Planbureau voor de Leefomgeving

AMPERE

Deriving carbon budgets for IAM models

Michiel Schaeffer (CA)
Maarten van den Berg (PBL)
Detlef van Vuuren (PBL/UU)

Why focus on CO_2 budgets

- Part of the community does not have all gases / full climate model CO_2 budget could link these models to other targets

- Running under CO_2 budgets reduces uncertainty and focus analysis on the area where most of the action would need to occur

- Budget might be interesting for policy-makers, allows for substitution in time – but also communicates the “eating away the cake “concept well (Nature budget papers from 2009)

CO_2 budgets

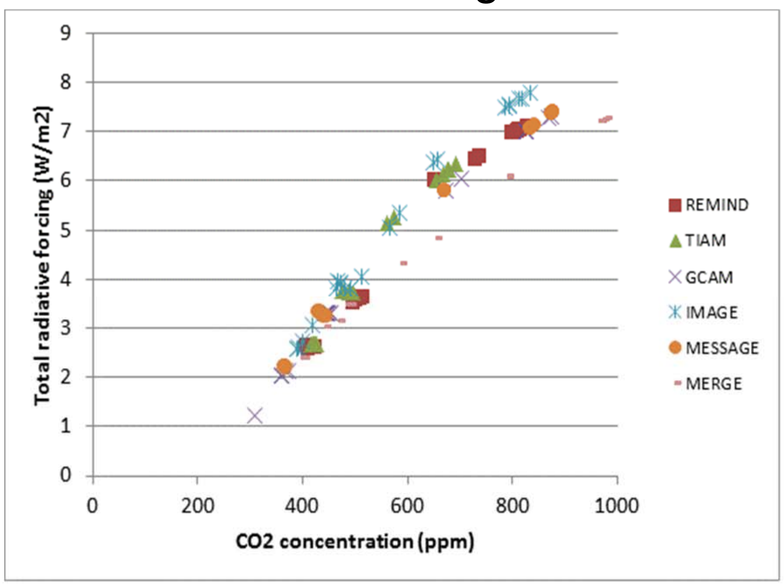
- Claim paper Meinshausen et al: CO2 budgets upto 2050 very good predictor for overshoot 2°

- Uncertainties:
  - Climate system (if related to temperature)
  - Carbon cycle (co2 removal rate; carbon cycle feedback)
  - Forcing from other gases:
    - CH4, N2O etc
    - Aerosols
  - Distribution CO2 energy vs. CO2 land

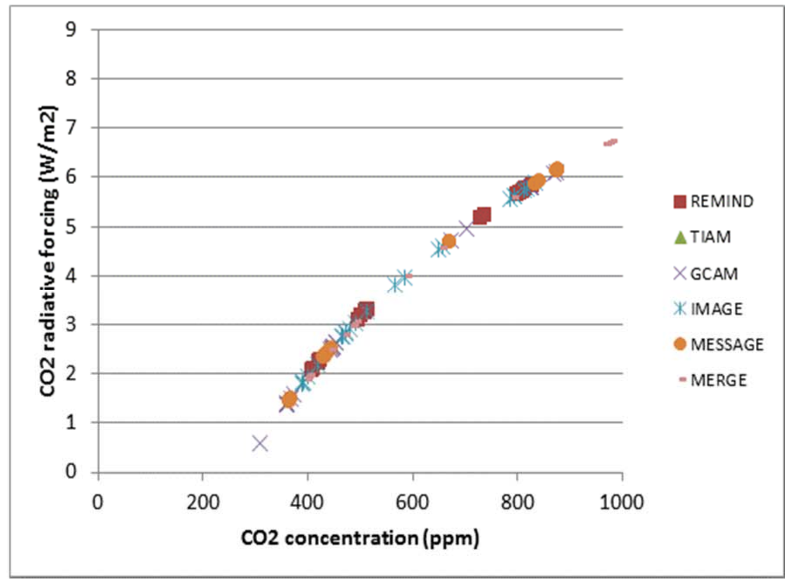
- Literature at the time of Meinshausen paper small at the low side (just a few models'

Concentration to radiative forcing

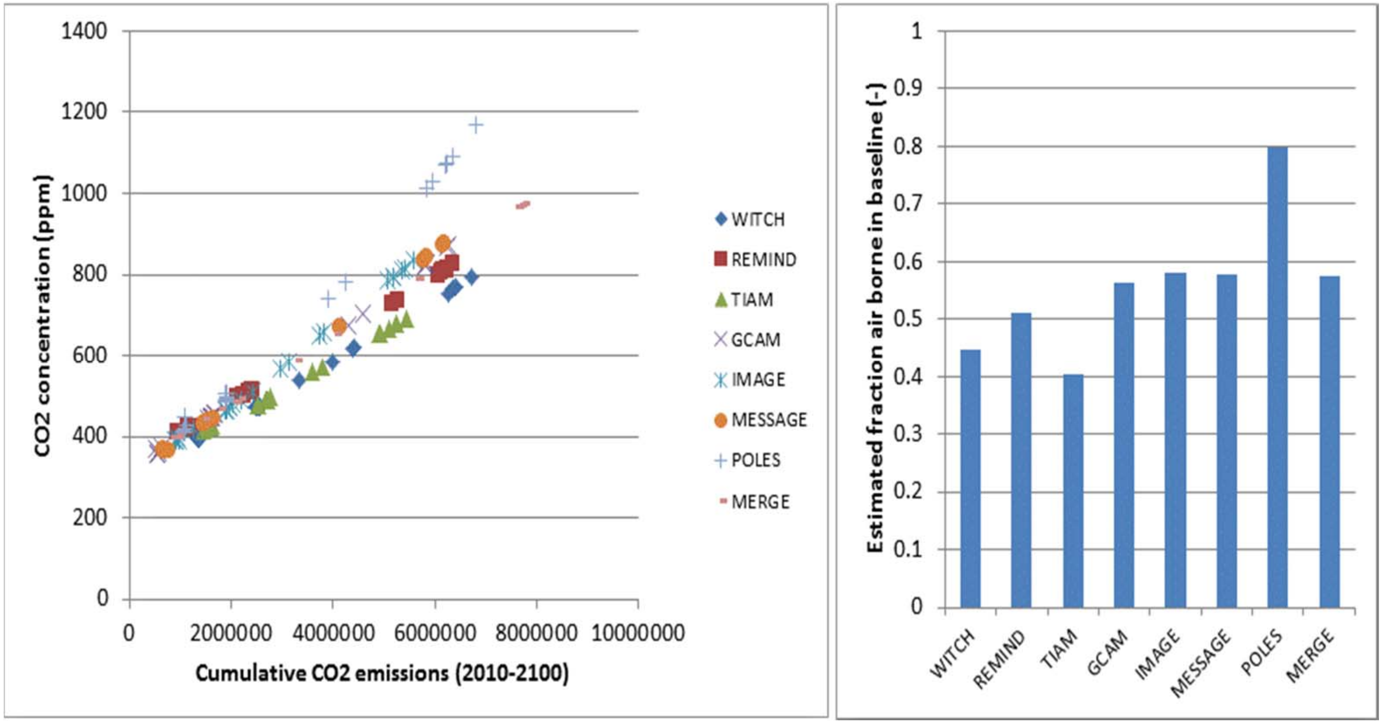
Total forcing

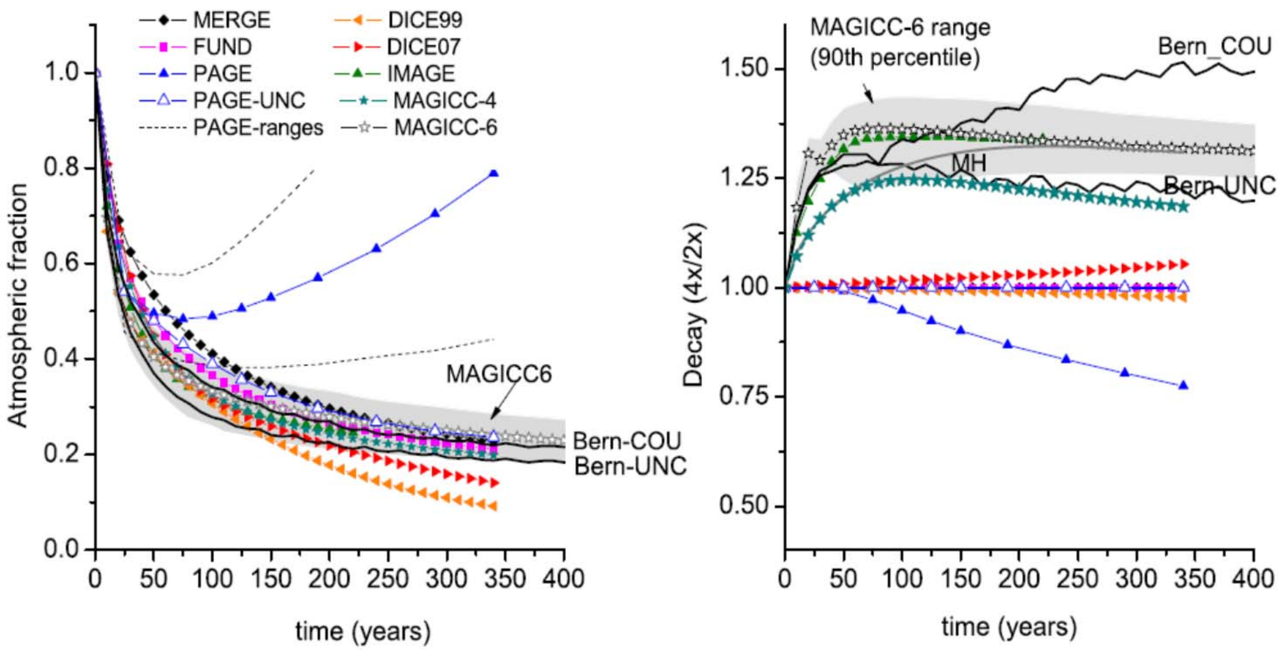


CO2 forcing

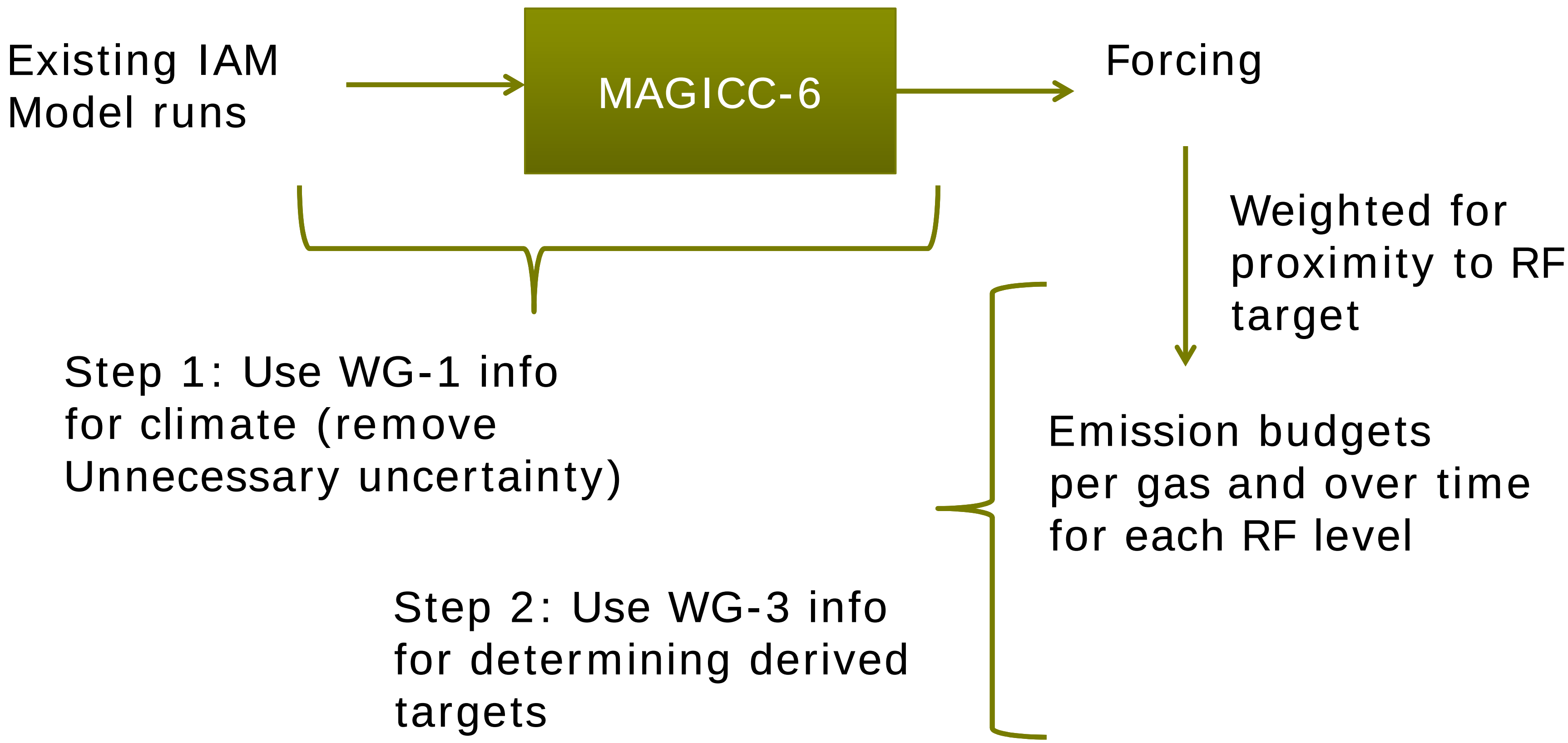


Emissions to concentrations



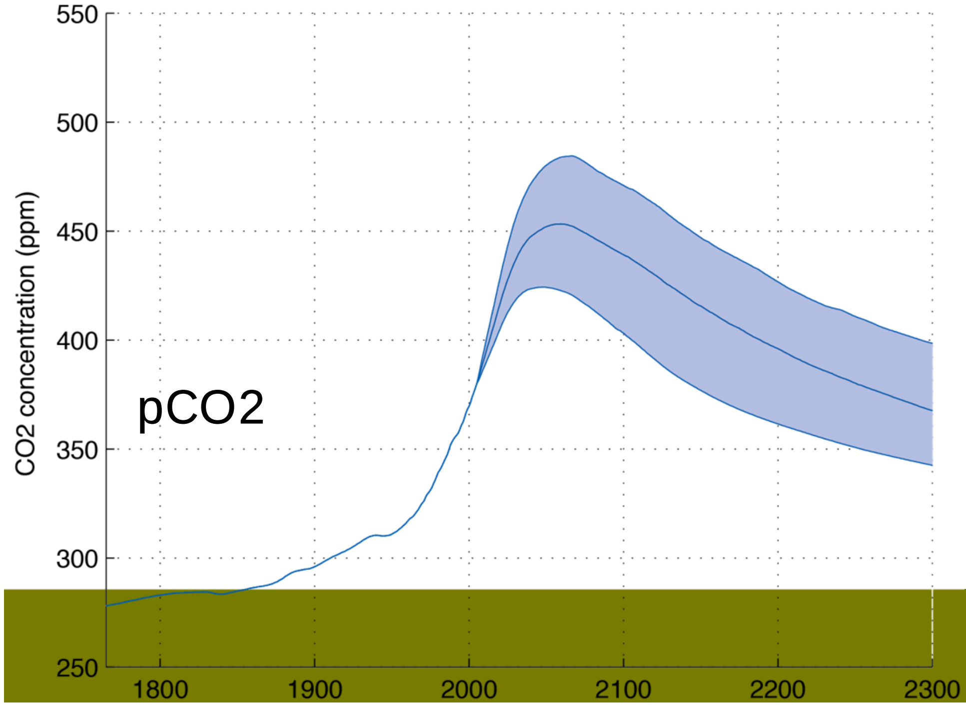

MERGE
FUND
PAGE
PAGE-UNC
PAGE-ranges
DICE99
DICE07
IMAGE
MAGICC-4
MAGICC-6
Atmospheric fraction
MAGICC6
Bern-COU
Bern-UNC
time (years)
MAGICC-6 range
(90th percentile)
Bern_COU
MH
Bern-UNC
Decay (4x/2x)
time (years)

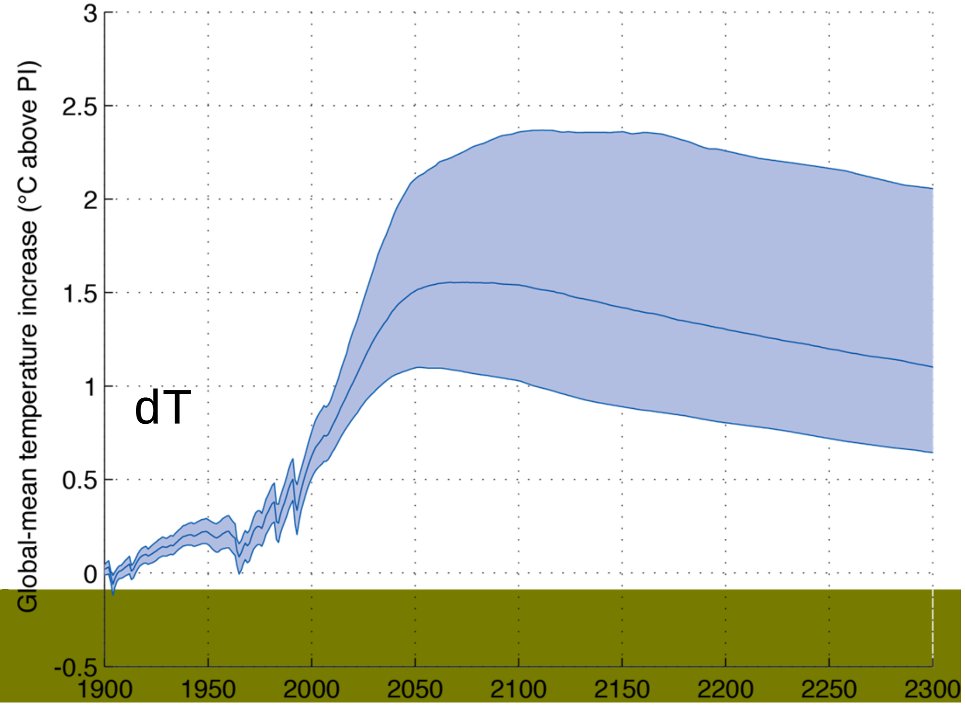
AMPERE Method to derive CO2 budgets



AMPERE Method to derive CO2 budgets

- AME and EMF24 scenario collections
- MAGICC6 Monte-Carlo setup
  (e.g. Meinshausen et al 2009; 2011 for RCPs)
  - 9 carbon-cycle model emulations (C4MIP)
  - 600 observationally constrained climate-model parameter sets reproducing climate sensitivity PDFs

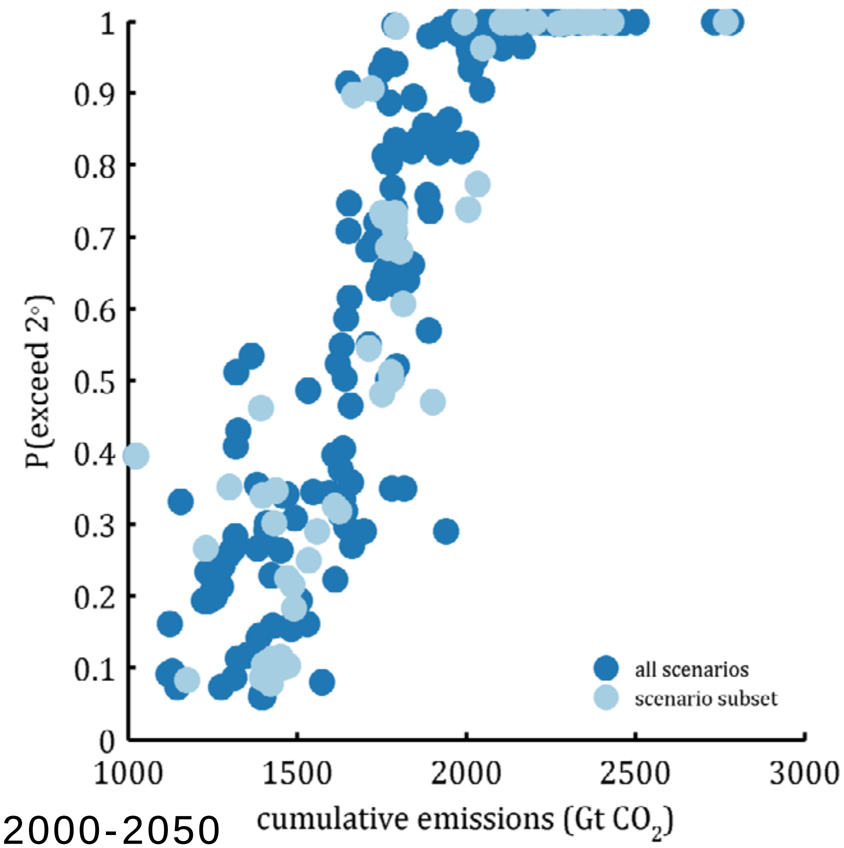




AME & EMF24 scenario library

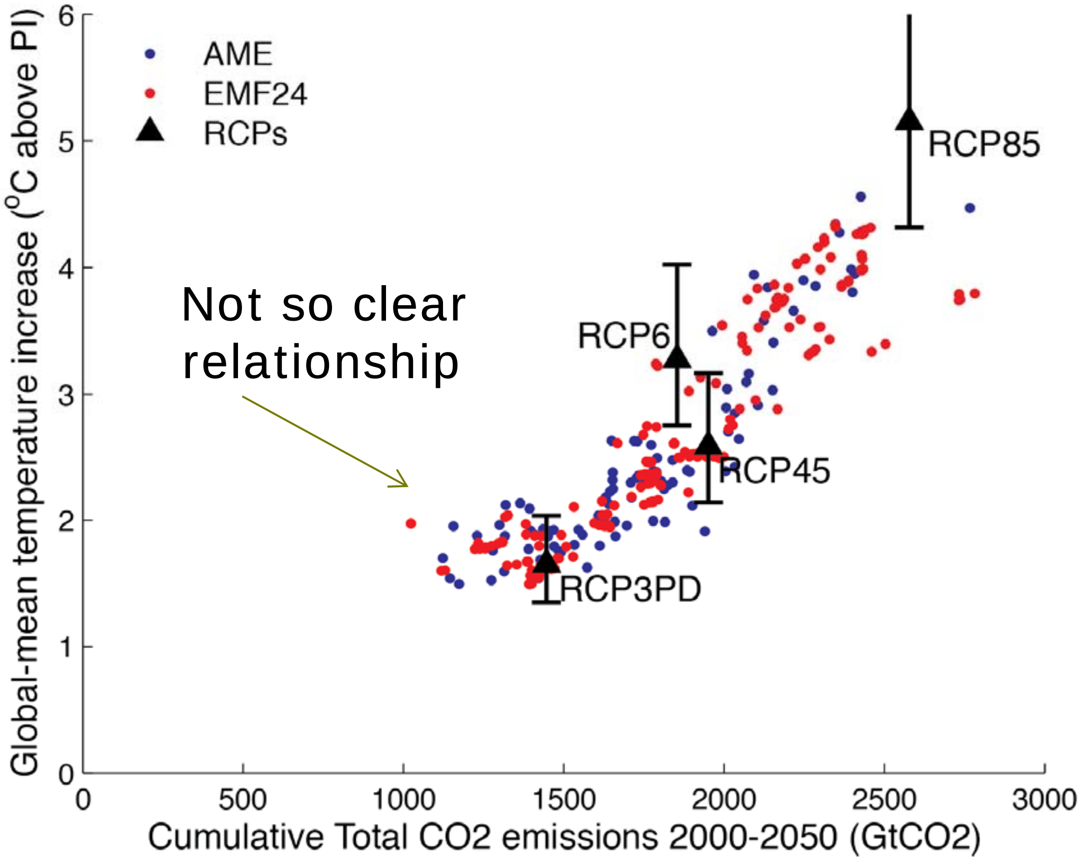
- 27 baseline scenarios
- 74 scenarios with all WMGHGs and aerosol precursors, as well as land-use CO_2
- 125 scenarios with at least energy-CO_2, CH_4, N_2O, SO_x
- 263 scenarios with at least energy-CO_2, CH_4, N_2O
- Total 318 scenarios (with at least energy-CO_2)

2°C probability all scenarios vs subset



2000-2050
total CO2

Warming by 2100 compared to RCPs



Warming by 2100 compared to RCP

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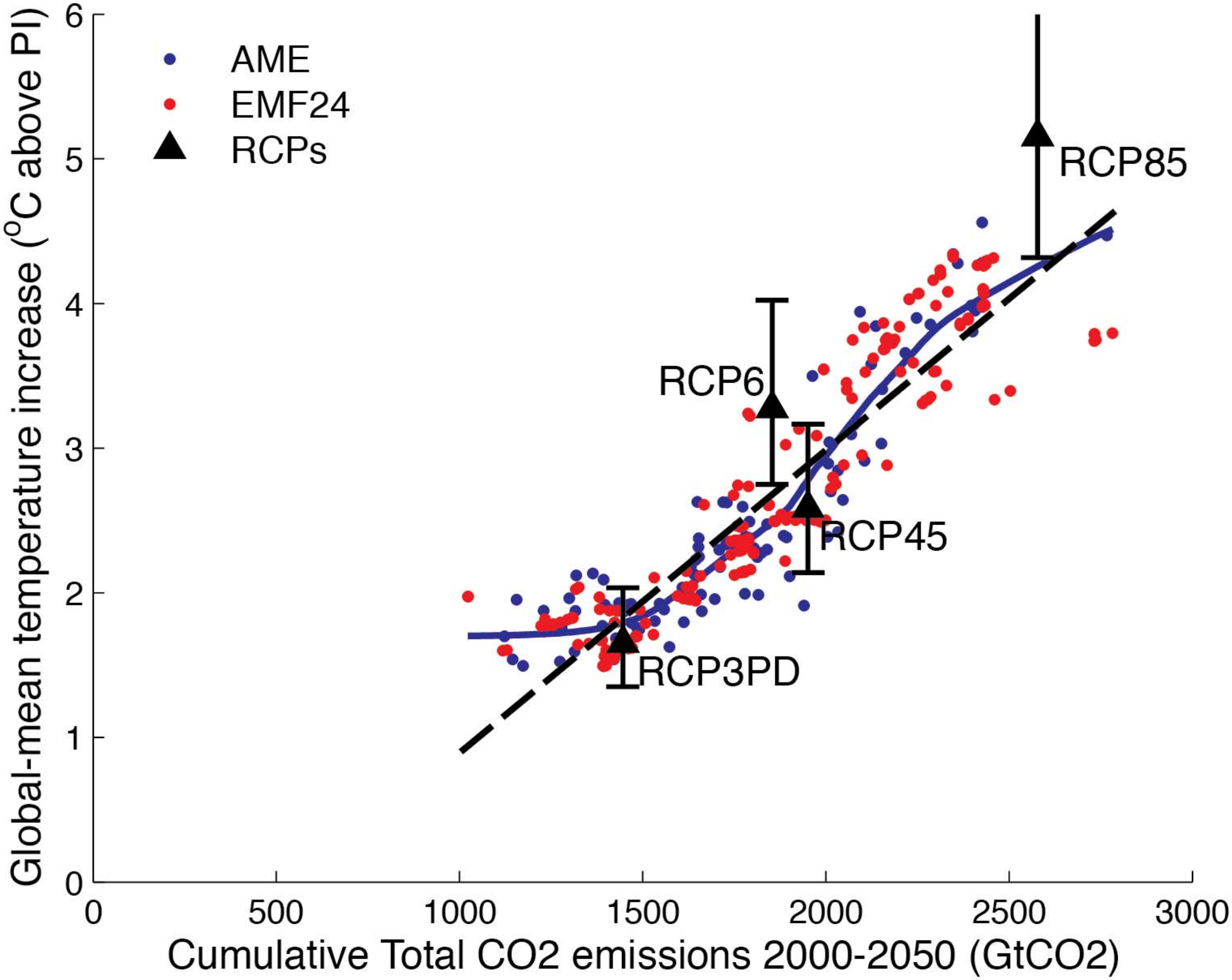

Effect of non-CO2 emissions on budgets

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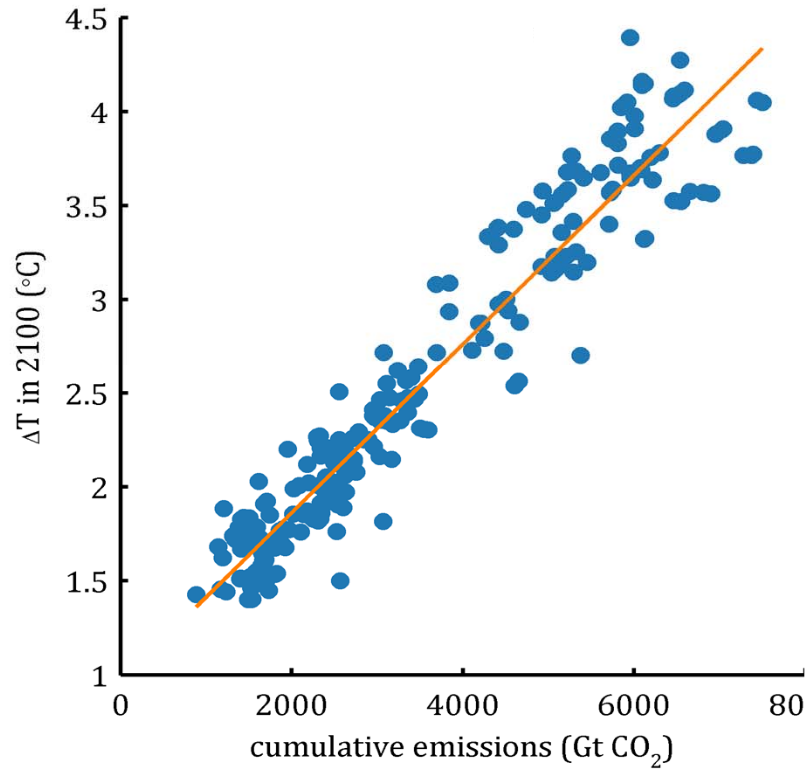
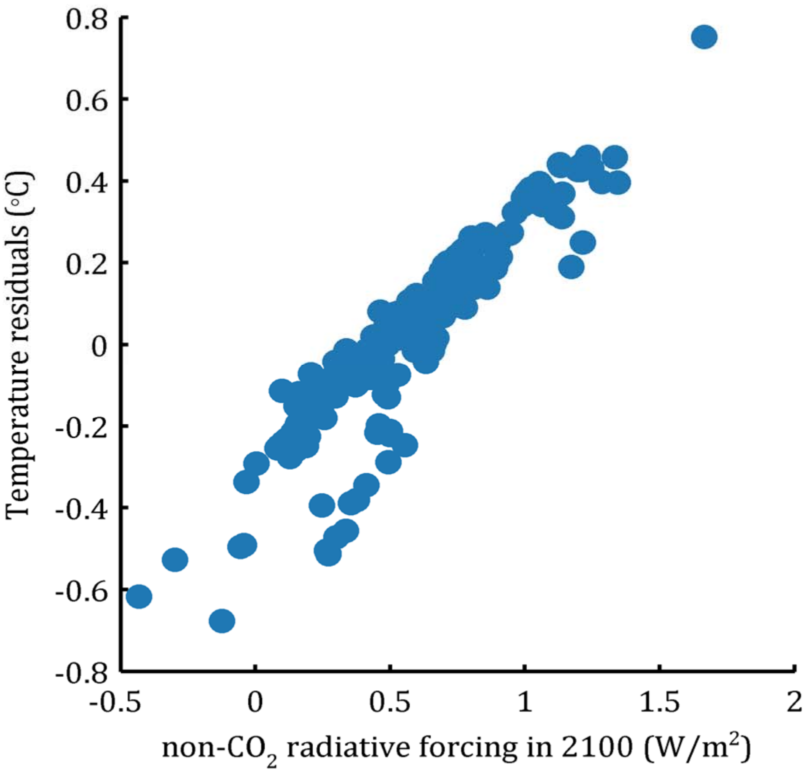
CO2 budget vs temperature



'Unexplained' temperature vs non-CO_2 forcing (2100)



2000-2100 total CO2

Effect of net-negative CO2 emissions on budgets

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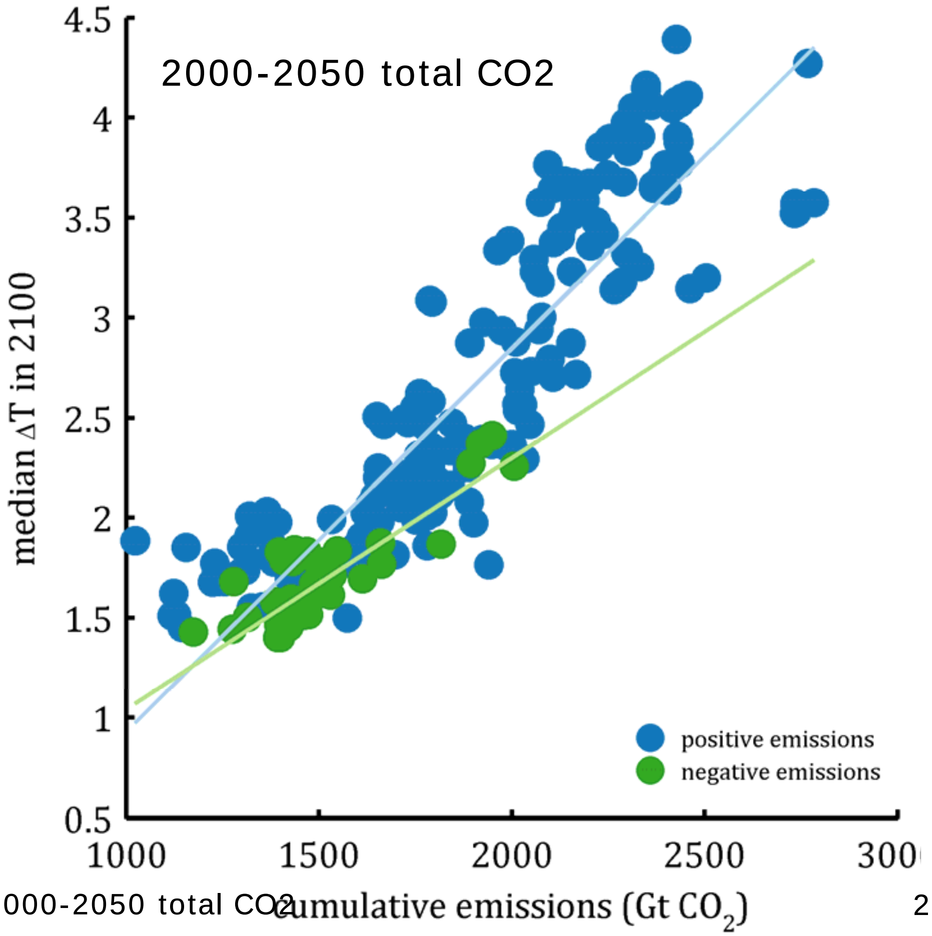
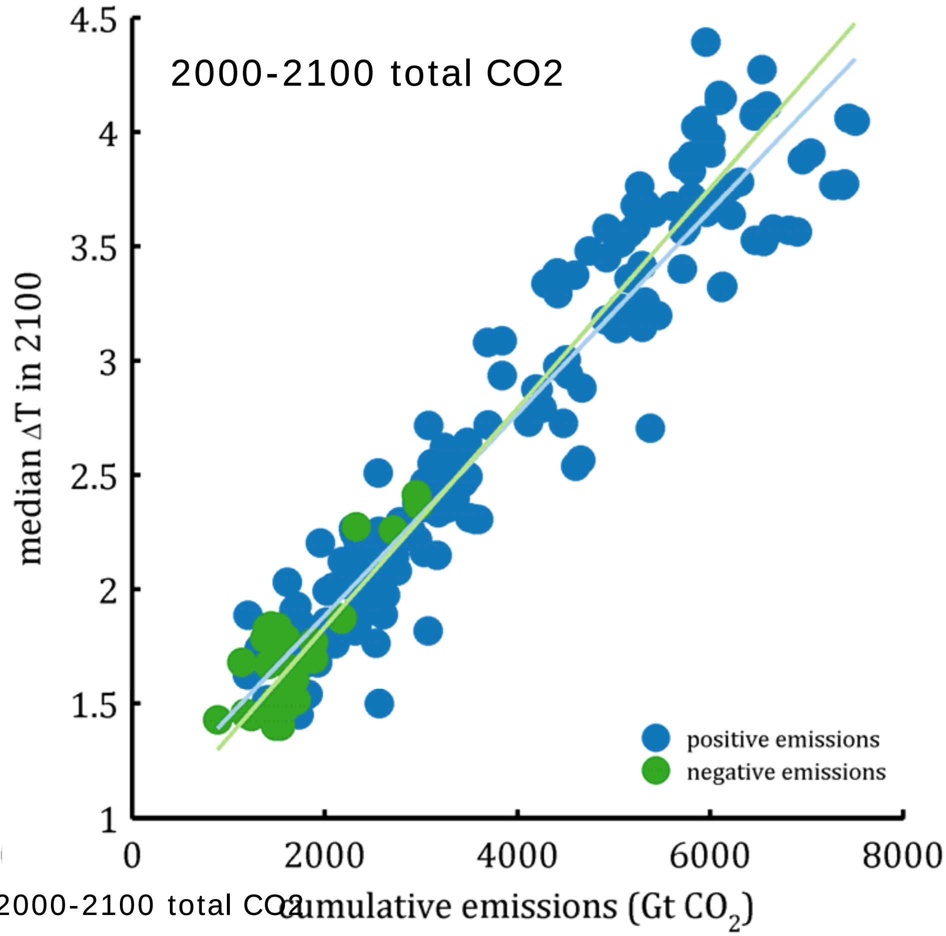


2000-2050 total CO2



2000-2100 total CO2

pCO2eq/RF budgets

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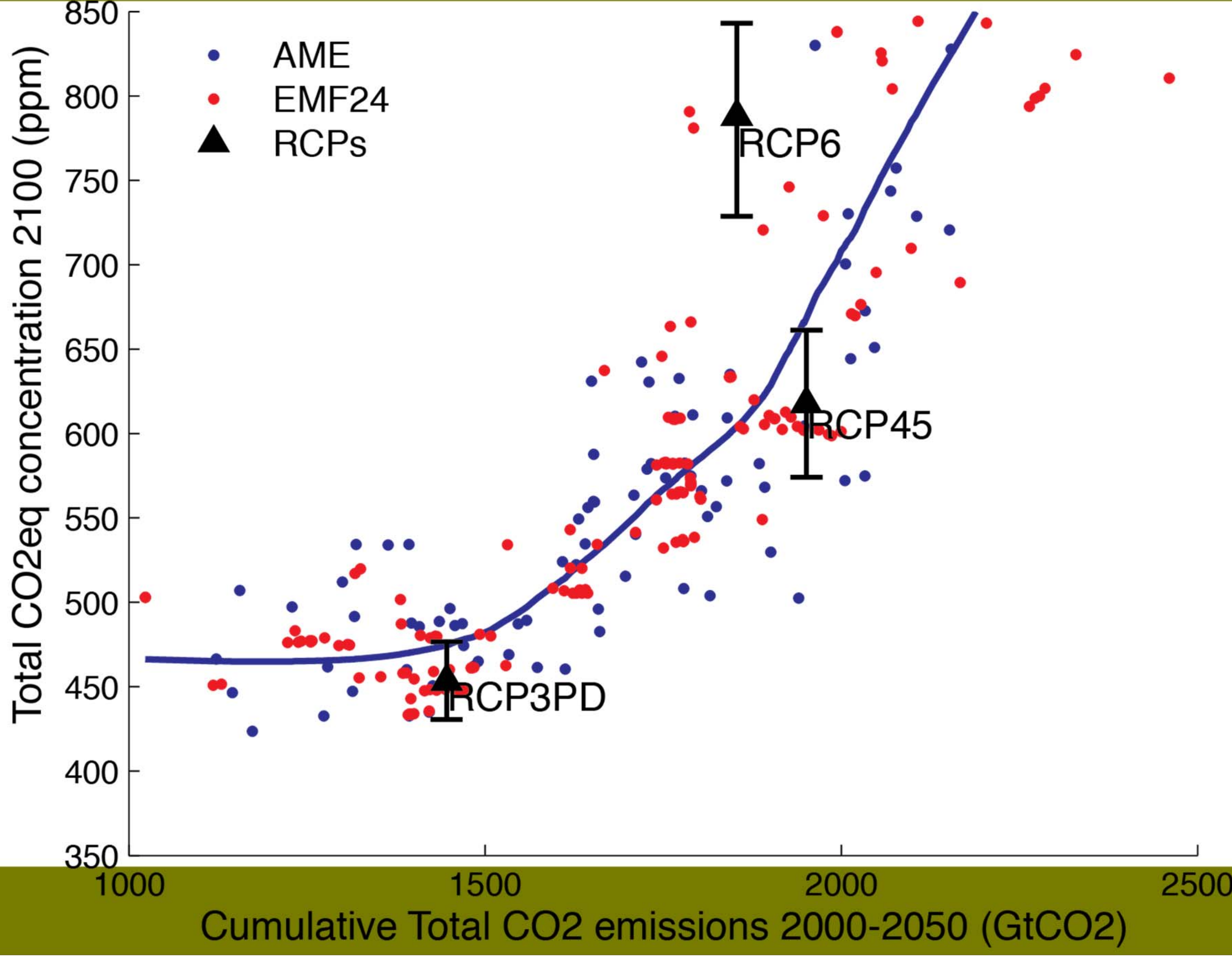

pCO2eq/RF budgets

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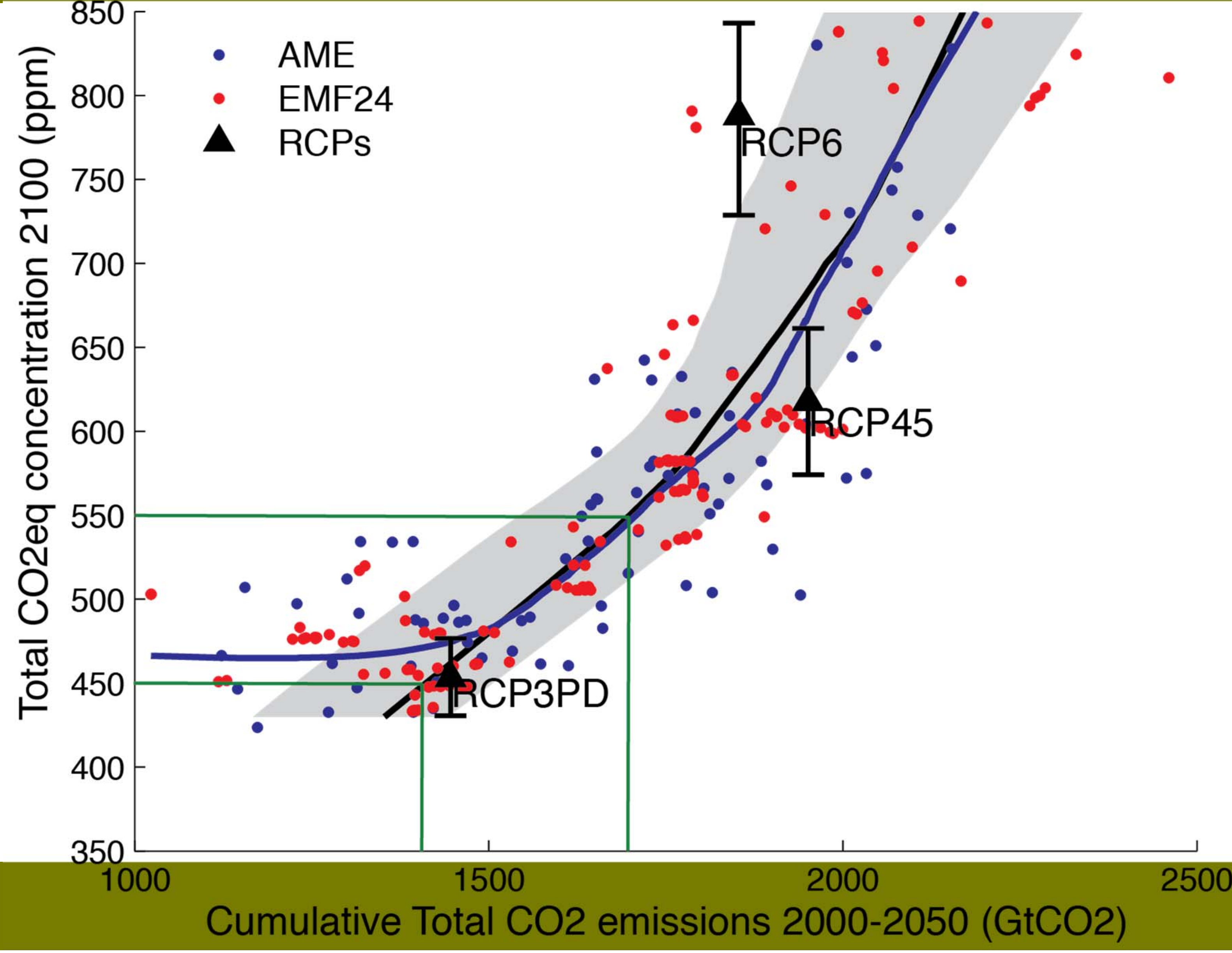

pCO2eq/RF budgets

Top row in each cell: median and 20-80%tile
Lower row in each cell: mean ±1SD

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target	450 ppm CO_2eq in 2100	500 ppm CO_2eq in 2100	550 ppm CO_2eq in 2100
Fossil-fuel CO_2 2020 ($GtCO_2$/yr)	30 (28-33) 30 ±3	31 (27-33) 30 ±4	36 (34-37) 35 ±2
Fossil-fuel CO_2 2030 ($GtCO_2$/yr)	24 (22-28) 24 ±4	28 (22-31) 27 ±6	36 (31-38) 35 ±4
Fossil-fuel CO_2 2050 ($GtCO_2$/yr)	12 (8-14) 12 ±4	17 (13-20) 17 ±4	26 (23-28) 26 ±3
Fossil-fuel CO_2 budget 2000-2049 ($GtCO_2$)	1200 (1200-1400) 1200 ±100	1300 (1200-1500) 1300 ±100	1600 (1500-1700) 1600 ±100
Fossil-fuel CO_2 budget 2000-2100 ($GtCO_2$)	1300 (1300-1500) 1400 ±200	1900 (1500-2000) 1800 ±300	2400 (2300-2600) 2400 ±200

target	450 ppm CO_2eq in 2100	500 ppm CO_2eq in 2100	550 ppm CO_2eq in 2100
Total GHG 2020 ($GtCO_2$e/yr)	44 (40-48) 44 ±4	46 (40-49) 44 ±6	50 (48-51) 49 ±2
Total GHG 2030 ($GtCO_2$e/yr)	39 (34-40) 37 ±3	41 (35-46) 40 ±6	49 (45-51) 48 ±3
Total GHG 2050 ($GtCO_2$e/yr)	21 (17-25) 21 ±5	27 (24-30) 27 ±4	36 (35-39) 37 ±3
Total GHG budget 2000-2049 ($GtCO_2$e)	1900 (1800-2000) 1900 ±100	2100 (1800-2200) 2000 ±200	2300 (2200-2400) 2300 ±100
Total GHG budget 2000-2100 ($GtCO_2$e)	2400 (2300-2600) 2500 ±200	3000 (2600-3200) 2900 ±300	3500 (3400-3700) 3600 ±100

“Predictive skill” of budgets

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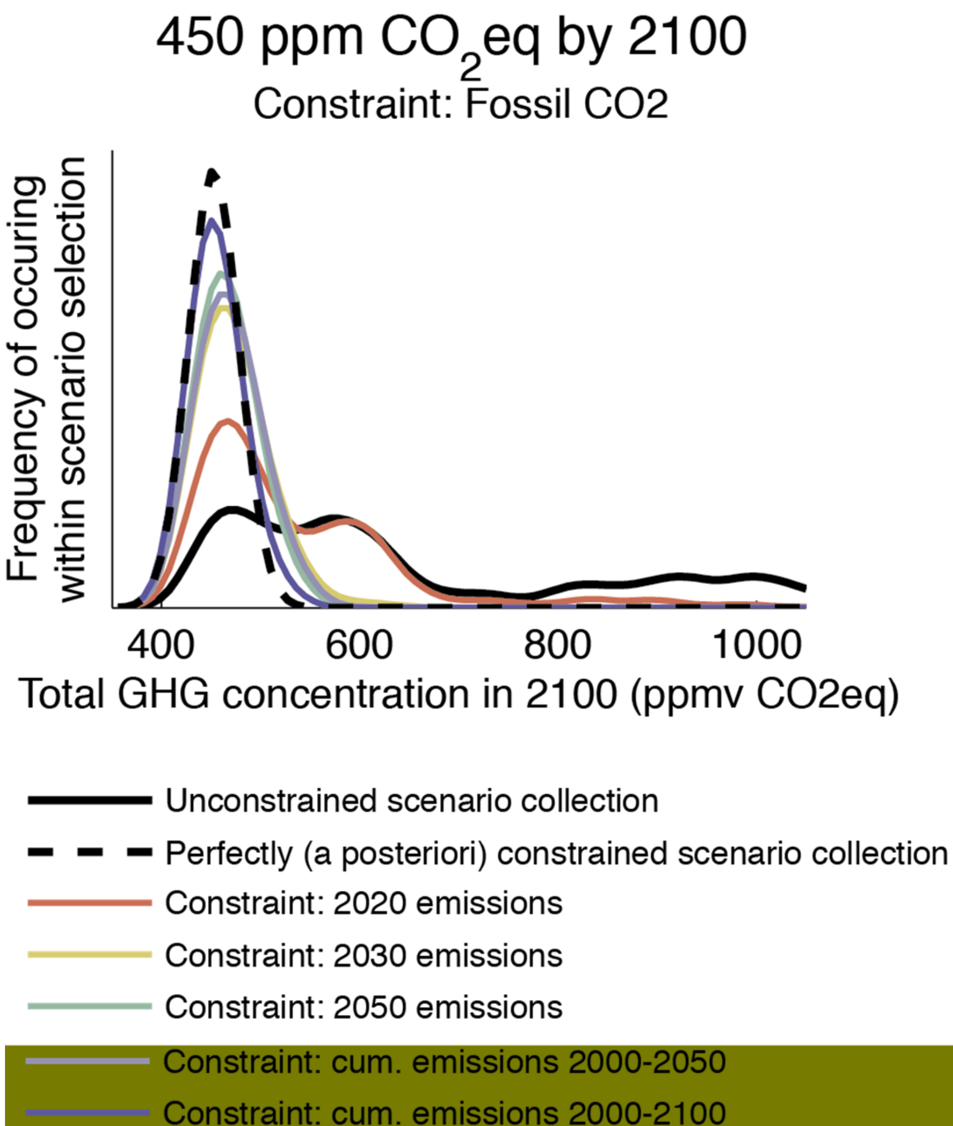

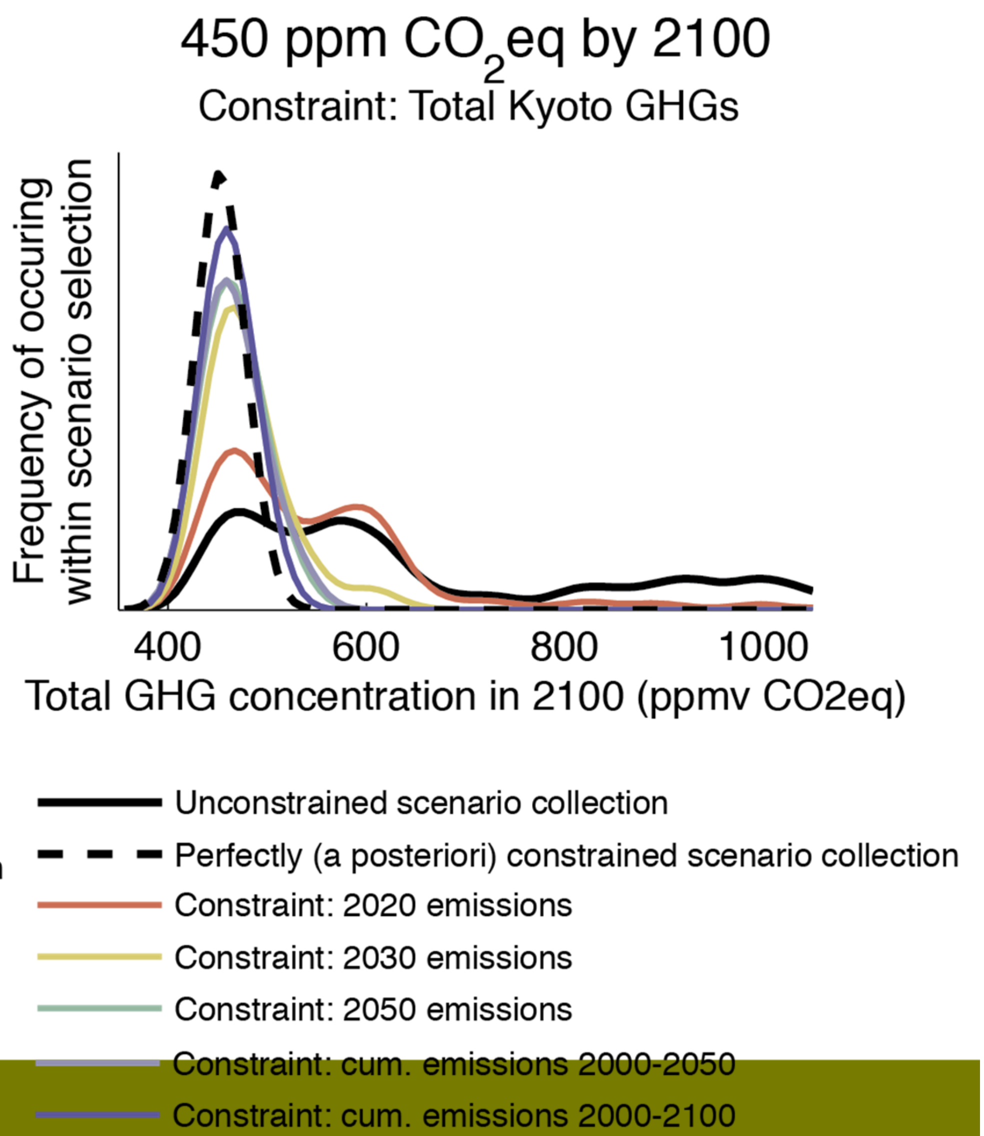

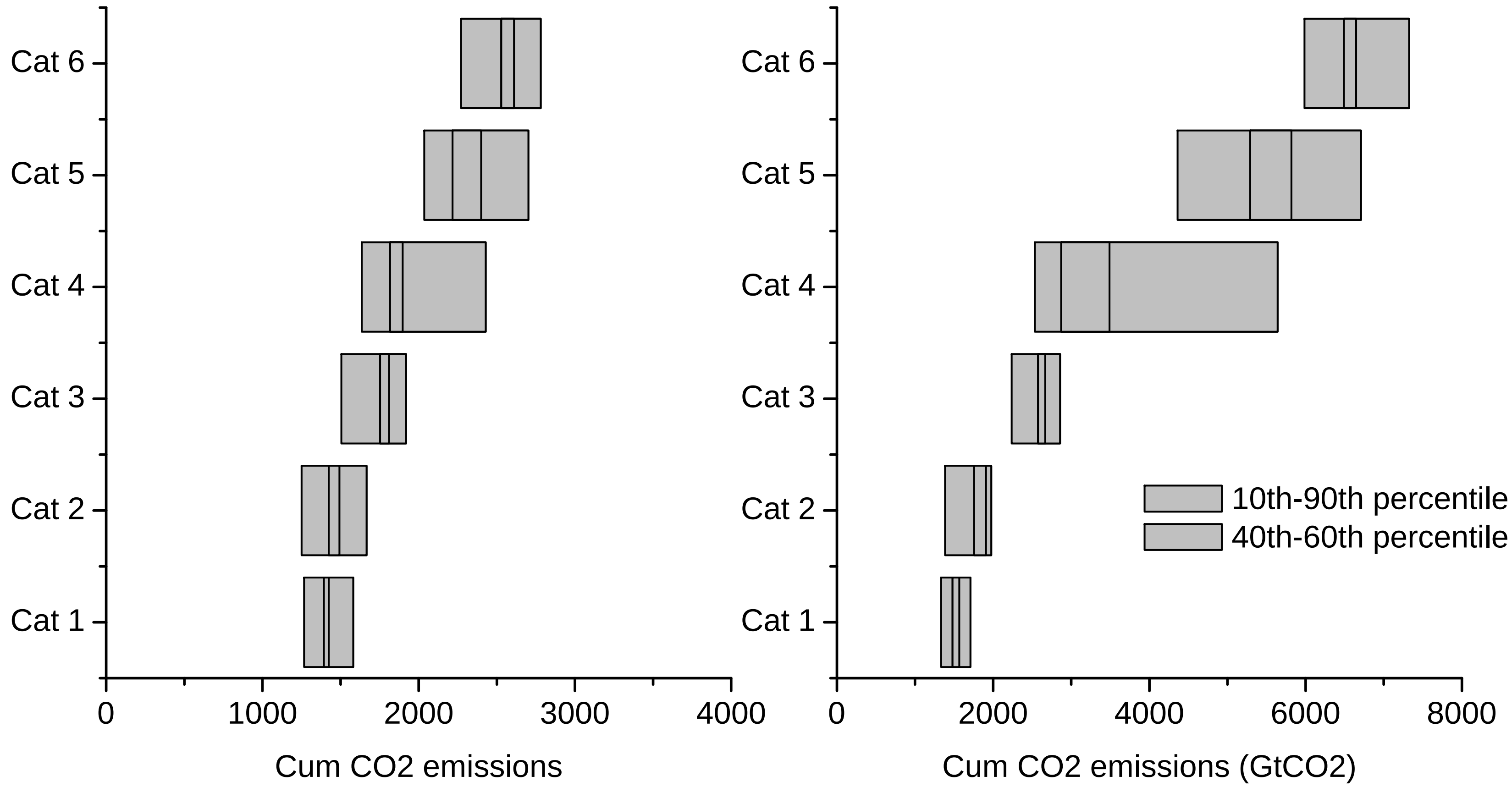
Cat 6
Cat 5
Cat 4
Cat 3
Cat 2
Cat 1
0
1000
2000
3000
4000
Cum CO2 emissions
0
2000
4000
6000
8000
Cum CO2 emissions (GtCO2)
10th-90th percentile
40th-60th percentile

Conclusions

- CO_2 budgets can help to connect different models
- But much more uncertain than suggested earlier
- We have an method to estimate budgets and uncertainty… but realize that at the low side, actually uncertainty might be even larger than suggested by our uncertainty ranges.