Can the inter-model diversity of aerosol vertical profiles be explained by specific processes?

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25 September 2013

Introduction

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- Direct and indirect effects of aerosol depend on its vertical profile.
- Vertical profiles are relatively poorly constrained by observations.
- Considerable variation in vertical profiles between models.

Aims

- Investivate the diversity of vertical profiles in the AeroCom Phase II models.
- Compare this with the variation in a single model (HadGEM3–UKCA) when each aerosol process is switched off.
- Assess whether differences in these processes might explain the inter-model diversity.

AeroCom models

Model	Type	Reanalysis	Resolution δlat $\times$ δlon $\times$ levels	Aerosol	Oxidants	Components SO_4	SS	BC	OA	DU
CAM4–Oslo	GCM	free-running	$1.9^\circ \times 2.5^\circ \times 26$	tagged	prescribed	Y	Y	Y	Y	Y
CAM5.1	GCM	free-running	$1.9^\circ \times 2.5^\circ \times 30$	modal (2m)	mixed	Y	Y	Y	Y	Y
CanAM4–PAM	GCM	free-running	$3.8^\circ \times 3.7^\circ \times 35$	pcwise-lgnrmal (2m)	prescribed	Y	Y	Y	Y	Y
ECHAM5–HAM	GCM	ERA-Int 2006	$1.9^\circ \times 1.9^\circ \times 31$	modal (2m)	prescribed	Y	Y	Y	Y	Y
ECHAM5–SALSA	GCM	ERA-Int 2006	$1.9^\circ \times 1.9^\circ \times 31$	sectional (2m)	prescribed	Y	Y	Y	Y	Y
EMAC	GCM	ERA-Int 2006	$2.8^\circ \times 2.8^\circ \times 19$	modal (2m)	online	Y	Y	Y	Y	Y
GEOS–Chem	CTM	GEOS-5 2006	$2.0^\circ \times 2.5^\circ \times 47$	sectional (1m)	online	Y	Y	Y	Y	Y
GISS–MATRIX	GCM	NCEP 2006	$2.0^\circ \times 2.5^\circ \times 40$	modal (2m QMOM)	online	Y	Y	Y	Y	Y
GISS–modelE	GCM	NCEP 2006	$2.0^\circ \times 2.5^\circ \times 40$	modal (1m), except DU: sectional (1m)		Y	Y	Y	Y	Y
GLOMAP-bin	CTM	ERA-Int 2006	$2.8^\circ \times 2.8^\circ \times 31$	sectional (2m)	prescribed	Y	Y	Y	Y	–
GLOMAP-mode	CTM	ERA-Int 2006	$2.8^\circ \times 2.8^\circ \times 31$	modal (2m)	prescribed	Y	Y	Y	Y	Y
GOCART	CTM	GEOS-4 2006	$2.0^\circ \times 2.5^\circ \times 30$	modal (1m), except SS, DU: sectional (1m)	prescribed	Y	Y	Y	m	Y
HadGEM2	GCM	ERA-Int 2006	$1.3^\circ \times 1.9^\circ \times 38$	modal (1m), except DU: sectional (1m)	online	Y	Y	Y	Y	Y
HadGEM3–UKCA	GCM	ERA-Int 2006	$1.3^\circ \times 1.9^\circ \times 63$	modal (2m), except DU: sectional (1m)	online	Y	Y	Y	Y	Y
INCA	GCM	IFS 2006	$1.9^\circ \times 3.8^\circ \times 19$	modal (2m)	online	Y	Y	Y	Y	Y
OsloCTM2	CTM	IFS 2006	$2.8^\circ \times 2.8^\circ \times 60$	modal (1m), except SS, DU: sectional (1m)	online	Y	Y	Y	Y	m
SPRINTARS	GCM	NCEP 2006	$1.1^\circ \times 1.1^\circ \times 56$	modal (2m)	prescribed	Y	Y	Y	Y	Y
TM5	CTM	ERA-Int 2006	$2.0^\circ \times 3.0^\circ \times 34$	modal (2m)	online	Y	Y	Y	Y	Y

HadGEM3–UKCA simulations

BASE: `xfxld` standard configuration from 2011, nudged to ERA-Interim 2009, at N96L38 ($1.25° \times 1.875° \times 38$ levels), plus in-plume convective scavenging and GFED3 biomass-burning.

Emissions
BB_SURF
BB_TROP/z
EM_LARGE
EM_SMALL

Microphysics/chemistry	
NO_COND	NO_WETOX
NO_COAG	AGE_INST
NO_NUCL	AGE_NEVER
WITH_BLN	NO_CLDPROC

V. transport
NO_BLMIX
NO_VADV
NO_CVTRANS

Deposition	
NO_DDEP	NO_RAINOUT
NO_LS_RO	NO_WASHOUT
NO_CV_RO	WITH_REEVAP

Table: Model configurations and processes tested

Results: global-mean mass profiles (SO_4)

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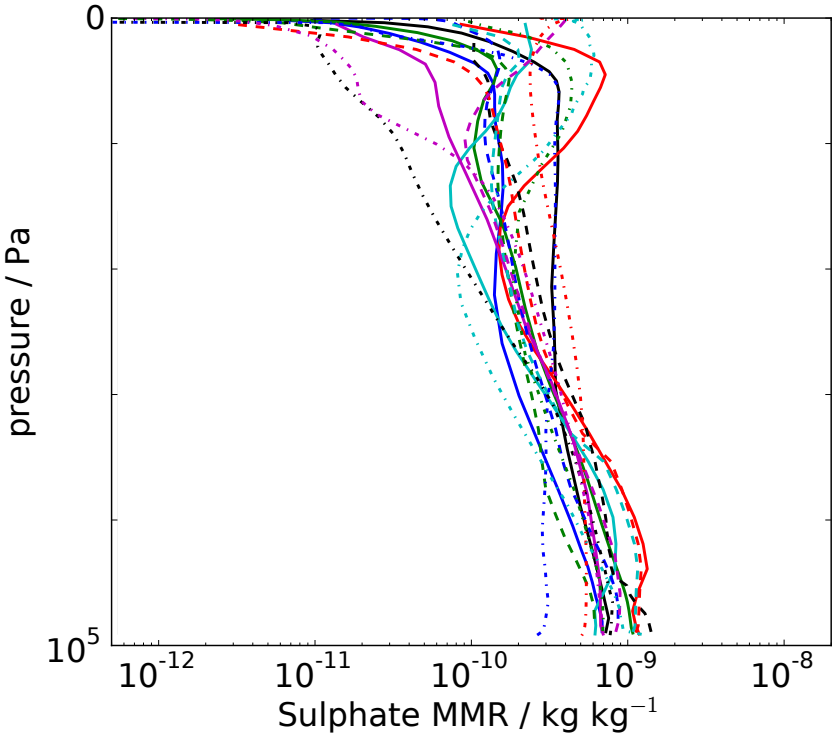
AeroCom A2.CTRL



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CAM5.1
CanAM4–PAM
ECHAM5–HAM
ECHAM5–SALSA
EMAC
GEOS–Chem
GISS–MATRIX
GISS–modelE
GLOMAP-bin
GLOMAP-mode
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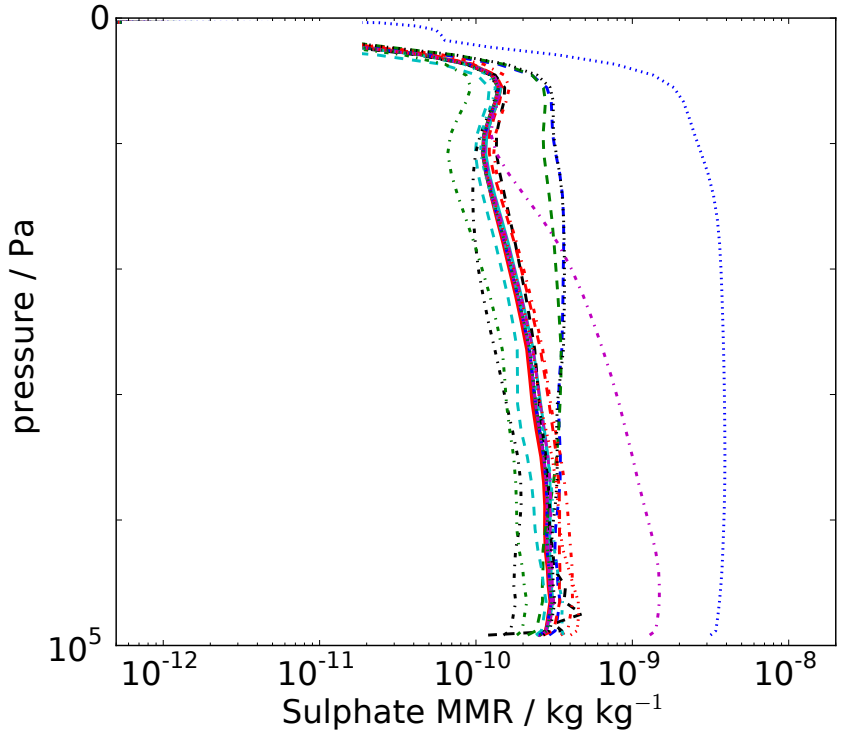
HadGEM2
HadGEM3–UKCA
INCA
OsloCTM
SPRINTARS
TM5

HadGEM3–UKCA



BASE
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BB_TROP/z
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NO_CVTRANS
NO_COND
NO_COAG
NO_NUCL
WITH_BLN
NO_WETOX
AGE_INST
AGE_NEVER
NO_CLDPROC
NO_DDEP
NO_LS_RO
NO_CV_RO
NO_RAINOUT
NO_WASHOUT
WITH_REEVAP

Results: global-mean mass profiles (SS)

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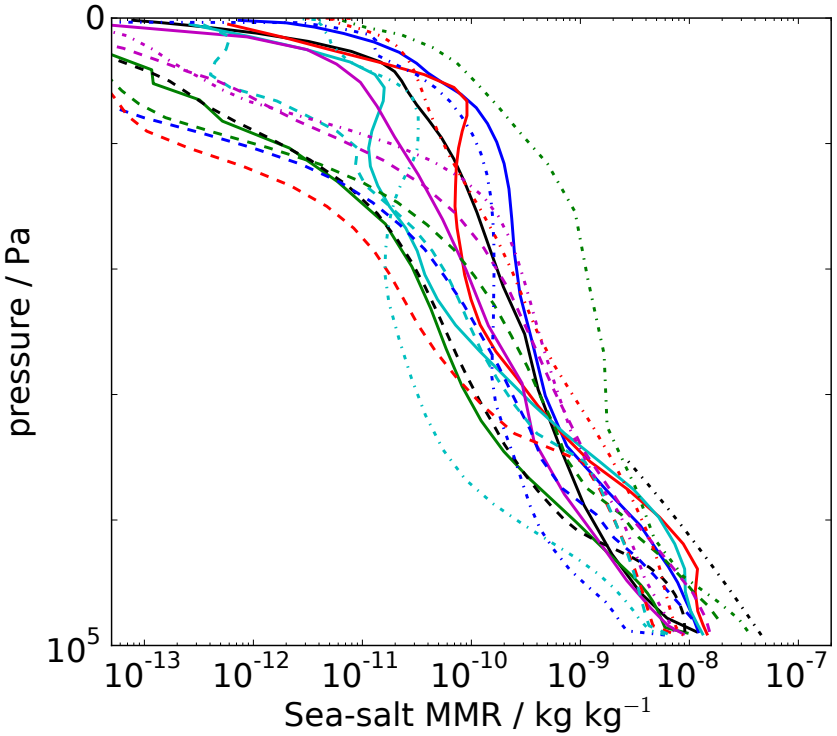

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EMAC
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GISS–MATRIX
GISS–modelE
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OsloCTM
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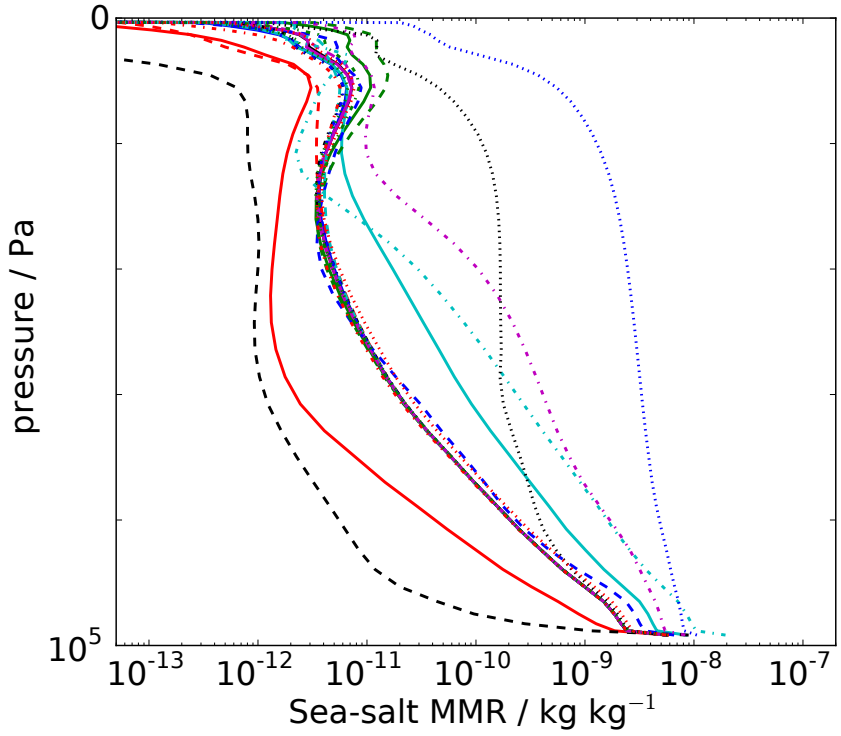
TM5

HadGEM3–UKCA



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BB_TROP/z
EM_LARGE
EM_SMALL
NO_VADV
NO_BLMIX
NO_CVTRANS
NO_COND
NO_COAG
NO_NUCL
WITH_BLN
NO_WETOX
AGE_INST
AGE_NEVER
NO_CLDPROC
NO_DDEP
NO_LS_RO
NO_CV_RO
NO_RAINOUT
NO_WASHOUT
WITH_REEVAP

Results: global-mean mass profiles (BC)

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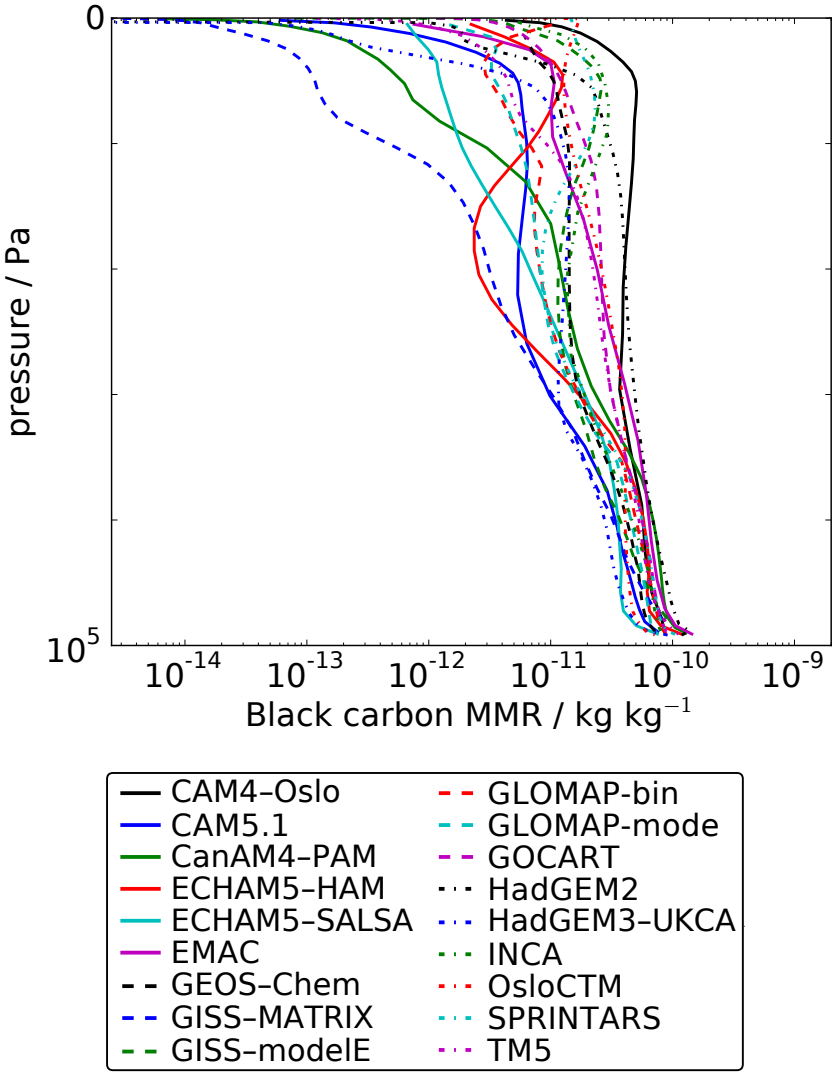
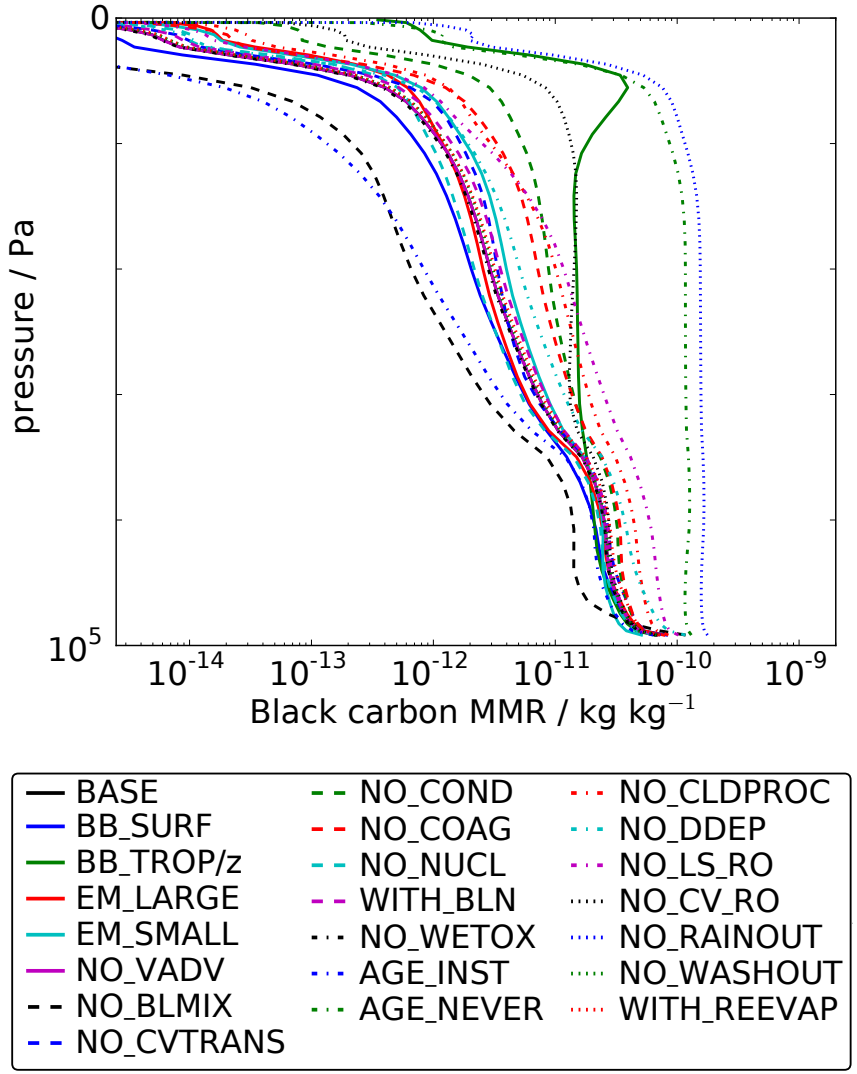


HadGEM3–UKCA



Results: global-mean mass profiles (OA)

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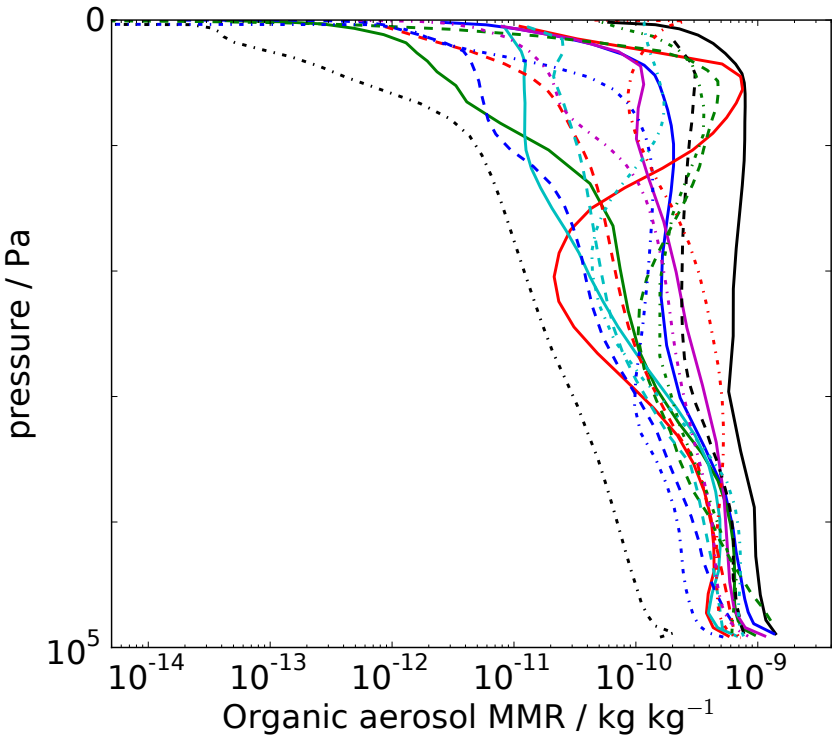

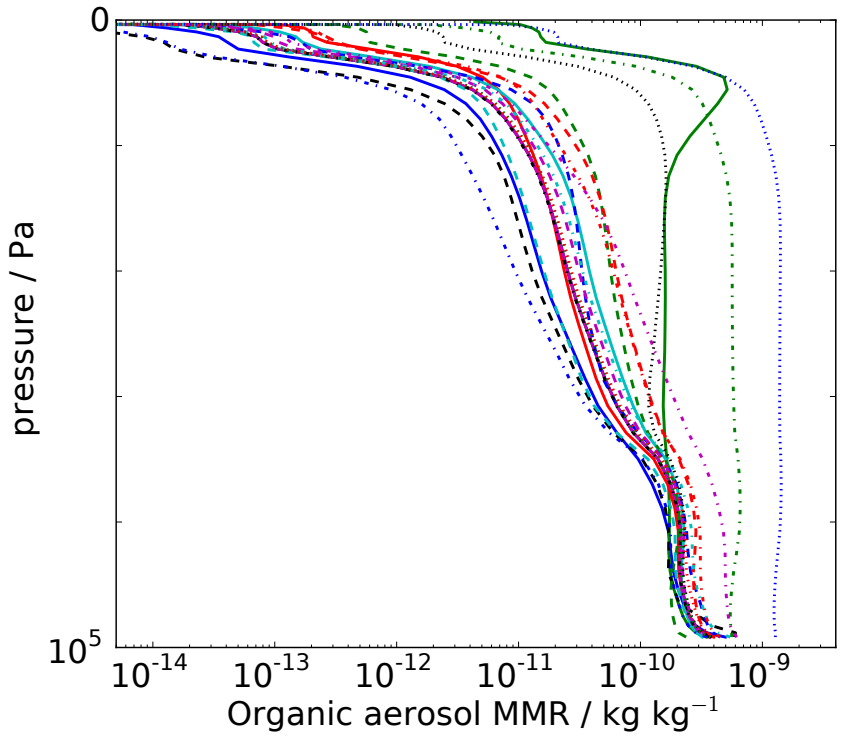

CAM4–Oslo
CAM5.1
CanAM4–PAM
ECHAM5–HAM
ECHAM5–SALSA
EMAC
GEOS–Chem
GISS–MATRIX
GISS–modelE
GLOMAP-bin
GLOMAP-mode
GOCART
HadGEM2
HadGEM3–UKCA
INCA
OsloCTM
SPRINTARS
TM5

BASE
BB_SURF
BB_TROP/z
EM_LARGE
EM_SMALL
NO_VADV
NO_BLMIX
NO_CVTRANS
NO_COND
NO_COAG
NO_NUCL
WITH_BLN
NO_WETOX
AGE_INST
AGE_NEVER
NO_CLDPROC
NO_DDEP
NO_LS_RO
NO_CV_RO
NO_RAINOUT
NO_WASHOUT
WITH_REEVAP

Results: global-mean mass profiles (DU)

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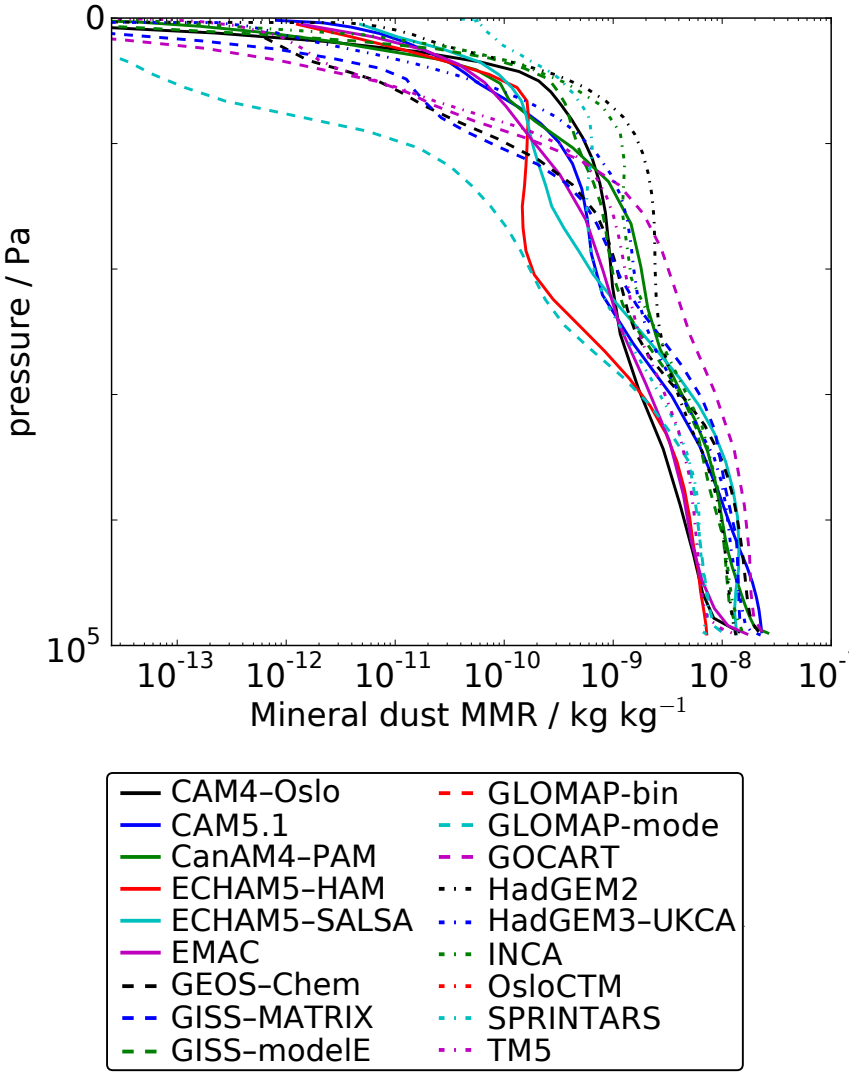
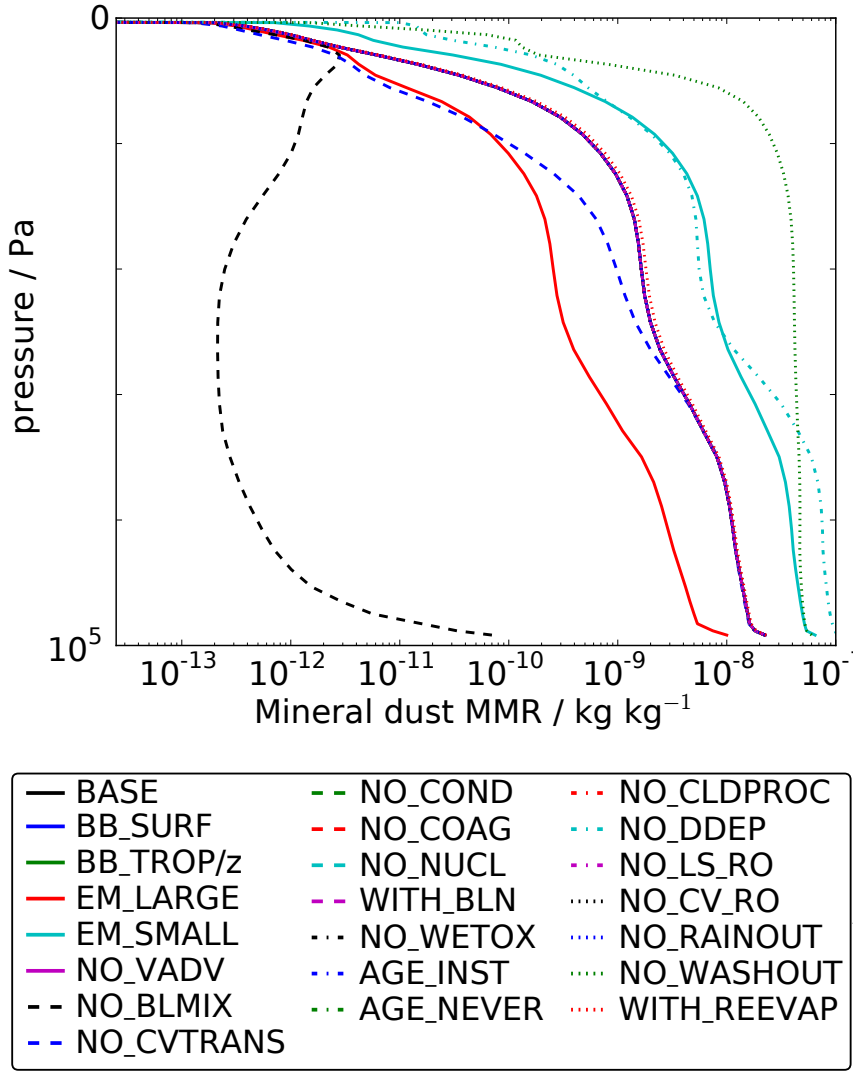


HadGEM3–UKCA



Results: global-mean mass profiles (summary)

Model	SO_4	BC	OA
ECHAM5–HAM	•	•	•
ECHAM–SALSA	•		
GISS–modelE		•	•
GOCART	•		
INCA	•	•	•
SPRINTARS	•	•	•

Table: Models exhibiting "inverted S"-shaped vertical profiles

Results: zonal-mean vertical centre-of-mass (SO_4)

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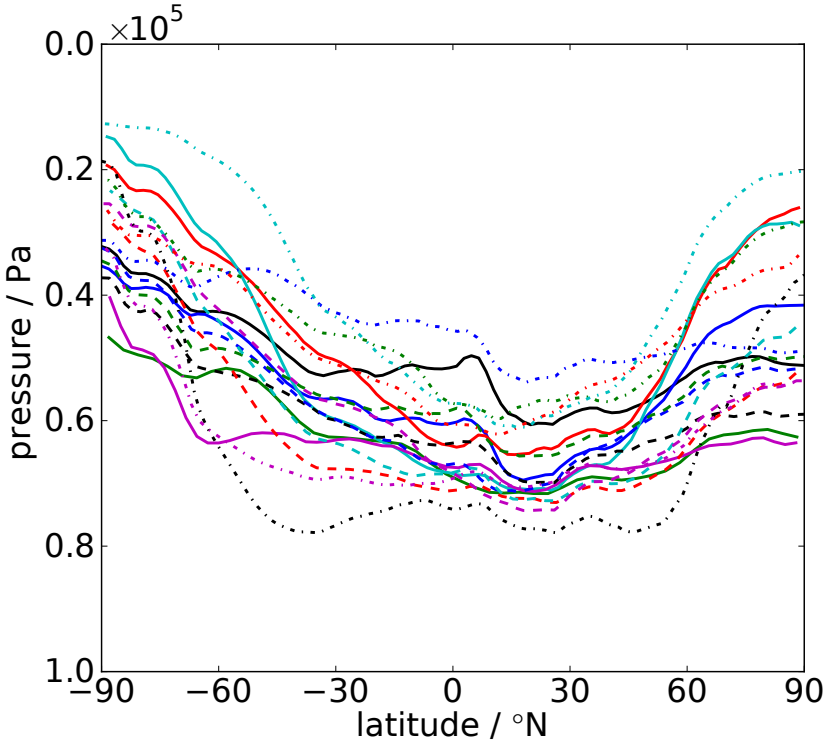

CAM4–Oslo
CAM5.1
CanAM4–PAM
ECHAM5–HAM
ECHAM5–SALSA
EMAC
GEOS–Chem
GISS–MATRIX
GISS–modelE
GLOMAP-bin
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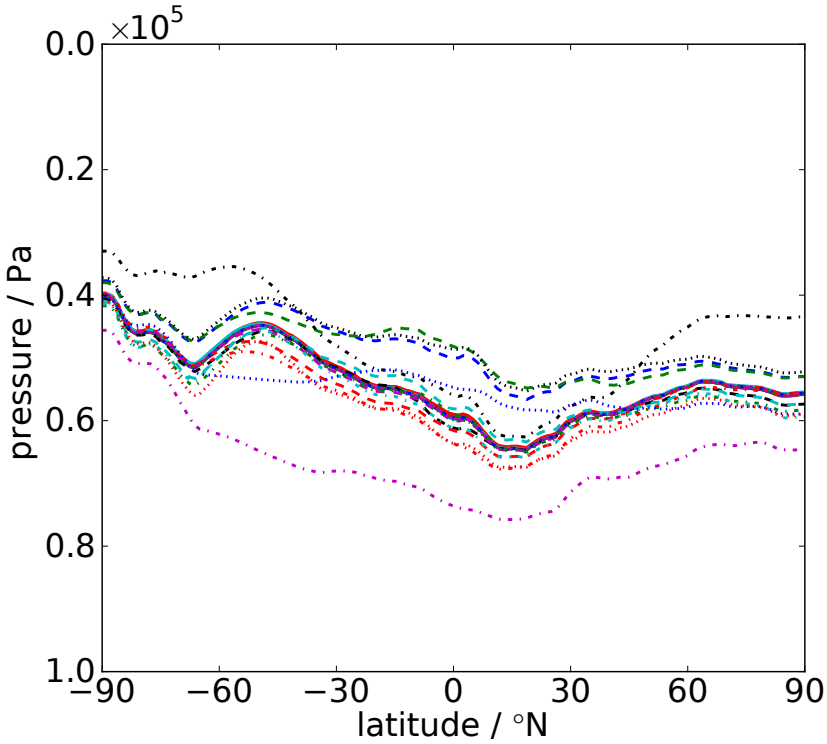
GOCART
HadGEM2
HadGEM3–UKCA
INCA
OsloCTM
SPRINTARS
TM5

HadGEM3–UKCA



BASE
BB_SURF
BB_TROP/z
EM_LARGE
EM_SMALL
NO_VADV
NO_BLMIX
NO_CVTRANS
NO_COND
NO_COAG
NO_NUCL
WITH_BLN
NO_WETOX
AGE_INST
AGE_NEVER
NO_CLDPROC
NO_DDEP
NO_LS_RO
NO_CV_RO
NO_RAINOUT
NO_WASHOUT
WITH_REEVAP

Results: zonal-mean vertical centre-of-mass (SS)

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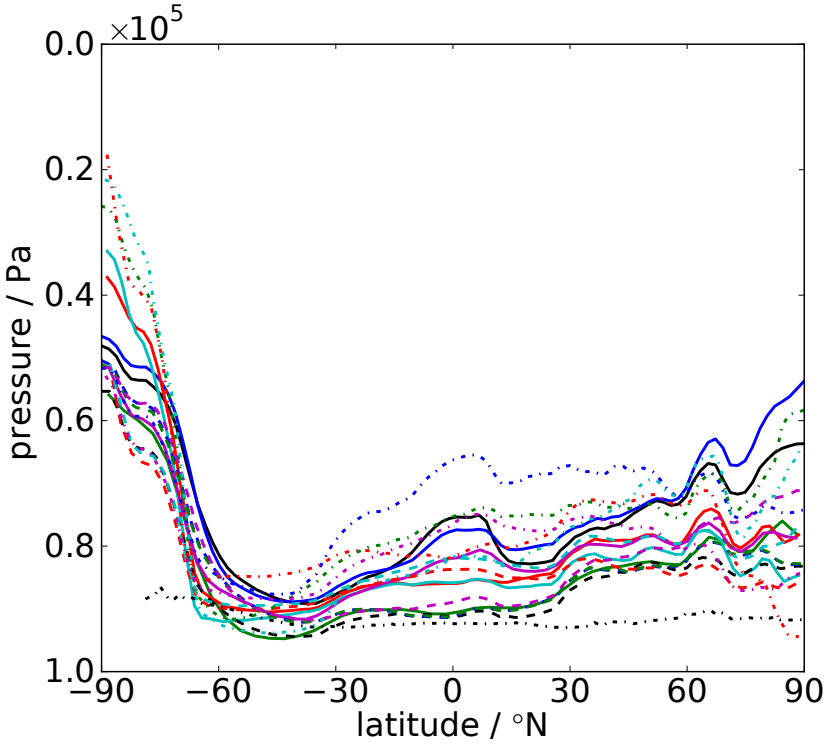

CAM4–Oslo
CAM5.1
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ECHAM5–SALSA
EMAC
GEOS–Chem
GISS–MATRIX
GISS–modelE
GLOMAP-bin
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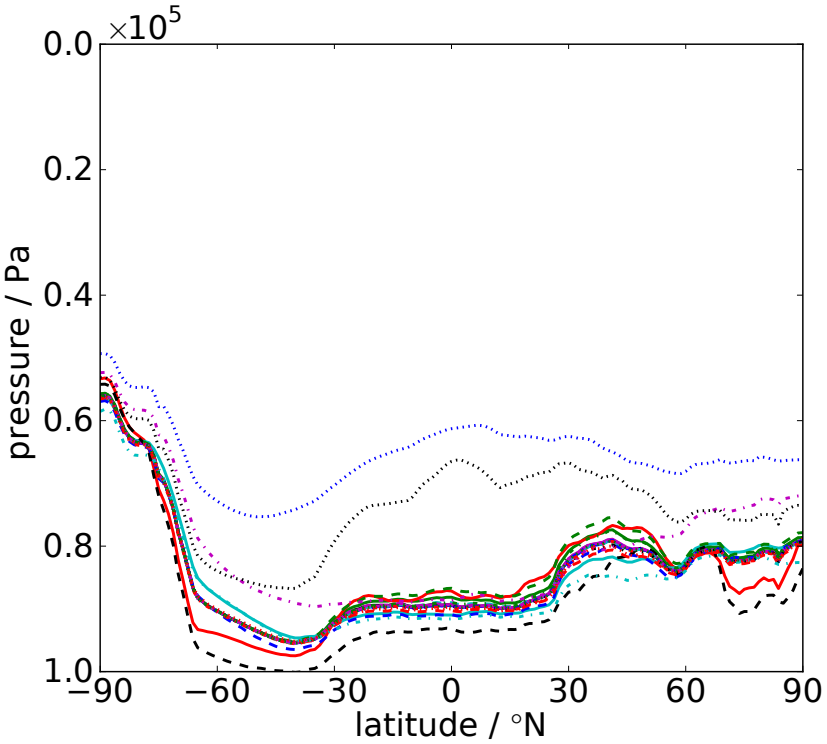
GOCART
HadGEM2
HadGEM3–UKCA
INCA
OsloCTM
SPRINTARS
TM5

HadGEM3–UKCA



BASE
BB_SURF
BB_TROP/z
EM_LARGE
EM_SMALL
NO_VADV
NO_BLMIX
NO_CVTRANS
NO_COND
NO_COAG
NO_NUCL
WITH_BLN
NO_WETOX
AGE_INST
AGE_NEVER
NO_CLDPROC
NO_DDEP
NO_LS_RO
NO_CV_RO
NO_RAINOUT
NO_WASHOUT
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Results: zonal-mean vertical centre-of-mass (BC)

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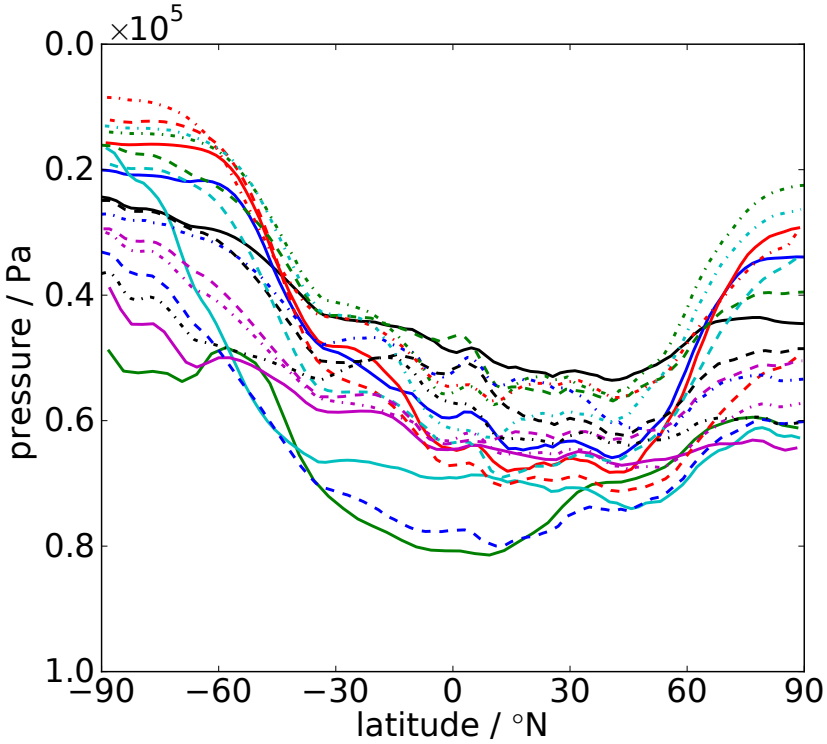

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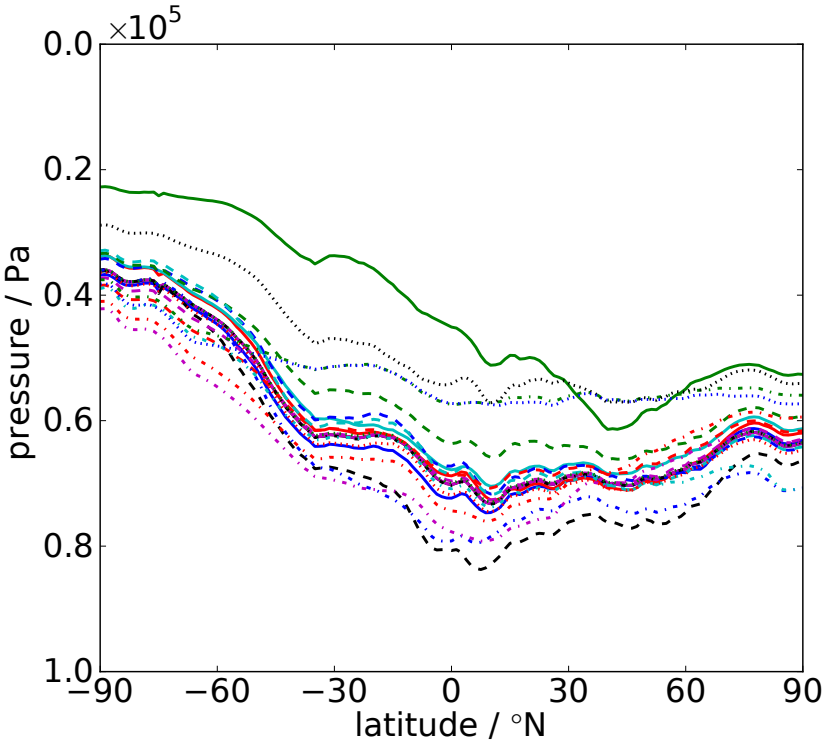
HadGEM3–UKCA



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EM_SMALL
NO_VADV
NO_BLMIX
NO_CVTRANS
NO_COND
NO_COAG
NO_NUCL
WITH_BLN
NO_WETOX
AGE_INST
AGE_NEVER
NO_CLDPROC
NO_DDEP
NO_LS_RO
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Results: zonal-mean vertical centre-of-mass (OA)

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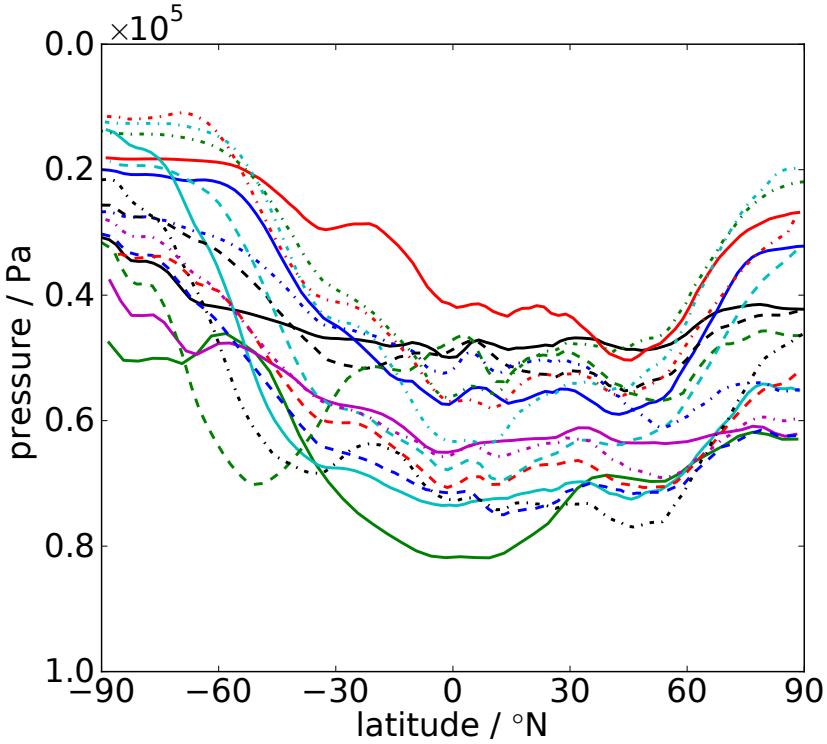

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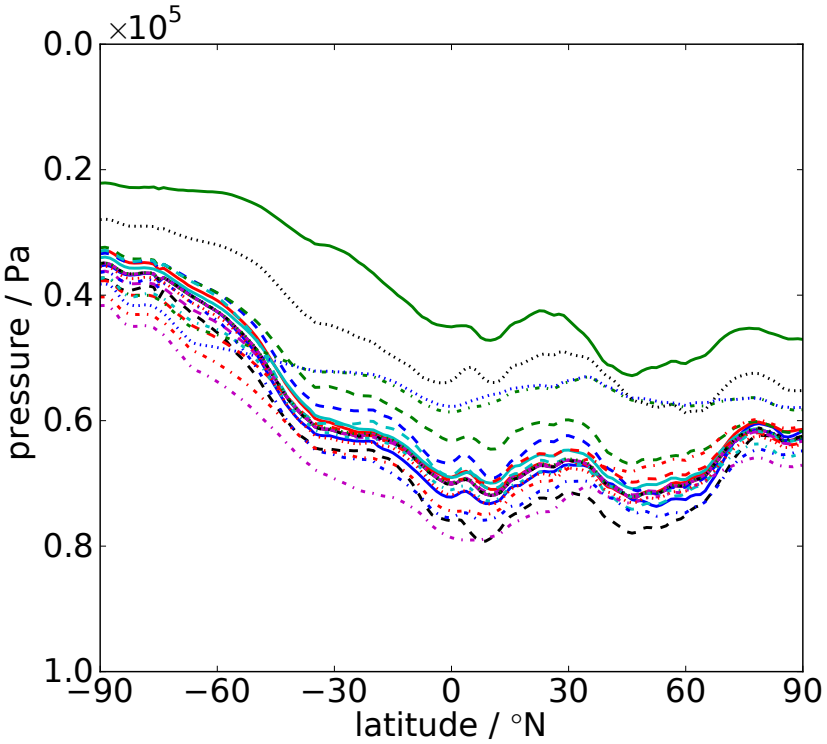
HadGEM3–UKCA



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NO_COAG
NO_NUCL
WITH_BLN
NO_WETOX
AGE_INST
AGE_NEVER
NO_CLDPROC
NO_DDEP
NO_LS_RO
NO_CV_RO
NO_RAINOUT
NO_WASHOUT
WITH_REEVAP

Results: zonal-mean vertical centre-of-mass (DU)

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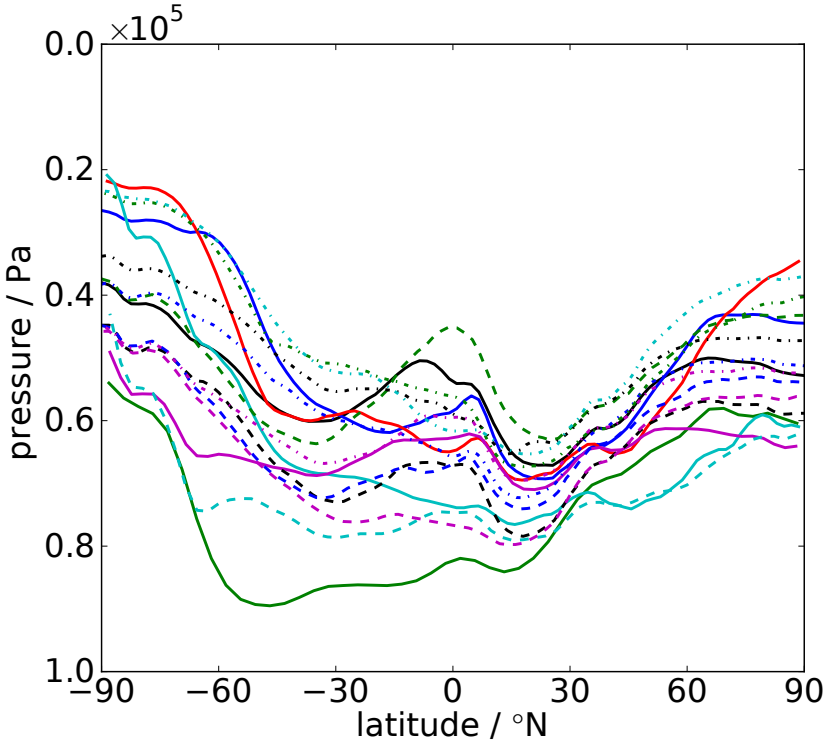

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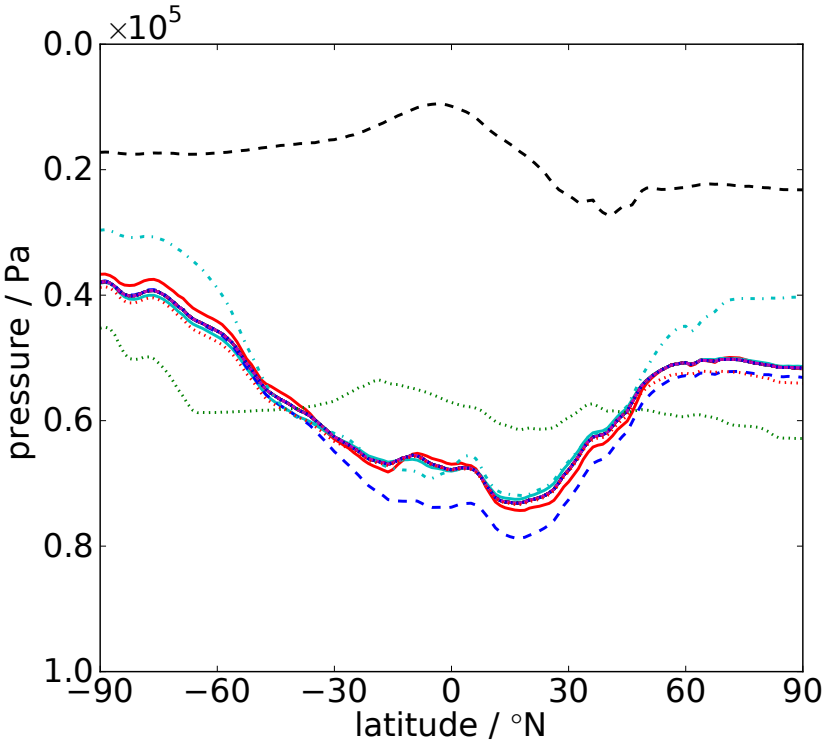
HadGEM2
HadGEM3–UKCA
INCA
OsloCTM
SPRINTARS
TM5

HadGEM3–UKCA



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NO_COND
NO_COAG
NO_NUCL
WITH_BLN
NO_WETOX
AGE_INST
AGE_NEVER
NO_CLDPROC
NO_DDEP
NO_LS_RO
NO_CV_RO
NO_RAINOUT
NO_WASHOUT
WITH_REEVAP

Results: zonal-mean vertical centre-of-mass (summary)

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Model	SO_4	BC	OA
CAM4–Oslo	•	•	•
CanAM4–PAM	•		
EMAC	•	•	•
GEOS–Chem	•	•	•
GISS–MATRIX			•
GISS–modelE	•		
GOCART		•	•
HadGEM2		•	•
HadGEM3–UKCA	•	•	•
TM5		•	•

Table: Models exhibiting flat (rather than U-shaped) meridional profiles of vertical centre-of-mass

Strongest effects on vertical profile

Simulation	SO_4	SS	BC	OA	DU
BB_TROP/z			⇑	⇑	
NO_BLMIX		↓	↓	↓	0
NO_CVTRANS	↑				
NO_COND	↑		↑	↑	
NO_WETOX	↑↑				
AGE_INST			↓	↓	
AGE_NEVER			↑	↑	
NO_DDEP					↑↑
NO_LS_RO	⇓	↑↑	↓	↓	
NO_CV_RO	↑	⇑	↑	↑	
NO_RAINOUT		⇑	↑	↑	
NO_WASHOUT					↑↓

↑, ↓	Global shift up, down
⇑, ⇓	Bigger shift up, down
↑↑	At high latitudes
↑↓	Opposite at low/high latitudes

Table: HadGEM3–UKCA simulations showing the strongest change (compared to BASE) in zonal-mean vertical centre-of-mass

Summary and conclusions

- Overall spread of global-mean profiles can be accounted for by processes.
  - "Inverted S" seen in several models cannot be reproduced in HadGEM3–UKCA.
- Spread of zonal-mean vertical centre-of-mass larger than can be accounted for.
  - Also, "U" shape seen in several models cannot be reproduced.
- This suggests that there are structural differences in the models, beyond the processes considered here, which are important for the vertical profile.
  - Perhaps the parameterisation of convective entrainment and detrainment?

The End

Any questions?