What has C^{4}MIP learned from CMIP5 Lessons for CMIP6

Pierre Friedlingstein

University of Exeter

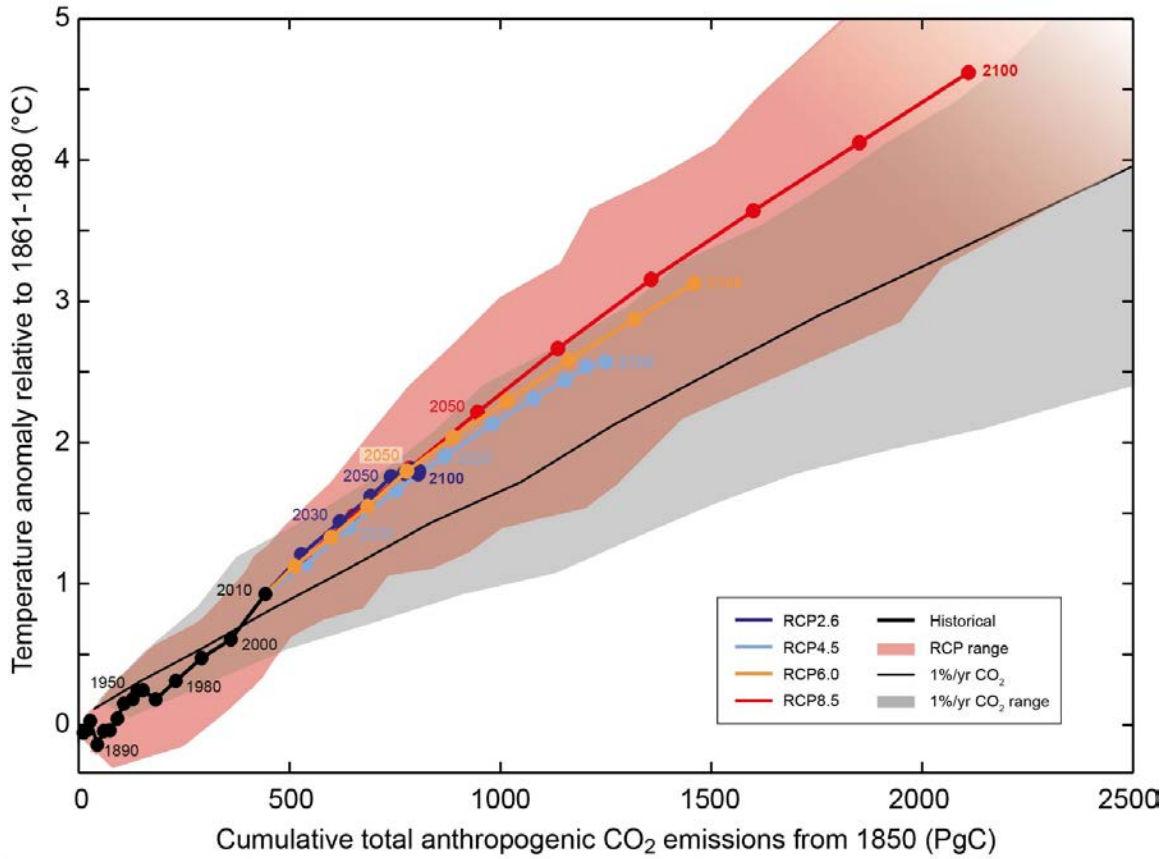
Modelling groups

- 11 modelling groups, about 15 models (BCC-CSM1, BNU-ESM, CanESM2, CESM1-BGC, GFDL-ESM2, HadGEM2-ES, INMCM4, IPSL-CM5, MIROC-ESM, MPI-ESM, NorESM)
- Simulations performed
  - 1pct , BGC, RAD
  - C-Driven Historical + RCPs
  - E-driven Historical + RCPs

Outputs

- 30+ CMIP5/carbon related publications
- C^4MIP special issue in J Climate: 10-15 papers
- Significant contribution to AR5 WG1 (chapters 6 & 12, TS and SPM)

AR5 SPM



Cumulative emissions of CO2 largely determine global mean surface warming by the late 21st century and beyond.

Limiting climate change will require substantial and sustained reductions of greenhouse gas emissions.

"All the News That's Fit to Print"

The New York Times

Late Edition

Today, mostly sunny skies, seasonable temperatures, high 72. **Tonight,** mostly clear skies, low 56. **Tomorrow,** partly sunny, still mild, high 73. Weather map, Page A13.

VOL. CLXIII . . . No. 56,273 NEW YORK, SATURDAY, SEPTEMBER 28, 2013 $2.50

Climate Panel Seeks Ceiling on Global Carbon Output

From Page A1

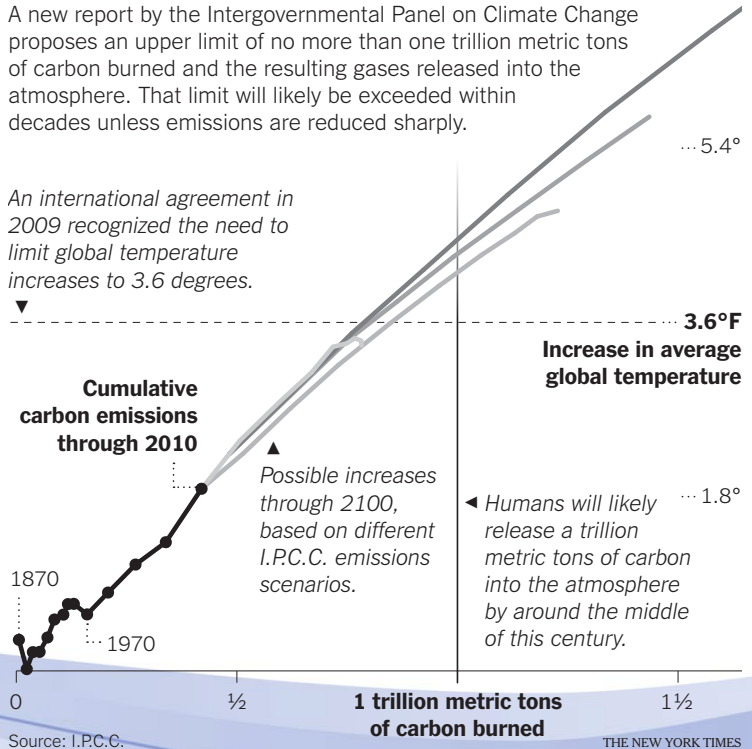
ence has been the dominant cause of the observed warming since the mid-20th century."

The new report is a 36-page summary for world leaders of a 900-page report that is to be released next week on the physical science of climate change. That will be followed by additional reports in 2014 on the most likely impacts and on possible steps to limit the damage. A draft of the summary leaked last month, and the final version did not change greatly, though it was edited for clarity.

Going well beyond its four previous analyses of the emissions problem, the panel endorsed a "carbon budget" for humanity — a limit on the amount of the primary greenhouse gas, carbon dioxide, that can be produced by industrial activities and the clearing of forests. No more than one trillion metric tons of carbon could be burned and the resulting gases released into the atmosphere, the panel found, if plane-

Setting a Carbon Limit

A new report by the Intergovernmental Panel on Climate Change proposes an upper limit of no more than one trillion metric tons of carbon burned and the resulting gases released into the atmosphere. That limit will likely be exceeded within decades unless emissions are reduced sharply.



Source: I.P.C.C.

THE NEW YORK TIMES

before," said Gerald A. Meehl, an American scientist who helped write the report. "It's more like a stair-step kind of thing."

Climate scientists not involved in writing the new report said the authors had made a series of cautious choices in their assessment of the scientific evidence. Regarding sea level rise, for instance, they gave the first firm estimates ever contained in an intergovernmental panel report, declaring that if emissions continued at a rapid pace, the rise by the end of the 21st century could be as much as three feet. They threw out a string of published papers suggesting a worst-case rise closer to five feet.

Similarly, the authors went out of their way to include recent papers suggesting that the earth might be less sensitive to carbon dioxide emissions than previously thought, even though serious questions have been raised about the validity of those estimates.

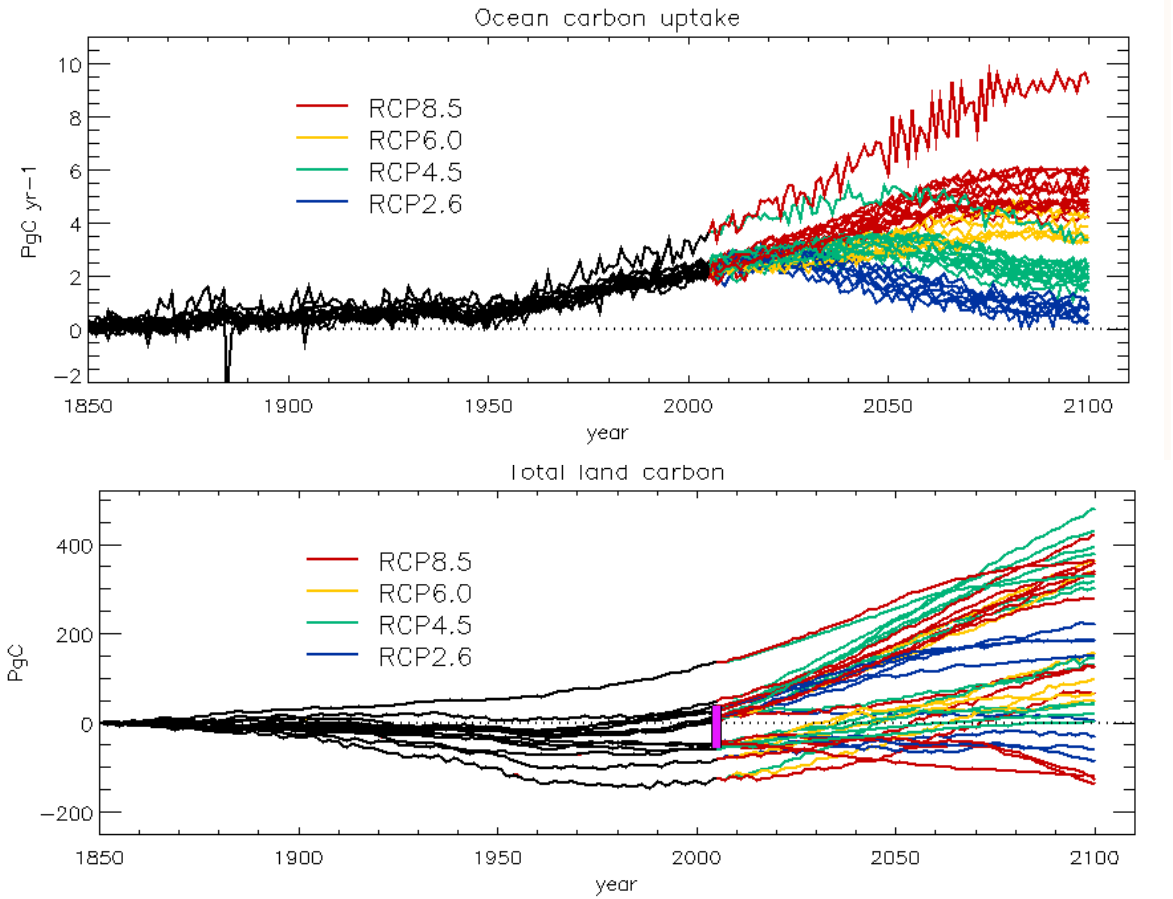
The new report lowered the bottom end of the range of potential warming that could be expected to occur over the long

AR5 SPM

- Climate change will affect carbon cycle processes in a way that will exacerbate the increase of CO_2 in the atmosphere (*high confidence*).
- Ocean uptake of anthropogenic CO_2 will continue under all four RCPs through to 2100, with higher uptake for higher concentration pathways (*very high confidence*). The future evolution of the land carbon uptake is less certain…
- Earth System Models project a global increase in ocean acidification for all RCP scenarios. The corresponding decrease in surface ocean pH by the end of 21st century is in the range of …

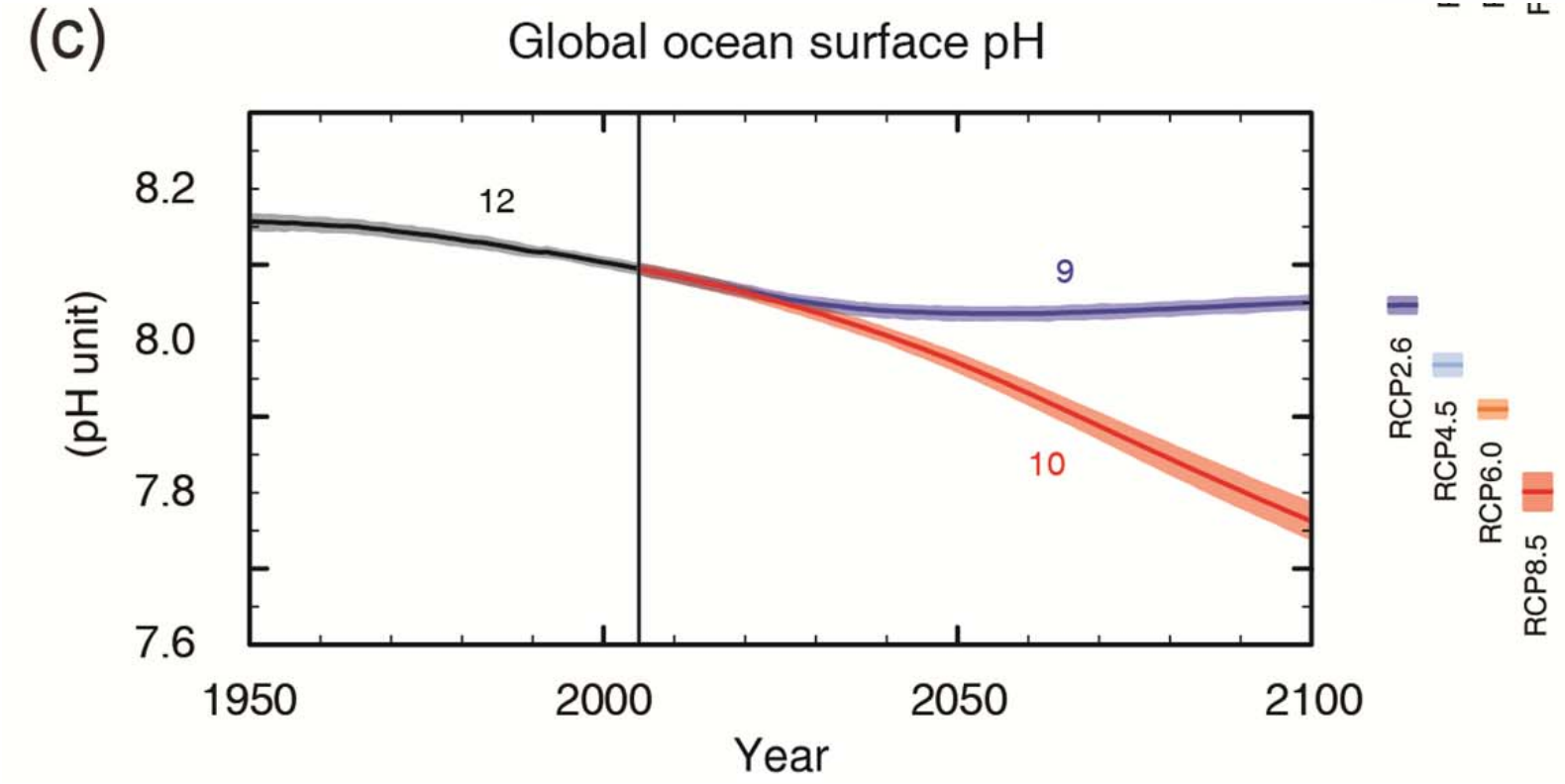
UNIVERSITY OF EXETER

Land & ocean uptakes



UNIVERSITY OF EXETER

Projections of surface pH



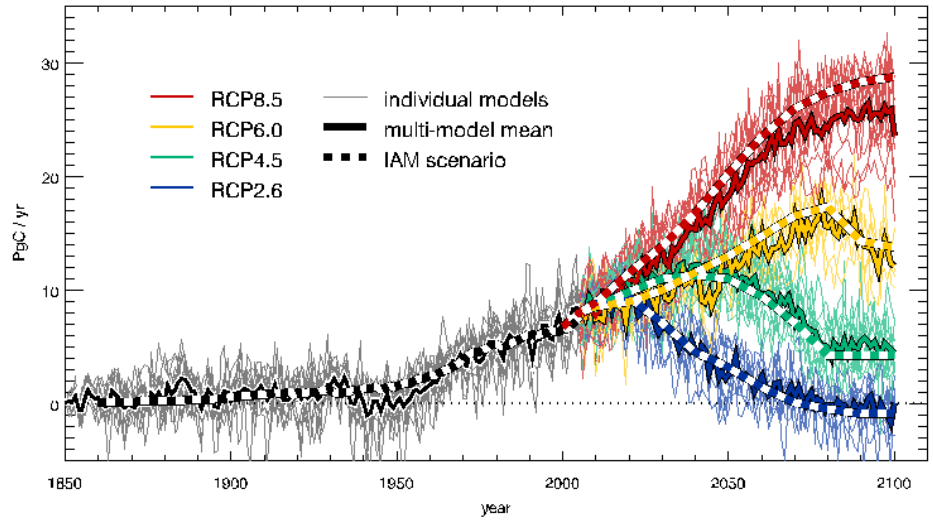
AR5 SPM

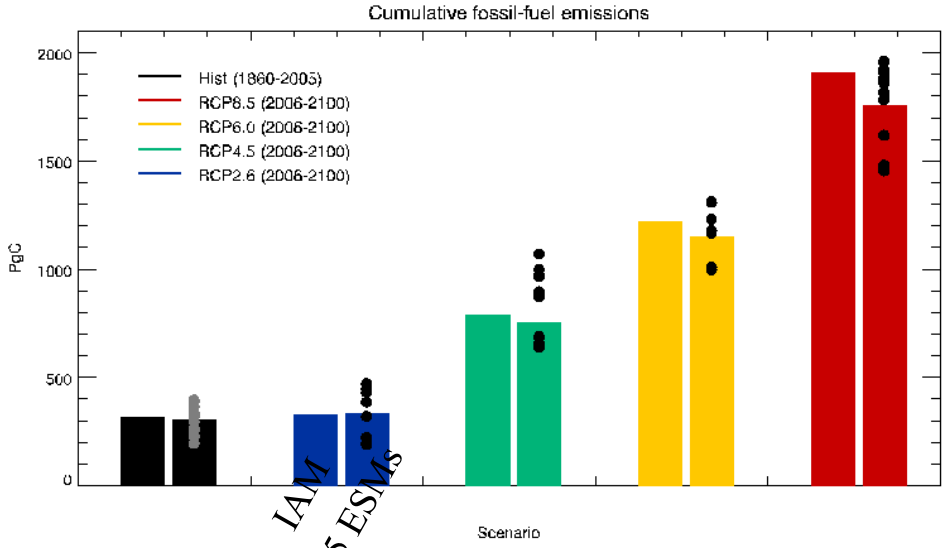
- Cumulative CO_2 emissions for the 2012–2100 period compatible with the RCP atmospheric CO_2 concentrations, as derived from 15 Earth System Models, range from …

- By 2050, annual CO_2 emissions derived from Earth System Models following RCP2.6 are smaller than 1990 emissions (by 14% to 96%). By the end of the 21st century, about half of the models infer emissions slightly above zero, while the other half infer a net removal of CO_2 from the atmosphere.

UNIVERSITY OF EXETER

Compatible emissions





UNIVERSITY OF EXETER

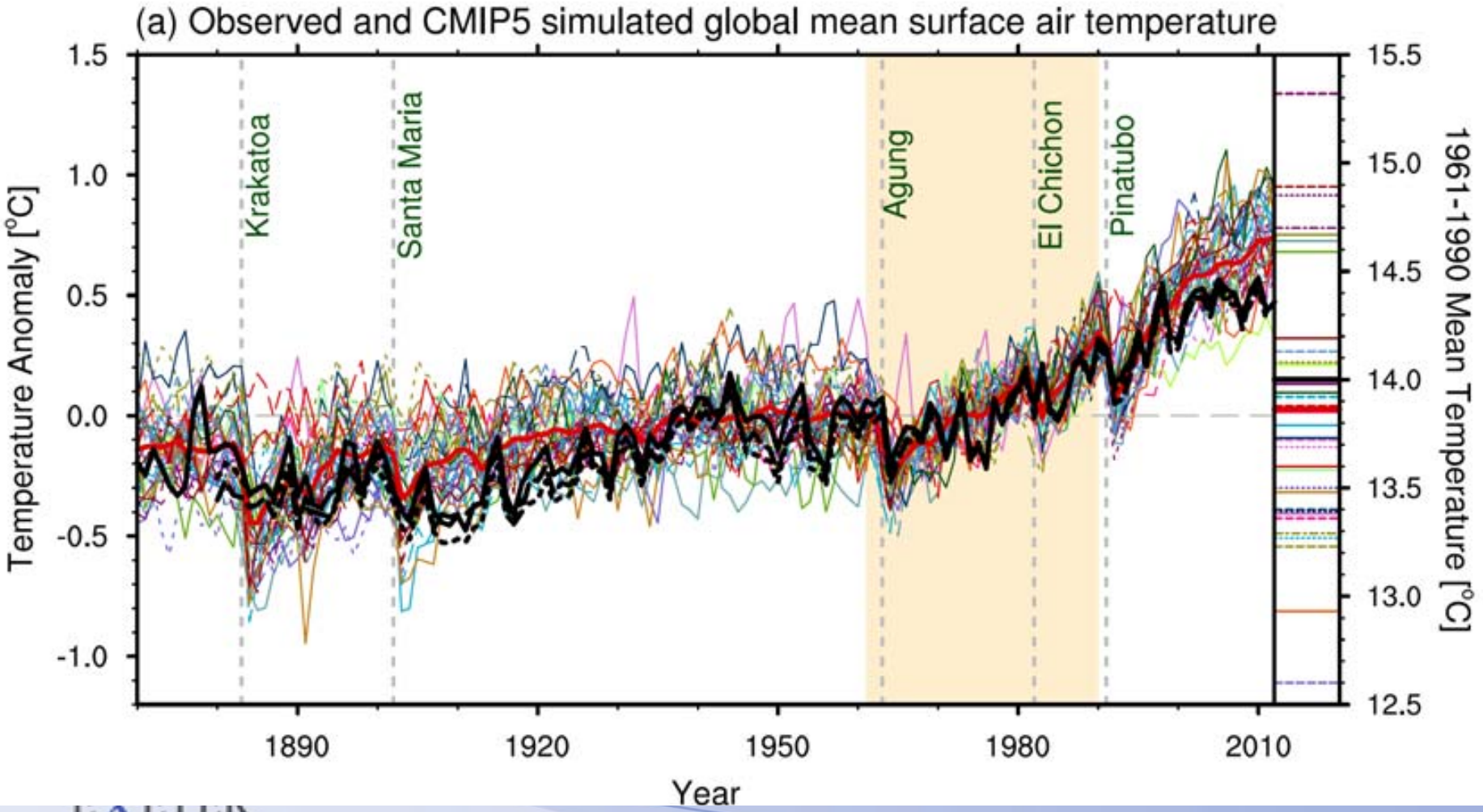
Lessons from CMIP5

- More ESMs with carbon cycle
- More analysis and publications
- Compared to AR4 (C^4MIP) more processes are included (land use change, nitrogen cycle) ☺ but this *artificially* enhances the models spread ☹
- Still large uncertainties, mainly due to the **land** carbon cycle…

- Model evaluation is quite embarrassing…
  - Obviously, carbon cycle wasn't part of the essential set of metrics during development/adjustment phase of CMIP5

Simulated atmospheric CO_2

Mauna Loa



Essential for CMI6

- **Model evaluation**
  - Obviously, not enough tuning/validation has been done in the model development phase (allow time between "CMIP-core" and "CMIP6-core"
- **TCRE**
  - Can become the "TCR of ESMs". Need to agree on simple scenario to diagnose it (eg. a 1% scenario)
- **Feedback quantification**
  - CO2-carbon (b) and climate-carbon (g) (eg. from two or three 1% scenarios)
- **Future of carbon cycle and compatible emissions (impact and policy relevant)**
  - Diagnosed from new scenarios (SSPs/RCPs matrix)

UNIVERSITY OF EXETER

CMIP6 roadmap

- **Requested (core)**
  - Control
  - 1%CO2 (COU, BGC, RAD)
  - Historical and scenarios `
- **Emission driven or Concentration driven runs?**
  - Both, sir.
- **C^{4}MIP "Governance"**
  - P. Friedlingstein, C. Jones and V. Arora
  - + "steering committee" (TBD) eg. L. Bopp, V. Brovkin, C. Koven, T. Ilyiana, S. Zaehle,…)

UNIVERSITY OF EXETER