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Updated Isoprene and Terpene Emission Factors for the Interactive BVOC Emission Scheme (iBVOC) in the Joint UK Land Environment Simulator (JULES)

JULES Science Meeting Oxford 2022

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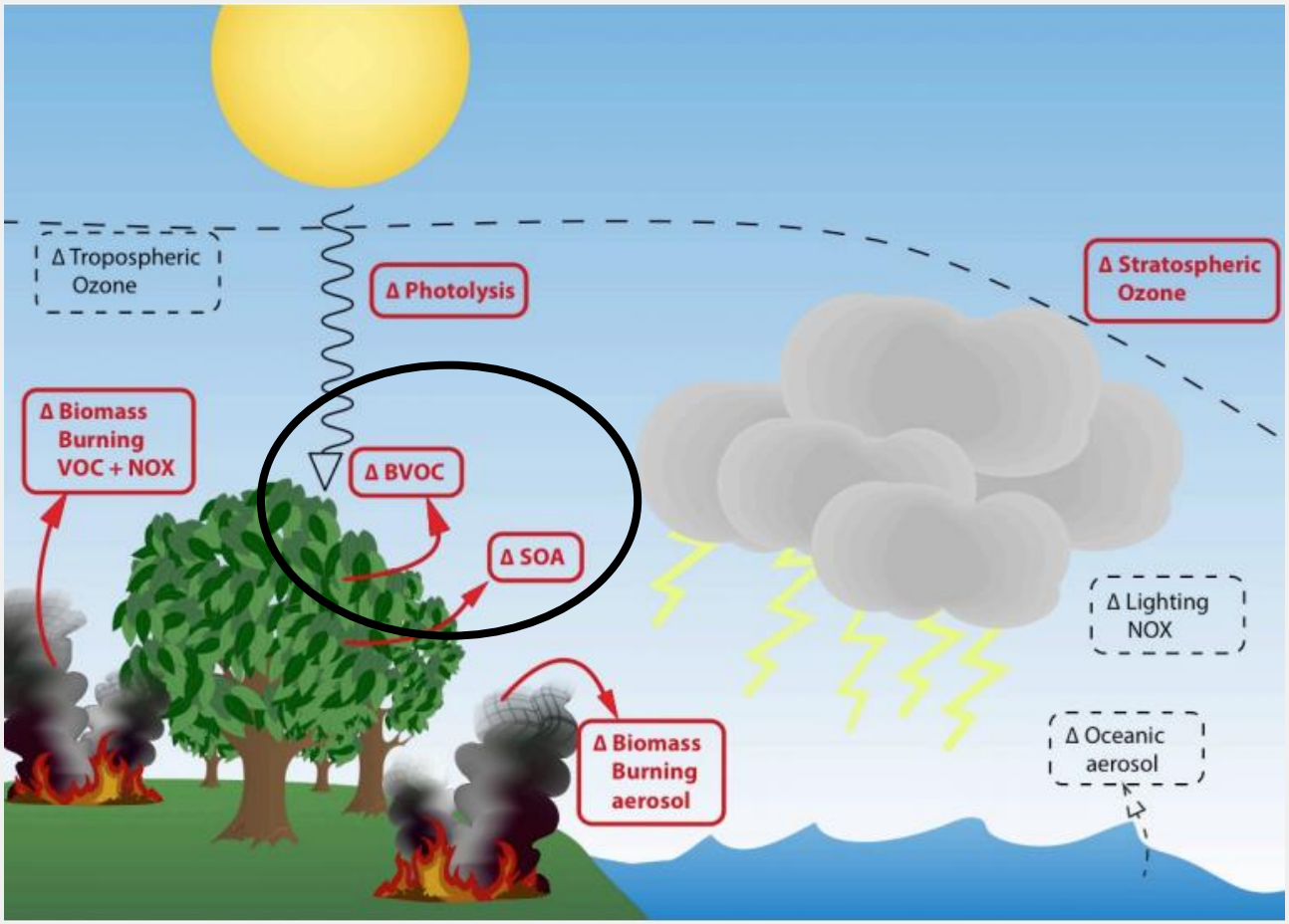
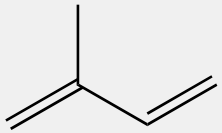
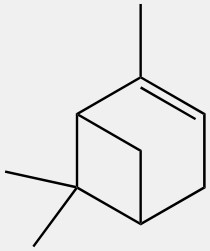
Plant Emissions and Atmospheric Chemistry

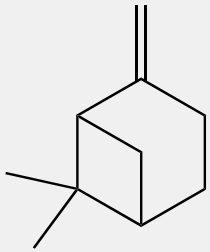




isoprene



α-pinene



β-pinene

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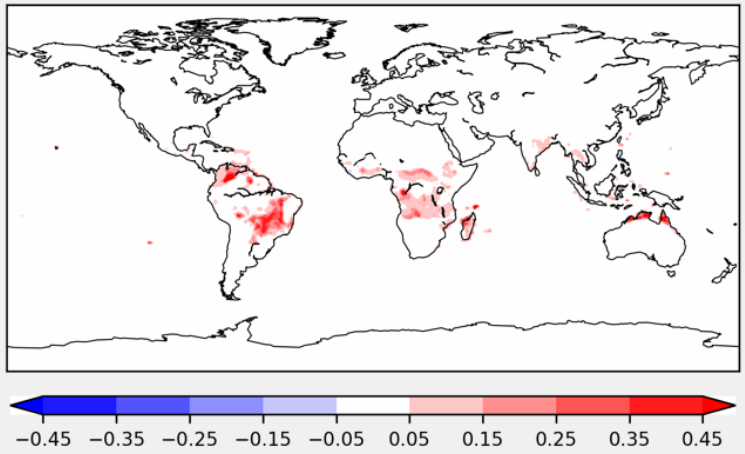
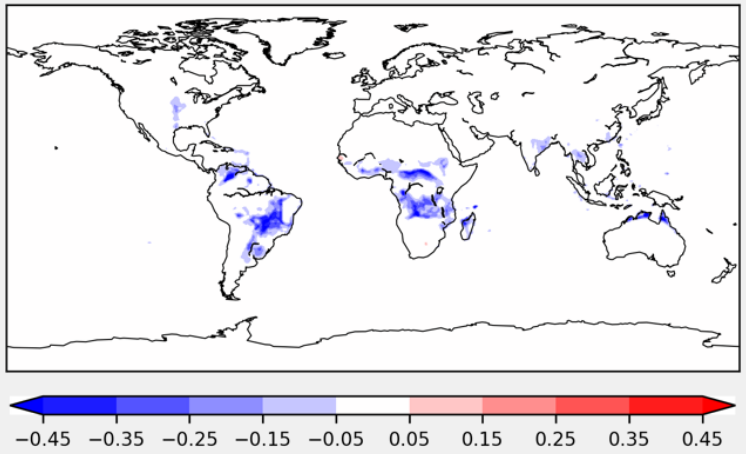
More tree, more isoprene?

Widescale reforestation scenario

(a) Broadleaf Evergreen Tropical

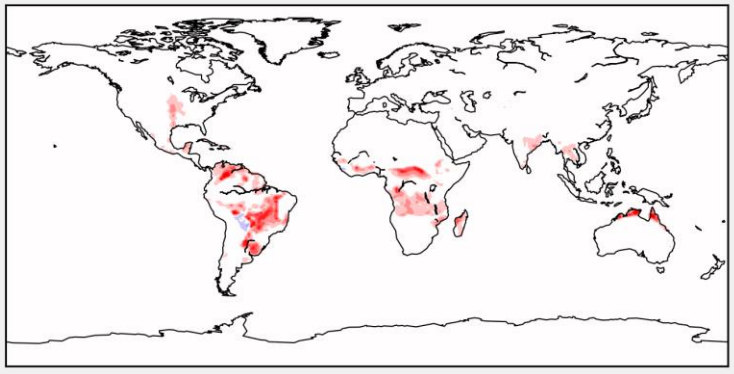


(b) C4 Grass



−0.45 −0.35 −0.25 −0.15 −0.05 0.05 0.15 0.25 0.35 0.45

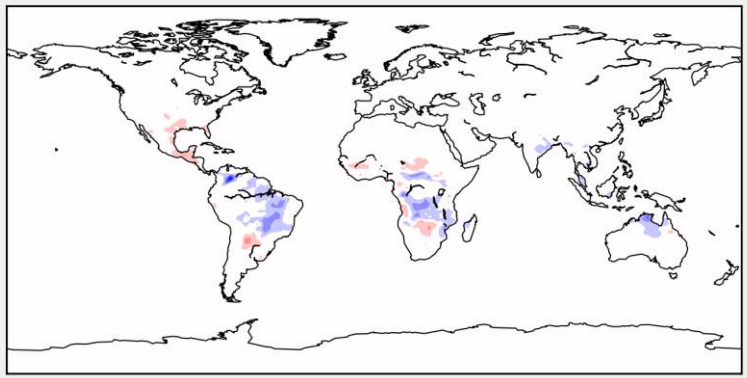
(c) CESM_2050 - CESM_2010 (+65 Tg yr^{-1})



−36 −28 −20 −12 −4 4 12 20 28 36

kg m^{-2} s^{-1}

(a) UKESM_default_2050 - UKESM_default_2010 (-25 Tg yr^{-1})



−36 −28 −20 −12 −4 4 12 20 28 36

kg m^{-2} s^{-1}

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iBVOC in JULES

$$E_{PFT,mass} = E_{PFT,mass,0} \times f_{CO_2} \times f_{\text{temp}} \times f_{photo} \times f_{LAI}$$

$\mu C\ g_{dw}^{-1}\ hr^{-1}$

Simulates isoprene and terpene emissions with:

- JULES standalone
- Fully-coupled UKESM
- Atmosphere-only (aka AMIP) UKESM (~UKCA)

Could be easily expanded to simulate acetone and methanol.

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Current Implementation: 5-PFT setup

PFT	IEF_{mass} / $\mu gC\ g_{dw}^{-1}\ hr^{-1}$
Broadleaf trees	35
Needleleaf trees	12
C3 grass	16
C4 grass	8
Shrubs	20

Pacifico et al (2011) running JULES standalone

500 Tg yr^{-1} isoprene

9% from C4 grass

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Current Implementation: 13-PFT setup

PFT	Abbreviation	iBVOC Std
Broadleaf deciduous trees	Br-Dec	35
Broadleaf evergreen tropical trees	Br-Ev-Trop	24
Broadleaf evergreen temperate trees	Br-Ev-Temp	16
Needleleaf deciduous trees	Ne-Dec	8
Needleleaf evergreen trees	Ne-Ev	8
C3 grass	C3 grass	16
C3 crop	C3 crop	5
C3 pasture	C3 pasture	5
C4 grass	C4 grass	24
C4 crop	C4 crop	5
C4 pasture	C4 pasture	5
Shrub deciduous	Shrub-Dec	10
Shrub evergreen	Shrub-Ev	20

was 8 with 5 PFTs

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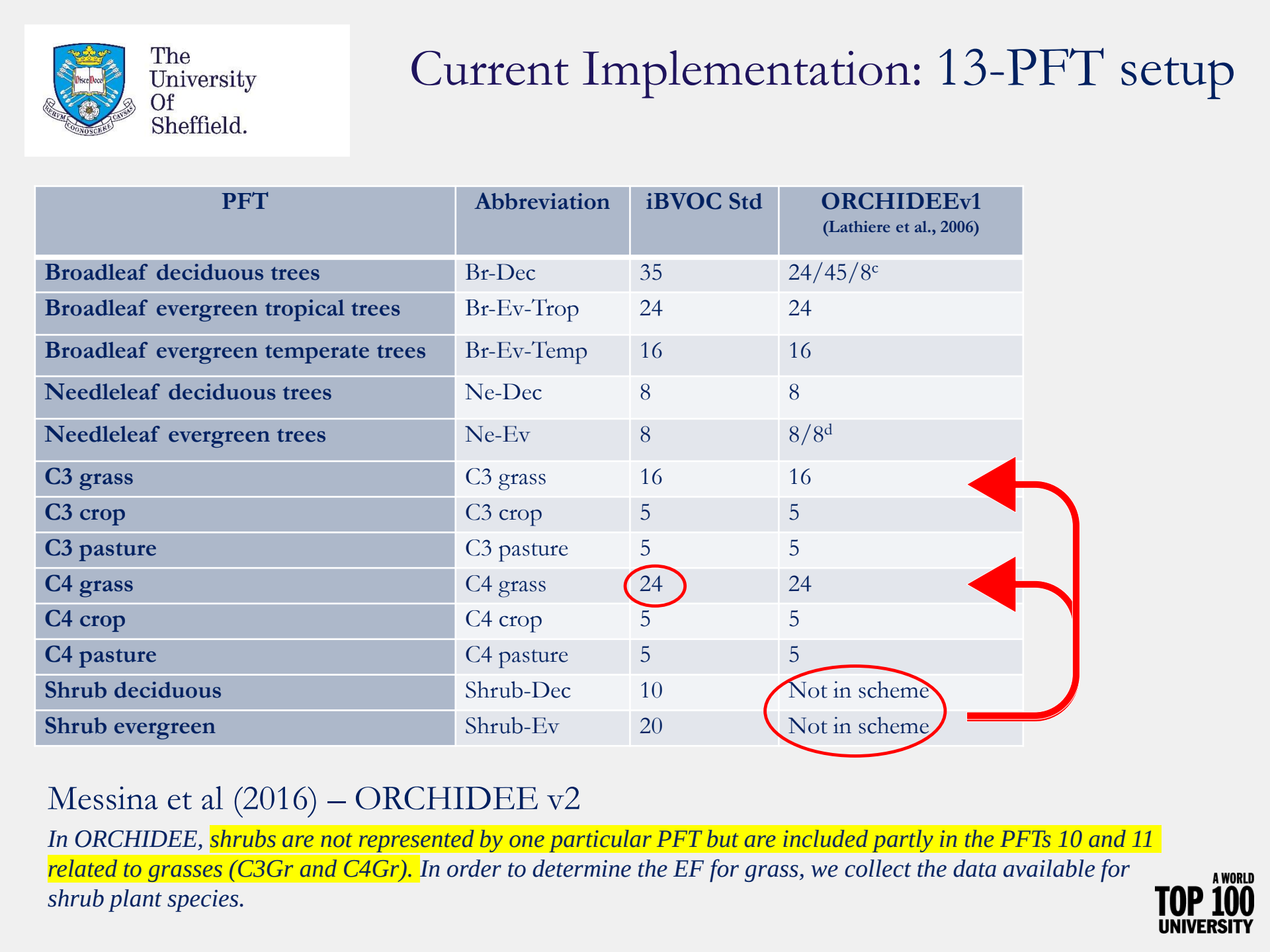
Current Implementation: 13-PFT setup

PFT	Abbreviation	iBVOC Std	ORCHIDEEv1 (Lathiere et al., 2006)
Broadleaf deciduous trees	Br-Dec	35	24/45/8[c]
Broadleaf evergreen tropical trees	Br-Ev-Trop	24	24
Broadleaf evergreen temperate trees	Br-Ev-Temp	16	16
Needleleaf deciduous trees	Ne-Dec	8	8
Needleleaf evergreen trees	Ne-Ev	8	8/8[d]
C3 grass	C3 grass	16	16
C3 crop	C3 crop	5	5
C3 pasture	C3 pasture	5	5
C4 grass	C4 grass	24	24
C4 crop	C4 crop	5	5
C4 pasture	C4 pasture	5	5
Shrub deciduous	Shrub-Dec	10	Not in scheme
Shrub evergreen	Shrub-Ev	20	Not in scheme



Messina et al (2016) – ORCHIDEE v2

In ORCHIDEE, shrubs are not represented by one particular PFT but are included partly in the PFTs 10 and 11 related to grasses (C3Gr and C4Gr). In order to determine the EF for grass, we collect the data available for shrub plant species.

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Current Implementation: 13-PFT setup

PFT	Abbreviation	iBVOC Std	ORCHIDEEv1 (Lathiere et al., 2006)	ORCHIDEE v2 (Messina et al., 2016)
Broadleaf deciduous trees	Br-Dec	35	24/45/8[c]	24/45/18[c]
Broadleaf evergreen tropical trees	Br-Ev-Trop	24	24	24
Broadleaf evergreen temperate trees	Br-Ev-Temp	16	16	16
Needleleaf deciduous trees	Ne-Dec	8	8	0.5
Needleleaf evergreen trees	Ne-Ev	8	8/8[d]	8/8[d]
C3 grass	C3 grass	16	16	12
C3 crop	C3 crop	5	5	5
C3 pasture	C3 pasture	5	5	5
C4 grass	C4 grass	24	24	18
C4 crop	C4 crop	5	5	5
C4 pasture	C4 pasture	5	5	5
Shrub deciduous	Shrub-Dec	10	Not in scheme	Not in scheme
Shrub evergreen	Shrub-Ev	20	Not in scheme	Not in scheme

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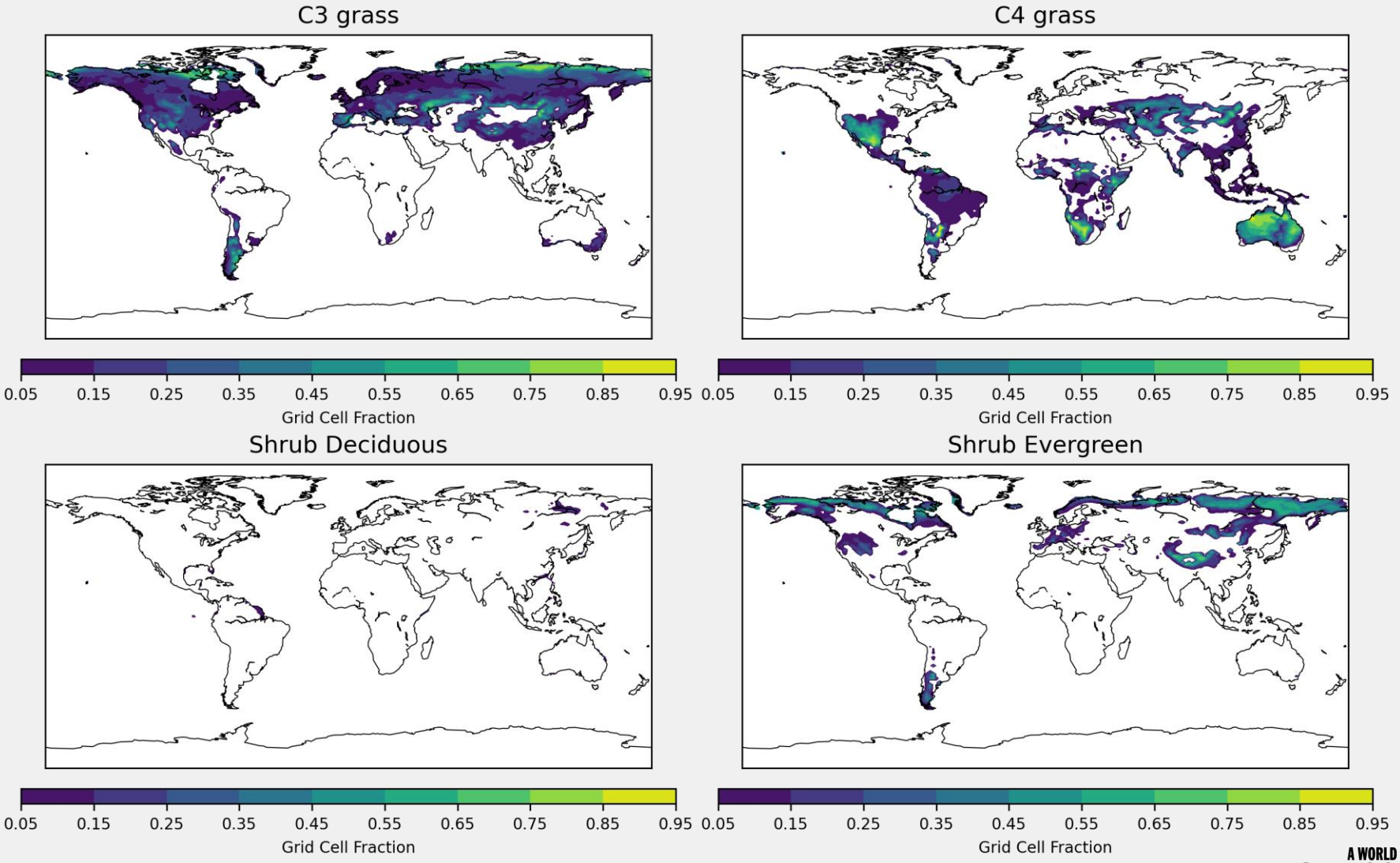

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Current Implementation: 13-PFT setup

UKESM1 Historical 2010 → ~40 % isoprene from C4 grass!

1.1% MEGAN v2.1 – Guenther et al (2012)

"Only C3 plants emit isoprene at considerable rates. The emission is virtually absent in Crassulacean acid metabolism (CAM) and C4 plants." – Loreto and Fineschi (2015)

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Convert MEGAN v2.1 EF for iBVOC Use

EF in MEGAN have units of $\mu_{species} m_{surface}^{-1} hr^{-1}$ → "EF_{area}"

$$EF_{mass} = EF_{area} \times \frac{1}{LAI_{ref}} \times \frac{1}{SLW} \times \frac{m_{Carbon}}{m_{species}} \times \frac{1}{C_{CE}}$$

As in Messina et al (2016)

Apply temperature scaling to account for difference in standard conditions between iBVOC and MEGAN.

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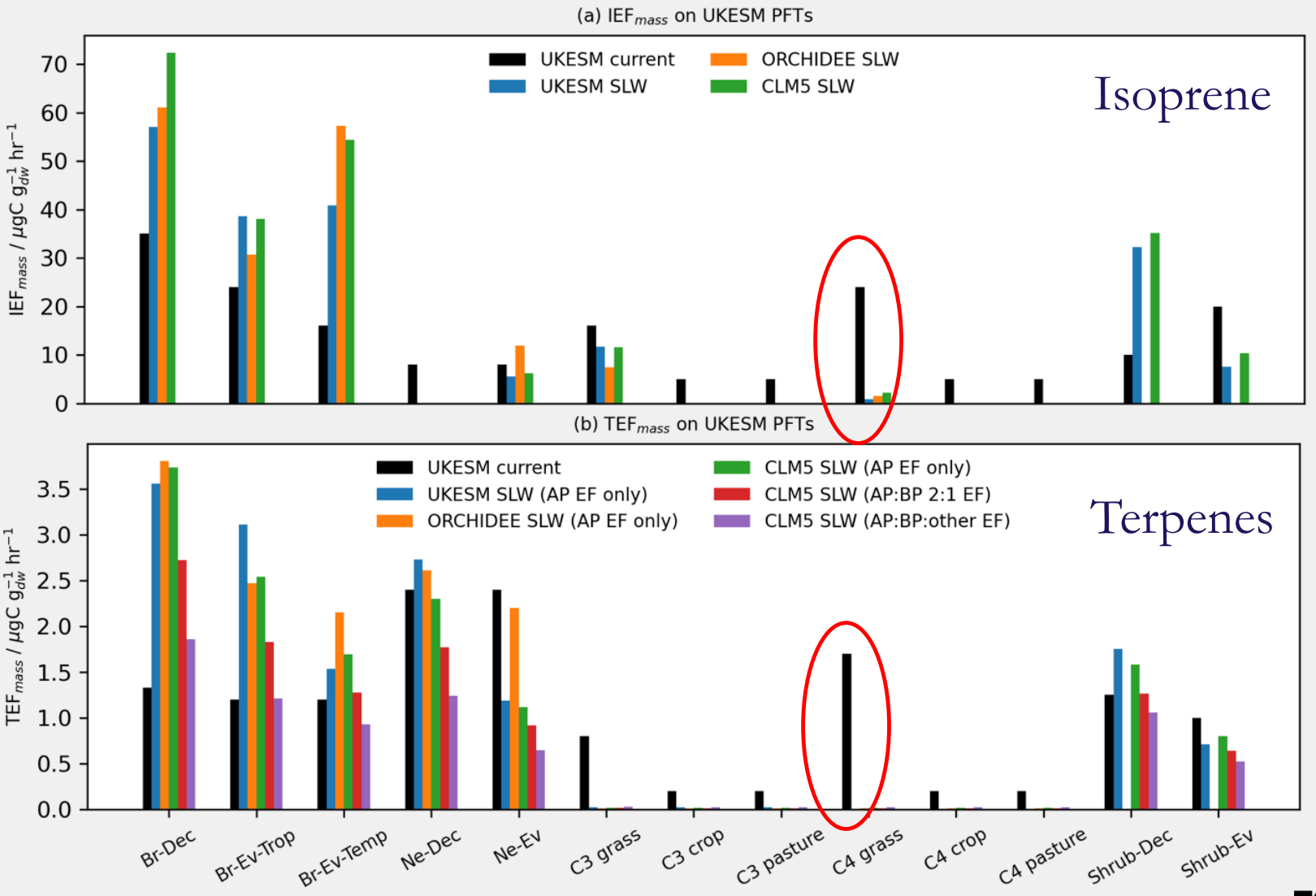
Updated EF_{mass}



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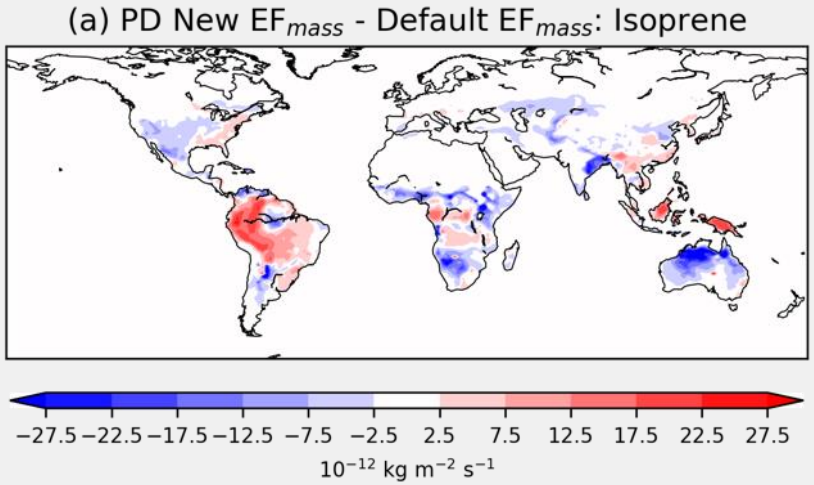
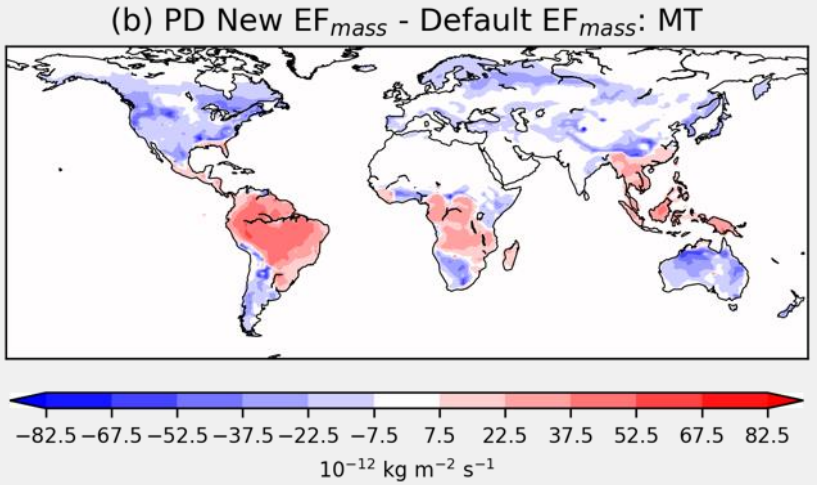
Impact of EF_{mass} Changes





	Global Isoprene Emissions / Tg yr^{-1}	Global Terpene Emissions / Tg yr^{-1}
Current PD	545	140
Updated PD	498	130
Current PI	744	140
Updated PI	645	125
Current 2050 SSP3-7.0	603	178
Updated 2050 SSP3-7.0	556	163

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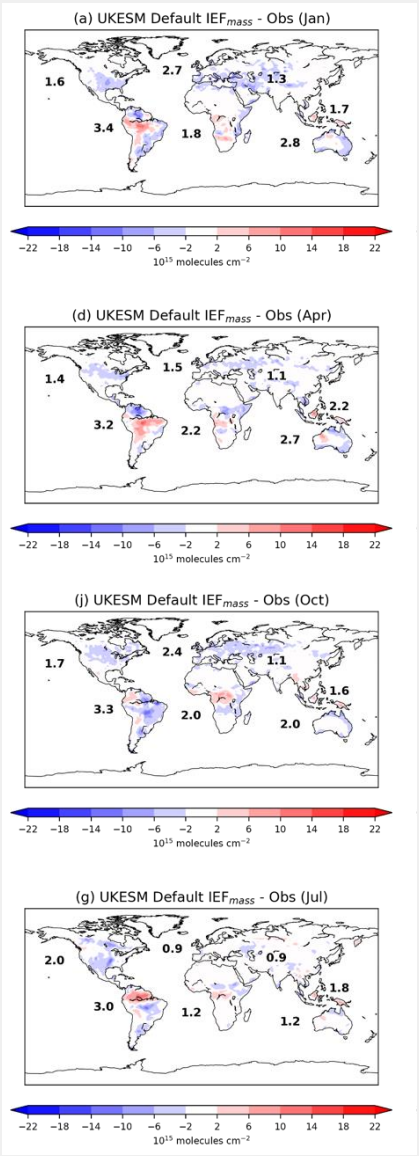
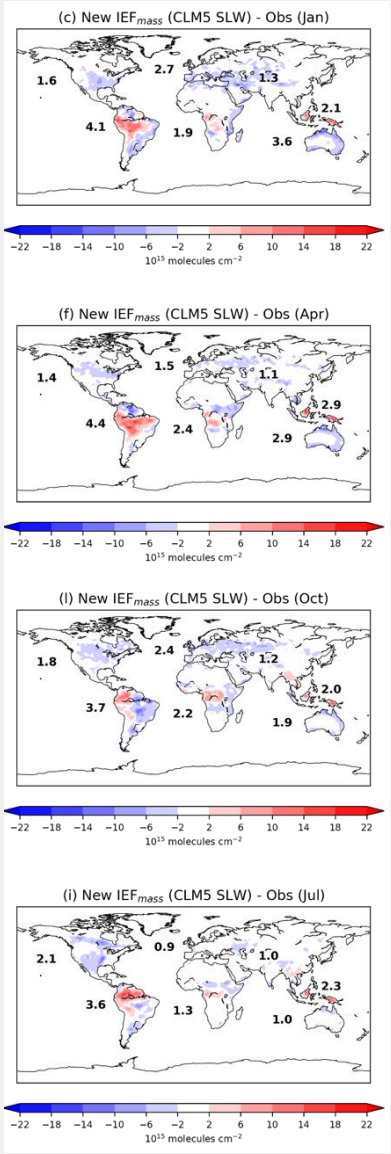
Isoprene Column Comparison





CriS
(Wells et al., 2020)

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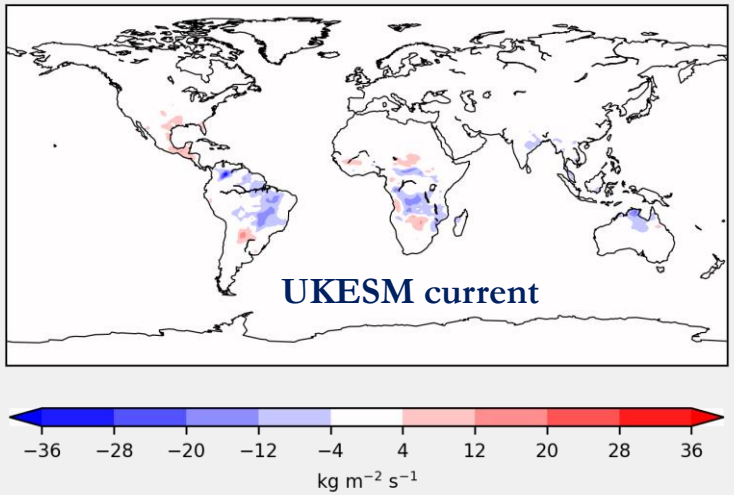
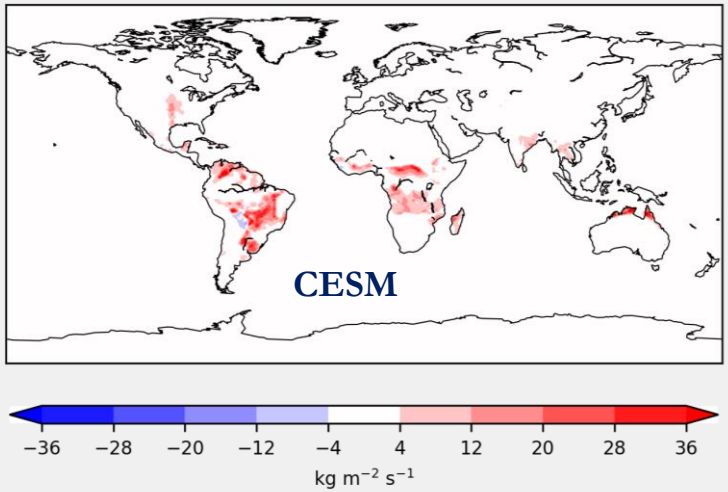
Revisiting Reforestation

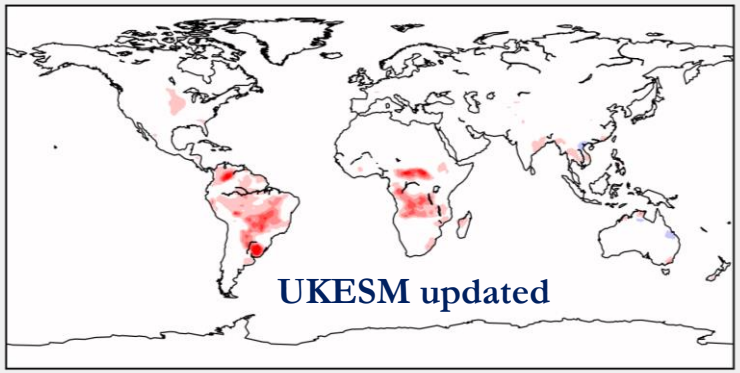
(a) UKESM_default_2050 - UKESM_default_2010 (-25 Tg yr^{-1})

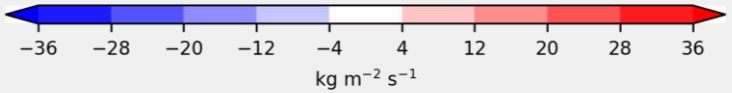


(c) CESM_2050 - CESM_2010 (+65 Tg yr^{-1})



(b) UKESM_update_2050 - UKESM_update_2010 (+63 Tg yr^{-1})





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Takeaways

1. Updates to EF for isoprene and terpene to values derived from MEGAN v2.1

2. Fixes problem with unrealistic emissions from C4 grass and increases emissions from tropical broadleaf trees.

3. Important implications for simulating the effect of land use change (e.g. de/reforestation) on BVOC emissions and knock on effects to climate.

4. Global emissions within literature range. High bias against isoprene column increases slightly but biases in land use, other emissions and chemistry may also contribute to this.

5. Longer term development to iBVOC would be worthwhile including more sophisticated dependencies on temperature and CO_2. Is there a hidden scaling issue in the JULES code?

6. Consider making full switch to MEGAN approach (emissions per unit area)?

Manuscript in review; GMD

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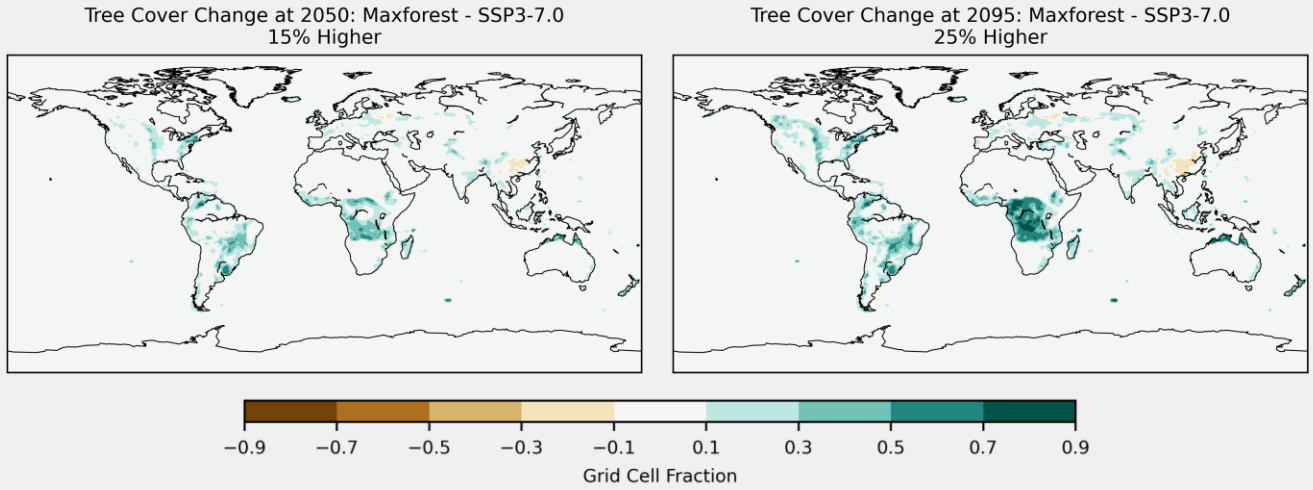
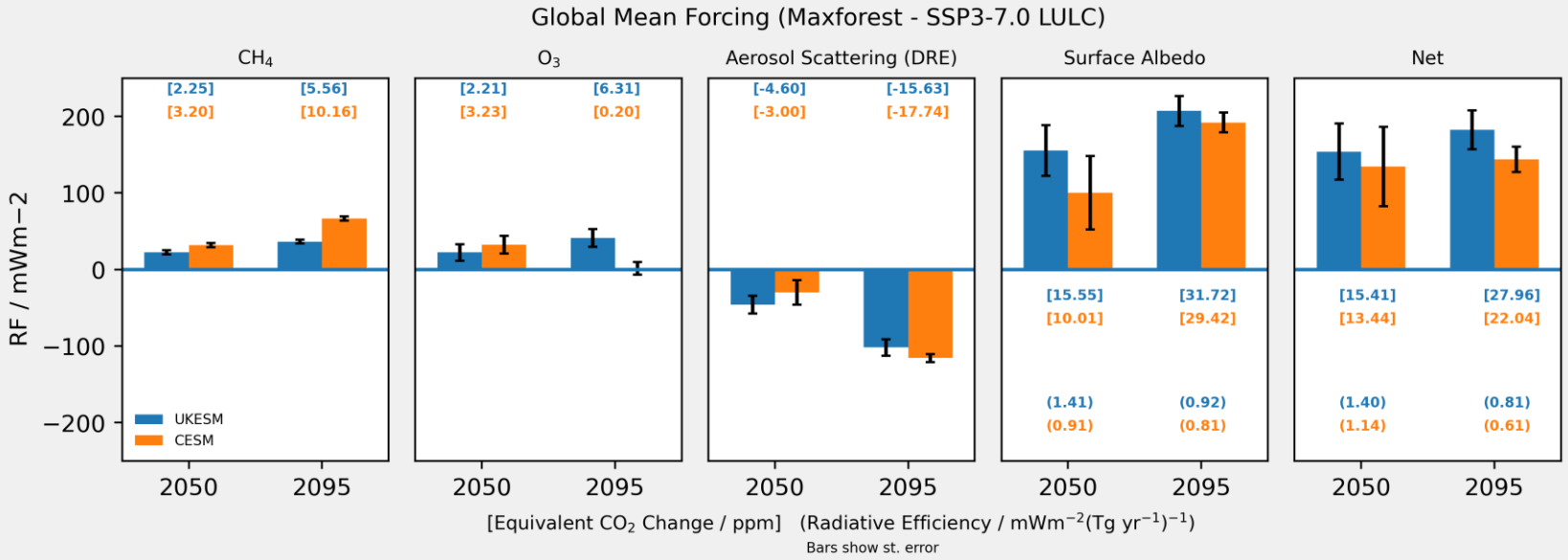
Climatic Impact of Widescale Reforestation

Maxforest scenario expands existing forests with the most suitable tree types while avoiding croplands.





Looking to use UKESM's CO_2 emission driven approach – please get in touch if interested!

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