Core Model Proposal 397: Update to Hector V3.2.0

Product: Global Change Analysis Model (GCAM)

Institution: Joint Global Change Research Institute (JGCRI)

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Related sector: emissions/climate

Type of development: code & queries

Purpose: Update the GCAM-Hector coupling from Hector V3 to V3.2.

Description of Changes

Hector behavior changes

Update the Hector-GCAM integration to Hector V3.2.0 (previously, GCAM used Hector V3.1.1), the changes associated with this CMP fall into two categories:

1. Hector behavior changes
2. Hector-GCAM coupling changes

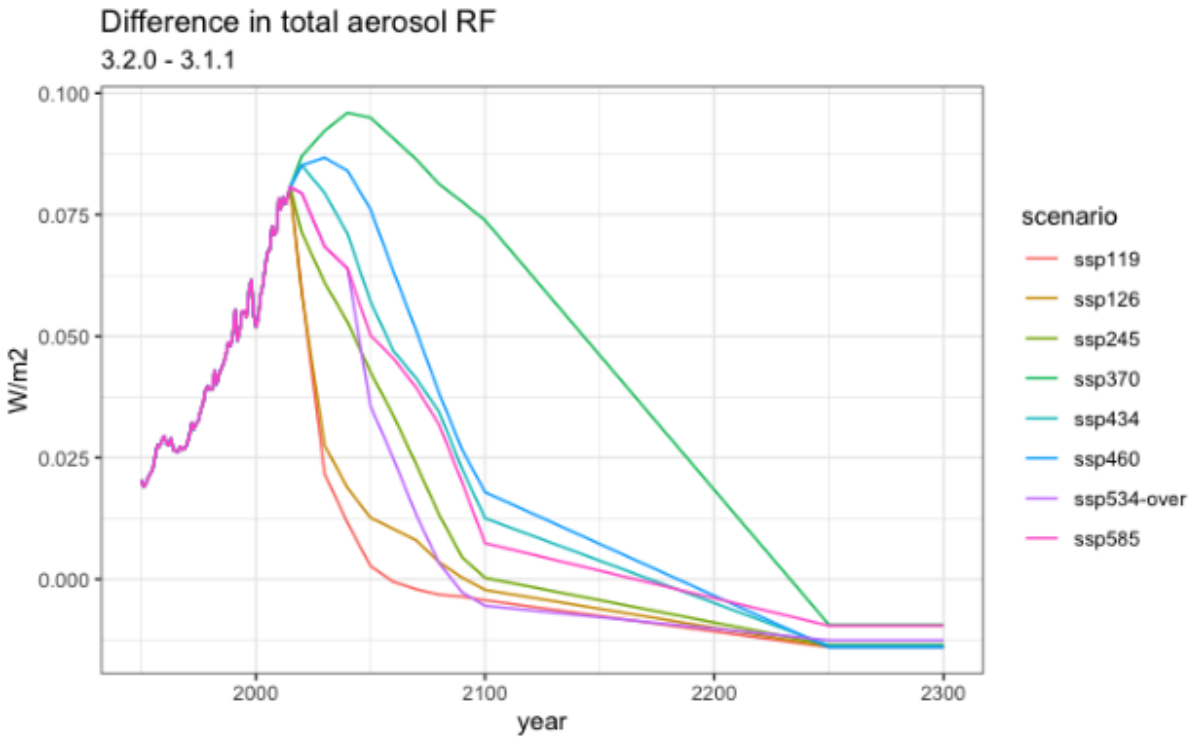
Hector V3.2.0 is the version documented in Dorheim et. al (accepted in GMD), the changes between the previous version coupled with GCAM were in response to the reviewer feedback. We corrected aerosol forcing coefficients based on Zelinka et al. (2023), enabled the permafrost module to be on by default, and recalibrated the model. These changes mean that we had to update the hector-gcam.ini file, it also causes some changes in Hector output behavior (described below) which may have implications on GCAM runs. Ultimately Hector is cooler by about 0.15 degrees, although this is scenario dependent.

Changes in aerosols

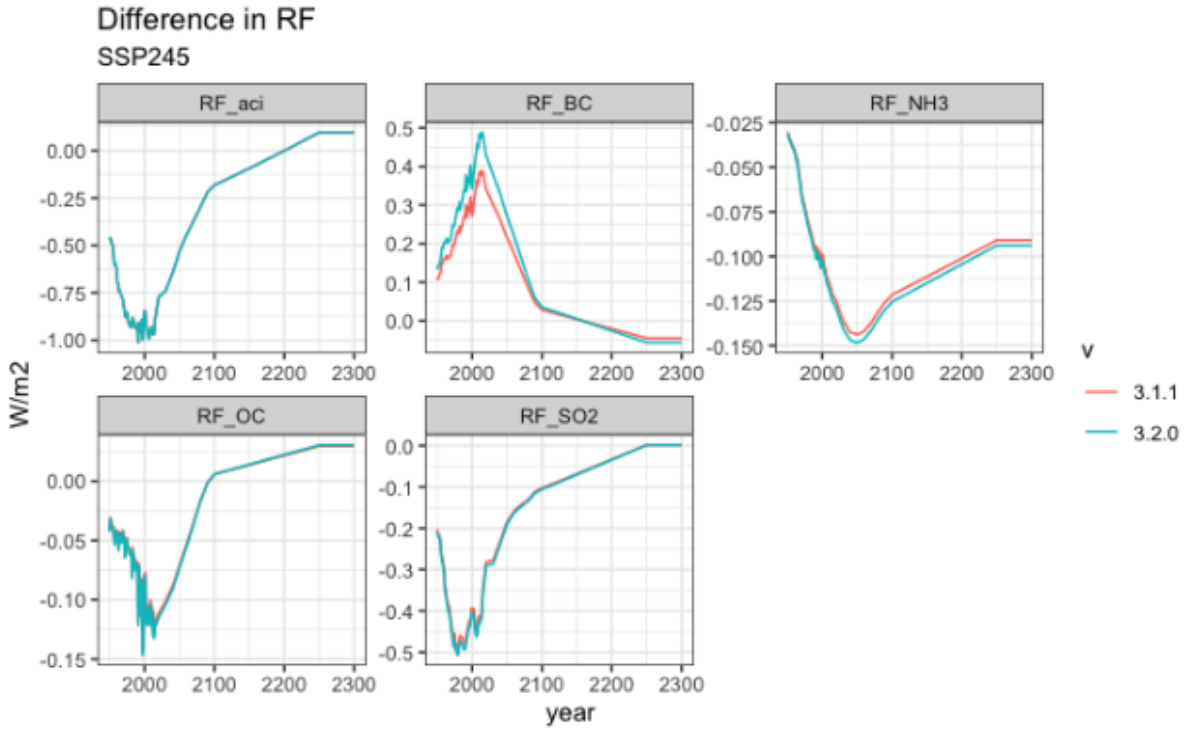
The aerosols were changed specifically in PR 724

Parameter	Old Value	New Value
aci_beta (aerosol cloud interaction)	2.09841432	2.279759
Rho_bc	0.0508	0.06386286
Rho_oc	-.00621	-0.006407143
Rho_so2	-.00000724	-7.469841e-06
rho_nh3	-.00208	-0.002146032

The change in parameter values cause the total aerosol RF (RF_ACI + RF_BC + RF_OC + RF_SO2 + RF_NH3) to change, but the magnitude and direction vary depending on year and scenario.

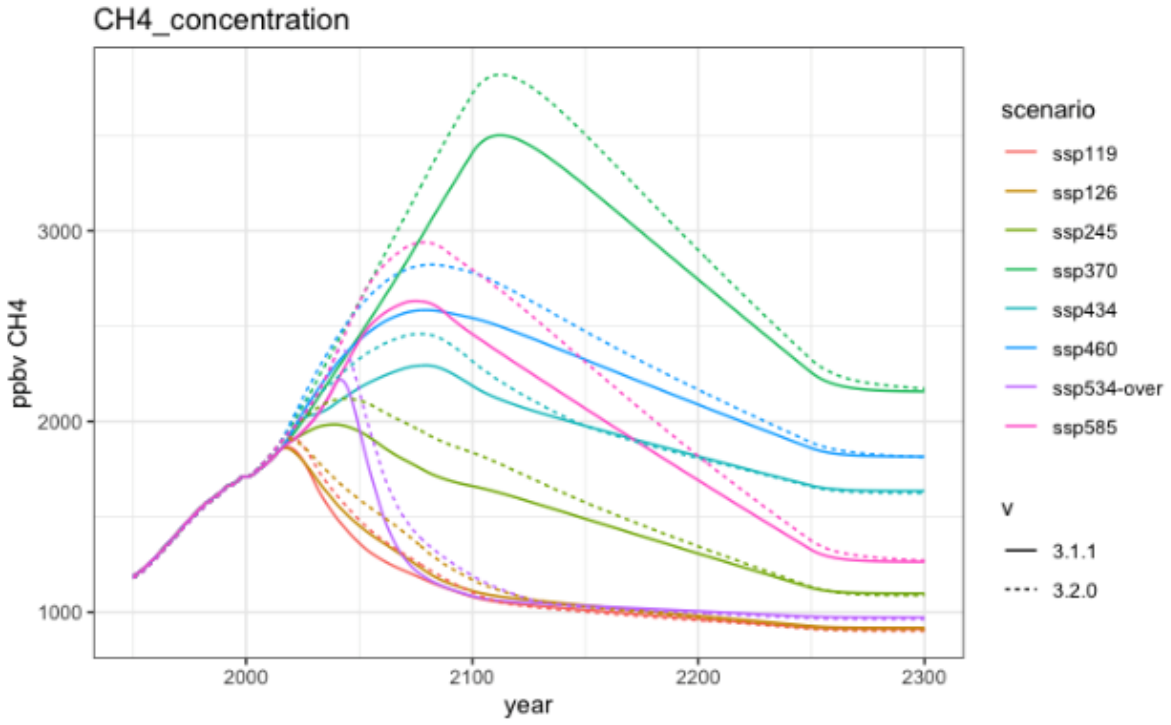


Which, in the grand scheme of things, represents about, at most a 3% change in total RF.

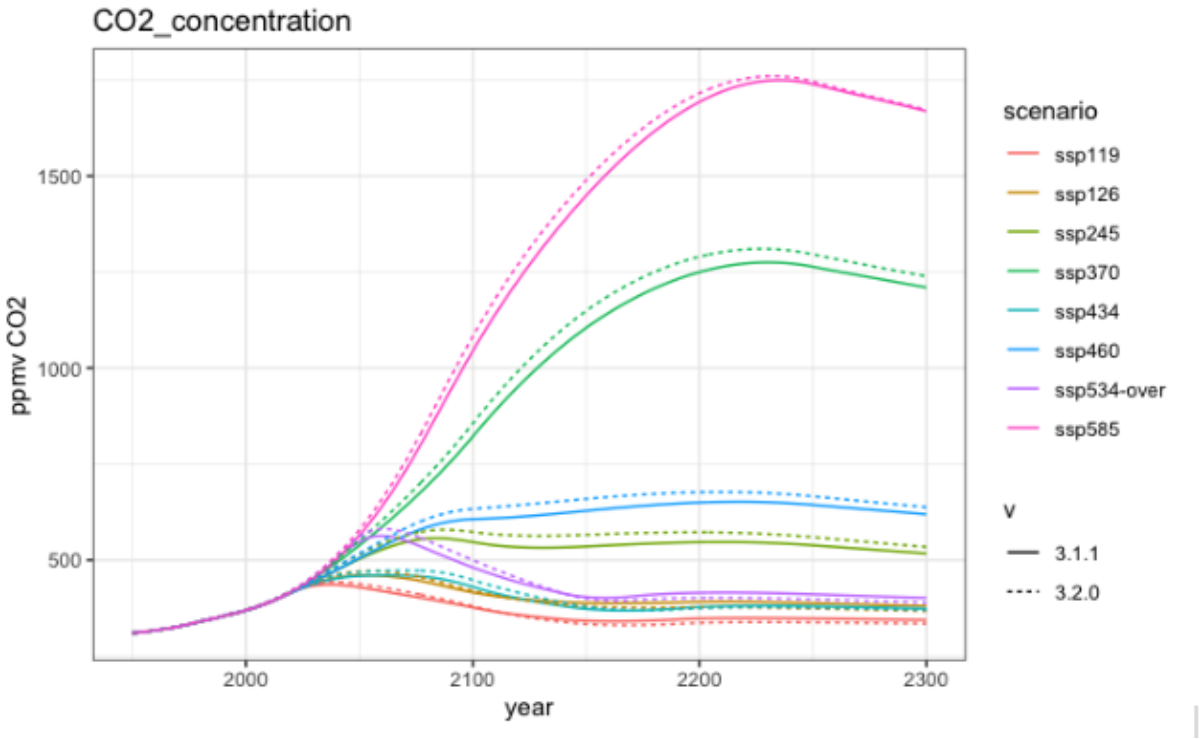


Carbon Cycle Changes

The permafrost module is now on by default as of PR 722! Which causes the atmospheric CH4 concentrations to increase. However, in the grand scheme of things, this translates to about a 2% change in total RF.



The permafrost feedback also increases CO2 concentrations (see Woodard et al. 2021) more so in higher warming scenarios.



The mean difference between Hector with the permafrost feedback on vs without is summarized in the table below

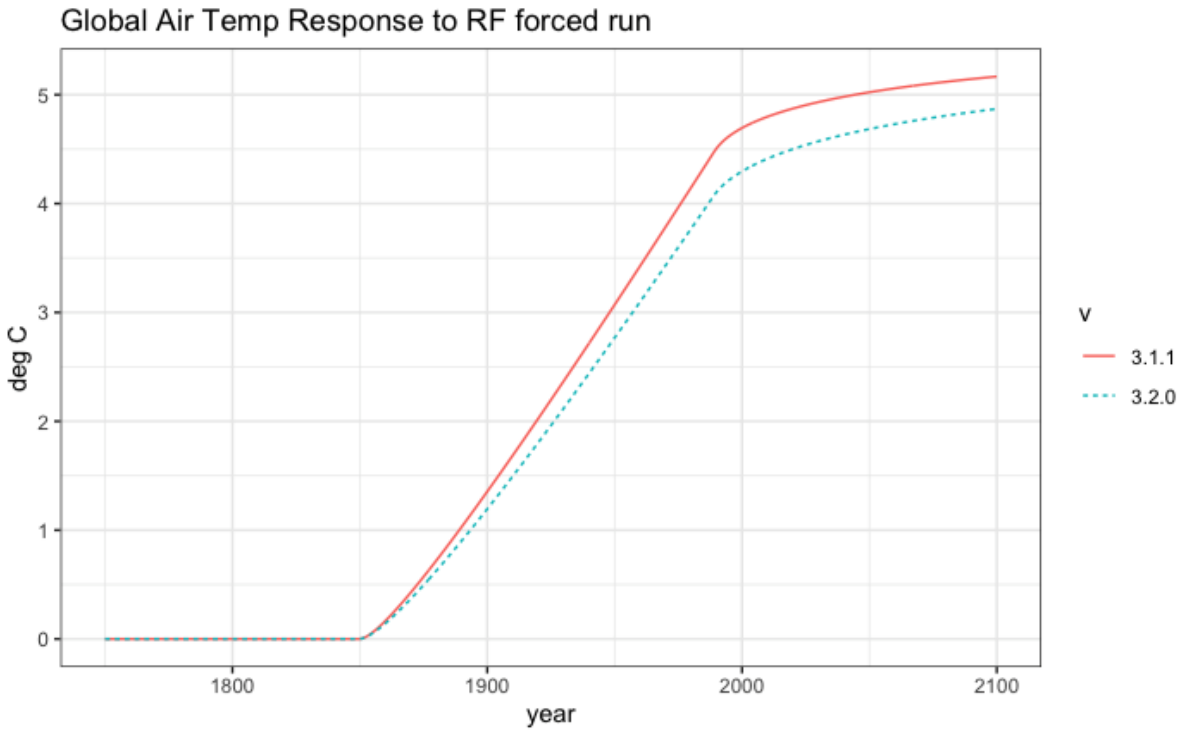
Mean Difference (Permafrost - without Permafrost)			
Scenario	CH4 conc (ppbv CH4)	CO2 conc (ppmv CO2)	Temp (deg C)
ssp119	41.8	2.94	0.033
ssp126	51.5	4.46	0.04
ssp245	70.8	6.24	0.05
ssp370	88.9	7.88	0.05
ssp434	63.8	4.92	0.04
ssp460	80.5	6.91	0.05
ssp534-over	72.6	6.96	0.06
ssp585	100	9.78	0.05

Changes in carbon cycle parameters weaken the carbon-climate interactions see PR 729 for more details

Parameter	Old Value	New Value
Beta (CO2 fertilization factor)	0.55	0.53
q10_rh	2.2	1.76

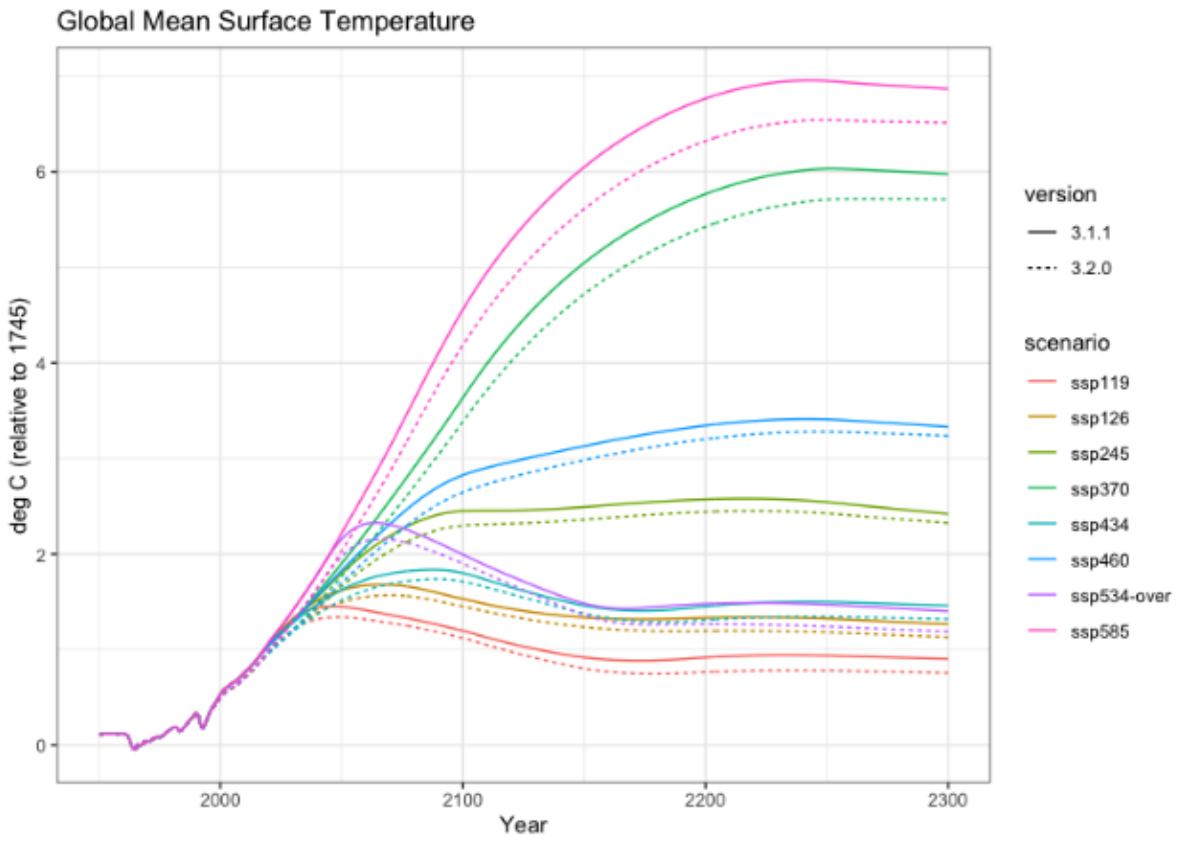
However, the change in ocean heat diffusivity as (see PR 729) ends up having the largest impact on Hector temperature. The change in the value of the diff parameter the direct results for the calibration protocol used in the Hector V3.2.0 documentation manuscript. Uncertainty surrounding this parameter is large, older versions of Hector set the default diff to 2.3 (see V2.2.0). The updated value for diff improves Hector's ability to reproduce historical global mean temperature observations and results in a TCRE and future warming levels consistent with IPCC AR6 (see Dorheim et al. in press for more details).

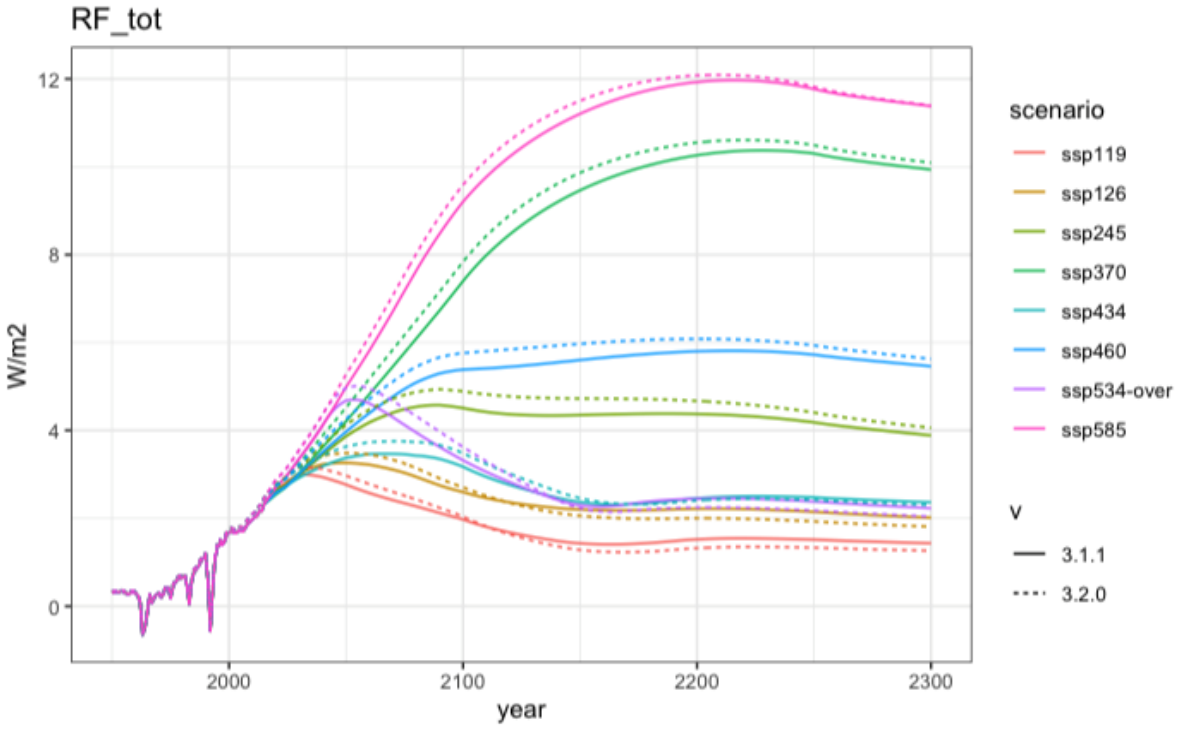
Parameter	Old Value	New Value
diff (ocean heat diffusivity)	1.16	2.38



Here Hector 3.2.0 and Hector 3.1.1 runs are setup for an idealized experiment during which both versions of the model are driven with a specific RF pathway (aka Hector is running in RF constraint mode). Due to changes in ocean heat uptake Hector V 3.2.0 is cooler than the previous version of the model.

So, when we look at the multiforcing runs, we ultimately see that Hector V 3.2.0 is cooler than the previous version of Hector. The change in ocean heat uptake drives the changes in global temperature even though some scenarios see a small increase in total RF.


Global Mean Surface Temperature
deg C (relative to 1745)
Year
version
3.1.1
3.2.0
scenario
ssp119
ssp126
ssp245
ssp370
ssp434
ssp460
ssp534-over
ssp585


RF_tot
W/m2
year
scenario
ssp119
ssp126
ssp245
ssp370
ssp434
ssp460
ssp534-over
ssp585
v
3.1.1
3.2.0

While Hector V3.2.0 is a cooler model, climate targets related to RF or CO2 concentrations may require similar or higher carbon prices.

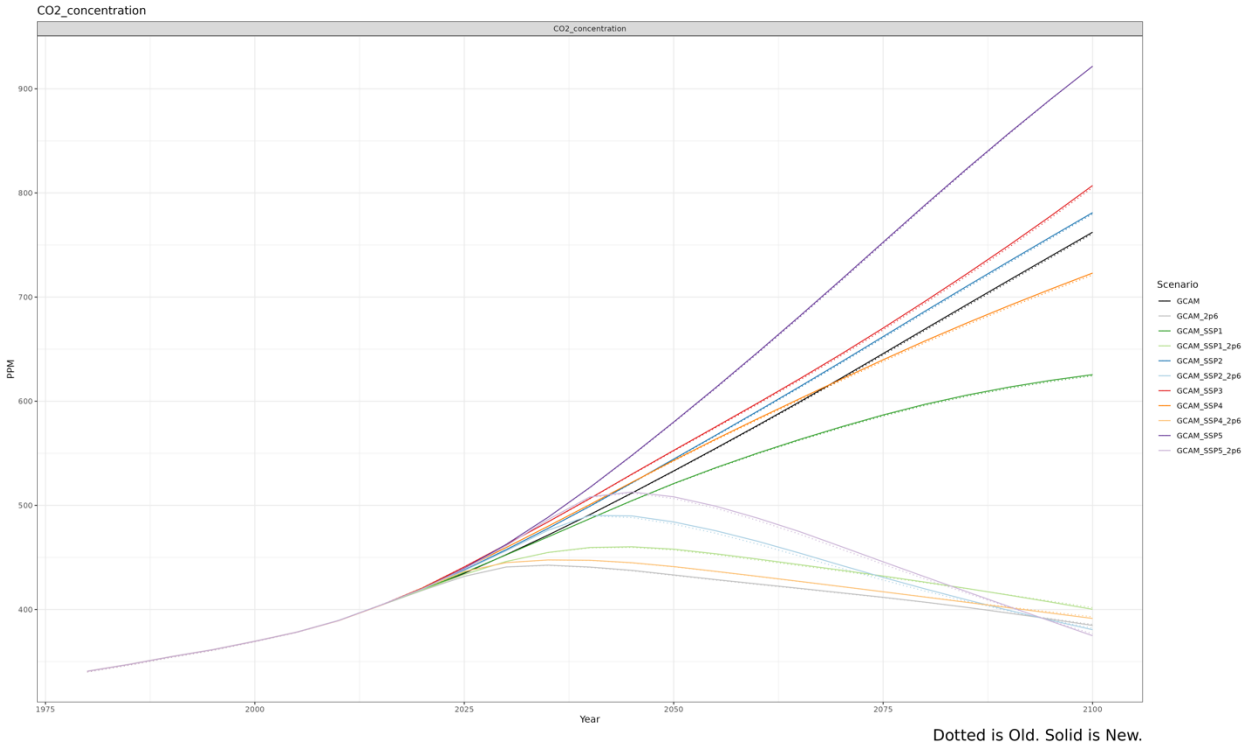
Changes in GCAM to accommodate Hector v3.2

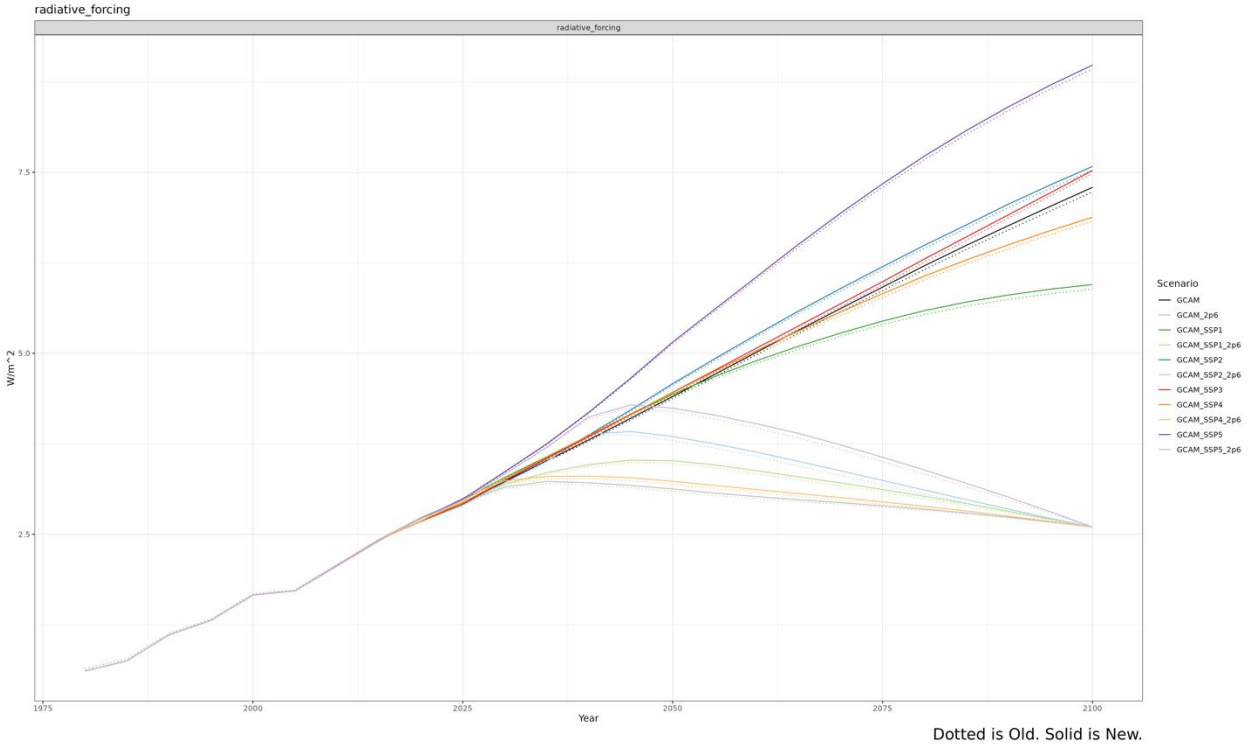
The changes to how Hector-GCAM are coupled with one another are relatively minor.

- Contents of the gcam emissions csv files were unchanged, we did correct a minor documentation problem (the units for the halocarbon emissions were for concentrations; this has now been fixed).
- Updated the GMAT_ADJUST & GMSAT_ADJUST values, the reference temperatures used to normalize the temperature results.
- As per requested by S. Smith we added Hector the additional aerosol RF values to the output saved by GCAM.

Validation

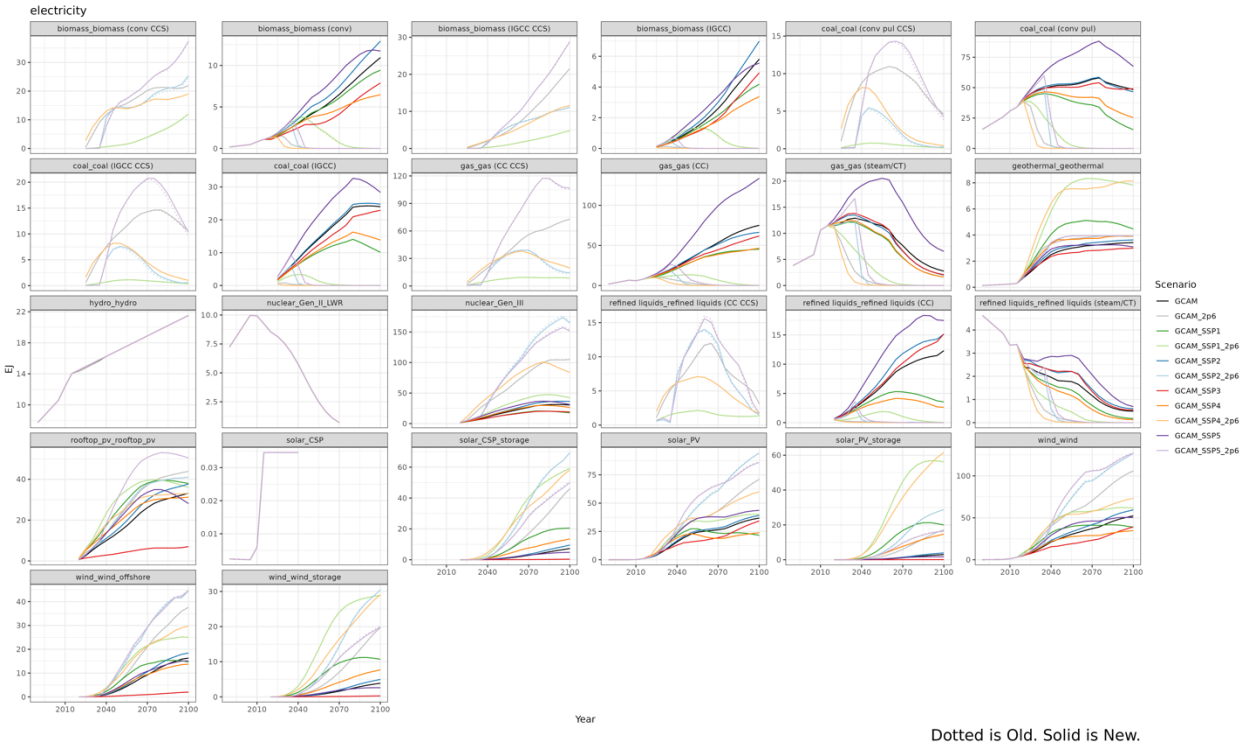
Recall from the figures above that V3.2.0 runs cooler than V3.1.0 when the same emission pathways are used, even though RF total increases slightly for the warmer scenarios. The GCAM RF and [CO2] output is consistent with what we were seeing from the stand-alone Hector comparisons.

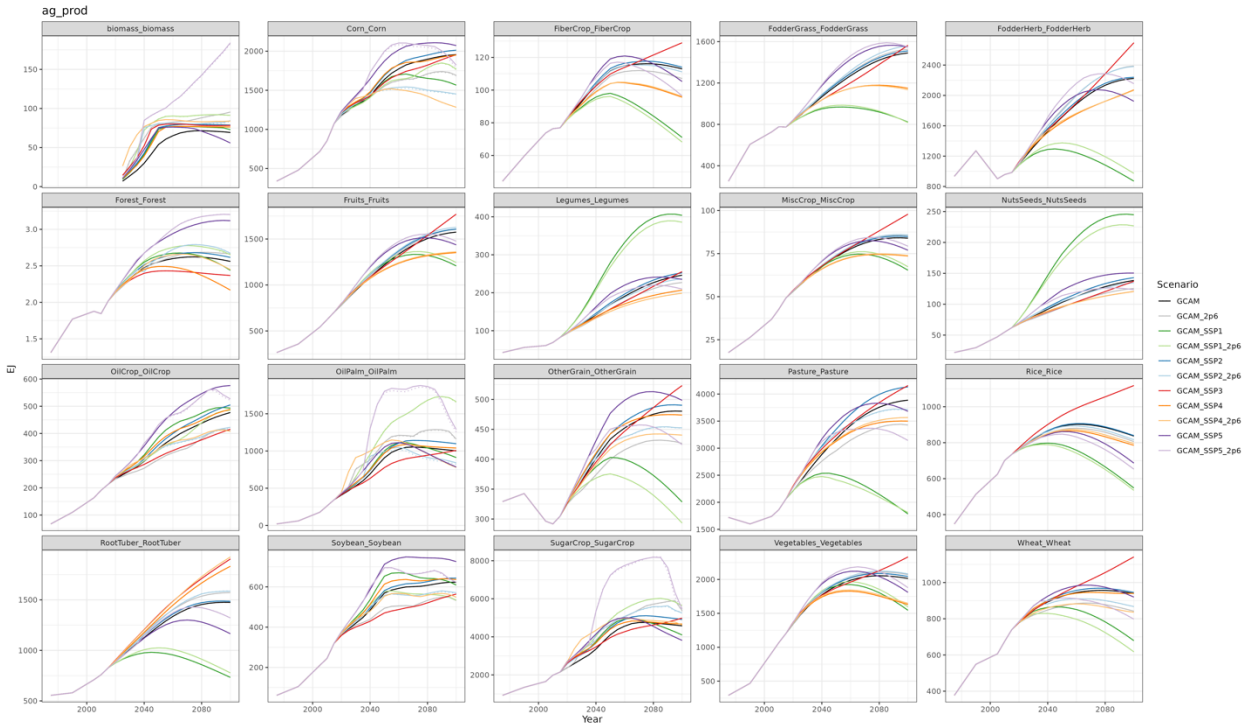




Since this PR impacts Hector, we expect no change in the GCAM Reference scenarios (these runs do not impact take climate effects into account). However, since the GCAM target finder

scenarios must exactly reach a RF target in 2100 and Hector's total RF has changed GCAM will use a different CO2 price to hit a target which affects almost all the results. Which is why in the electricity and ag_prod plots show differences only the target policy runs. whereas there is a single line from the reference scenarios.





Dotted is Old. Solid is New.