Novel, speculative highly-scaled carbon removal study on a reduced complexity model, showing a return to preindustrial temperatures by 2100 and updates to achieving net-zero for Anthropocene reversal. Poster B43K2705 presented at AGU23, 11-14 Dec. 2023

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Abstract

Speculations extend the opportunity space of possible future climates by increasing the potential to provide plausible estimated qualities and quantities to further scientific research and aid engineering solutions. This novel work outlines the first steps to achieving an Anthropocene reversal that completes in Zoomers' lifetimes — by 2100. The novel experimental high-scale carbon removal pathway, which was studied in MAGICC 6.8, required CDR to counterbalance all accumulated anthropogenic emissions since 1750 to return to preindustrial temperature (0.07ºC over the 1720-1800 and 0.14ºC over the 1850-1900) means by 2100 and complete GHG phaseouts by 2077, excluding Ammonia. The experimental pathway set extreme front loading of emissions reductions to reach net zero, and avoid tipping points, then achieve scaled removal to reach 300 ppm of CO_2 concentration by roughly mid-century. This work's findings recommend exploring carbon removal of cumulative anthropogenic emissions totaling 600 GtC to 775 GtC on a recent model ensemble with 1.55 to 1.7 times preindustrial CO_2 concentration driven by forcings from emissions and calibrate to reproduce present-day temperatures to provide more detailed projections of temperature, holding below 1.5ºC, regional temperatures, below ground CO_2 mineralization, sea-level rise, ENSO, AMOC, and jet-stream turnover, evolve.

Continued fossil-fuel use is unable to yield complete emissions phaseouts or deep removals necessary to match a preindustrial climate. The findings support the utmost urgency to attain a maximally scaled sustainable zero-carbon intensity green growth development. And reinforce the increased global commitment to achieve net zero sooner and to avoid setting off more climate tipping points. The possibility of reaching a preindustrial climate should help inform the debate of maximally scaled sustainable green growth development for the fastest path to net zero, phase out of anthropogenic emissions sources, and scaled carbon removals with zero-carbon intensity to develop a more equal future world.

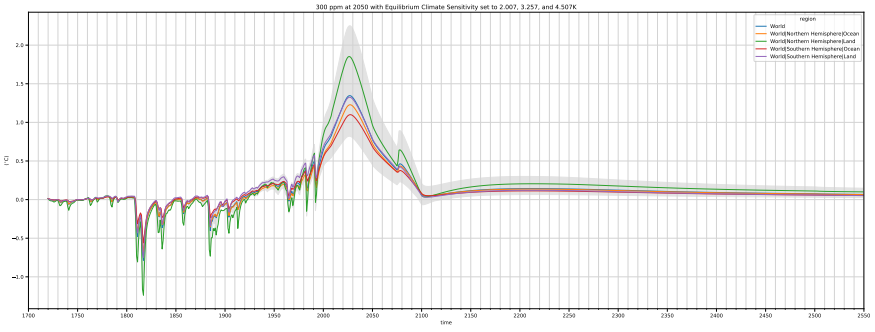


Figure 1: 300 x 2050 Pathway with ECS = 2, 3.26, and 4.5K

Novel, Speculative Highly-Scaled Carbon Removal Study on a Reduced Complexity Model, Showing a Return to Preindustrial Temperatures by 2100 and Updates to Achieving Net Zero for Anthropocene Reversal.

WHAT DOES IT TAKE TO GET TO 0ºC BY 2100?

Faster to Net Zero, 300 ppm by 2050, then 0ºC by 2100 for Anthropocene Reversal?

Simple Climate Modeling Experiment "RCP 0"?

CDR Modeling Experiments

calibrates MAGICC 6.8, models 300x2050, SSP1-1.9 & SSP1-2.6

300x2050 Pathway

Achieved 0ºC at 2100 by soonest Peak Emissions, fastest to **N**et **Z**ero, then **N**egative **E**missions of cumulative CO_2 (FF+LUC) emissions & FF GHG phaseout. CO_2 concentration drops significantly to 237.38 ppm at 2100 before recovering to mostly preindustrial by 2200, yet temperatures remain above 0ºC likely from heat exchange and long-lived aerosols.

Linear CDR caused the least , CO_2 conc., RF post-CDR perturbation after 2100. See **Projected Climate Response**: **Surface Temp, RF, ATM. CO_2 Conc.**

Aerosols, & N_2O induced temperature rebound minimized by moving FF phaseout 1-2 decades before 2100 and completing CDR.

Magnitude of CDR to reach 0ºC by 2100 requires full transition to fossil fuel phase out, thus **REDEFINES *HIGHLY SCALED SUSTAINABLE GREEN GROWTH DEVELOPMENT*** **as: 'ZERO-CARBON INTENSITY ENERGY AND ECONOMIC SYSTEMS, ZERO-WASTE CIRCULAR GLOBAL ECONOMY, ECOSYSTEMS REHABILITATION, PRESERVATION, AND EXPANSION, EXTENDING SUSTAINABLE DEVELOPMENT.'**

Although highly-speculative, the model predicts an ocean upwelling recovery. Regional temperature splitting of the hemispheres and ocean and land results with the northern hemisphere land over 1.5ºC, and over 2ºC for a 4.5ºC ECS. See: **POSSIBLE REGION DIFFERENCES: Surface Temperature | 300 x 2050, 300 x 2050 Pathway with ECS... .**

Model Calibration

Heuristically set MAGICC 6.8 to 2015-2020ºC means, 2020 CO_2, present emissions (2020) & return reasonable **NE** results. NE Equilibrium Climate calibration increased Sensitivity, lowered and raised other settings. Emissions were calibrated to the Global Carbon Budget, 2021. Temperature was set to HadCRUT5 means and regions via CRUTEM5 means, (min. compared to 1815-1817 est. high-uncertainty see CDRMEx) CO_2 conc. to the Keeling curve from NOAA/GML. All settings and data are relative to calibration and are proportional but not highly reflective of present day conditions. Simulation & data normalized to 1720-1800 mean temperature. Results baseline 0.073ºC warmer than 1850-1900. Simulated scaled **NE** & compared to CMIP6 members. Tests equilibrate over 2500 years. See **NE & ECS/TCR/TCRE & NE Calibration Result, a-e.** Inferred Ocean outgassing: all FF emissions were removed instead opposed to just atmospheric emissions. LUC also removed for NE.

Issues

Durable below-ground carbonation, Ice flow/ice coverage, Permafrost unsupported by model.

Land use change for SSP 1-1.9 differs from the others.

Calibration changed Ocean heat exchange, and speeds up Δ ºC.

CO_2 conc. was about 8 ppm higher at 2020 than NOAA GML.

Aerosol/N_2O artifact at GHGs phaseout.

Calibration of fertilization, plant, terrestrial fluxes can change the liftoff from 0ºC at 2100. Seeks guidance from soil/land use/forestry studies for more realistic calibration.

Unable to find higher certainty for 1815-1817, for more accurate min to lower uncertainty in ECS.

Originated from 2018, 300x2050 was constrained to have the fastest peak emissions, soonest Net Zero then deeply carbon negative, to impart the least global ecological damage, and avoid climate tipping points. Yet is implausible with present day ambition and clean industrial development.

Unable to run CDRMEx code to generate the experiments on MAGICC 7.x.

For the Future

Open for investigation: ESM studies with emissions forcing from 1.55x to 1.7x of preindustrial CO_2 conc., removing 600 GtC (2198.4 $GtCO_2$) to 775GtC (2839.6 $GtCO_2$), calibrating model to present-day temperature and CO_2, additionally projecting future temps. inc. region differences, holding below 1.5ºC, below ground CO_2 mineralization, sea-level rise, and how AMOC, ENSO, and jet-stream turnover evolve.

Strongly recommends scenarios include a path to zero-carbon intensity energy and economic systems, to ***bring*** about a ***highly scaled sustainable green growth development within this century***.

Notes additional advice to provide more ambitious energy modeling to allow businesses and others to build to net zero, and help play a more positive role to eventually reverse the Anthropocene.

Additional Info

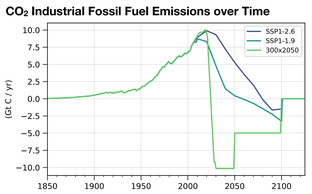
MAGICC = Model for the Assessment of Greenhouse Gas Induced Climate Change

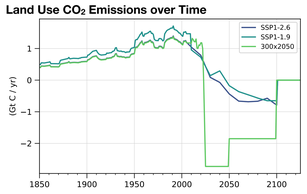
Pymagicc = python management toolkit controlling MAGICC and other Reduced Complexity Model

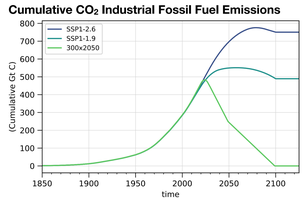
Color scale from AR6 WG1, Climate Stripes Fig 1.25: https://dx.doi.org/10.1017/9781009157896.003

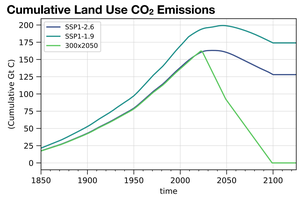
IF IT'S NOT PLANNED, IT'S LIKELY TO REMAIN SCI FI.

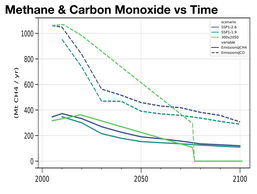
HOW MUCH CDR, AND FF PHASE OUT TO 0ºC?



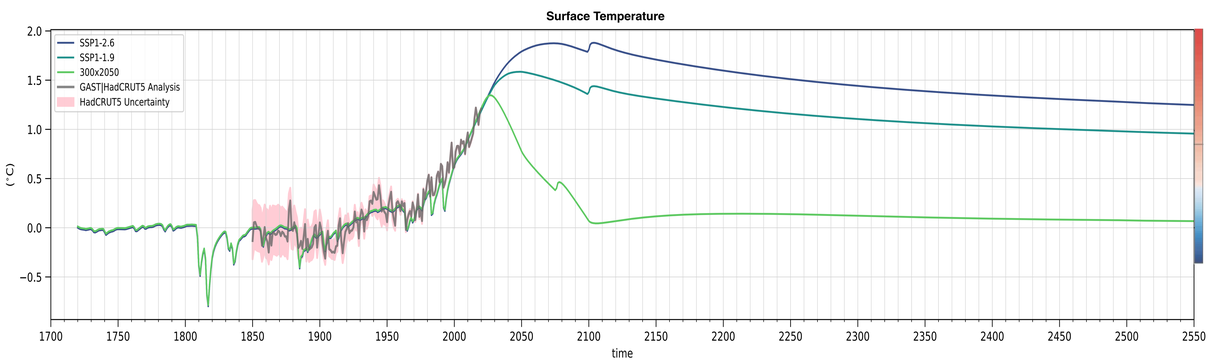


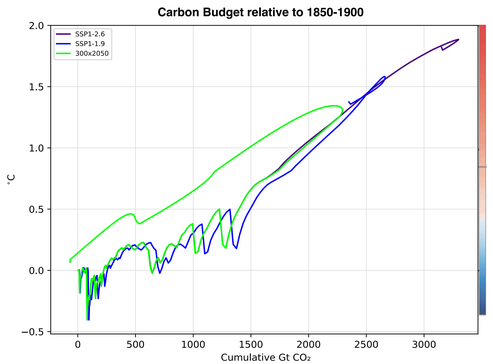


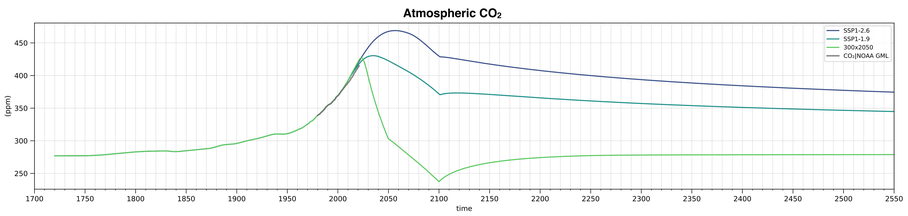


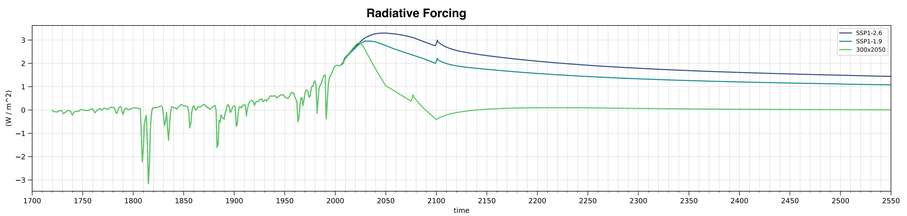


PROJECTED CLIMATE RESPONSE









300x2050 Stats

CDR TOTAL
2363 $GtCO_2$
FF 483 GtC
1769 $GtCO_2$
LUC 162 GtC
594 $GtCO_2$

CDR RATES
≃ -47 $GtCO_2$/yr to 2050
≃ -25 $GtCO_2$/yr to 2100

20 FF GHG PHASE OUT 2077: CH_4, N_2O, SOx, CO, NMVOC, NOX, BC, OC, CF_4, C_2F_6, C_6F_{14}, HFC23, HFC32, HC4310 HFC125, HFC134A, HFC143A, HFC227AE, HFC245FA, SF6 excluding NH_3.

Peak Emissions
2019

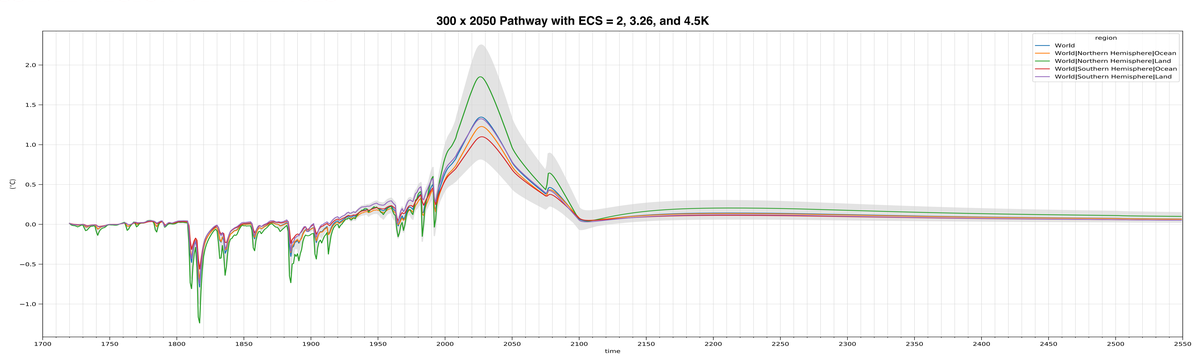
Net Zero
2023

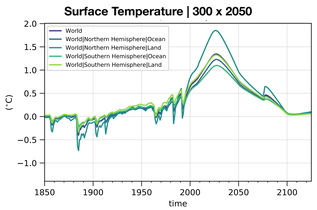
Max CO_2
427.36 ppm - 2023
1.54x Preindconc

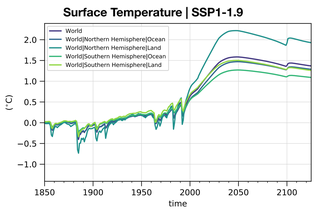
Max
1.34ºC - 2027
NHL 1.85ºC - 2026

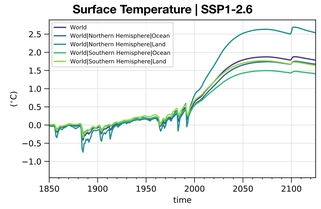
Min
-0.786ºC - 1817

POSSIBLE REGION DIFFERENCES









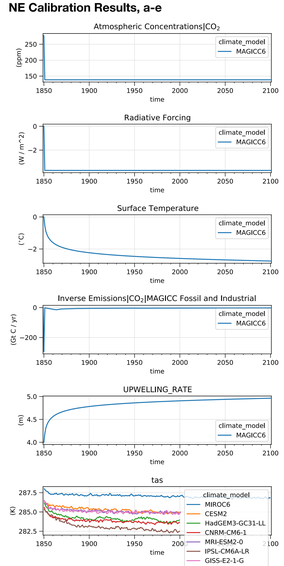
NE & ECS/TCR/TCRE

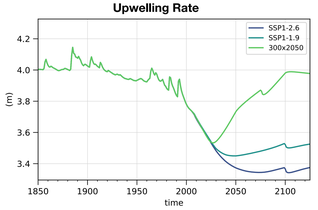
```
MAGICC ECS setting: 3.257K, MAGICC ΔQ2xCO2 setting: 3.71K
Calculating ECS from abrupt-2xCO2.
Calculating TCR & TCRE from 1pctCO2.
TCR is 2.0882, ECS is 3.2376 kelvin and TCRE is 2.420048 K / 1000 GtC
Calculating ECS from abrupt-0p5xCO2.
Calculating TCR & TCRE from 1pctCO2-cdr.
TCR is 2.0882, ECS is 3.2555 kelvin and TCRE is 2.420048 K / 1000 GtC
```

Pymagicc/MAGICC 6.8 Configuration Parameters

```
core_climatesensitivity : 3.257
#core_delq2xco2: 3.71                  # unmodified from MAGICC
core_verticaldiffusivity : 2           # 2.3 default (per magicc6.8)
core_verticaldiffusivity_min : .1      # (1.0000D0e-001 per mag6.8)
core_rlo : 1.45                        # (1.3 per magicc6.8)
core_heatxchange_landocean : 2.35,     # (1 per magicc6.8)
core_amplify_ocn2land_heatxchng : .9,  # default (per magicc6.8)
core_heatxchange_northsouth : 3.45,    # 1 per magicc6.8
co2_preindco2conc : 276.744,
# f_terr initial bin sizes
co2_gpp_initial : 40,                  # Default is NPP, 70
co2_plantpool_initial : 450,           # 1200
co2_detrituspool_initial : 85,         # 120
co2_soilpool_initial : 1100,           # 2000
co2_respiration_initial : 12,
# start of fluxes Δ
co2_fraction_gpp_2_plant : 0.305,      #3.5e-001 live.magicc
co2_fraction_gpp_2_detritus : 0.3,     #6.0e-001 live.magicc
co2_fraction_plant_2_detritus : 0.35,  # .21
co2_fraction_detritus_2_soil : 0.3,    # 5.0e-002 live.magicc
co2_fraction_deforest_plant : 0.29,    # .7
co2_fraction_deforest_detritus : .4,   # 0.05
co2_tempfeedback_yrstart : 1750,
co2_tempfeedback_switch : 1,
co2_feedbackfactor_soil : 0.046,       # .2 (live.magicc)
co2_fertilization_yrstart : 1750,
co2_fertilization_method : 1.03,       # 1.97 (live.magicc)
co2_fertilization_factor : .63,
co2_gifford_conc_for_zeronpp : 31,     # 80.0 (live.magicc default
```

NE Calibration Results, a-e





The experiment and cached data are at https://github.com/hsbay/***CDRMEx***.
The preprint is at https://doi.org/10.31223/x5k37c.

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