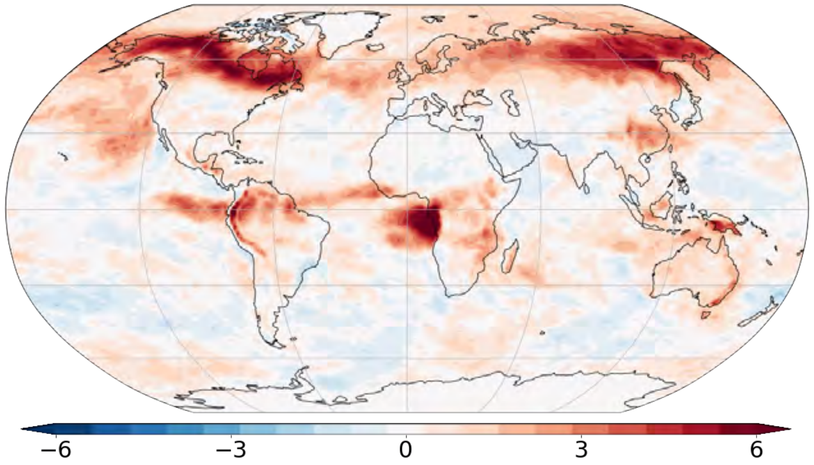
CDNC (10^9 m^{-2}):



LWP (10^{-2} kg m^{-2}):



CRE (W m^{-2}):



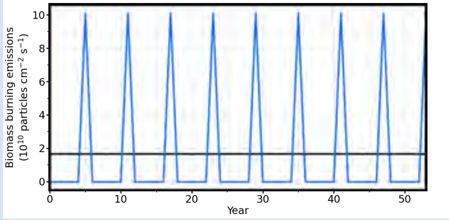
Thinner clouds

Less clouds

More SW reaching surface due to cloud differences

Cloud effect results in time-integrated forcing

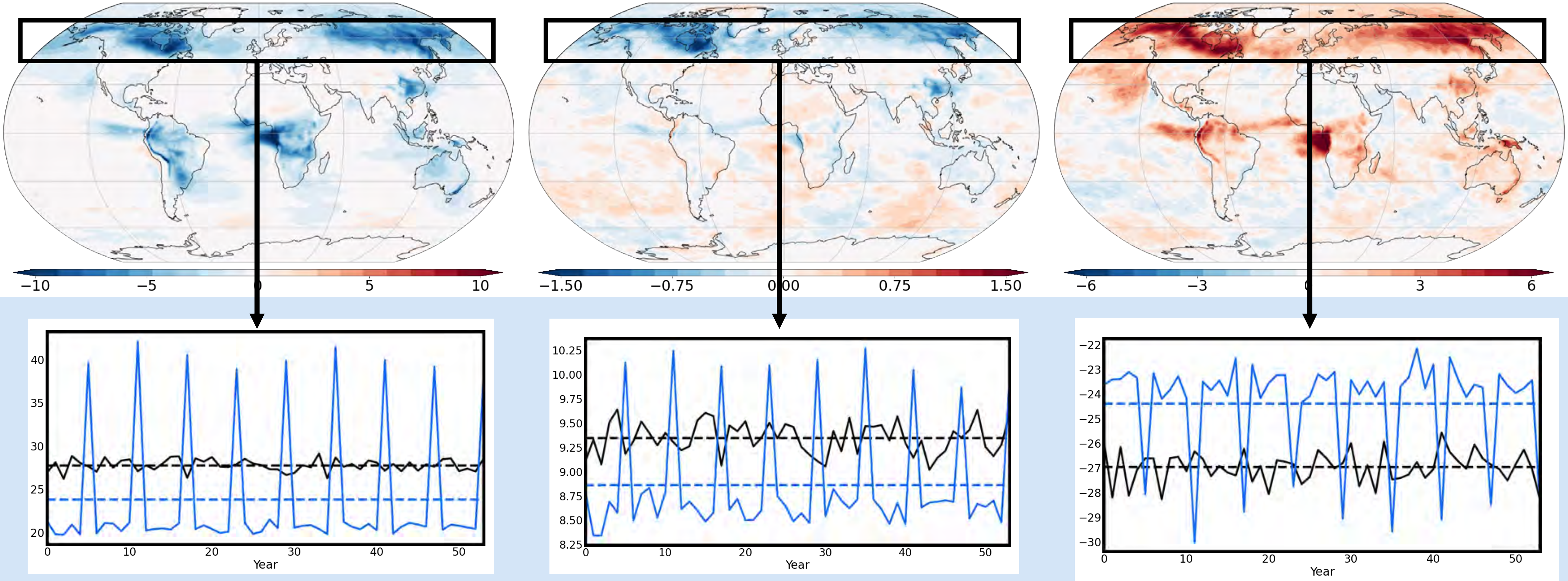
*Using idealized emissions variability



CDNC (10^9 m^{-2}):

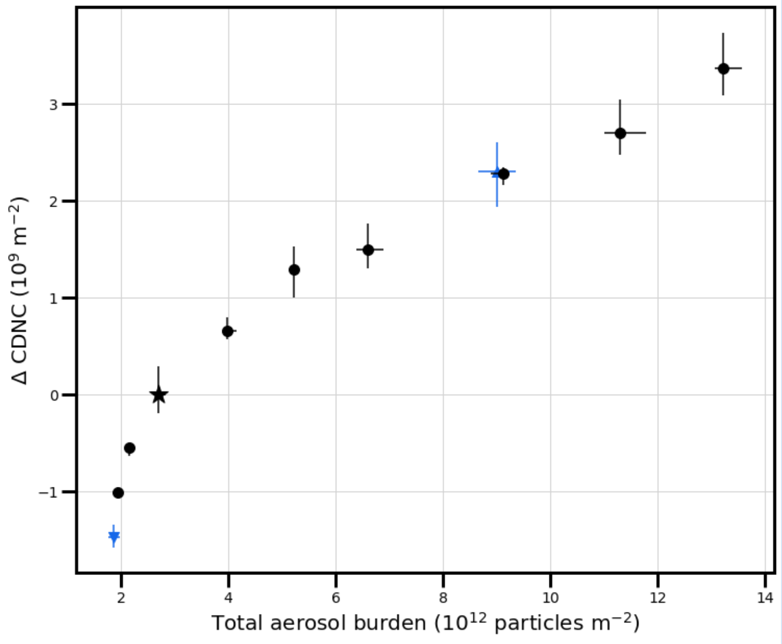
LWP (10^{-2} kg m^{-2}):

CRE (W m^{-2}):

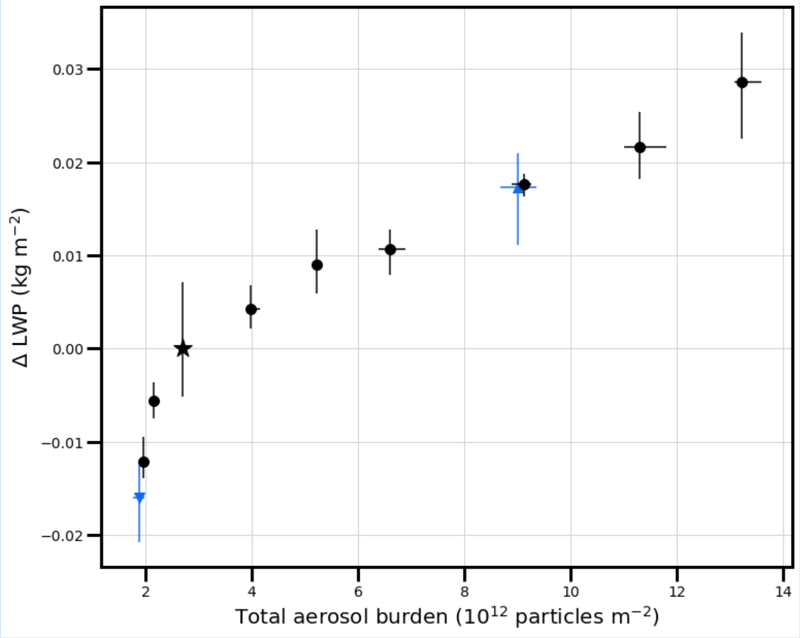


Time-integrated forcing the result of nonlinear aerosol-cloud response

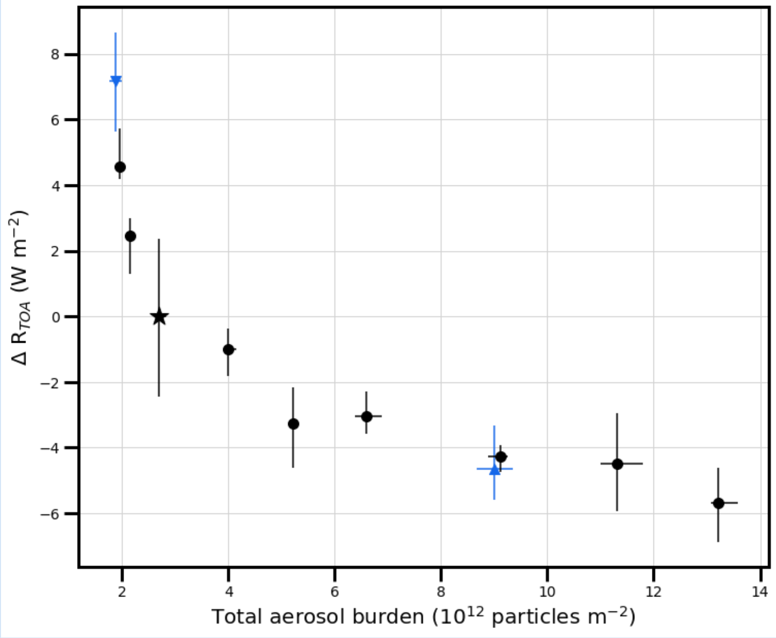
CDNC:



LWP:



Forcing:

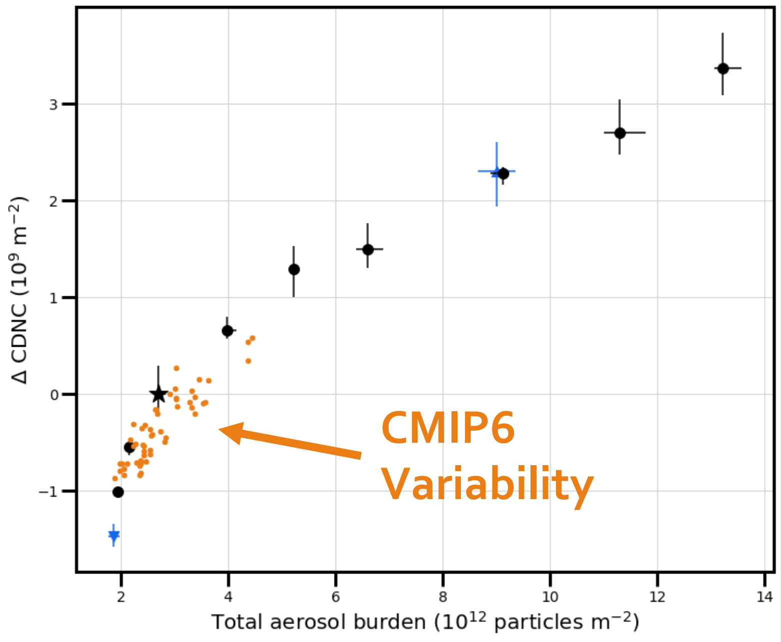


Nonlinear aerosol-cloud response* → **Nonlinear response in forcing**

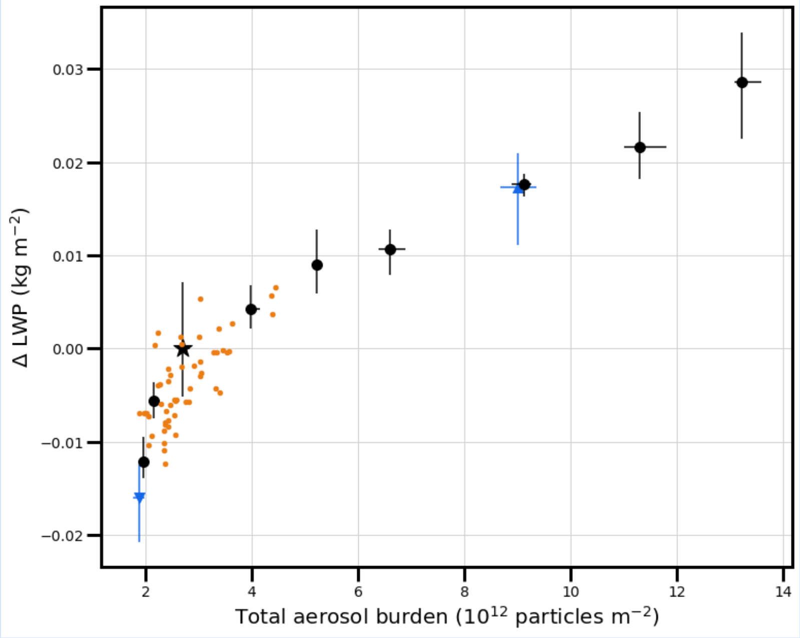
*Nonlinearity between aerosol burden and clouds shown by *Carslaw et al. (2013), Nature*

Time-integrated forcing the result of nonlinear aerosol-cloud response

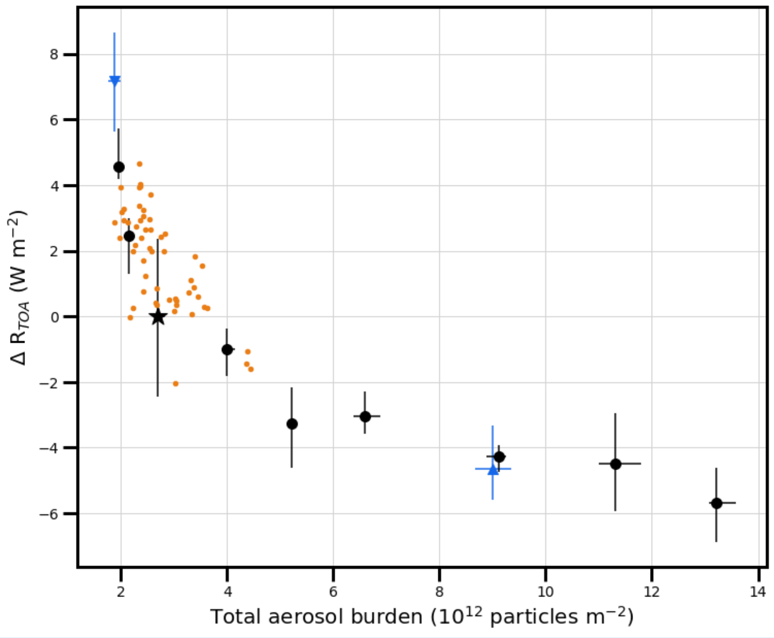
CDNC:



LWP:



Forcing:



Nonlinear aerosol-cloud response* → **Nonlinear response in forcing**

Time-integrated forcing the result of nonlinear aerosol-cloud response

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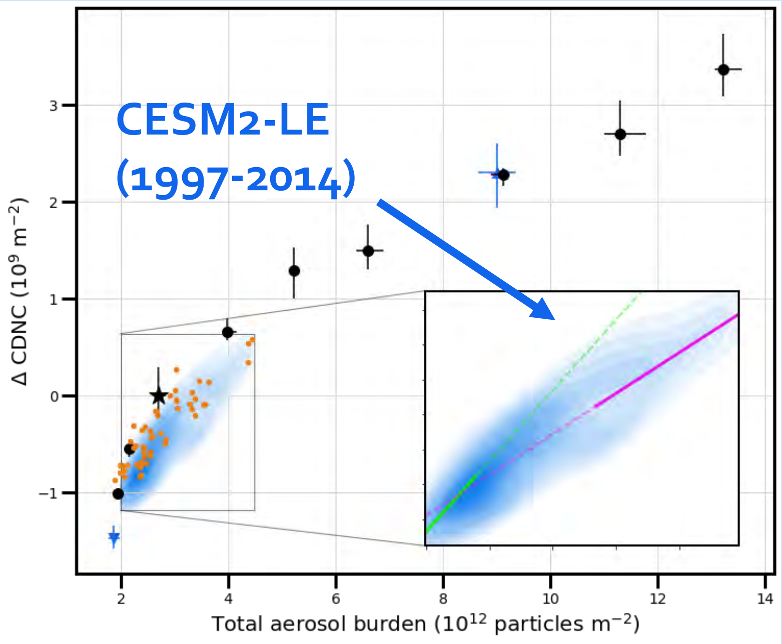
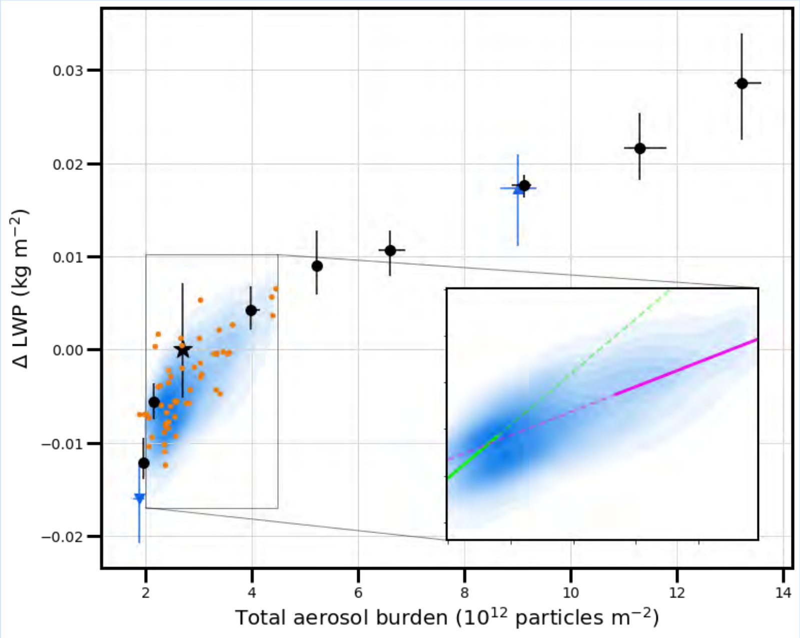
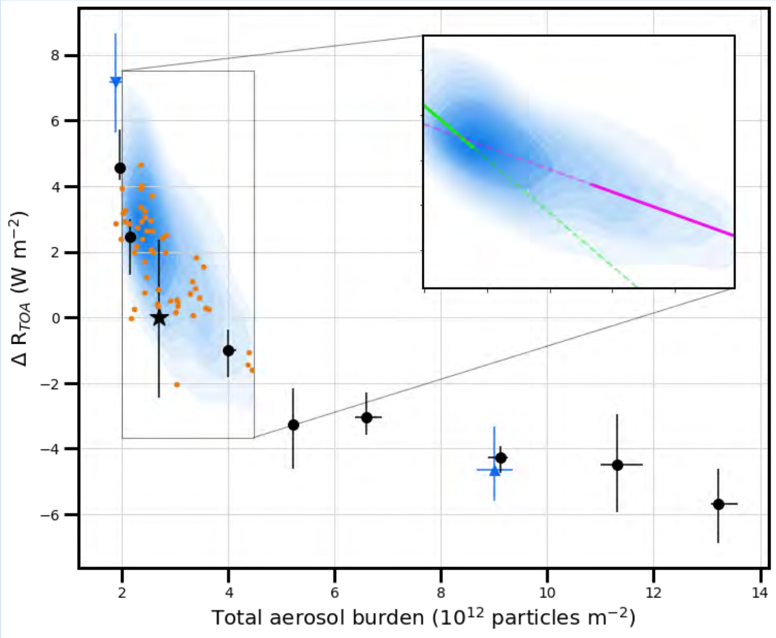


LWP:



Forcing:



Nonlinear aerosol-cloud response* → **Nonlinear response in forcing**

Conclusions

- The variability in aerosol emissions has large impact to the aerosol radiative forcing
- Increases in variability of biomass burning emissions reduces the total negative forcing
- Increased biomass burning variability acts to warm surface and amplify hydrologic cycle – particularly in NH mid- to high latitudes
- Forcing contribution from aerosol variability is due to a nonlinear aerosol-cloud response

Thank you

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