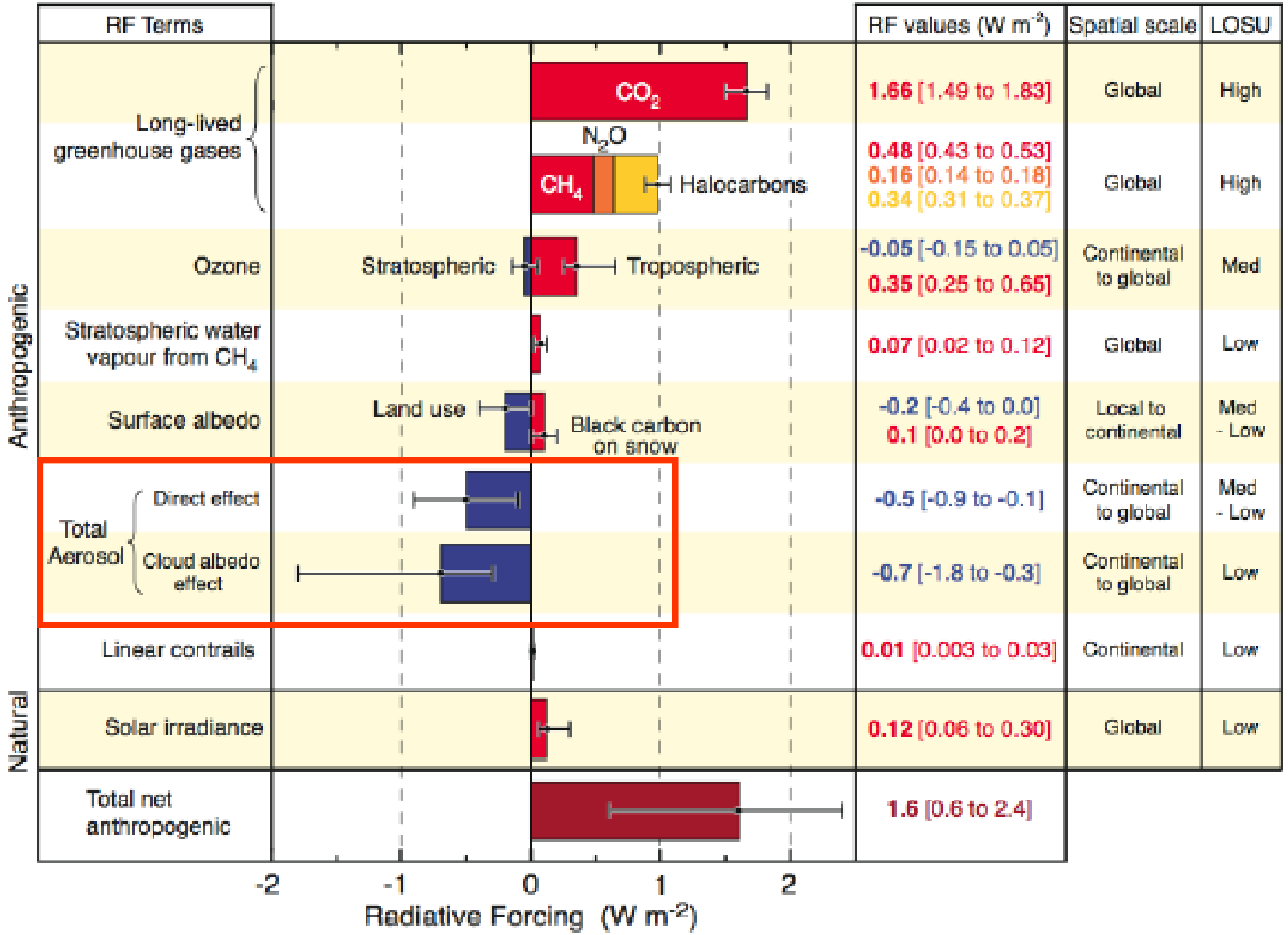
Particles – the dark horse in climate and air pollution policies.

HC Hansson
Department of Applied Environmental Science
Stockholm University

Concepts used

- Forcing – change in the radiation either cooling or heating the globe
- Climate sensitivity - global temperature response to 1 W/m^2 change in total forcing (Temperature change / forcing)
  - High climate sensitivity → high temperature response to increasing CO2 concentrations
  - Low climate sensitivity → low temperature response to increasing CO2 concentrations
- Particles both cool and heat the climate, i.e. have components that have a negative or a positive forcing. Soot is such a component which strongly heats the atmosphere.
- Total aerosol forcing is the sum of both climate warming and cooling caused by the atmospheric anthropogenic aerosol.

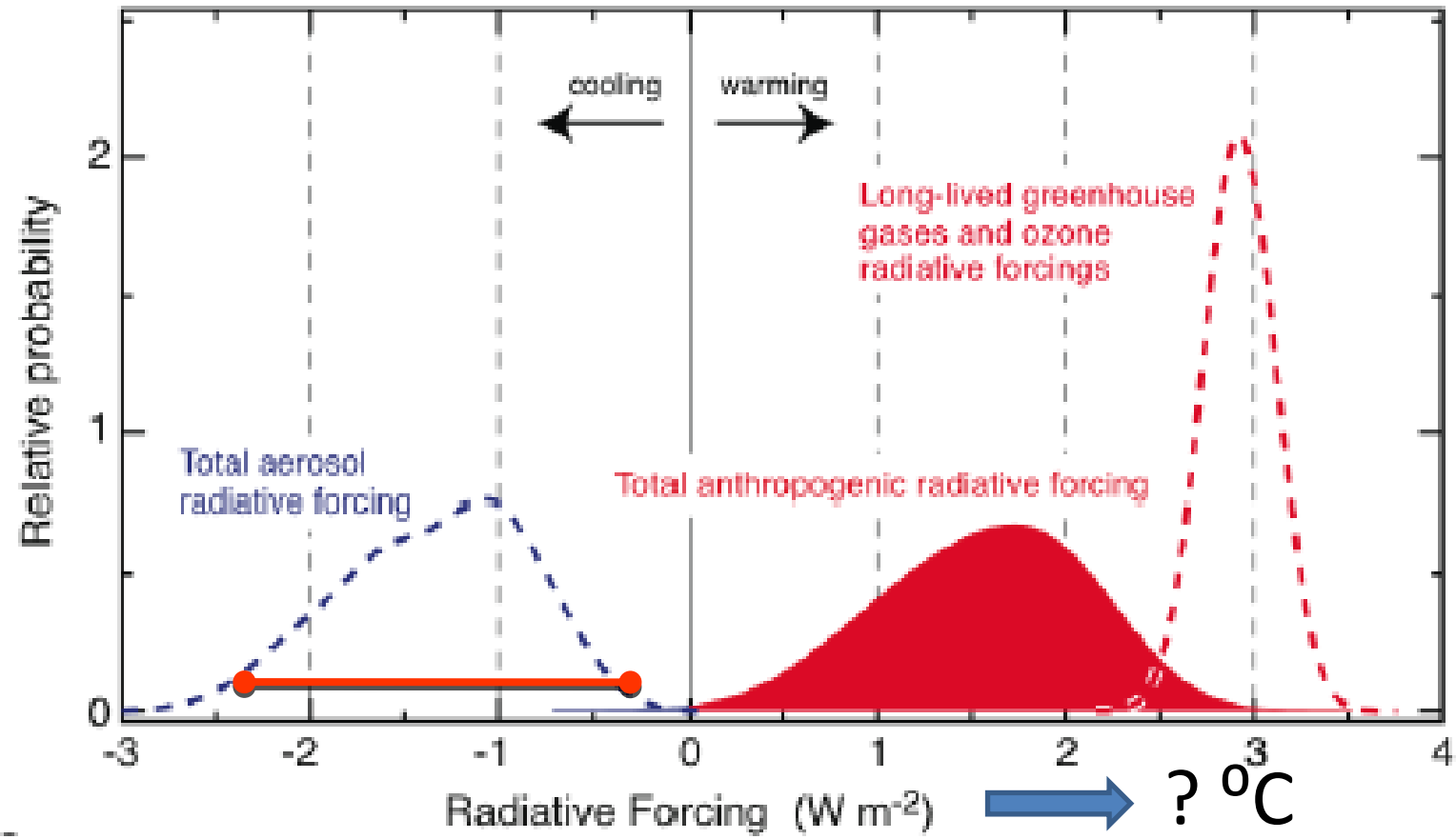
Radiative Forcing Components



Different processes adding to the indirect particle climate effect

Effects	Cloud type	Description	Forcing
First indirect aerosol effect (Twomey effect)	All clouds	The more numerous smaller cloud particles reflect more solar radiation	- 0.5 to - 1.9
Second indirect aerosol effect (Albrecht affect)	All clouds	Smaller cloud particles decrease the precipitation efficiency, thereby prolonging cloud lifetime	- 0.3 to - 1
Semi-direct effect	All clouds	Absorption of solar radiation by soot may cause evaporation of cloud particles	+ 0.1 to - 0.5
Glaciation indirect effect	Mixed ice and liquid water clouds	More ice nuclei increase the precipitation efficiency	0.2 to 1
Thermodynamic effect	Mixed ice and liquid water clouds	Smaller cloud droplets delay the onset of freezing	Uncertain
Riming indirect effect	Mixed ice and liquid water clouds	Smaller cloud droplets decrease the riming efficiency	Uncertain

Greenhouse gases + particles =



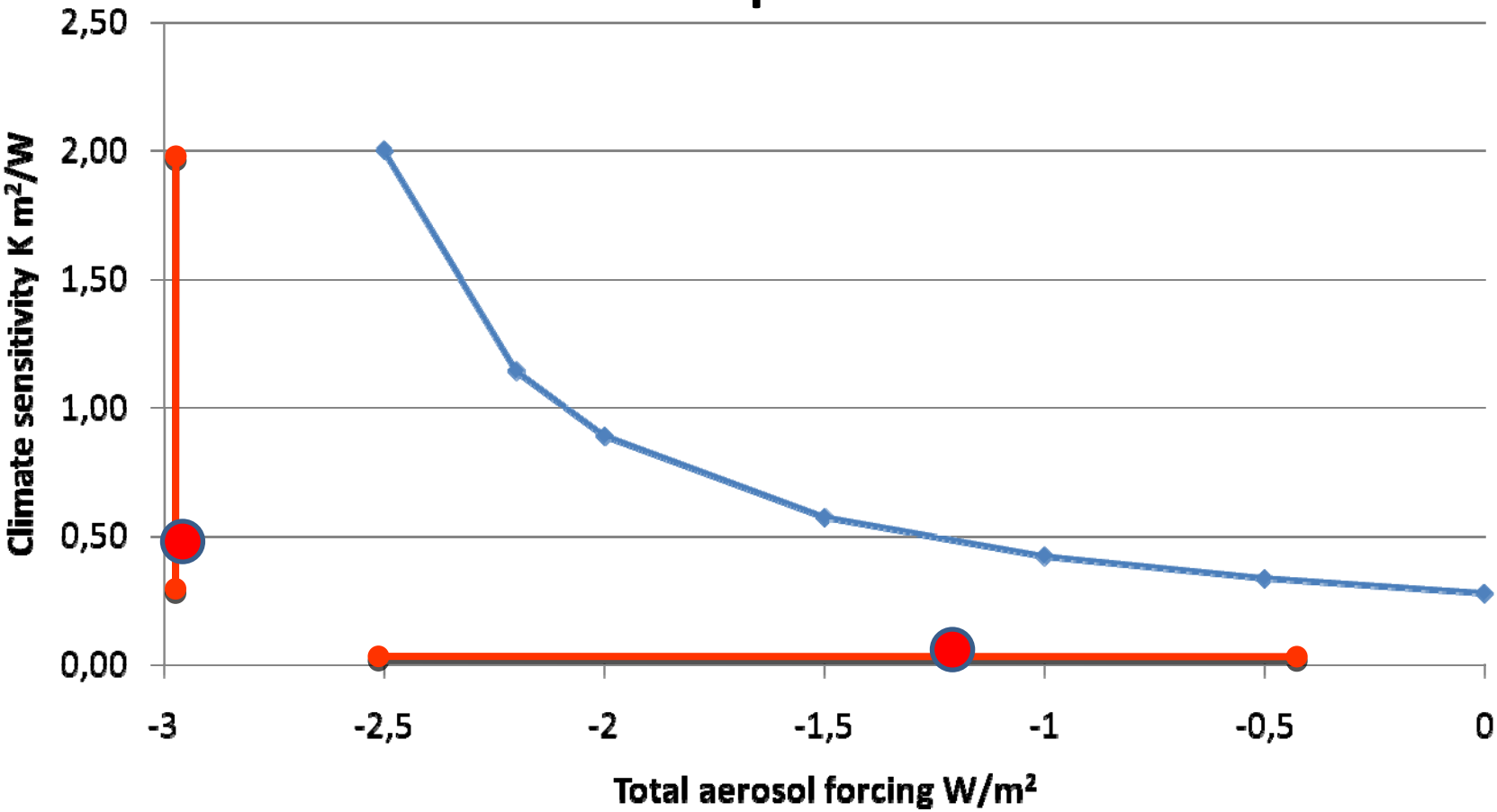
IPCC, chapt. 2, 2007

The influence of aerosol forcing at the projected temperature at $2xCO_2$

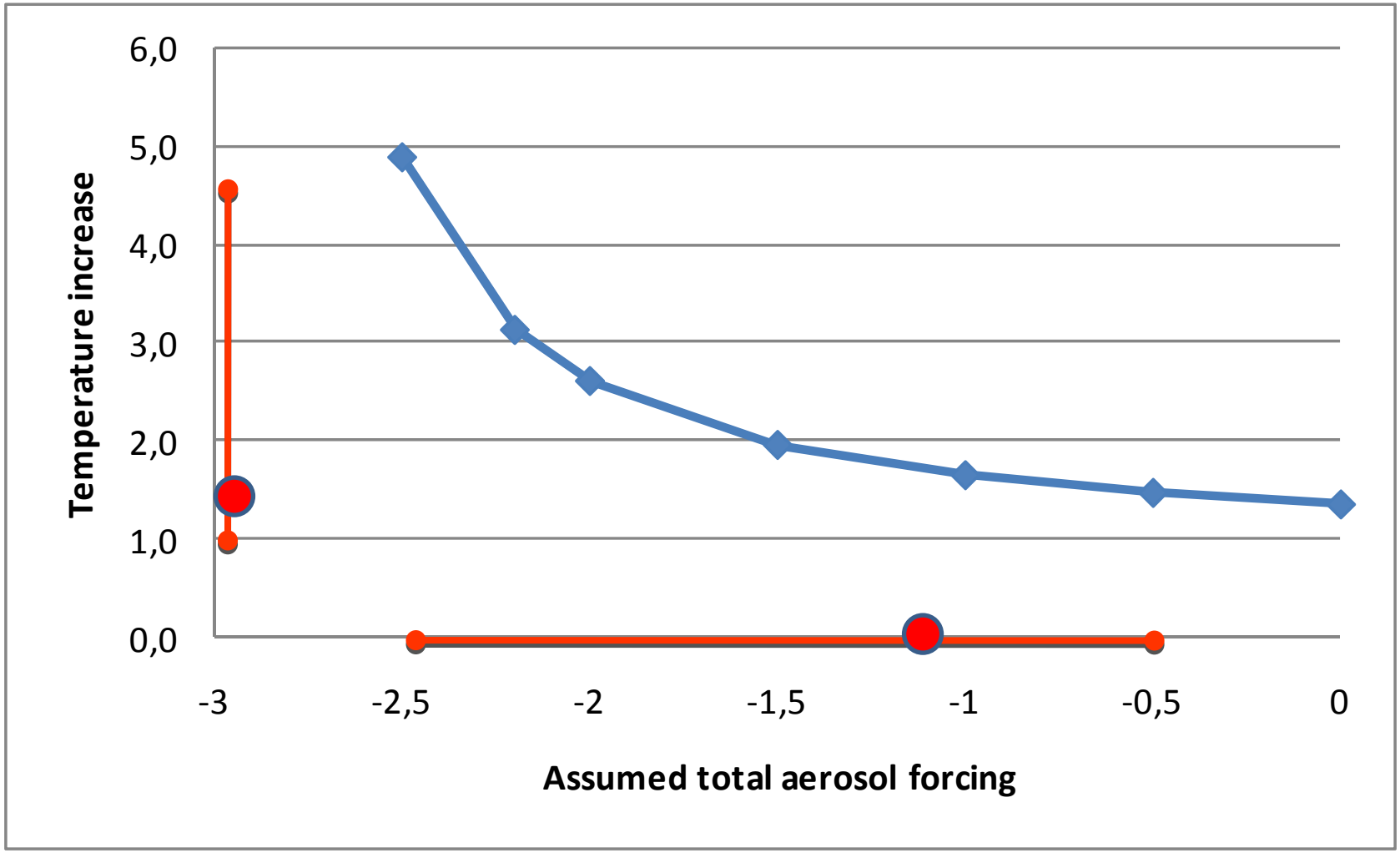
based on IPCC estimates

Present forcing						Projected forcing at double CO_2			
Aerosol	Gases	Total	Deltatemp	Climate sensitivity		Aerosol	Gases	Totalt	Temp increase
(W/m^2)	(W/m^2)	(W/m^2)	(^oC)	($^oC\ m^2/W$)		(W/m^2)	(W/m^2)	(W/m^2)	(arb unit)
-0,5	2,9	2,4	0,8	0,33		-0,5	4,9	4,4	1,5
-2,5	2,9	0,4	0,8	2,0		-2,5	4,4	2,4	4,9

Present total aerosol forcing determine future climate development



Temperature increase at double CO_2 concentration



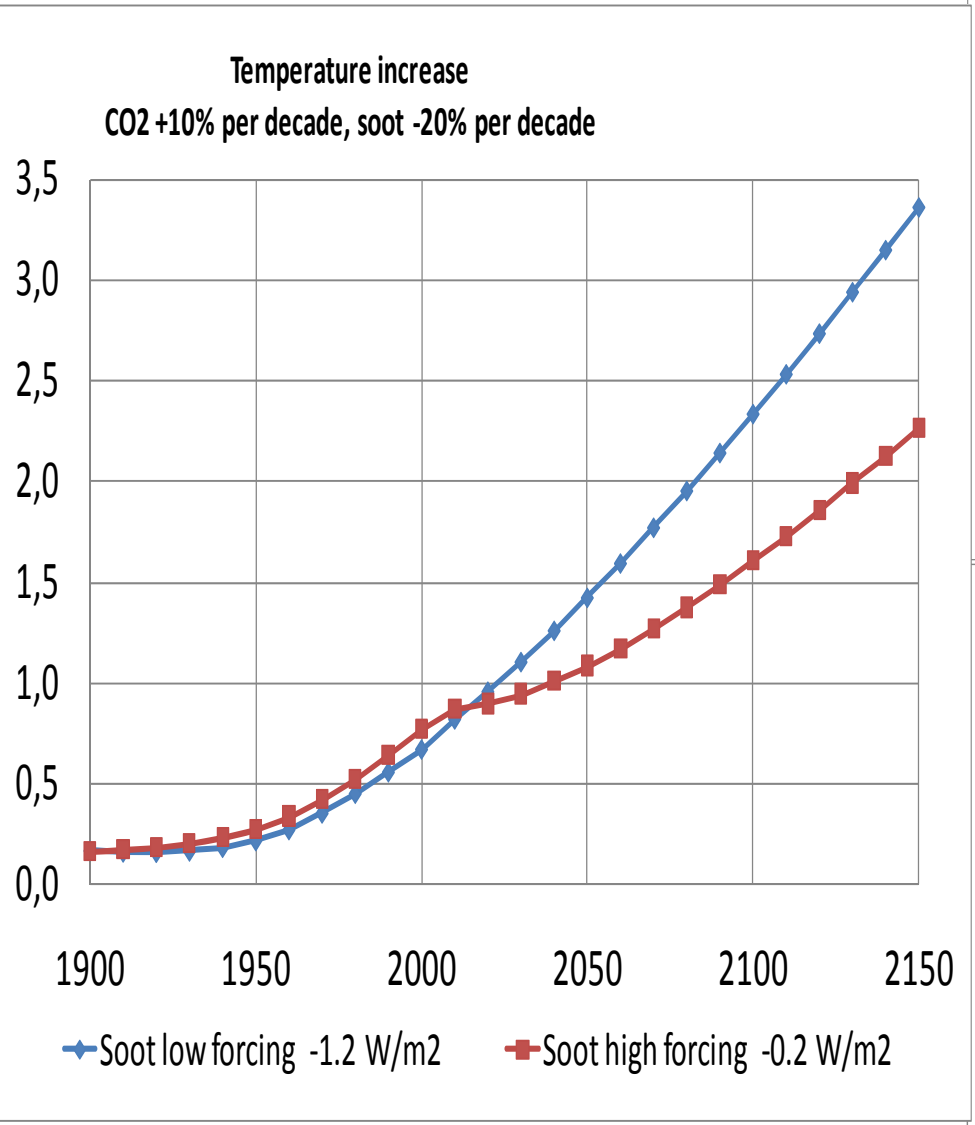
Is it possible to find any robust recommendations in spit of uncertainties?

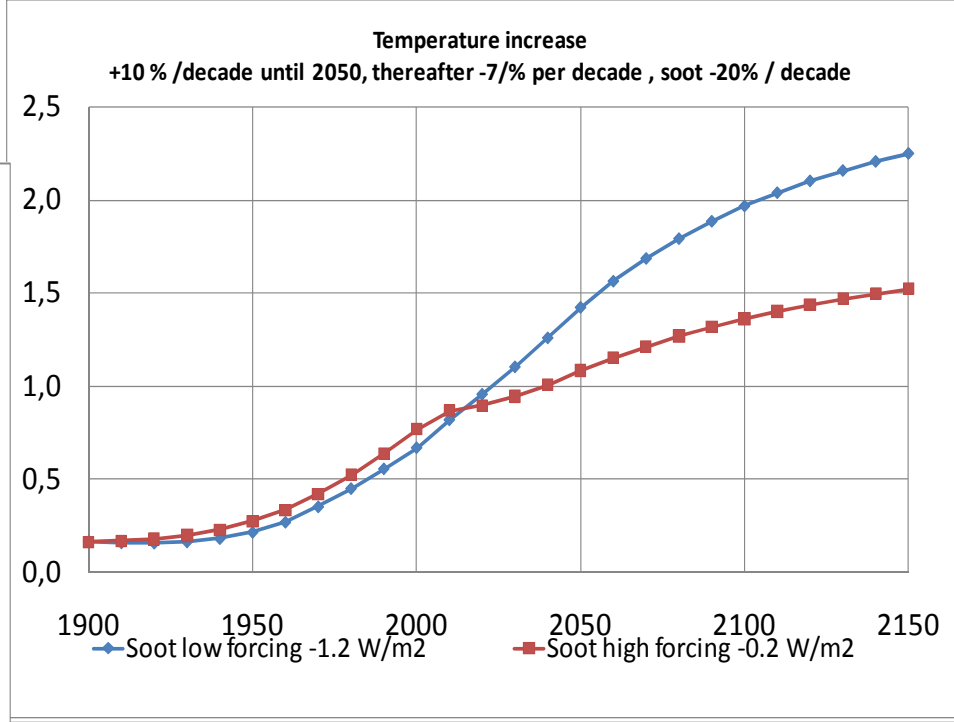
- Assume CO_2 forcing proportional to 5.35*ln (C/C_o) and other forcing to the anthropogenic concentration respectively.
- Historic concentrations of soot, particles and ozone not well known, thus only estimated for illustration.
- One component at a time with min and max while others at mean estimate of forcing.

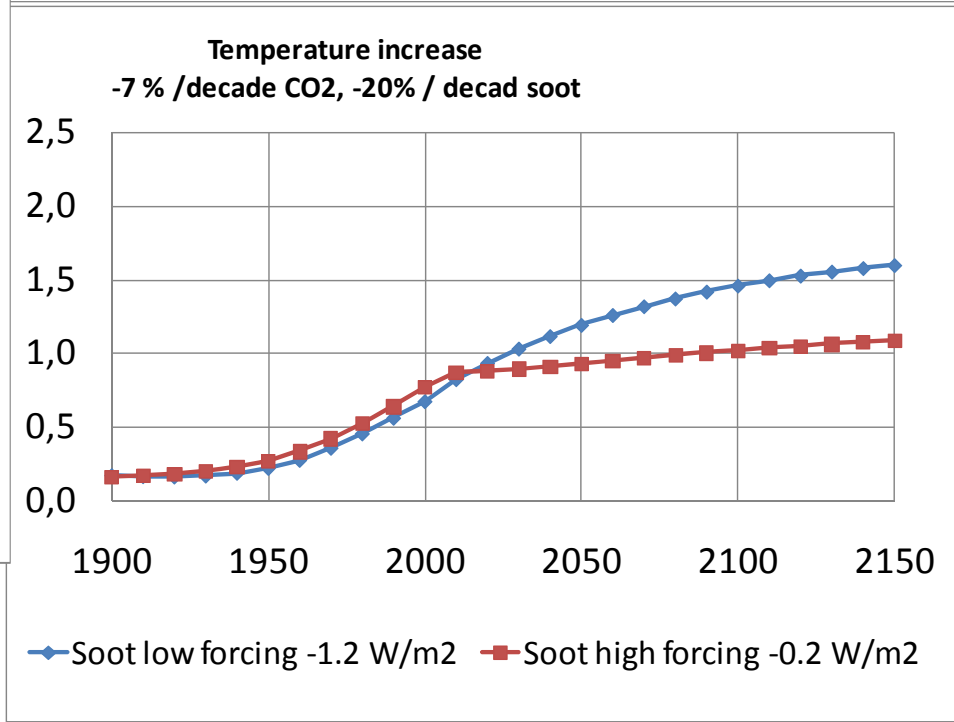
How does different estimates of present soot warming change the picture?

- Assume a low and a high soot forcing scenario
- Assume mean forcing as given by IPCC except for soot

Forcing (W/m2)		Low	High			Aerosol forcing	Climate sensitivity
Present	CO2	1,66	1,66		Low	-1,2	0,48
	soot	0,2	1,2		High	-0,2	0,32
	ozone	0,35	0,35				
	direct	-0,7	-0,7				
	indirect	-0,7	-0,7				


Temperature increase
CO2 +10% per decade, soot -20% per decade
3,5
3,0
2,5
2,0
1,5
1,0
0,5
0,0
1900
1950
2000
2050
2100
2150
Soot low forcing -1.2 W/m2
Soot high forcing -0.2 W/m2


Temperature increase
+10 % /decade until 2050, thereafter -7/% per decade , soot -20% / decade
2,5
2,0
1,5
1,0
0,5
0,0
1900
1950
2000
2050
2100
2150
Soot low forcing -1.2 W/m2
Soot high forcing -0.2 W/m2


Temperature increase
-7 % /decade CO2, -20% / decad soot
2,5
2,0
1,5
1,0
0,5
0,0
1900
1950
2000
2050
2100
2150
Soot low forcing -1.2 W/m2
Soot high forcing -0.2 W/m2

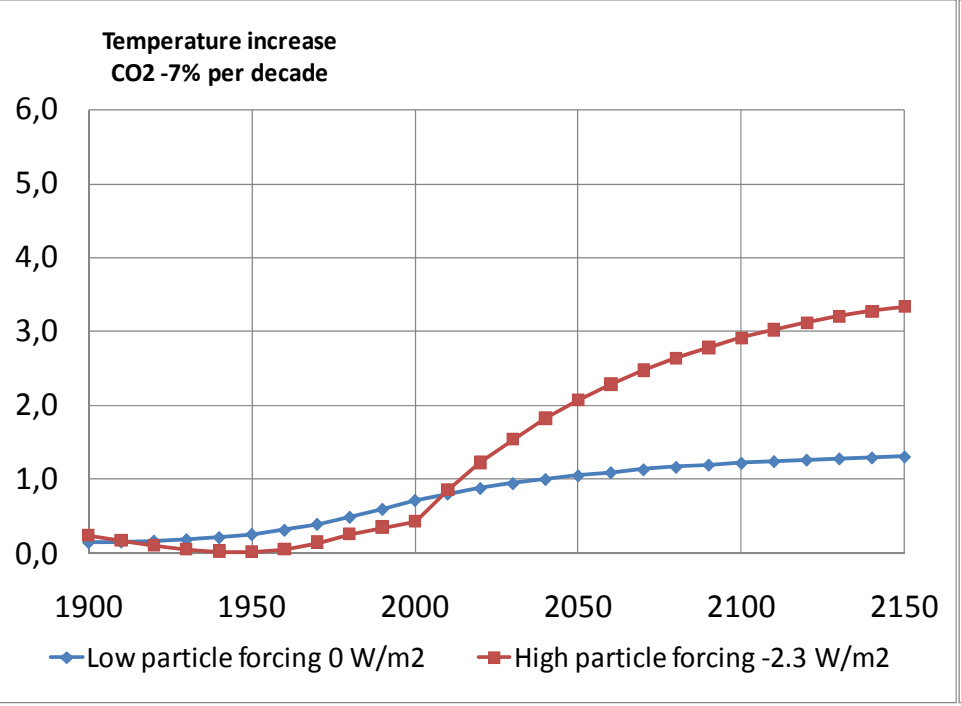
Conclusion concerning soot

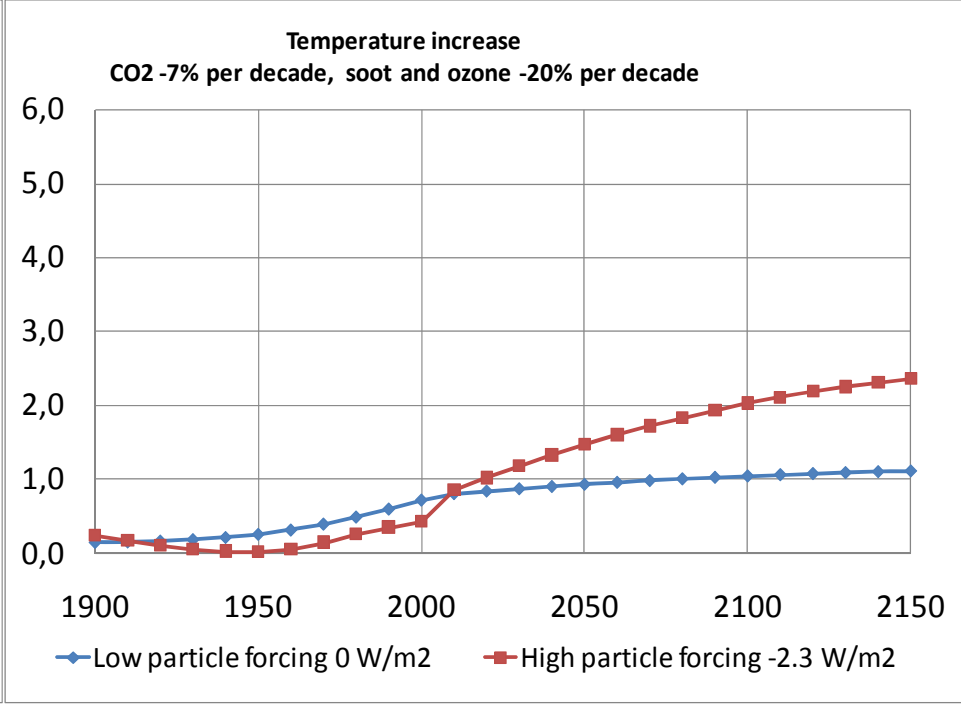
- Delay in CO2 abatement will give higher CO2 concentrations so NO time is gained if high soot warming at present.
- A high present climate forcing of soot implies a low climate sensitivity.
- Abatement of soot will lower the temperature increase at $2xCO_2$ proportional to soot forcing /total forcing
- Abatement of soot will imply indirectly abatement of particulate organic carbon which is cooling the atmosphere. Net effect probably << assumed soot forcing.

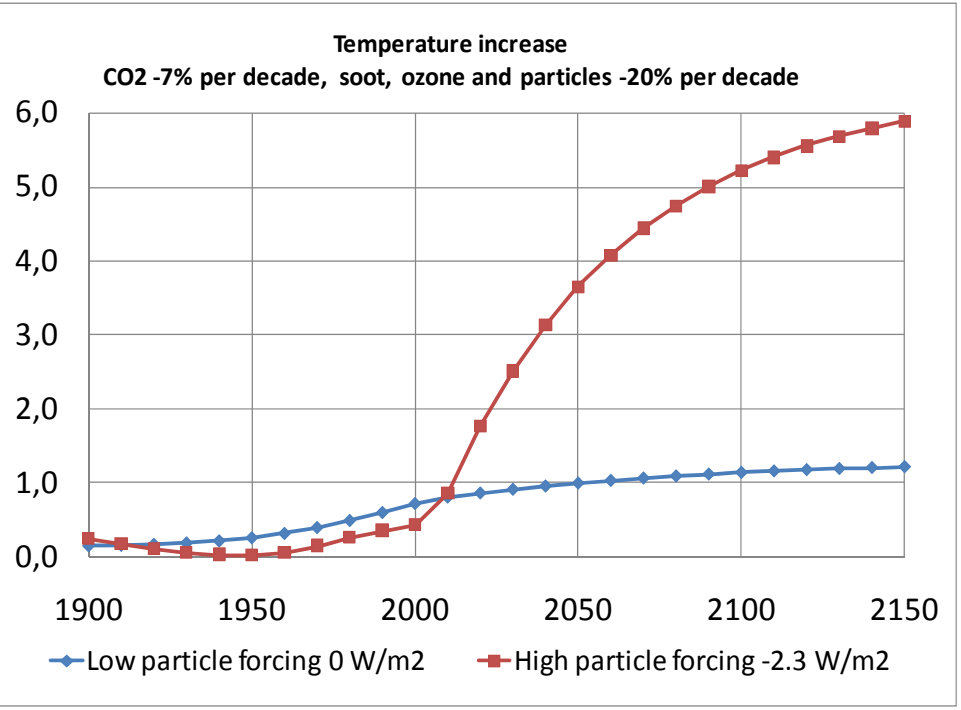
How does different estimates of present particle cooling change the picture?

- Assume a low and a high particle forcing scenario
- Assume mean forcing as given by IPCC except for particles

Forcing		Low	High			Aerosol forcing	Climate sensitivity
Present	CO2	1,66	1,66		Low	0	0,28
	soot	0,4	0,4		High	-2,3	1,36
	ozone	0,35	0,35				
	direct	-0,1	-0,9				
	incirect	-0,3	-1,8				


Temperature increase
CO2 -7% per decade
6,0
5,0
4,0
3,0
2,0
1,0
0,0
1900
1950
2000
2050
2100
2150
Low particle forcing 0 W/m2
High particle forcing -2.3 W/m2


Temperature increase
CO2 -7% per decade, soot and ozone -20% per decade
6,0
5,0
4,0
3,0
2,0
1,0
0,0
1900
1950
2000
2050
2100
2150
Low particle forcing 0 W/m2
High particle forcing -2.3 W/m2


Temperature increase
CO2 -7% per decade, soot, ozone and particles -20% per decade
6,0
5,0
4,0
3,0
2,0
1,0
0,0
1900
1950
2000
2050
2100
2150
Low particle forcing 0 W/m2
High particle forcing -2.3 W/m2

Conclusions for the particle effect

- High present particle climate forcing implies very high climate sensitivity giving very high temperature increase at $2xCO_2$.
- Total abatement of soot and ozone in this scenario will reduce this while abatement of particles will increase the temperature increase.
- This is a direct reflection on the assumed relation between the magnitude of the climate forcing for soot, ozone and particle, respectively.
- It is crucial to determine the total aerosol effect to get a better estimate of the climate sensitivity and thus a better estimate of the temperature at $2xC0_2$

Suggestion for policy recommendations

- Start CO_2 abatement now!
- Air quality abatement should include particles, soot, ozone and methane and be climate neutral using a balanced abatement strategy on a regional scale.
- Climate and air quality abatement should focus on combustion as the main source of anthropogenic CO_2, particles, soot and ozone
- Determine climate sensitivity, i.e. the total climate forcing of aerosols to establish target CO_2 concentration