Quantifying Uncertainty in Projecting Atmospheric Chemistry and Greenhouse Gases: Using the CMIP5/ACCMIP Ensembles

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Scenarios for future climate change assume a causal chain from human activities through to climate change. It is important to assess this chain with appropriate uncertainties [*e.g., Prather et al., 2009*]. The RCP scenarios present a complete projection of future climate forcing, but do not adequately address the uncertainties in assessing anthropogenic emissions from the AFLOU sector or in atmospheric chemistry that links emissions to radiative forcing [*e.g., Meinshausen et al., 2011*]. For example, current anthropogenic emissions of CH4 & N2O have uncertainties of order ±25% and ±50%, respectively. We look at how the Atmospheric Chemistry & Climate MIP (**ACCMIP**, a subset of CMIP5 models) can be used to improve the RCP projections of CH4 from emissions and include uncertainty.

Atmospheric CH4 loss is a combination of inverse lifetimes with respect to losses by tropospheric OH (1/11yr), stratospheric OH (1/120yr),tropospheric Cl (1/200yr), and soil uptake (1/150yr). Primary loss by tropospheric OH depends on projected pollutant emissions (anthro+natural) and climate.

Changes in the OH-lifetime of CH4 have been calculated under ACCMIP (Fig.1 from A. Voulgarakis). Models have a wide range in current lifetime ( ), well outside current best estimates. The critical piece of information here is change in OH-lifetime: this change and its uncertainty are key pieces needed to project future CH4.

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Fig. 1. ACCMIP projected atmospheric chemistry

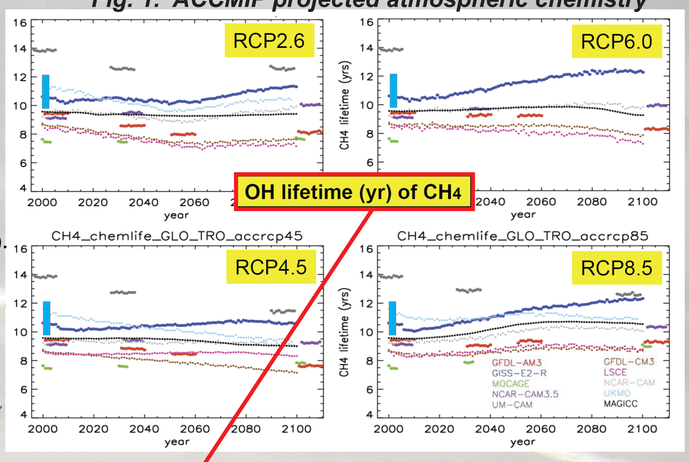

Table 1. Primary Quantities (P ± 1σ)

Table A1. Primary Quantities						
code	primary quantity	gas	value		%	abs
a1	atmospheric mass (Tg)	dry air	**5.113E+09**	±		
b1	molecular weight (Daltons)	dry air	**28.97**	±		
b2		N2O	**28.0**	±		
b3		CH4	**16.0**	±		
b4		HFC-134a	**102.0**	±		
b5		MCF	**133.4**	±		
c1*	fill factor (atmospheric to tropospheric abundance)	N2O	**0.970**	±	1.0%	**0.01**
c2*		CH4	**0.973**	±	1.0%	**0.01**
c3*		HFC-134a	**0.97**	±	2.1%	**0.02**
c4*		MCF	**0.92**	±	1.1%	**0.01**
d1*	Preindustrial (PI) abundance (ppb)	N2O	**270**	±	2.6%	**7**
d2*		CH4	**700**	±	3.6%	**25**
d3*		HFCs	**0**	±	0	**0**
e1*	Present day (PD = year 2010) abundance (ppb, HFCs in ppt)	N2O	**323**	±	**1.0%**	3.2
e2*		CH4	**1795**	±	**1.0%**	18.0
e3*		HFC-134a	**58**	±	**5.0%**	2.9
f1*	PD growth rate (ppb/yr)	N2O	**0.8**	±	12.5%	**0.1**
f2*		CH4	**5**	±	20.0%	**1**
g1	RF factor (W /m2 /ppb)	N2O	**3.03E-03**	±	**6.0%**	1.82E-04
g2		CH4	**3.70E-04**	±	**6.0%**	2.22E-05
g3		HFC-134a	**0.16**	±	**6.0%**	9.60E-03
h1	temperature (K) for scaling trop-OH reactions		**272**	±	1.8%	**5**
i1	ratio of OH reaction rates at 272K: [OH+gas]/[OH+MCF]	CH4	**0.601**	±	**10.0%**	0.060
i2		HFC-134a	**0.427**	±	**10.0%**	0.043
j1	ratio of OH reaction rates at 225K: [OH+gas]/[OH+CH4]	HFC-134a	**0.816**	±	**10.0%**	0.082
k1*	global decay rate (/y)	MCF	**0.181**	±	2.8%	**0.005**
l1	stratospheric lifetime (y)	N2O	**131**	±	7.6%	**10**
l2		CH4	**120**	±	20.0%	**24**
l3		MCF	**42.6**	±	14.1%	**6**
m1	oceanic loss frequency (/y)	MCF	**0.000**	±	n/a	**0.0071**
n1	lifetime vs. soil uptake (y)	CH4	**150**	±	33.3%	**50**
o1	lifetime vs. trop-Cl (y)	CH4	**200**	±	50.0%	**100**
p1	Change in trop-OH, PI:PD	OH	**0.95**	±	10.5%	**0.10**
q1	OH lifetime feedback, S = -dln(OH)/dln(CH4)	CH4	**0.32**	±	15.6%	**0.05**
r1	Change in trop-OH, Y2100 : PD, due to NOx,VOC,temp.	OH	**1.00**	±	15.0%	**0.15**
s1	lifetime(L) feedback, S = dlnL/dlnN2O	N2O	**-0.08**	±	25%	**0.02**
t1	PI – PD lifetime (y)	N2O	**11**	±	n/a	10
u1	to other than N2O change	N2O	**-2**	±	n/a	6
v1	Change in natural emissions, PI:PD	N2O	**1.00**	±	**10%**	0.10
v2		CH4	**1.00**	±	**10%**	0.10

Table 2. Derived Quantities (Q ± 1σ)

Table A2. Derived Quantities							
code	derived quantity	gas	value		%	abs	derivation and notes
A1		dry air	**0.1765**	±		**0**	(a1) / (b1) (*10^{-9}), <0.5% uncertainty
B1	Burden : trop-mean (Tg/ppb)	N2O	**4.79**	±	**1.0%**		(A1) * (b2) * (c1)
B2		CH4	**2.75**	±	**1.0%**		(A1) * (b3) * (c2)
B3		HFC-134a	**17.5**	±	**2.1%**		(A1) * (b4) * (c3)
C1	PD burden (Tg)	N2O	**1548**	±	**1.4%**	22	(B1) * (e1)
C2		CH4	**4932**	±	**1.4%**	71	(B2) * (e2)
C3		HFC-134a	**1.01**	±	**5.4%**	0.05	(B3) * (e3)
D1	PI burden (Tg)	N2O	**1294**	±	**2.8%**	36	(B1) * (d1)
D2		CH4	**1923**	±	**3.7%**	71	(B2) * (d2)
D3		HFC-134a	**0**	±	**2.1%**	0	(B3) * (d3)
E1	ratio of trop-OH loss to MCF	CH4/MCF	**0.601**	±	**10.1%**	0.061	(i1) + 1.7% uncertainty from (h1) propagating through exp(-1775/T) /
E2		HFC-134a	**0.427**	±	**10.0%**	0.043	(i2) + 0.7% uncertainty from (h1) propagating through exp(-1630/T) /
F1	trop-OH inverse lifetime (/y)	MCF	**0.1575**	±	5.9%	**0.0093**	(k1) - 1/(l3) - (m1)
F2		MCF**	**0.1449**	±	**6.0%**	0.0087	(F1) * (c4), normalized to uniform MCF abundance.
F3		CH4**	**0.0871**	±	**11.8%**	0.0103	(F2) * (E1), inverse OH-lifetime for uniform CH$_4$ abundance.
F4		CH4	**0.0895**	±	**11.8%**	0.0106	(F3) / (c2); OH-lifetime = 11.2 ± 1.3 y
F5		HFC-134a	**0.0638**	±	**11.9%**	0.0076	(F2) * (E2) / (c3).
G1	strat inverse lifetime (/y)	HFC-134a	**0.0068**	±	**22.4%**	0.0015	(j1) / (l2)
H1	total inverse lifetime (/y)	CH4	**0.1095**	±	10.3%	**0.0112**	(F4) + 1/(l2) + 1/(n1) + 1/(o1), lifetime = 9.14 y ± 10%
H2		HFC-134a	**0.0706**	±	10.9%	**0.0077**	(F5) + (G), lifetime = 14.2 y ± 11%
I1	PD loss rate (Tg/y)	N2O	**11.8**	±	**7.8%**	0.9	(C1) / (l1)
I2		CH4	**540**	±	**10.4%**	56	(C2) * (H1)
J1	PD growth rate (Tg/y)	N2O	**3.8**	±	**12.5%**	0.5	(B1) * (f1)
J2		CH4	**14**	±	**20.0%**	3	(B2) * (f2)
K1	PD emissions (Tg/y)	N2O	**15.7**	±	6.6%	**1.0**	(I1) + (J1)
K2		CH4	**554**	±	10.1%	**56**	(I2) + (J2)
L1	PD-PI abundance (ppb, ppt)	N2O	**53**	±	14.5%	**8**	(e1) - (d1)
L2		CH4	**1095**	±	2.8%	**31**	(e2) - (d2)
L3		HFC-134a	**58**	±	5.0%	**3**	(e3) - (d3)
M1	RF: PD-PI (W/m2)	N2O	**0.161**	±	**15.7%**	0.025	coupled [*Forster et al.* , 2007]; the key numbers here are the uncerta
M2		CH4	**0.405**	±	**6.6%**	0.027	Approximated as (L2) * (g2), see above
M3		HFC-134a	**0.009**	±	**7.8%**	0.001	(L3) * (g3) / 1000
N1	perturbation lifetime (y)	N2O	**121**	±	**7.9%**	9.5	(I1) / [1 - (s1)]
N2		CH4	**12.4**	±	**11.5%**	1.4	1 / [(F4) * [1-(q1)] + 1/(l2) + 1/(n1) + 1/(o1)]
N3		HFC-134a	**14.2**	±	**10.9%**	1.5	1 / (H2)
O1	GWP (100 year)	N2O	**317**	±	**9.9%**	31	298 * (N1) / 114, scaled from AR4, uncertainty in (N1) and (g1)
O2		CH4	**26**	±	**12.9%**	3	25 * (N2) / 12, scaled from AR4, uncertainty in (N2) and (g2).
O3		HFC-134a	**1447**	±	**12.5%**	180	1430 * (N3) / 14, scaled from AR4, uncertainty in (N3) and (g3).
P1	PI lifetime (y)	N2O	**142**	±	10.0%	**14**	(I1) + (t1)
P2		CH4	**9.5**	±	**13.3%**	1.3	1 / [(F4) * (p1) + 1/(l2) + 1/(n1) + 1/(o1)]
Q1	PI (natural) emissions (Tg/y)	N2O	**9.1**	±	11%	**1.0**	(D1) / (P1), uncertainty from MC calculation.
Q2		CH4	**202**	±	14%	**28**	(D2) / (P2), as above.
R1	PD (natural) emissions (Tg/y)	N2O	**9.1**	±	14%	**1.3**	(Q1) / (v1), uncertainty from MC calculation.
R2		CH4	**202**	±	17%	**35**	(Q2) / (v2), as above.
S1	PD anthrop.emissions (Tg/y)	N2O	**6.5**	±	20%	**1.3**	(K1) - (R1), uncertainty from MC calculation.
S2		CH4	**352**	±	13%	**45**	(K2) - (R2), as above.

for SRES A1B [*Fleming et al.* , 2011], large uncertainty from can

See v2

Uncertainty based on estimated 10% decline in natural wetland s

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Figs. 2-5. Generate anthropogenic emission uncertainties and then GHG abundances with uncertainties