Mitigation, Carbon and Solar Geoengineering Over Time

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(Work in progress)

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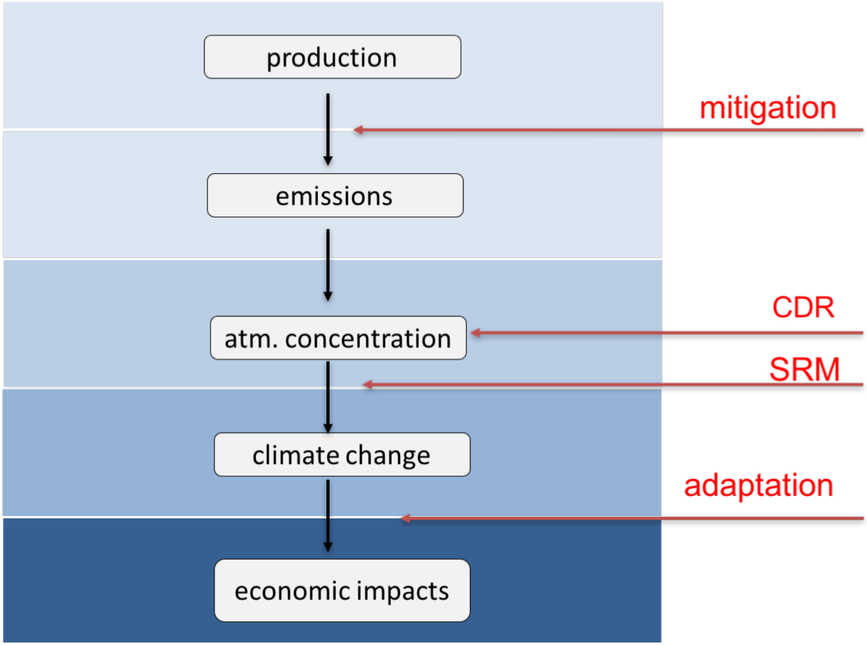
Four climate policy instruments



"DICE+" Literature

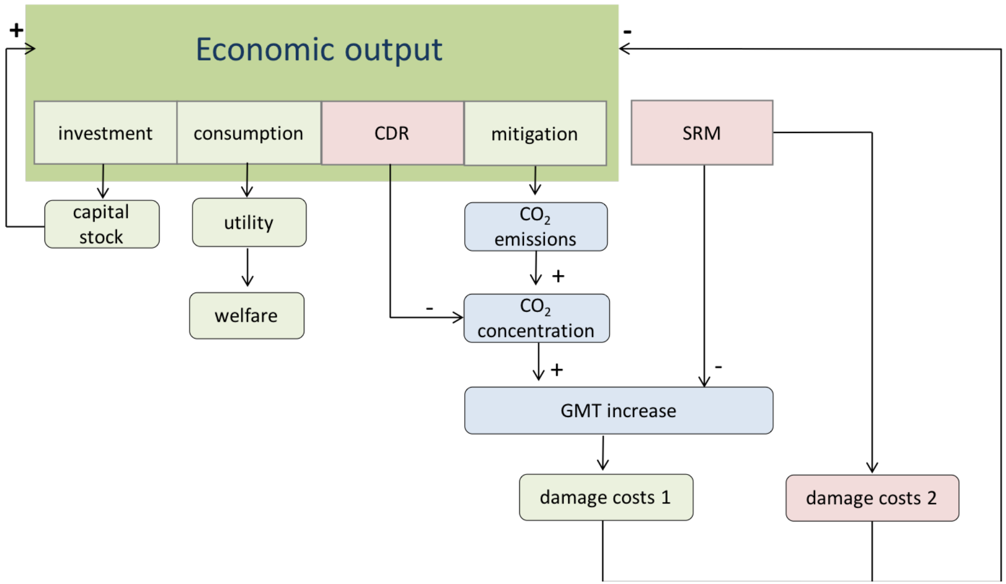
1. Mitigation & SRM
   Gramstad and Tjotta (2010), Moreno-Cruz and Keith (2013), Bickel (2013), Emmerling and Tavoni (2017), Heutel et al. (2018)
2. Mitigation & Adaptation & SRM
   Bahn et al. (2015)
3. Mitigation & CDR
   Rickels et al. (2018)
4. Mitigation & Adaptation & CDR & SRM
   Moreno-Cruz et al. (2018): partial equilibrium model
5. Mitigation & CDR & SRM
   Bickel &Lane (2009): both SRM and CDR are prescribed
   Heutel et al. (2015): static model
   Long and Shepherd (2014): discussion

This paper: dynamic model, welfare maximization; CDR and SRM are policy variables

Objectives

- What is the role of CDR and SRM in the extended climate policy portfolio?
- How does this portfolio composition alter over time in response to alternative model specifications?
- Derive the "napkin diagram"

Extended climate policy portfolio: mitigation + CDR + SRM



DICE-2016:

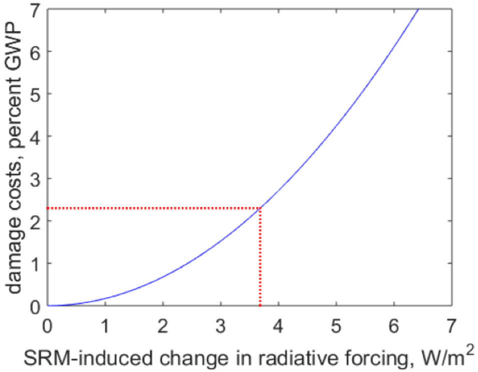
- 1-year timestep
- + CDR costs
- + SRM and side-effects

SRM damage calibration

- SRM costs = 0 ("Free driver"), only damages D
- Keep it simple—i.e., parametric:

$$D = d \cdot (\frac{G}{F_{2\times CO2}})^2$$

- Calibration, based on no evidence: Solar geoengineering G fully compensating for $2 \times CO_2$ induces D equal to damages from warming due to $2 \times CO_2$



SRM damages D

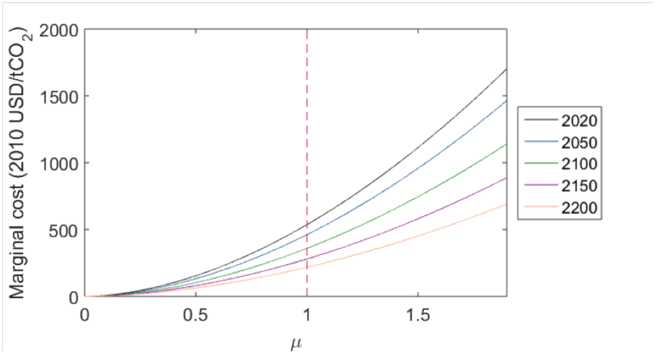
CDR cost calibration

Three central assumptions:

- Marginal costs decrease over time
- Marginal costs increase with emissions cut/carbon removed
- Marginal costs of CDR exceed those of abatement

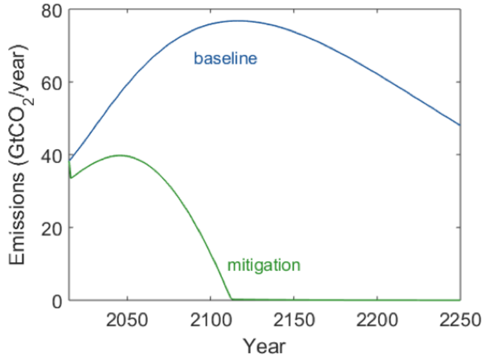
μ = fraction of emissions controlled

- Abatement: $\mu \in [0; 1]$
- CDR allows for $\mu > 1$

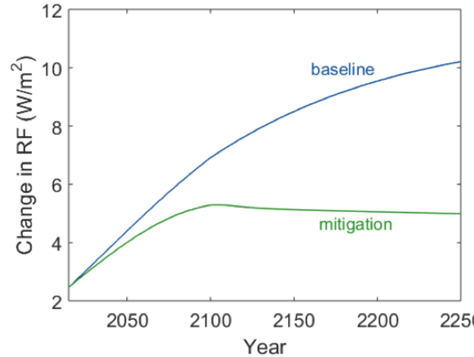


Mitigation and CDR costs function

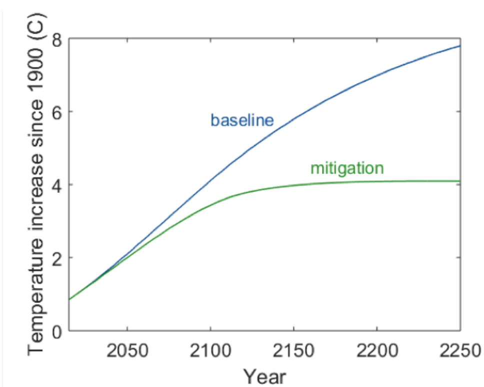
Mitigation only



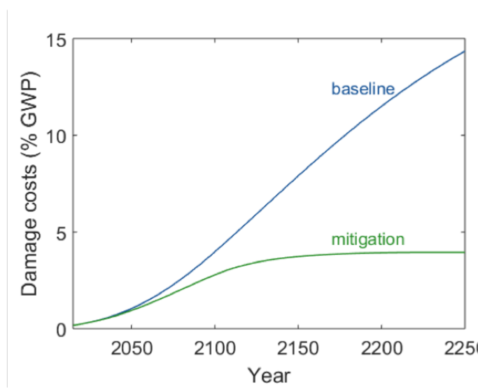
(a) Emissions



(b) Radiative Forcing

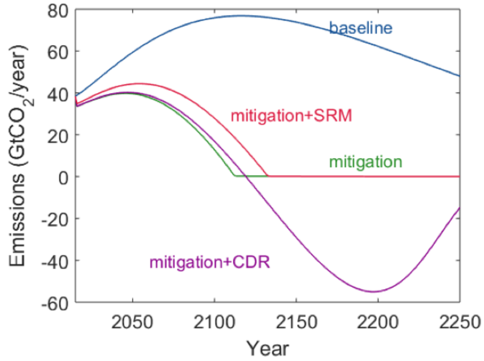


(c) Temperatures

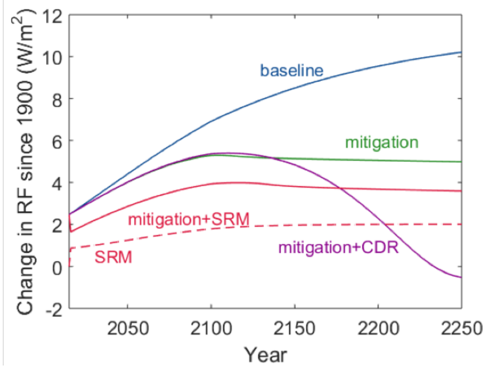


(d) Damages

Mitigation + CDR v Mitigation + SRM only



(a) Emissions



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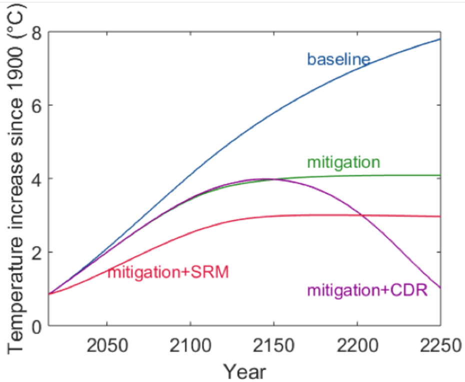
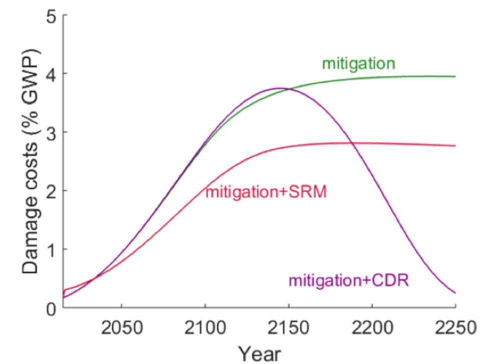
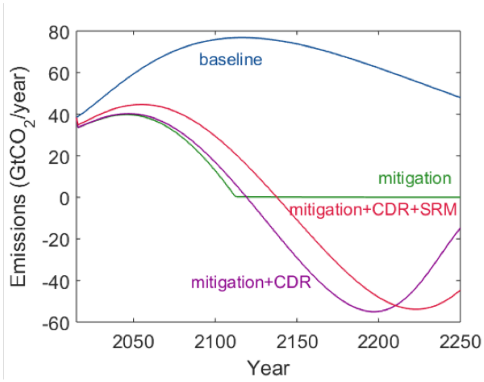


(c) Temperatures

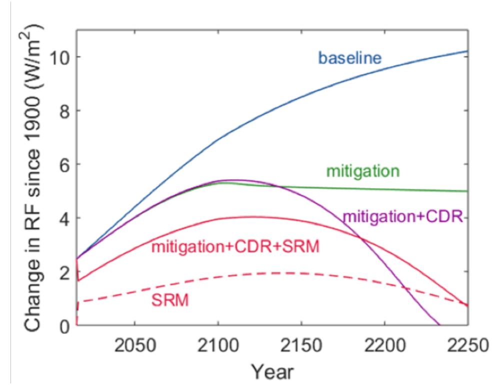


(d) Damages

Mitigation + CDR + SRM



(a) Emissions



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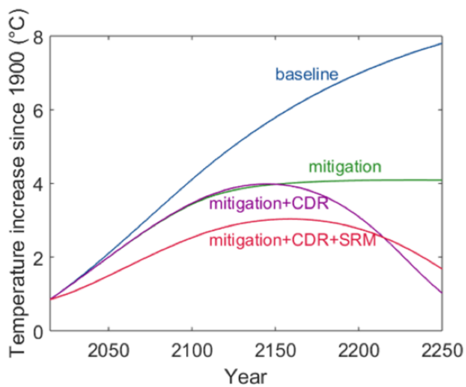
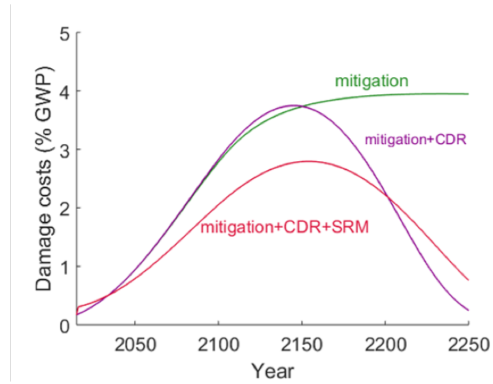
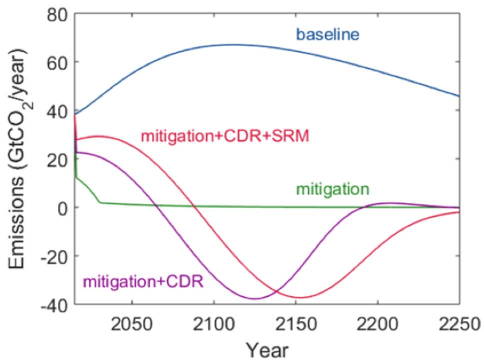


(c) Temperatures

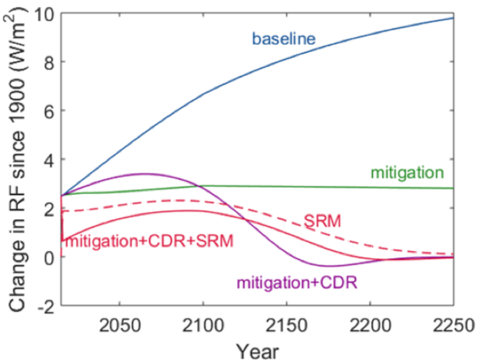


(d) Damages

S1. Smaller discount rate (zero PRTP)



(a) Emissions



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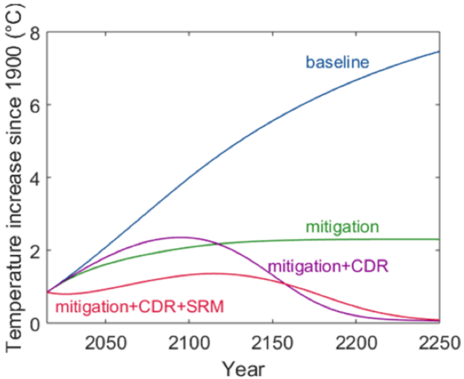
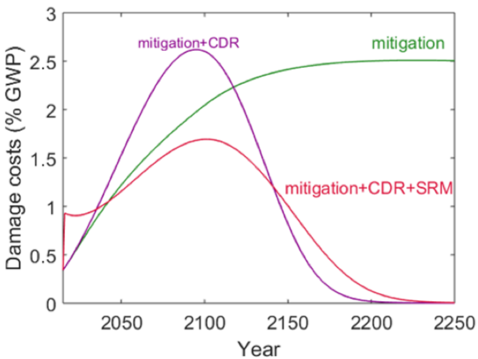
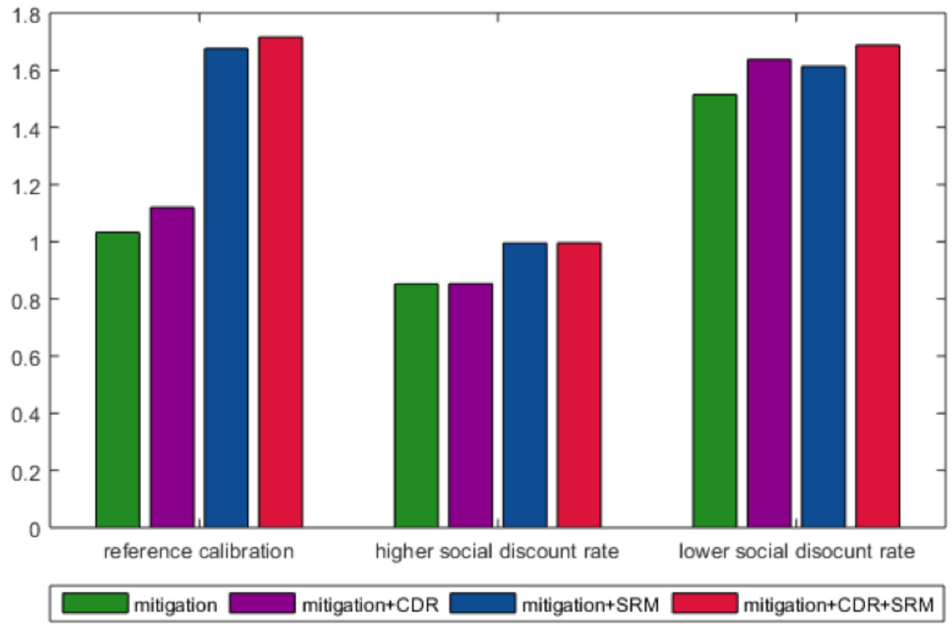


(c) Temperatures



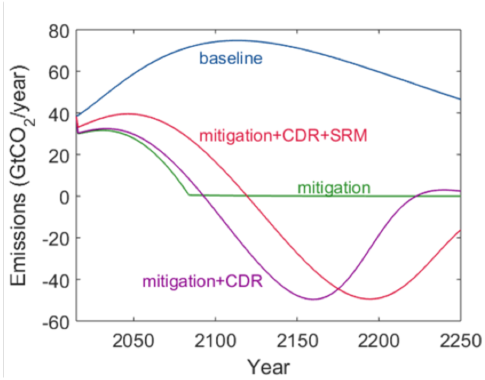
(d) Damages

S1. Welfare gains under 1.5%, 3%, and 0% PRTP

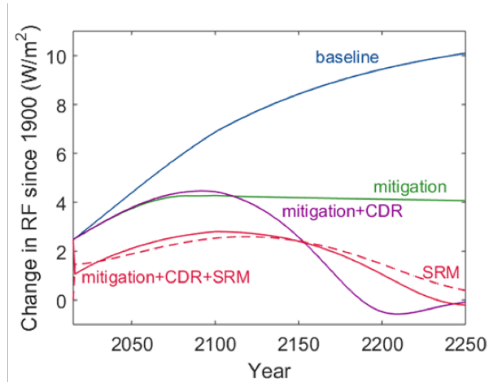


Percentage change in welfare relative to a baseline policy

S2. Twice larger climate damages



(a) Emissions



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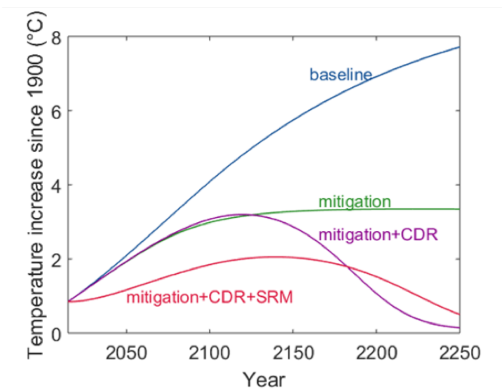
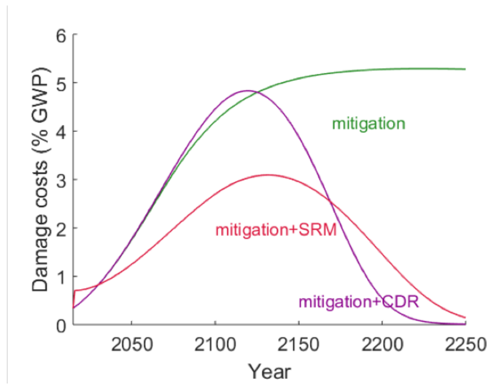
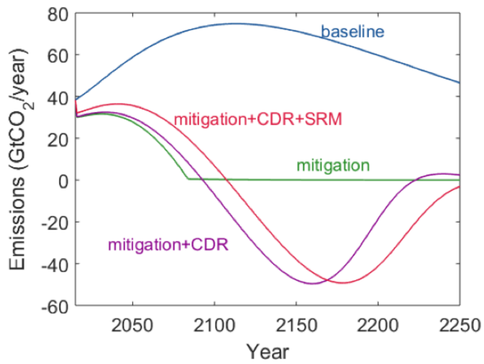


(c) Temperatures

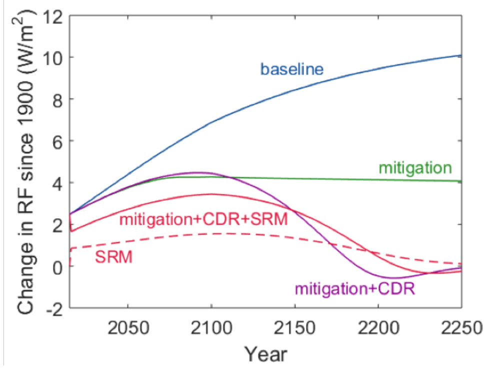


(d) Damages

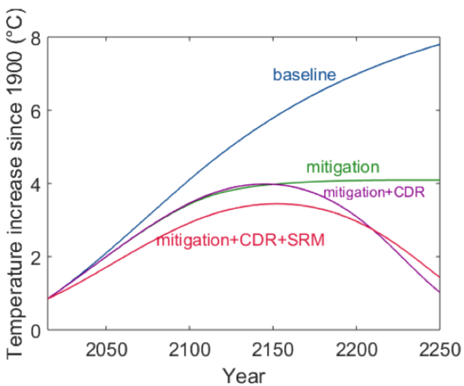
S3. Twice larger SRM damages



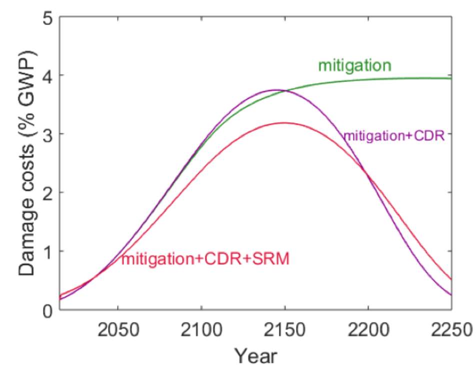
(a) Emissions



(b) Radiative Forcing

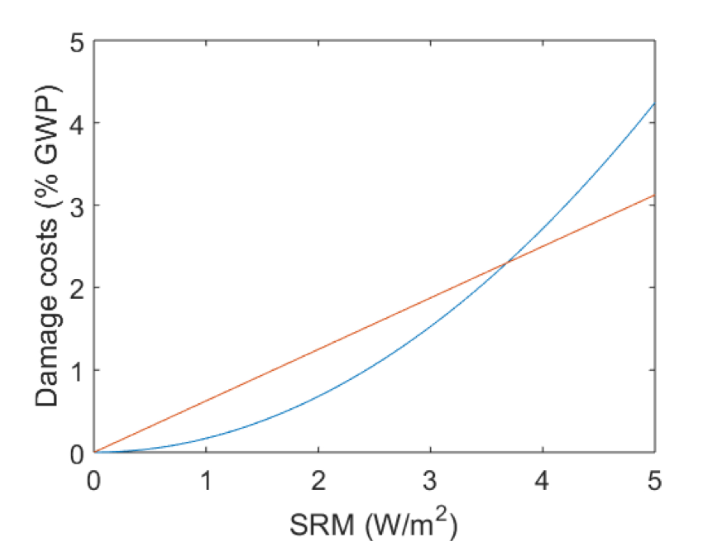


(c) Temperatures

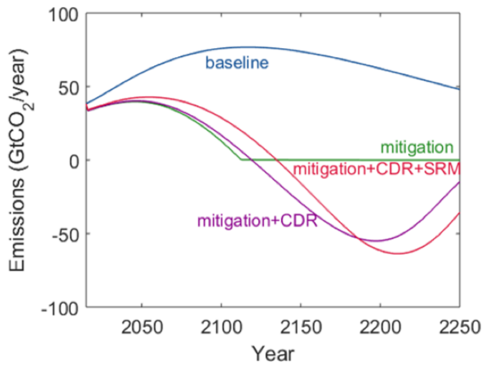


(d) Damages

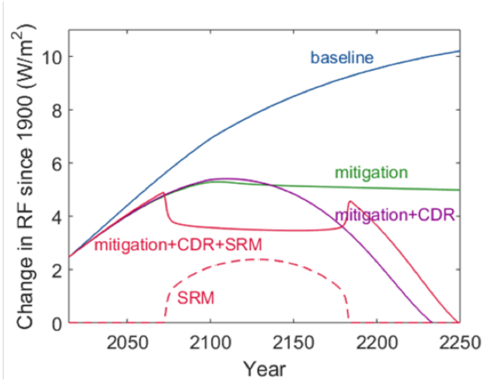
S4. Linear SRM side-effects



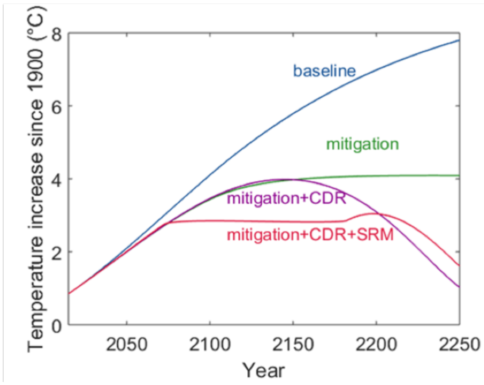
S4. Linear SRM side-effects



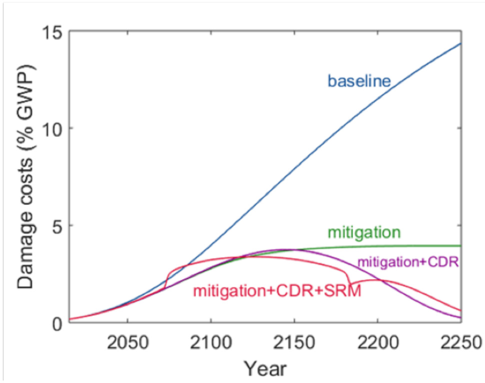
(a) Emissions



(b) Radiative Forcing



(c) Temperatures



(d) Damages

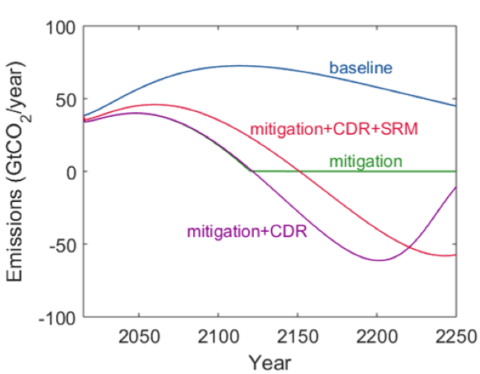
Summary

- Even assuming disproportionally large external costs, SRM is part of a climate policy portfolio, largely because of timing vis-á-vis mitigation & CDR.
  (SRM is not anti-CO_2, only a complement to mitigation & CDR.)
- Larger climate damages call for more mitigation, more SRM.
- CDR reduces the long-term damage costs, even though CDR is always more expensive than mitigation.
- SRM shaves off temperature peak, reducing extreme damages.
- Both CDR and SRM delay mitigation efforts.

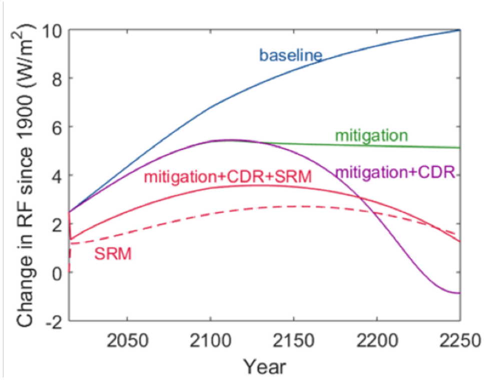
Next steps

- Role of inertia
- Delay in climate policy implementation
- ???

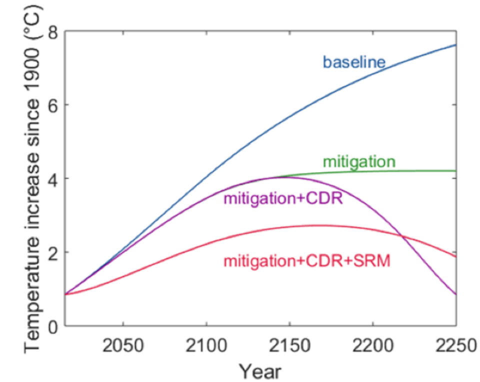
S5. Larger discount rate (PRTP of 3% vs. 1.5%)



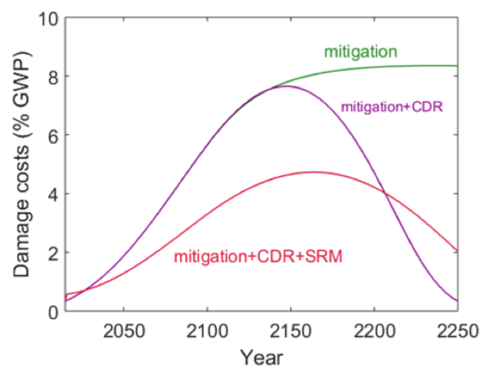
(a) Emissions



(b) Radiative Forcing



(c) Temperatures



(d) Damages

Summary: SRM

	Scenario	Year				
		2020	2050	2100	2150	2200
	Reference scenario	0.91 (33.33)	1.25 (30.37)	1.79 (31.18)	1.93 (33.19)	1.56 (35.61)
S1	Larger discount rate	1.19 (43.94)	1.62 (39.39)	2.4 (40.88)	2.71 (43.5)	2.44 (45.91)
S2	Smaller discount rate	1.88 (70.29)	2.11 (57.59)	2.26 (54.75)	1.47 (60.44)	0.44 (124.67)
S3	Twice larger climate change damage costs	1.48 (54.73)	1.89 (47.20)	2.53 (47.46)	2.42 (50.1)	1.47 (58.25)
S4	Linear SRM side-effects function	0 (0)	0 (0)	2.1 (36.98)	2.2 (38.84)	0 (0)
S5	Twice larger SRM side-effects	0.89 (18.73)	1.19 (17.72)	1.55 (18.45)	1.34 (19.85)	0.61 (22.44)

SRM, W/m^2 in alternative scenarios. In brackets: percent of GHG forcing compensated for by SRM

Summary: CDR

	Scenario	Year		
		2100	2150	2200
	Reference scenario	0	10.84	48
S1	Larger discount rate	0	0	39.55
S2	Smaller discount rate	9.8	37.21	16.57
S3	Twice larger climate change damage costs	0	27.43	49
S4	Linear SRM side-effects function	0	15.76	61.54
S5	Twice larger SRM side-effects	0	19.2	52.85

CDR, $GtCO_2/year$