Historical aerosol forcing diagnosis and analysis in CMIP6, AerChemMIP and AeroCom models

Michael Schulz, Dirk Olivie, Jan Griesfeller

NORWEGIAN METEOROLOGICAL INSTITUTE

ACKNOWLEDGMENT: NorESM team, Crescendo, AEROCOM, AerChemMIP, RFMIP, CMIP6, ESGF

Linking CMIP6 and Aerocom

		AEROCOM-PHASE-II-IND3	AMAP	CMIP6	HTAP-PHASE-I
AEROCOM_EMISSIONS	AEROCOM-PHASE-III-2019	AEROCOM-PHASE-III-Trend	BACCHUS	ECLIPSE	HTAP-PHASE-II
AEROCOM-PHASE-I	AEROCOM-PHASE-III-CTRL2018	AEROCOM-PHASE-I-IND	C3S-Aerosol	ECMWF	SATELLITE-DATA
AEROCOM-PHASE-II	AEROCOM-PHASE-II-IND2	AEROCOM-PHASE-II-PRESCRIBED-2013	CCI-Aerosol	EURODELTA	

AERCHEMMIP
RFMIP
(DAMIP)

	GISS		GISS
	BCC-CUACE_HIST		BCC-ESM1_historical*
A	CAM5-ATRAS_AP3-CTRL		
A	CAM5-ATRAS_AP3-HIST	C	CanESM5_historical
			CESM2_historical
	EC-Earth3-AerChem_AP3-CTRL2019	C	CESM2-WACCM_historical
	ECHAM6.3-HAM2.3-met2010_AP3-CTRL		
A	ECMWF-IFS-CY45R1-CAMS-CTRL_AP3-CTRL-2019-PI		CNRM-CM6-1_historical*
	ECMWF-IFS-CY45R1-CAMS-CTRL-met2010_AP3-CTRL	C	CNRM-ESM2-1_historical*
A	GEOS-i33p2-met2010_AP3-CTRL	C	E3SM-1-0_historical
	GFDL-AM4-amip_HIST		GFDL-CM4_historical
	GFDL-AM4-fSST_AP3-CTRL		
	GFDL-AM4-met2010_AP3-CTRL	C	IPSL-CM6A-LR_historical
	GFDL-AM4-met2010_InSitu-RH30		
	GFDL-ESM4-fSST_AP3-CTRL		MIROC6_historical*
	MIROC-SPRINTARS_AP3-CTRL	C	MPI-ESM-1-2-HAM
	NorESM2-CPL_HIST	C	MRI-ESM2-0_historical*
A	OsloCTM3v1.01-met2010_AP3-CTRL		NorESM2-LM_historical
	OsloCTM3v1.01-met2010_AP3-HIST	C	UKESM1-0-LL_historical*
A	TM5_AP3-CTRL2019		

* in ESGF, but not yet in AeroCom

Overview

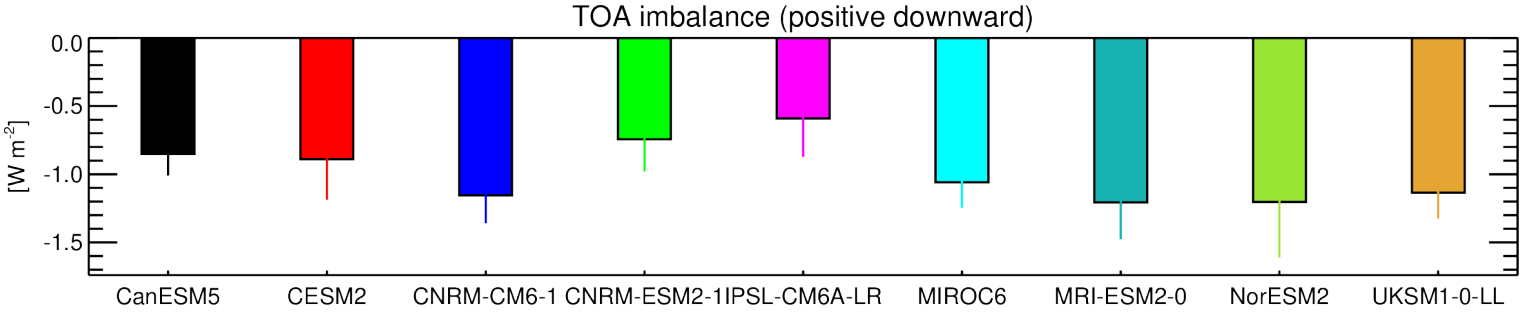
- Topics
  - 30-year fixed-SST simulations
  - AOD analysis (via idl AeroCom tools)
  - Historical RFMIP fixed-SST simulations
  - Historical AerChemMIP fixed-SST simulations
  - Aerosol ERF split (Ghan, 2013)

30-year fixed-SST simulations AerChemMIP+RFMIP

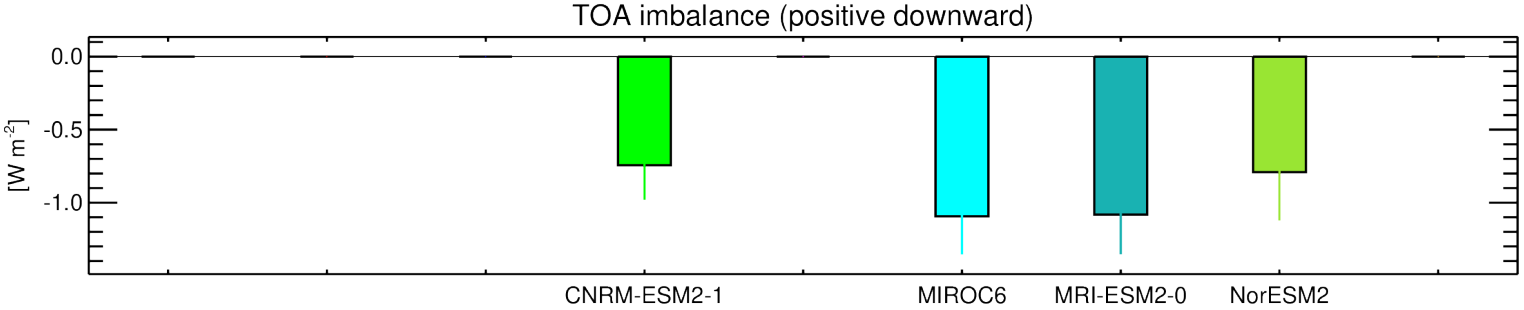
	piClim-control	piClim-aer	piClim-BC	piClim-OC	piClim-SO2	piClim-NTCF
BCC-ESM1	Yes					Yes
CanESM5	Yes	Yes				
CNRM-CM6-1	Yes	Yes				
CNRM-ESM2-1	Yes	Yes	Yes	Yes	Yes	Yes
IPSL-CM6A-LR	Yes	Yes				
MIROC6	Yes	Yes	Yes	Yes	Yes	Yes
MRI-ESM2-0	Yes	Yes	Yes	Yes	Yes	Yes
NorESM2	Yes	Yes	Yes	Yes	Yes	Yes
UKESM1-0-LL	Yes	Yes	Yes			

Aerosol effective radiative Forcing (ERF) in 2014

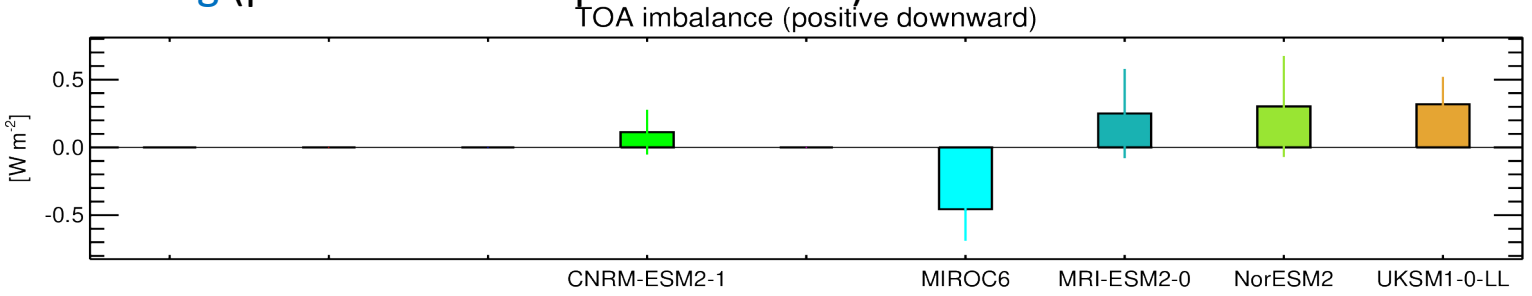
- Aerosol forcing (piClim-aer minus piClim-control)



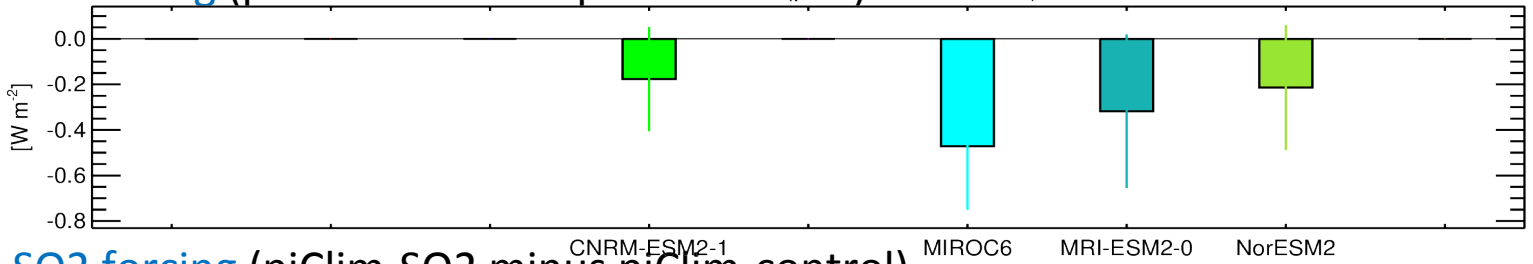
- NTCF forcing (aerosols + ozone) (piClim-NTCF minus piClim-control)



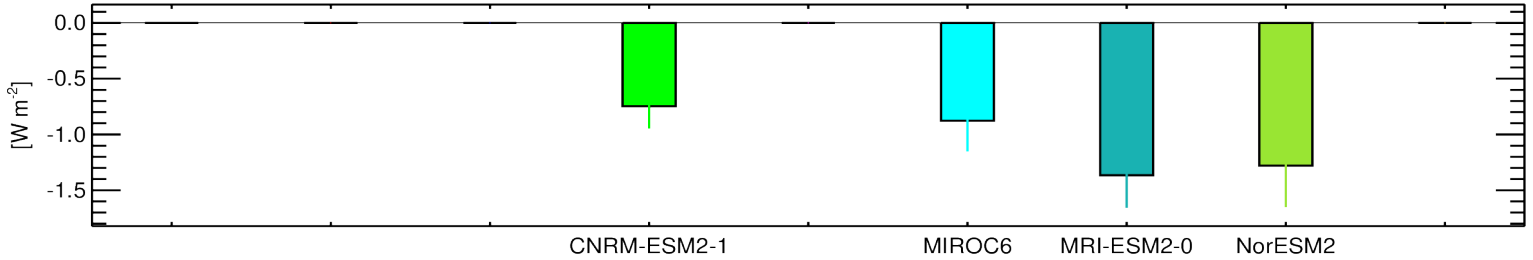
- BC forcing (piClim-BC minus piClim-control)



- OC forcing (piClim-OC minus piClim-control)



- SO2 forcing (piClim-SO2 minus piClim-control)



ERF in 2014 [W m^{-2}] / CMIP6 models

	Aerosol	BC	OC	SO2	Ozone NTCF-AER	BC+OC+SO2
CanESM5	-0.85					
CESM2	-0.89					
CNRM-CM6-1	-1.16					
CNRM-ESM2-1	-0.75	0.11	-0.18	-0.75	0.00 ??	*-0.81*
IPSL-CM6A-LR	-0.59					
MIROC6	-1.06	-0.46 ??	-0.47	-0.88	-0.03	*-1.81 ??*
MRI-ESM2-0	-1.21	0.25	-0.32	-1,37	+0.13	*-1.43*
NorESM2	-1.21	0.30	-0.22	-1.30	+0.40	*-1.23*
UKESM1-0-LL	-1.14	0.32				

Model	Anthro AOD	Natural AOD	ant Fraction
CESM2_historical	0.014	0.128	10%
GEOS-i33p2-met2010_AP3-CTRL	0.016	0.110	12%
CESM2-WACCM_historical	0.019	0.125	13%
ECHAM6.3-HAM2.3-met2010_AP3-CTRL	0.023	0.125	16%
NorESM2-LM_historical	0.032	0.141	19%
OsloCTM3v1.01-met2010_AP3-HIST	0.028	0.102	21%
IPSL-CM6A-LR_historical	0.030	0.081	27%
GFDL-CM4_historical	0.045	0.105	30%
CanESM5_historical	0.045	0.100	31%
CAM5-ATRAS_AP3-HIST	0.041	0.083	33%
MIROC-SPRINTARS_AP3-CTRL	0.033	0.065	34%
Mean	0.030	0.106	22%
Standard Deviation / Mean	38%	22%	40%

CAM family

AOD analysis with AeroCom tools

Analysis ERF of aerosol

Model	AOD anthro	AOD Natural	ant AOD Fraction	ERF_{aer}
CESM2_historical	0.014	0.128	10%	-0.89
NorESM2-LM_historical	0.032	0.141	19%	-1.21
CanESM5_historical	0.045	0.100	31%	-0.85
MIROC-SPRINTARS_AP3-CTRL	0.033	0.065	34%	(-1.06)

⇒ more models, SSA and AAOD inclusion, direct effect from double calls, impact of natural aerosols on indirect effect, role of rapid adjustments

RFMIP historical^{+} simulations

- Simulations used

	piClim-control	piClim-histall	piClim-histaer
CanESM5	Yes	Yes	Yes
MIROC6	Yes	Yes	Yes
NorESM2	Yes	Yes	Yes

- Timeseries 1850-2100 : historical + SSP2-4.5

  piClim-control: fixed Sea Surface Temperature from pre-industrial control

  histall: all forcings evolving

  histaer: only aerosols evolving

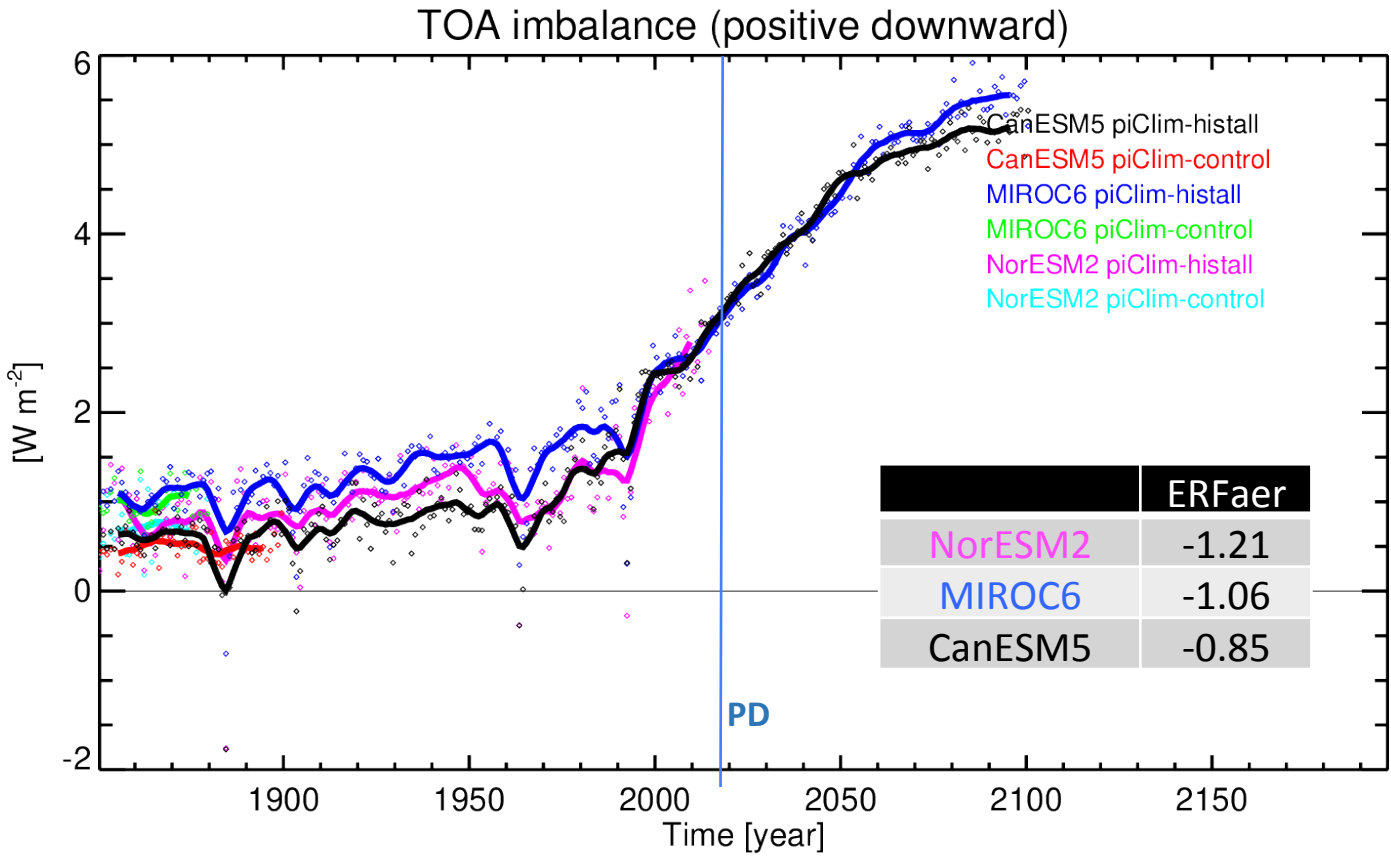
RFMIP : total ERF

- Simulations : piClim-histall and piClim-control.
- Total ERF : GHGs + ozone + aerosols + landuse + volcanoes + solar + …

Future scenario SSP2 / 4.5

Volcanoes included

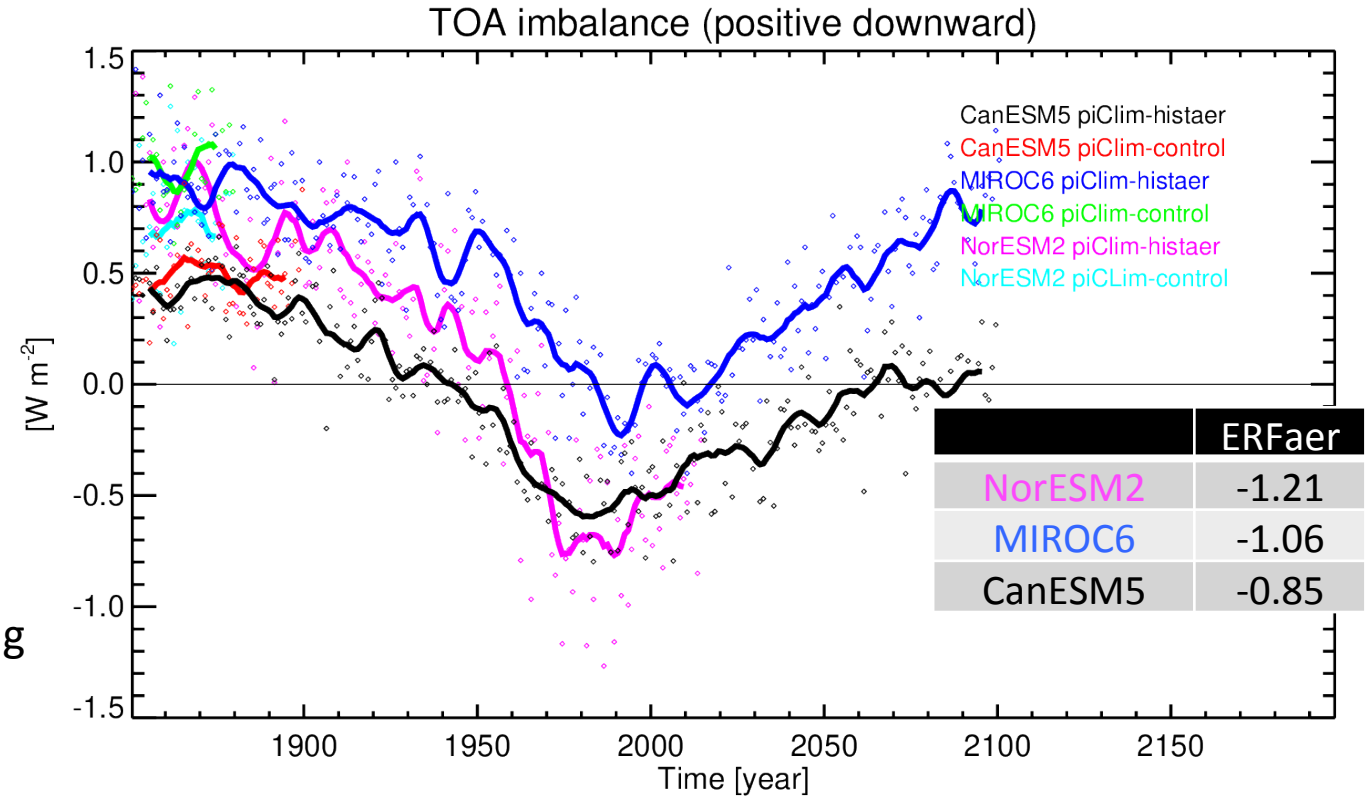
- Remark
  - Models have offset in 1850 (fixed-SST piClim-control is not in balance)
  - Forcing in 2100 is close to 4.5 W m^{-2}



RFMIP : evolving aerosols-only ERF / all other agents PI

- Simulations :
- piClim-histaer and piClim-control.
- ERF (aerosols only)

- Remark
  - Strongest negative forcing around -1 to -1.3 W m^{-2}



	ERFaer
NorESM2	-1.21
MIROC6	-1.06
CanESM5	-0.85

AerChemMIP historical simulations using evolving fixed SST from historical simulations

	histSST	histSST-piaer	histSST-piNTCF
BCC-ESM1	Yes		Yes
CESM2-WACCM	Yes		Yes
CNRM-ESM2-1	Yes		Yes
MIROC6	Yes	Yes	Yes
NorESM2	yes	Yes	Yes

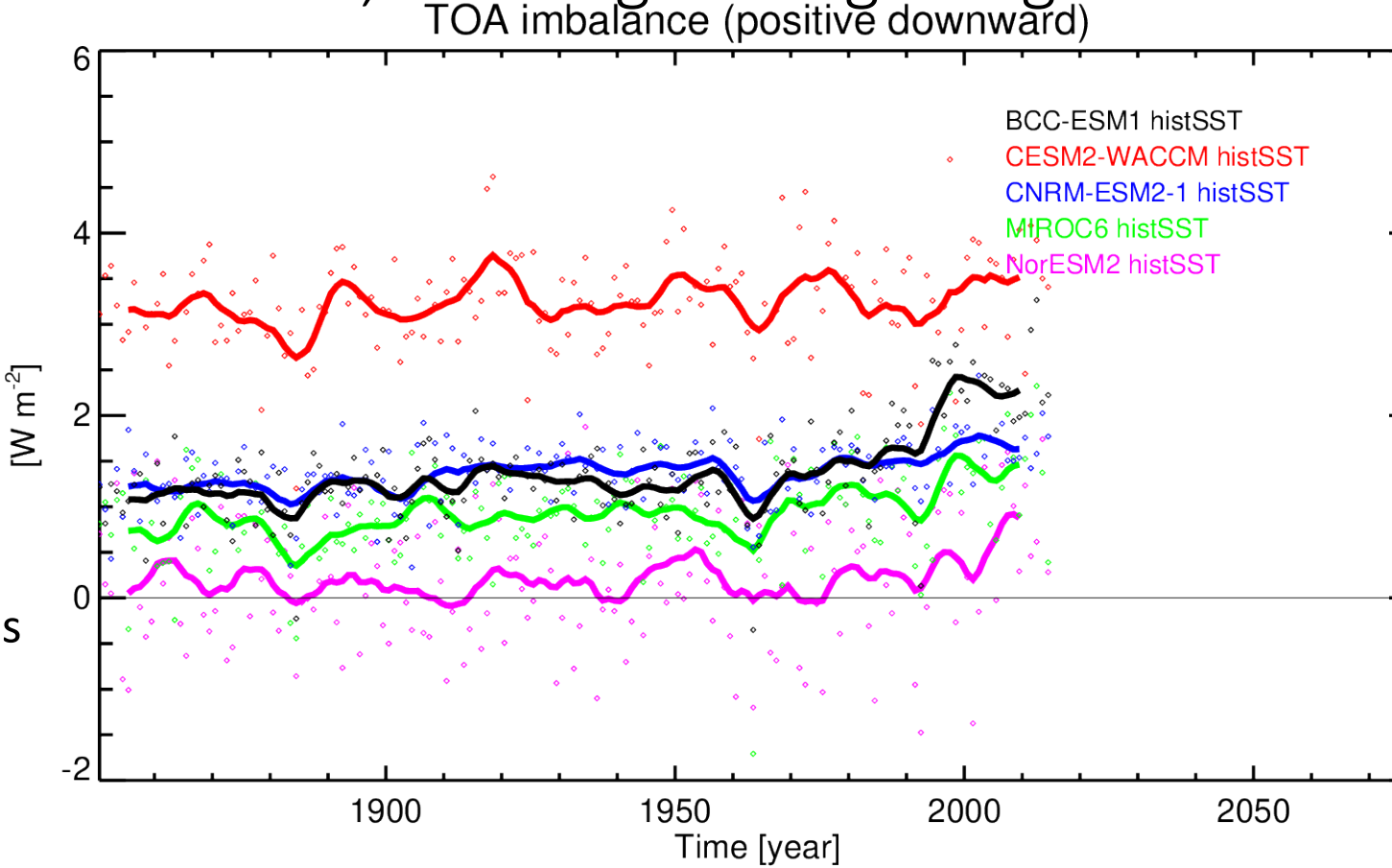
histSST: Historical simulations with evolving SST fields from coupled historical model
histSST-piaer: as histSST but with aerosol fixed to 1850
histSST-piNTCF: as histSST but with Near Term Climate Forcers fixed to 1850

AerChemMIP
control with historic SST, evolving forcing all agents

- Simulations :
- histSST

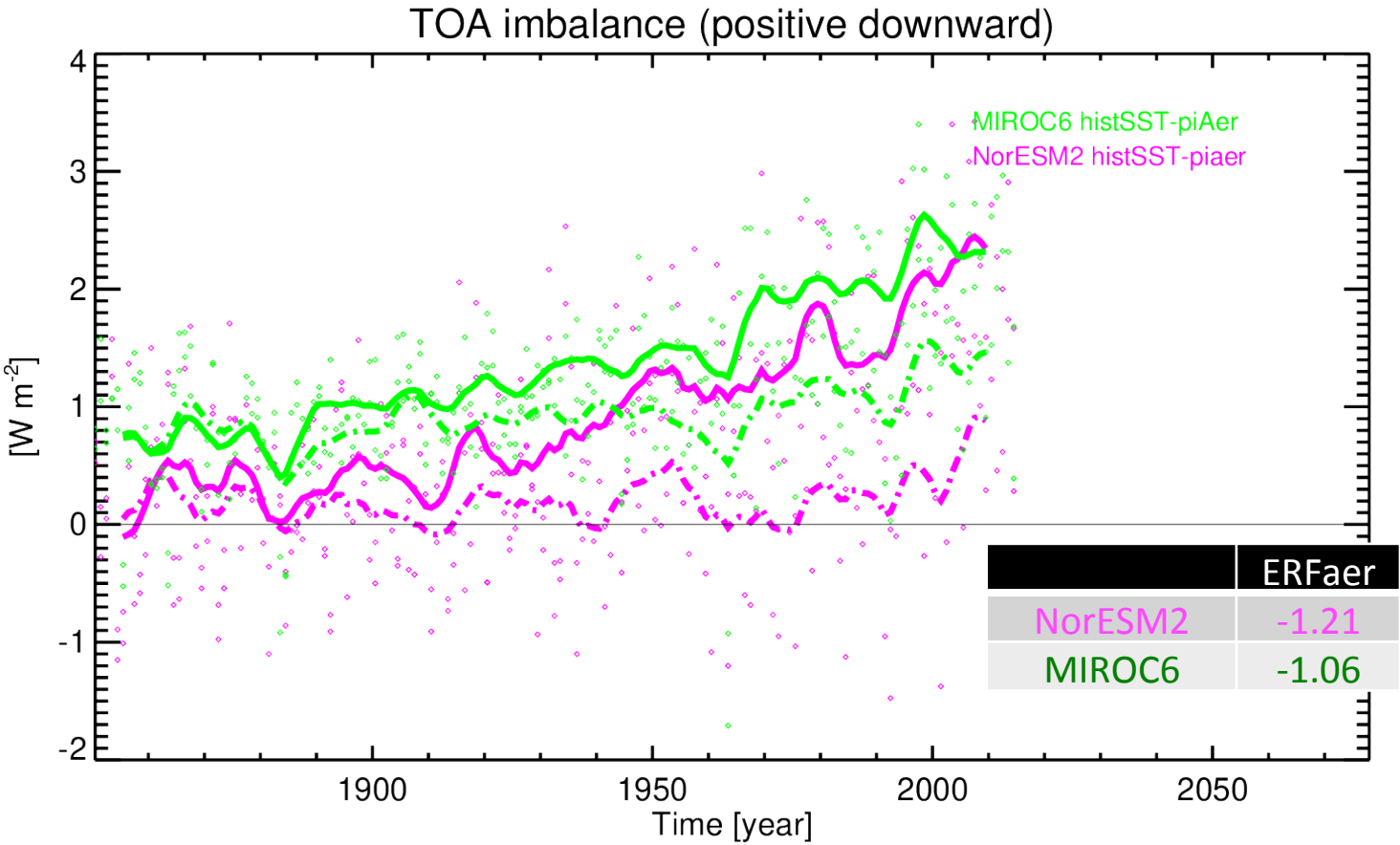
- Remark

All models have offset in 1850 (fixed-SST histSST is not in balance in 1850)



AerChemMIP :
PI aerosol forcing / all other forcings historical

- Simulations :
- histSST-piAer (full line)
- and histSST (dashed line)



	ERFaer
NorESM2	-1.21
MIROC6	-1.06

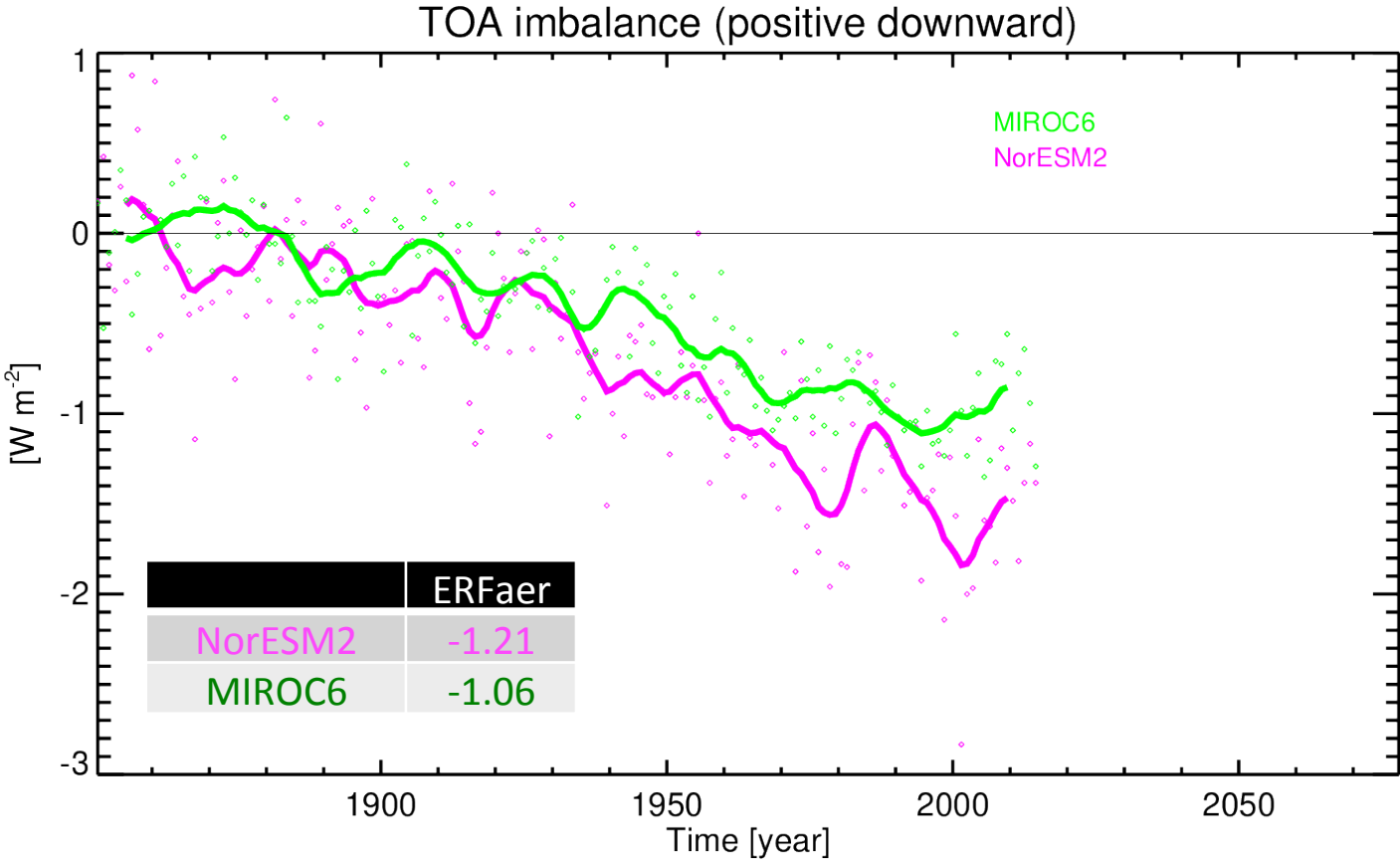
AerChemMIP : evolving aerosol ERF

Simulations :

histSST –
histSST-piaer

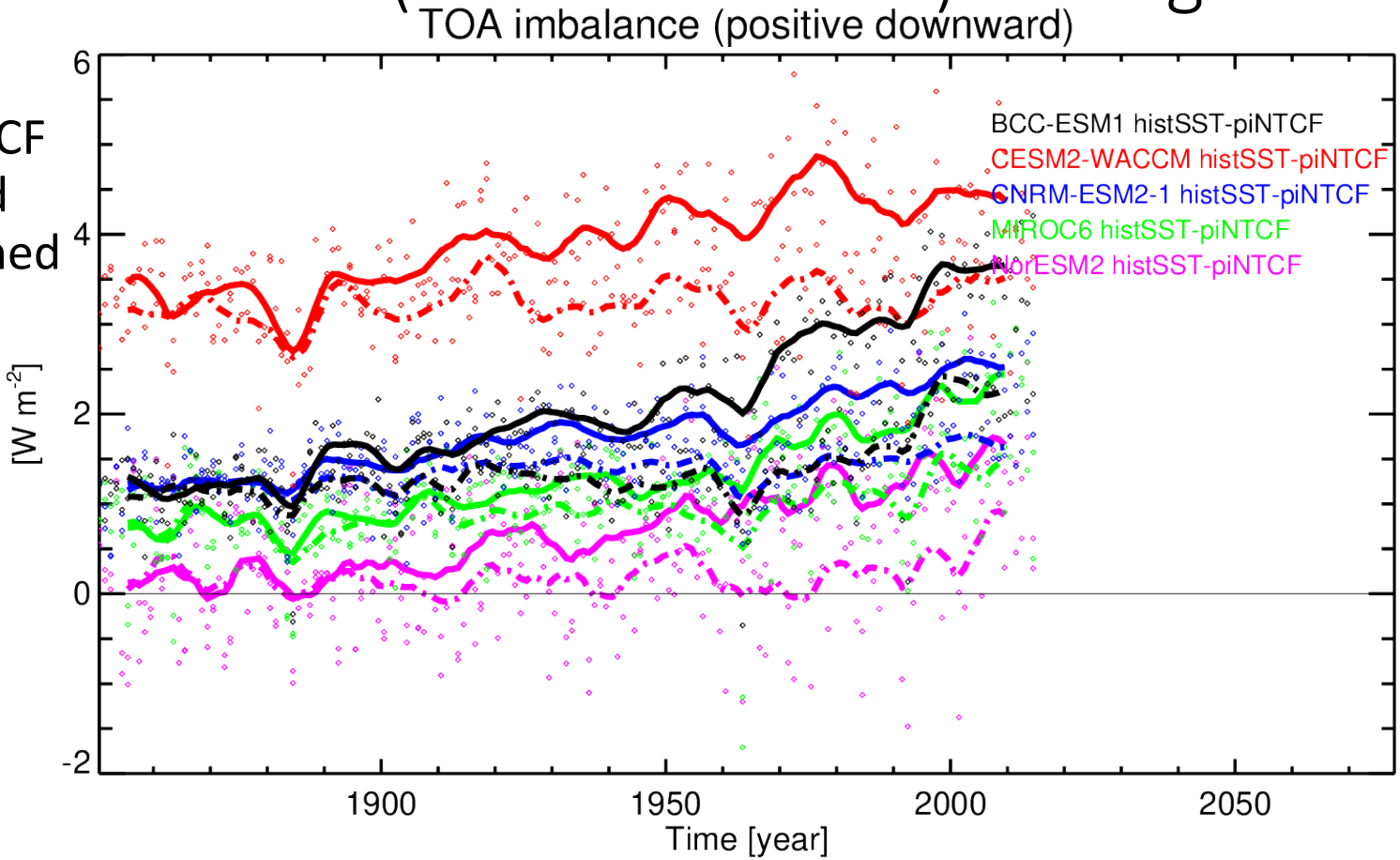
Remarks

- Volcanic signal removed
- large variability
- Larger than ERF?



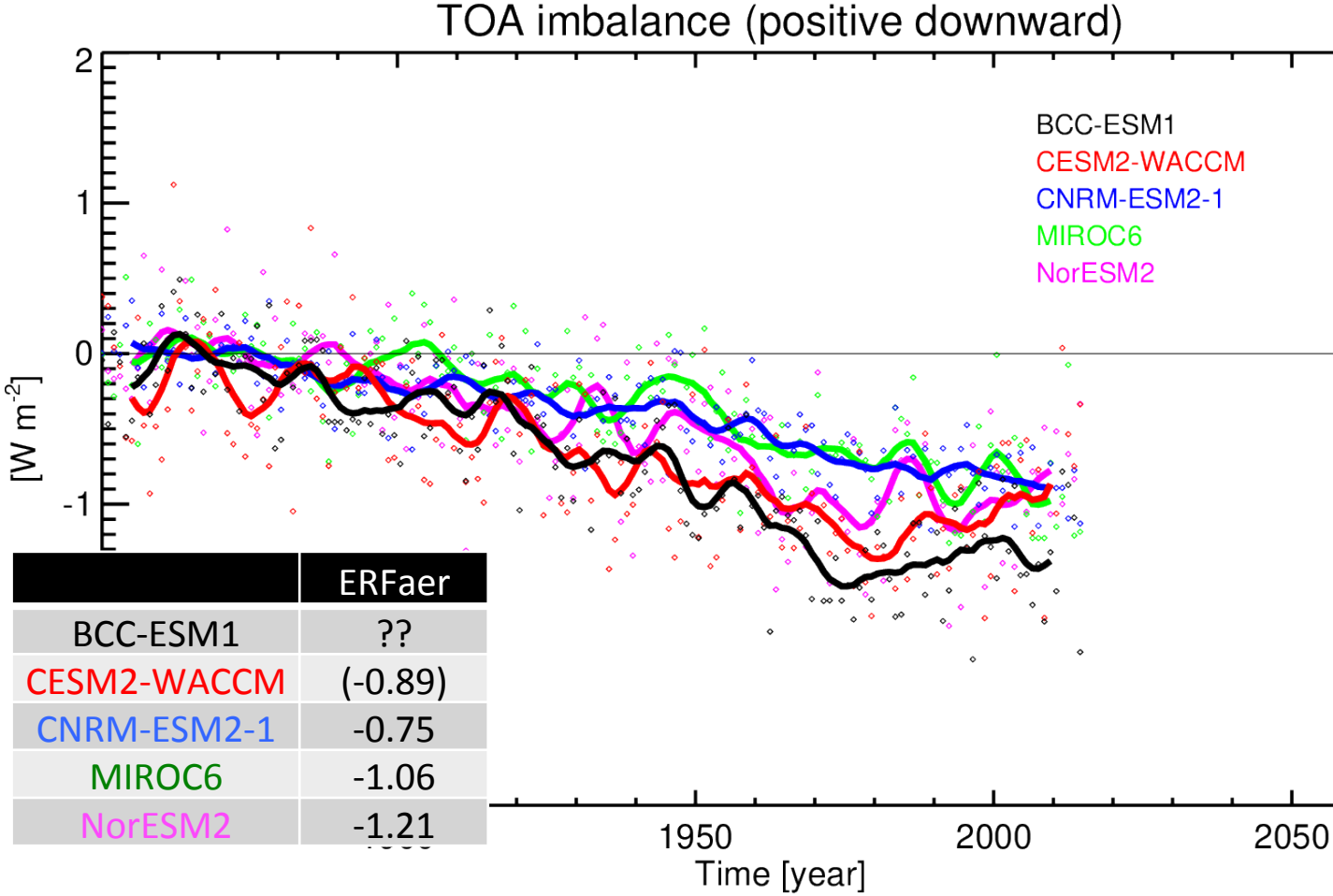
AerChemMIP : NTCF (aerosol + ozone) forcing

- Simulations : histSST-piNTCF (full line) and histSST (dashed line)



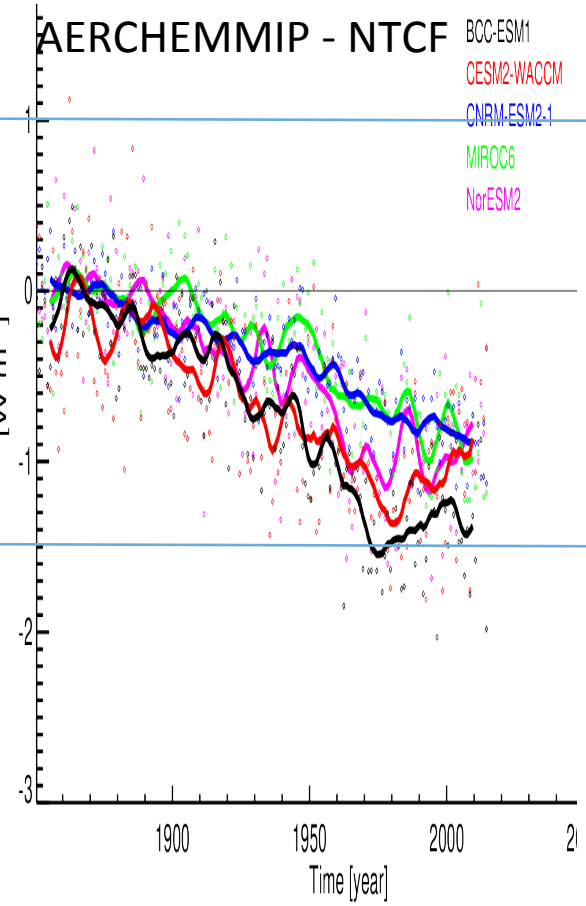
AerChemMIP : NTCF (aerosol + ozone) ERF

- Simulations
  histSST –
  histSST-piNTCF

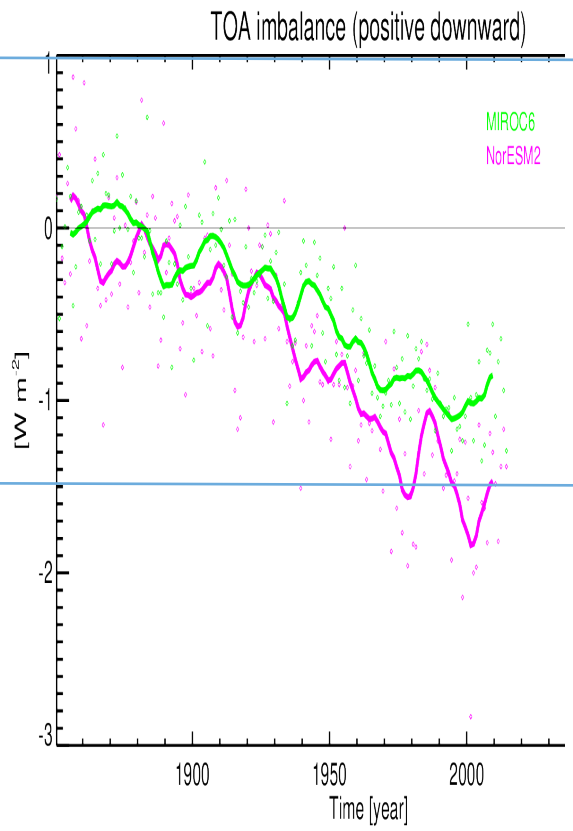


	ERFaer
BCC-ESM1	??
CESM2-WACCM	(-0.89)
CNRM-ESM2-1	-0.75
MIROC6	-1.06
NorESM2	-1.21

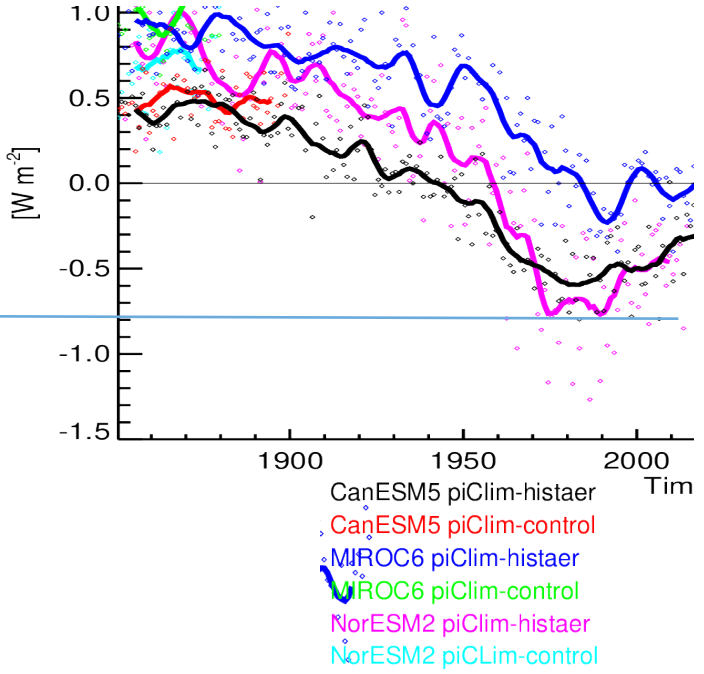
AERCHEMMIP - NTCF



AERCHEMMIP - AEROSOL



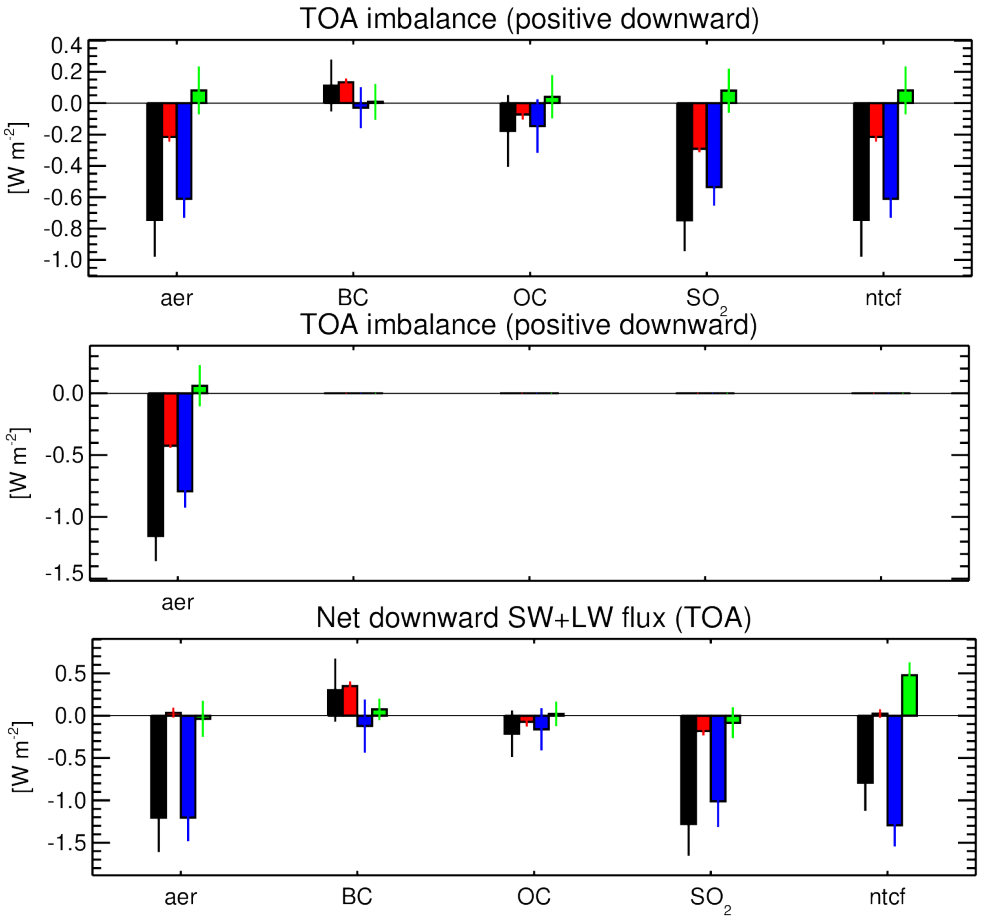
RFMIP- AEROSOL



Split of 2014 aerosol ERF : Ghan [2013, ACP]

Aerosol ERF = direct RF + cloud RF + surface albedo forcing

- CNRM-ESM2-1
- CNRM-CM6-1
- NorESM2



Split of historical aerosol ERF : Ghan [2013, ACP]

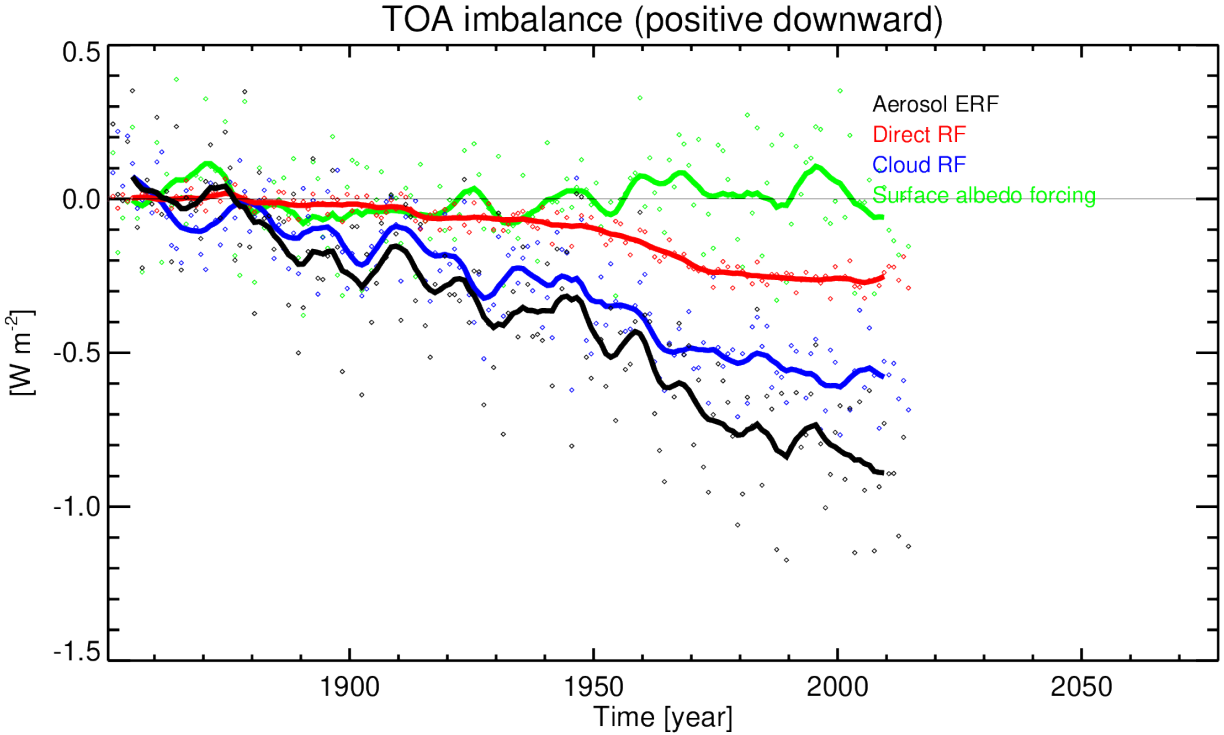
- Simulations :

histSST – hist-piNTCF

- Model :

CNRM-ESM2-1

- Aerosol ERF = direct RF + cloud RF + surface albedo forcing



https://wiki.met.no/aerocom/aerchemmip/start

AerChemMIP and RF MIP paper outline (status 26.Aug 2019):
Short note on planned papers
The deadline for paper submission for it to be cited in AR6 is December 31, 2019.

Further AerChemMIP Information:
AerChemMIP GMD paper Collins et al. (2017)
Multimodel AerChemMIP Status (google sheet courtesy Fiona O'Connor)
Download AerchemMIP Data from ESGF, tutorial on how to download data from ESGF
ESGF CMIP6 AerChemMIP Data Holdings
AerChemMIP experiments via ES-DOC
Get Model information via ES-DOC (choose Model under Document Type to see select the model for which information is needed)
EXCEL tables of AerChemMIP data request
AerChemMIP email list
Frequently Asked Questions

Conclusions & Outlook

- Consistent ERF in several models (Aerosol 1 W m-2)
- Evolving ERF shows slightly larger aerosol ERF in 2014
- NTCF impact large until 1990 ? GHG impact only after ??

⇒ Completion of workup, December 2019...

⇒ Link to evaluation of optical properties, “Control” properties (life time, vertical distritution, SSA, CDNC, loads, forcing efficiencies)

⇒ Temporal resolution of Forcing history ?

⇒ Best estimate of aerosol forcing history TOA, surface