C4MIP/CMIP5 Coupled Carbon Climate Model Intercomparisons Project

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Presentation derives from

- Friedlingstein et al., submitted to JOC, "CMIP5 cliamte projections and uncertainties due to carbon cycle feedbacks"
- Jones et al., submitted to JOC, "21st century compatible CO2 emissions and airborne fraction simuated by CMIP5 Earth System models under 4 representative concentration pathways."
- Arora et al. submitted to JOC, "Carbon-concentration and carbonclimate 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



684 685 CL21ge (K.) IROU THE / LEMA CENESION CITVEL (DIRCE INCE) and concentration driven (rec. Ince) Friedlingstein et al., submitted 687 Simulations. Also shown is the full range of (c) simulated atmospheric CO₂ (ppm) and (d) global

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Land/Atmosphere fluxes (b) Ocean/atmosphere fluxes 1: **`}**,∎⊓. **)** 2 1 400 MI LLX **100**. **4**11 Sardadas es katan -00. ᇒ 2 ٦ 1 . 3001 The second s ቈ -00. **_**1±±⊾ **-**2000. 2466 3**7**94 100 -**T**.... 1740 500 Yem V B (\mathbf{r}) (_) 44 Currelative alocal and thes (PeC) 🗘 🗥 i Adhe 44 15 Stend fus (Pe 🕽 *** **164 N M M** 744 tinu p Den ún Ж¥ ≥⊳∢ ≥⊳€ MI J. ∎M L $\mathbf{H} \rightarrow \mathbf{H}$ v **≥ 1**50 M Í&→ Ľ.∳J ĽУ ж **34**50 Yeu ¥-ĸ∎

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n94 Egure 5, Range of (a) changlated global air to Frieldlingstein rethal Could mitted and air air

595 to occan carbon flux (PgC) from the 7 ESMs emission driven simulations. Also shown is the fall





full range) for the concentration driven runs from the CMIP5 models (full database available) and

- from the 7 CM IP5 ESMs analysed here, and for the emission driven runs from the 7 CM IP5 ESMs
- analysed here and from the CM IP $3/C^4$ M IP emulation using the MAGICC6 m odel.

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 (Ar ora et al., 2011) is shown by the vertical pink bar in the top panel.

Jones et al., sub



In some cases, uncertainties in models as large as rcp

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.

Jones et al.,



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

Jones et al.,

Jones et al., submtted

• 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., submit

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Figure 3: Components of the atmospheric carbor bedget of the participating mine models based 11:0 1151 on equation (7) in panel (a) and equation (10) in panel (b) using results from the fully-conclude 1%1152 per year increasing CO₂ simulation. The models are arranged in a descending order based on their currulative emissions values. In panel (7) the airborne fraction and fractional emissions JI AR taken up land and ocean are also noted for individual models. 1154

Arora et al.,

- 11.55
- 1150
- 1147
- 1158
- 11.59 1160
- 4.4.5.4



1230 Figure 9: Gain g_F (equation 13) and its estimated value based on feedback parameters (\hat{g}_F 1231 equation 15) for the nine participating models.

Arora et al



Hoffman et al.



What is causing the bias?

 Ocean uptake is too weak

MIROC-ESM

MIROC-ESM

ullet

In 5 of the 8 models, the land sink over compensates, and is too strong

Carbon Cycle Bias Conclusions

- Tuning the carbon cycle to contemporary atm. CO₂ 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 carbonconcentration 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 CO₂ Estimates for 2008

Hoffman et al., in prep.



Meon ts rcp45_2041- 1981-2000 / stddev



Consistency ts rcp45_2041- 1981-2000





Mean change

Model

Change/Stddev Temperature a 2050

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



Mean pr rcp45_2041- 1981-2000 / stddev



Consistency pr rcp45_2041- 1981-2000



-5.	-4,	-3,	-2.	-1.00	0.000	1.00	2,	3.	4,	5.
-4.	-3,	-2,	-1.60	-0.80	0.000	0.80	1.60	2.	3.	4.
.000	0.10	0.20	D.30	0.40	0.50	0.60	0.70	0.80	0.90	1,00

 Some areas get more precip, some less: some coherence over land



Mean pe rcp45_2041- 1981-2000 / stddev



Consistency pe rcp45_2041- 1981-2000



-5,	-4,	-3.	-2.	-1,00	0.000	1.00	2.	3.	4.	5,
-4,	-3.	-2.	-1.60	-0.80	0.000	0.80	1.60	2.	.3.	-4,
.000	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00

 P-E: some areas moisture, some not: not so much coherence over land







Consistency npp rcp45_2041- 1981-2000





 Model suggests higher Net primary production (growth), consistently, almost everywhere

Model consistency





Above ground vegetation
Mean higher, almost change everywhere

- Change/Stddev Models pretty Optimistic! True? Most models have too strong of carbon fertilization, probably
 - If not true: more carbon will stay in atmosphere.









-3,	-2.	-1,80	-1.20	-0.60	0.000	0.60	1,20	1.80	2.	3.
-4,	-3.	-2.	-1.60	-0.80	0.000	0.80	1.60	2,	3.	-4,
000.	0.10	0.20	0.30	0.40	0.50	0.60	0,70	0.80	0.90	1.00

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

