C4MIP/CMIP5
Coupled Carbon Climate Model Intercomparisons Project

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Presentation derives from

• Friedlingstein et al., submitted to JOC, “CMIP5 climate projections and uncertainties due to carbon cycle feedbacks”
• Jones et al., submitted to JOC, “21st century compatible CO2 emissions and airborne fraction simulated by CMIP5 Earth System models under 4 representative concentration pathways.”
• Arora et al. submitted to JOC, “Carbon-concentration and carbon-climate feedbacks in CMIP5 Earth System models”
• Hoffman and Randerson, and has a working title of "The Causes and Implications of Persistent Atmospheric CO2 Biases in Earth System Models", in prep
• Mahowald et al., in prep
• Others on PCMDI website: 16 total
Black: conc forced

Red: emis forced

Friedlingstein et al., submitted
Land/Atmosphere fluxes

Ocean/atmosphere fluxes

Friedlingstein et al., submitted
Figure 9. Model estimate of 2100 warming relative to present day (average, standard deviation and full range) for the concentration driven runs from the CMIP5 models (full database available) and from the 7 CMIP5 ESMs analysed here, and for the emission driven runs from the 7 CMIP5 ESMs analysed here and from the CMIP 3/C4MIP emulation using the MAGICC6 model.

Friedlingstein et al., submitted
FIG. 2. Changes in total land carbon store (top) vegetation carbon (bottom left) and soil carbon (defined as cSoil + cLitter; bottom right) for the CMIP5 models. An observationally derived estimate of net changes (Arora et al., 2011) is shown by the vertical pink bar in the top panel.

Model variability as large as RCP variability

Jones et al., sub
FIG. 4. Changes in annual oceanic carbon uptake (top) and cumulative uptake since 1850 (bottom) from the CMIP5 models. An observationally derived estimate of net changes (Arora et al., 2011; Le Quere, personal communication) is shown by the vertical pink bar in the bottom panel.

In some cases, uncertainties in models as large as rcp
FIG. 5. Compatible fossil fuel emissions from CMIP5 models for the historical period (black) and the 4 RCP scenarios for the 21st century (colours). Timeseries of annual emissions (top panel): the thick solid lines denote the multi-model mean and the thick dashed lines the historical and RCP scenarios. Individual model estimates are shown in the thin lines. The bottom panel shows cumulative emissions for historical (1850-2005) and 21st century (2006-2100). The left hand bars in each pair show the cumulative emissions from the historical reconstruction or from the RCP scenario as generated by IAM models, and the right hand bars the CMIP5 multi-model-mean. Black/gray circles show individual model values.

Left bar: RCP
Right bar: model mean, dots are spread

Jones et al.,
Jones et al., submitted

- The uncertainty in land carbon uptake due to differences among models is comparable with the spread of differences among RCP scenarios and is due in part to differing representation of anthropogenic land use change. The CMIP5 models estimate cumulative (2006-2100) fossil-fuel emissions of 331±117, 861±160, 1147±124, 1783±187 PgC respectively for the RCP2.6, RCP4.5, RCP6.0 and RCP8.5 scenarios.
Arora et al., submitted
Future (2048-2052) vs. Contemporary (2006-2010) Atmospheric Carbon Dioxide

Contemporary (2006-2010) Carbon Dioxide Mole Fraction (ppm)

Future (2048-2052) Carbon Dioxide Mole Fraction (ppm)

360 365 370 375 380 385 390 395 400 405 410 415 420

460 480 500 520 540 560 580 600 620 640

Oberved Contemporary Mole Fraction

Chinese Model (BCC_CSM1.1)

Chinese Model (BCC_CSM1.1_M)

Chinese Model (BNU_ESM)

Canadian Model (CanESM2)

Russian Model (INM_CM4)

U.S. Model (CESM1_BGC)

Chinese Model (FGOALS_S2.0)

Canadian Model (MPI_ESM_LR)

Japanese Model (MRI_ESM1)

U.K. Model (HadGEM2_ES)

Japanese Model

R2 = 0.804

Hoffman et al.
What is causing the bias?

- Ocean uptake is too weak
- In 5 of the 8 models, the land sink over compensates, and is too strong

Hoffman et al.
Carbon Cycle Bias Conclusions

• Tuning the carbon cycle to contemporary atm. CO$_2$ levels would reduce future uncertainty in a given RCP scenario because carbon cycle biases are persistent on decadal timescales.

• For the next 50 years or so, structural biases regulating carbon-concentration feedbacks and land use change emissions may be more important error sources than climate-carbon feedbacks.

• Carbon – concentration feedbacks are linked with many structural model components that do not change rapidly:
  – Rates of Southern Ocean overturning
  – Sensitivity of photosynthesis to elevated carbon dioxide
  – Allocation of NPP to wood and litter

• More fundamentally, on land, carbon cycle response times limited by:
  – Residence times of litter and soil carbon
  – Lifetime of trees
  – Timescales for recruitment and establishment of species

Hoffman et al.
(b) Zero Bias Model Relative to Model CO$_2$ Estimates fo r2008

Hoffman et al., in prep.
Temperature at 2050

- **RCP4.5:** medium-low scenario
- It's warming

**Mean change**

**Change/Stddev**

**Model consistency**

- Temperature at 2050
- **RCP4.5:** medium-low scenario
- It’s warming

Mahowald et al., in prep
• Some areas get more precip, some less: some coherence over land
• P-E: some areas moisture, some not: not so much coherence over land

Mahowald et al., in prep
Model suggests higher Net primary production (growth), consistently, almost everywhere

Mahowald et al., in prep
• Above ground vegetation higher, almost everywhere

• Models pretty optimistic! True? Most models have too strong of carbon fertilization, probably

• If not true: more carbon will stay in atmosphere.

Mahowald et al., in prep
Aerosols? Very limited comparison in literature of CMIP5 (only Shindell et al., ACCMIP; BC in ACCMIP)