

Supporting Information for “Radiative flux and forcing parameterization error in clear, clean skies”

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Introduction

Data Set S1: Atmospheric conditions Atmospheric conditions for radiative transfer calculations. Conditions are provided as a set of ASCII files by case following the CIRC protocol. Present-day and $4\times\text{CO}_2$ files are identical except for the carbon dioxide concentration. Aerosol and cloud files are provided for consistency but all values are 0 everywhere.

Data Set S2: Radiative fluxes at select levels Radiative fluxes computed by all models at the top-of-atmosphere and at the surface, for each case in present-day and with

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carbon dioxide concentrations quadrupled. Results are provided as a netCDF4 file with dimensions (level, case, model, band, condition).

Data Set S3: Selected radiative fluxes at all levels Profiles of radiative flux as in Data Set S2. Only some models provided this information; unfortunately the benchmark model did not.

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Table S1. Radiative transfer reference models and parameterizations.

Institution	Code name	References
Longwave reference models		
AER	LBLRTM v12.2	<i>Clough et al.</i> [2005]
AER	LBLRTM v9.4+	<i>Clough et al.</i> [2005]; <i>Alvarado et al.</i> [2013]
U. Hamburg, U. Chalmers	ARTS	<i>Buehler et al.</i> [2005]; <i>Eriksson et al.</i> [2011]
GFDL	RFM-GFDL-LBL-LW	<i>Paynter and Ramaswamy</i> [2011]
GFDL	GFDL-LBL-LW	<i>Schwarzkopf and Ramaswamy</i> [1999]
Met Office	SOCRATES	<i>Edwards and Slingo</i> [1996]
	300-band k -distribution (GA7 reference)	
Longwave parameterizations		
NCAR, MPI	RRTMG-LW v4.84	<i>Mlawer et al.</i> [1997]; <i>Iacono et al.</i> [2008]
	MPI implementation is PSrad	[<i>Pincus and Stevens</i> , 2013]
CCCma	CCC	<i>Li and Barker</i> [2005]; <i>von Salzen et al.</i> [2013]
CNRM, LMDZ	RRTMG	<i>Morcrette et al.</i> [2008]
	Modified from AER version for ECWMF IFS; two separate implementations	
GISS	Model-E radiation	<i>Schmidt et al.</i> [2014]
GFDL	GFDL-SEA-LW	<i>Schwarzkopf and Ramaswamy</i> [1999]
LMDZ (CMIP5)	Morcrette	<i>Morcrette et al.</i> [1986]
AORI	MSTRNX	<i>Sekiguchi and Nakajima</i> [2008]
Met Office	SOCRATES GA7	<i>Edwards and Slingo</i> [1996]
Met Office (CMIP5)	SOCRATES GA3	<i>Edwards and Slingo</i> [1996]; <i>Walters et al.</i> [2011]
Shortwave reference models		
AER	LBLRTM v12.2	<i>Clough et al.</i> [2005]
AER	LBLRTM v9.4+	<i>Clough et al.</i> [2005]; <i>Alvarado et al.</i> [2013]
Met Office	SOCRATES	<i>Edwards and Slingo</i> [1996]; <i>Walters et al.</i> [2011]
	260-band k -distribution (GA7 reference)	
Shortwave parameterizations		
NCAR, MPI	RRTMG-SW v3.8	<i>Mlawer et al.</i> [1997]; <i>Iacono et al.</i> [2008]
	MPI implementation is PSrad	[<i>Pincus and Stevens</i> , 2013]
CCCma	CCC	<i>Li and Barker</i> [2005]; <i>von Salzen et al.</i> [2013]
CNRM, LMDZ	Fouquart-Bonnel	<i>Fouquart and Bonnel</i> [1980]; <i>Morcrette et al.</i> [2007]
	CNRM uses 6-band version; LMDZ 2-band versions	
GFDL	GFDL-SEA-SW	<i>Freidenreich and Ramaswamy</i> [1999]
GISS	Model-E radiation	<i>Schmidt et al.</i> [2014]
AORI	MSTRNX	<i>Sekiguchi and Nakajima</i> [2008]
Met Office	SOCRATES GA7	<i>Edwards and Slingo</i> [1996]
Met Office (CMIP5)	SOCRATES GA3	<i>Edwards and Slingo</i> [1996]; <i>Walters et al.</i> [2011]

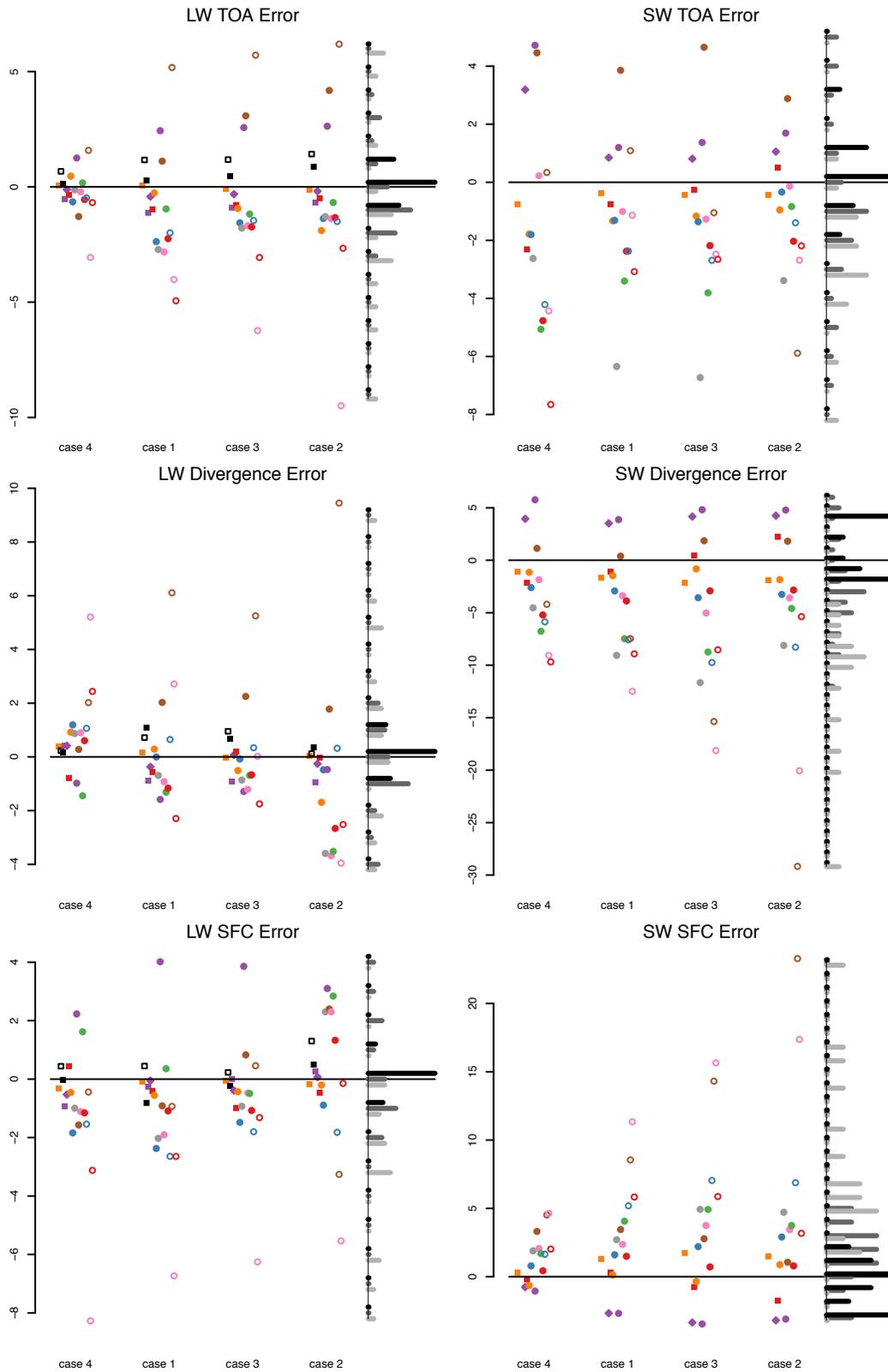


Figure S1. Errors in present-day net downward flux (W/m^2). Legend as in main text Figure

1. Longwave results are in the left column and shortwave on the right. Rows correspond to the

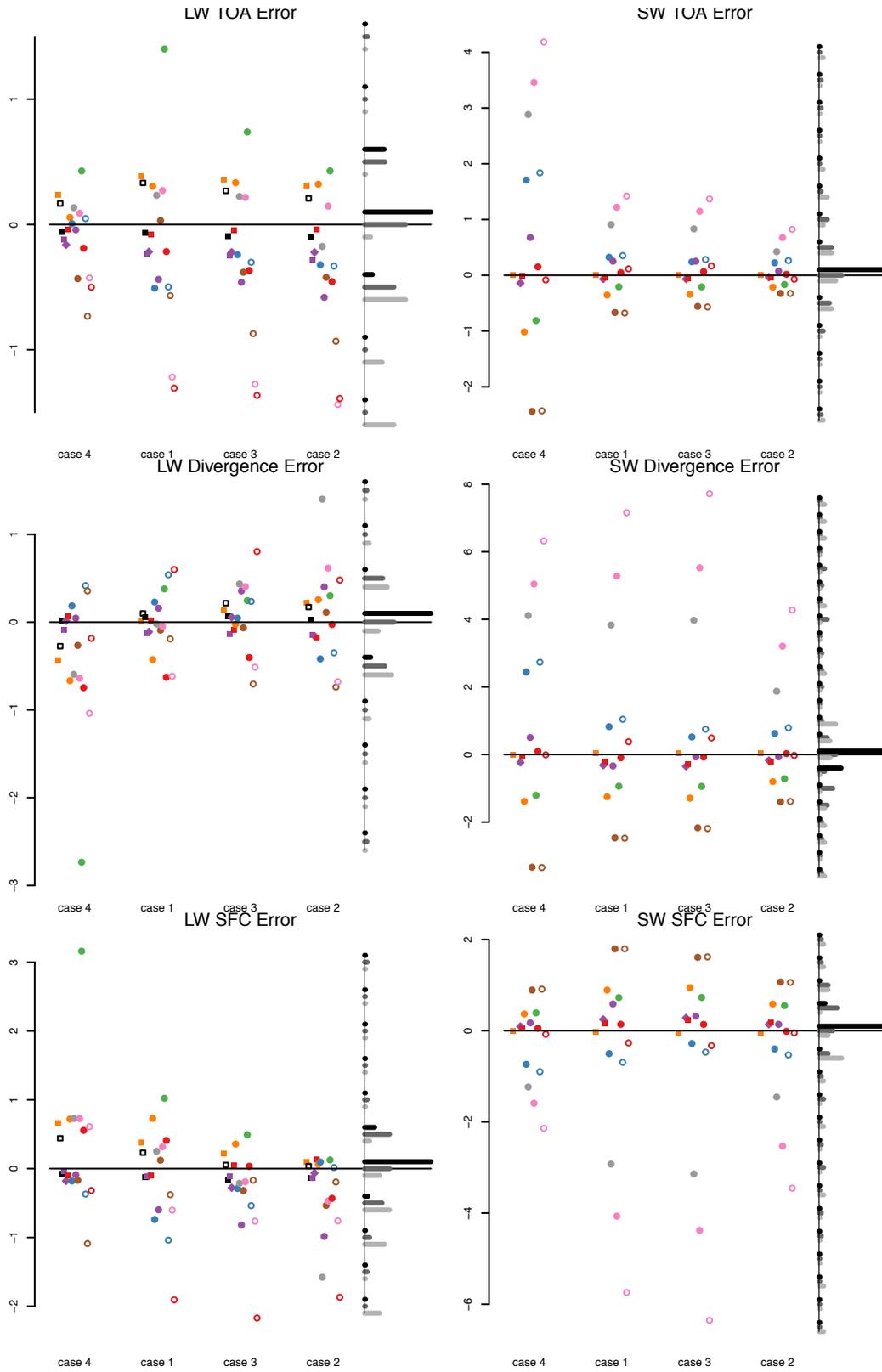


Figure S2. Errors (W/m^2) in forcing from CO_2 concentrations quadrupled from present-day values. Legend as in main text Figure 1; layout as in Figure S1.

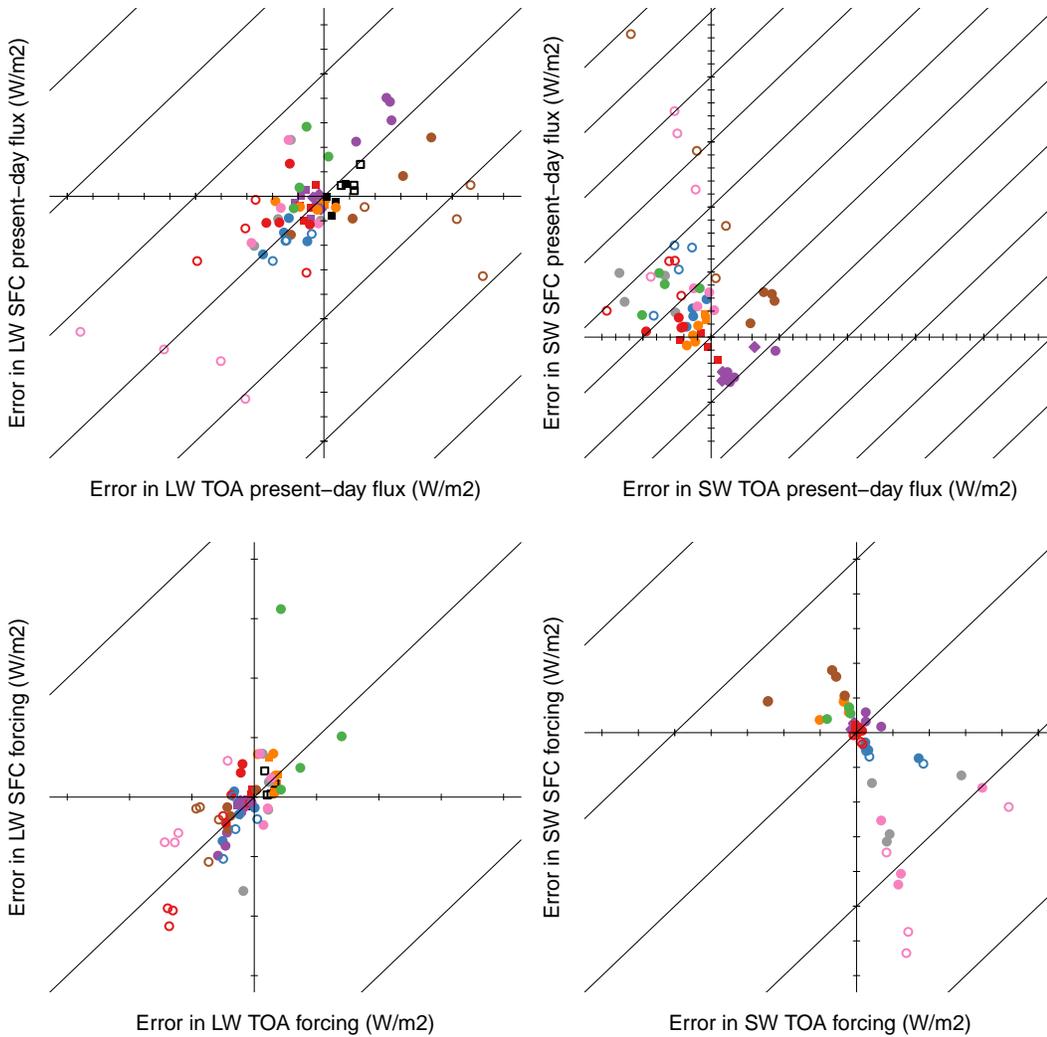


Figure S3. Errors at the surface as a function of errors at the top-of-atmosphere, along with (diagonal) isolines of constant error in absorption inferred from boundary fluxes. Longwave results are in the left column and shortwave on the right. Results for present-day conditions are in the top row; results for forcing from $4\times\text{CO}_2$ concentrations below.

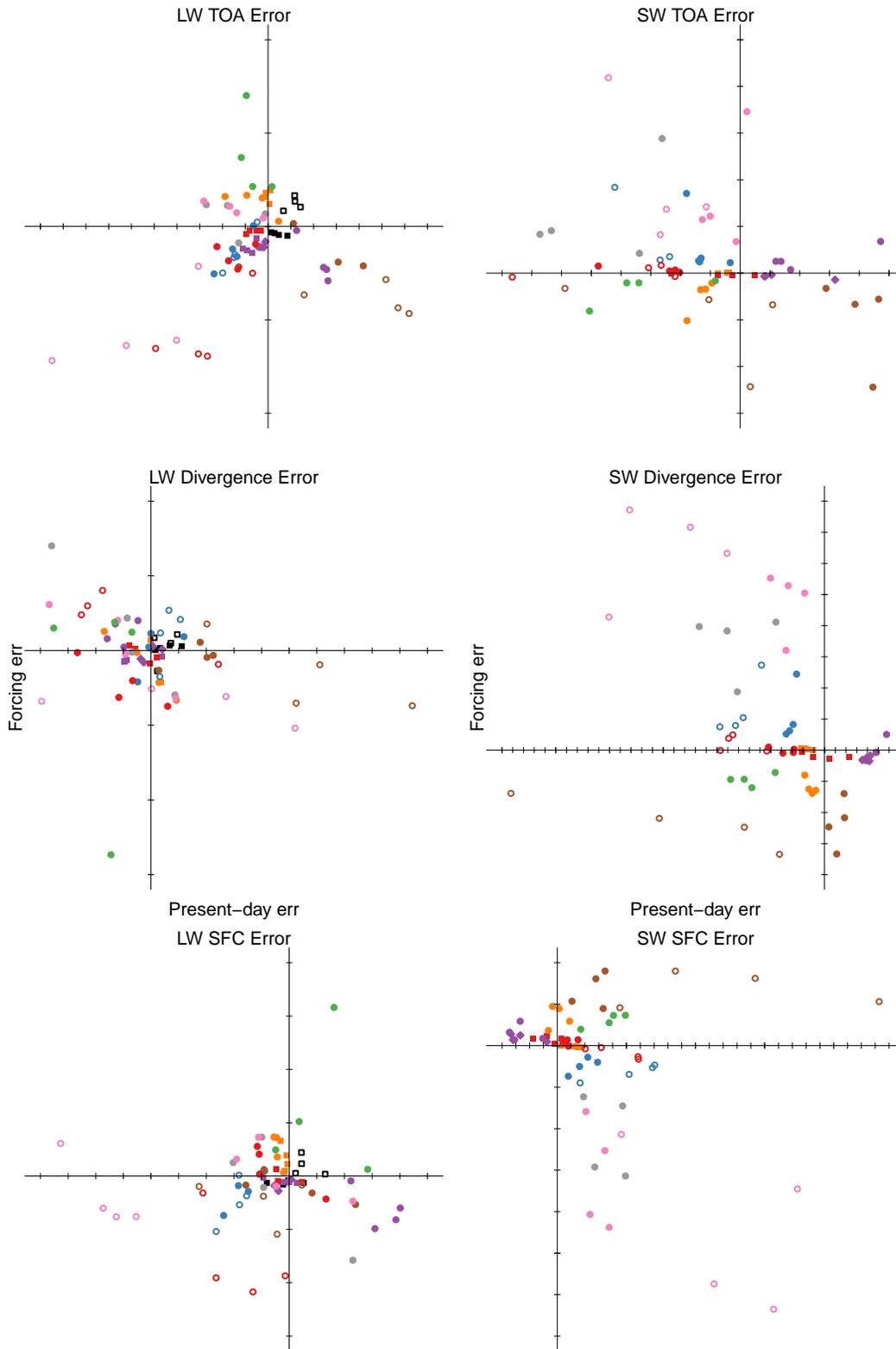


Figure S4. Error in forcing as a function of error in the present-day. Legend as in main text Figure 1; layout as in Figure S1.

Table S2. Reference model (LBLRTM v12.2) calculations of net flux (W/m^2). Forcing is defined as $4\times\text{CO}_2$ minus present-day. Shortwave values are positive down; longwave positive up.

	CIRC case number			
	(increasing column-integrated water vapor)			
	4	1	3	2
	Longwave, present-day			
TOA	230.28	303.78	280.18	292.01
Emission	137.01	147.43	155.47	216.74
SFC	93.27	156.35	124.71	75.27
	Shortwave, present-day			
TOA	341.36	741.65	857.40	463.07
Absorption	128.65	163.06	202.64	151.71
SFC	212.71	578.59	654.76	311.36
	Longwave forcing			
TOA	2.493	7.238	6.472	6.672
Δ Emis.	4.316	-0.390	-1.704	-3.398
SFC	6.809	6.848	4.768	3.274
	Shortwave forcing			
TOA	2.542	0.727	0.628	0.346
Δ Abs.	3.655	3.315	3.259	1.707
SFC	-1.113	-2.588	-2.631	-1.361