



CMIP6 Analysis Online Poster Seminar

11.00-12.00 Monday 20 April



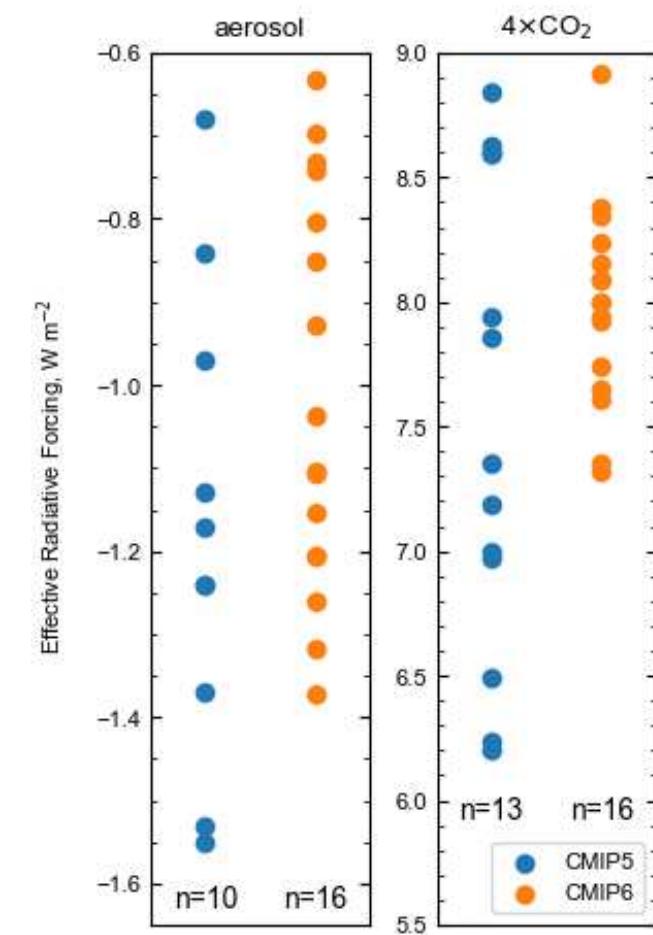
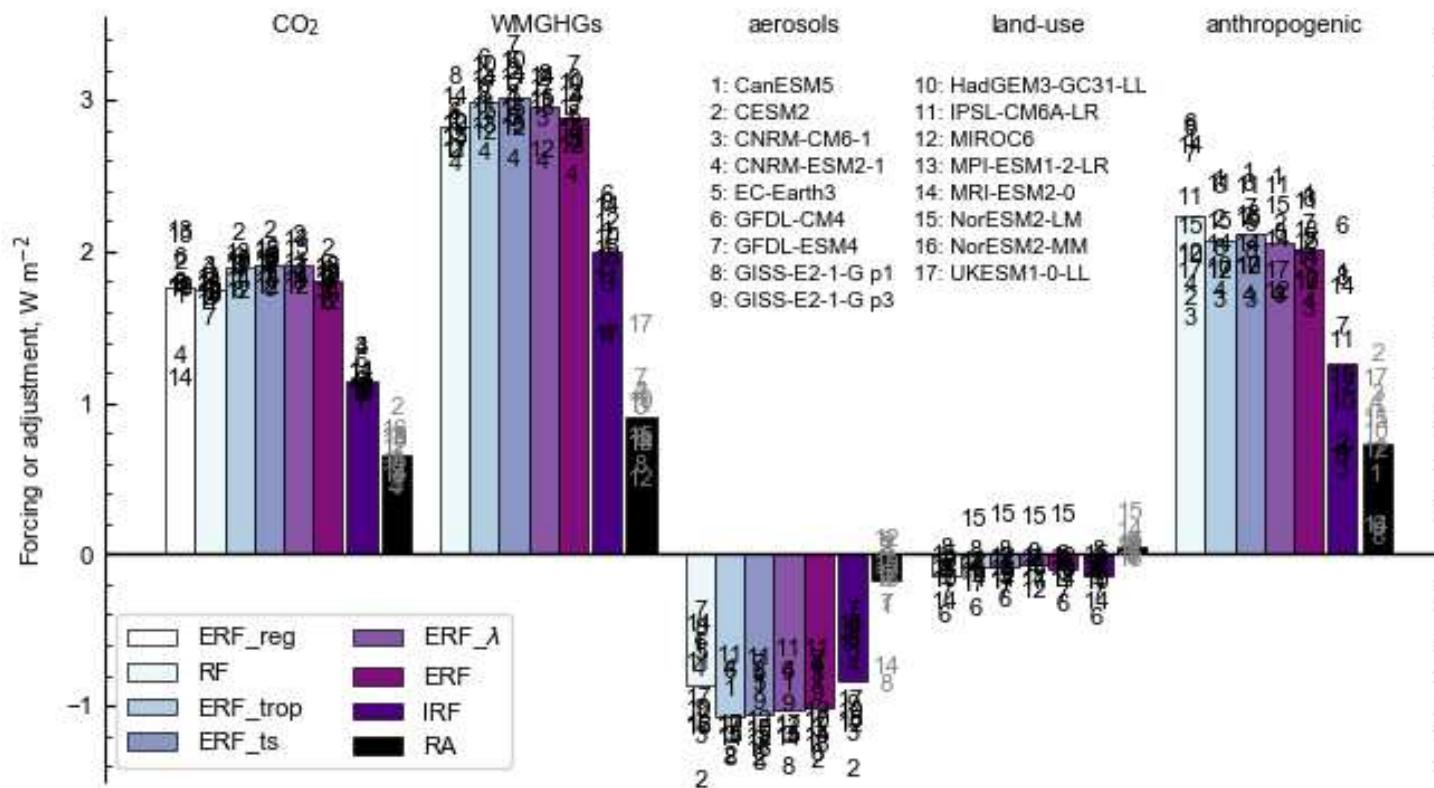


Chris Smith
University of Leeds

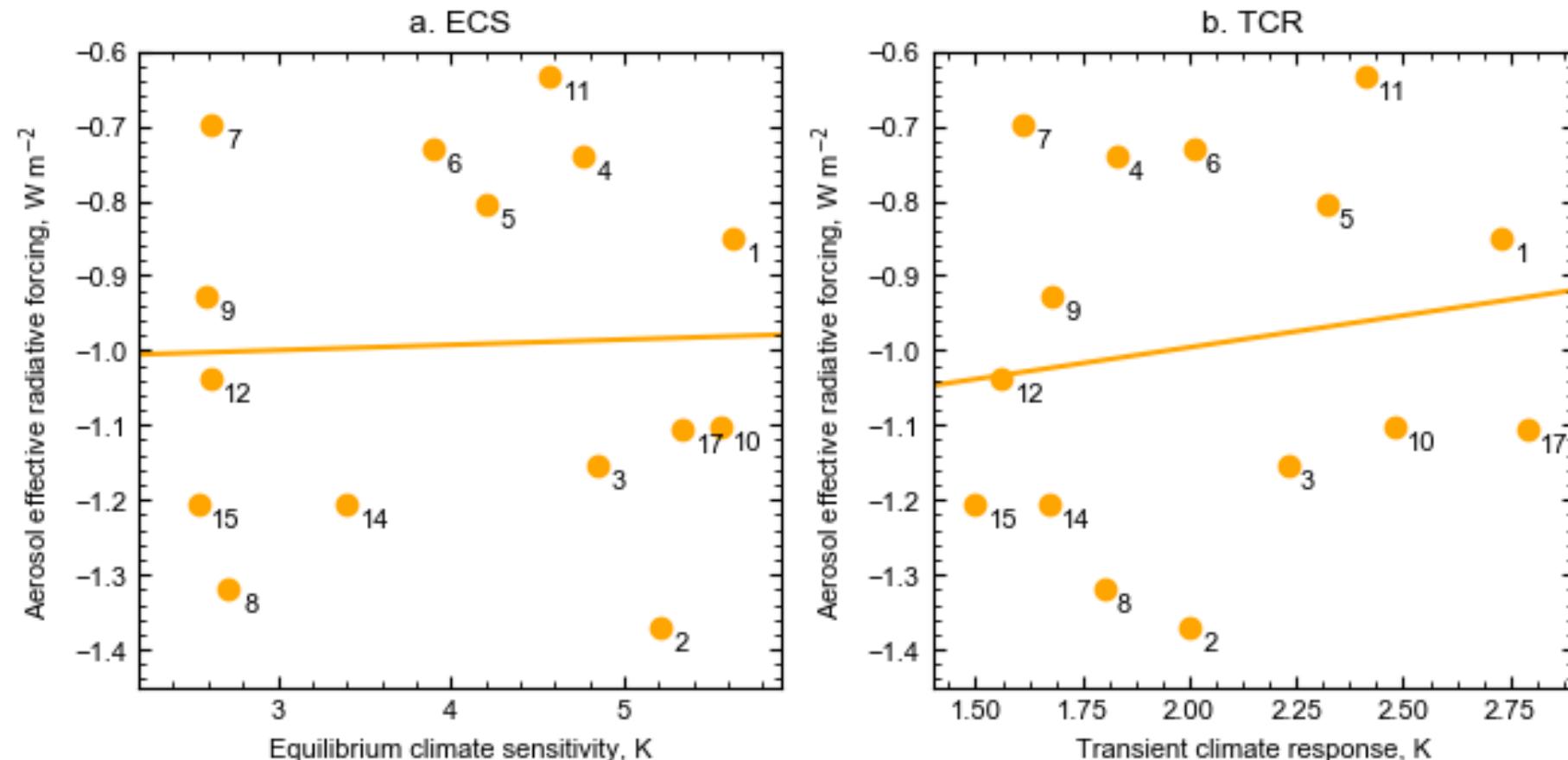


Effective Radiative Forcing and adjustments in CMIP6 models

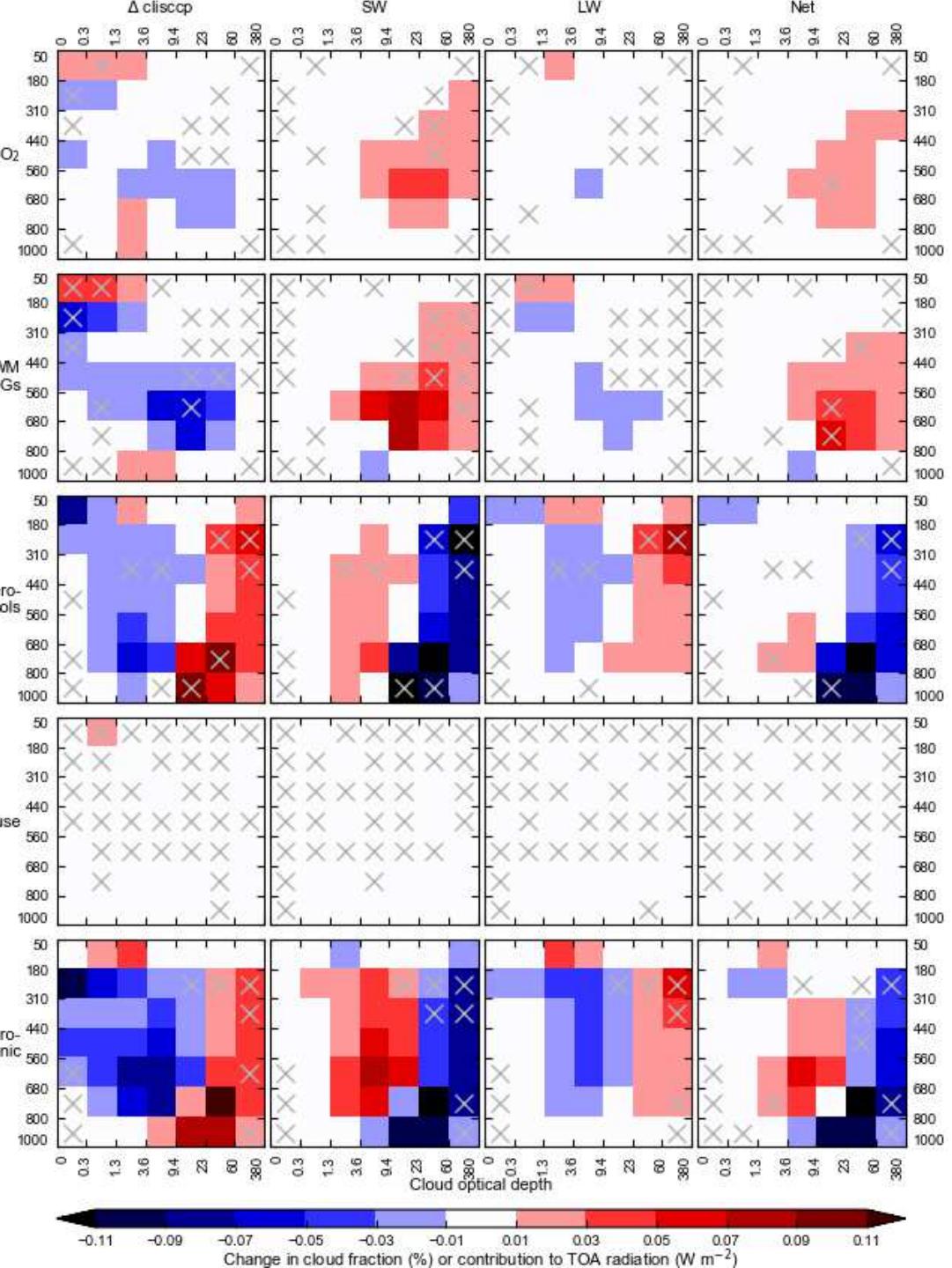
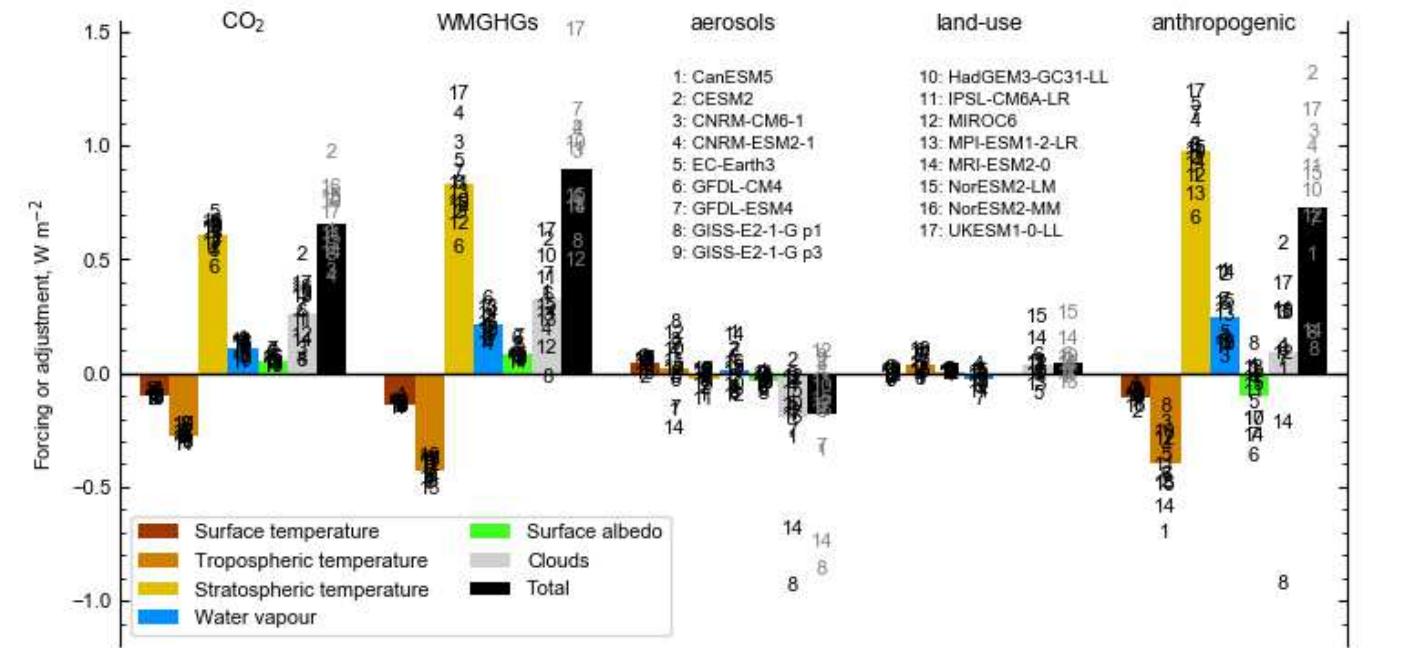
- Good participation from community: 16 models from 12 groups for 6× 30yr time slices
- Radiative Forcing Model Intercomparison Project (RFMIP) tier I: ERF from 4×CO₂ and present-day GHGs, aerosols, land use and total anthropogenic
- ERF is better constrained in CMIP6 compared to CMIP5



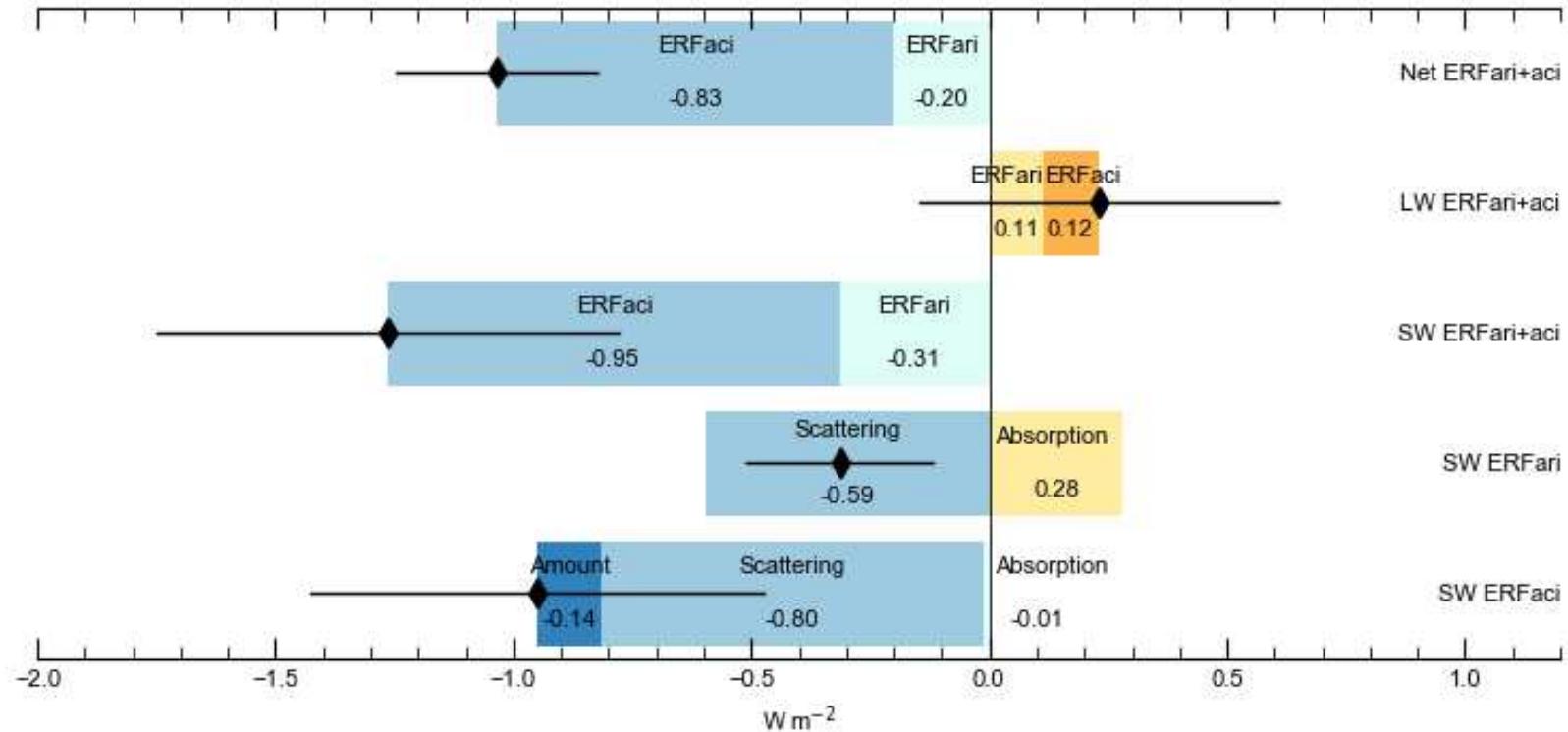
- However, aerosol forcing does not constrain climate sensitivity.
- The corollary of this is that modelling groups are not using correspondence of their CMIP historical runs to observed temperature as an explicit tuning constraint.
- We would expect a significant negative correlation between aerosol ERF and TCR especially.



- Using radiative kernels we can diagnose [rapid] adjustments.
- Many models included the ISCCP simulator diagnostics, allowing insights into how clouds behave.
- For greenhouse gases, stratospheric adjustments dominate, but tropospheric adjustments are significant. This justifies use of ERF over RF.



- We can diagnose the aerosol-radiation and aerosol-cloud interaction components of ERF (ERFaci and ERFari) using the Approximate Partial Radiative Perturbation method
- Aerosol forcing is $-1.03 (\pm 0.22) \text{ W m}^{-2}$, made up of -0.20 W m^{-2} ERFaci and -0.83 W m^{-2} ERFari
- **One key conclusion:** GCM aerosol forcing is less negative and more constrained than CMIP5, and does not explain high ECS in CMIP6 models.



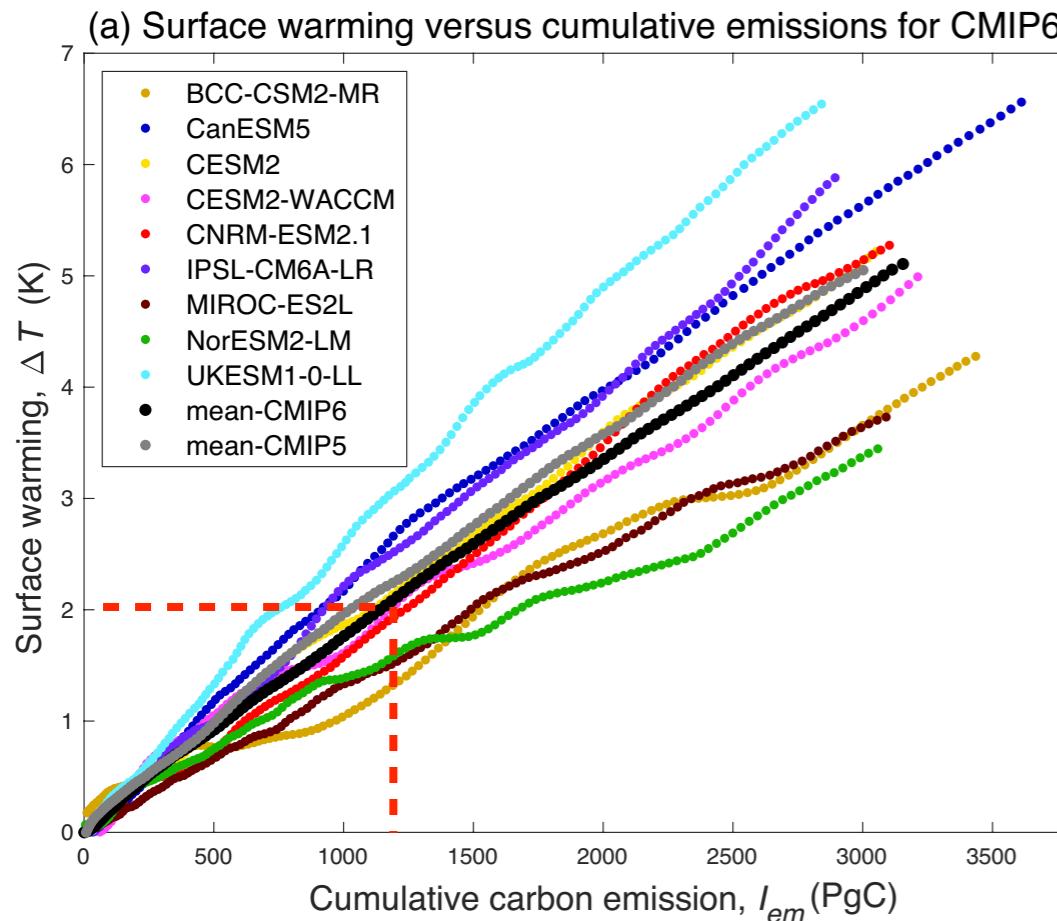


Ric Williams
University of Liverpool



Controls on the Transient Climate Response to Emissions

Ric Williams (Liverpool), Paulo Ceppi (Imperial) & Anna Katavouta (NOC, Liverpool)



diagnose surface warming response from 9 CMIP6 & 7 CMIP5 models for a 1% annual increase in CO₂ over 140 years

$\Delta T(t)$ = change in global-mean surface air temperature

$I_{em}(t)$ = cumulative carbon emission (PgC)

A climate metric: *the Transient Climate Response to Emissions*

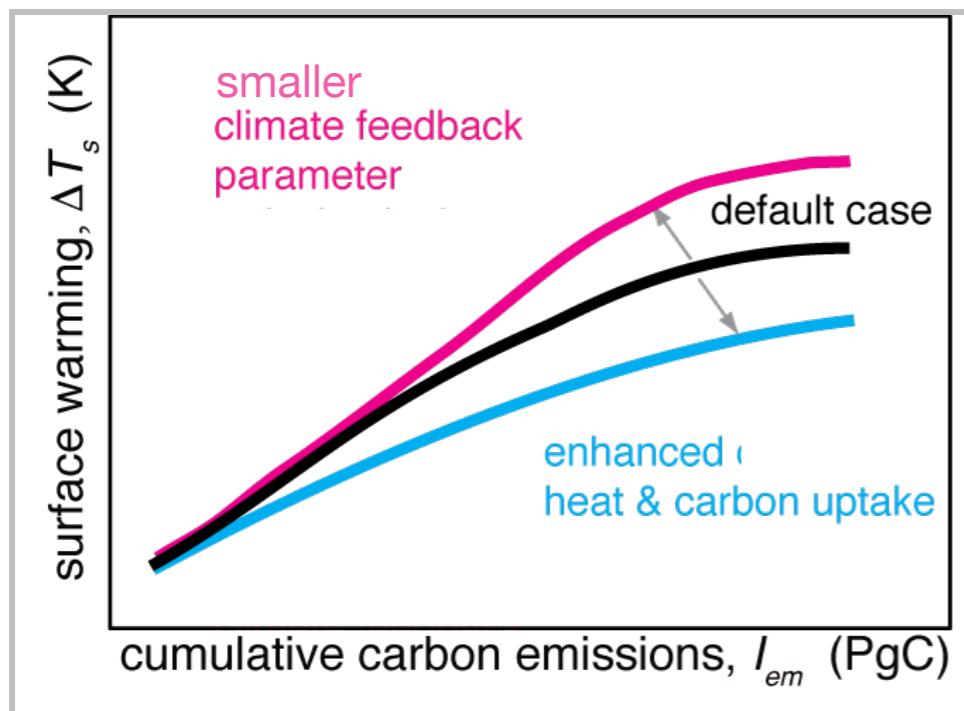
$$\text{TCRE} \equiv \frac{\Delta T(t)}{I_{em}(t)}$$

To gain insight, connect the TCRE to radiative forcing

$$\text{TCRE} = \frac{\Delta T(t)}{I_{em}(t)} = \left(\frac{\Delta T(t)}{\Delta F(t)} \right) \left(\frac{\Delta F(t)}{I_{em}(t)} \right)$$

thermal response
from dependence of
surface warming on
radiative forcing

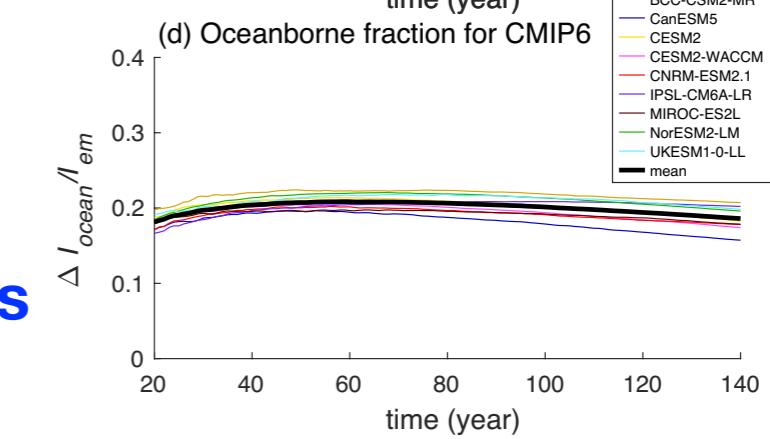
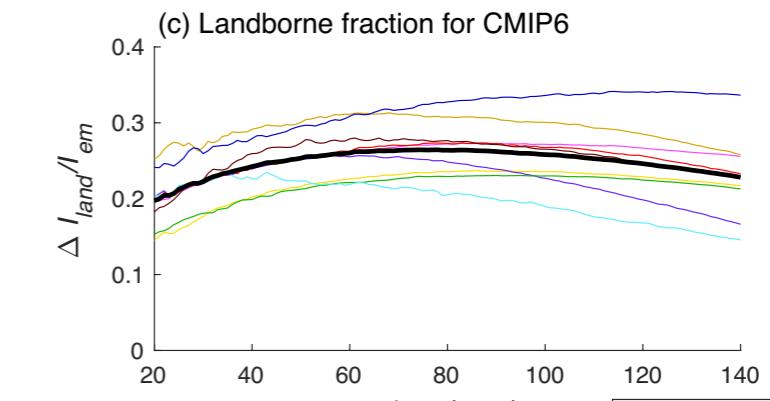
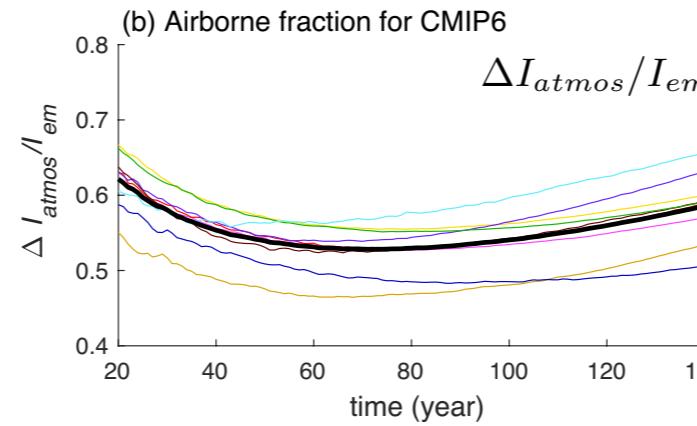
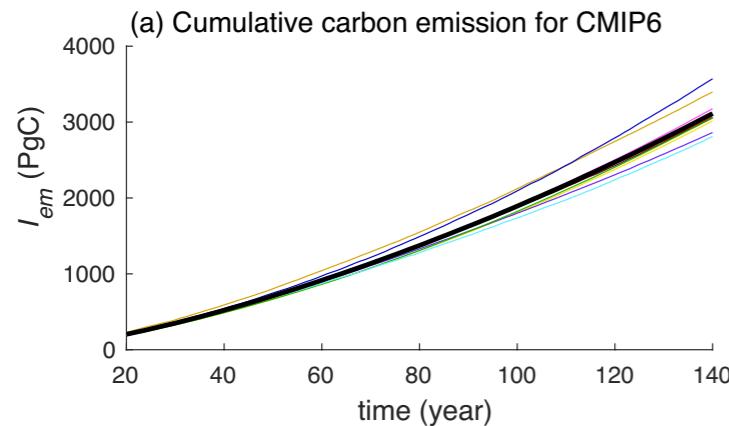
dependence of
radiative forcing on
carbon emissions



$\Delta F(t)$ = change in radiative forcing

Carbon view

$$I_{em}(t) = \Delta I_{atmos}(t) + \Delta I_{ocean}(t) + \Delta I_{ter}(t).$$



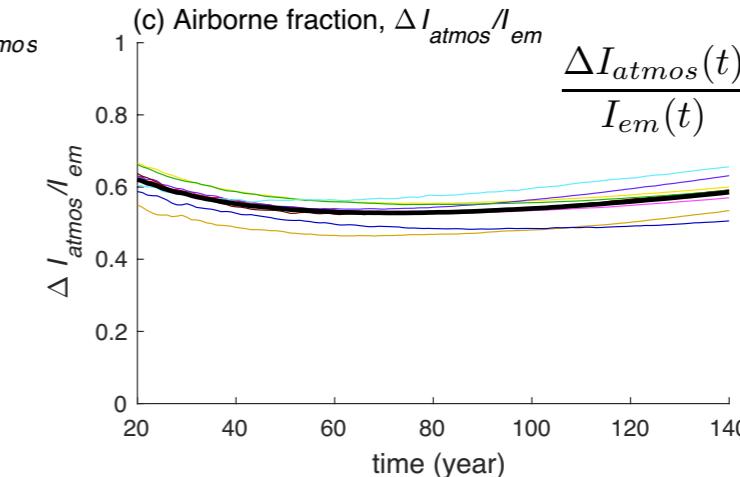
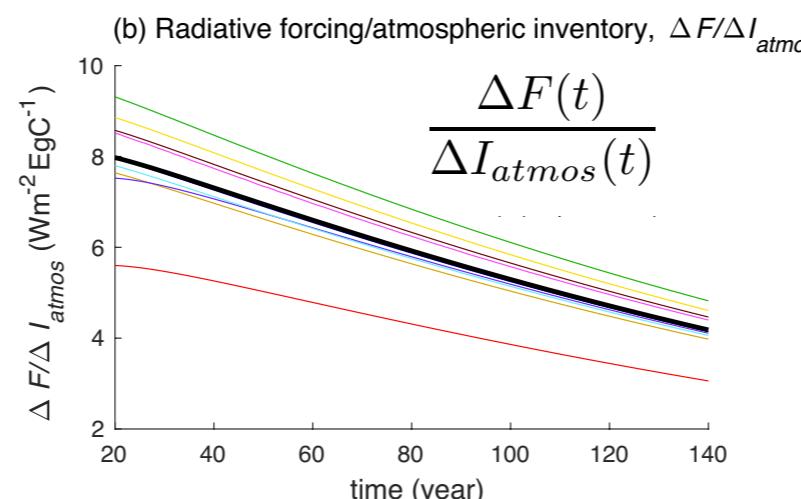
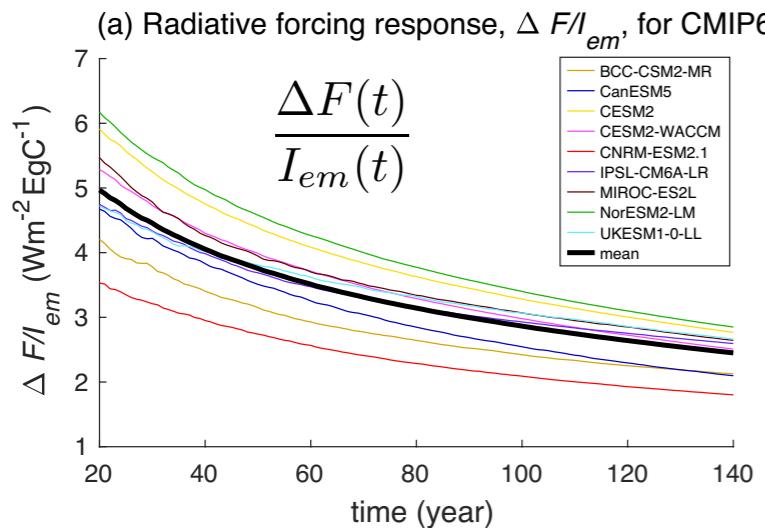
Dependence of radiative forcing on carbon emissions

dependence of radiative forcing on carbon emissions

$$\frac{\Delta F(t)}{I_{em}(t)} = \left(\frac{\Delta F(t)}{\Delta I_{atmos}(t)} \right) \left(\frac{\Delta I_{atmos}(t)}{I_{em}(t)} \right)$$

dependence of radiative forcing on atmospheric CO₂

airborne fraction



Key points:

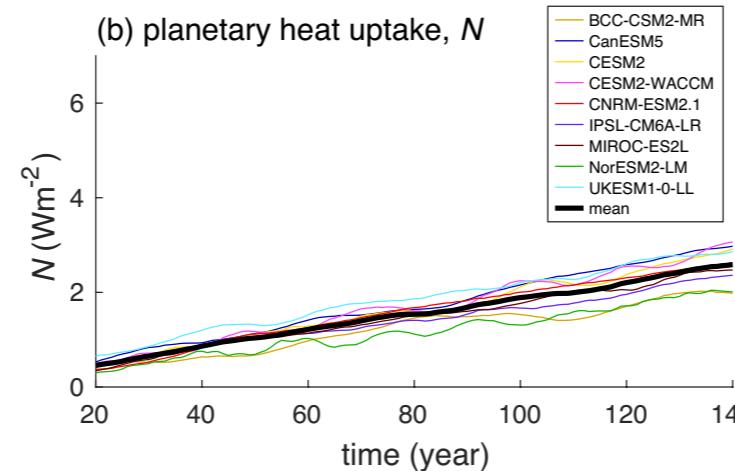
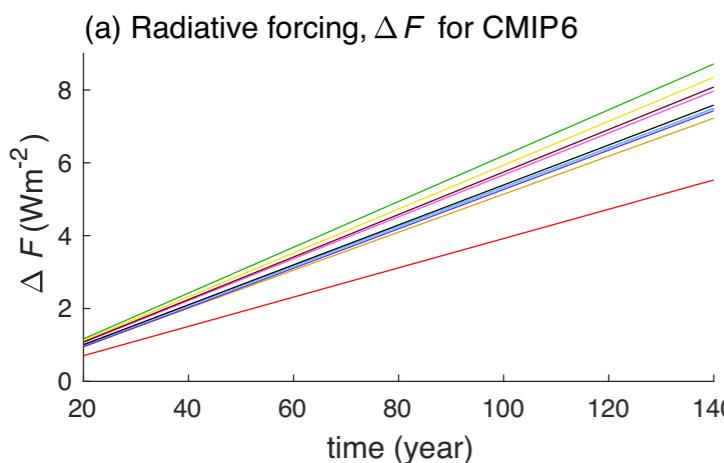
- radiative forcing dependence on atmospheric CO₂ declines in time due to saturating effect

$$\Delta F(t) = a \ln(\text{CO}_2(t)/\text{CO}_2(t_0))$$
- intermodel differences mainly from radiative forcing dependence

Thermal view

$$\Delta F(t) = \lambda(t)\Delta T(t) + N(t),$$

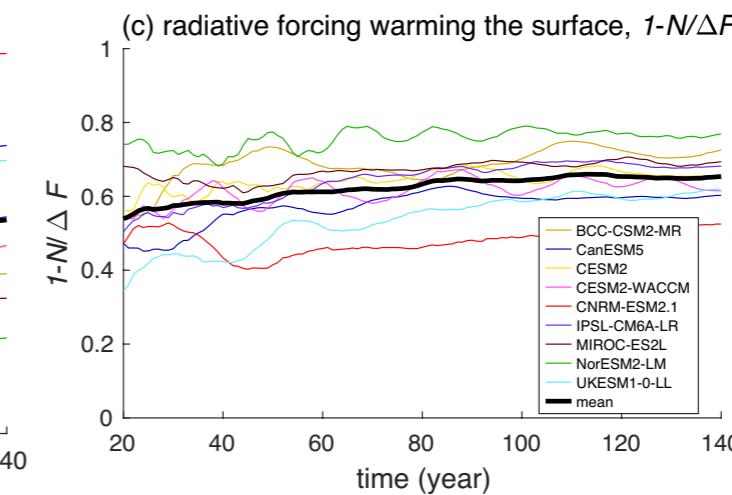
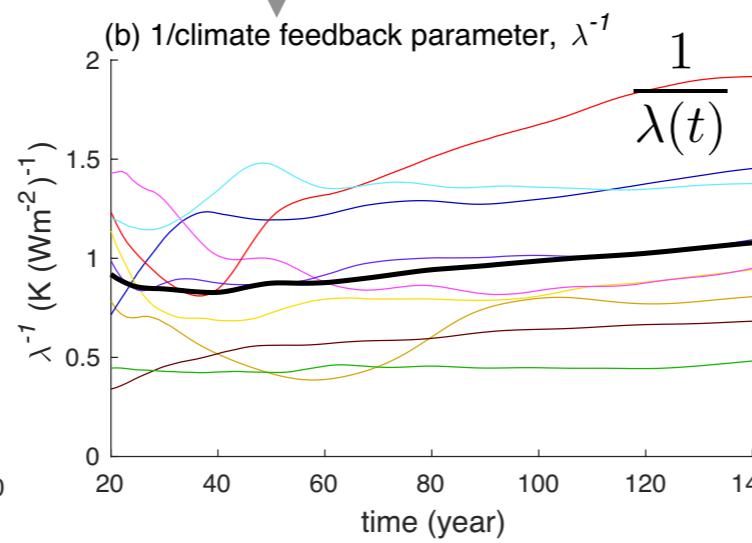
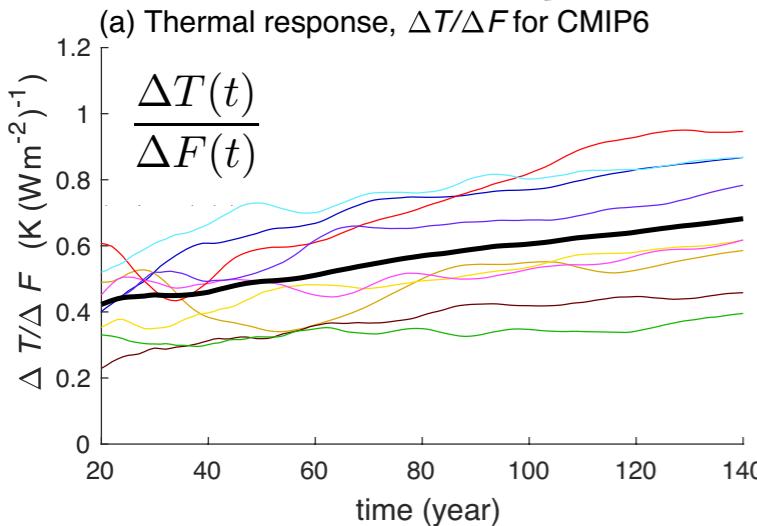
radiative forcing radiative response planetary heat uptake



Dependence of surface warming on radiative forcing

dependence of surface warming on radiative forcing

$$\frac{\Delta T(t)}{\Delta F(t)} = \frac{1}{\lambda(t)} \left(1 - \frac{N(t)}{\Delta F(t)} \right)$$



$$\left(1 - \frac{N(t)}{\Delta F(t)} \right)$$

Key points:

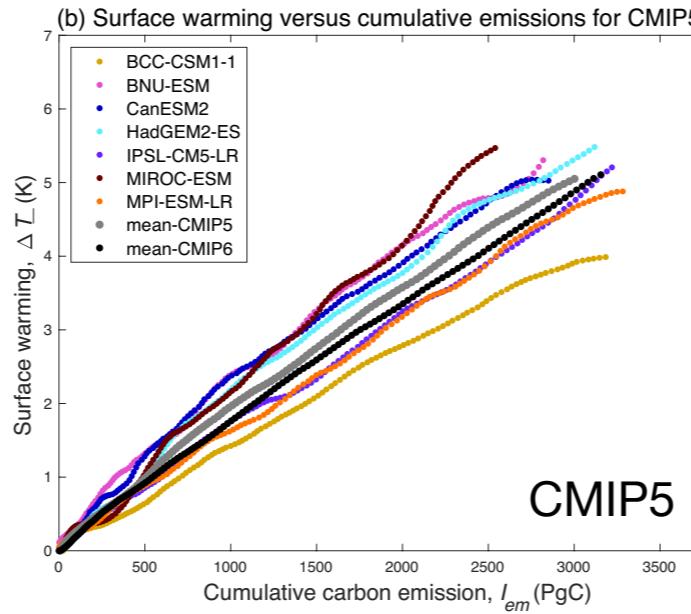
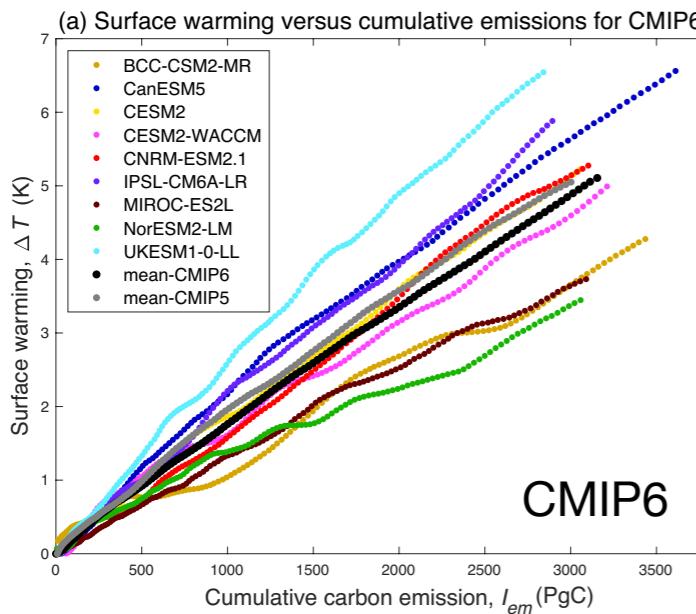
- surface warming dependence on radiative forcing increases in time due to decrease in climate feedback and decline in fraction of heat taken up by ocean interior
- intermodel differences mainly from differences in climate feedback parameter

$N(t)$ = planetary heat uptake from 1% annual CO₂ experiment

$\Delta F(t) = a \ln(\text{CO}_2(t)/\text{CO}_2(t_0))$
 a from abrupt 4xCO₂ experiment

$\lambda(t)$ = climate feedback parameter
from regression of radiative response
 $\Delta R(t)$ versus $\Delta T(t)$

CMIP6 & CMIP5 differences in Transient Climate Response to Emissions



$$\text{TCRE} = \frac{\Delta T(t)}{I_{em}(t)} :$$

$$= \left(\frac{\Delta T(t)}{\Delta F(t)} \right) \left(\frac{\Delta F(t)}{\Delta I_{atmos}(t)} \right) \left(\frac{\Delta I_{atmos}(t)}{I_{em}(t)} \right)$$

thermal response

radiative dependence on atmospheric CO₂

airborne fraction

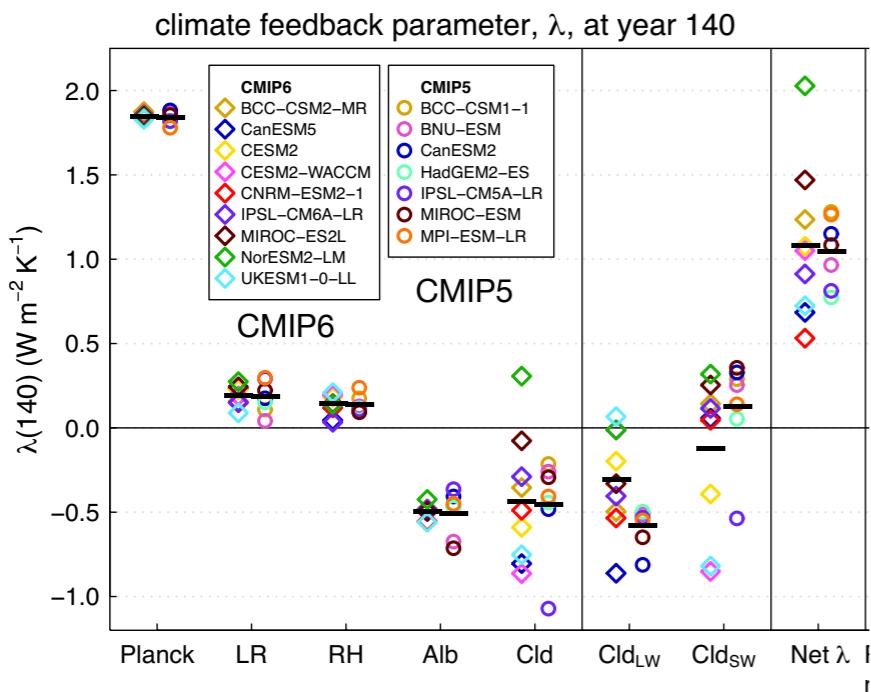


Table of relative standard deviation for TCRE components

	thermal response	airborne fraction
σ_x/\bar{x}	$\Delta T/\Delta F$ $\text{K}(\text{W m}^{-2})^{-1}$	$\Delta F/\Delta I_{atmos}$ $(\text{W m}^{-2})(\text{Eg C})^{-1}$
CMIP6	0.30	0.12
CMIP5	0.15	0.14
		$\Delta I_{atmos}/I_{em}$
		0.07
		0.10

Conclusions

- Intermodel differences in the TCRE are mainly due to the thermal response rather than the airborne fraction for 9 CMIP6 models
- Larger spread in thermal response due to climate feedback & ocean heat uptake
- Wider range in climate feedback from longwave and shortwave cloud effects



World Climate Research Programme

Femke Nijssse
University of Exeter



Constraining climate sensitivity:

Both:

- How much warmer would it be if CO₂ were doubled?

Equilibrium climate sensitivity (ECS):

- Quadruple CO₂
- Wait until it reaches equilibrium
- Divide temperature by 2.

Transient climate response (TCR):

- Increase CO₂ 1% per year
- Wait until it has doubled (70 years)
- Then take average over year 60-80

Motivation

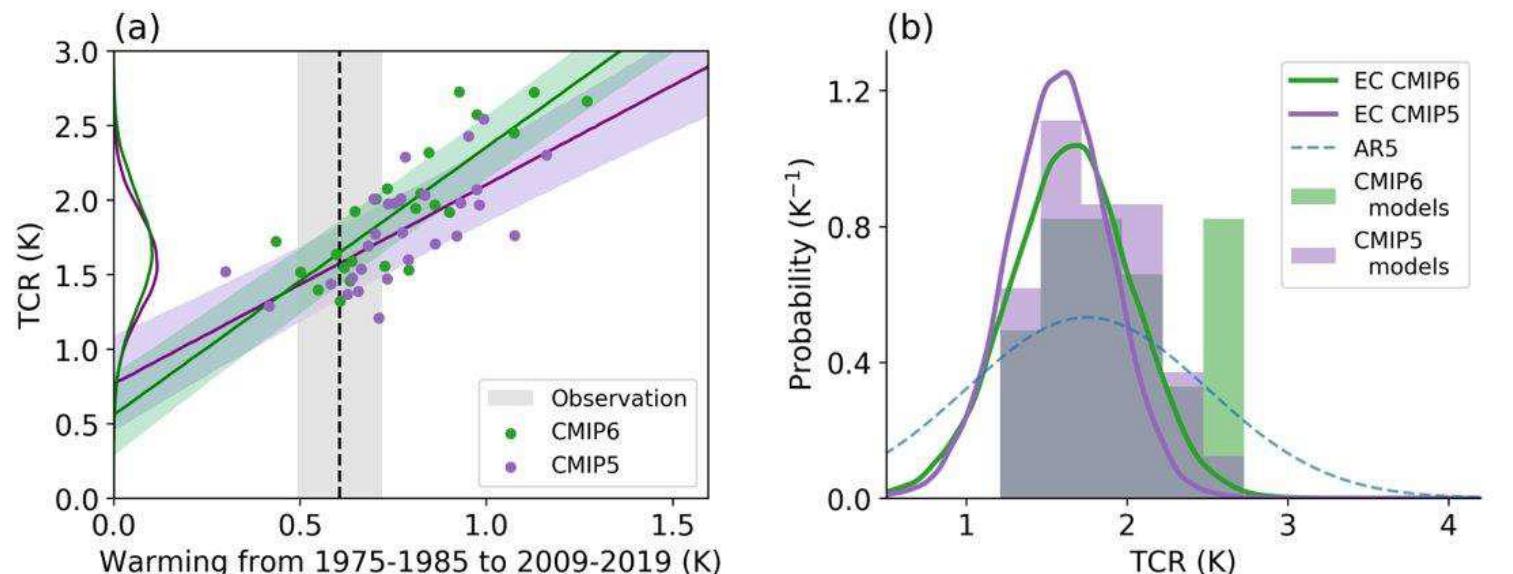
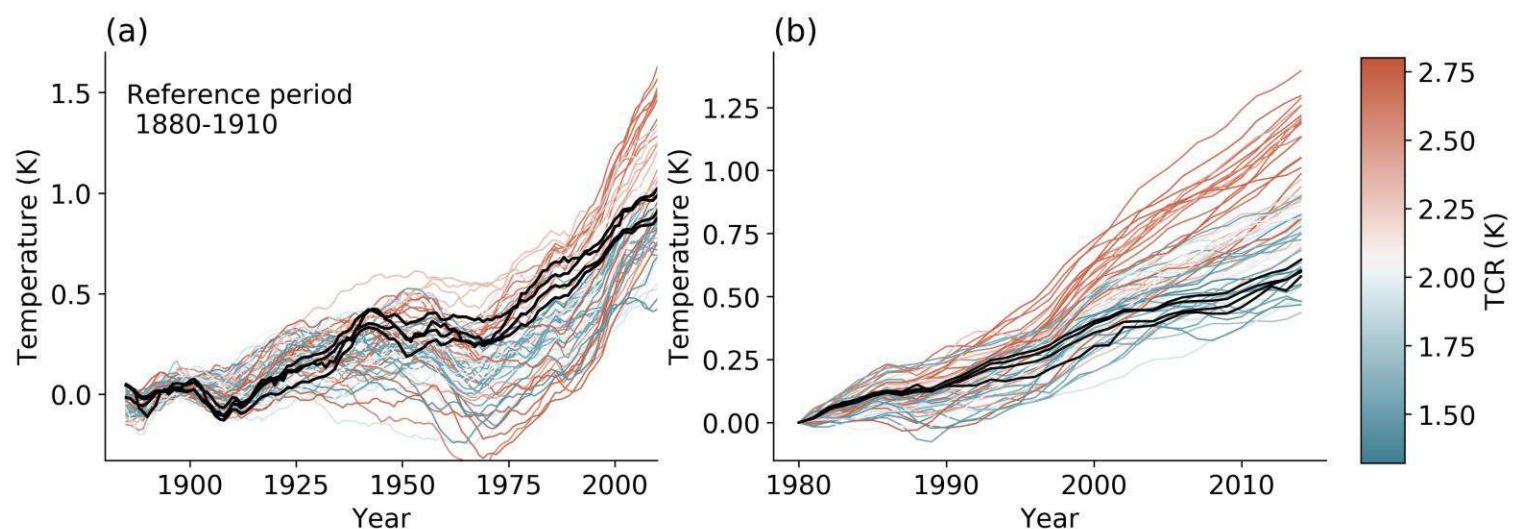
- Important for carbon budget
- Many impacts scale with climate sensitivity

Temperature evolution

- Entire period chaos
- Identified period: beautiful simplicity

Emergent constraint

- Observational error includes estimate of internal variability
- CMIP6 more variable.
- **TCR: 1.65 [5-95%, 1.02 - 2.10]**

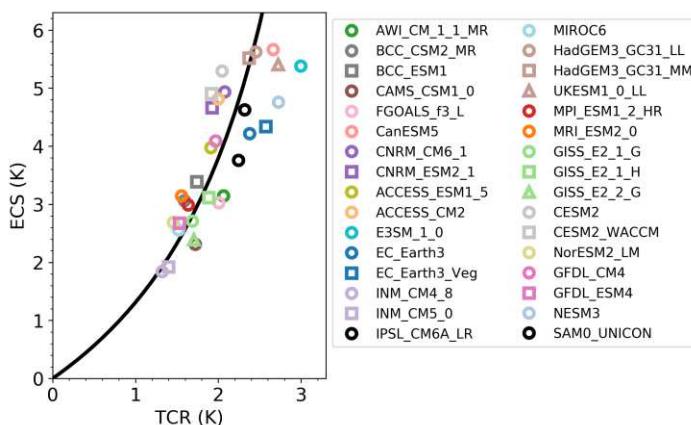


Internal variability explicit in observation.

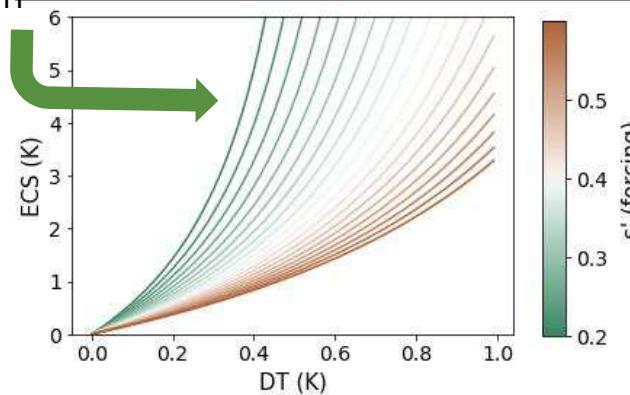
Emergent constraint on ECS: theory

Approximation	Valid when	Equations
Full equations		$C \frac{dT}{dt} = -\lambda T + Q - \epsilon \gamma (T - T_0)$ $C_0 \frac{dT_0}{dt} = \gamma (T - T_0)$
No deep ocean warming	< century	Algebra
Upper ocean equilibrium	> decade	Algebra
	s' : percentage doubling CO_2 e' : ocean heat uptake	ECS = $\Delta T / (s' - e' \Delta T)$

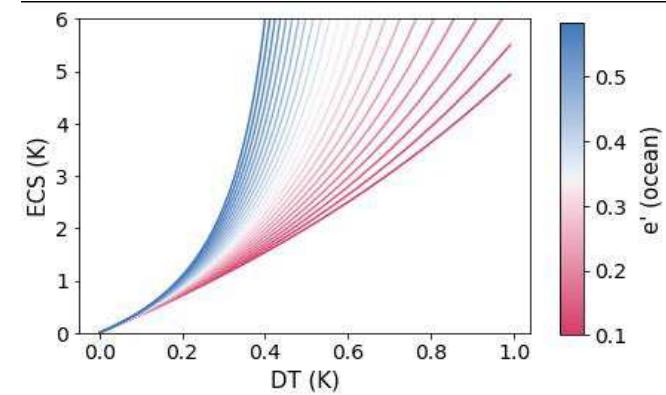
TCR vs ECS



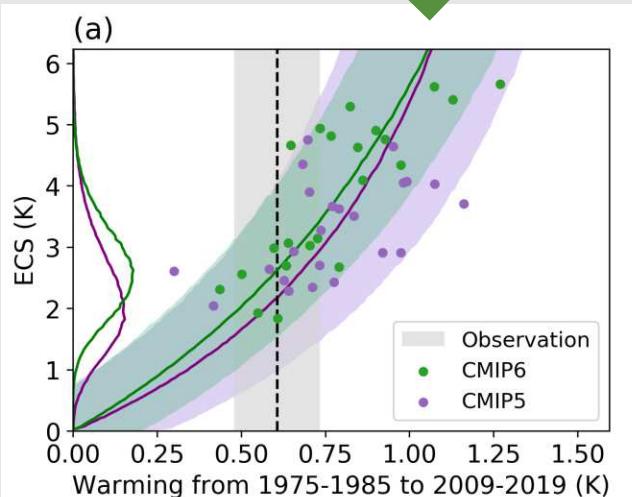
Steep: difficult to constrain



Behaviour parameters



Emergent constraint



Similar lines; but different parameters.

CMIP5: $e': 0.233$

$s' : 0.420$

CMIP6: $e': 0.138$

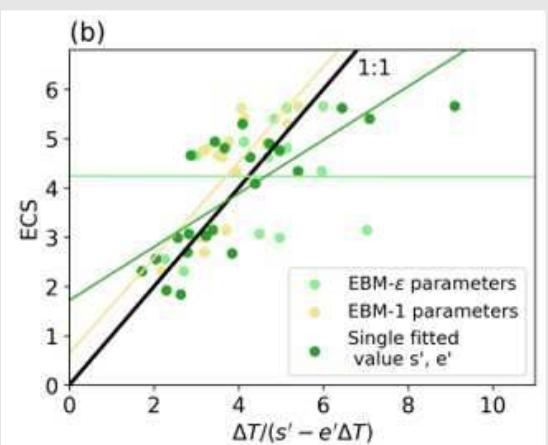
$s' : 0.315$

Model parameters:

CMIP6: $e': 0.240$

$s': 0.200$

Double check theory



If theory perfect, all points would be on 1:1 line.

Comparing two simple models

Possible to constraint further?

The emergent constraint:

- Final ECS CMIP5 weaker than CMIP6.
- Consistent upper bound
- ECS: 2.62 K [5-95%, 1.51 - 4.04]

Checking with respect to theory.

1. Taking model DT
2. fitted the ocean and forcing parameter per model
3. Put in equation and compare real ECS



World Climate Research Programme

Jeremy Walton
Met Office



UKESM CMIP6 data processing & availability - an update

Matthew Mizielski, Jeremy Walton, Piotr Florek, Stephen Haddad, Tim Andrews, Alejandro Bodas, Robin Chadwick, Mohit Dalvi, William Ingram, Andy Jones, Ron Kahana, Fraser Lott, Ruth McDonald, Nicky Stringer, Ranjini Swaminathan, Yongming Tang, Jonathan Tinker
jeremy.walton@metoffice.gov.uk



What / whither CMIP6 data?

- Produced by converting model output

- into standard (cf-netCDF) file format, e.g.

`ta_Amon_HadGEM3-GC31-LL_piControl_r1i1p1f1_gn_185001-185912.nc`

- for selected experiments, variables and frequencies

- Uploaded to (CEDA node of) ESGF

- <https://esgf-index1.ceda.ac.uk/search/cmip6-ceda/>

- searchable interface, downloadable data

- currently 63,832 datasets from UK (i.e. MOHC / NERC)

- *dataset* = **variable** on a **mip table** from a **realization** of an **experiment** run using a **model** by an institution

- CEDA node has UK data plus selected variables from other institutions

Which models & experiments?

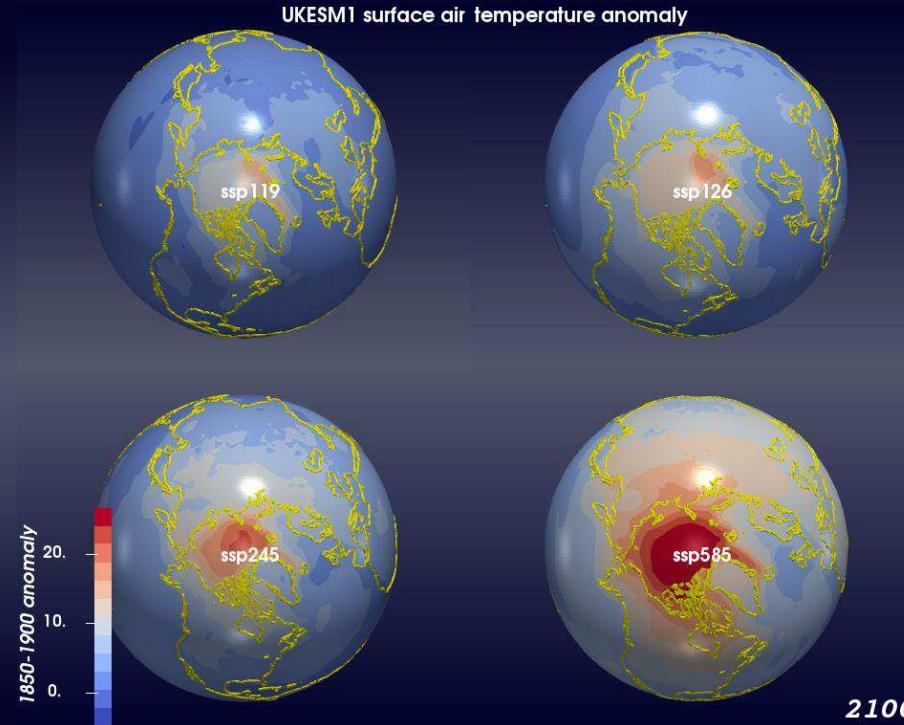
- UKESM1-N96ORCA1
 - DECK (piControl, 1%CO₂, 4xCO₂, AMIP) & historical (9 members)
 - ScenarioMIP (4 from Tier 1, 3 from Tier 2. 5 members)
 - some expts from AerChemMIP, C4MIP, LUMIP, GeoMIP, RFMIP
- HadGEM3-GC3.1-N96ORCA1
 - DECK (piControl, 1%CO₂, 4xCO₂, AMIP) & historical (4 members)
 - ScenarioMIP (3 from Tier 1. 4 members)
 - some expts from DAMIP, CFMIP, RFMIP, HighResMIP
- HadGEM3-GC3.1-N216ORCA025
 - DECK (piControl, 1%CO₂, 4xCO₂, AMIP) & historical (2 members)
- see also HighResMIP / PRIMAVERA

Which variables & frequencies?

- All variables that have been scientifically reviewed
 - no upload without (successful) review
- Currently monthly & daily frequencies only
 - sub-daily (6hr, 3hr, 1hr) to follow from end April 2020
 - for a subset of variables
- High-priority (requested) variables
 - IPCC list: 97% are available, with 8x 3hr variables to follow
 - ISIMIP3 list: 92% are available, with 2x 6hr, 3x 3hr variables to follow
 - other variables available on request

What other questions?

- Progress with data upload
 - ukesm.ac.uk/cmip6
- Model description
 - explore.esdoc.org
- Data errata
 - errata.esdoc.org
- Questions / requests to
 - cmip6@ukesm.ac.uk



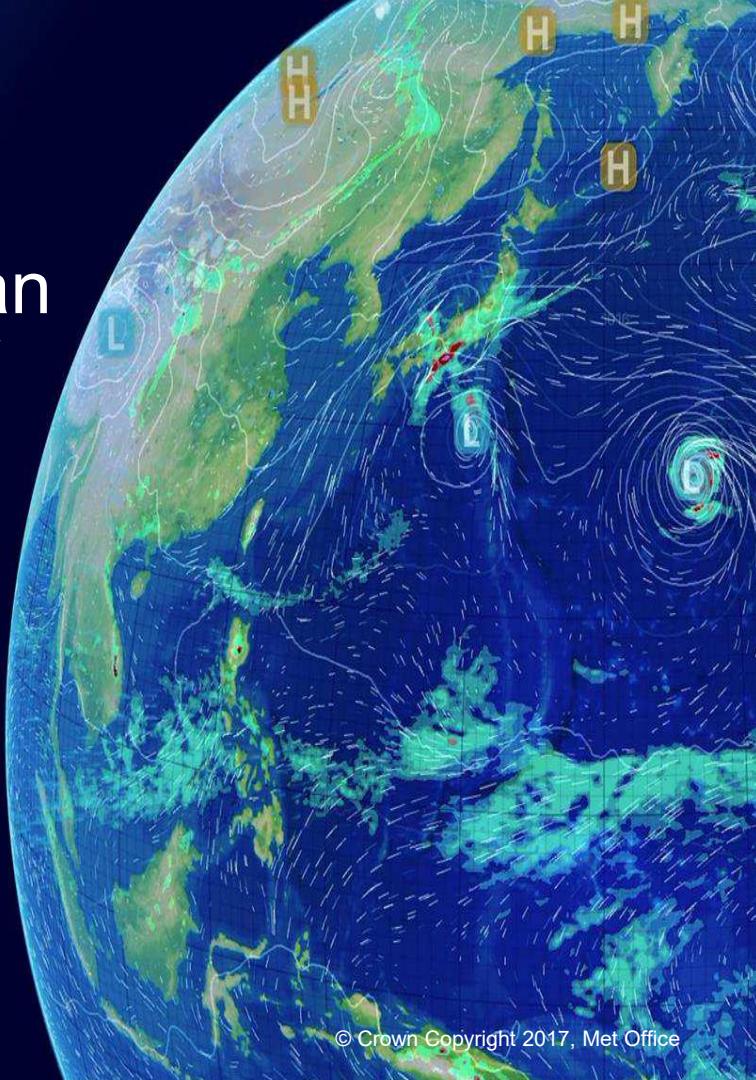


Laura Jackson
Met Office



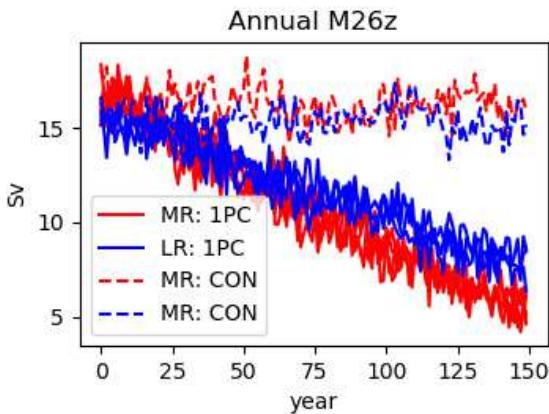
Impact of ocean resolution and mean state on the rate of AMOC weakening

L Jackson, M Roberts, H Hewitt,
D Iovino, T Koenigk, V Meccia,
C Roberts, Y Ruprich-Robert,
R Wood

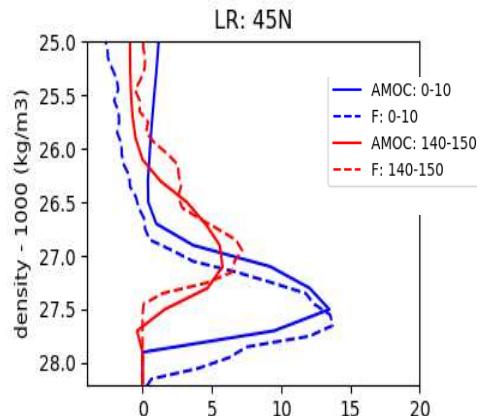


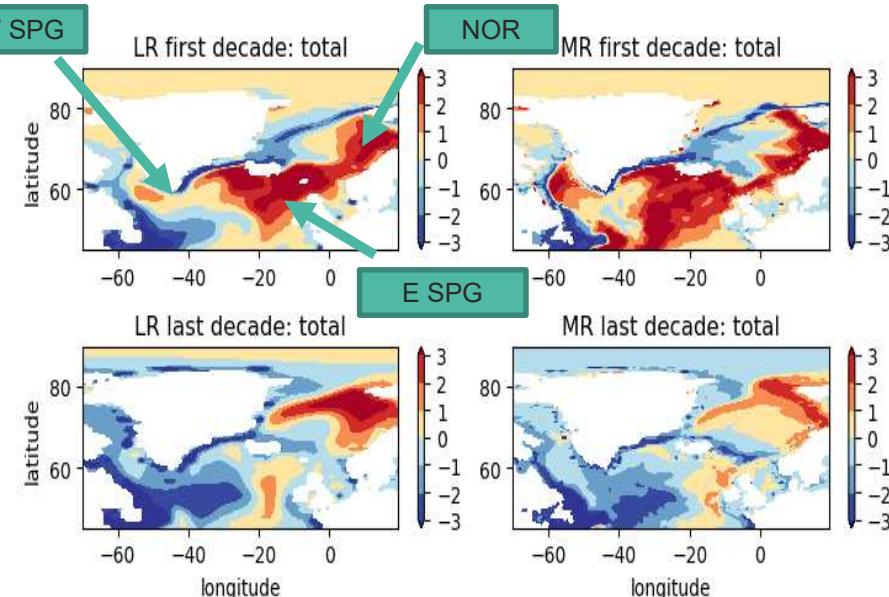
Use two Met Office CMIP6 models with differing horizontal resolution: HadGEM3-GC3.1LL and HadGEM3-GC3.1MM in 1% CO₂ increase scenarios.

MM has a stronger AMOC in the control and a greater weakening, both absolute weakening and fractional weakening.



The overturning circulation in density space is essentially equivalent to the transformation of density. Most transformation occurs through surface fluxes, so we can calculate the implied overturning from surface fluxes F .





Transformation of lighter waters in E subpolar gyre, and transformation of dense waters in Norwegian seas and W subpolar gyre.

MM has greater transformation in W SPG.

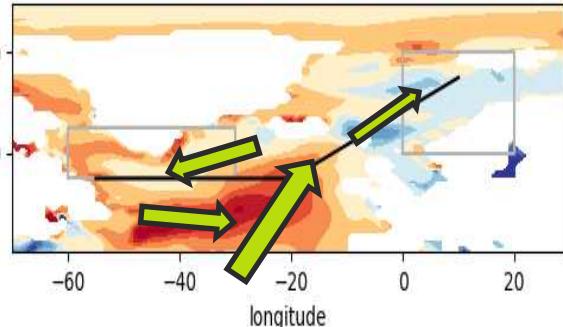
Transformation in W SPG stops with 1% run, but that in GIN seas move north.

Since MM has greater transformation in W SPG, when it stops it has a greater impact on the total AMOC weakening.

Reduced northwards heat transport reduces ocean-atmosphere temperature gradient which stops dense water transformation in W SPG.

MR-LR: saln at 200m

latitude

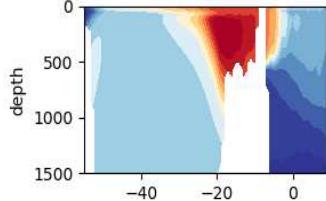


MM is warmer, more saline and denser in the W SPG than LL.

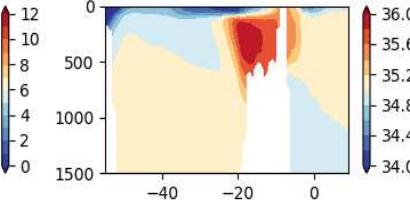
It also has a stronger subpolar gyre circulation and a more westerly North Atlantic current.

May lead to more warm, saline water subtropical water reaching the W SPG and hence more density transformation there.

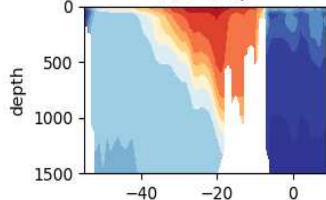
LR: temp



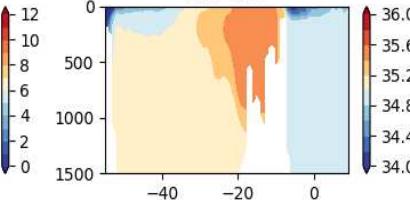
LR: saln



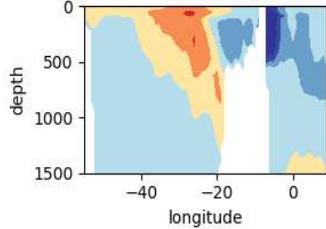
MR: temp



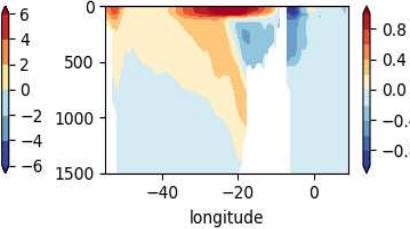
MR: saln



MR-LR: temp



MR-LR: saln

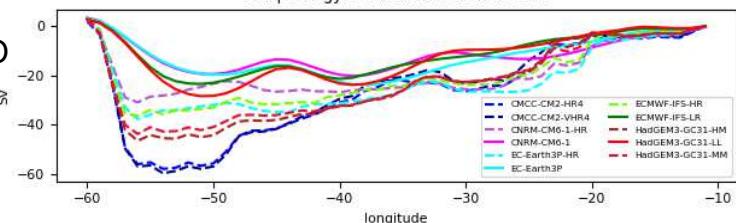
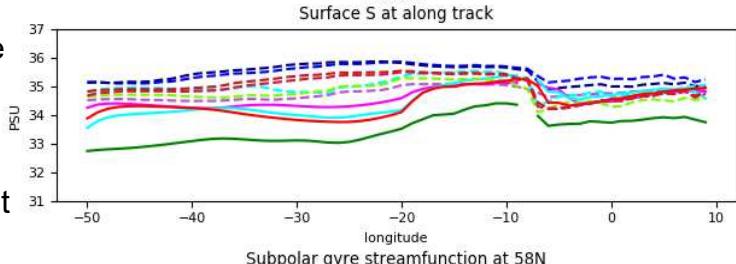
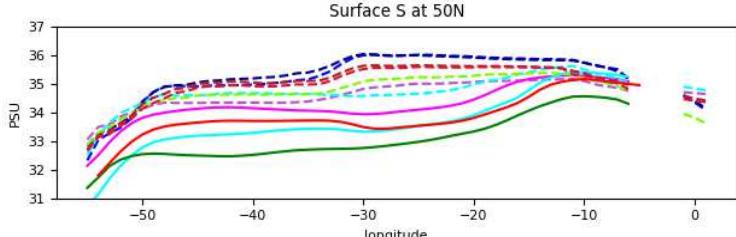
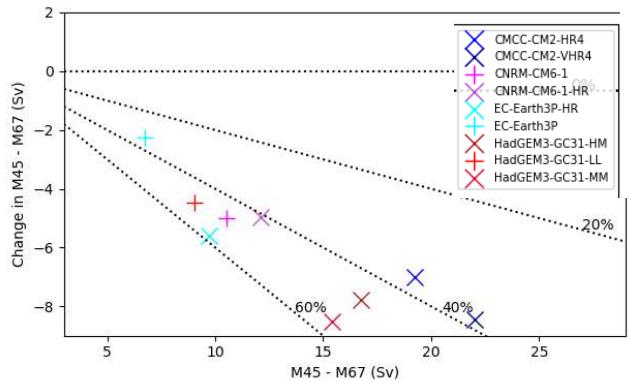


Use HighResMIP-PRIMAVERA ensemble.

Models with higher resolution have stronger AMOC and greater AMOC weakening in future scenario

Models with high resolution have stronger subpolar gyre, more westerly N Atlantic current and more saline W SPG.

However all use the same ocean model NEMO



Conclusions:

In these models resolution affects AMOC weakening because it influences the mean state and the mean state affects AMOC weakening.