International Institute for Applied Systems Analysis
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science for global insight

Integrating SLCF futures in climate research

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21 July 2015 – EMF Summer Workshop on Climate Change Impacts snd Integrated Assessment (CCI/IA) – Snowmass, CO

SLCF and climate research

Two key questions:

1. What effect do SLCFs have (today)?
2. How is this effect expected to change in the future? (i.e., how can we influence it?)

What effect do SLCFs have (today)?

Active research question:

- Emission levels
- Radiative forcing
- Atmospheric lifetime
- Timescales of warming
- Mixing states
- Precipitation effects
- …

What effect do SLCFs have (today)?

Direct radiative forcing (DRF) of black carbon

- Recent assessments
  - IPCC 2013: DRF about 0.6-0.7 W/m^2
  - Bond *et al.* JGR 2013: DRF BC 0.7 W/m^2 with 90% uncertainty bounds of (+0.08, +1.27) W/m^2
- Latest papers
  - Hødnebrog *et al.* Nature Comm. 2014: 0.2-0.3 W/m^2
  - Jacobson JGR 2014: 0.5 W/m^2
  - Wang *et al.* ACP 2014: 0.2 (0-0.5) W/m^2

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SLCFs and climate (policy) research

First occurrences in literature: ~2000

- Hansen *et al.*, *PNAS*, 2000
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Uses GISS (ver. SI2000) to determine present-day forcing contributions and a stylized scenario

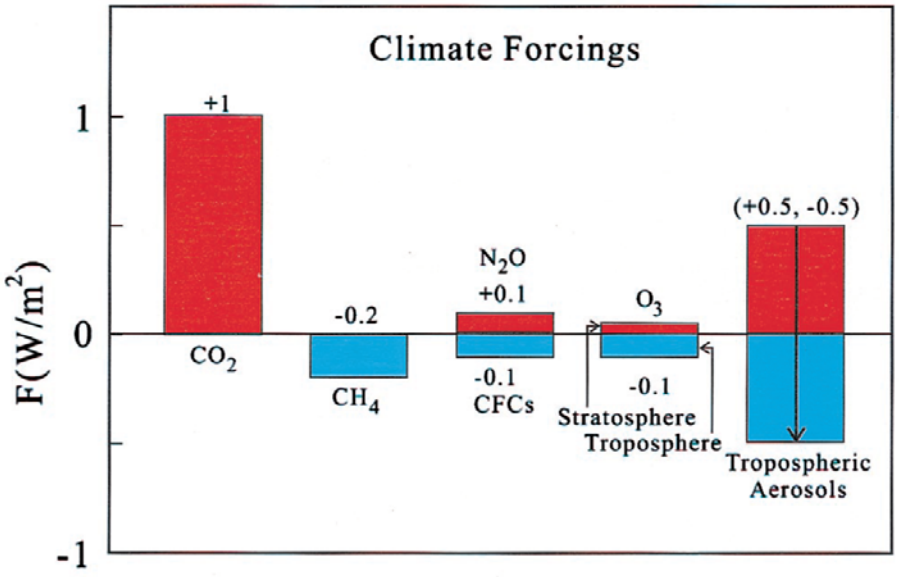

Fig. 5. A scenario for additional climate forcings between 2000 and 2050. Reduction of black carbon moves the aerosol forcing to lower values.

"We argue that black carbon aerosols, by means of several effects, contribute significantly to global warming. This conclusion suggests one antidote to global warming, if it becomes a major problem."

SLCFs and climate (policy) research

First occurrences in literature: ~2000

- Jacobson, *GRL*, 2000 and *nature*, 2001

  Uses detailed aerosol model (GATOR-GCMM) to determine present-day forcing of black carbon

  "The present study suggests that BC controls may be as – or more – beneficial than methane controls."

SLCFs and climate (policy) research

First occurrences in literature: ~2000

- Hansen *et al.*, *PNAS*, 2000
- Jacobson, *GRL*, 2000, and *nature*, 2001

Recent renewed attention:

- Ramanathan *et al.*, *PNAS*, 2008 & 2010
- Shindell *et al.*, *Science*, 2012

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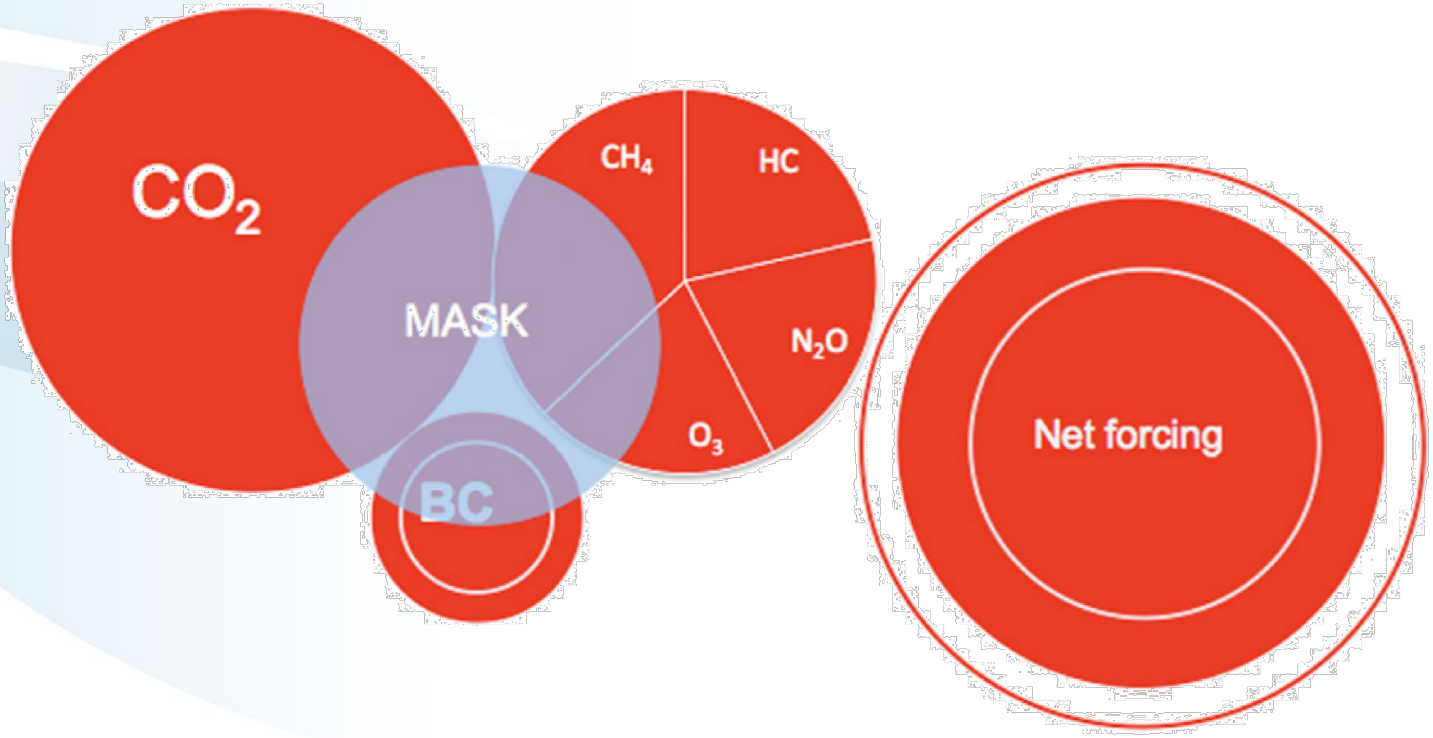


SLCFs and climate (policy) research

Recent renewed attention:

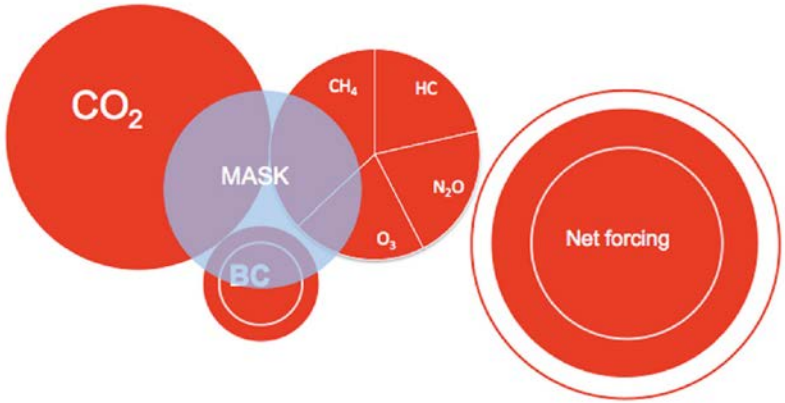
- Ramanathan *et al.*, *PNAS*, 2008 & 2010

  Three avenues for mitigation:

  I. Decrease the rate of thickening of the GHG blanket (reduce CO2)

  II. Offset warming from the reduction of aerosol masking (BC, tropospheric O3)

  III. Thin the GHG blanket (methane, HFCs)



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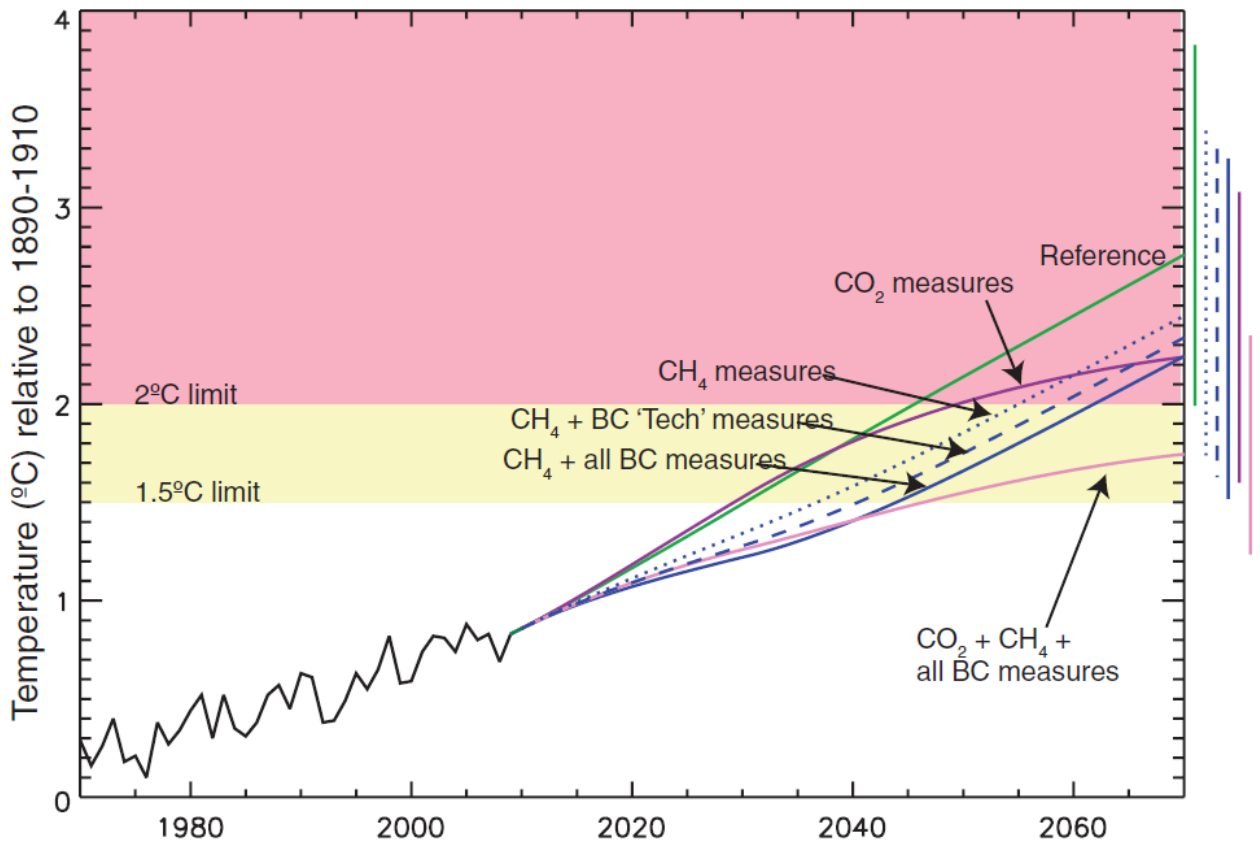


SLCFs and climate (policy) research

Responses in the literature:

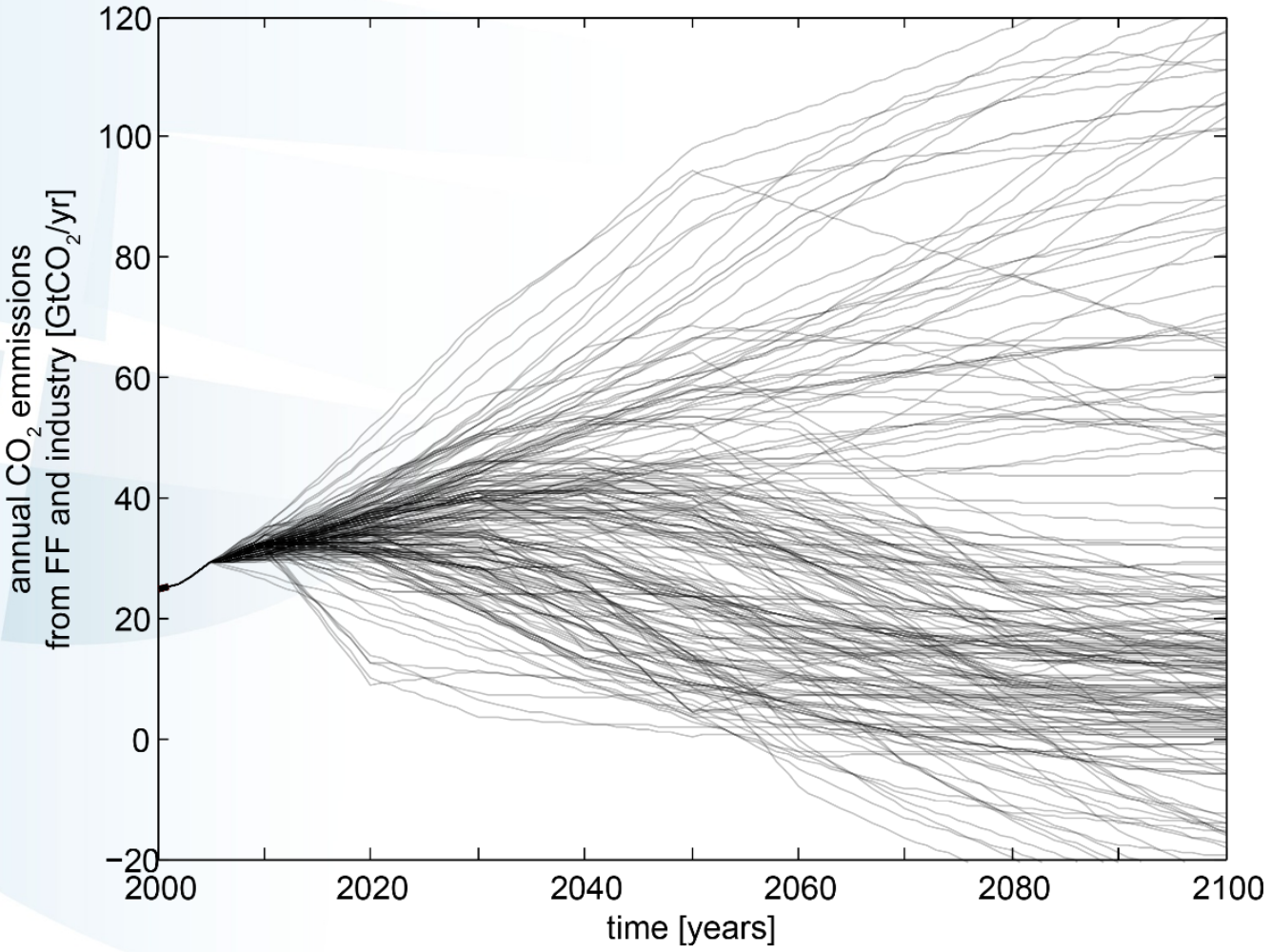
- Smith and Mizrahi, *PNAS*, 2013
  Lower effect than Shindell *et al.* because:
  - A “more realistic” climate and atmospheric response (cf. Q1)
  - Other scenario assumptions (cf. Q2)
    - A lower methane reference case
    - Some other scenario-related differences

SLCFs and climate (policy) research

Recent further studies:

- Exploration of consistent baseline and mitigation emissions
  Rogelj *et al., Nature Climate Change,* 2014
- Implications for temperature projections and climate protection
  Rogelj *et al., PNAS*, 2014
- Implications for carbon budgets
  Rogelj *et al.,* ERL, 2015

Exploration of consistent air pollutant emissions for wide range of CO_2 emissions



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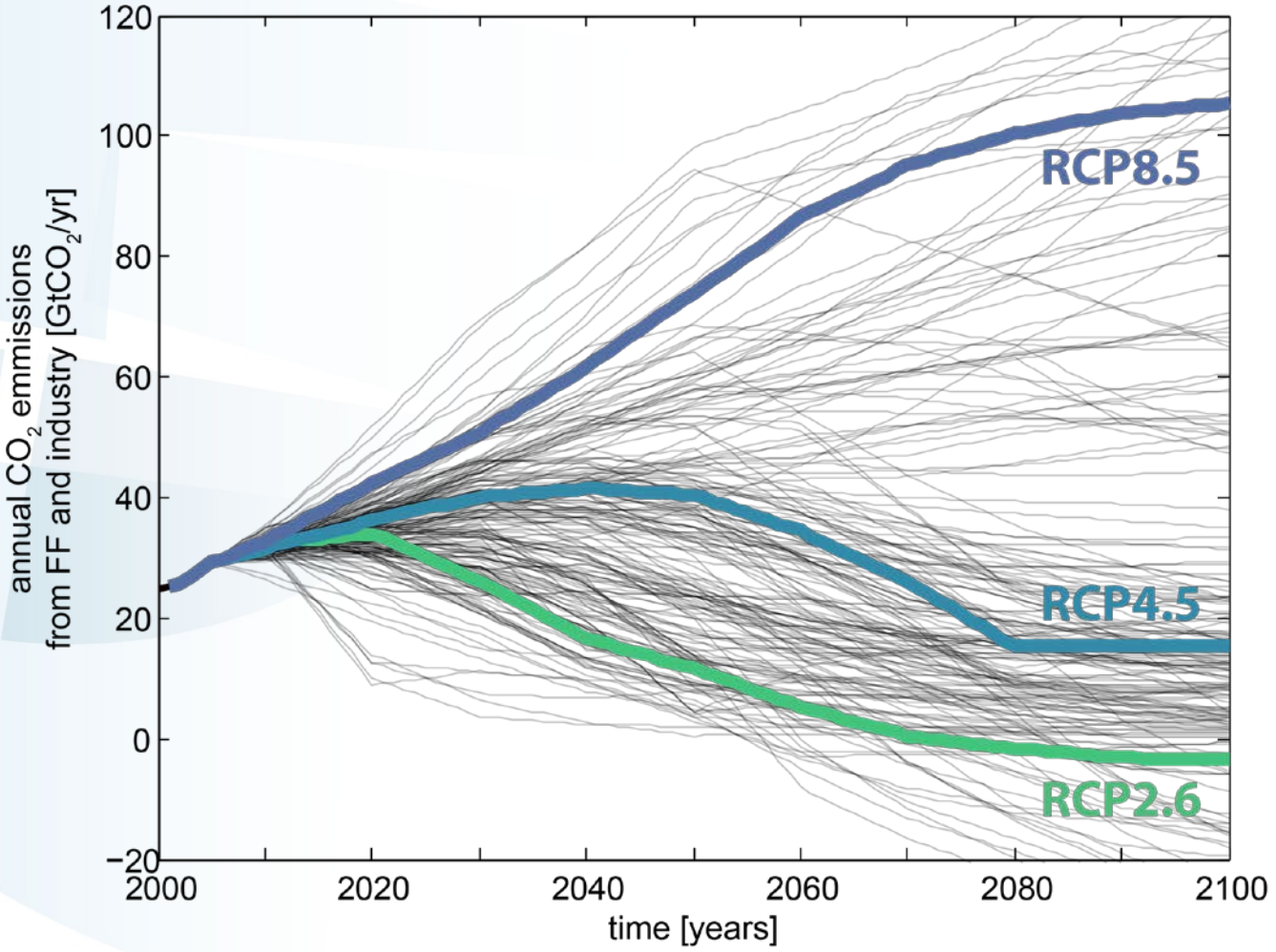

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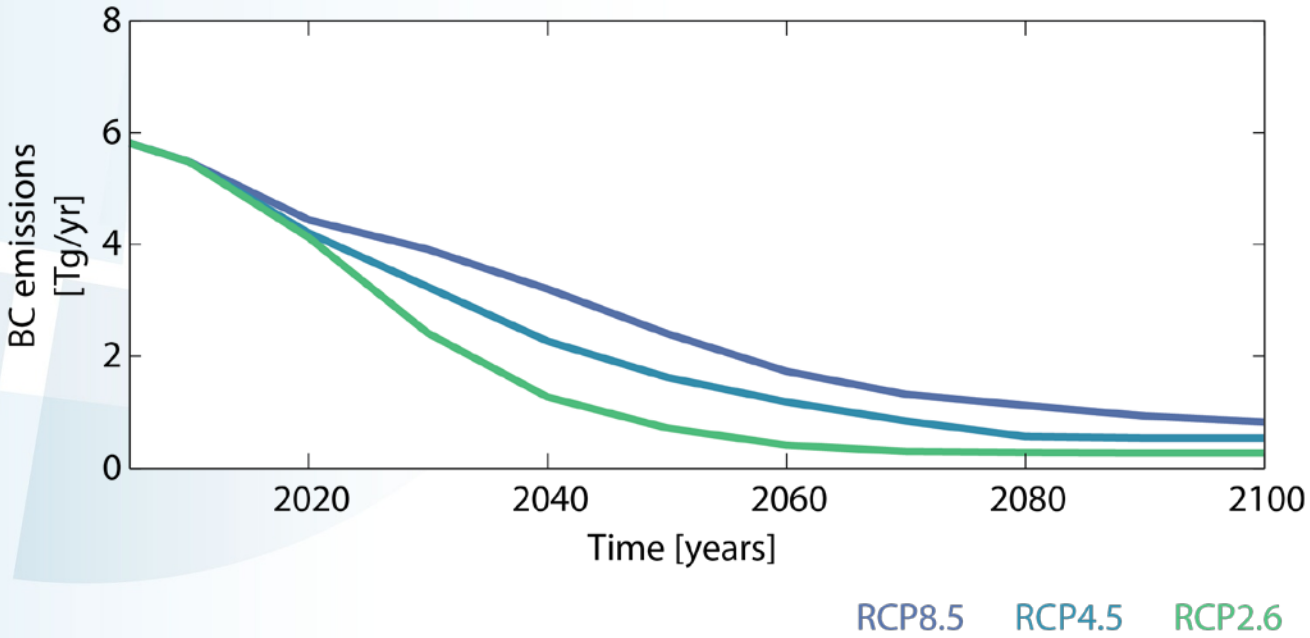
Consistent BC emissions (current legislation)



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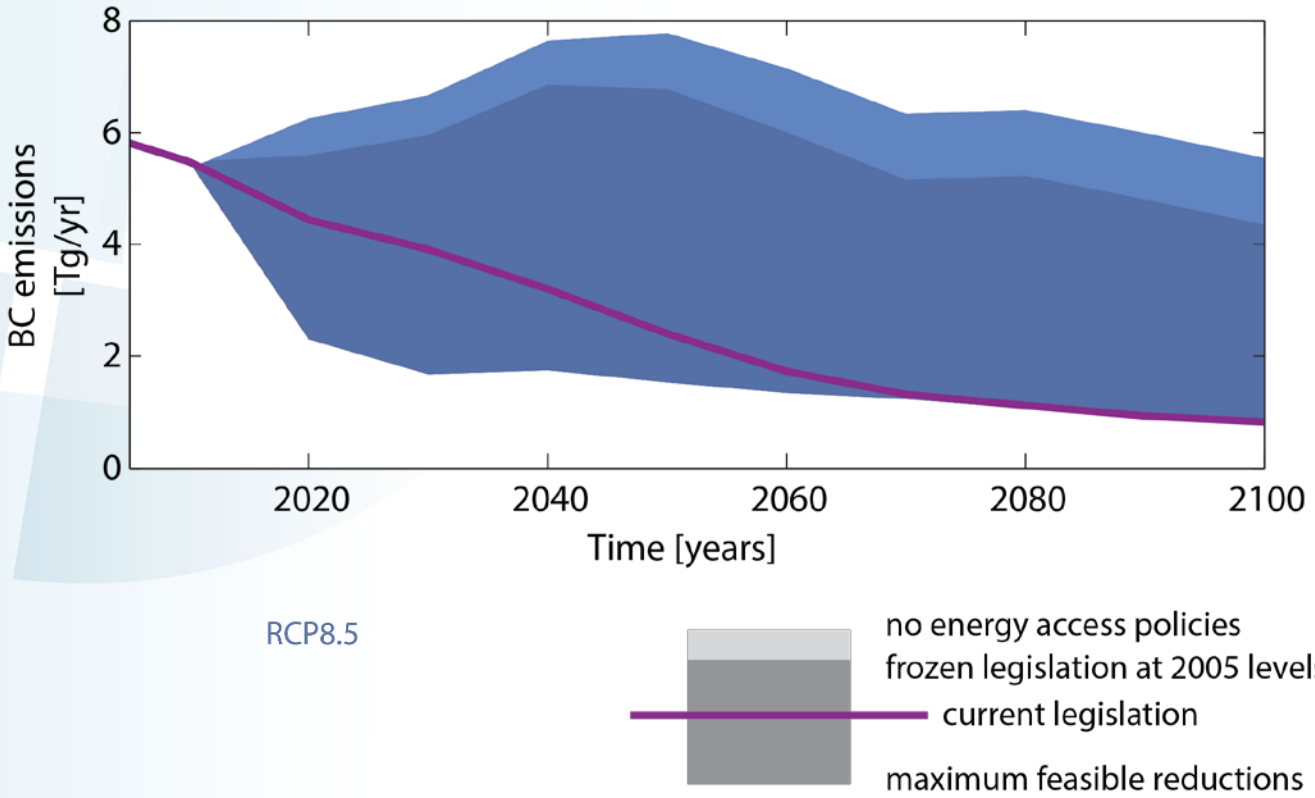
Consistent BC emissions air pollution control variations



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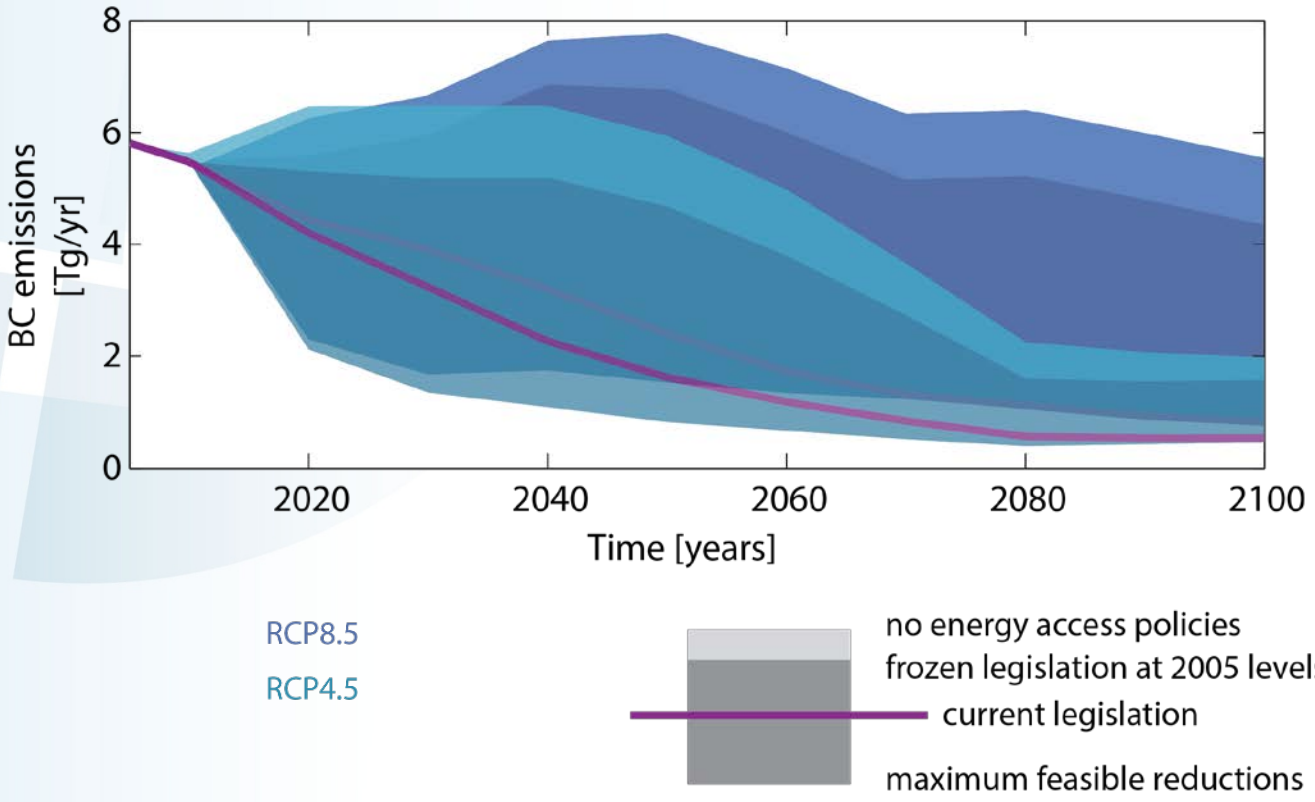

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Consistent BC emissions
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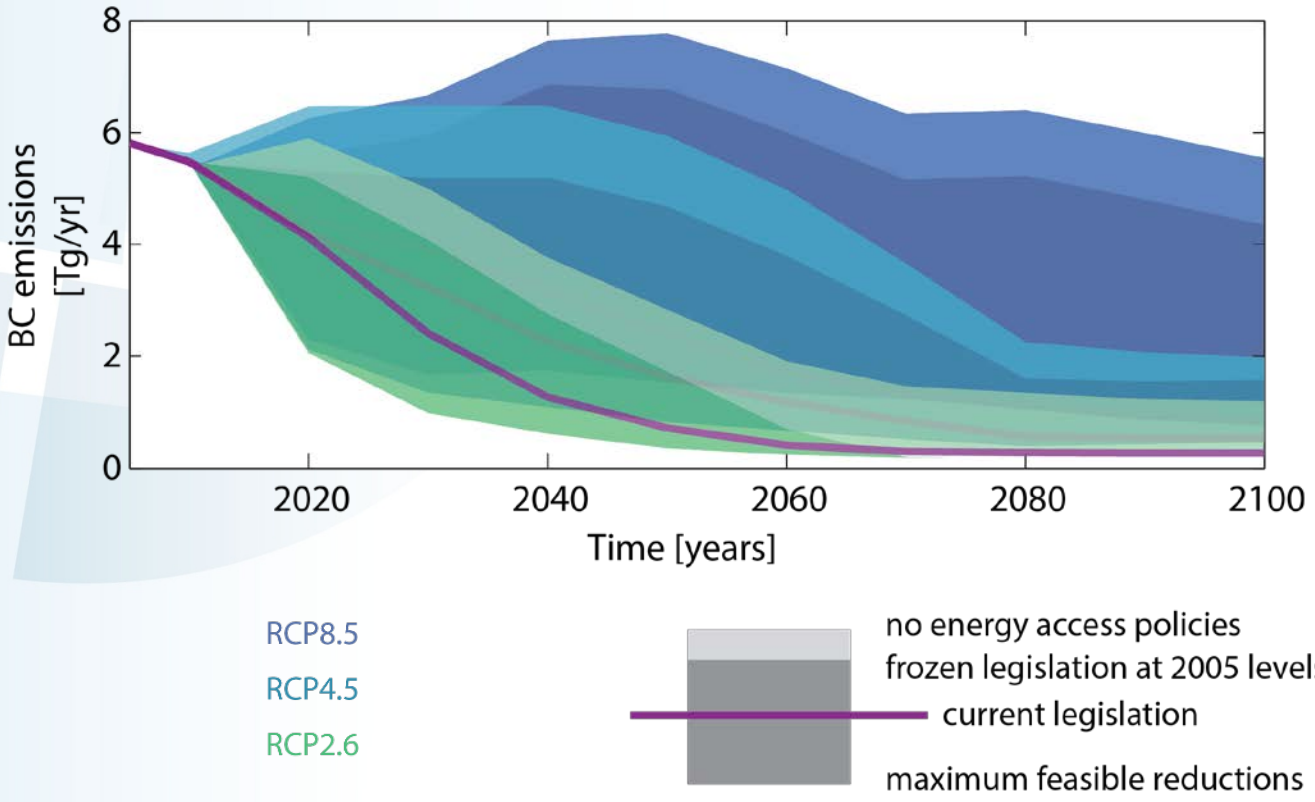

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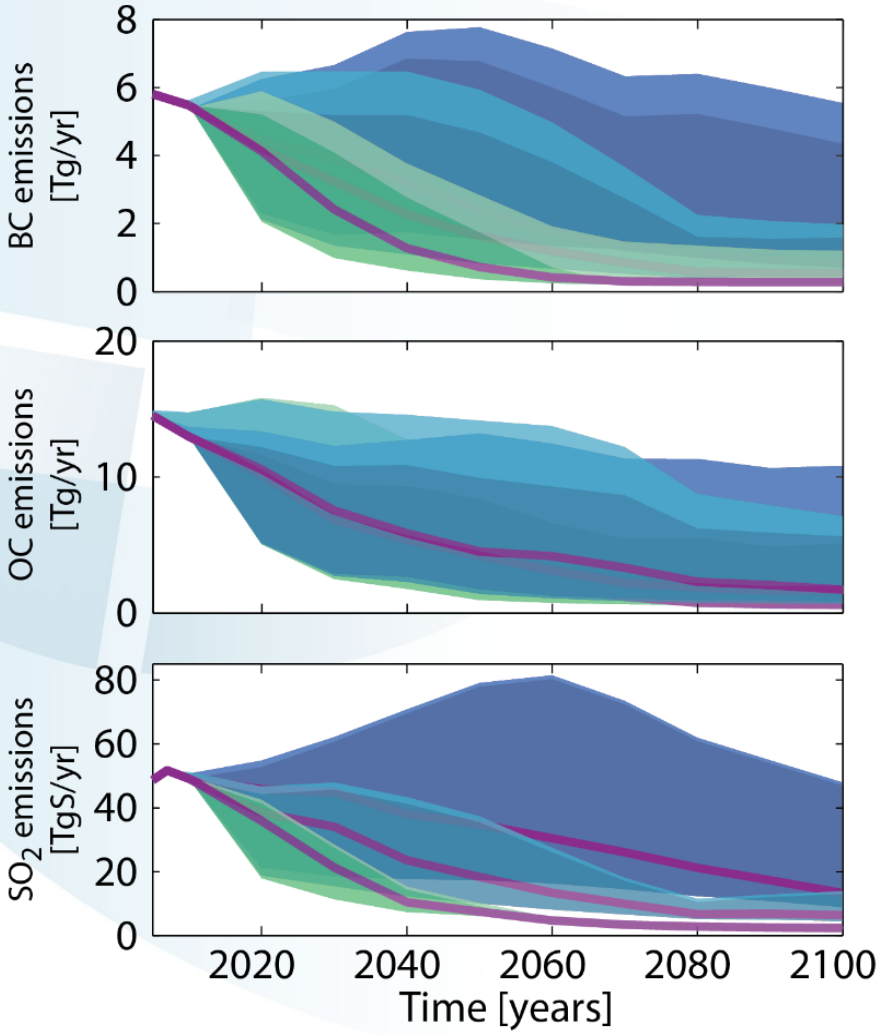
Variations differ across air pollutant species



no energy access policies

frozen legislation at 2005 levels

current legislation

maximum feasible reductions

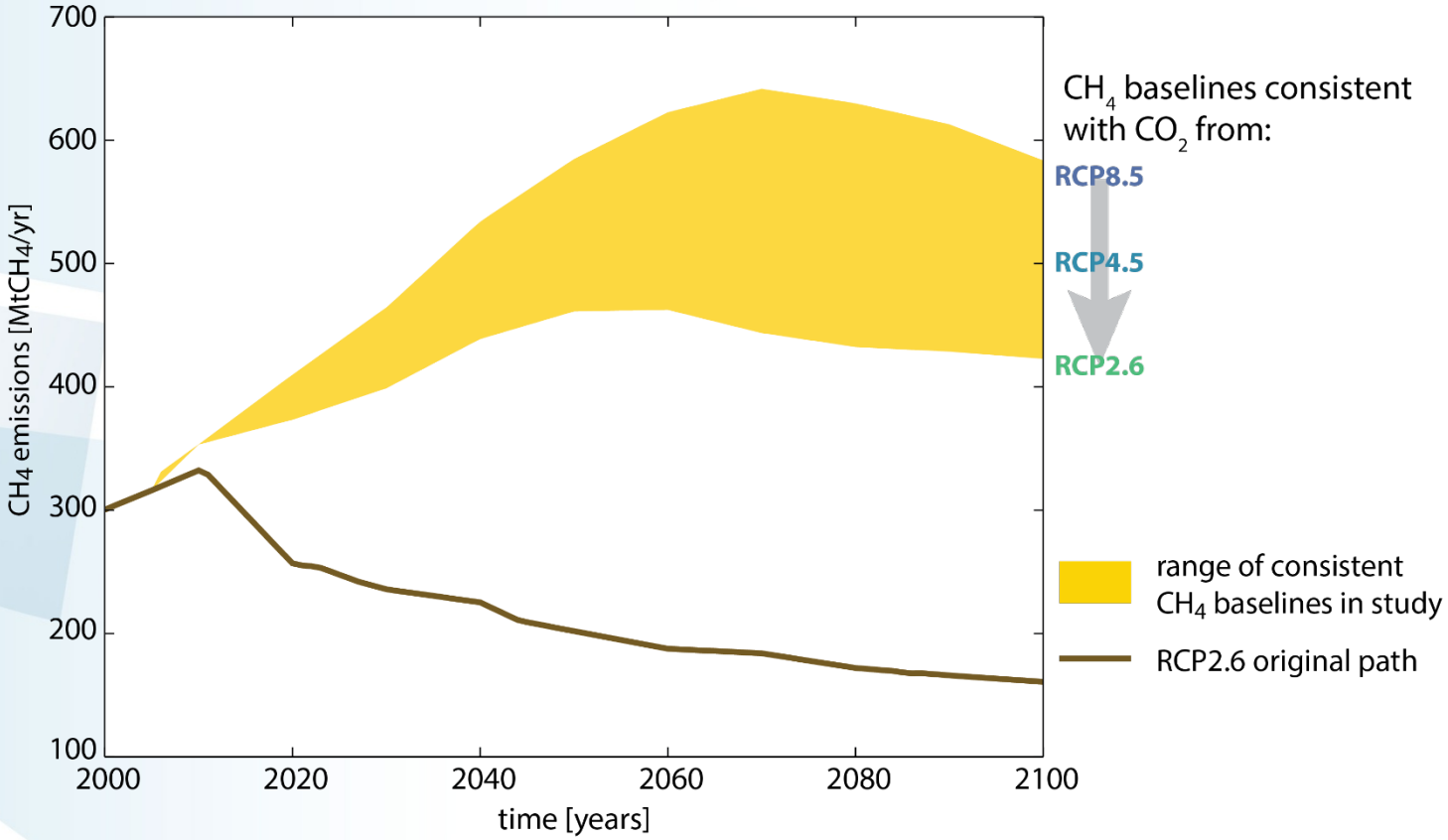
RCP8.5

RCP4.5

RCP2.6

Rogelj *et al*, 2014, Nature Clim. Change

Consistent baseline CH_4 emissions across range of CO_2 pathways



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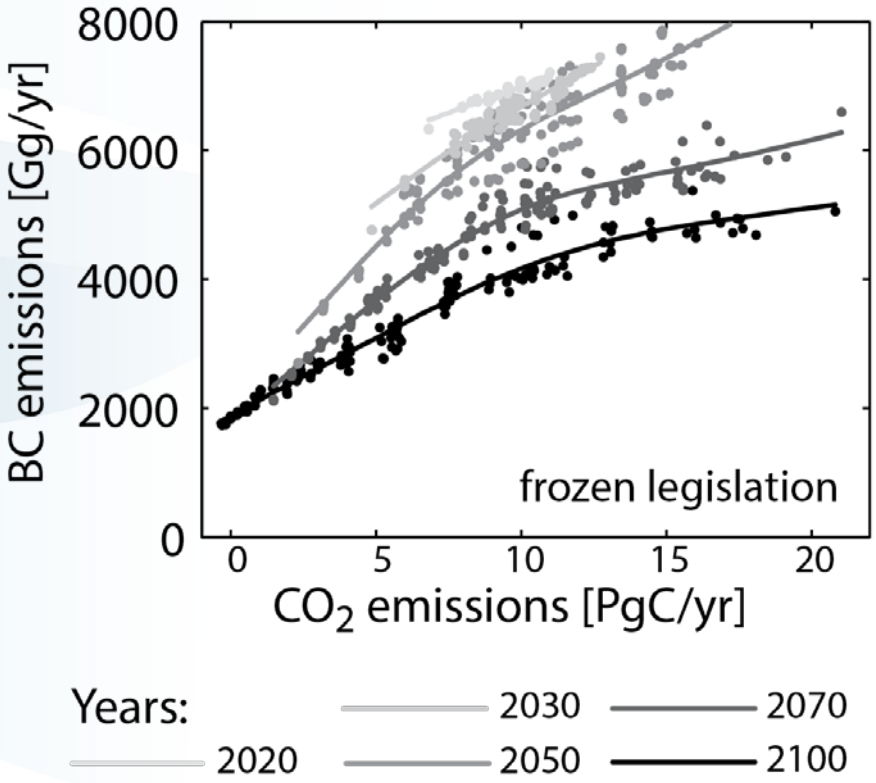
Freely available tool for deriving consistent air pollutant emissions

CO_2 – air-pollutant relationships extracted
from a structured scenario set per decadal time increment and
for 4 levels of air pollution legislations stringency



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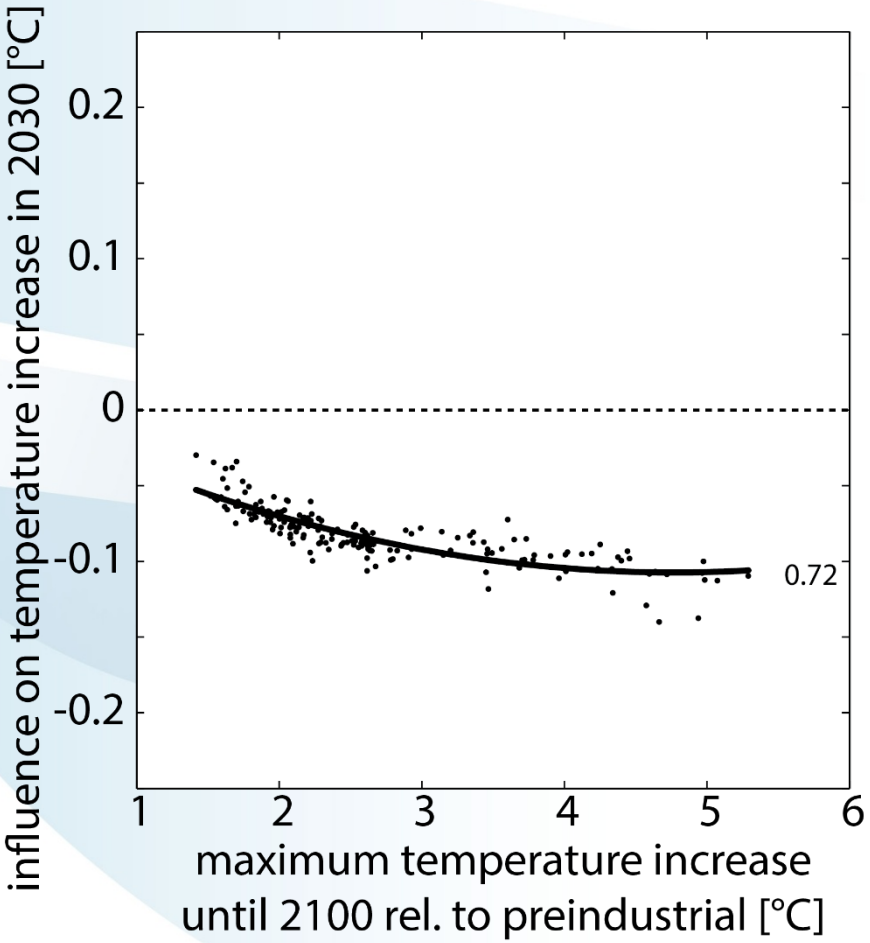
Implications for temperature projections: near vs long-term



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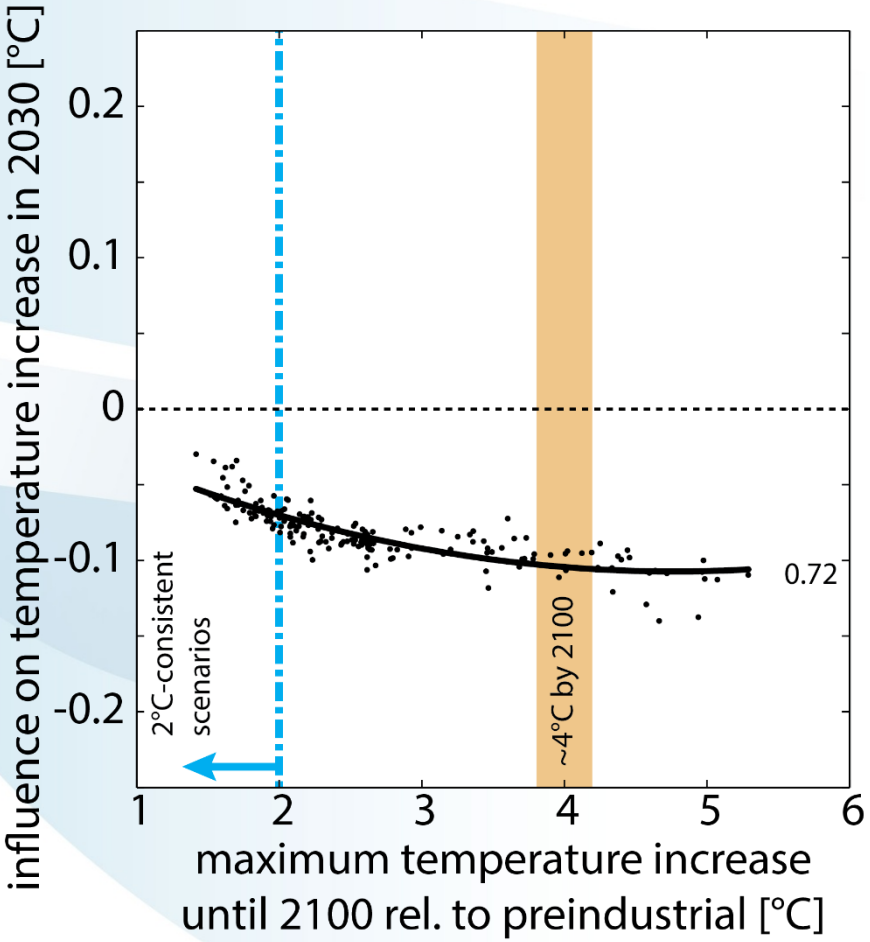

stringent BC-rel. measures vs current legislation

Rogelj *et al*, 2014, PNAS

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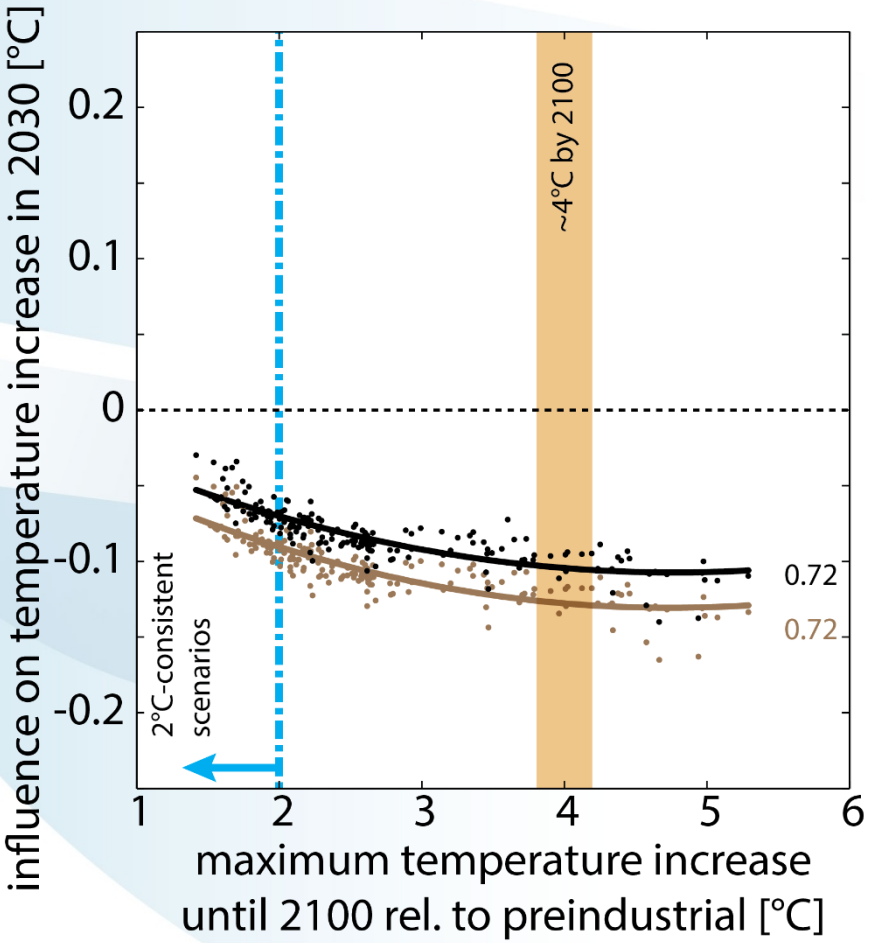

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stringent BC-rel. measures if no energy access in baseline

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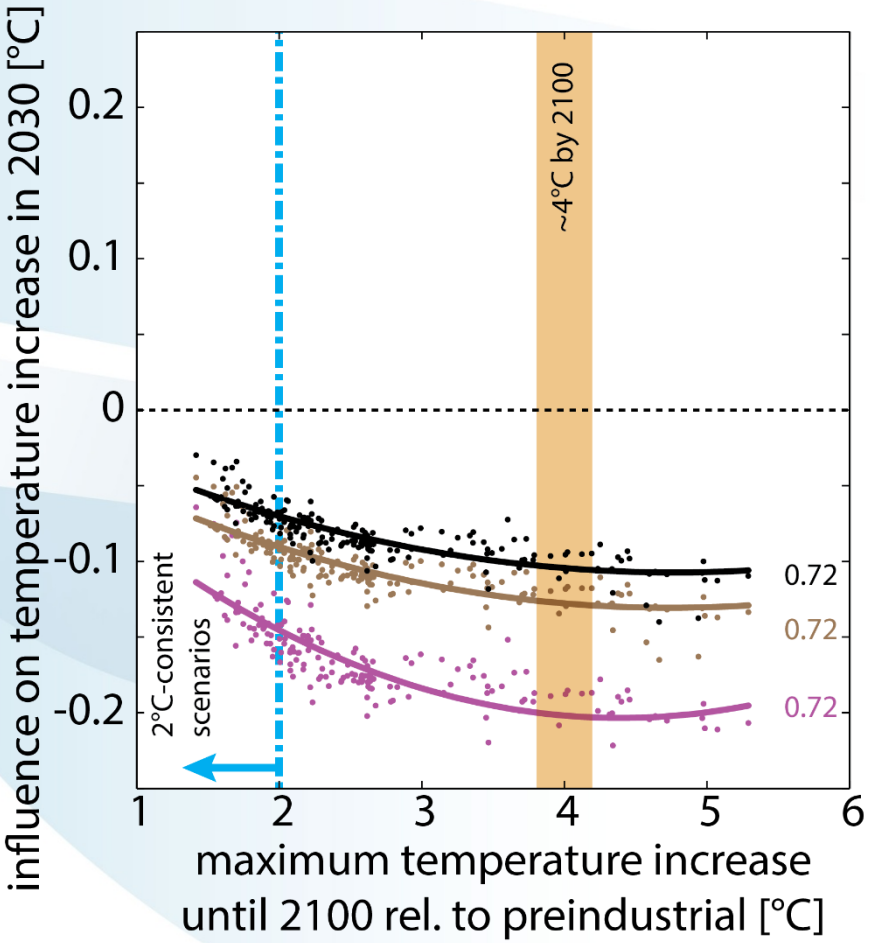

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stringent BC-rel. measures vs frozen 2005 legislation

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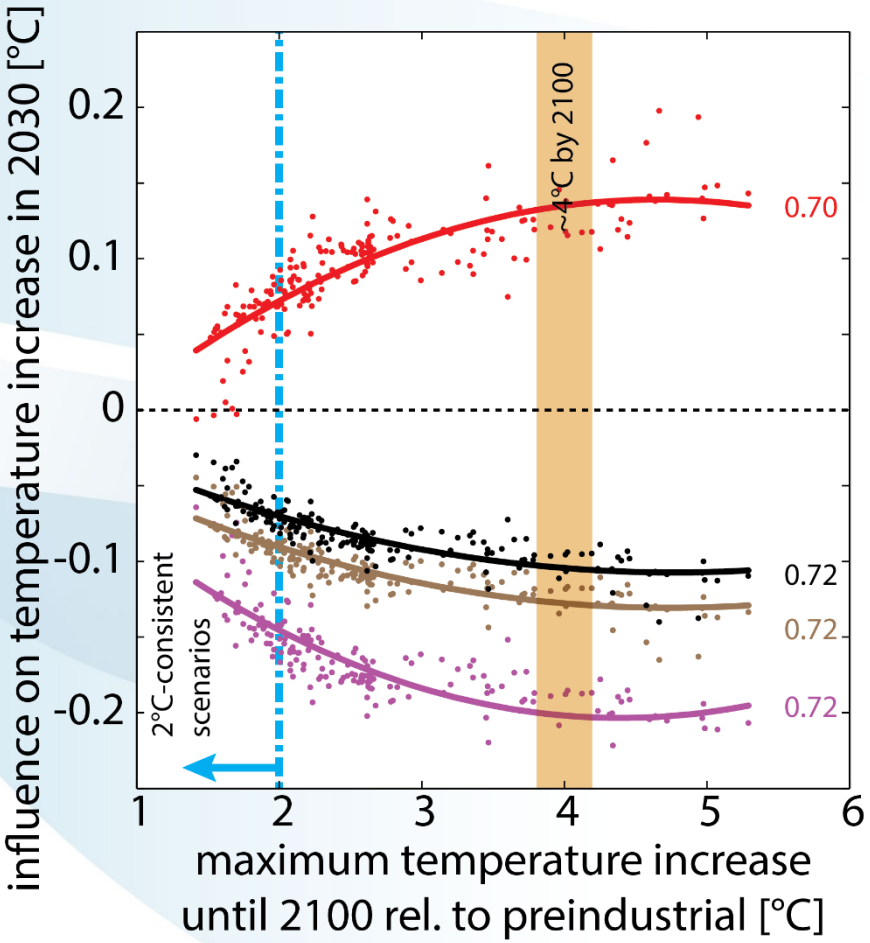

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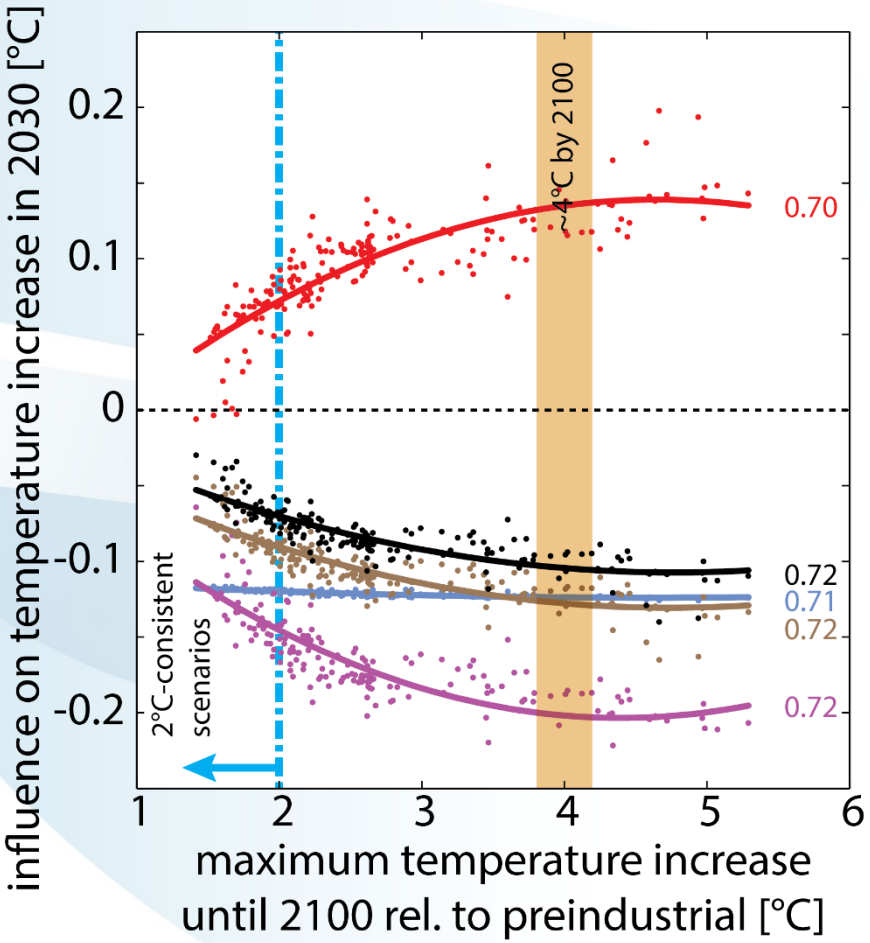

- stringent BC-rel. measures vs current legislation
- stringent BC-rel. measures if no energy access in baseline
- stringent BC-rel. measures vs frozen 2005 legislation
- stringent SO_2 control
- UNEP/WMO SLCF report "all measures" case

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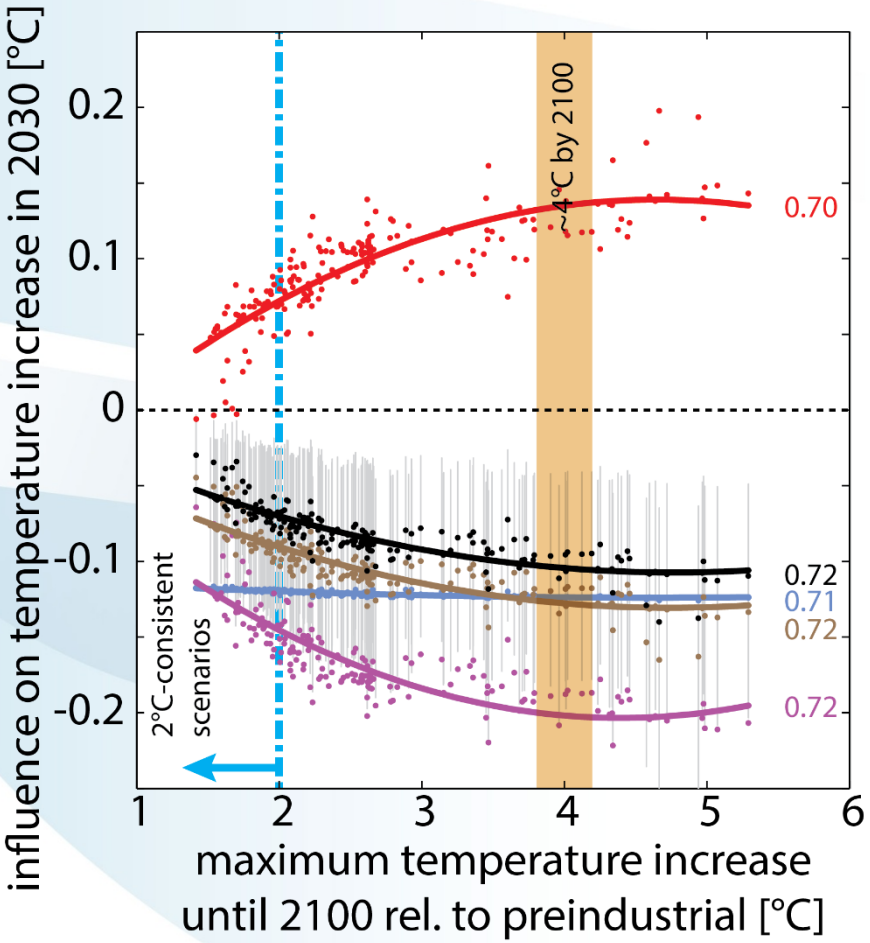

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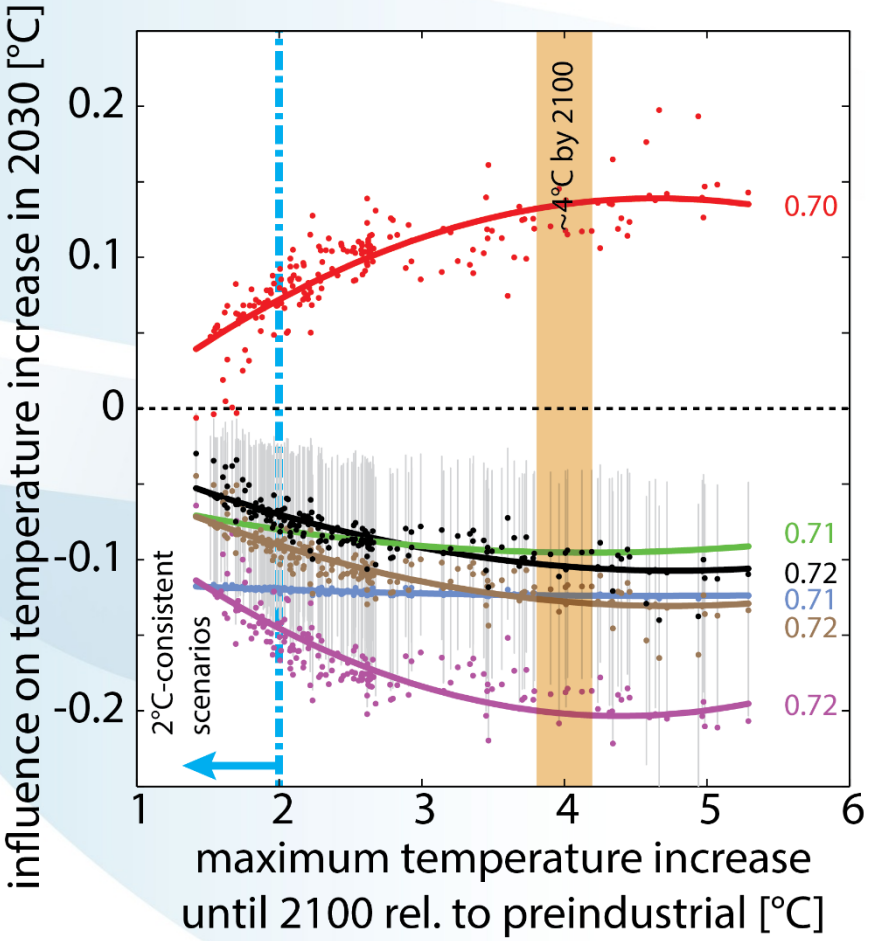

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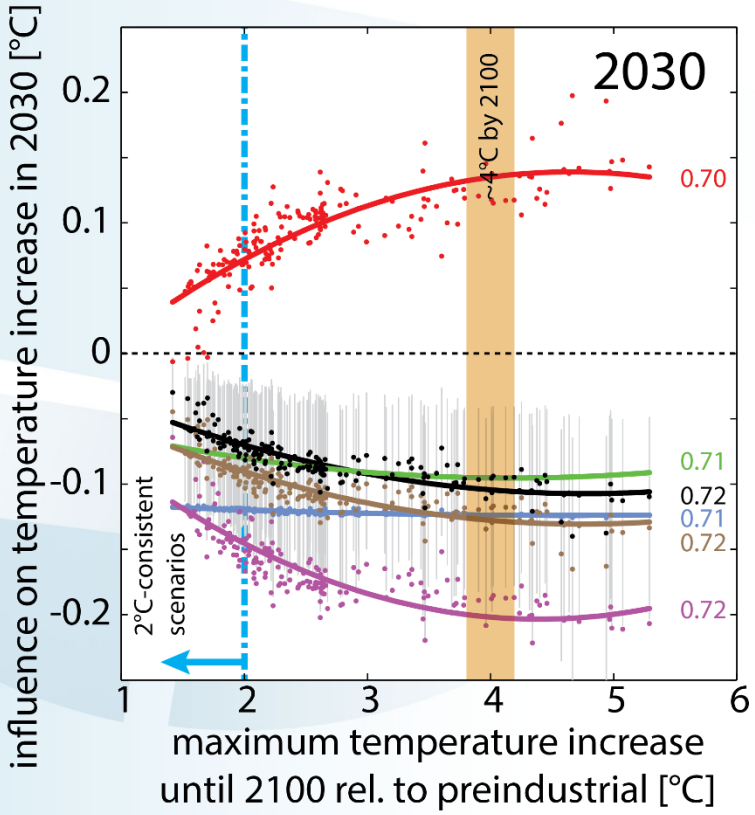

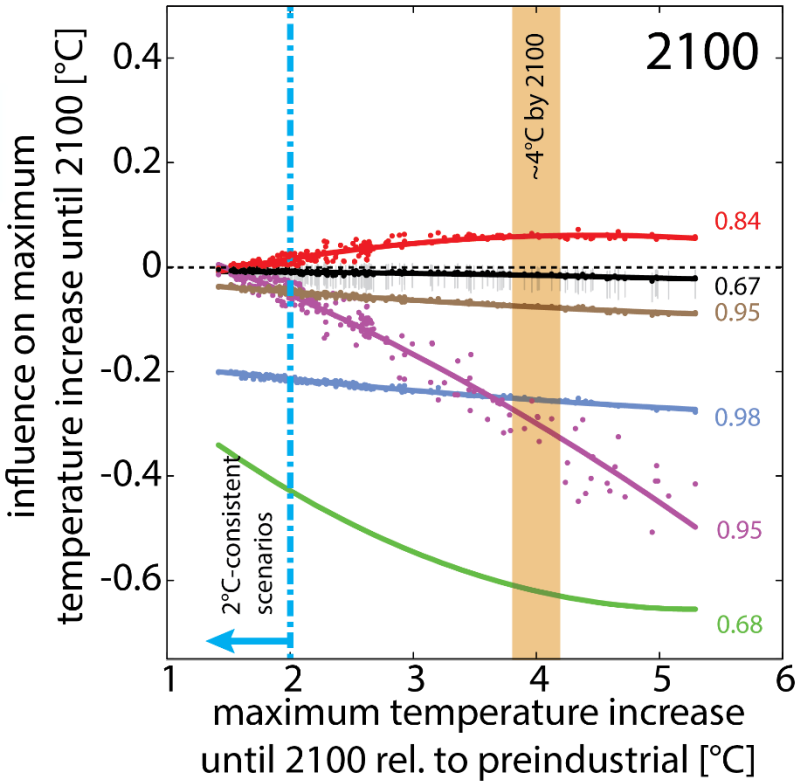

stringent BC-rel. measures vs current legislation
stringent BC-rel. measures if no energy access in baseline
stringent BC-rel. measures vs frozen 2005 legislation
stringent SO_2 control

UNEP/WMO SLCF report "all measures" case
90% uncertainty ranges around
RCP2.6 CH_4 vs CH_4 reference

Rogelj *et al*, 2014, PNAS

Implications for temperature projections: rate of change – decreasing vs increasing

Rogelj *et al*, 2014, PNAS

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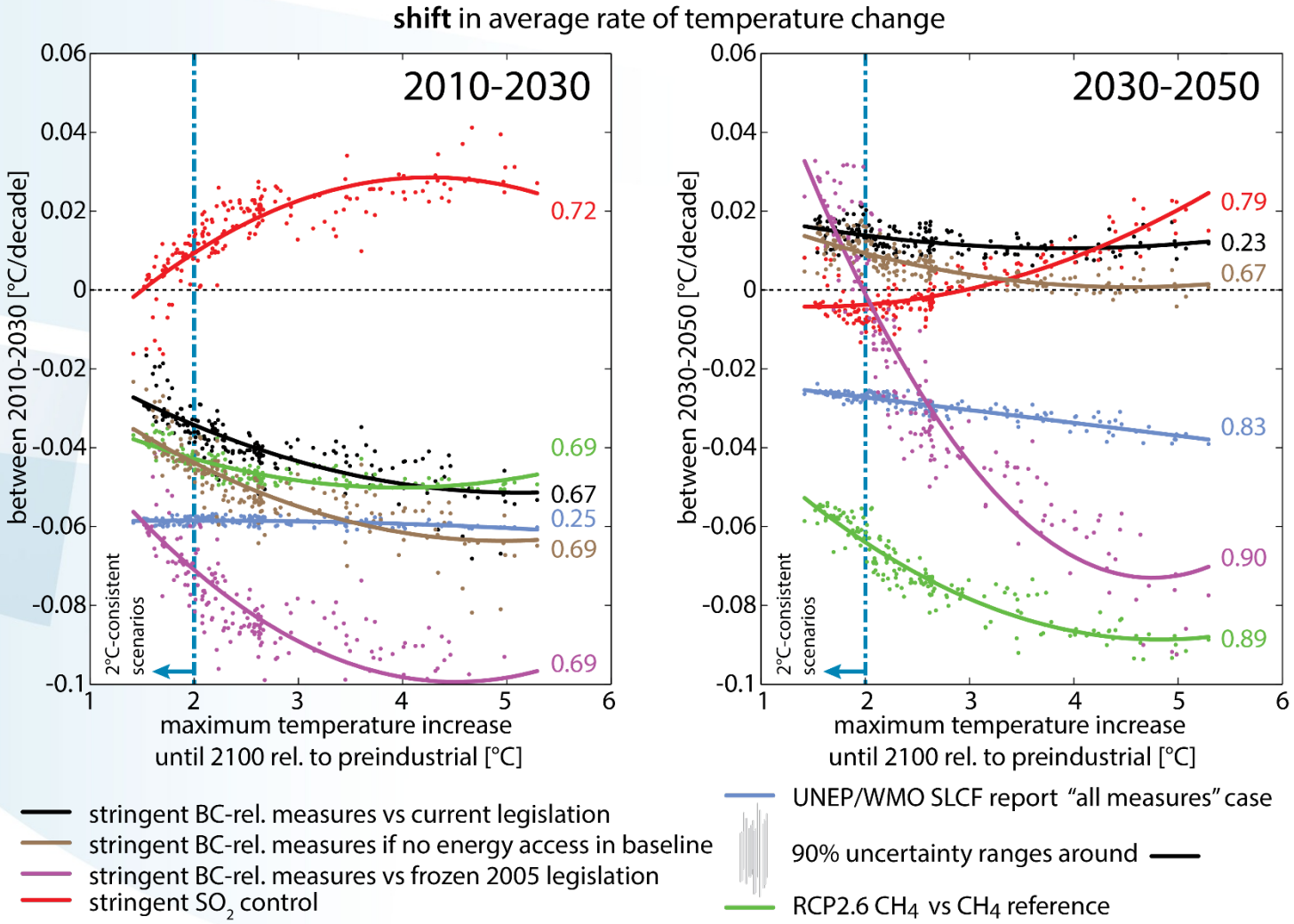

average rate of temperature change between 2010-2030 and between 2030-2050: 0.23 °C/decade

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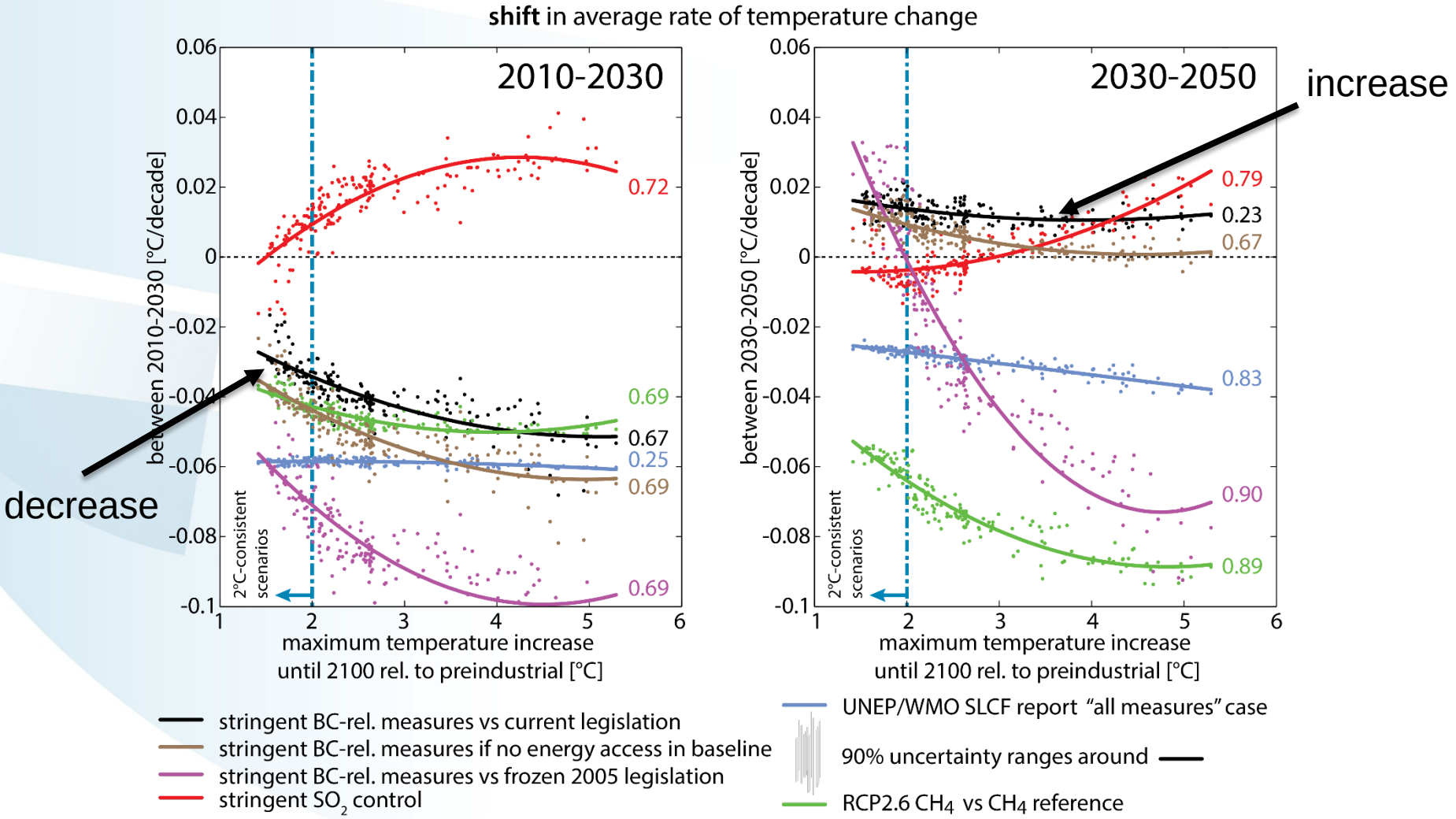

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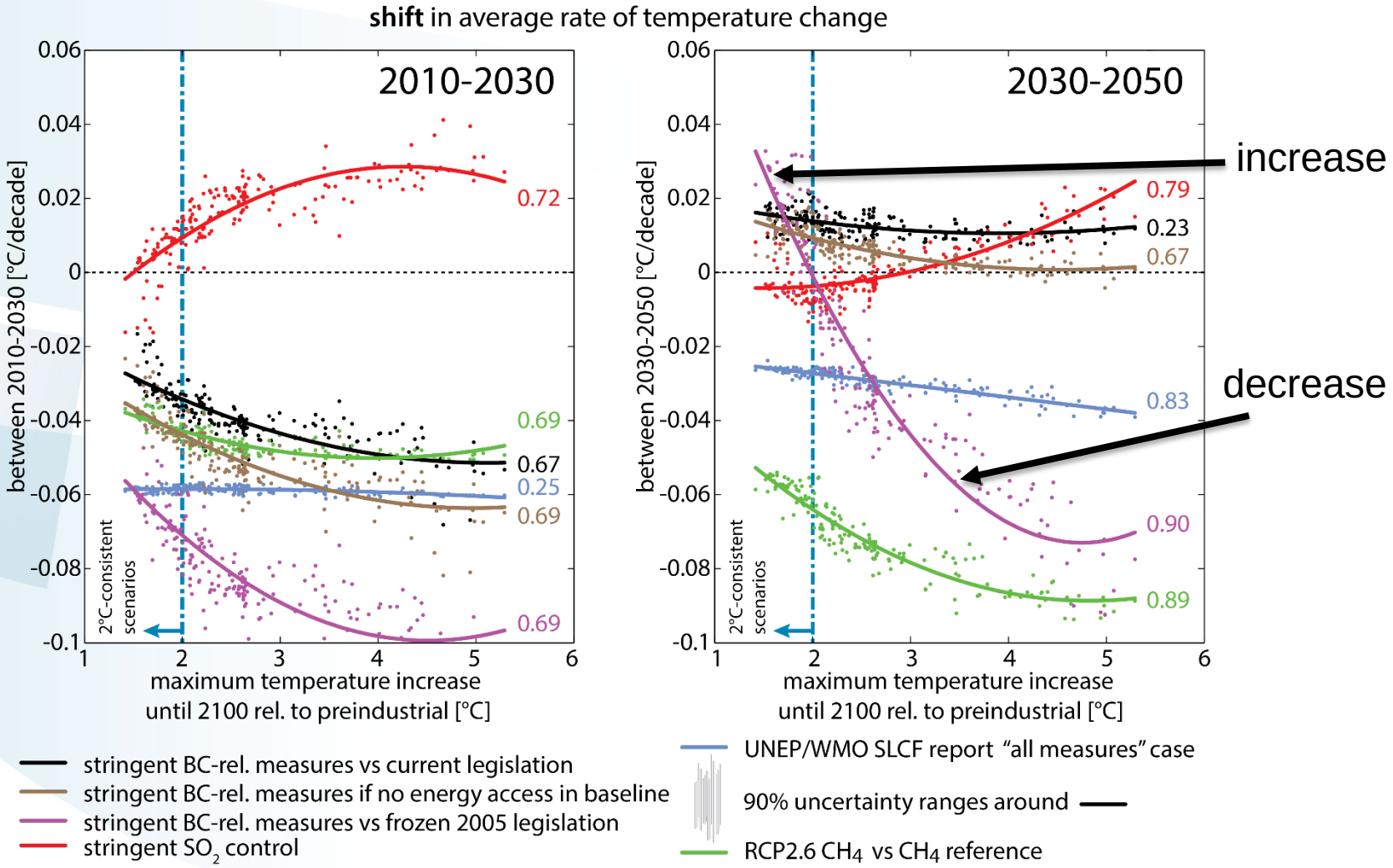

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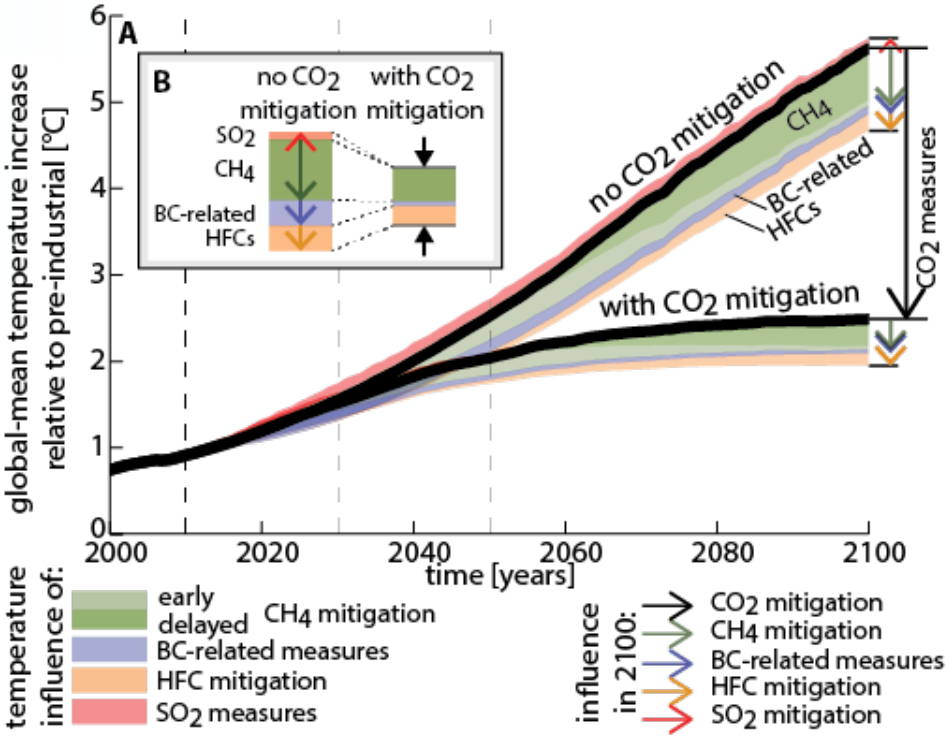
Summary: Disentangling the effects of CO_2 and short-lived climate forcers (SLCF)

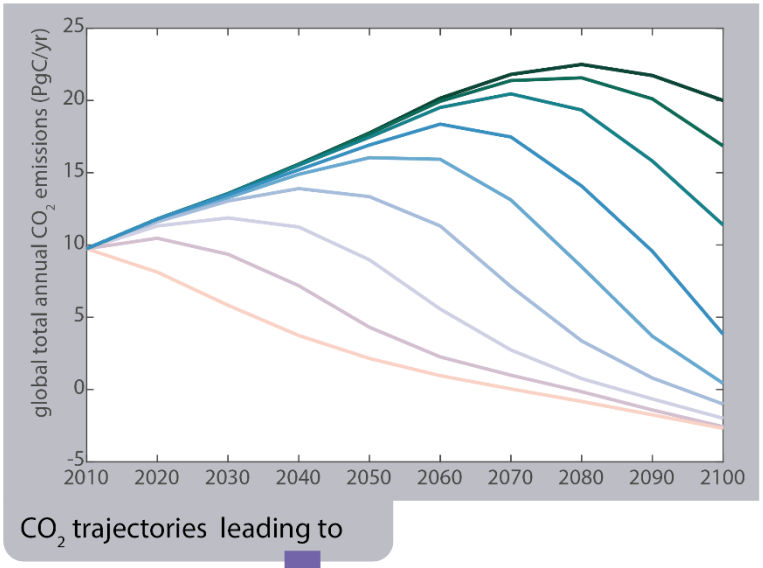
Important differences between high and low CO_2 pathways

→ 2050 effect very dependent on baseline assumption
BUT: consistently overestimated by about 100% if not accounting for CO_2 co-evolution



Rogelj *et al*, PNAS (2014)

SLCF influence on carbon budget



Rogelj *et al*, 2015, ERL

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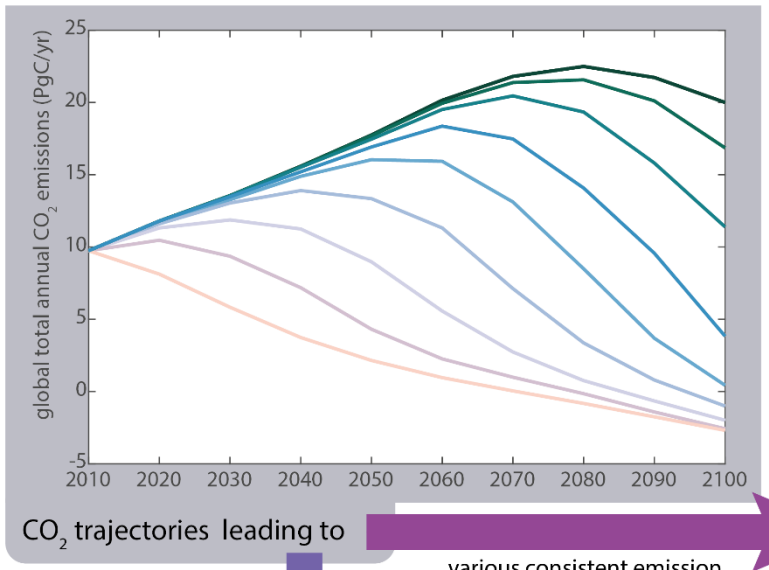

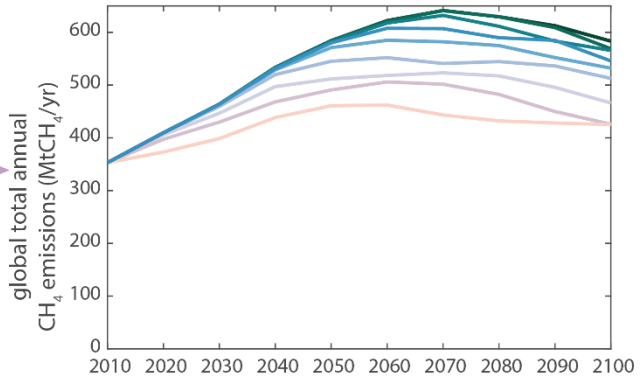

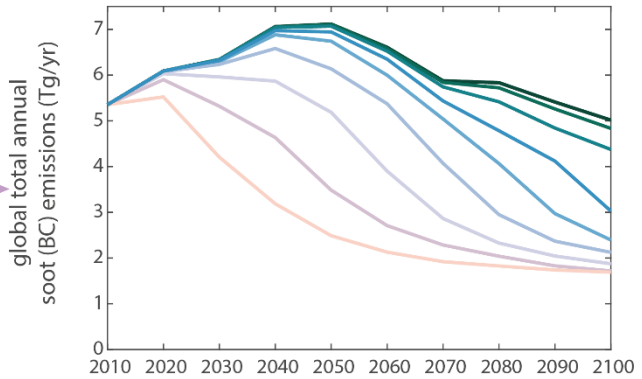

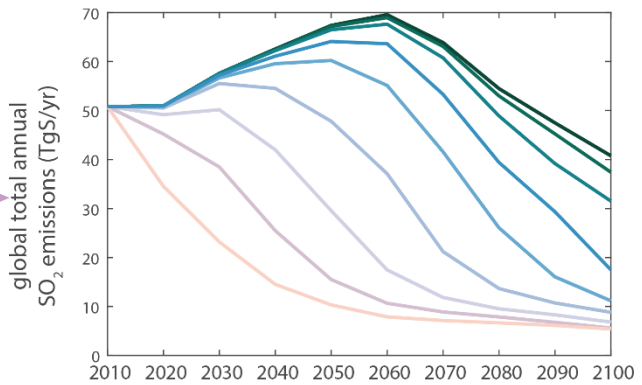

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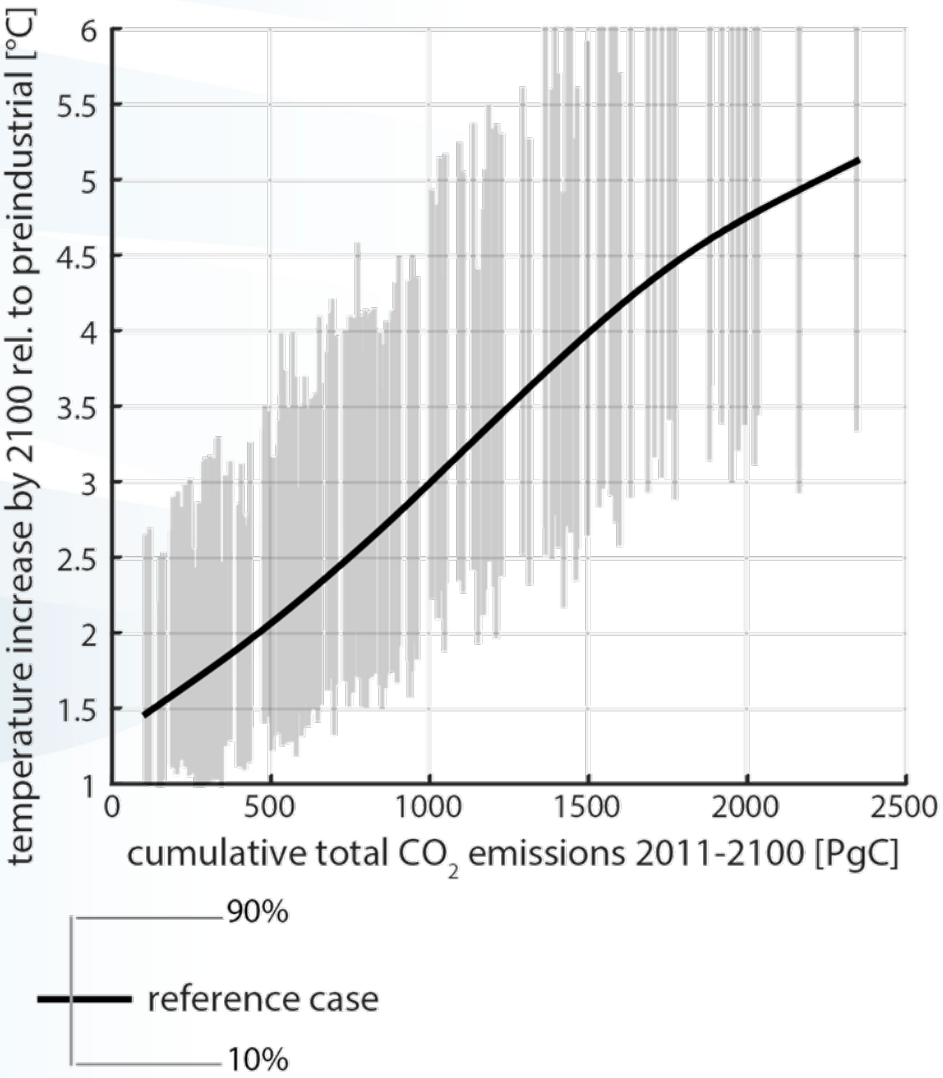

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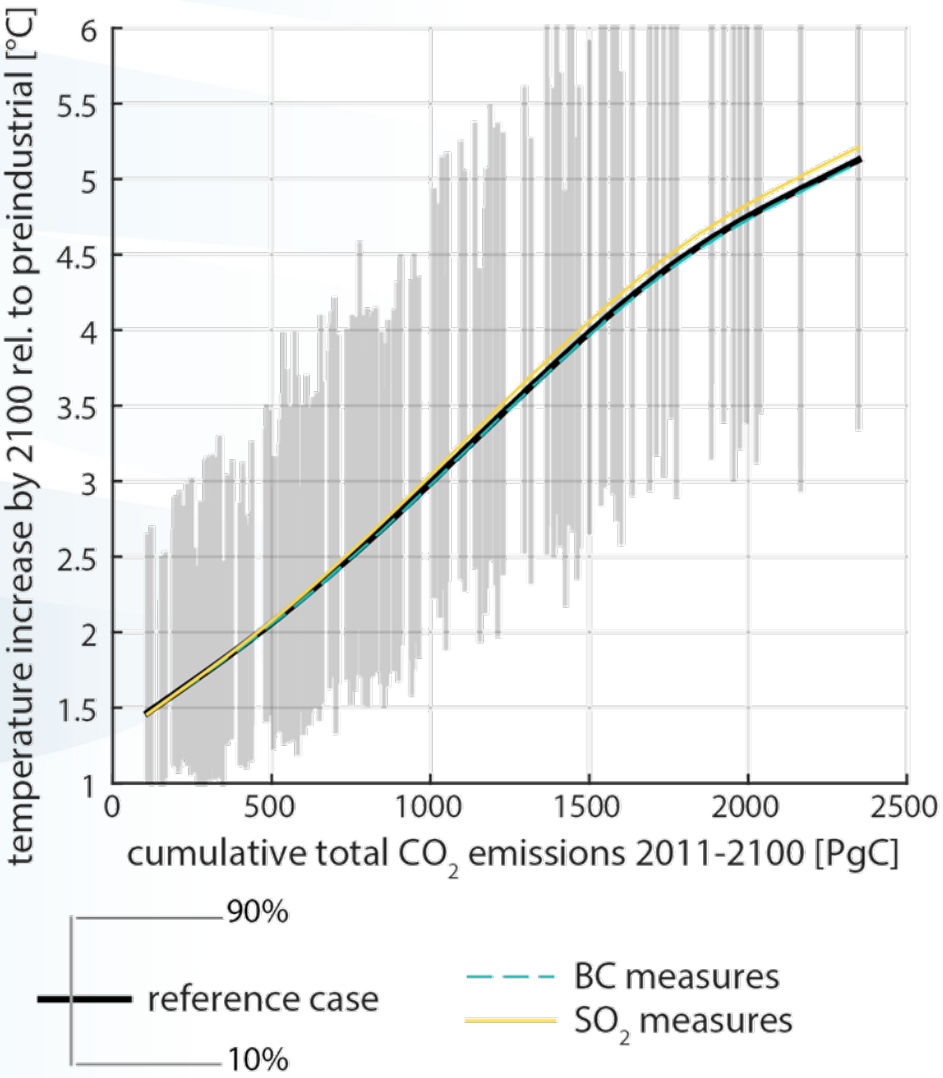

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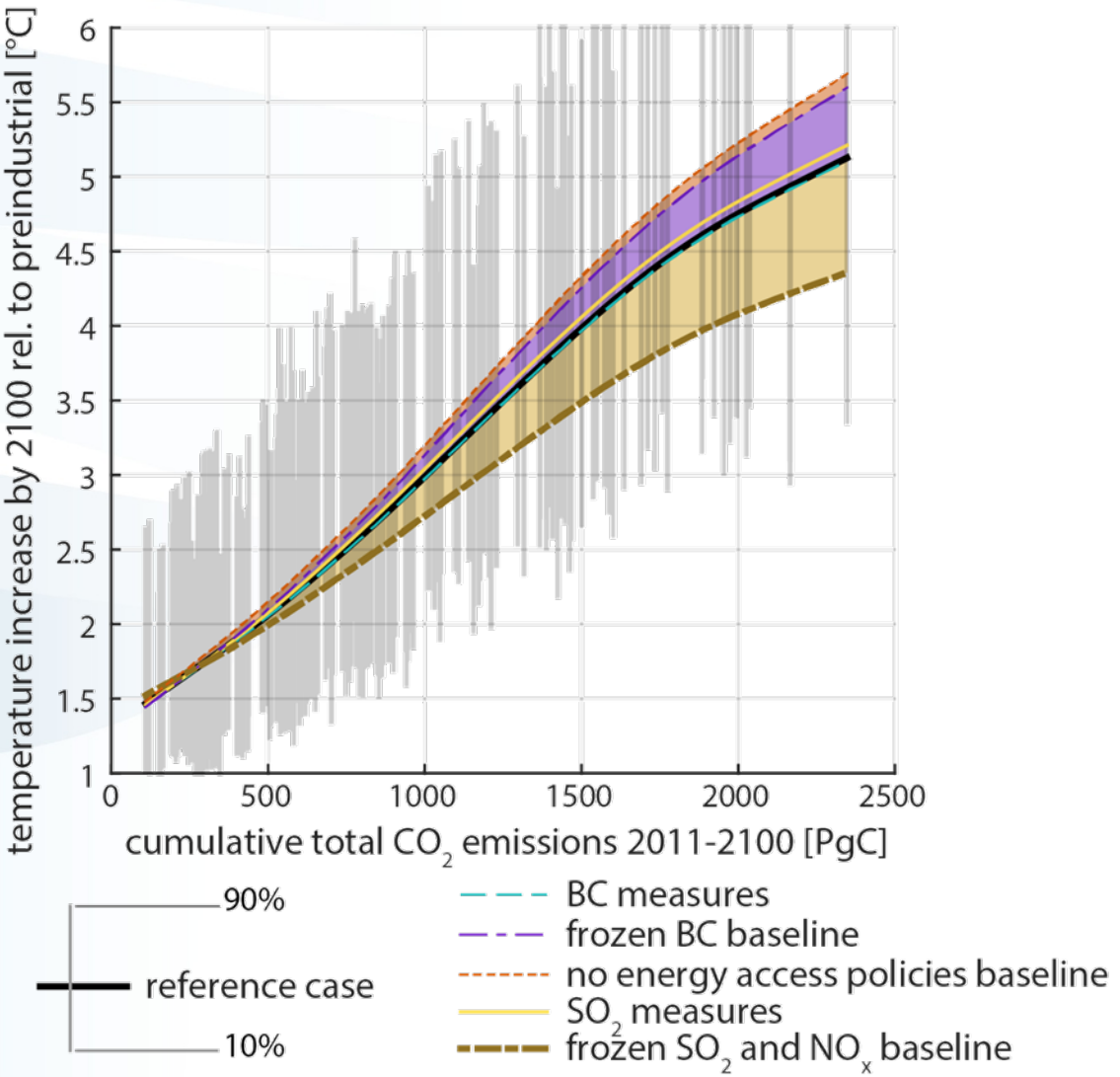

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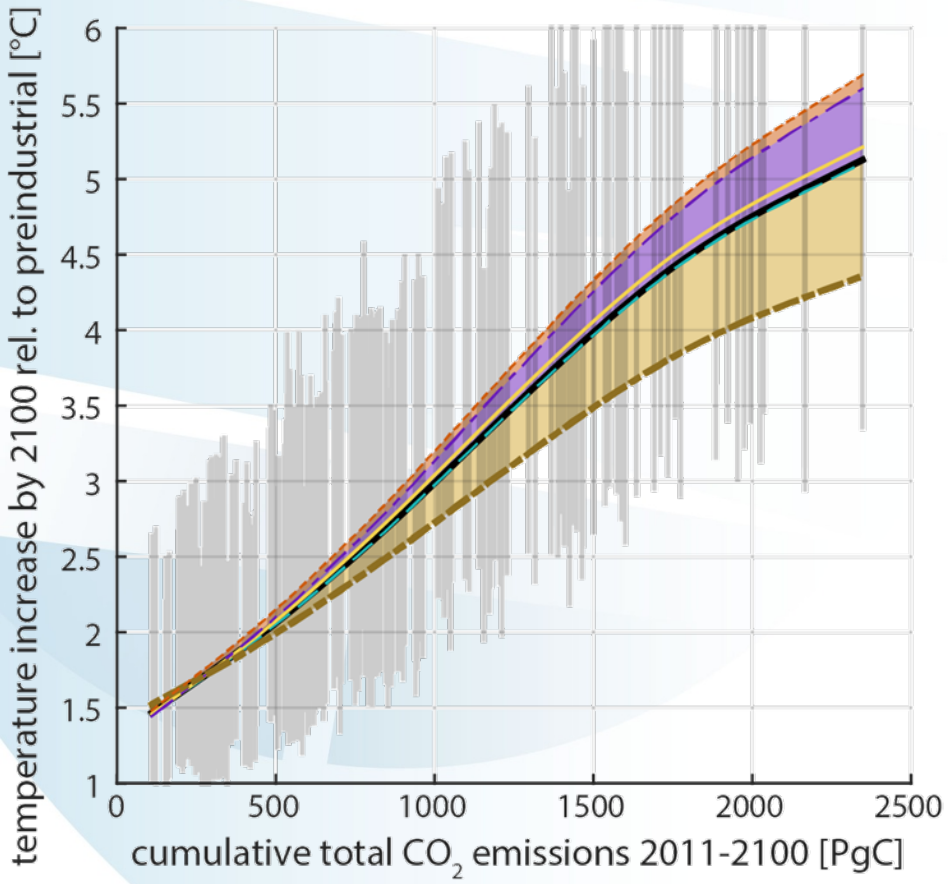

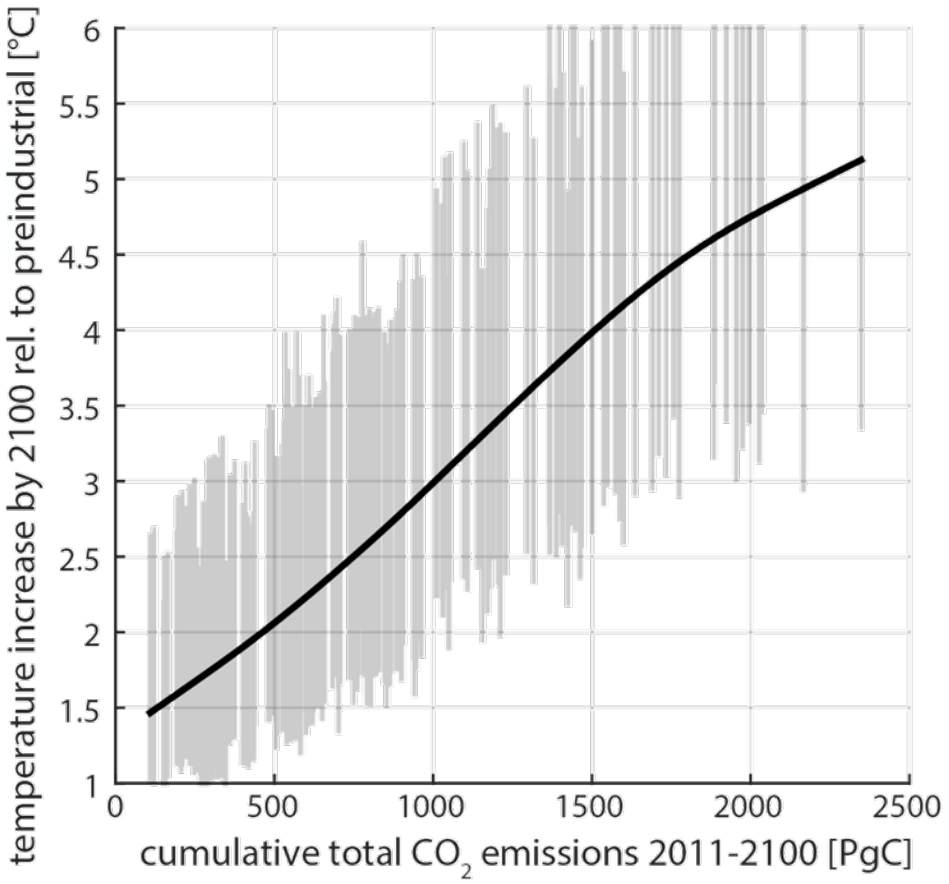

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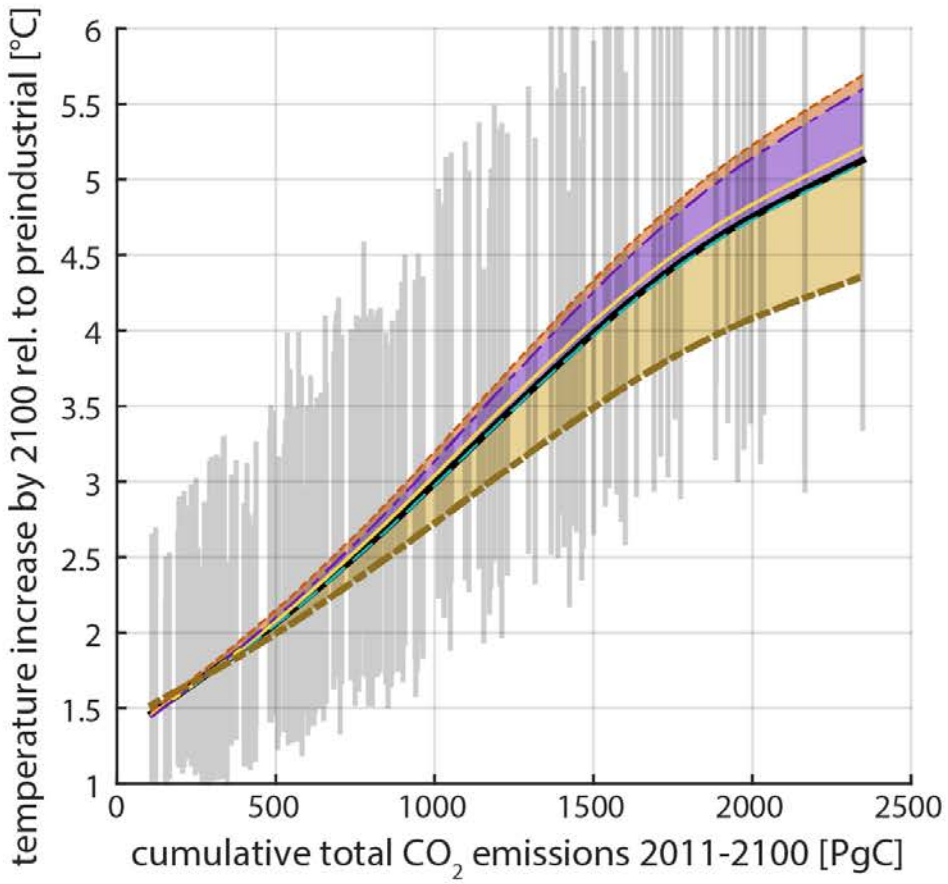

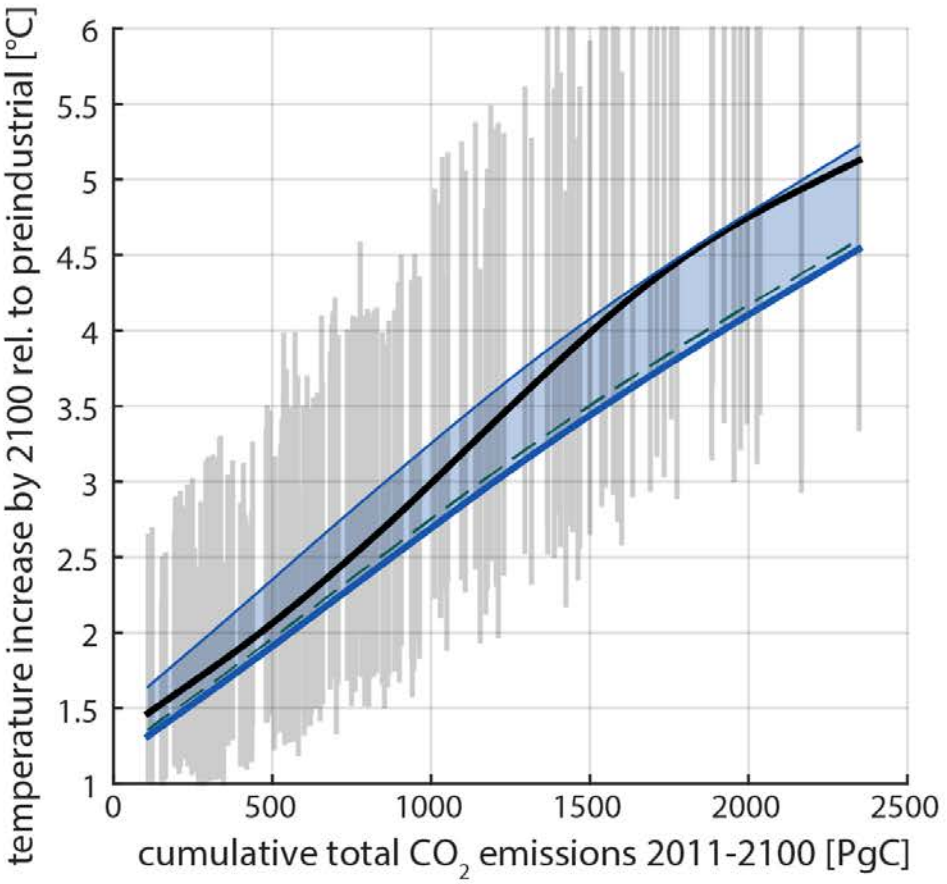

Rogelj *et al*, 2015, ERL

Summary

Points of (dis-)agreement

– Future baseline evolution

– Mitigation potential

(– Net climate effect of SLCF mixtures)

– SLCF mitigation at global scale complement but no substitute to carbon-dioxide mitigation

– Interaction with other policy objectives at national scale

Outlook

- **Beyond single model analysis**
  → critical importance EMF30 and MIPs
- **Non-homogenic forcing**
  → critical importance to look at geographical distribution of forcing
- **Multi-objective policy context**
  → critical importance to develop scenarios for climate research that DO NOT start from a climate-centred policy assumption
  (cf. upcoming work in the CD-LINKS project)

Thank you

… and enjoy the rest of the workshop