Die Unterschätzung des Klimawandels

Zum Einfluss inhaltsfremder Werte auf die Modellierung

Anna Leuschner, KIT
Seiten 74 - 88 in
C. Dieckhoff, A. Leuschner (Hrg),
Die Energiewende und ihre Modelle:
Was uns Energieszenarien sagen können - und was nicht,
Forschungsgruppe "Limits and Objectivity of Scientific Foreknowledge: The Case of Energy Outlooks (LOBSTER)",
Karlsruhe Institut für Technologie,
transcript Verlag, Bielefeld, 2016

sogar Beobachtungen, Daten sind selektiv und theoriebeladen
Temperaturkurve beruht auf Wettermodell-gestützten Interpolationen von Realanalysedaten
Unsicherheiten über die Funktionsweisen des Klimasystems: unbekannte Feedbacks
Konstruktion der Modelle hinsichtlich bestimmter Parameter ("Parametrisierung") recht willkürlich - teilweise einfach Fit-Parameter
Klimamodell-Ensembles: viele darin können dieselben Lücken aufweisen, dieselben Vereinfachungen enthalten, dieselben Idealisierungen vorgenommen haben
Robustheit: zuverlässig, aber nur gegeben den derzeitigen Wissensstand
gesicherter Wissensstand: von inhaltsfremden impliziten Werten geprägt
pragmatische Faktoren: kulturell bedingte Begrenzung des Horizonts der beteiligten Wissenschaftler (z.B. AkEnd & surfcx)
politischer Druck, Schutzverhalten der Wissenschaftler (lieber falsch-negativ als falsch-positiv)
Unsichere Bandbreiten drücken aus anderen Wissensgebieten übernommene relevante Abweichungen aus

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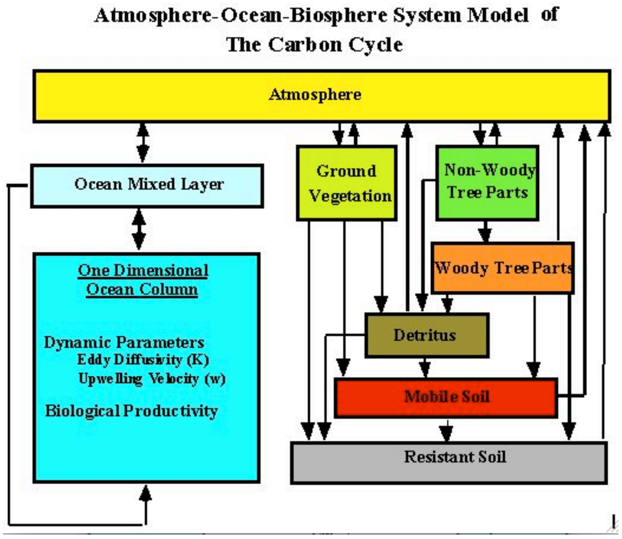
From carbon_cycle_short-term.rtfd

I. "The Land Breathes"

Integrated (Climate) Science Assessment Model (ISAM)
a fully coupled ocean-atmosphere-terrestrial biogeochemistry model
Atul Jain, U Illinois
http://climate.atmos.uiuc.edu/isam2/index.html
David Archer, U Chicago: http://climatemodels.uchicago.edu/isam/

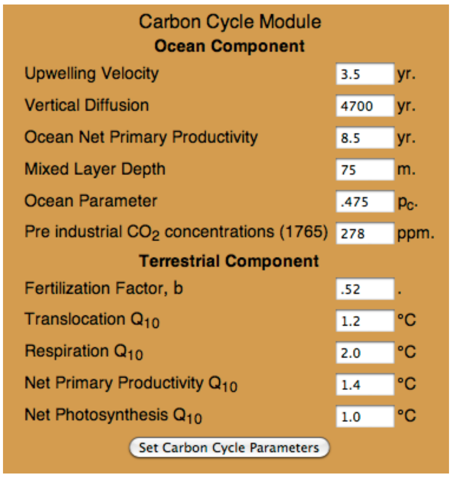
more models
David Archer, U Chicago: http://climatemodels.uchicago.edu/models.html



The concentration of CO2 is calculated by a globally averaged carbon cycle model (Figure 3), which consists of 4 reservoirs, namely

- the atmosphere,
- the terrestrial biosphere,
- the mixed ocean layer, and
- the deep ocean (Jain et al., 1995, 1996).

The atmosphere and the mixed layers are modeled as well mixed reservoirs.



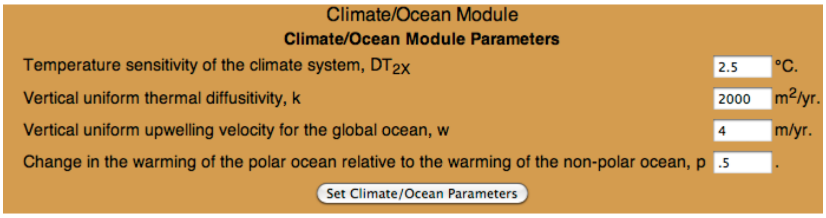
Carbon Cycle Module

Ocean Component

Upwelling Velocity	3.5	yr.
Vertical Diffusion	4700	yr.
Ocean Net Primary Productivity	8.5	yr.
Mixed Layer Depth	75	m.
Ocean Parameter	.475	p_c.
Pre industrial CO_2 concentrations (1765)	278	ppm.

Terrestrial Component

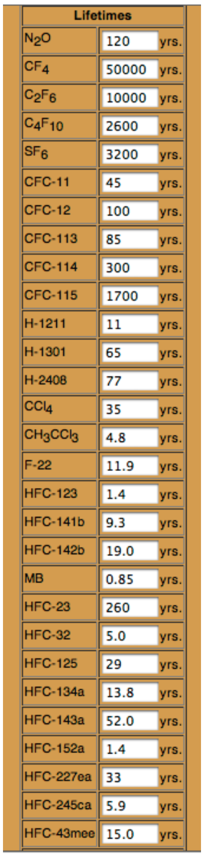
Fertilization Factor, b	.52	.
Translocation Q_{10}	1.2	°C
Respiration Q_{10}	2.0	°C
Net Primary Productivity Q_{10}	1.4	°C
Net Photosynthesis Q_{10}	1.0	°C



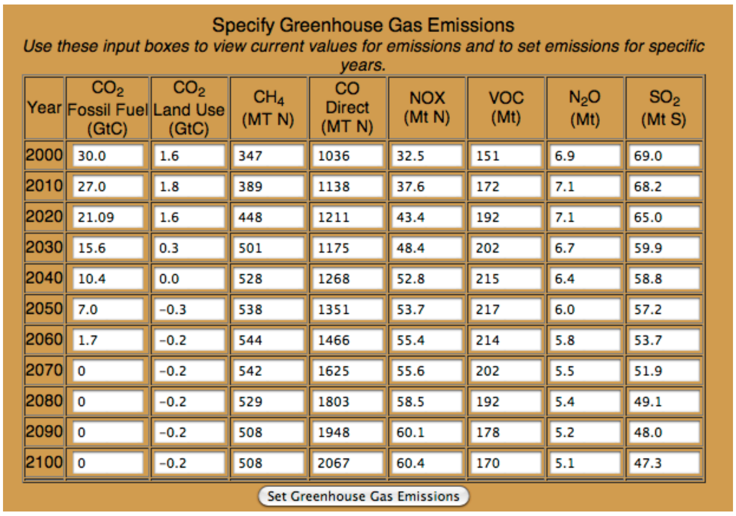
Climate/Ocean Module

Climate/Ocean Module Parameters

Temperature sensitivity of the climate system, DT_{2X}	2.5	°C.
Vertical uniform thermal diffusivity, k	2000	m^2/yr.
Vertical uniform upwelling velocity for the global ocean, w	4	m/yr.
Change in the warming of the polar ocean relative to the warming of the non-polar ocean, p	.5	.



Lifetimes		
N_2O	120	yrs.
CF_4	50000	yrs.
C_2F_6	10000	yrs.
C_4F_{10}	2600	yrs.
SF_6	3200	yrs.
CFC-11	45	yrs.
CFC-12	100	yrs.
CFC-113	85	yrs.
CFC-114	300	yrs.
CFC-115	1700	yrs.
H-1211	11	yrs.
H-1301	65	yrs.
H-2408	77	yrs.
CCl_4	35	yrs.
CH_3CCl_3	4.8	yrs.
F-22	11.9	yrs.
HFC-123	1.4	yrs.
HFC-141b	9.3	yrs.
HFC-142b	19.0	yrs.
MB	0.85	yrs.
HFC-23	260	yrs.
HFC-32	5.0	yrs.
HFC-125	29	yrs.
HFC-134a	13.8	yrs.
HFC-143a	52.0	yrs.
HFC-152a	1.4	yrs.
HFC-227ea	33	yrs.
HFC-245ca	5.9	yrs.
HFC-43mee	15.0	yrs.

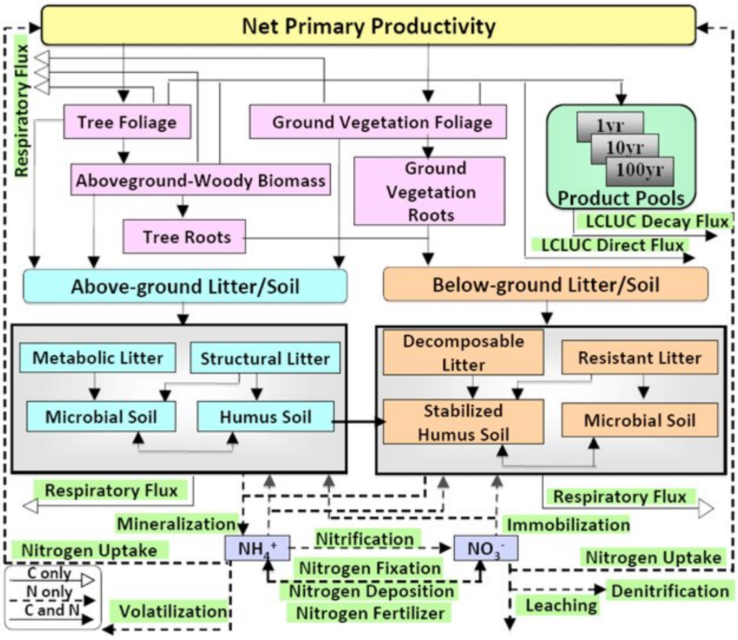


Specify Greenhouse Gas Emissions

Use these input boxes to view current values for emissions and to set emissions for specific years.

Year	CO_2 Fossil Fuel (GtC)	CO_2 Land Use (GtC)	CH_4 (MT N)	CO Direct (MT N)	NOX (Mt N)	VOC (Mt)	N_2O (Mt)	SO_2 (Mt S)
2000	30.0	1.6	347	1036	32.5	151	6.9	69.0
2010	27.0	1.8	389	1138	37.6	172	7.1	68.2
2020	21.09	1.6	448	1211	43.4	192	7.1	65.0
2030	15.6	0.3	501	1175	48.4	202	6.7	59.9
2040	10.4	0.0	528	1268	52.8	215	6.4	58.8
2050	7.0	-0.3	538	1351	53.7	217	6.0	57.2
2060	1.7	-0.2	544	1466	55.4	214	5.8	53.7
2070	0	-0.2	542	1625	55.6	202	5.5	51.9
2080	0	-0.2	529	1803	58.5	192	5.4	49.1
2090	0	-0.2	508	1948	60.1	178	5.2	48.0
2100	0	-0.2	508	2067	60.4	170	5.1	47.3

ISAM - Refinement



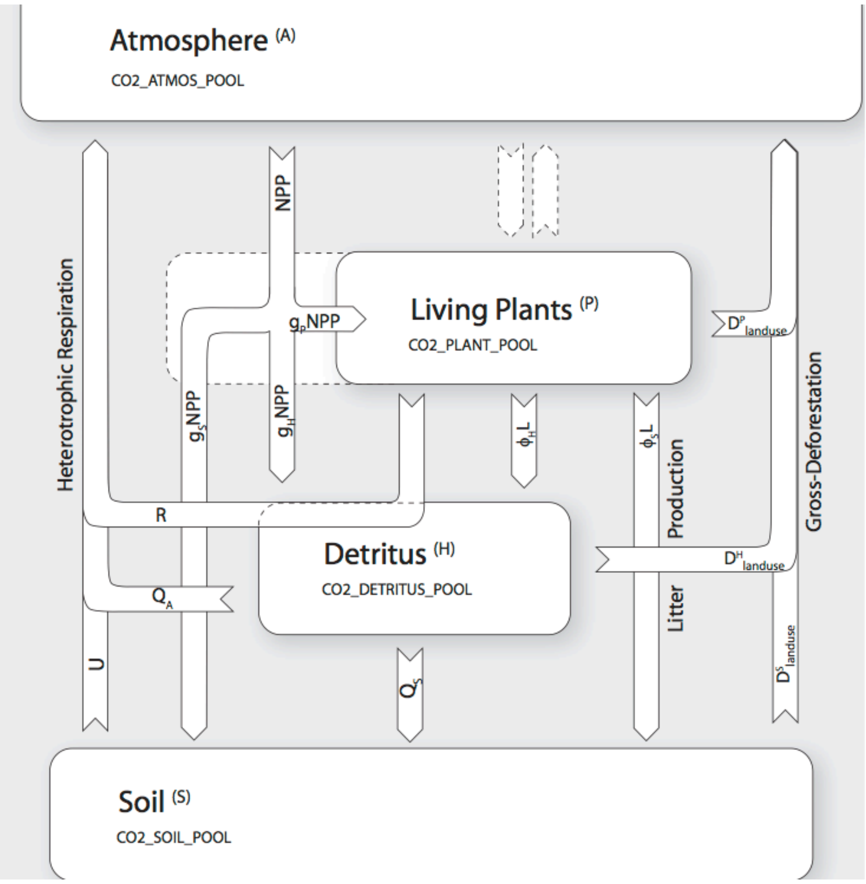
WGIAR5_al_final.pdf

MAGICC

M. Meinshausen1, S. C. B. Raper2, and T. M. L. Wigley3,
Emulating coupled atmosphere-ocean and carbon cycle models with a simpler model, MAGICC6 – Part 1: Model description and calibration,
Atmos. Chem. Phys., 11, 1417–1456, 2011
www.atmos-chem-phys.net/11/1417/2011/
doi:10.5194/acp-11-1417-2011
(im Cache)

The '**Model for the Assessment of Greenhouse Gas Induced Climate Change' (MAGICC6**, Meinshausen et al., 2011a), is a reduced-complexity carbon cycle, atmospheric composition and climate model that has been widely used in prior IPCC Assessments and policy literature. This model is used with its parameter set as identical to that employed in AR5 for backwards compatibility. This model has been shown to match temperature trends very well compared to **CMIP5** models (Collins et al., 2013; Clarke et al., 2014).

Linear Compartment System with Constant Coefficients



$DC/Dt = E_{foss} + E_{landuse} + E_{fCH4} - F_{ocn} - F_{terr}$

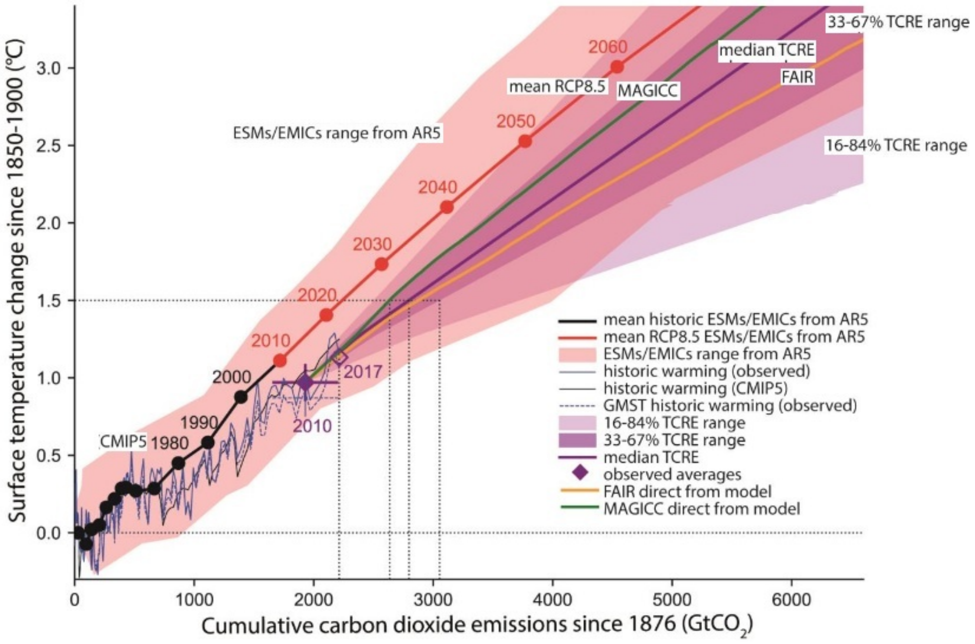
E_{foss}	CO2 emissions from fossil and industrial sources
E_{lu}	directly human induced CO2 emissions/removals from/to terrestrial biosphere
E_{fCH4}	emissions due to oxidized methane of fossil fuel origin
F_{ocn}	flux due to ocean carbon uptake
F_{terr}	net carbon uptake or release by terrestrial biosphere due to CO2 fertilization and climate feedback
NPP	Net Plant Production

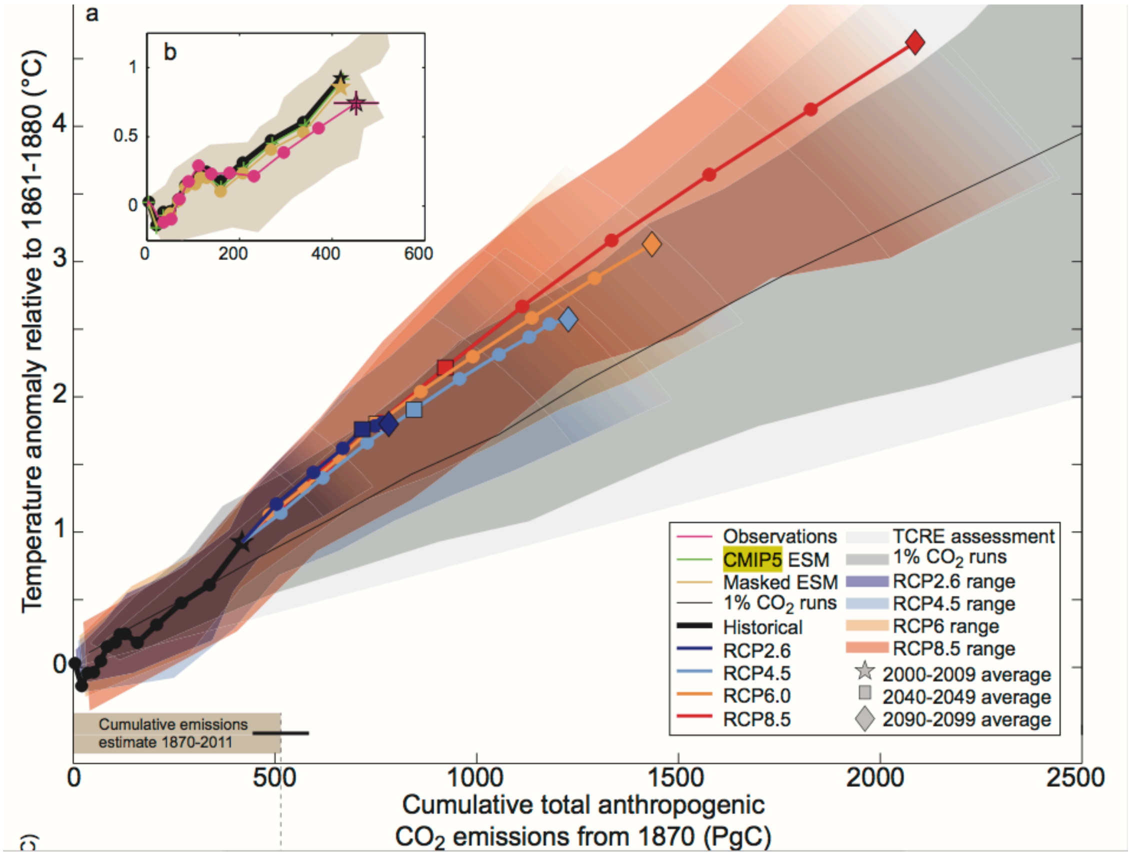
linear compartment system with constant coefficients

- atmosphere
- living plant $DP/Dt = g_P NPP - R - L - D_{landuse}^P$
    - woody material, leaves/needles, grass, and roots, but does not include the rapid turnover part of living biomass, which can be assumed to have a zero lifetime on the timescales of interest here (dashed extension of plant box P in Fig. A2). Thus, a fraction of gross primary product (GPP) cycles through the plant box directly back to the atmosphere due to autotrophic respiration and can be ignored (dashed arrows). Only the remaining part of GPP, namely the net primary production NPP is simulated.
    - $g_p = 35\%$, $g_H = 60\%$, $g_S = 5\%$
    - R = heterotrophic respiration
    - L = litter production
        - $O_H = 98\%$, $O_S = 2\%$
    - D = gross deforestation
- detritus ("humus" H) $DH/Dt = g_H NPP + O_H L - Q_A - Q_S - D_{landuse}^H$
    - source: litter production ($O_H L$), sink to atmosphere
        - due to land use ($D_{landuse}^H$)
        - to atmosphere: non-land use related oxidation (Q_A)
        - to soil: (Q_S)
- soil organic matter (S) $DS/Dt = g_S NPP + O_S L + Q_S - U - D_{lu}^S$
    - source: litter production ($O_S L$), detritus (Q_S),
    - sink: flux to atmosphere due to land use ($D_{landuse}^S$), non-land use related oxidation (U)

decay rates (fluxes L, Q, U) are assumed to be proportional to the pool's masses P, H, S (linear system)
turnover times t^P, t^H, t^S determined by steady state conditions ($_o$)

- flux $L_o = P_o / t_o^P$
- flux $Q_o = H_o / t_o^H$
- flux $U_o = S_o / t_o^S$


Surface temperature change since 1850-1900 (°C)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
33-67% TCRE range
median TCRE
FAIR
2060
mean RCP8.5
MAGICC
2050
ESMs/EMICs range from AR5
16-84% TCRE range
2040
2030
2020
2010
2017
2000
1990
2010
CMIP5
1980
mean historic ESMs/EMICs from AR5
mean RCP8.5 ESMs/EMICs from AR5
ESMs/EMICs range from AR5
historic warming (observed)
historic warming (CMIP5)
GMST historic warming (observed)
16-84% TCRE range
33-67% TCRE range
median TCRE
observed averages
FAIR direct from model
MAGICC direct from model
0
1000
2000
3000
4000
5000
6000
Cumulative carbon dioxide emissions since 1876 ($GtCO_2$)


a
b
1
0.5
0
0
200
400
600
Temperature anomaly relative to 1861-1880 (°C)
4
3
2
1
0
Observations
CMIP5 ESM
Masked ESM
1% CO_2 runs
Historical
RCP2.6
RCP4.5
RCP6.0
RCP8.5
TCRE assessment
1% CO_2 runs
RCP2.6 range
RCP4.5 range
RCP6 range
RCP8.5 range
2000-2009 average
2040-2049 average
2090-2099 average
Cumulative emissions
estimate 1870-2011
0
500
1000
1500
2000
2500
Cumulative total anthropogenic
CO_2 emissions from 1870 (PgC)

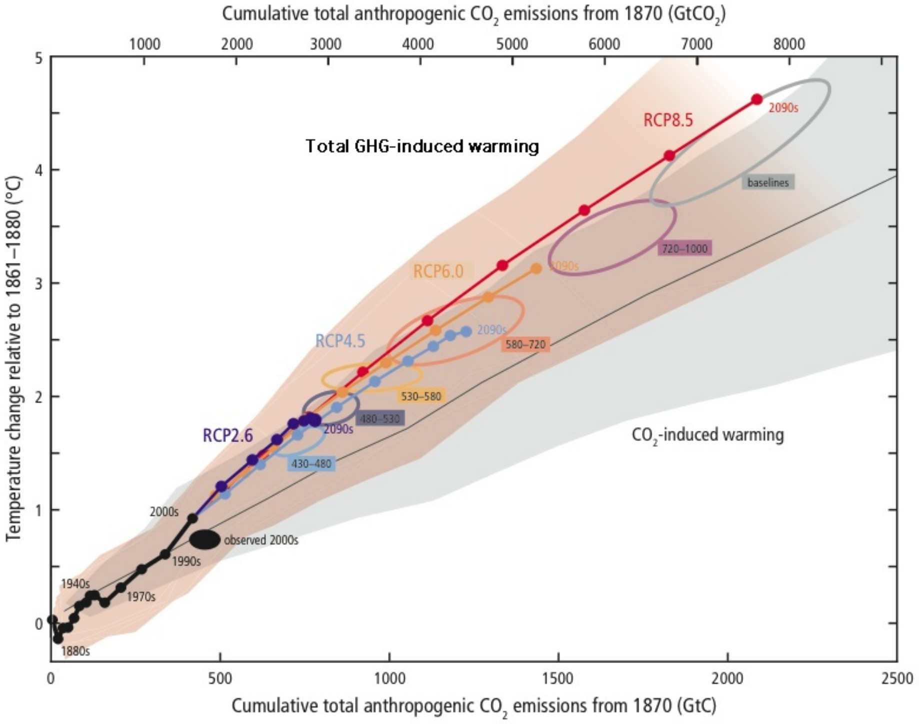
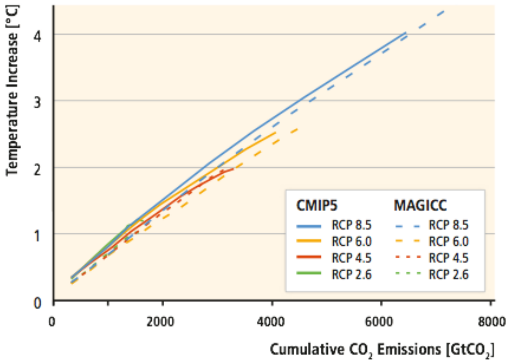
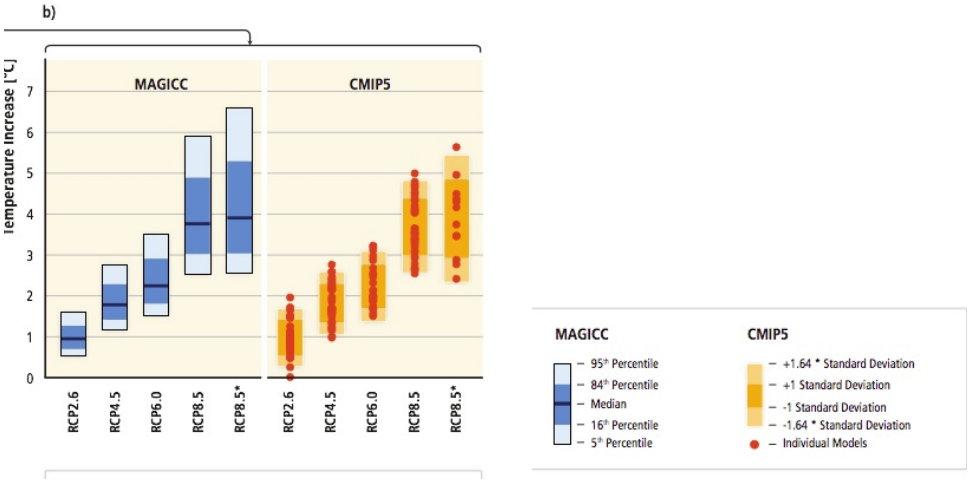


Figure 2.3 I Global mean surface temperature increase as a function of cumulative total global carbon dioxide (CO2 only, no other C-species!) emissions from various lines of evidence.

- *Multi-model results from a hierarchy of climate / carbon-cycle models* for each Representative Concentration Pathway (RCP) until 2100 are shown (*coloured lines*).
- The *coloured plume* illustrates the *multi-model spread over the four RCP scenarios* and fades with the decreasing number of available models in RCP8.5.
- The multi-model mean and range simulated by CMIP5 models, forced by a CO2 [exclusively CO2] increase of 1% per year (*1% yr–1 CO2 simulations*), is given by the thin black line and grey area (centered around thin black line). For a specific amount of cumulative CO2 emissions, the 1% per year CO2 simulations exhibit lower warming than those driven by RCPs, which include additional non-CO2 forcings.
- Model results over the historical period (1860 to 2010) are indicated in black.
- Dots indicate decadal averages, with selected decades labelled.
- *Ellipses* show total anthropogenic warming in 2100 versus cumulative CO2 emissions from 1870 to 2100 from a simple climate model [*MAGICC*?] (median climate response) under the scenario categories [x-z] used in WGIII.
- Temperature values are always given relative to the 1861–1880 period, and emissions are cumulative since 1870.
- Black filled ellipse shows observed emissions to 2005 and observed temperatures in the decade 2000–2009 with associated uncertainties.



Temperature increases relative to the 1986 - 2005 average for the concentration-driven runs of a subset of CMIP5 models against cumulative CO2 emissions back-calculated by these models from the prescribed CO2 concentration pathways (full lines) and temperature increase projected by the MAGICC model against cumulative CO2 emissions (dotted lines) (based on WGI Figure SPM.10). Cumulative emissions are calculated from 2000 onwards



SR15 Special Report, IPCC
Seite 96 aus
SR15 Chapter 2
"**Mitigation Pathways Compatible with 1.5°C in the Context of Sustainable Development**"

Cumulative CO2 emissions are kept within a budget by reducing global annual CO2 emissions to net zero.
This assessment suggests a remaining budget [from the start of 2018 until the time of net zero global emissions]
of about **420 GtCO2** for a two- thirds chance of limiting warming to 1.5°C, and
of about **580 GtCO2** for an even chance (medium confidence).

The remaining carbon budget is defined here as cumulative CO2 emissions from the start of 2018 until the time of net zero global emissions for global warming defined as a change in global near-surface air temperatures.

Uncertainties
- Remaining budgets applicable to 2100 would be approximately **100 GtCO2** lower than this to account for
    - permafrost thawing and
    - potential methane release from wetlands in the future, and more thereafter.
- These estimates come with an additional geophysical uncertainty of at least **±400 GtCO2**, related to non-CO2 response and TCRE distribution. [TCRE = Transient climate response to cumulative CO2 emissions (transient global average surface temperature change per unit cumulative CO2 emissions, usually 1000 GtC)]
- Uncertainties in the level of historic warming contribute **±250 GtCO2**.
- In addition, these estimates can vary by **±250 GtCO2** depending on non-CO2 mitigation strategies as found in available pathways. {2.2.2, 2.6.1}
    - Staying within a remaining carbon budget of 580 GtCO2 implies that CO2 emissions reach carbon neutrality in about 30 years,
    - reduced to 20 years for a 420 GtCO2 remaining carbon budget (high confidence).
- The ±400 GtCO2 geophysical uncertainty range surrounding a carbon budget translates into a variation of this timing of carbon neutrality of roughly ±15–20 years.
- If emissions do not start declining in the next decade, the point of carbon neutrality would need to be reached at least two decades earlier to remain within the same carbon budget. {2.2.2, 2.3.5}

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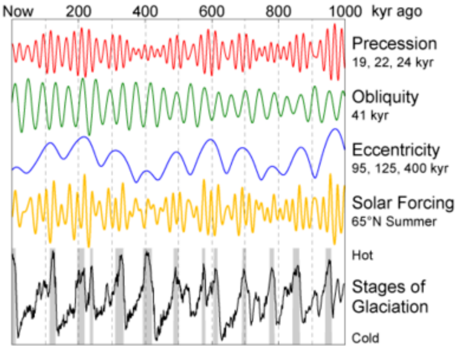
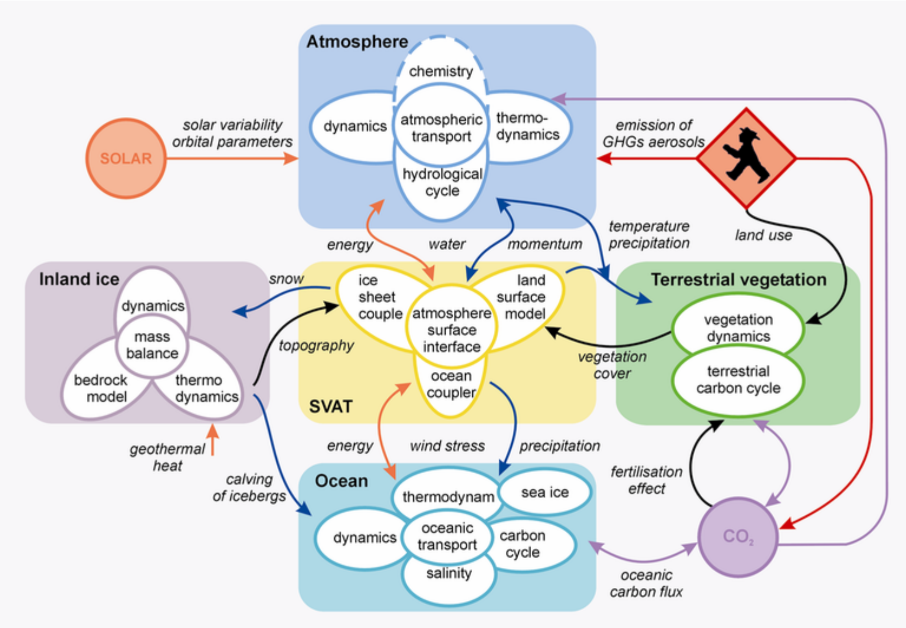
from carbon_cycles_long-term_(paleoclimatology).rtfd

II. "The Ocean Breathes"





CLIMate and BiosphERe Model (CLIMBER-2)
https://www.pik-potsdam.de/research/earth-system-analysis/models/climber/climber-2
https://www.pik-potsdam.de/research/earth-system-analysis/models/climber

CLIMBER-2 is an Earth-system model of intermediate complexity for long-term and paleo-climate simulations. It is based on the 2.5-dimensional statistical-dynamica atmospheric model Potsdam, a 2-dimensional 3-basin ocean model and the 3-dimensional polythermal ice sheet model SICOPOLIS (3D polythermal Ice Sheet Model)

We have succeeded in simulating eight full ice age cycles with prescribed CO2 concentration using CLIMBER-2. Preliminary simulations driven only by orbital cycles (with predicted greenhouse gas changes) show that glacial cycles during the Quaternary (the last 2.6 million years) represent a **strongly nonlinear response of the climate-cryosphere system to astronomical forcing**;

- aeolian dust,
- CO2 and other GHGs

provide positive feedbacks which amplify glacial cycles, and
the removal of terrestrial sediments by the ice sheets can explain the transition from short (41,000 yrs) to long (100,000 yrs) cycles around 1 million years ago.

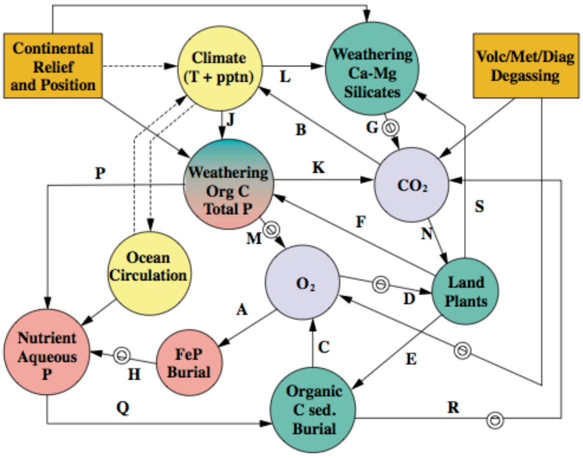
III. "The Rocks Breathe"
100 Million Year Cycles

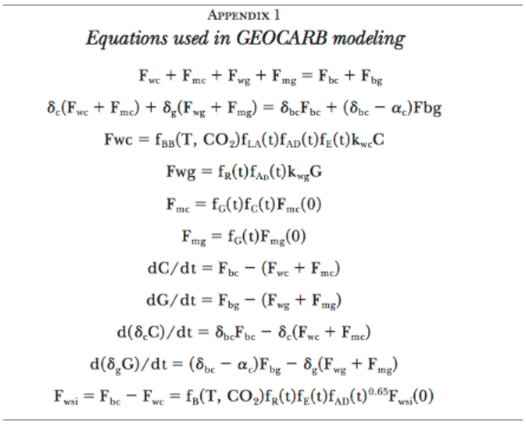
GEOCARB III: A REVISED MODEL OF ATMOSPHERIC CO2 OVER PHANEROZOIC TIME
ROBERT A. BERNER and ZAVARETH KOTHAVALA,
Department of Geology and Geophysics, Yale University, New Haven, Connecticut 06520-8109,
American Journal of Science, Vol. 301, February, 2001, P. 182–204

and

A New Look at the Long-term Carbon Cycle
Robert A. Berner
GSA Today, Vol. 9, No. 11, November 1999, Pages 1-6
excerpts

feedback analysis





APPENDIX 1

Equations used in GEOCARB modeling

$$F_{wc} + F_{mc} + F_{wg} + F_{mg} = F_{bc} + F_{bg}$$

$$\delta_c(F_{wc} + F_{mc}) + \delta_g(F_{wg} + F_{mg}) = \delta_{bc}F_{bc} + (\delta_{bc} - \alpha_c)Fbg$$

$$Fwc = f_{BB}(T,\ CO_2)f_{LA}(t)f_{AD}(t)f_E(t)k_{wc}C$$

$$Fwg = f_R(t)f_{AD}(t)k_{wg}G$$

$$F_{mc} = f_G(t)f_C(t)F_{mc}(0)$$

$$F_{mg} = f_G(t)F_{mg}(0)$$

$$dC/dt = F_{bc} - (F_{wc} + F_{mc})$$

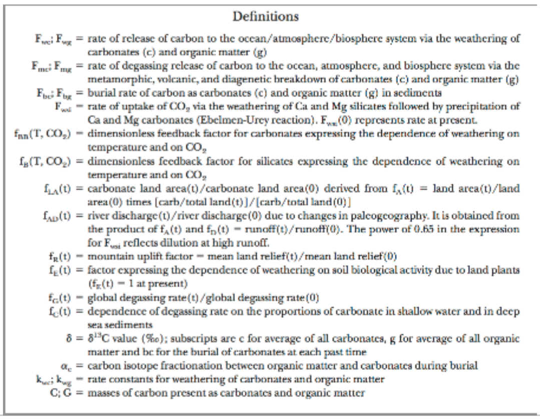
$$dG/dt = F_{bg} - (F_{wg} + F_{mg})$$

$$d(\delta_c C)/dt = \delta_{bc}F_{bc} - \delta_c(F_{wc} + F_{mc})$$

$$d(\delta_g G)/dt = (\delta_{bc} - \alpha_c)F_{bg} - \delta_g(F_{wg} + F_{mg})$$

$$F_{wsi} = F_{bc} - F_{wc} = f_B(T,\ CO_2)f_R(t)f_E(t)f_{AD}(t)^{0.65}F_{wsi}(0)$$

C = mass of carbon in lithosphere
c = carbon as carbonate, g = carbon as organic matter
w = weathering, m = metamorphism, b = burial
F = release rate
F_{wc} = release rate of carbon to the ocean/atmosphere/biosphere system via weathering
F_{mc} = release rate via degassing from metamorphic breakdown of carbonates
F_{bc} = burial rate of carbon as carbonate
f_{BB}(T, CO2) = feedback factor for carbonates weathering dependence on (T, CO2)
f_B(T, CO2) = feedback factor for silicates weathering dependence on (T, CO2)
k = weathering rate constants



Definitions

$F_{wc}; F_{wg}$ = rate of release of carbon to the ocean/atmosphere/biosphere system via the weathering of carbonates (c) and organic matter (g)
$F_{mc}; F_{mg}$ = rate of degassing release of carbon to the ocean, atmosphere, and biosphere system via the metamorphic, volcanic, and diagenetic breakdown of carbonates (c) and organic matter (g)
$F_{bc}; F_{bg}$ = burial rate of carbon as carbonates (c) and organic matter (g) in sediments
F_{wsi} = rate of uptake of CO_2 via the weathering of Ca and Mg silicates followed by precipitation of Ca and Mg carbonates (Ebelmen-Urey reaction). $F_{wsi}(0)$ represents rate at present.
$f_{BB}(T, CO_2)$ = dimensionless feedback factor for carbonates expressing the dependence of weathering on temperature and on CO_2
$f_B(T, CO_2)$ = dimensionless feedback factor for silicates expressing the dependence of weathering on temperature and on CO_2
$f_{LA}(t)$ = carbonate land area(t)/carbonate land area(0) derived from $f_A(t)$ = land area(t)/land area(0) times [carb/total land(t)]/[carb/total land(0)]
$f_{AD}(t)$ = river discharge(t)/river discharge(0) due to changes in paleogeography. It is obtained from the product of $f_A(t)$ and $f_D(t)$ = runoff(t)/runoff(0). The power of 0.65 in the expression for F_{wsi} reflects dilution at high runoff.
$f_R(t)$ = mountain uplift factor = mean land relief(t)/mean land relief(0)
$f_E(t)$ = factor expressing the dependence of weathering on soil biological activity due to land plants ($f_E(t) = 1$ at present)
$f_G(t)$ = global degassing rate(t)/global degassing rate(0)
$f_C(t)$ = dependence of degassing rate on the proportions of carbonate in shallow water and in deep sea sediments
δ = δ^{13}C value (‰); subscripts are c for average of all carbonates, g for average of all organic matter and bc for the burial of carbonates at each past time
α_c = carbon isotope fractionation between organic matter and carbonates during burial
$k_{wc}; k_{wg}$ = rate constants for weathering of carbonates and organic matter
C; G = masses of carbon present as carbonates and organic matter