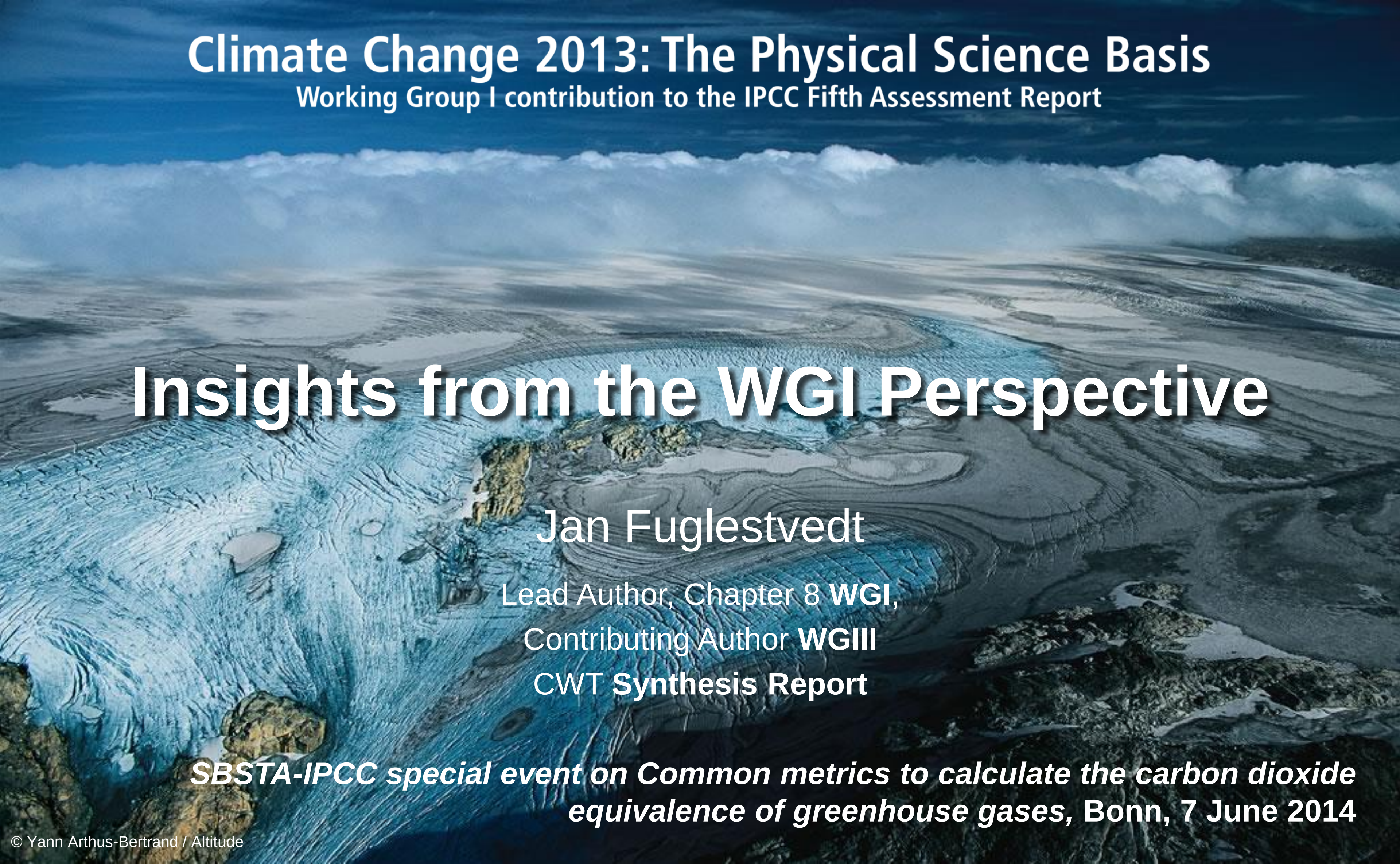


Climate Change 2013: The Physical Science Basis

Working Group I contribution to the IPCC Fifth Assessment Report

Insights from the WGI Perspective

Jan Fuglestvedt

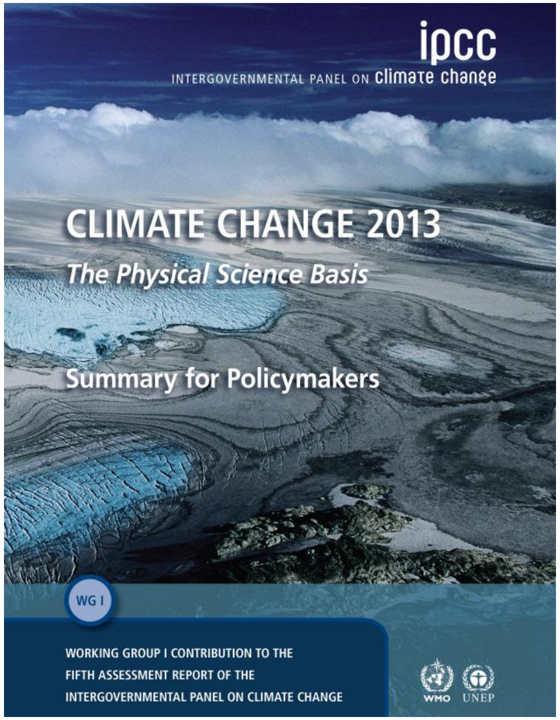
Lead Author, Chapter 8 **WGI**,

Contributing Author **WGIII**

CWT **Synthesis Report**

***SBSTA-IPCC special event on Common metrics to calculate the carbon dioxide equivalence of greenhouse gases,* Bonn, 7 June 2014**

From **Summary for Policymakers**



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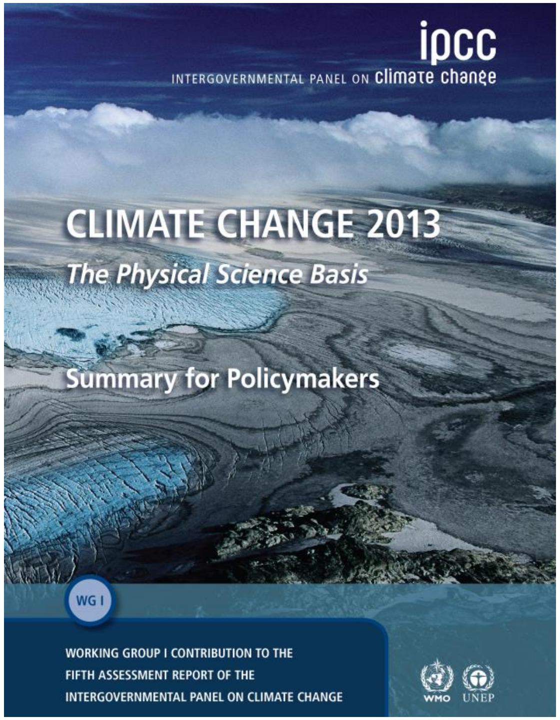

The most appropriate metric and time horizon will depend on which aspects of climate change are considered most important to a particular application.

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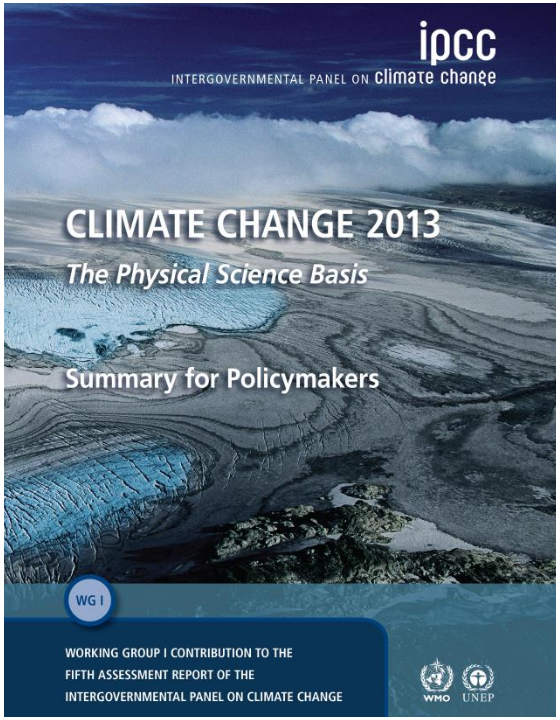

The most appropriate metric and time horizon will depend on which aspects of climate change are considered most important to a particular application.

No single metric can accurately compare all consequences of different emissions, and all have limitations and uncertainties.

Key Messages on metrics:

Metrics do not define policies or goals

…. but facilitate evaluation and implementation of multi-gas policies to meet particular goals

All choices of metric contain implicit value-related judgements

The Global Warming Potential (GWP) and Global Temperature change Potential (GTP) have limitations, and there are inconsistencies related to indirect effects and feedbacks

GWP is not directly related to a temperature limit (e.g., 2°C target)

No single metric for all applications

Many applications:

- Climate agreements
- Emission trading
- Climate policy assessments
- Trade-offs in policy making
- Design and operation (e.g. aircraft)
- Information about **properties** of components and **uncertainties**
- Scientific studies

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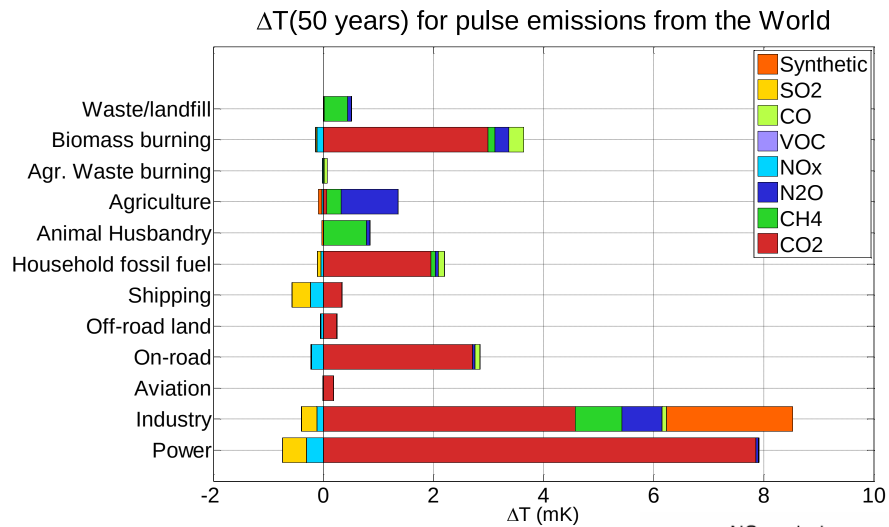
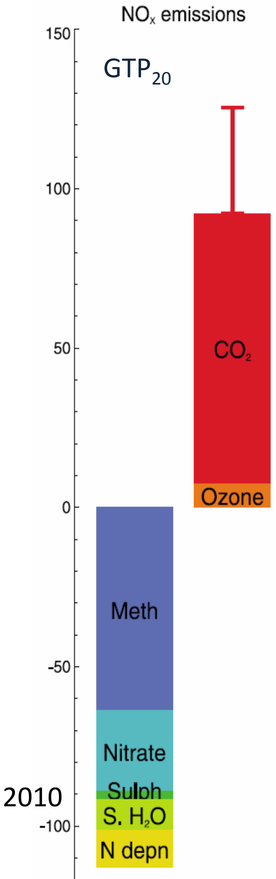
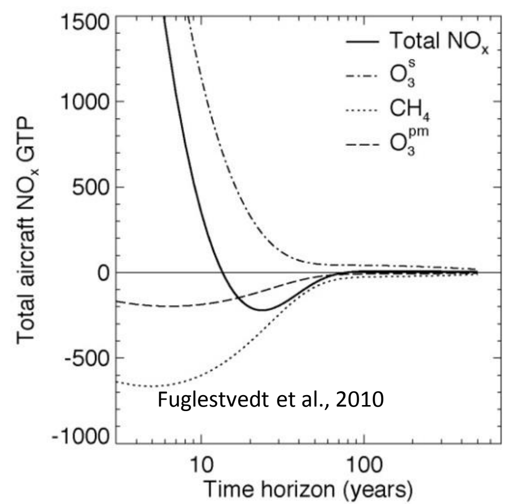
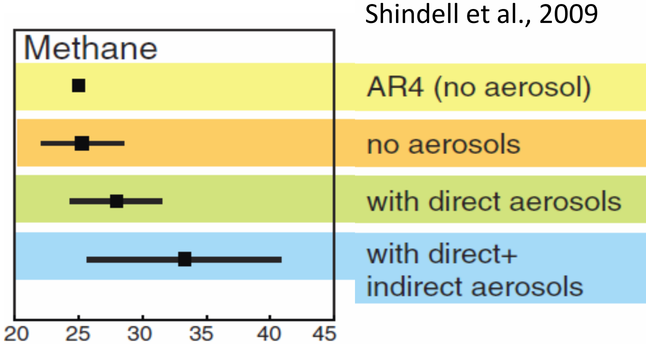




Collins et al., 2010



Shindell et al., 2009



What is new since AR4?

No recommendation for metric choice is given in AR5

Uncertainties emphasized and better quantified

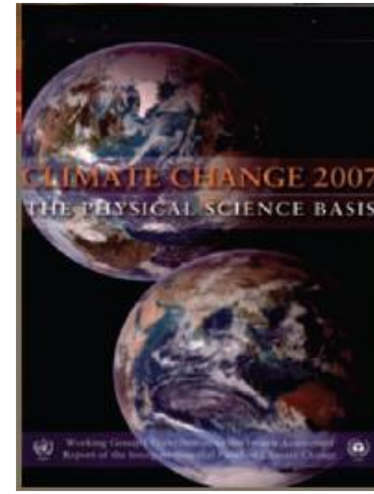
Point to inconsistent treatment of **indirect effects / feedbacks**

Point to implicit **value-based judgments**

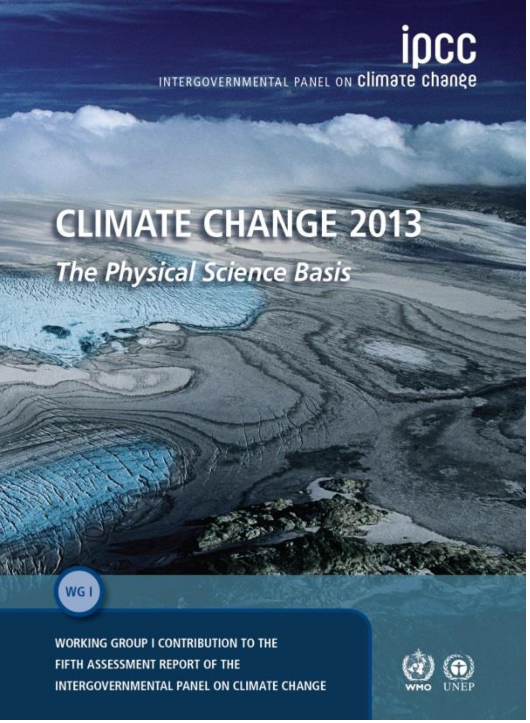
Assessed **alternatives** to GWP

Updated values of both GWP and GTP for > 200 compounds

Statement on GWP in IPCC AR4

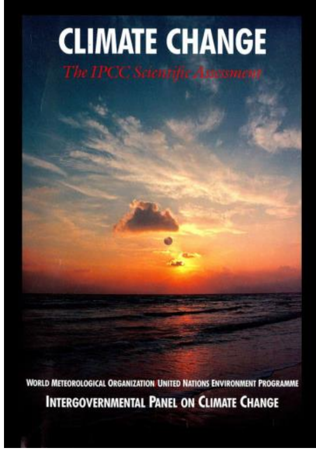


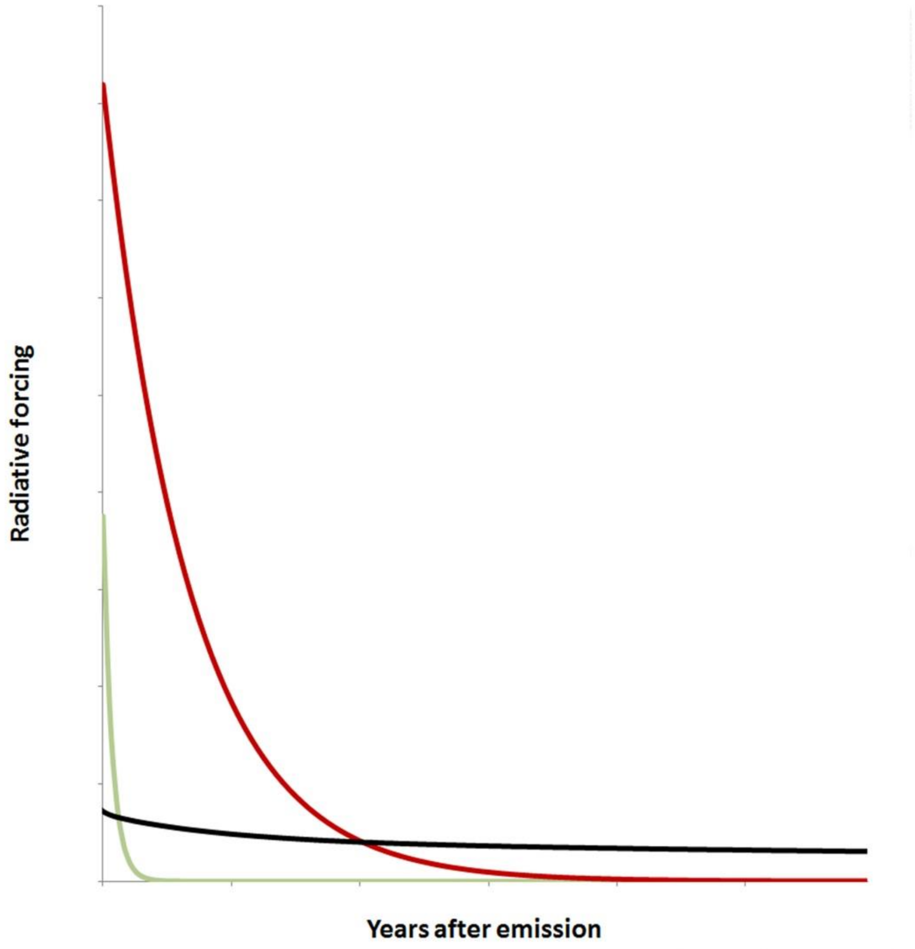
Although it has several known shortcomings, a multi-gas strategy using GWPs is very likely to have advantages over a CO_2-only strategy (O'Neill, 2003). Thus, GWPs remain the recommended metric to compare future climate impacts of emissions of long-lived climate gases.



… provides an assessment that focuses on the scientific aspects and utility of emission metrics. Extending such an assessment to include more policy-oriented aspects of their performance and usage such as simplicity, transparency, continuity, economic implications of usage of one metric over another, etc., is not given here as this is beyond the scope of WGI. However, consideration of such aspects is vital for user assessments.

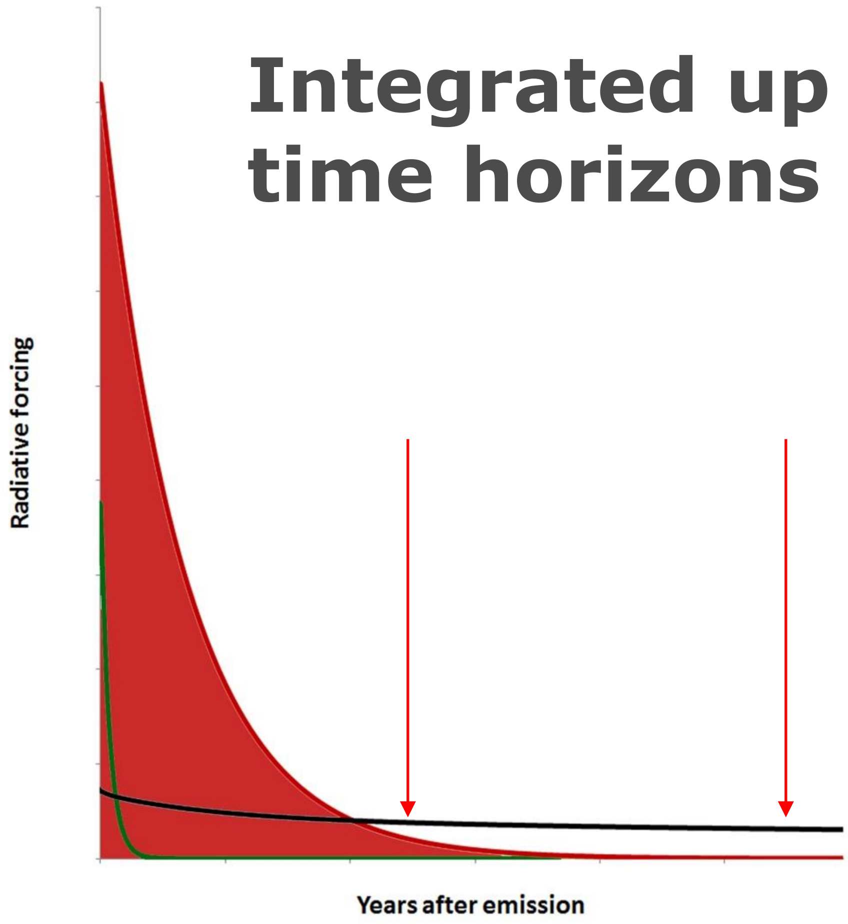
GWP: Based on pulses of different gases

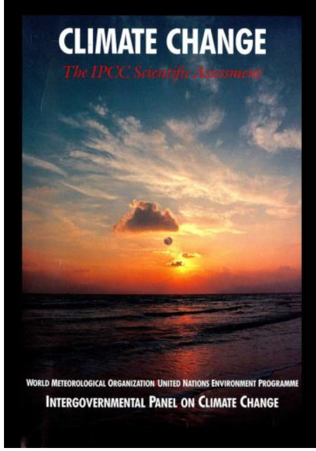




GWP: Based on pulses of different gases

Integrated up to chosen time horizons (H)





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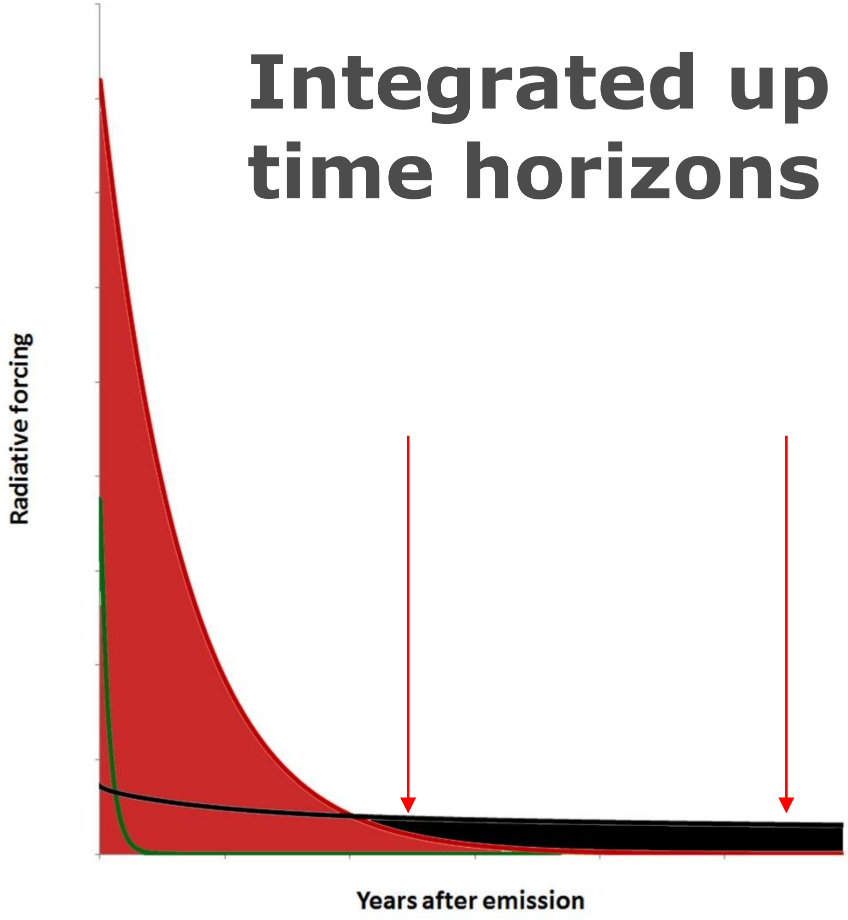

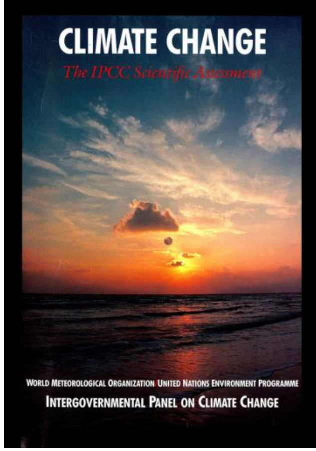

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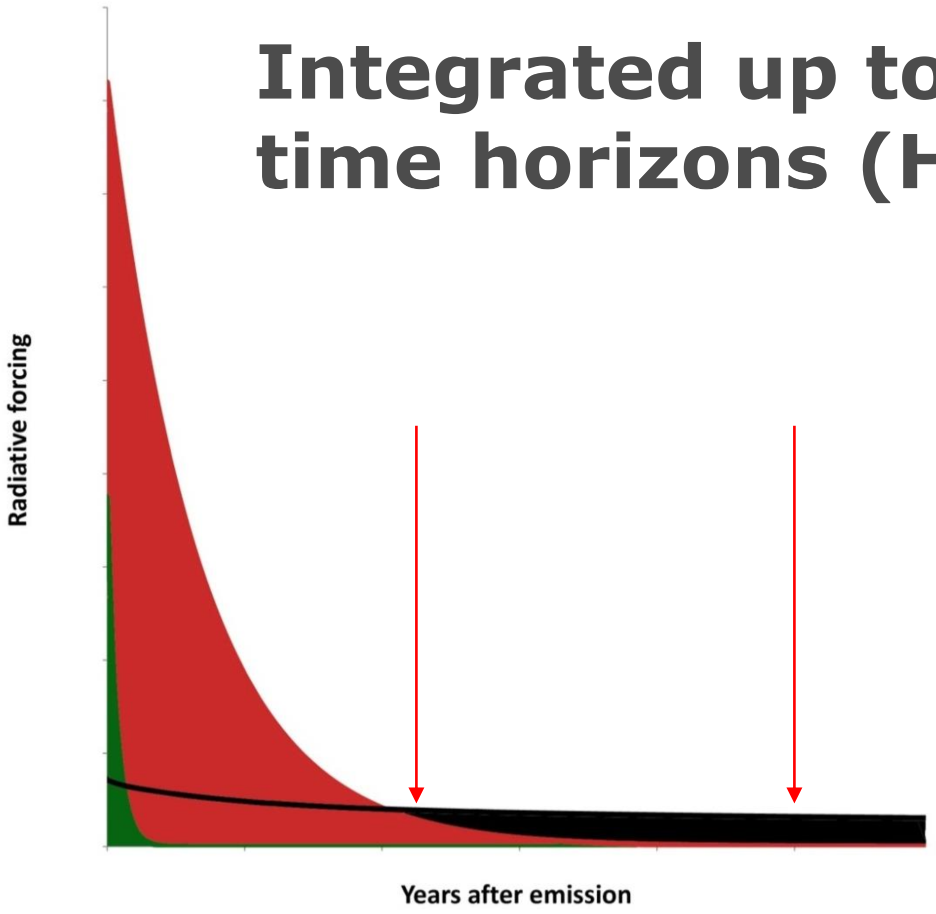

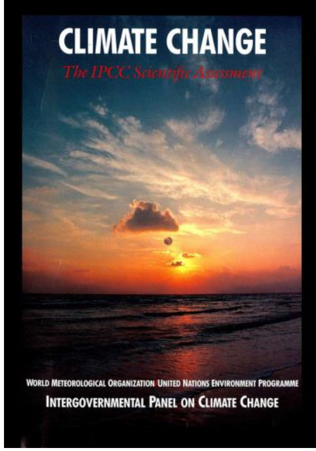

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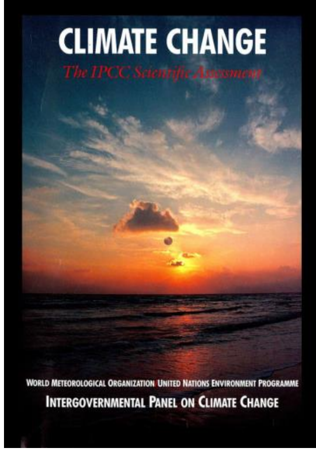

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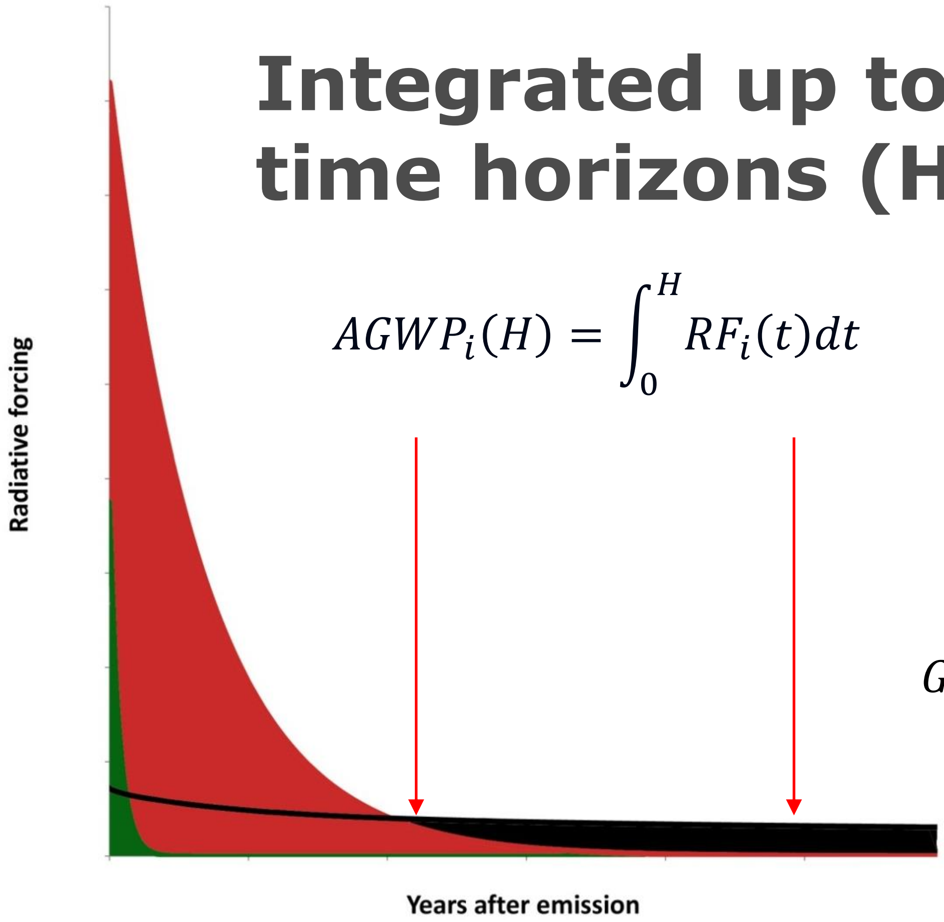


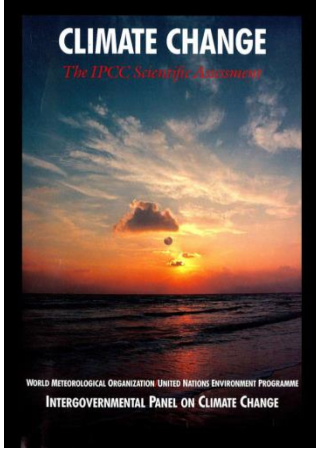
$$AGWP_i(H) = \int_0^H RF_i(t)dt$$

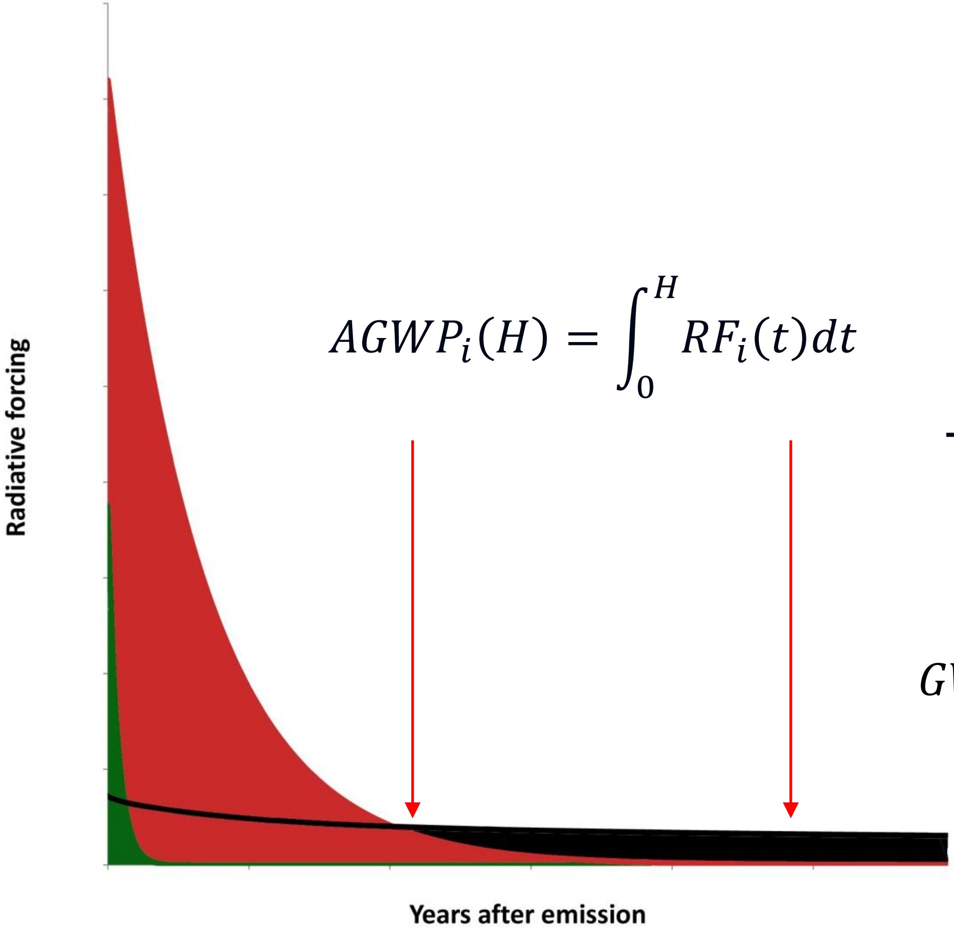
Then normalized to AGWP for CO_2:

$$GWPi(H) = \frac{AGWP_i(H)}{AGWP_{CO_2}(H)} = \frac{\int_0^H RF_i(t)dt}{\int_0^H RF_{CO_2}(t)dt}$$

GWP has a strong and «artificial» memory.

Often misunderstood; no climate response included.





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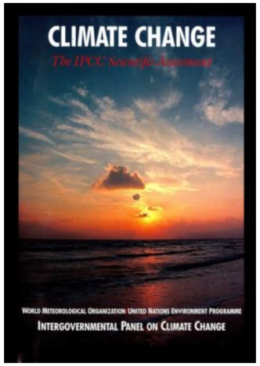
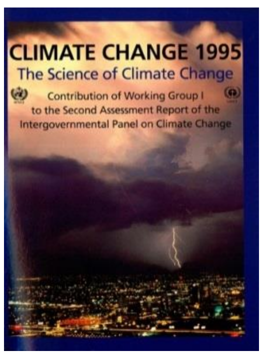


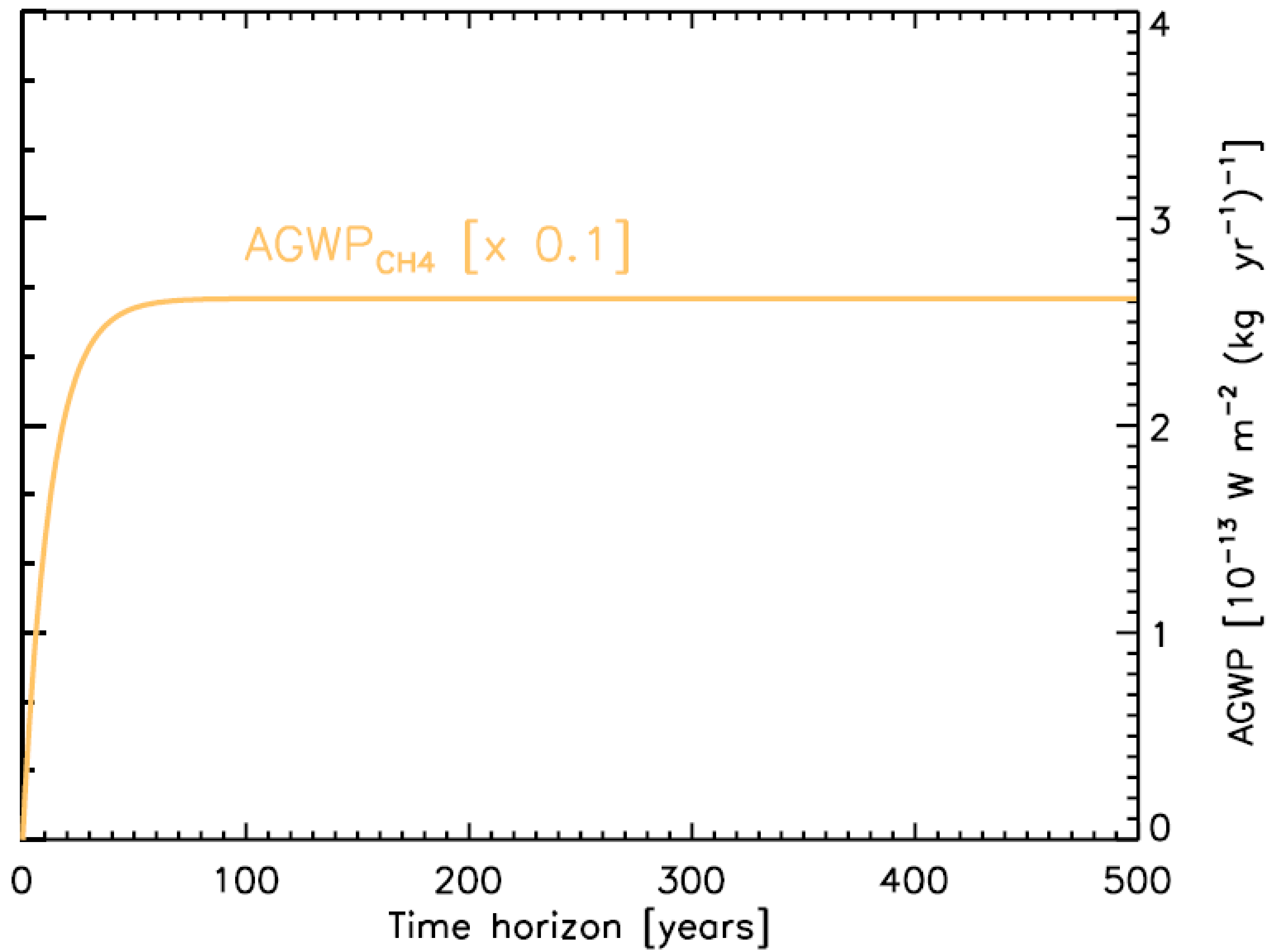
Time horizon

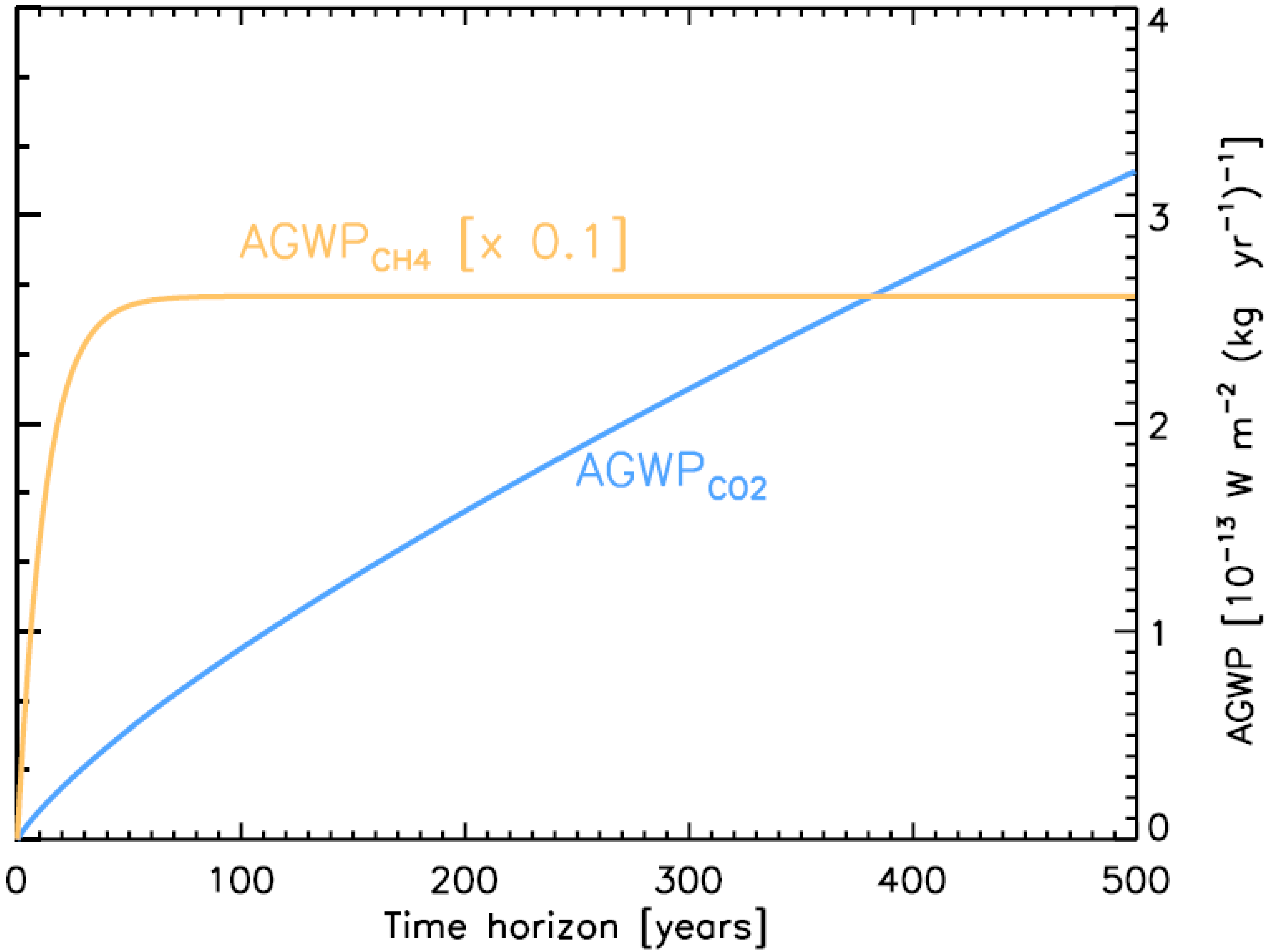
IPCC 1990 presented three time-horizons (20, 100 and 500 yr)



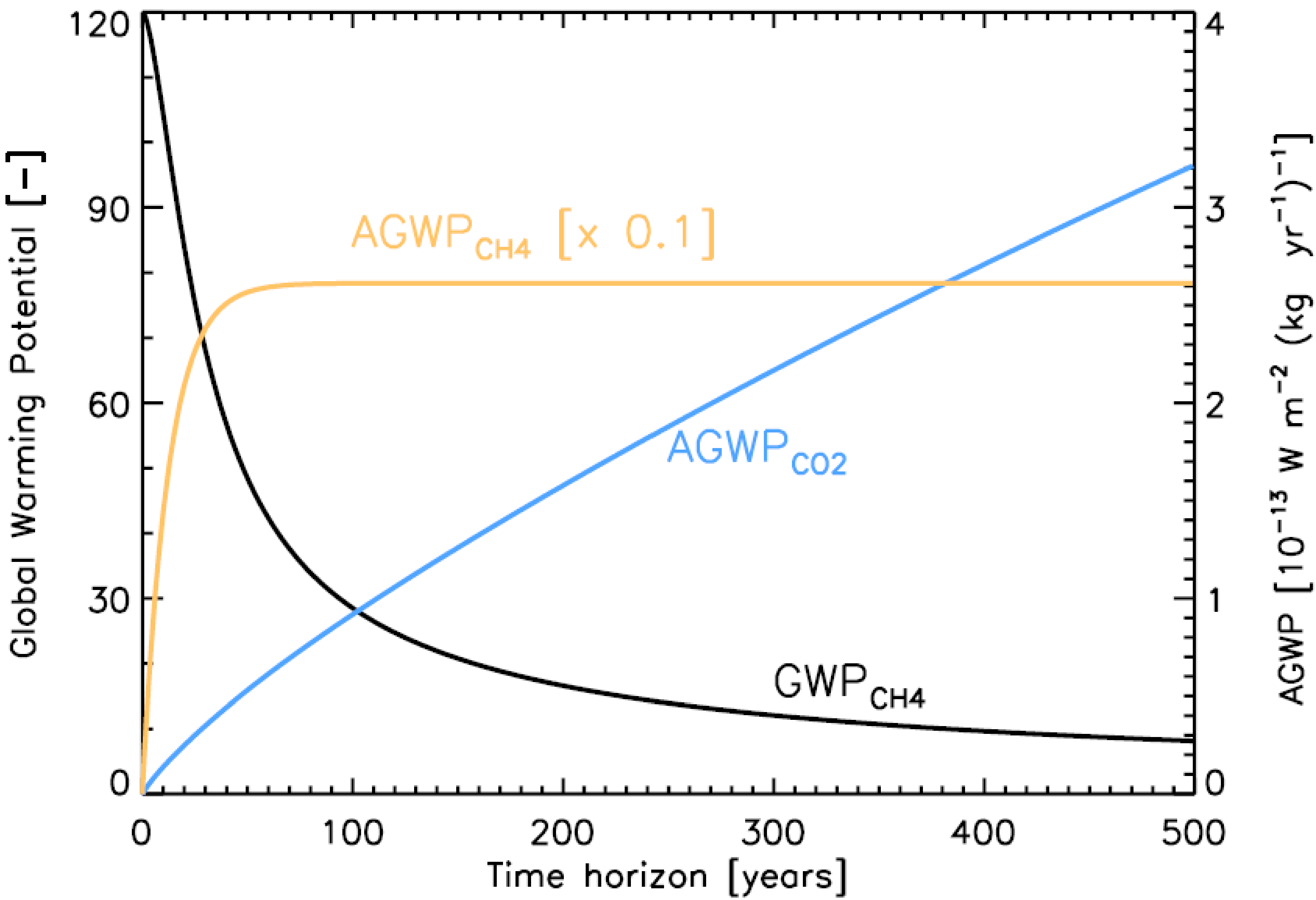
Kyoto Protocol: 100 years

SAR	GWP_{20}	**GWP_{100}**	GWP_{500}
CH_4	56	**21**	6.5


AGWP$_{CH4}$ [x 0.1]
0
100
200
300
400
500
Time horizon [years]
0
1
2
3
4
AGWP [10^{-13} W m^{-2} (kg yr^{-1})$^{-1}$]

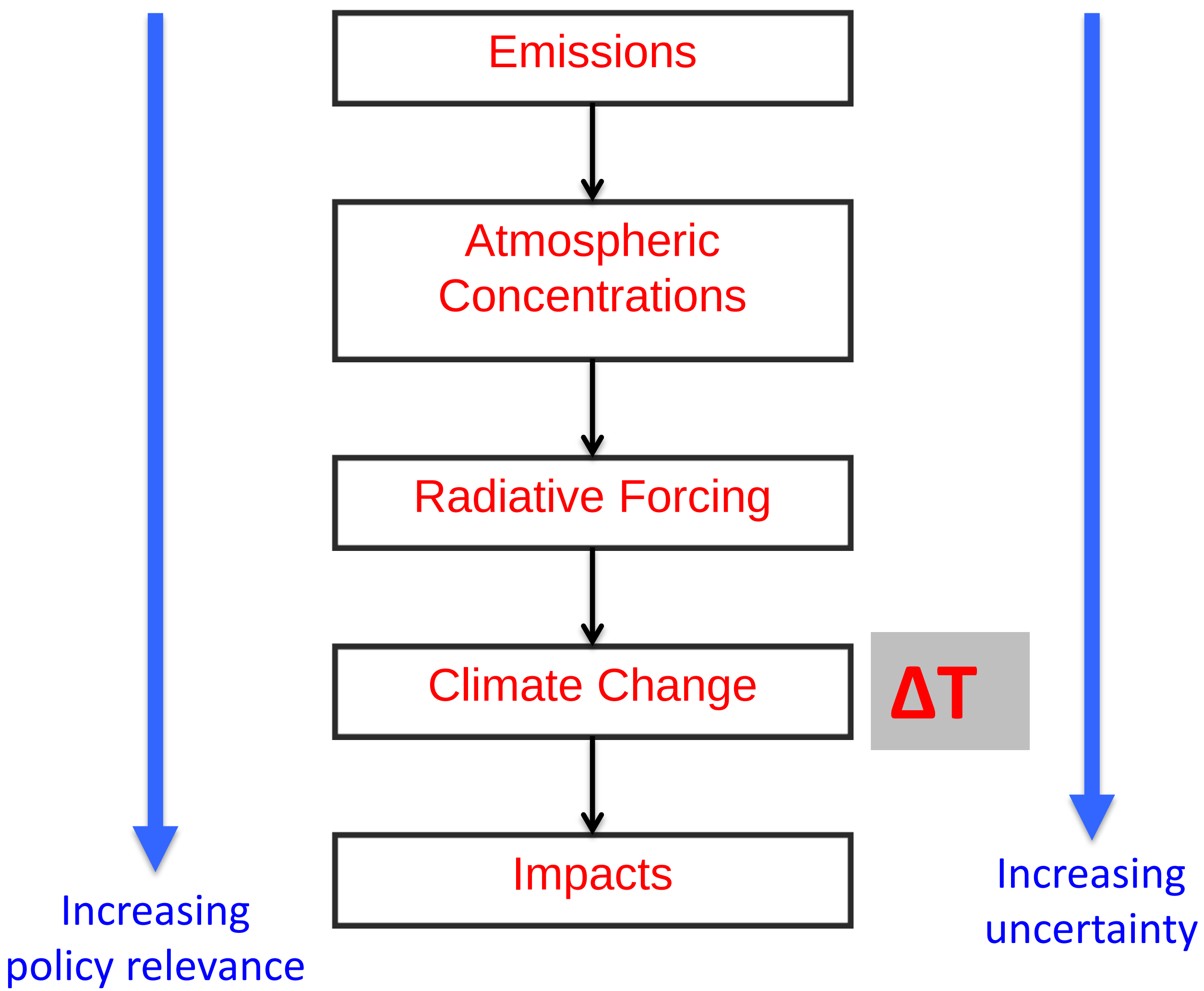


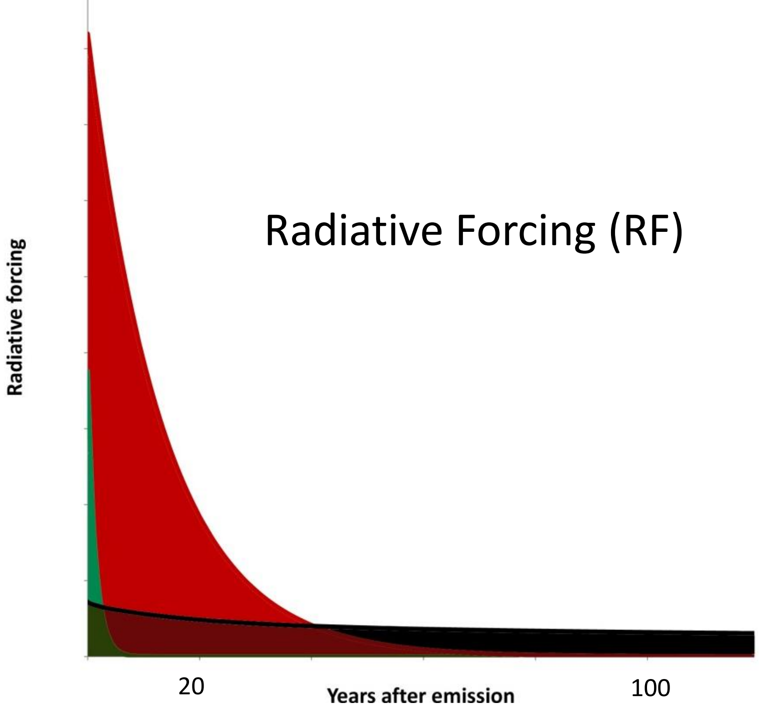
AGWP$_{CH4}$ [x 0.1]
AGWP$_{CO2}$
0
100
200
300
400
500
Time horizon [years]
0
1
2
3
4
AGWP [10^{-13} W m^{-2} (kg yr^{-1})$^{-1}$]



Global Warming Potential [-]
AGWP [10^-13 W m^-2 (kg yr^-1)^-1]
AGWP CH4 [x 0.1]
AGWP CO2
GWP CH4
Time horizon [years]
0
30
60
90
120
0
100
200
300
400
500
0
1
2
3
4

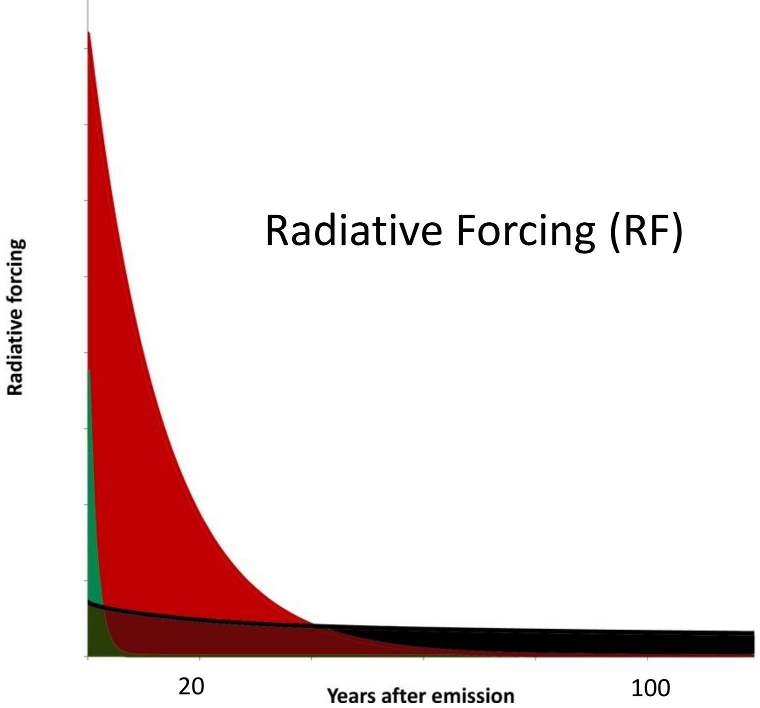
Choice of climate impact





$$GWP_i(H) = \frac{\int_0^H RF_i(t)dt}{\int_0^H RF_{CO_2}(t)dt} = \frac{AGWP_i(H)}{AGWP_{CO_2}(H)}$$

➔ strong memory
(often misunderstood; no
climate response included)



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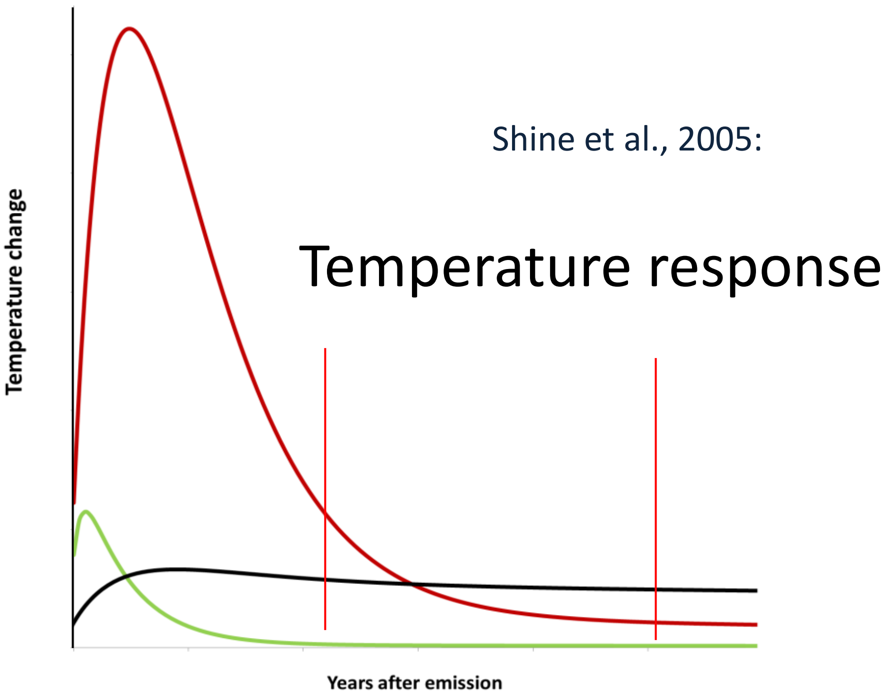
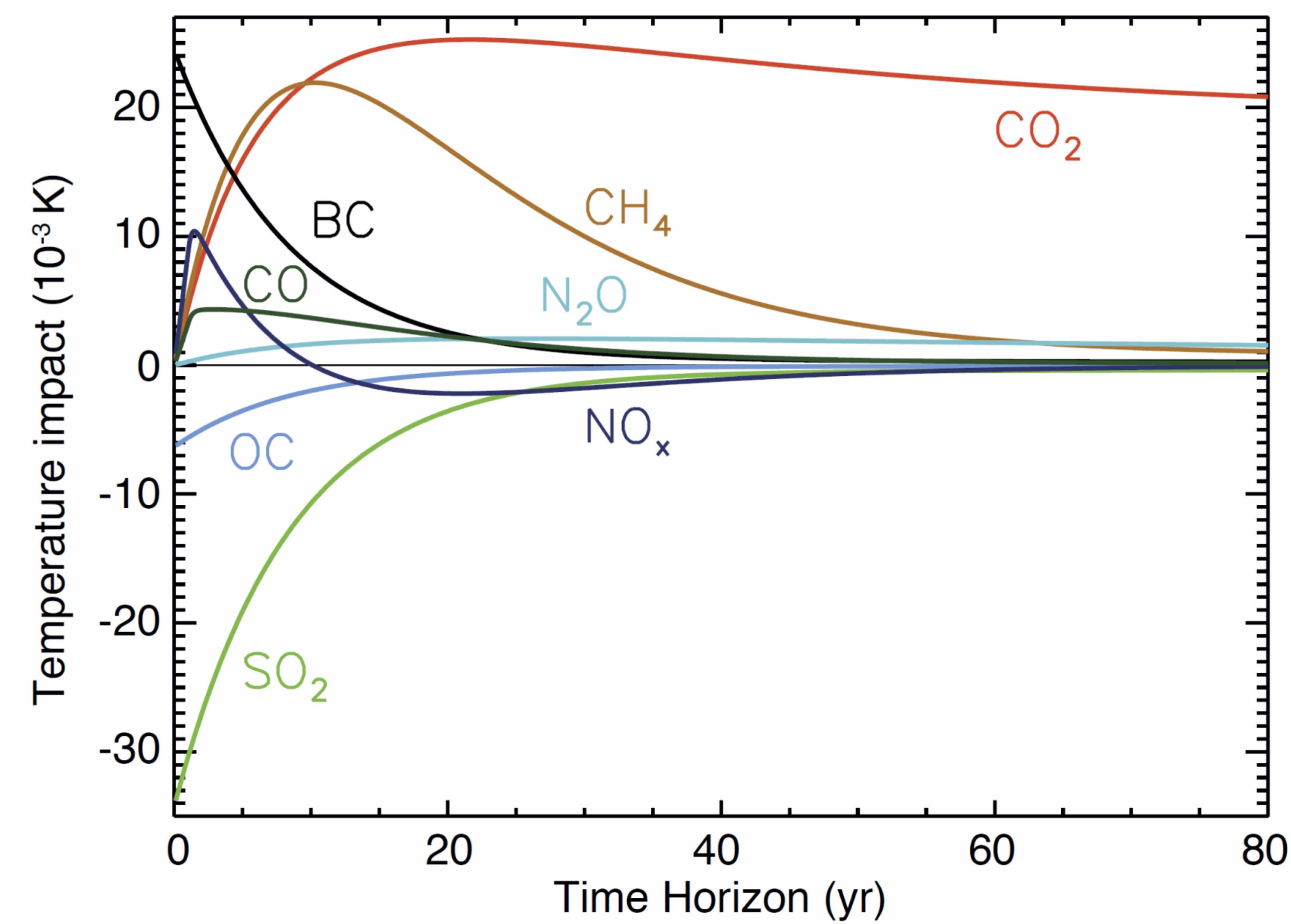


$$GTP_i(t) = \frac{AGTP(t)_i}{AGTP(t)_{CO_2}} = \frac{\Delta T(t)_i}{\Delta T(t)_{CO_2}}$$

Large differences between GTP and GWP for short-lived components

Application of (A)GTP – an example

Temperature responses for total anthropogenic emissions for a one year emissions



Myhre et al., 2013, AR5

Metric table from AR5

> 200 gases

Acronym, Common Name or Chemical Name	Chemical Formula	Lifetime (Years)	Radiative Efficiency ($W m^{-2} ppb^{-1}$)	AGWP 20-year ($W m^{-2} yr kg^{-1}$)	**GWP 20-year**	AGWP 100-year ($W m^{-2} yr kg^{-1}$)	**GWP 100-year**	AGTP 20-year ($K kg^{-1}$)	**GTP 20-year**	AGTP 50-year ($K kg^{-1}$)	**GTP 50-year**	AGTP 100-year ($K kg^{-1}$)	**GTP 100-year**
Carbon dioxide	CO_2	see*	1.37e-5	2.49e-14	**1**	9.17e-14	**1**	6.84e-16	**1**	6.17e-16	**1**	5.47e-16	**1**
Methane	CH_4	12.4†	3.63e-4	2.09e-12	**84**	2.61e-12	**28**	4.62e-14	**67**	8.69e-15	**14**	2.34e-15	**4**
Fossil methane‡	CH_4	12.4†	3.63e-4	2.11e-12	**85**	2.73e-12	**30**	4.68e-14	**68**	9.55e-15	**15**	3.11e-15	**6**
Nitrous Oxide	N_2O	121†	3.00e-3	6.58e-12	**264**	2.43e-11	**265**	1.89e-13	**277**	1.74e-13	**282**	1.28e-13	**234**
Chlorofluorocarbons													
CFC-11	CCl_3F	45.0	0.26	1.72e-10	**6900**	4.28e-10	**4660**	4.71e-12	**6890**	3.01e-12	**4890**	1.28e-12	**2340**
CFC-12	CCl_2F_2	100.0	0.32	2.69e-10	**10,800**	9.39e-10	**10,200**	7.71e-12	**11,300**	6.75e-12	**11,000**	4.62e-12	**8450**
HCFC-123a	$CHClFCF_2Cl$	4.0	0.23	3.37e-11	**1350**	3.39e-11	**370**	4.51e-13	**659**	4.44e-14	**72**	2.81e-14	**51**
HCFC-124	$CHClFCF_3$	5.9	0.20	4.67e-11	**1870**	4.83e-11	**527**	7.63e-13	**1120**	7.46e-14	**121**	4.03e-14	**74**
HCFC-132c	CH_2FCFCl_2	4.3	0.17	3.07e-11	**1230**	3.10e-11	**338**	4.27e-13	**624**	4.14e-14	**67**	2.58e-14	**47**
HCFC-141b	CH_3CCl_2F	9.2	0.16	6.36e-11	**2550**	7.17e-11	**782**	1.27e-12	**1850**	1.67e-13	**271**	6.09e-14	**111**
HCFC-142b	CH_3CClF_2	17.2	0.19	1.25e-10	**5020**	1.82e-10	**1980**	3.01e-12	**4390**	8.46e-13	**1370**	1.95e-13	**356**

In previous reports: 20, 100 and 500 years.

Values for 500 years not presented in AR5
Long-term effects addressed in other ways

We also give AGWP and AGTP to separate out changes due to reference gas CO_2

Changes in GWP_{100} values since AR4

CH_4: 25 → **28**

N_2O: 298 →**265**

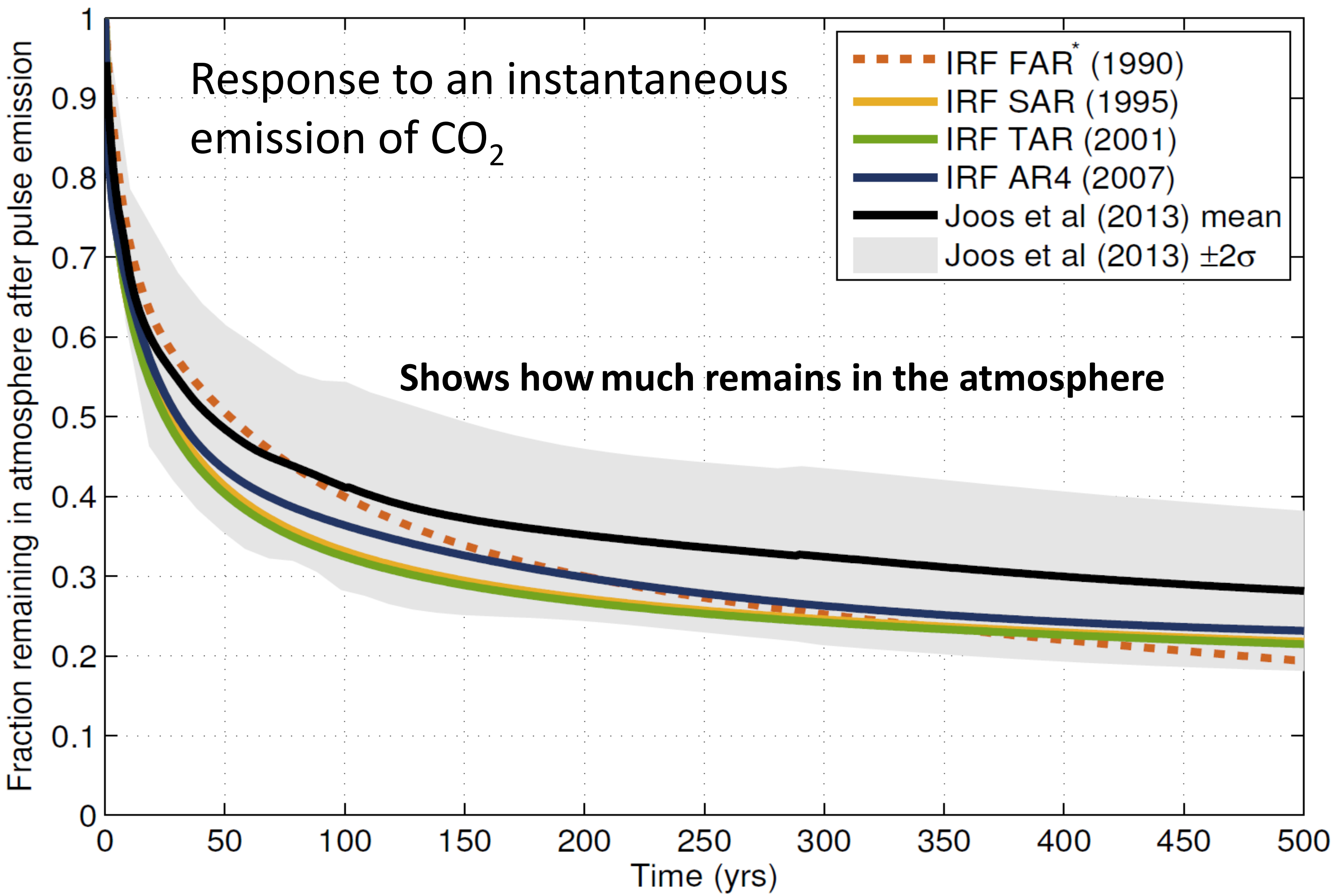
SF_6: 22 800→ **23 500**

HFC143a: 4470 → **4800**

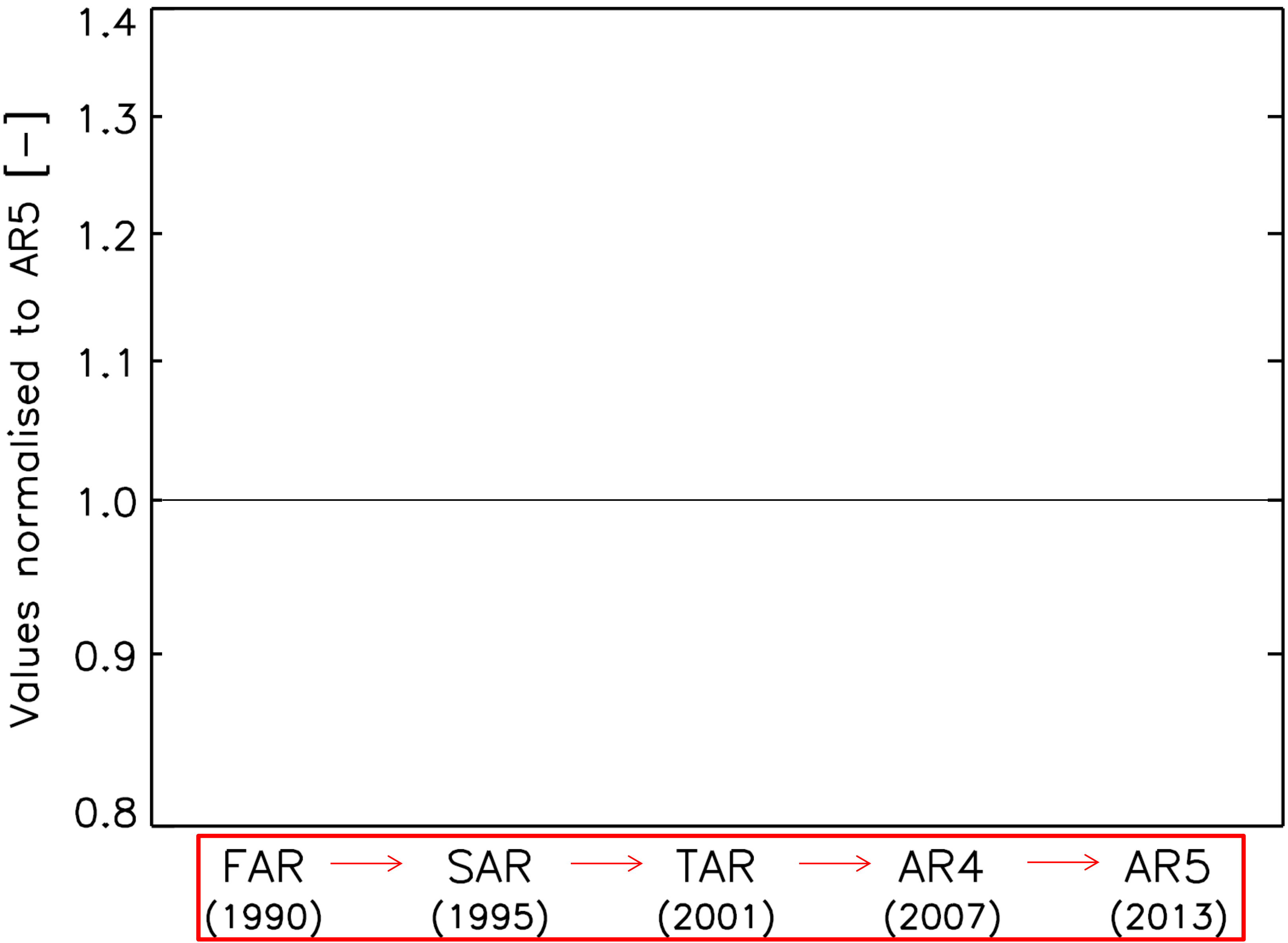
HFC245fa: 1030 → **858**

WHY HAVE THEY CHANGED?

The reference gas: CO_2



The reference gas: A moving target



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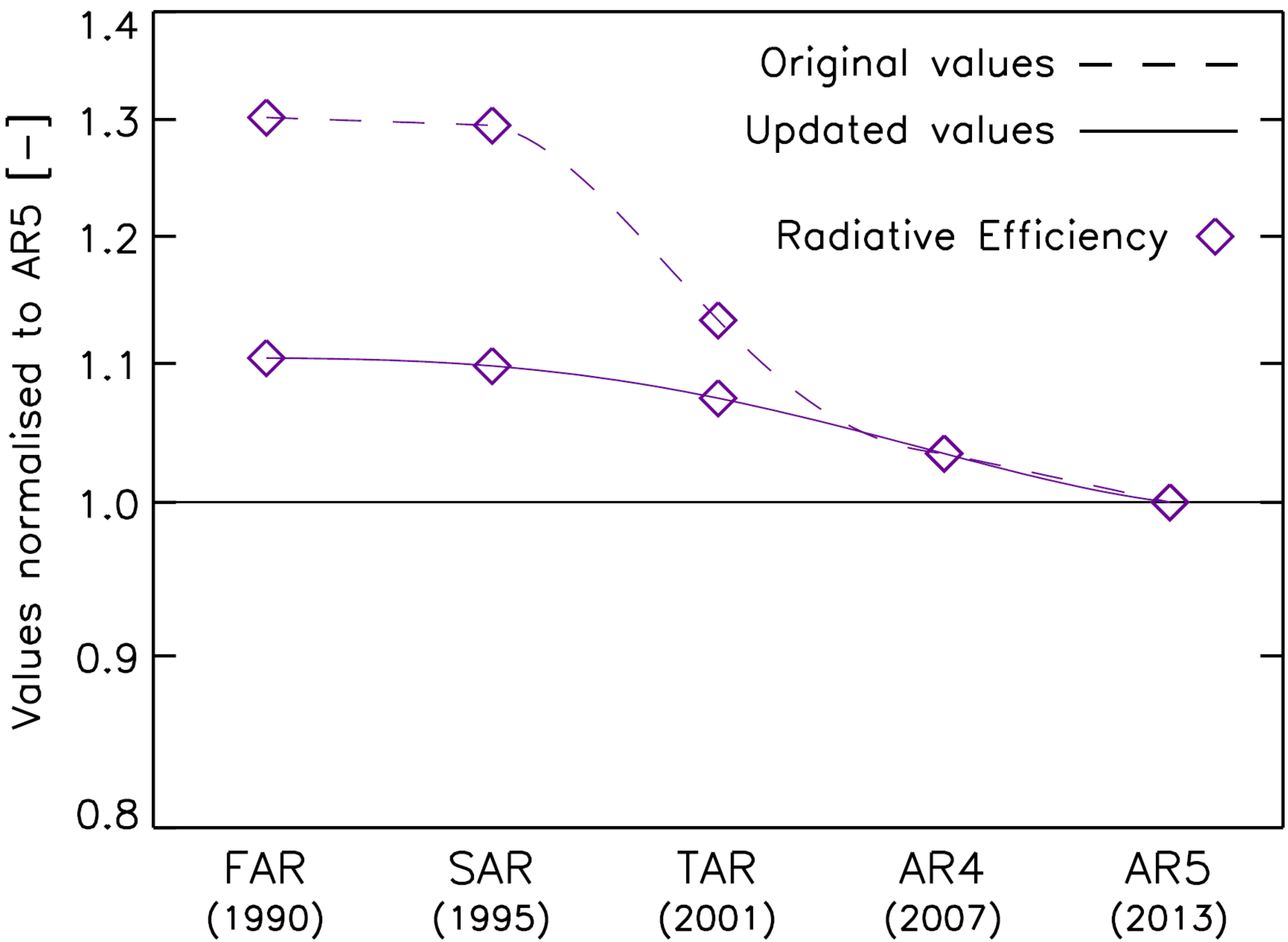

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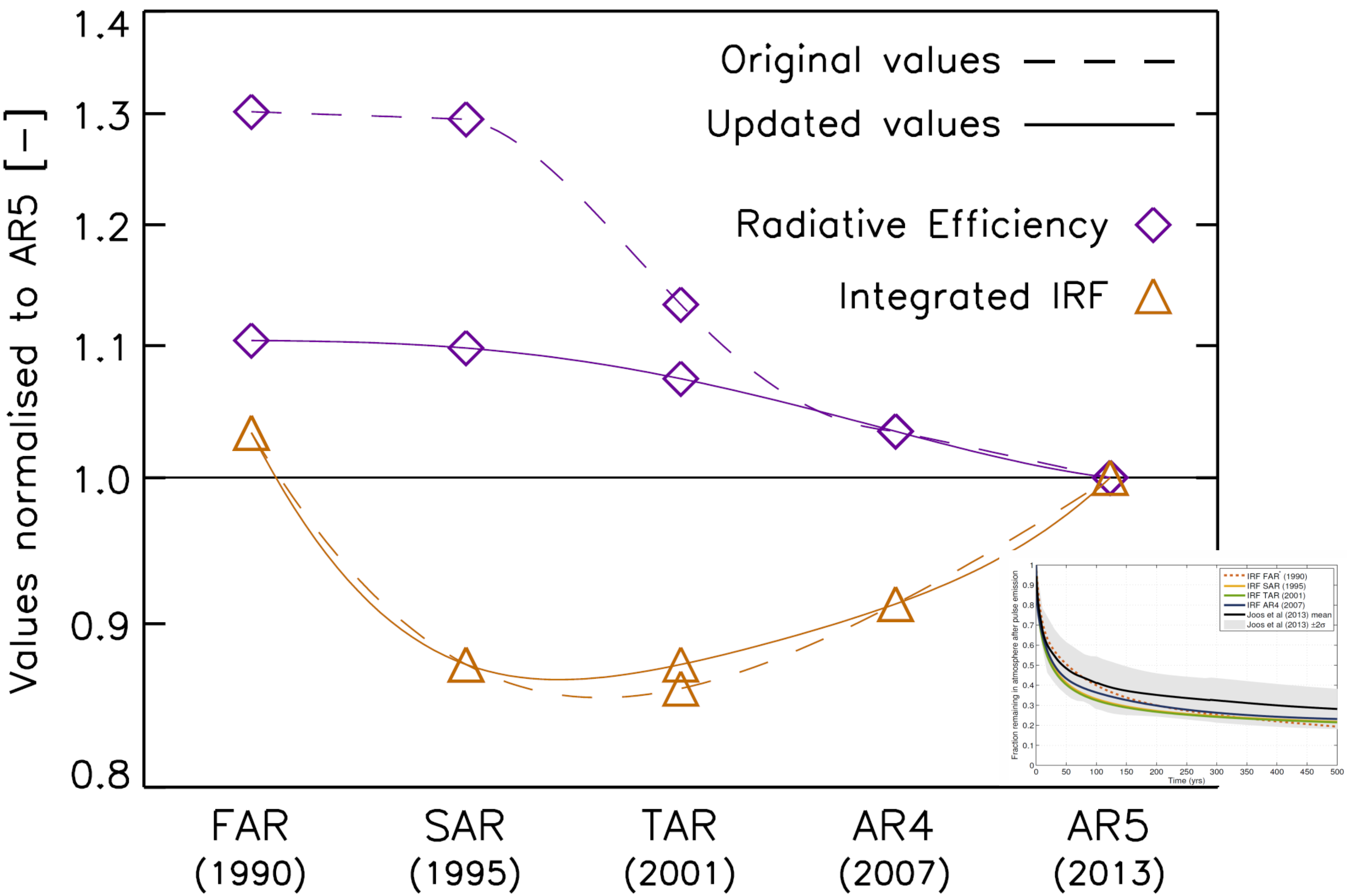

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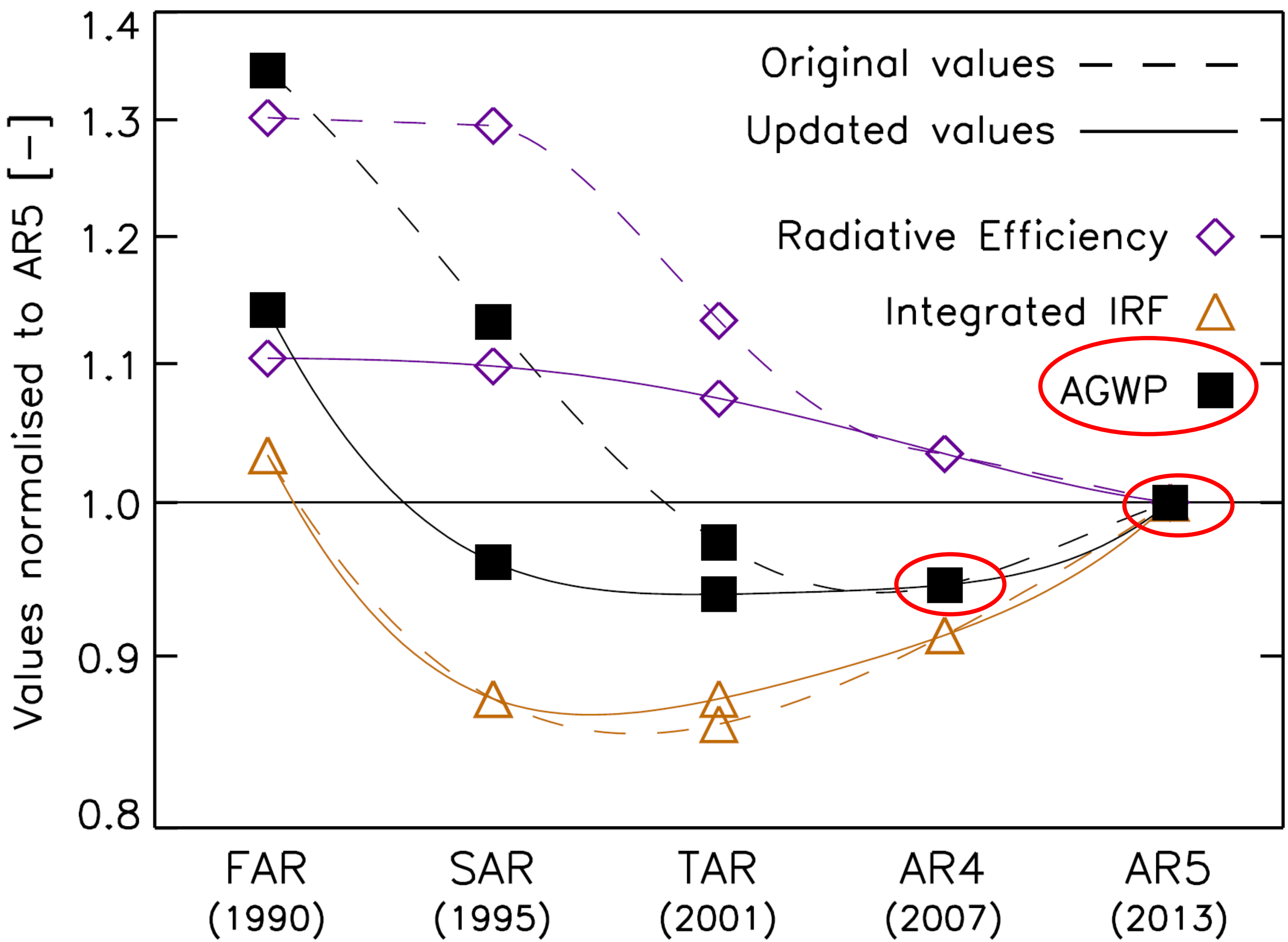


Why has the GWP for methane changed since AR4?

$$GWP_{100} = \frac{AGWP_{CH4}}{AGWP_{CO2}} =$$

Why has the GWP for methane changed since AR4?

$$GWP_{100} = \frac{AGWP_{CH4}}{AGWP_{CO2}} = \frac{(1 + f_{O3} + f_{H2O}) * RE_{CH4} \int_0^{100} e^{-t/\tau_{CH4}} dt}{RE_{CO2} \int_0^{100} IRF_{CO2} dt}$$

+ 13%

+ 20%

+ 6%

12 → 12.4 yrs

Factors affecting the metric values

User related choices

- Impact (RF, ΔT, …)
- Time horizon
- Discount rate
- Global vs regional
- Inclusion of indirect effects/feedbacks?
- Background conditions

Scientific uncertainties

- Radiative efficency (Wm^{-2}/kg)
- Lifetime of non-CO_2 components
- Impulse response function for CO_2
- Climate sensitivity and impulse response function for ΔT

For a change in time horizon from 20 to 100 years for CH_4:

GWP: 84 → 28
GTP: 67 → 4

Effects of scientific uncertainties (5 to 95% uncertainty range)

CH_4: GWP_{20}: ±30% GWP_{100}: ±40%

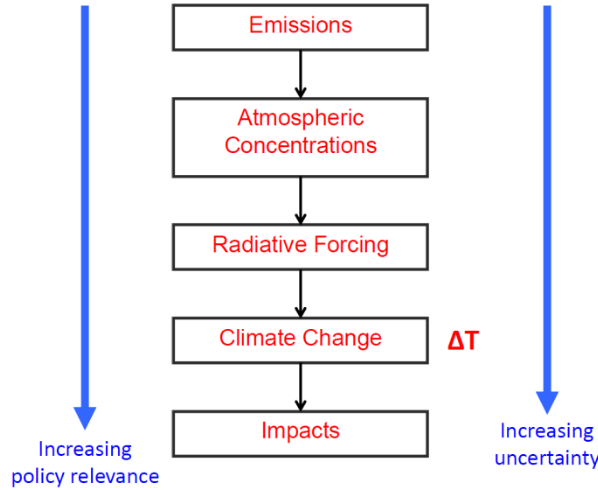
The uncertainty is dominated by CO_2 and indirect effects.

For gases with lifetimes of a **few decades:** in the order of ±25% and ±35% for 20 and 100 years.

For gases with lifetimes of a **century or more**: order of ±20% and ±30% for 20- and 100-year horizons.

Are the uncertainties in GTP larger than for GWP?

GTP for CH_4: ±75%



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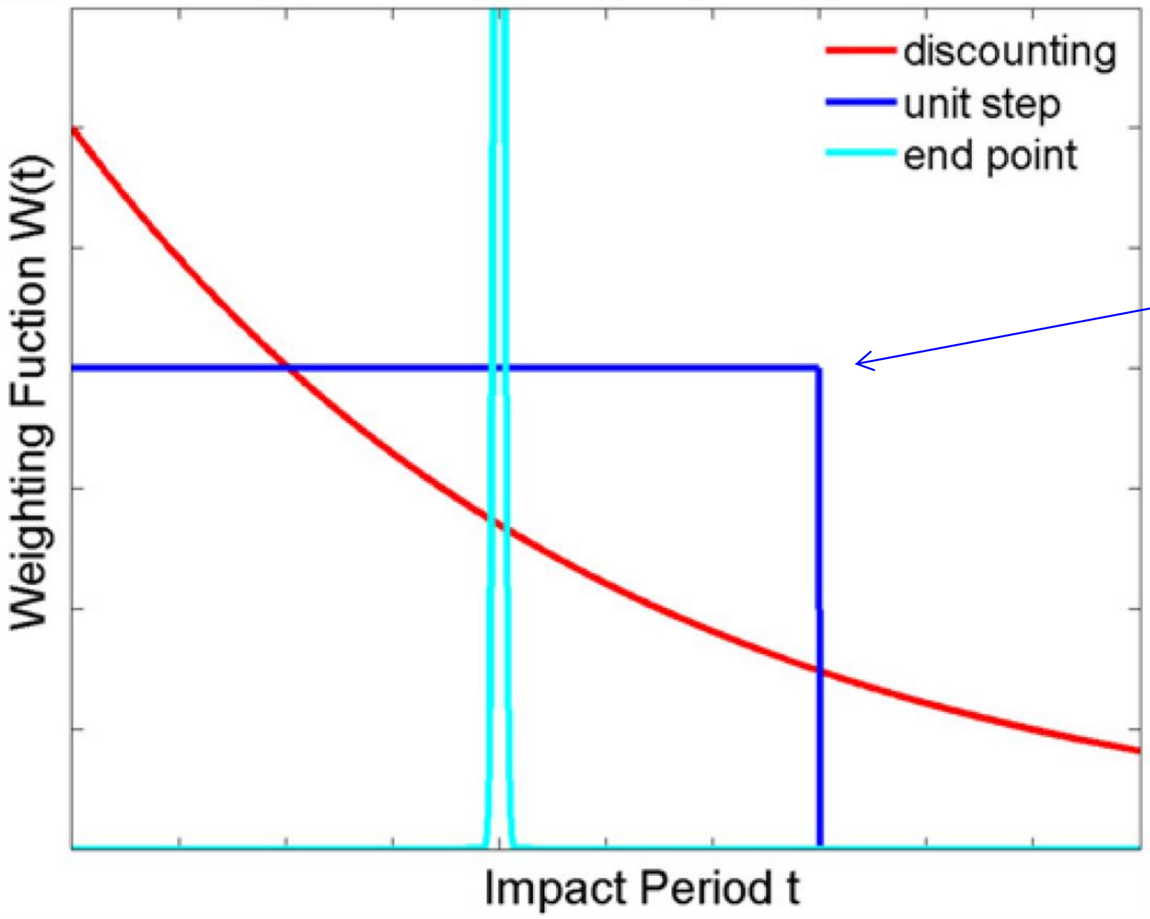
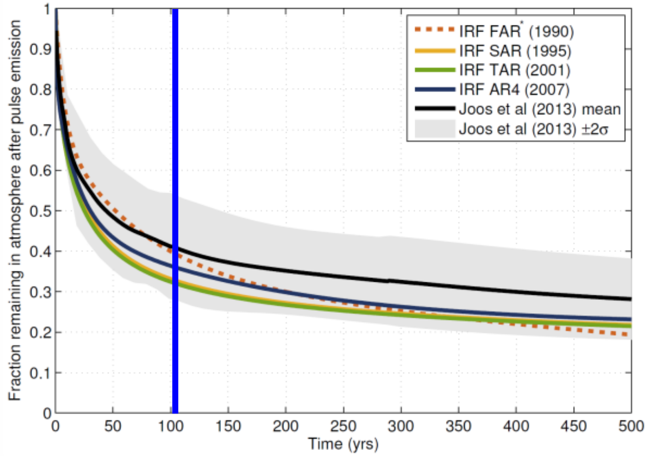
Implict value judgements in metrics

Weighting of effects over time



$$AGWP_i(H) = \int_0^H RF_i(t)\,dt$$



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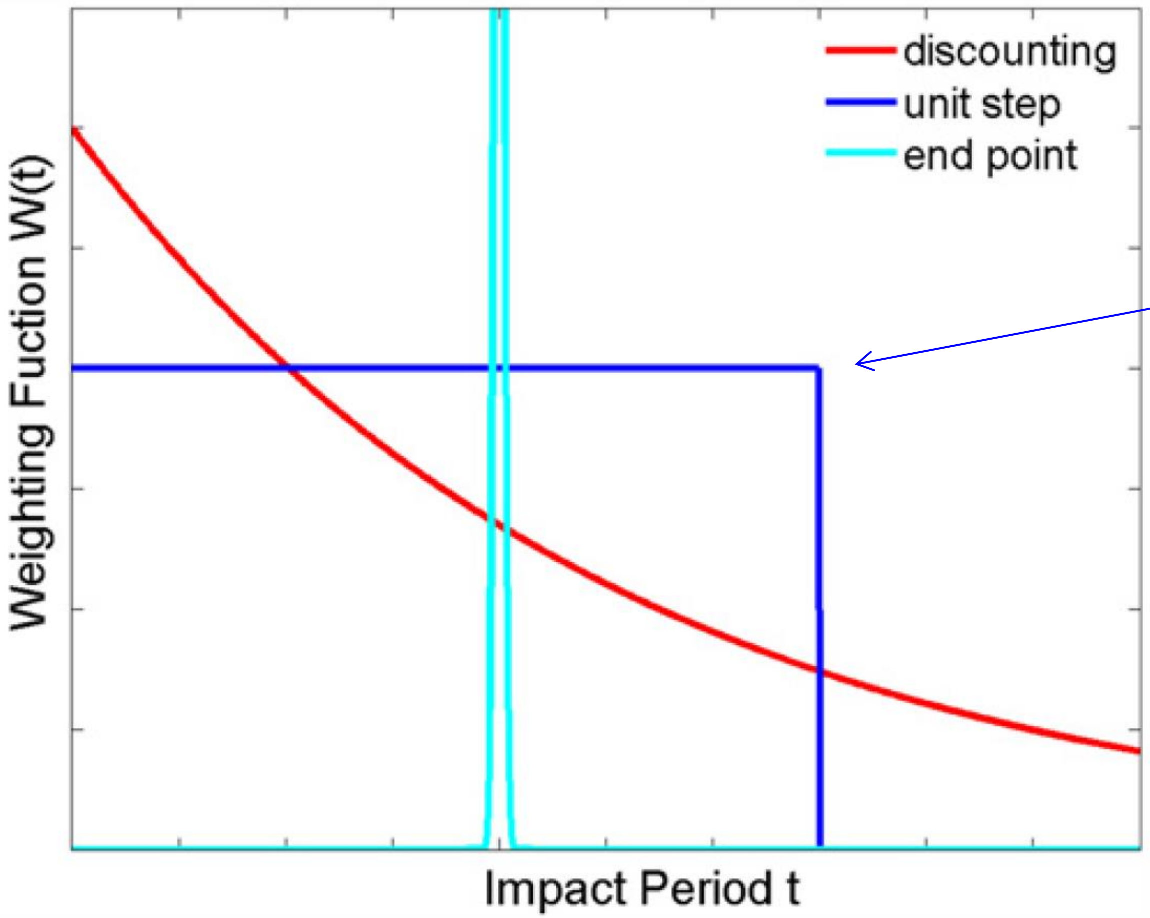

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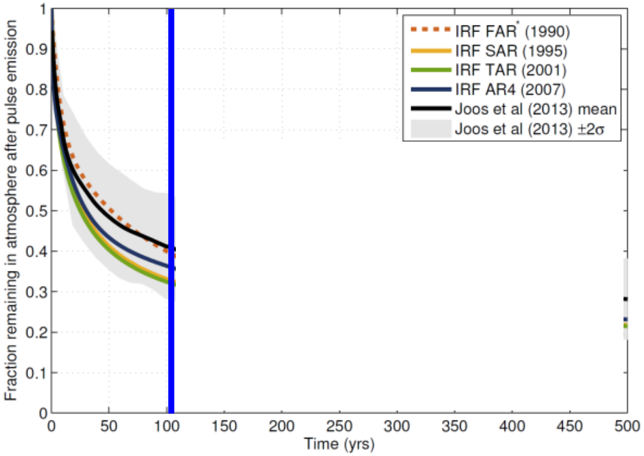

Limitation:

Inconsistent treatment of climate-carbon feedbacks

Previously: Included for CO_2 but not for non-CO_2 components

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Inconsistent treatment of climate-carbon feedbacks

Previously: Included for CO_2 but not for non-CO_2 components

AR5 includes this tentatively:

CH_4: $GWP_{100} = 28 \rightarrow 34$ $GTP_{100} = 4 \rightarrow 11$

N_2O: $GWP_{100} = 265 \rightarrow 298$ $GTP_{100} = 234 \rightarrow 297$

… review and assess the metrics for SLCF – give overviews of metric values in the literature – we do not «adopt» or recommend these values

Table 8.A.3 | GWP and GTP for NO_X from surface sources for time horizons of 20 and 100 years from the literature. All values are on a per kilogram of nitrogen basis. Uncertainty for numbers from Fry et al. (2012) and Collins et al. (2013) refer to 1-σ. For the reference gas CO_2, RE and IRF from AR4 are used in the calculations. The GWP_{100} and GTP_{100} values can be scaled by 0.94 and 0.92, respectively, to account for updated values for the reference gas CO_2. For 20 years the changes are negligible.

	GWP		GTP	
	H = 20	H = 100	H = 20	H = 100
NO_X East Asia[a]	6.4 (±38.1)	–5.3 (±11.5)	–55.6 (±23.8)	–1.3 (±2.1)
NO_X EU + [cut]				
NO_X North				
NO_X South				
NO_X four a				
Mid-latitu				
Tropical NC				
NO_X global				
NO_X global				

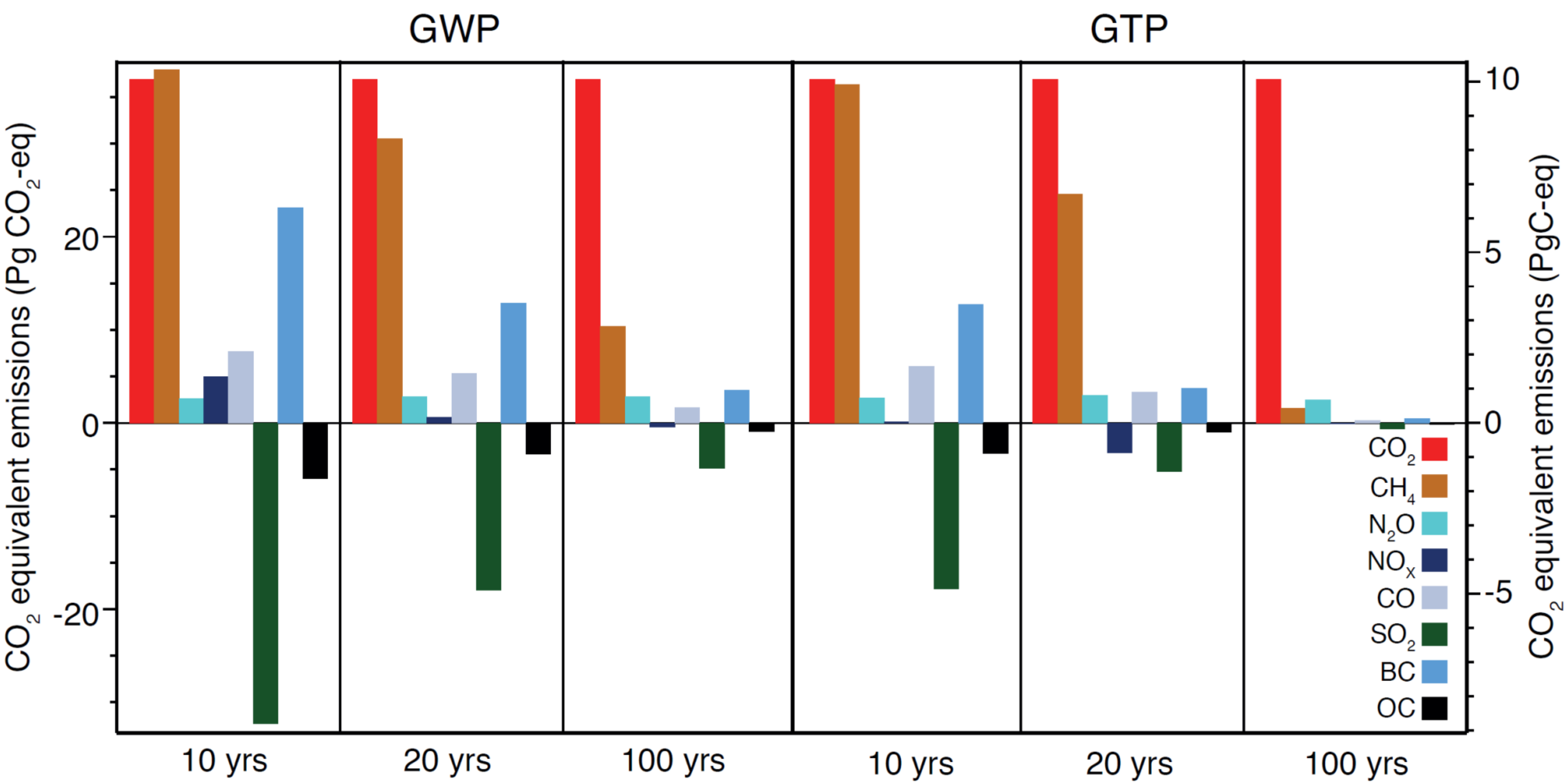
	GWP		GTP	
	H = 20	H = 100	H = 20	H = 100
CO East Asia[a]	5.4 (±1.7)	1.8 (±0.6)	3.5 (±1.3)	0.26 (±0.12)
CO EU + N				
CO North				
CO South				
CO four re				
CO global[b]				
CO global[c]				

	GWP		
	H = 20	H = 100	H = 20
VOC East Asia[a]	16.3 (±6.4)	5.0 (±2.1)	8.4 (±4.6)
VOC EU			
VOC Nor			
VOC Sou			
VOC fou			
VOC glo			

	GWP		
	H = 20	H = 100	
BC total, global[c]	3200 (270 to 6200)	900 (100 to 1700)	92
BC (four regions)[d]	1200 ± 720	345 ± 207	
BC global[a]	1600	460	
BC aerosol–radiation interaction +albedo, global[b]	2900 ± 1500	830 ± 440	
OC global[a]	–240	–69	
OC global[b]	–160 (–60 to –320)	–46 (–18 to –19)	

IPCC AR5 Working Group I
Climate Change 2013: The

Global emissions weighted by GWP and GTP for different horizons



Assessment of metrics for policy making

Scientific performance

Policy performance & benefits

SUMMARY

- Metrics do not define policies or goals; facilitate implementation of multi-gas policies to meet particular goals
- GTP and GWP fundamentally different
- No single metric for all applications
- AR5: No clear recommendation as in AR4
- Choices of metric contain implicit value-related judgements
- GWP not directly related to a temperature target
- The GWP and GTP have limitations; inconsistent treatment of indirect effects and feedbacks
- There are alternatives to the current implementation of the multi-gas policies (multi-basket; gas-by-gas)