Priestley International Centre for Climate
Delivering research to underpin robust and timely climate solutions

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Emission Scenarios for Risk Assessments

Piers Forster

Thanks to:

Chris Smith, Tom Richardson

Overview

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- Developments in emission scenarios
- Using them to assess impacts
- Emulation of complex models
- Carbon budgets

Emission scenarios

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Possible future anthropogenic emissions of greenhouse gases (e.g. CO_2, CH_4), pollutants (e.g. sulphur dioxide, black carbon) and land-use change

- Thought experiments
  - Shell Sky
- Sector models
  - 100% renewable (Creutzig et al., 2017; Jacobson et al., 2017)
- Integrated assessment models
  - Representative Concentration Pathways (RCPs)
  - Shared Socioeconomic Pathways (SSPs)

Integrated Assessment Models

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Whole system consistent approach (economy, society, environment)

- Process based interactions between sectors/elements
- GHG pricing mechanisms
- **Recent developments couple more to regional land use models for bioenergy, water-use, food security etc.**
- Known to underestimate speed of some transformations
- Nearly all exclude climate impacts
- Cost estimates of carbon dioxide removal

Shared Socioeconomic Pathways (SSPs)

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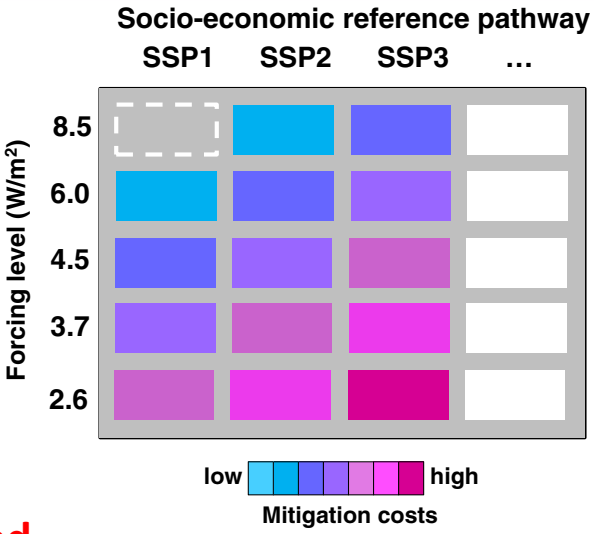
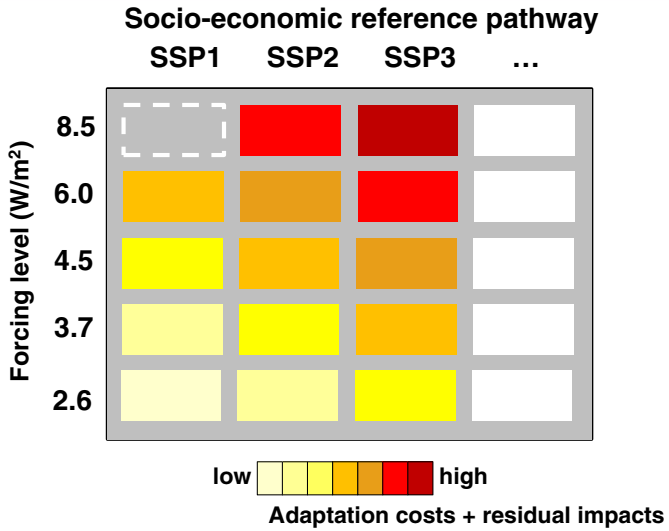
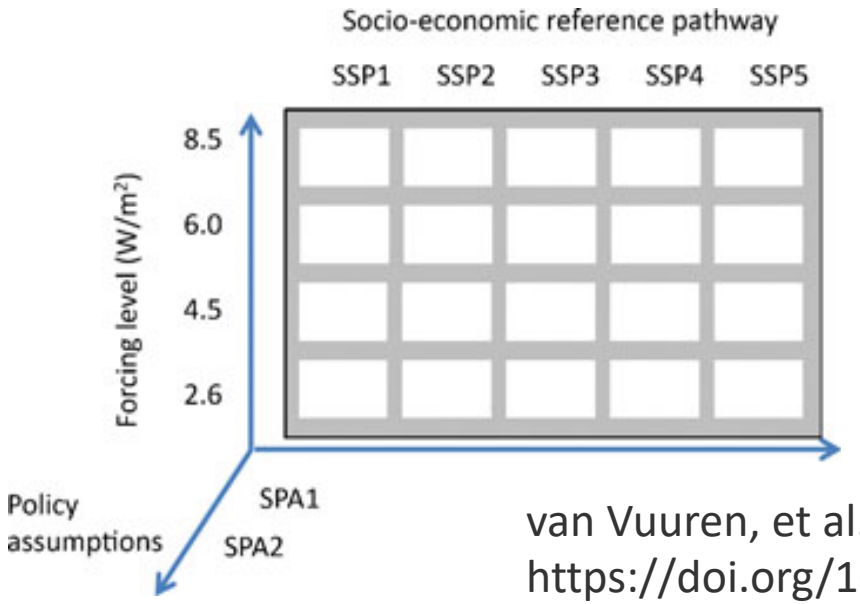




1.9Wm^{-2} added Rogelj et al 2018, Nat. Clim.Change



van Vuuren, et al. Climatic Change (2014) https://doi.org/10.1007/s10584-013-0906-1

SSP database

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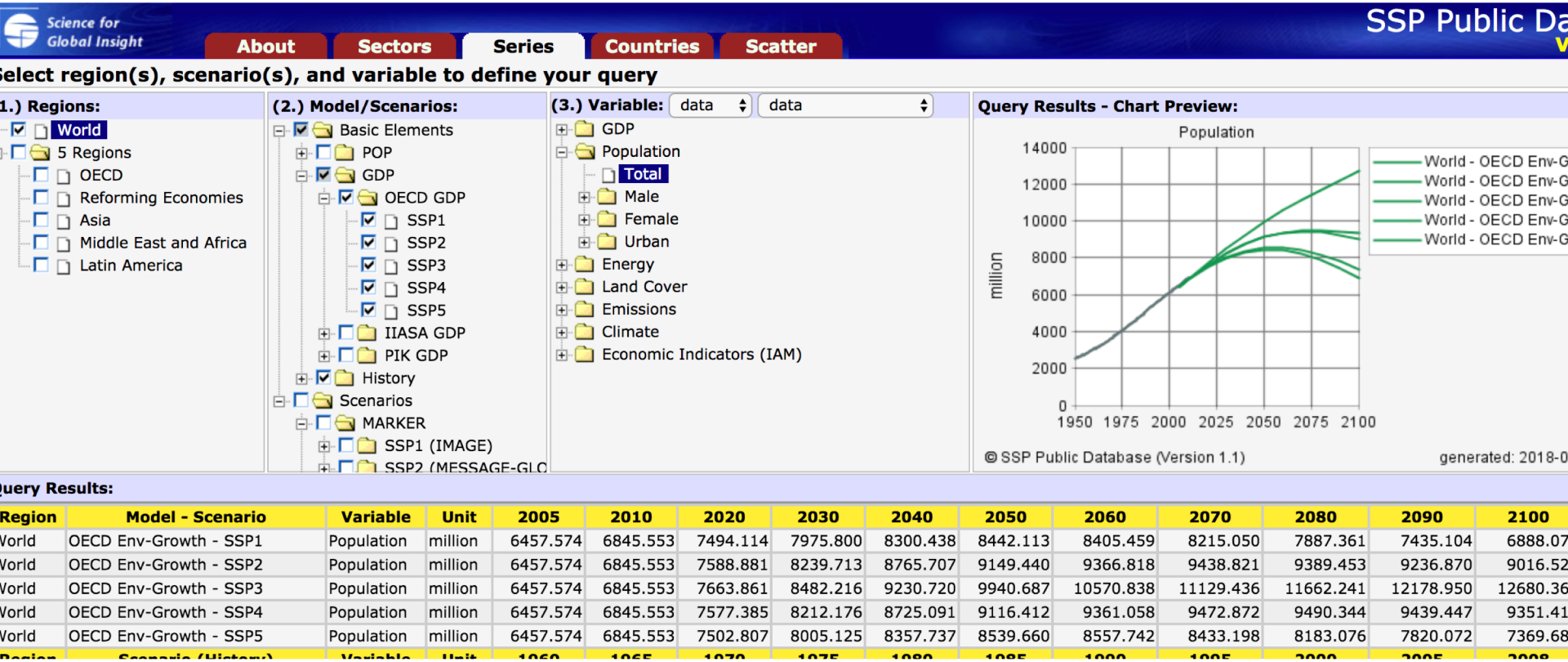

Query Results:

Region	Model - Scenario	Variable	Unit	2005	2010	2020	2030	2040	2050	2060	2070	2080	2090	2100
World	OECD Env-Growth - SSP1	Population	million	6457.574	6845.553	7494.114	7975.800	8300.438	8442.113	8405.459	8215.050	7887.361	7435.104	6888.07
World	OECD Env-Growth - SSP2	Population	million	6457.574	6845.553	7588.881	8239.713	8765.707	9149.440	9366.818	9438.821	9389.453	9236.870	9016.52
World	OECD Env-Growth - SSP3	Population	million	6457.574	6845.553	7663.861	8482.216	9230.720	9940.687	10570.838	11129.436	11662.241	12178.950	12680.36
World	OECD Env-Growth - SSP4	Population	million	6457.574	6845.553	7577.385	8212.176	8725.091	9116.412	9361.058	9472.872	9490.344	9439.447	9351.41
World	OECD Env-Growth - SSP5	Population	million	6457.574	6845.553	7502.807	8005.125	8357.737	8539.660	8557.742	8433.198	8183.076	7820.072	7369.68

[IASA - International Institute for Applied Systems Analysis]

Use in Climate Models: ScenarioMIP

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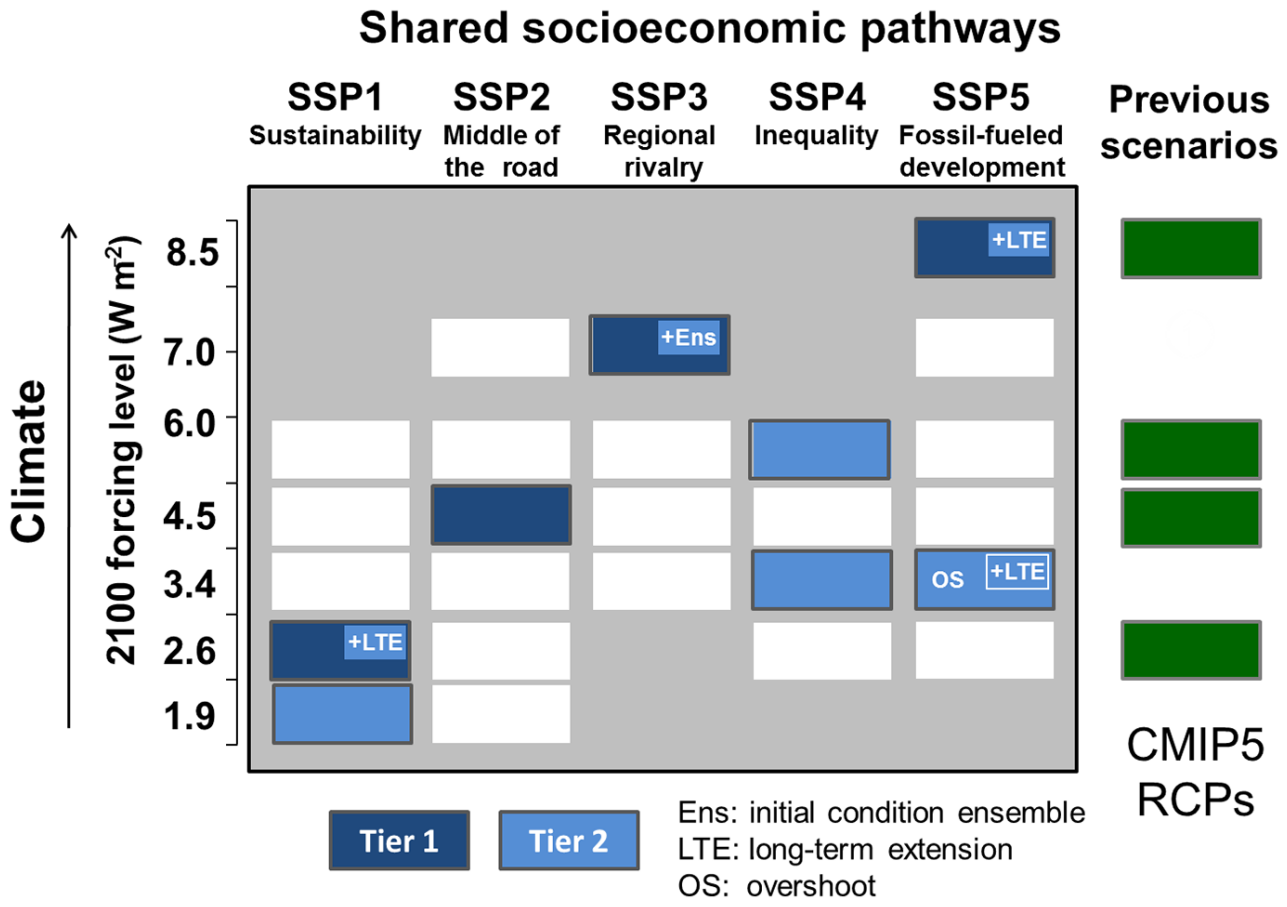

O'Neill et al. GMD 2016, doi:10.5194/gmd-9-3461-2016

Emulators: FaIR model

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FaIR (Finite amplitude Impulse Response) model

- Based on IPCC 5th Assessment Report/CMIP5 models
- Converts emissions of CO_2 and other greenhouse gases to atmospheric concentrations
- Includes forcing from ozone, aerosols, land use change and other sectors based on input emissions
- Option to include solar fluctuations and volcanoes
- Simulates the action of radiative forcing on planetary temperature change based on responses from contemporary climate models

Smith et al. GMD, 2018

Use historical constraints to make projections

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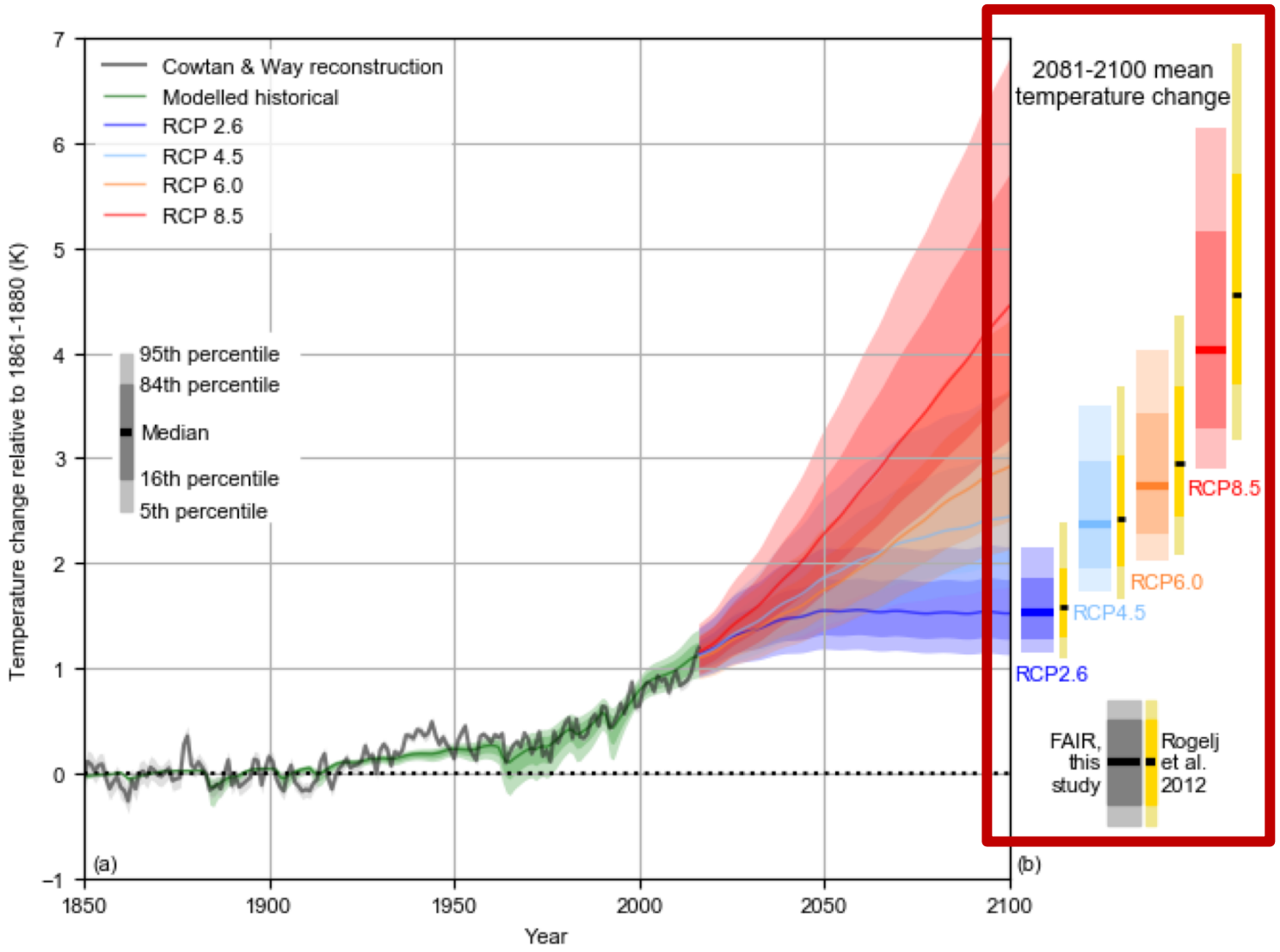

Emulation of rainfall patterns

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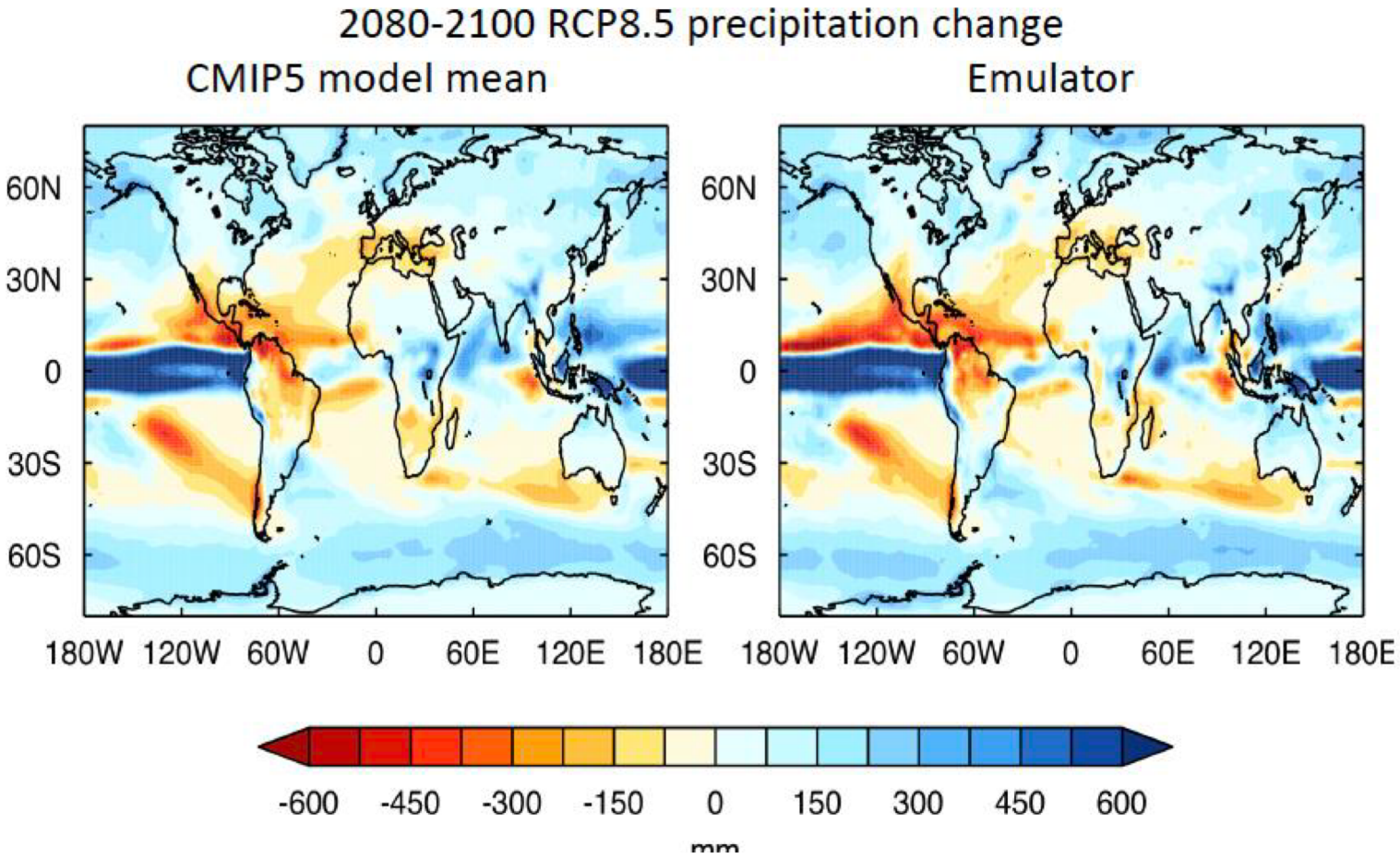

Tom Richardson, Piers Forster in preparation

Characterising uncertainty

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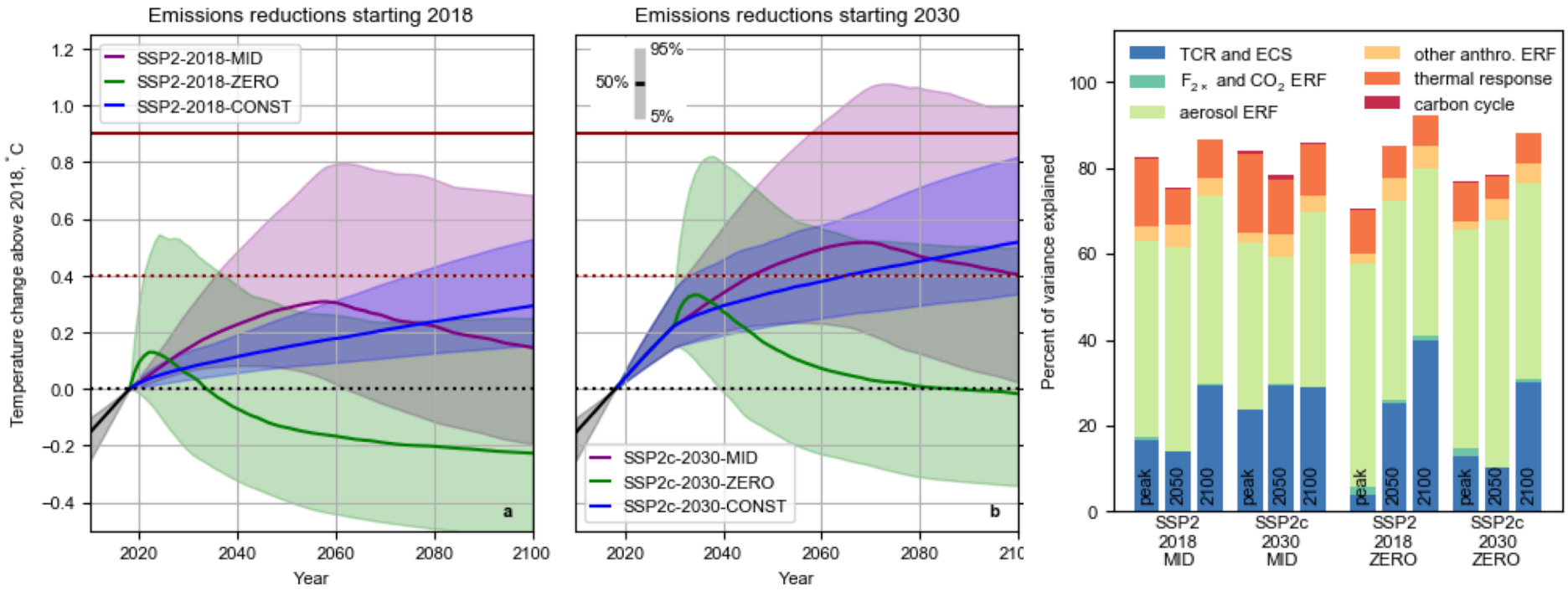

- 62% of staying under 1.5°C if fossil fuel infrastructure is phased out based on historical lifetimes starting this year
- 38% chance if mitigation delayed until 2030
- Most uncertainty in peak warming relates to present day aerosol cooling

Smith et al., submitted

Carbon budget analysis

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- Temperature change scales (approximately) linearly with cumulative carbon emissions
- Use this to derive “carbon budgets”: how much can be emitted to stay under 1.5°C
- Complicated by non-CO_2 emissions
- **Exact definition has large effect as 1.5°C threshold approached**

Remaining carbon budget

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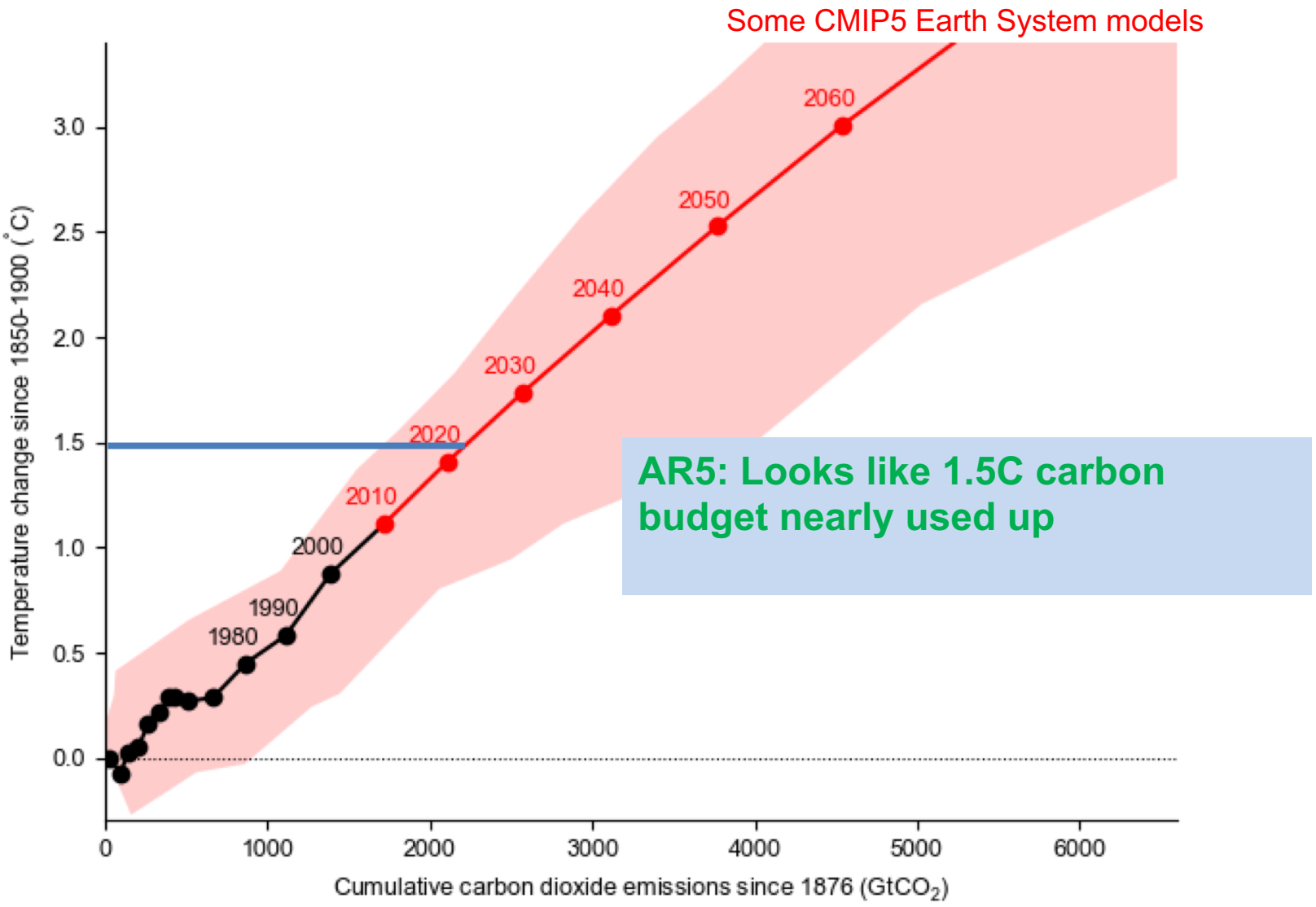

AR5: Looks like 1.5C carbon budget nearly used up

Remaining carbon budget

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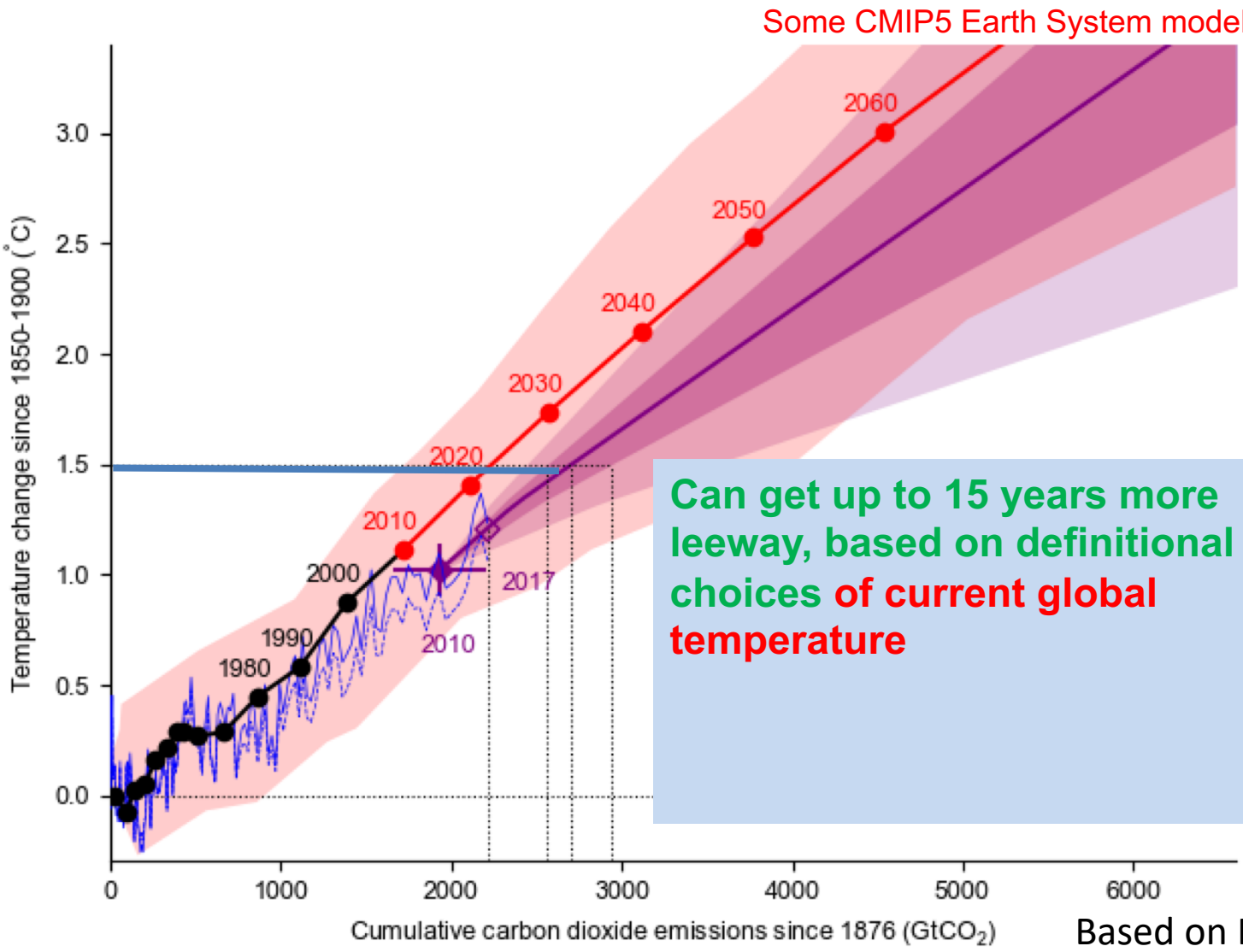

Can get up to 15 years more leeway, based on definitional choices of current global temperature

Based on IPCC SR1.5

Conclusions

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- SSPs emissions well established and useful ranges to assess risks for different emission scenarios. Shouldn't combine risk across scenarios: Treat each as a story
- CMIP6 with emulation will provide robust tools for exploring future and characterising uncertainties across scenarios
  - Natural forcing and variability remain issues for emulation (watch this space)

Do It Yourself

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- FAIR is written in Python and open source
- Interactive example: https://mybinder.org/v2/gh/OMS-NetZero/FAIR/master?filepath=Example-Usage.ipynb
- Home page: https://github.com/OMS-NetZero/FAIR
- User guide: https://fair.readthedocs.io

References:

- Smith, C. J., Forster, P. M., Allen, M., Leach, N., Millar, R. J., Passerello, G. A., and Regayre, L. A.: FAIR v1.3: A simple emissions-based impulse response and carbon cycle model, Geosci. Model Dev., https://doi.org/10.5194/gmd-2017-266, 2018 (in press)
- Millar, R. J., Nicholls, Z. R., Friedlingstein, P., and Allen, M. R.: A modified impulse-response representation of the global near-surface air temperature and atmospheric concentration response to carbon dioxide emissions, Atmos. Chem. Phys., 17, 7213-7228, https://doi.org/10.5194/acp-17-7213-2017, 2017.