On how longterm warming and steric sea level rise relate to carbon emissions

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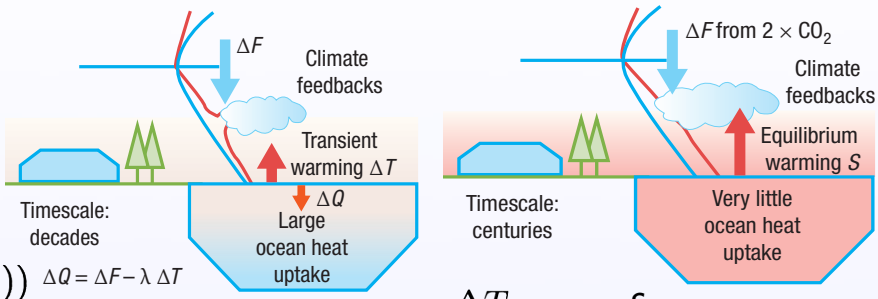
1. Climate sensitivity

global surface temperature change varies with atmospheric CO_2

$$\Delta T = \underbrace{\Delta T_{2\times CO_2}}_{} \frac{\ln(CO_2(t_{equilib})/CO_2(t_o))}{\ln 2}$$

climate sensitivity= 2 to 4.5 K, mean of 3 K



$\Delta T_{2\times CO_2}$ =S

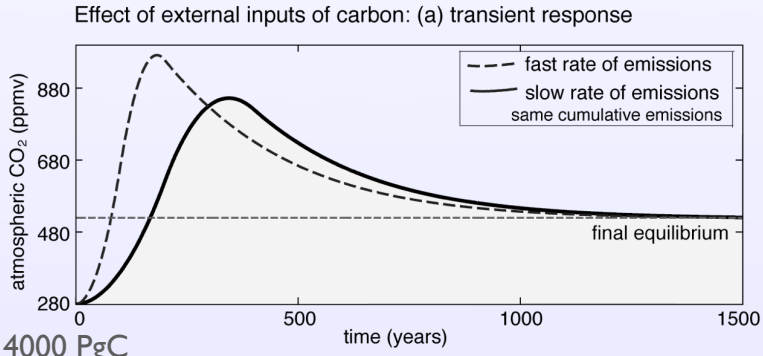
Knutti and Hegerl (2008) Nature Geosciences

2. Longterm atmospheric CO_2 and carbon emissions

+ve feedback:
atmospheric CO_2 *rises*,
increase ocean acidity,
less carbonate, more ocean CO_2,
inhibits ocean uptake of CO_2

$$CO_2(t_{equilib}) = CO_2(t_o)\exp\left(\Delta I_{emission}/I_B\right)$$

I_B is 3500 PgC, nearly conserved for emissions up to 4000 PgC



Goodwin et al. (2007, 2009) GBC, Nature Geoscience

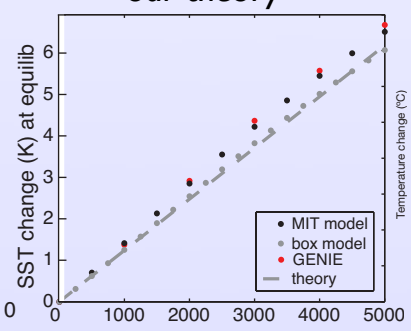
3. Implications for surface warming & steric sea level rise

$$\underbrace{\Delta T}_{} = \left(\frac{\Delta T_{2\times CO_2}}{I_B \ln 2}\right)\underbrace{\Delta I_{emission}}_{}$$

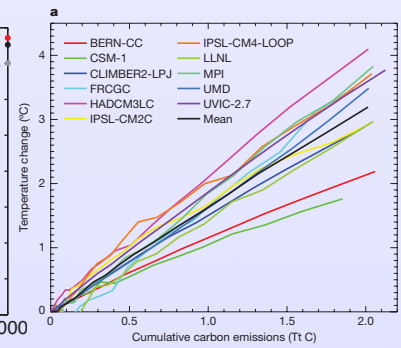
surface temperature change — cumulative carbon emission

Our theory:
global warming is ~1.5 K for every 1000 PgC
(range of 0.8 to 1.9 K for every 1000 PgC)

our theory



Carbon emissions (PgC)



Earth system models find 1 to 2.1 K for every 1000 PgC (Matthews et al., 2009)

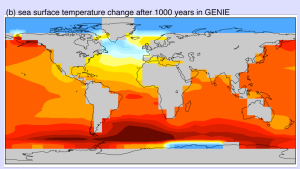
$$\underbrace{\Delta\eta}_{} = \left(\frac{\alpha D \Delta T_{ocean:2\times CO_2}}{I_B \ln 2}\right)\underbrace{\Delta I_{emission}}_{}$$

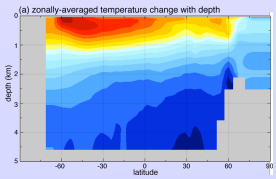
surface steric change — cumulative carbon emission

$\Delta T_{ocean:2\times CO_2}$ — ocean climate sensitivity is poorly known, ~ 1 K

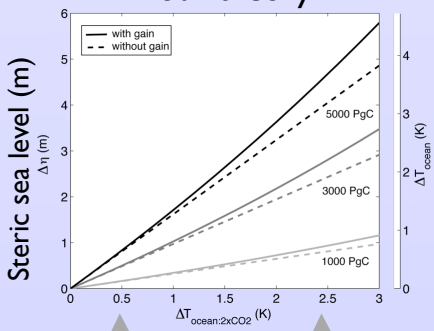
Our theory:
emission of 5000 PgC, longterm steric sea level rise is 1 to 5m, plus mass change

Temperature change in GENIE after 1000 y with emission of 5000 PgC





our theory



Ocean climate sensitivity (K)

Ref.: Williams, R.G., P. Goodwin, A. Ridgwell and P.L. Woodworth, 2012.. Geophysical Research Letters.