Quantifying methane-induced warmth during the Pliocene

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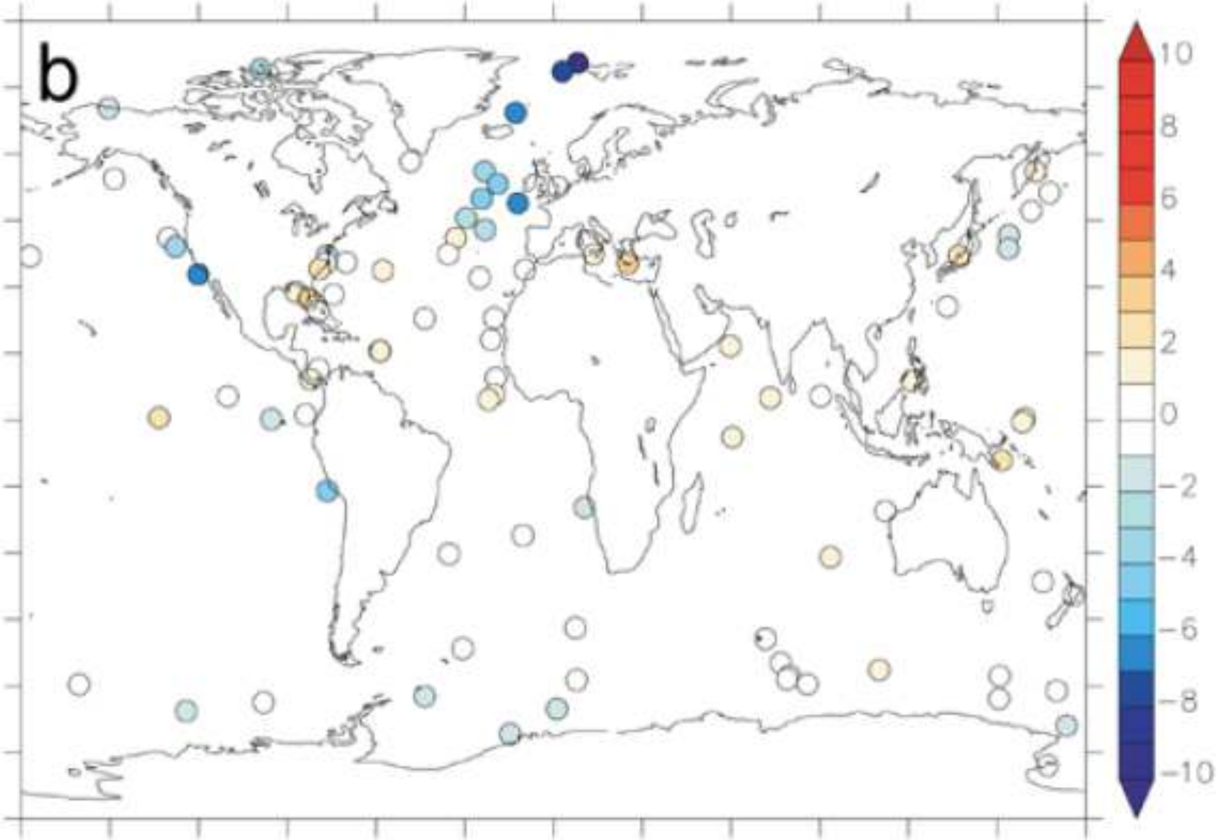
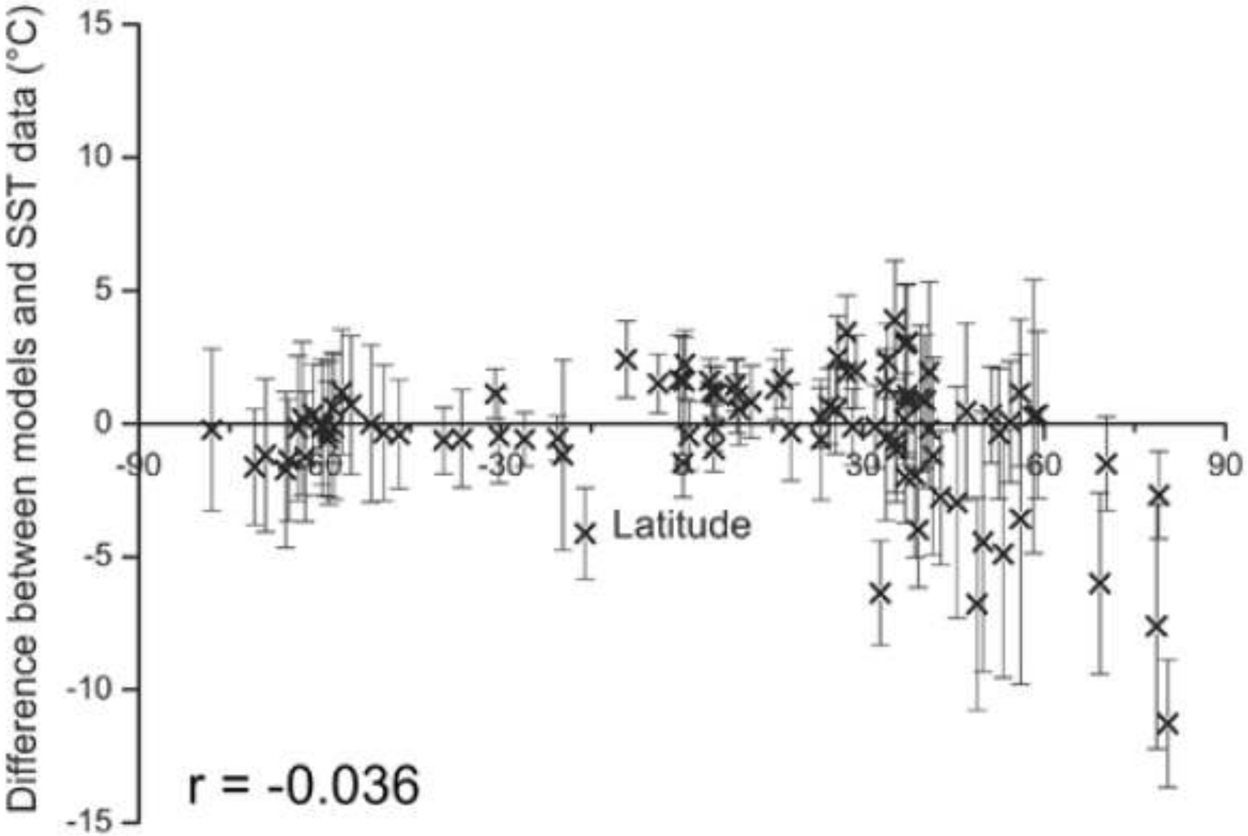
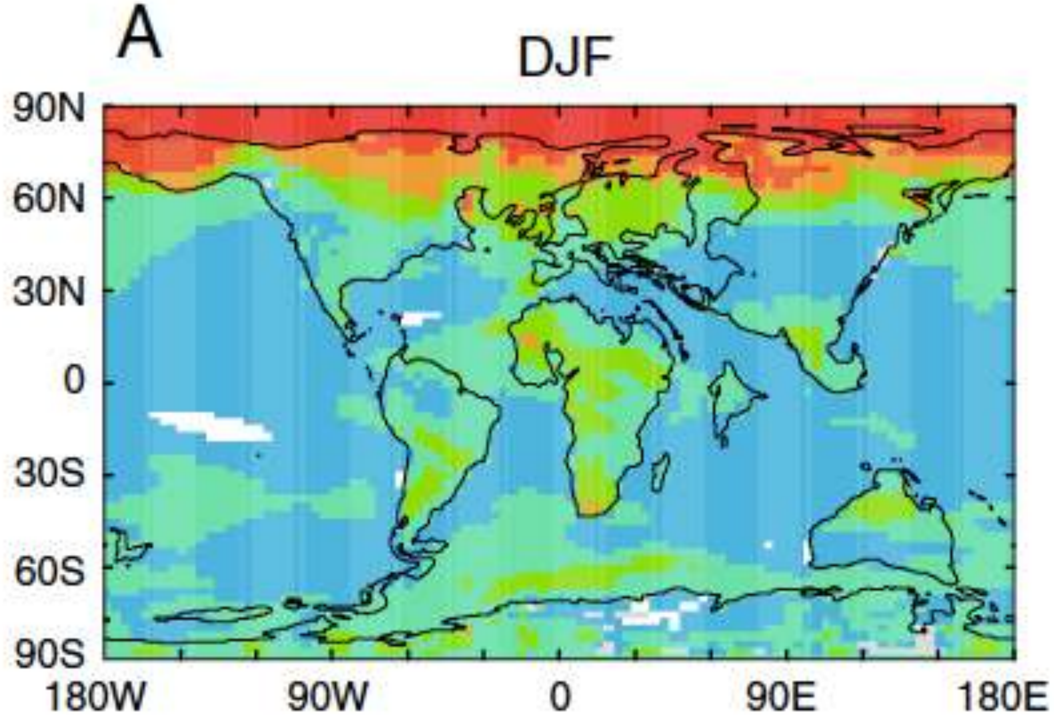
PLIOMIP missing warming in GCM simulations



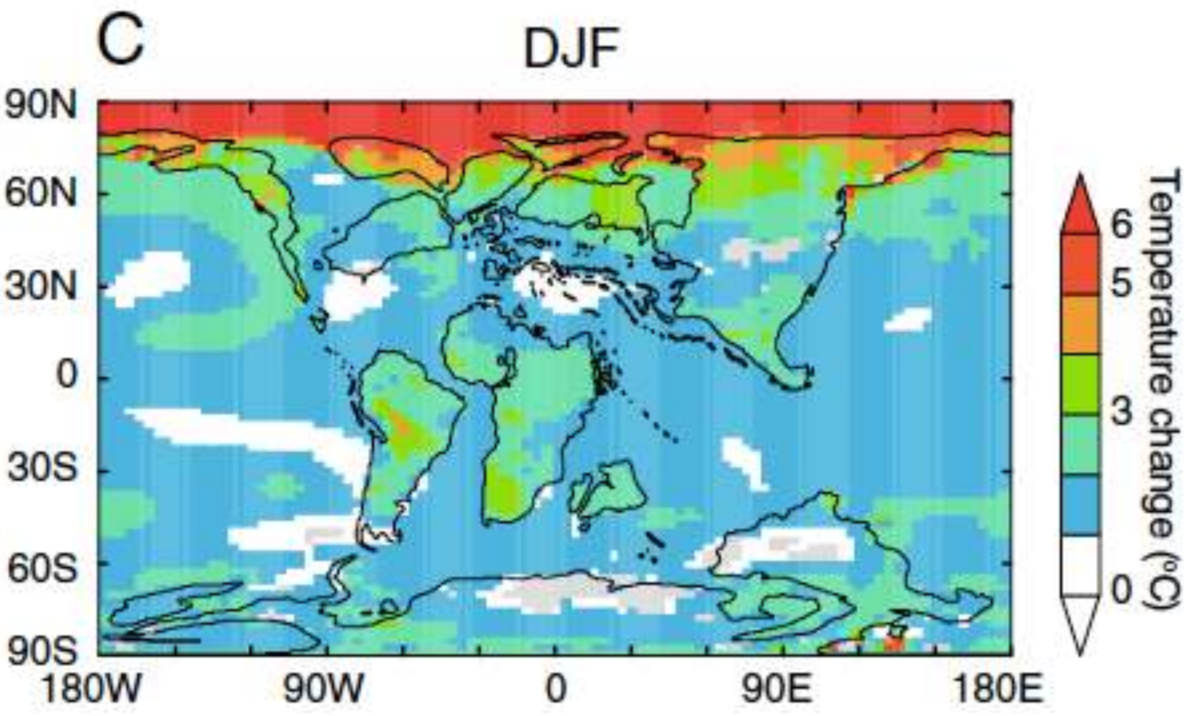


Haywood et al 2013, *Climate of the Past*

Simulated trace-gas induced warming



Early Eocene



Late Cretaceous

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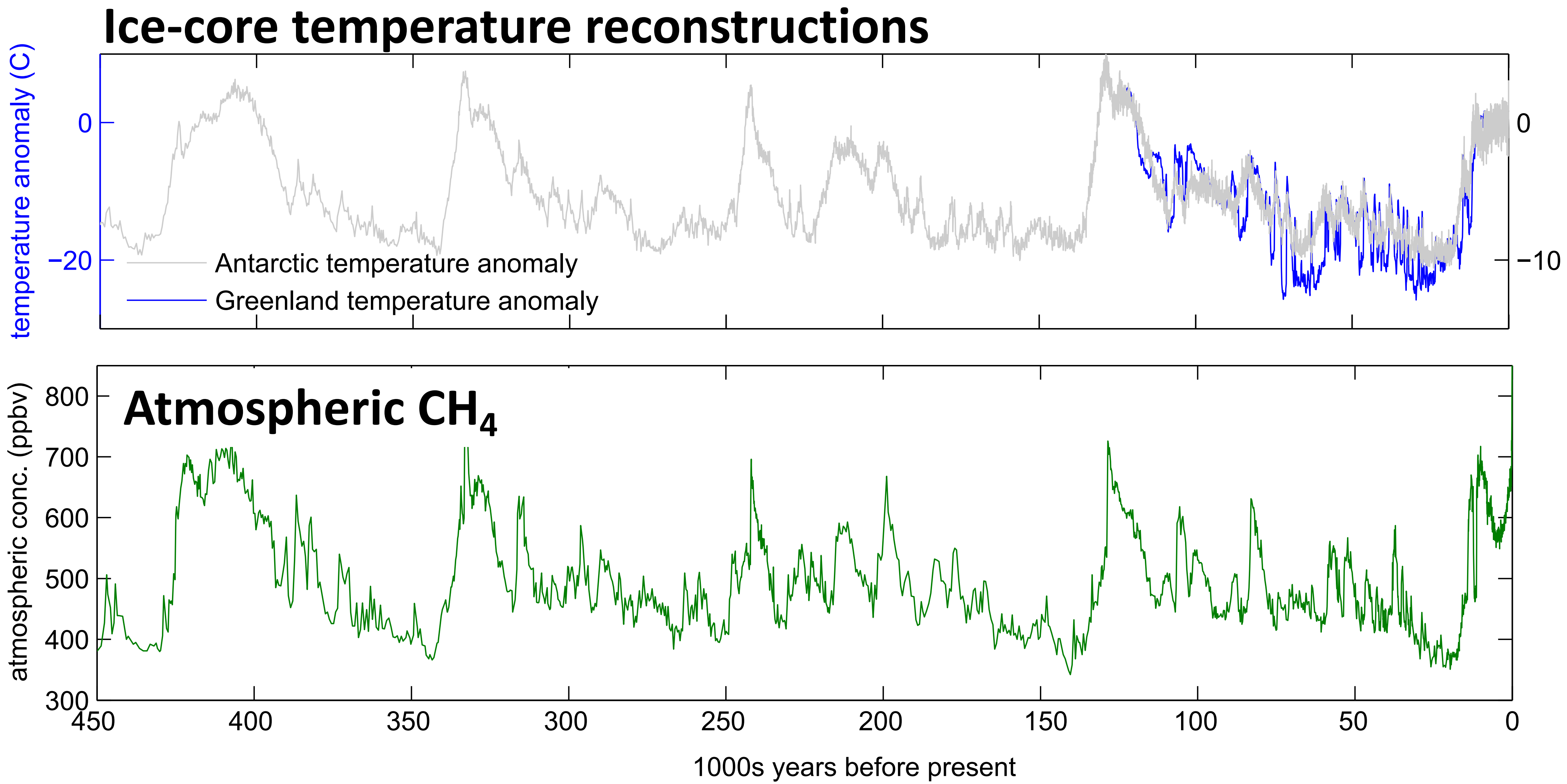
Beerling et al 2011, *PNAS*



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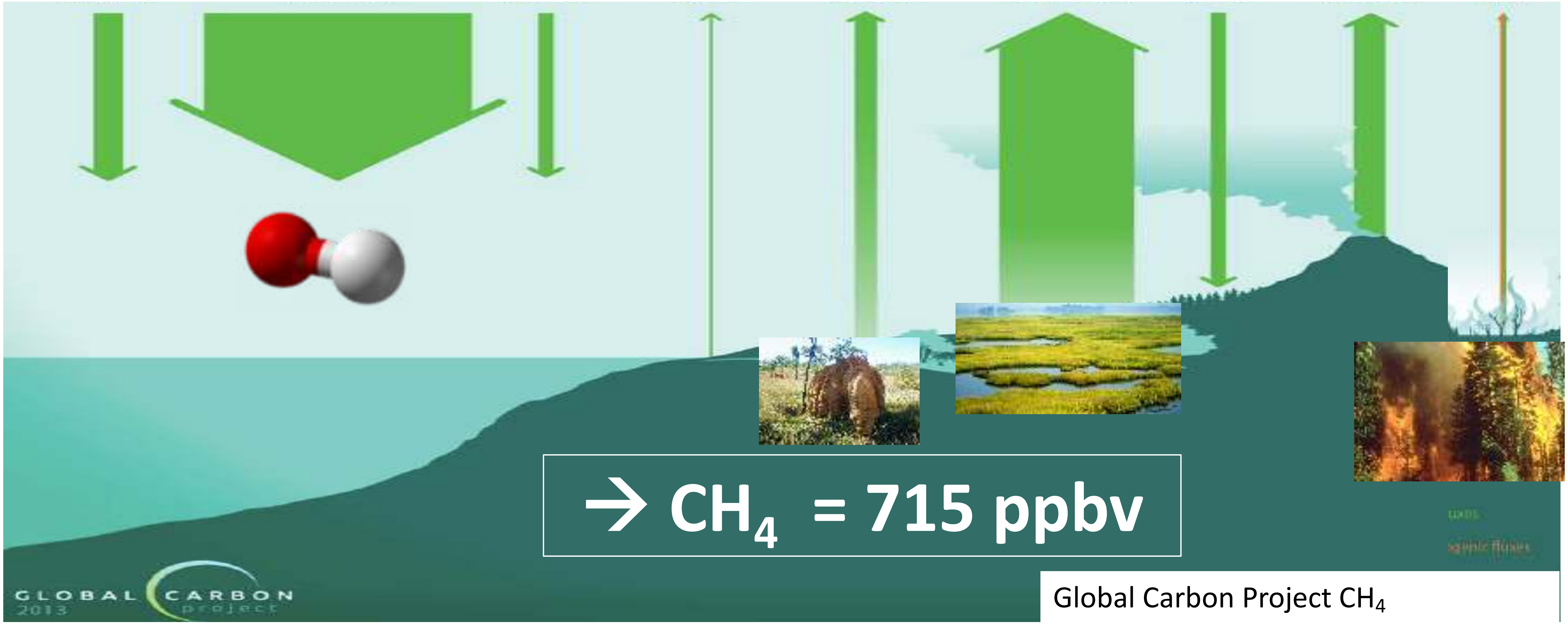
Stratospheric Loss	Tropospheric OH	Tropospheric Cl	Hydrates	Termites	Wetlands (+ lakes)	Soil uptake	Geological	Fires
18 Tg/yr	**167** Tg/yr	**6** Tg/yr	**10** Tg/yr	**20** Tg/yr	**140** Tg/yr	**11** Tg/yr	**10** Tg/yr	**21** Tg/yr



Hopcroft et al 2018, *Geophys Res Lett;* Petrenko et al 2017, *Nature;* Nicewonger et al 2018, *PNAS*

Stratospheric Loss	Tropospheric OH	Tropospheric Cl	Hydrates	Termites	Wetlands (+ lakes)	Soil uptake	Geological	Fires
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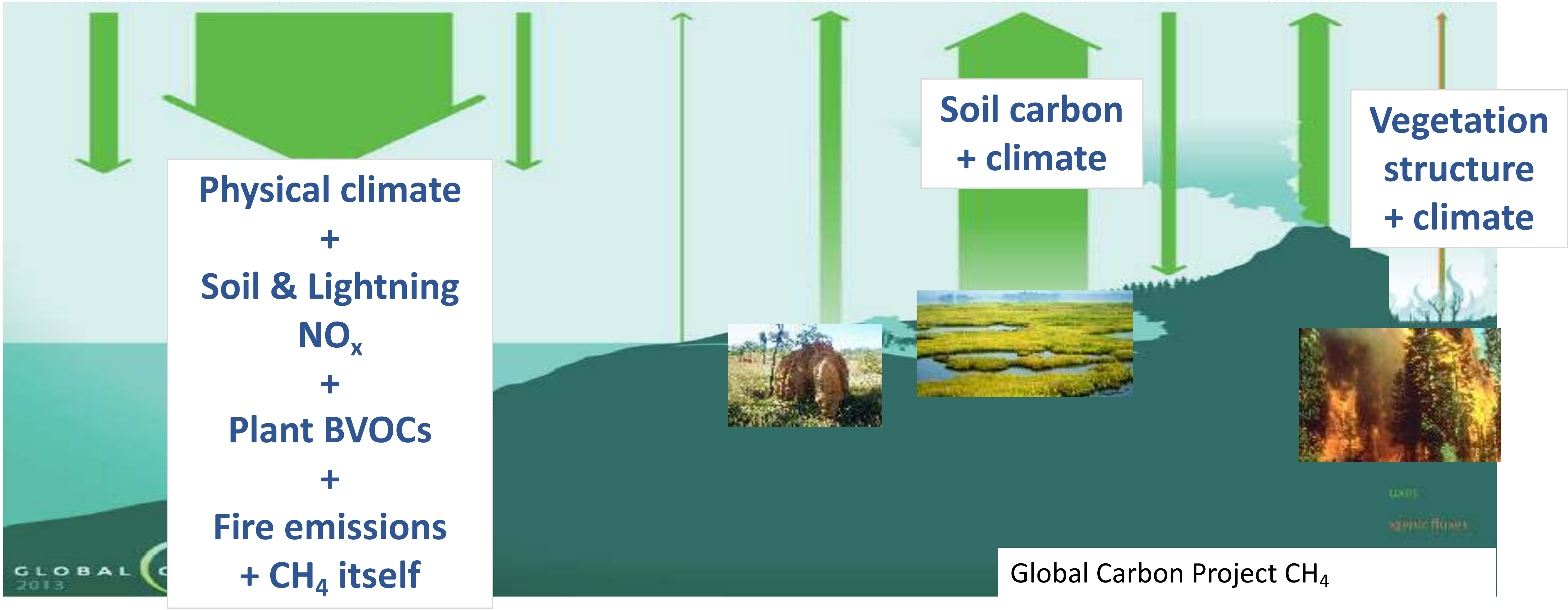


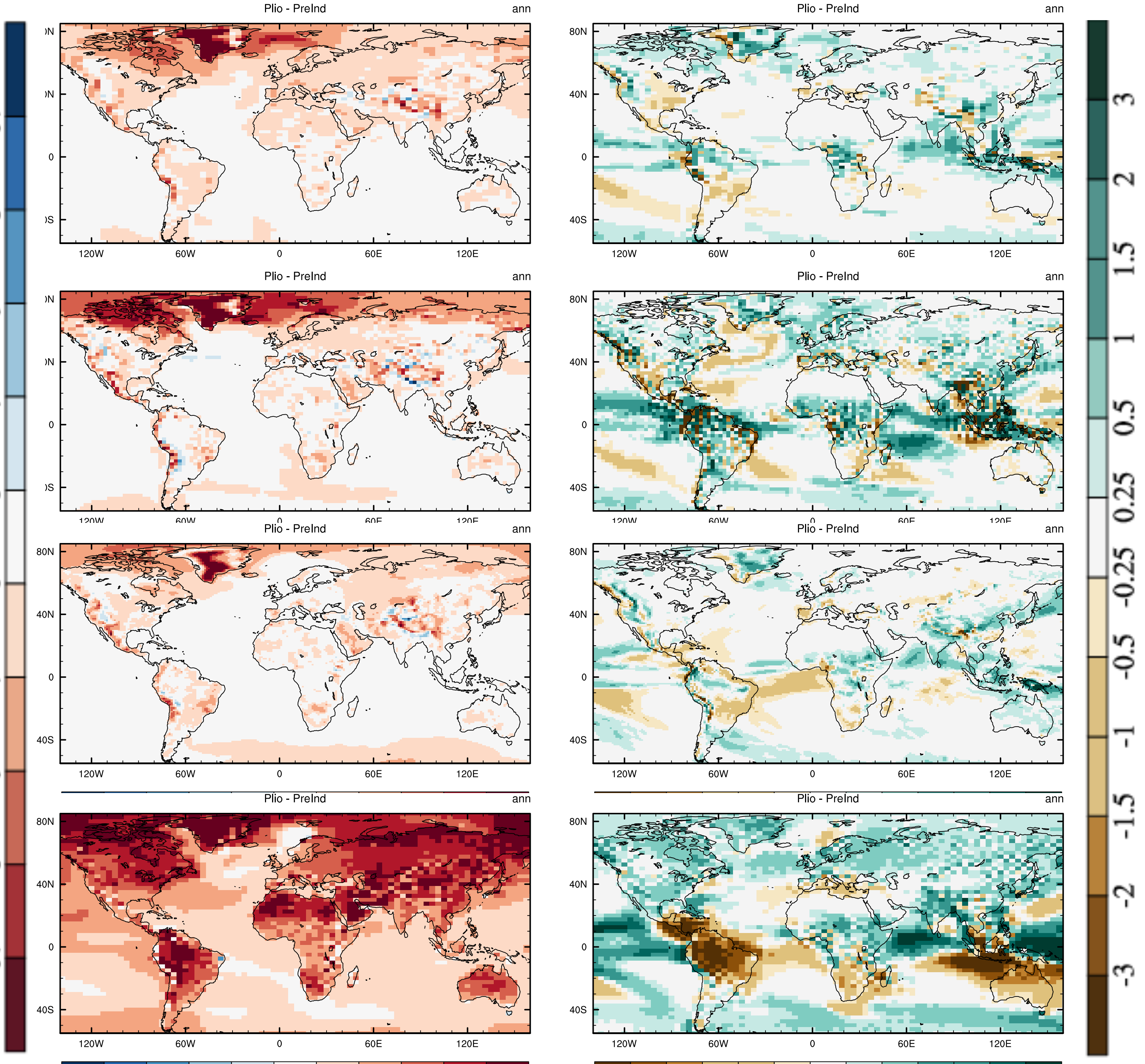
Hopcroft et al 2018, *Geophys Res Lett;* Petrenko et al 2017, *Nature;* Nicewonger et al 2018, *PNAS*

CCSM4
+1.8 K

GISS-E2-R
+1.9 K

IPSL-CM5A-LR
+2.2 K

HadCM3L
+5.3 K



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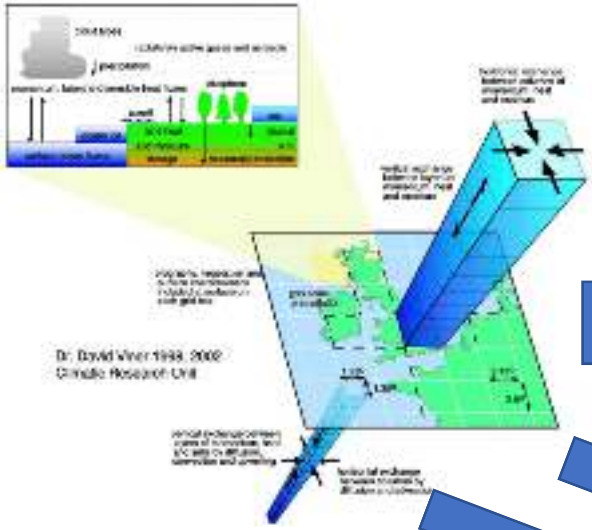
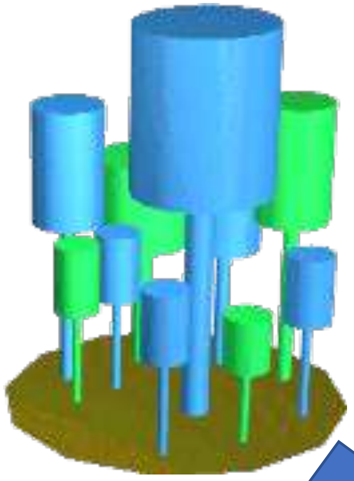
Modelling framework

GCMs



Vegetation
LPJ-GUESS



Fire CH_4
Fire other
Isoprene
Monoterpene
Soil
Carbon

Wetland

Soil NOx

CH_4 box model

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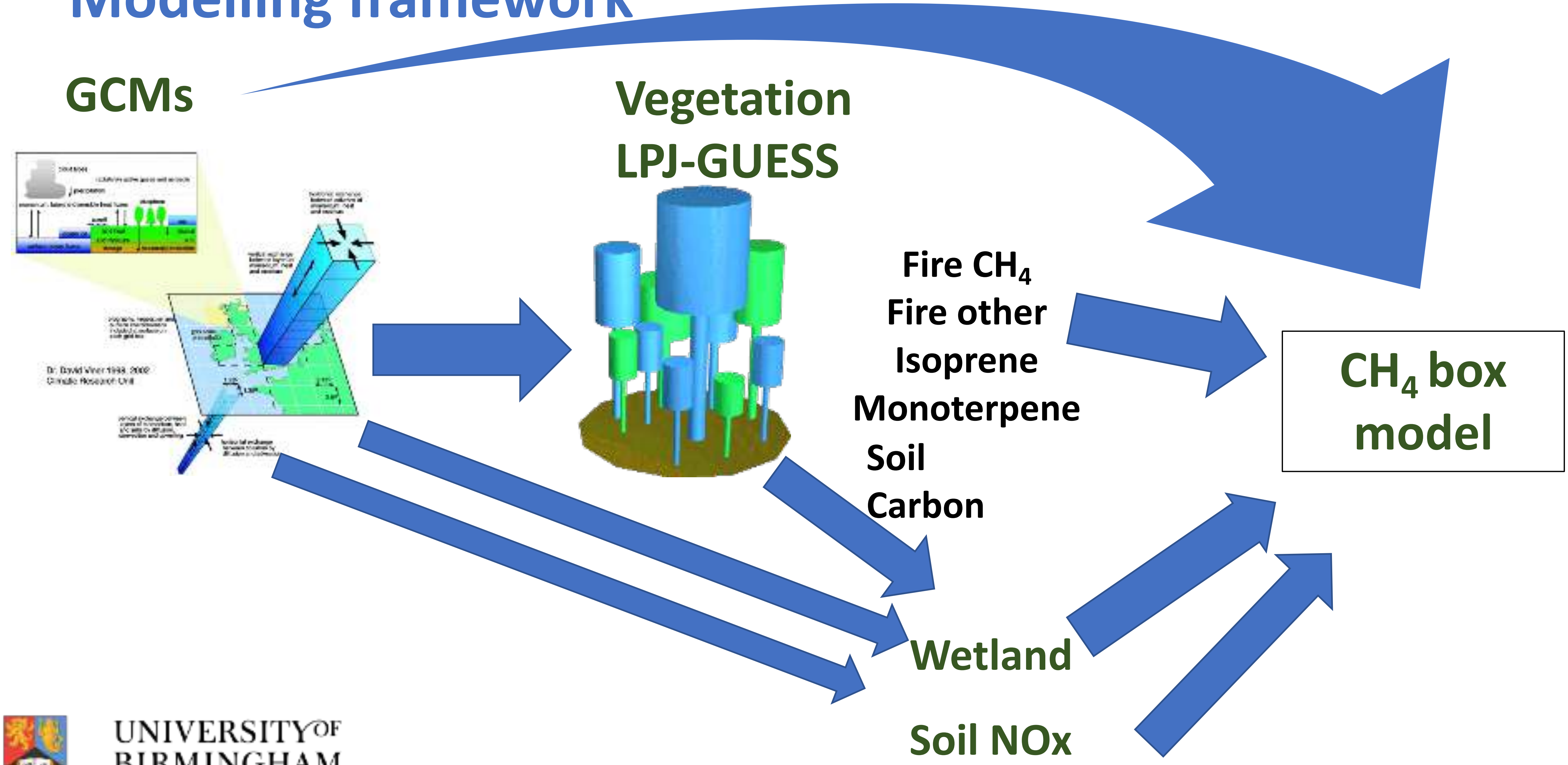
Modelling framework



1 box atmospheric chemistry model

$B = S\tau$

B = atmospheric CH_4 burden (Tg)
S = CH_4 emissions (Tg/year)
τ = CH_4 lifetime (years)

$$ln(\tau_{CH4\times OH}(t)) = ln(\tau_{CH4\times OH}(t_0)) + \Sigma_i \alpha_i \Delta ln(F_i)(t)$$

Holmes et al 2013, *Atmos Chem Phys*

$\boldsymbol{\alpha_i}$ evaluated based on 3x 3D chemistry-transport models:
(UTI CTM, Oslo CTM3
and GEOS-Chem)

Variable [b]	Adopted [d]
Chemistry-climate interactions	
Air temperature [e]	-3.0 ± 0.8
Water vapor [e]	-0.32 ± 0.03
Ozone column, 40° S–40° N	$+0.55 \pm 0.11$
Lightning NO_x *emissions*	-0.16 ± 0.06
Biomass burning emissions [i]	$+0.020 \pm 0.015$
CH_4 abundance [k]	$+0.31 \pm 0.04$

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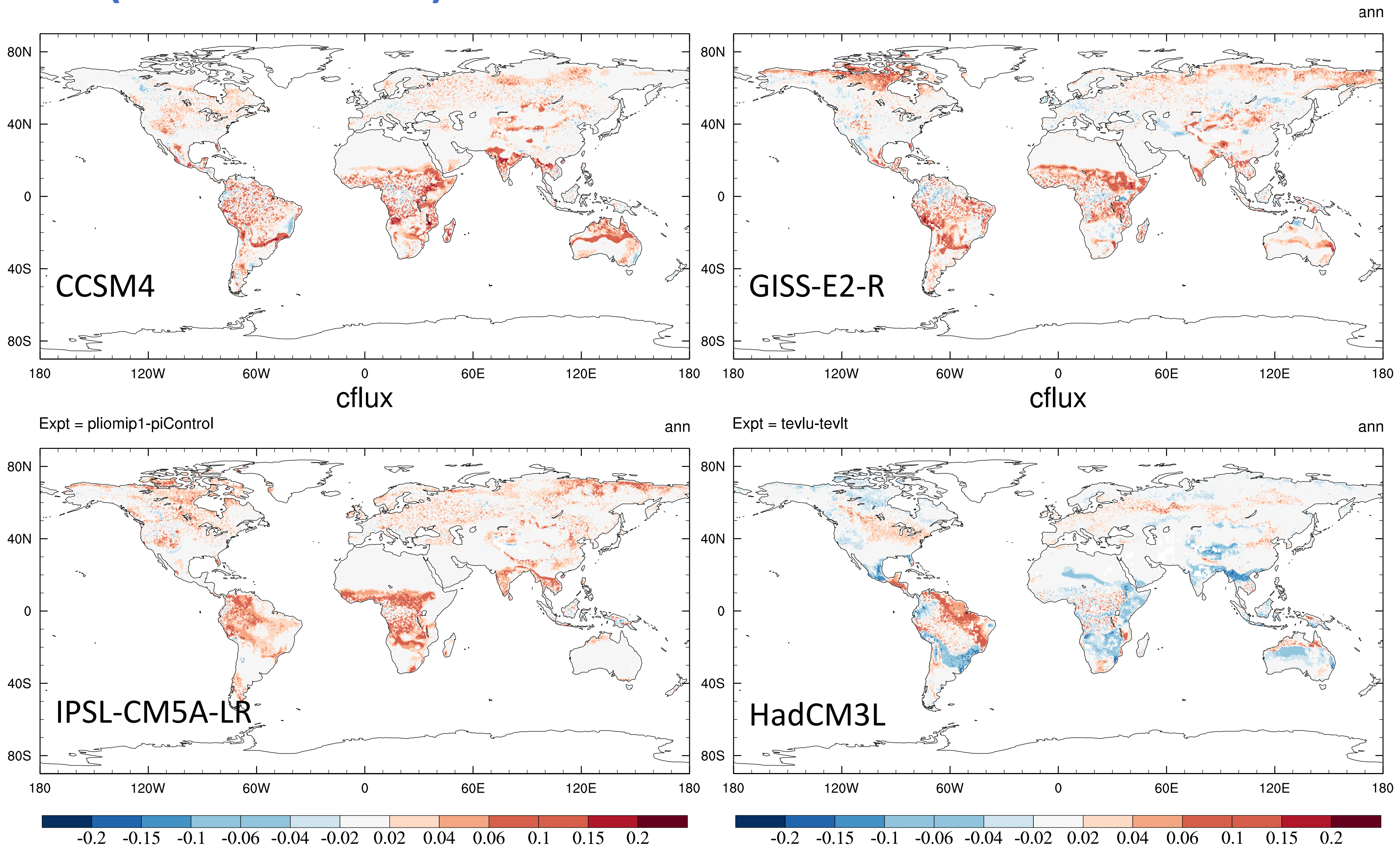
Wildfires (LPJ-GUESS)



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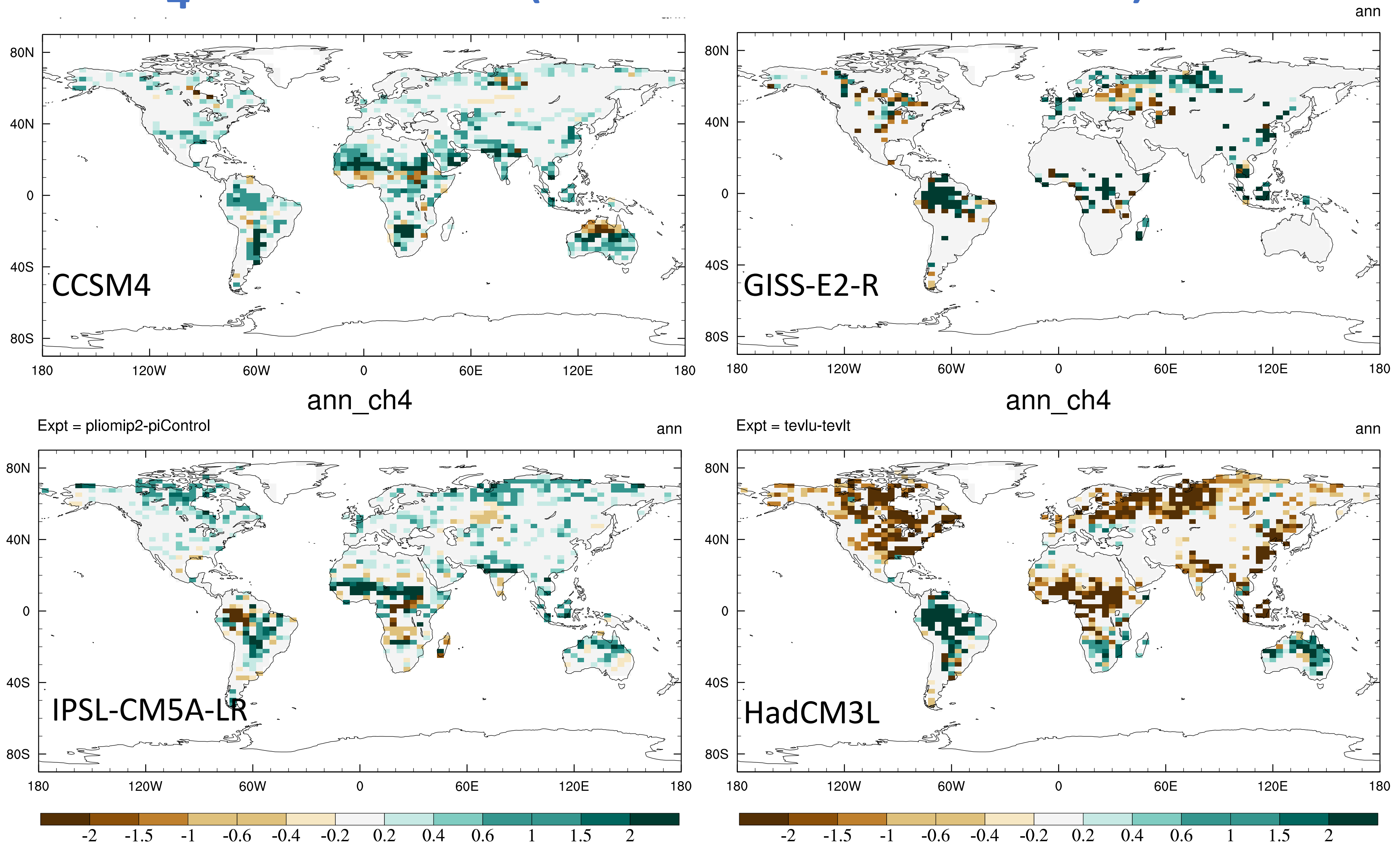
Wetland CH_4 emissions (LPJ-GUESS +SimTOP)



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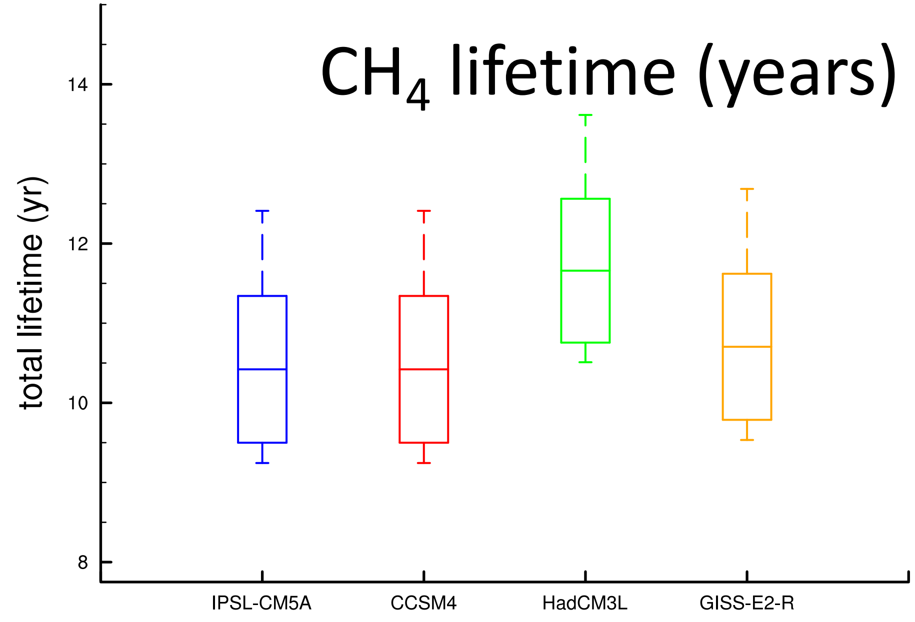
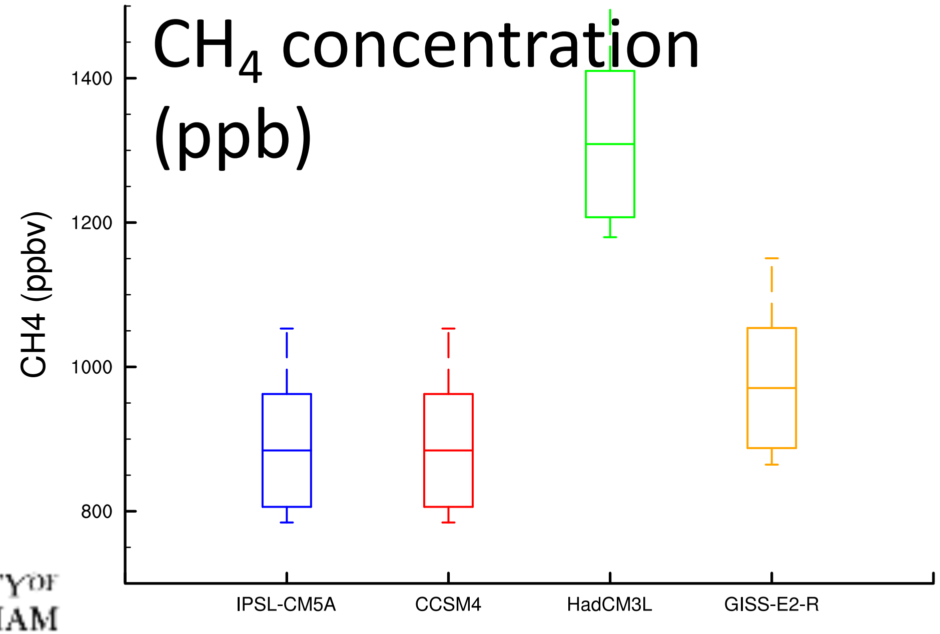
Wetland CH_4 emissions

CH_4 lifetime (years)

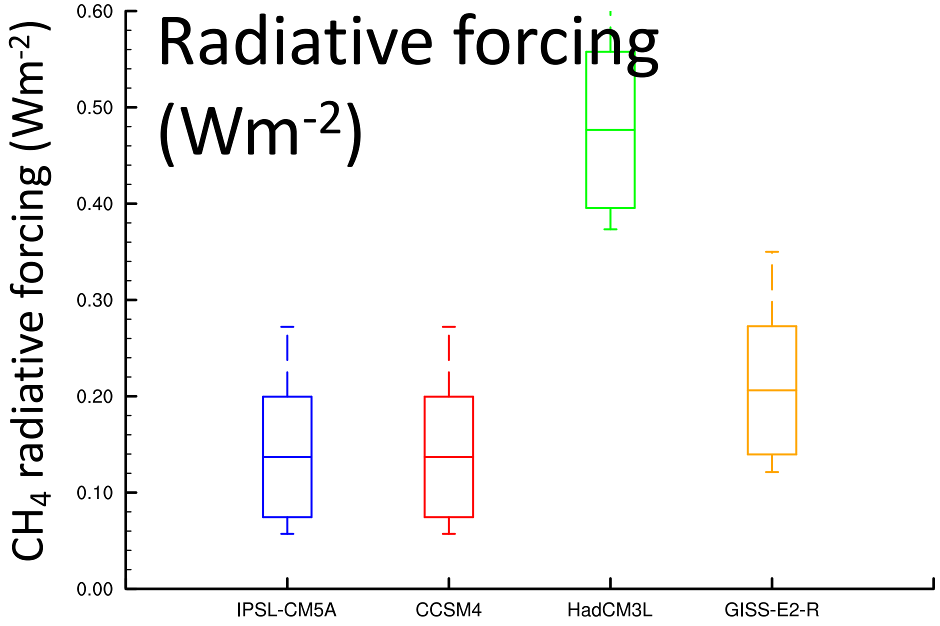


IPSL
CCSM4
HadCM3l
GISS-E2-R

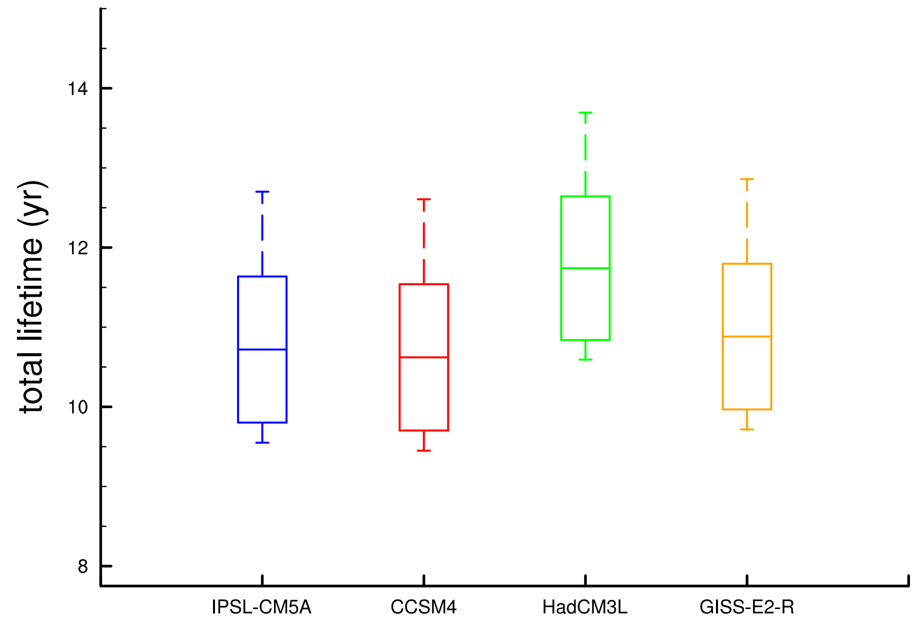
CH_4 concentration (ppb)



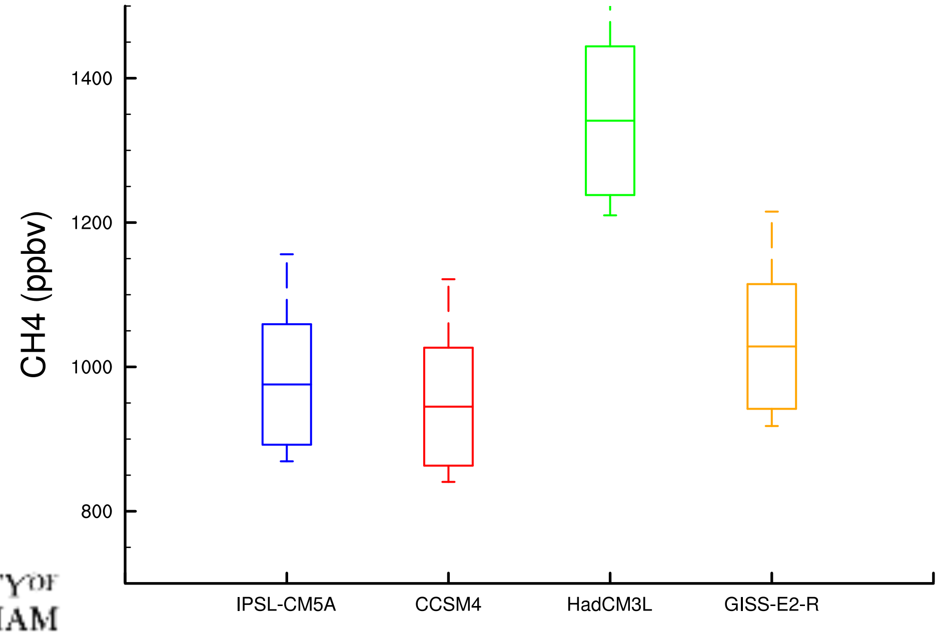
Radiative forcing (Wm^{-2})

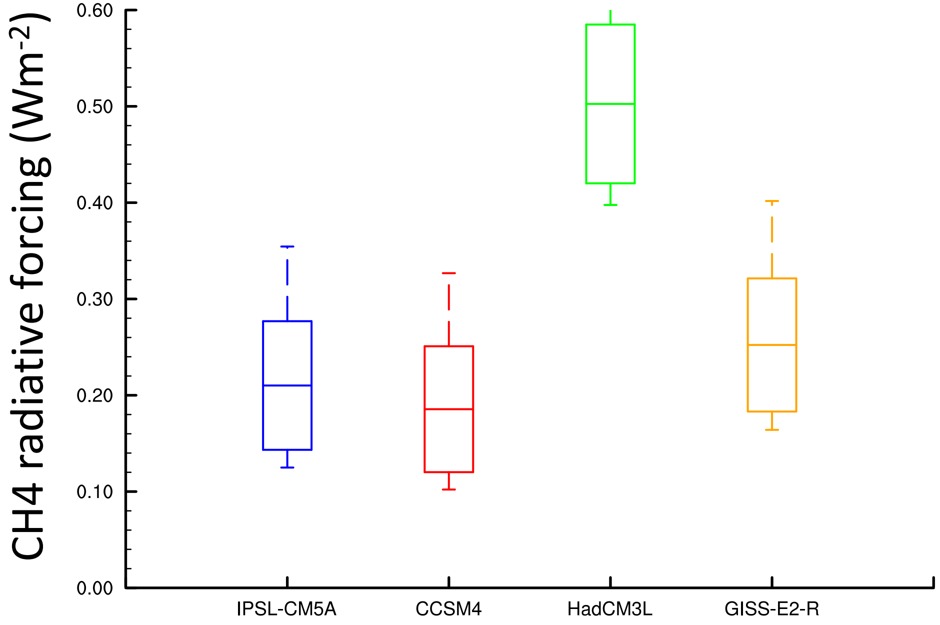


Wetland CH_4 emissions + fire CH_4 emissions



IPSL
CCSM4
HadCM3l
GISS-E2-R





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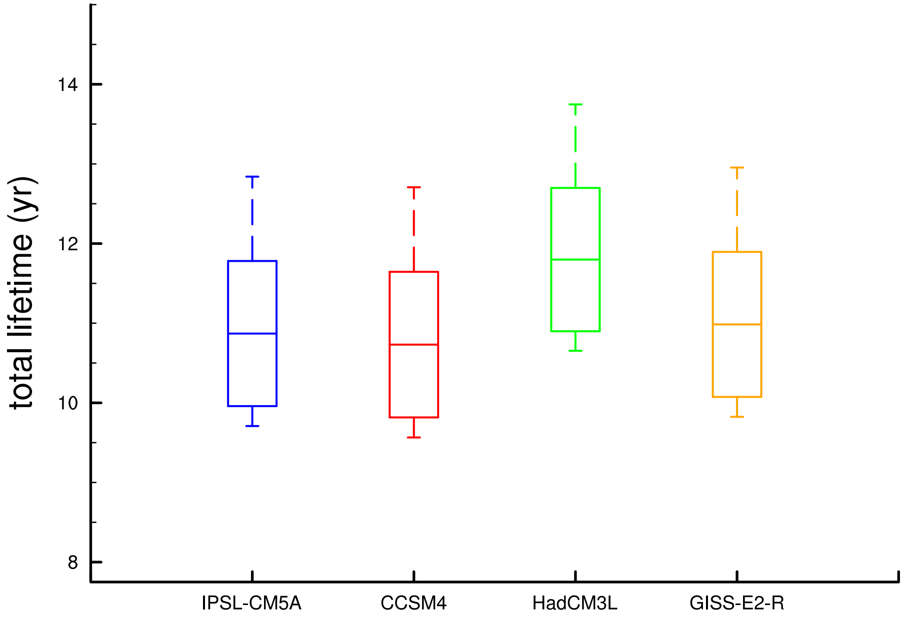
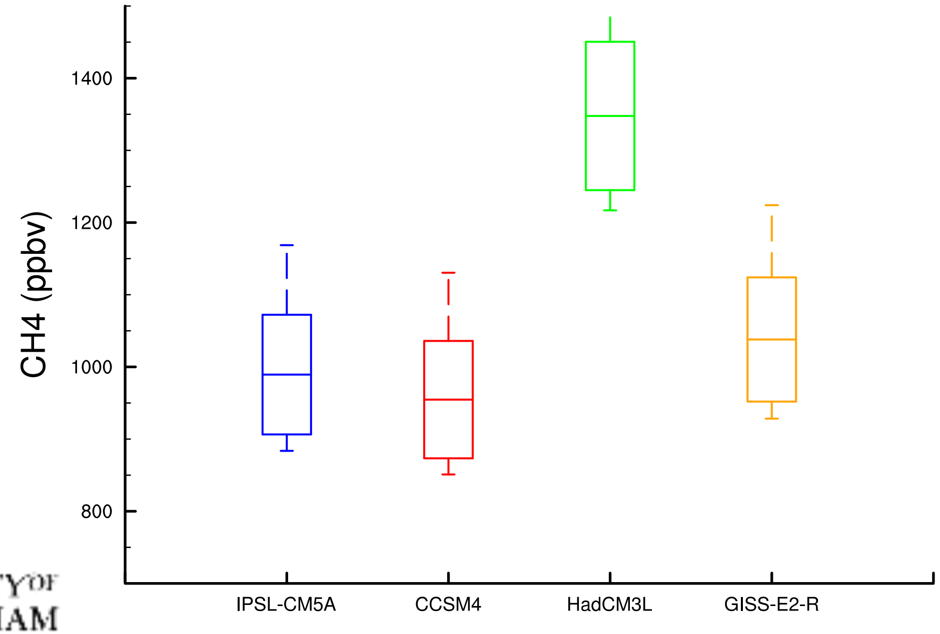
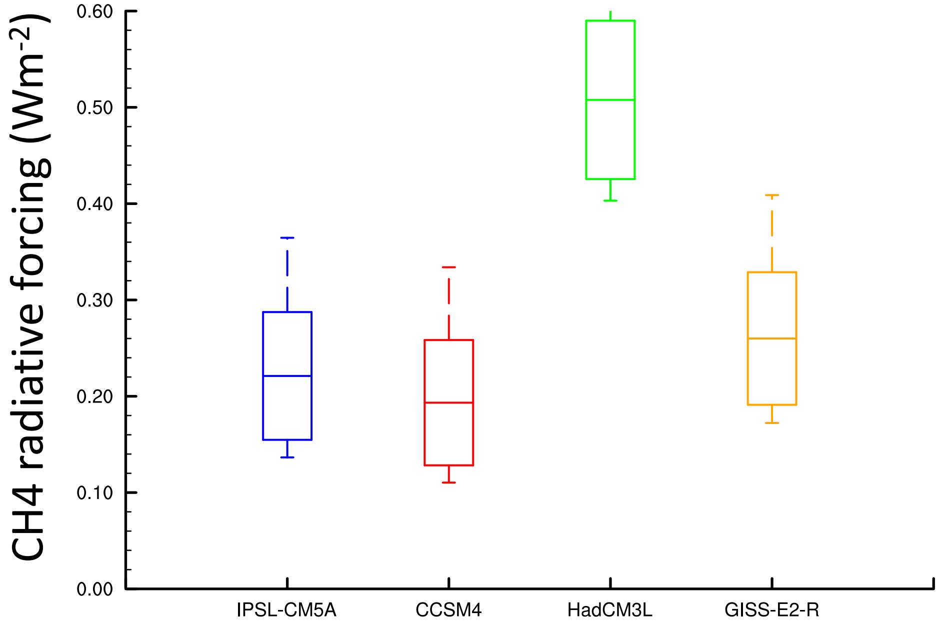
Wetland CH_4 emissions
+ fire CH_4 emissions
+ fire other emissions



IPSL
CCSM4
HadCM3l
GISS-E2-R





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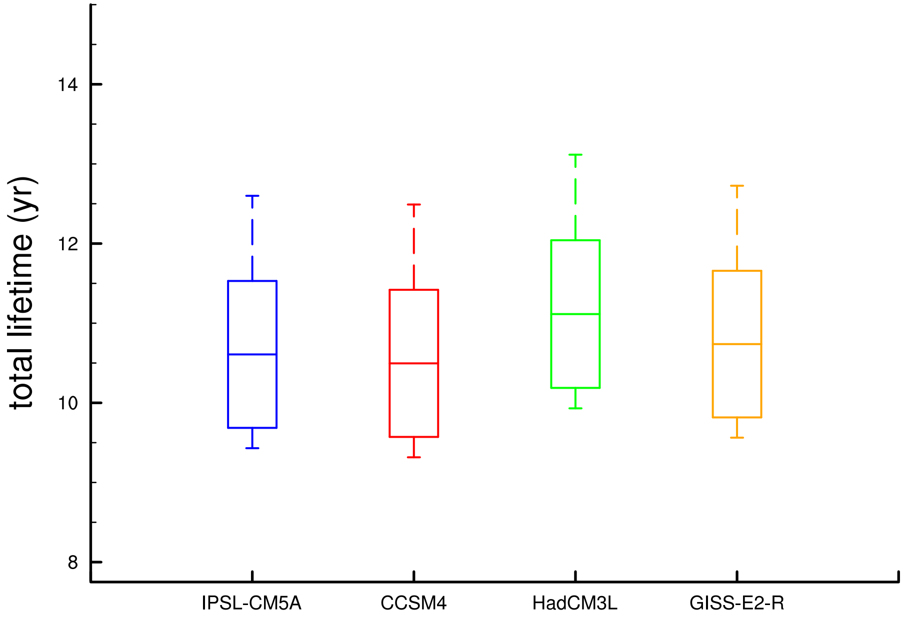
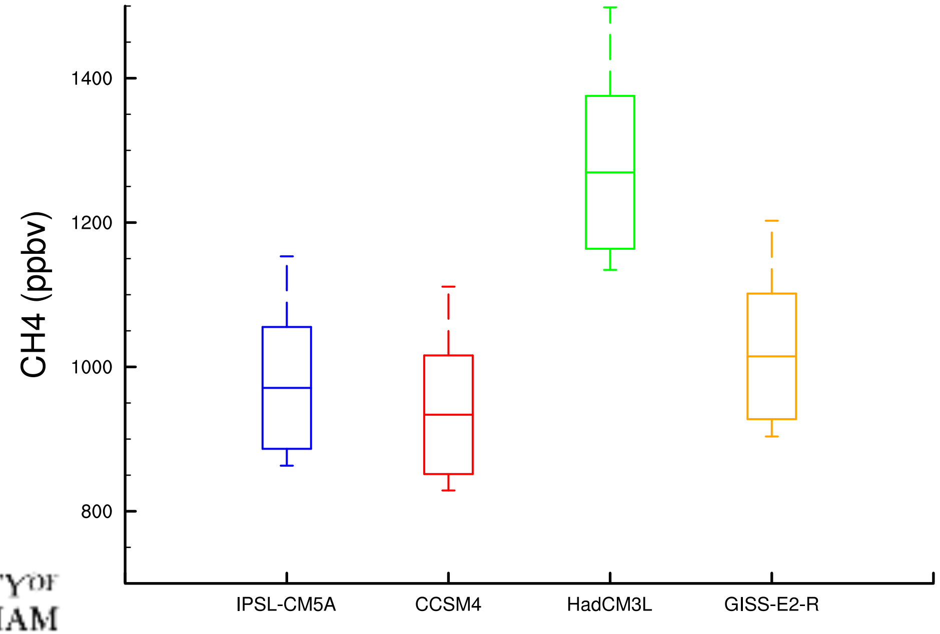
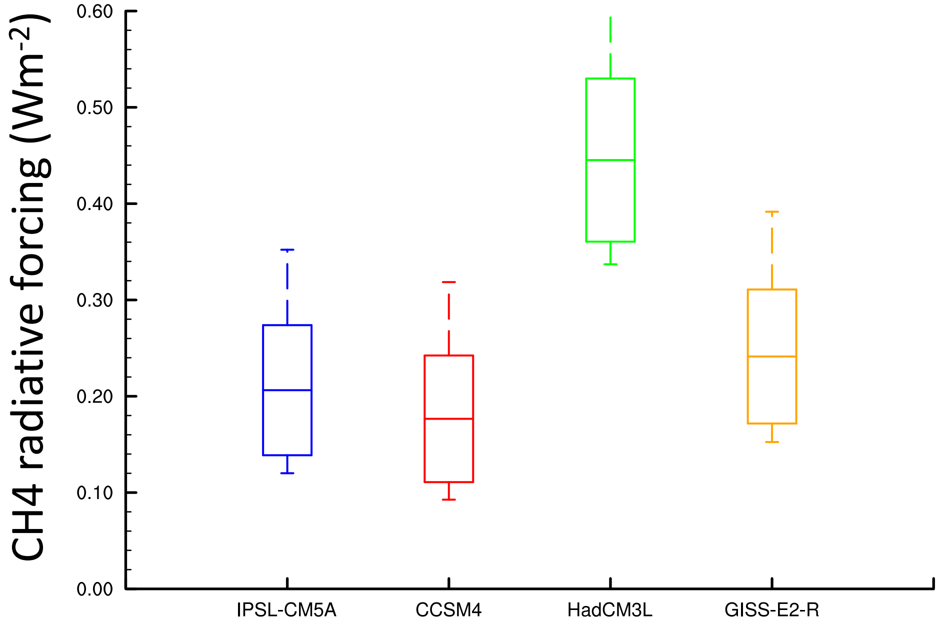
Wetland CH_4 emissions
+ fire CH_4 emissions
+ fire other emissions
+ atmospheric warming



IPSL
CCSM4
HadCM3l
GISS-E2-R





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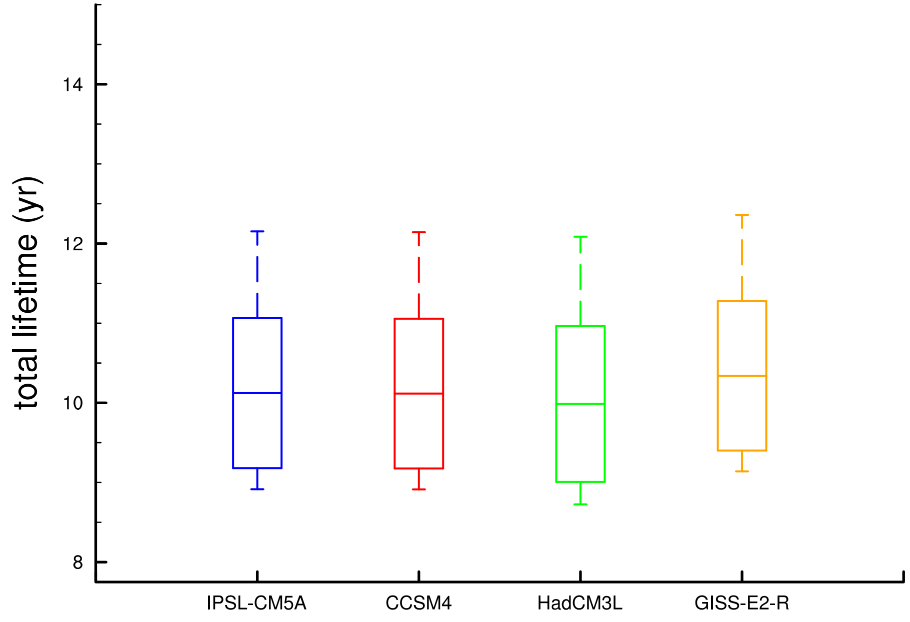
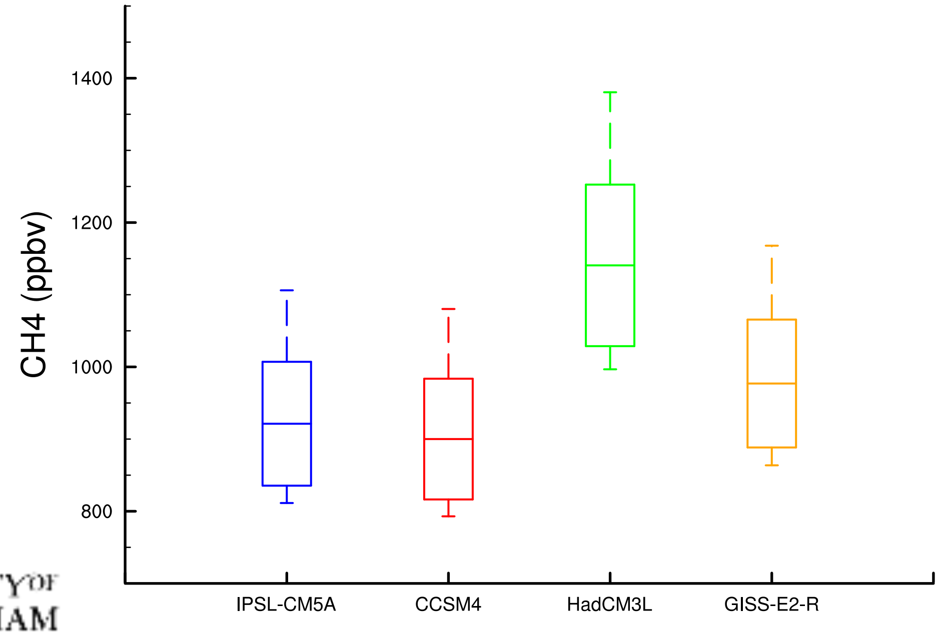
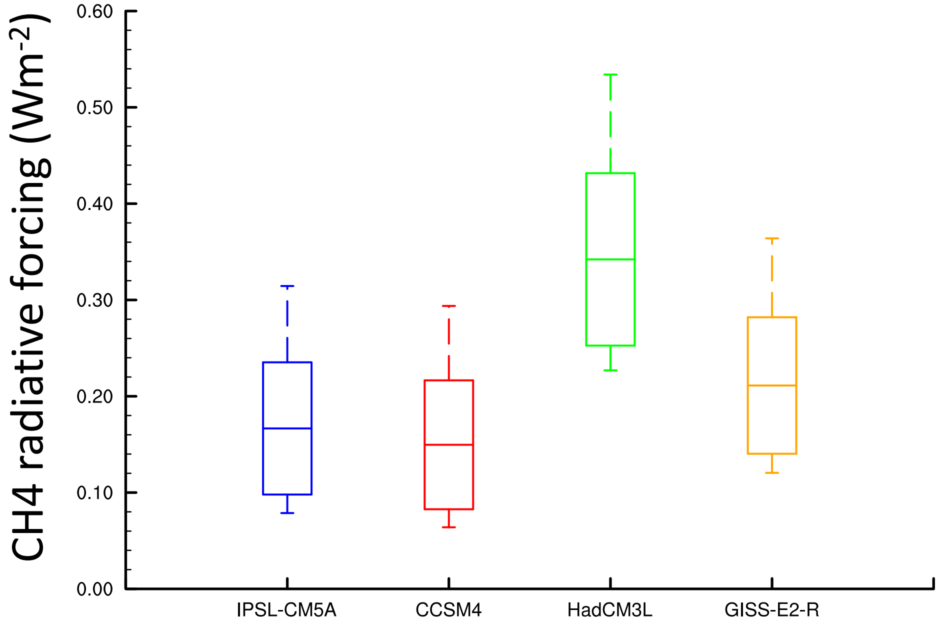
Wetland CH_4 emissions
+ fire CH_4 emissions
+ fire other emissions
+ atmospheric warming
+ humidity change

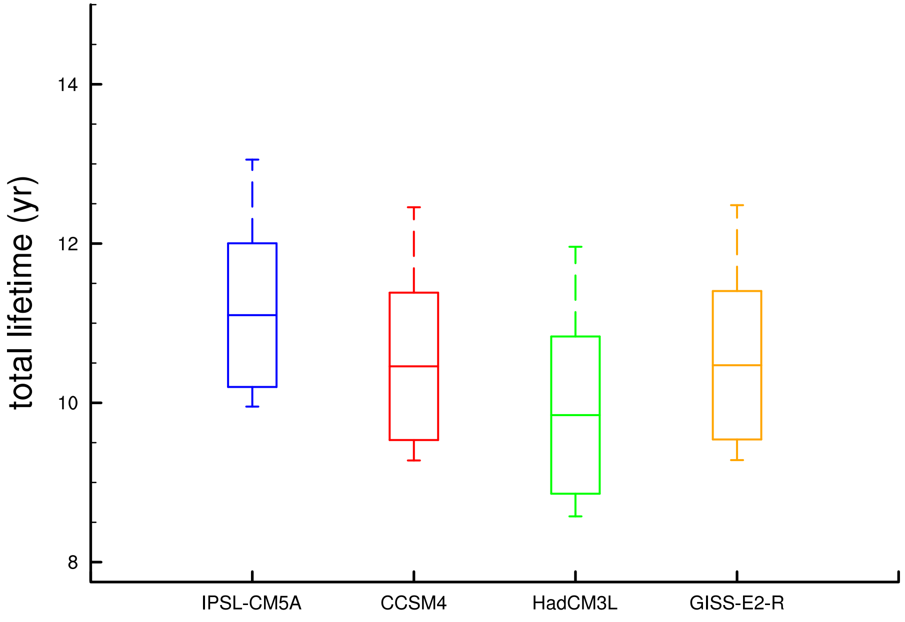


IPSL
CCSM4
HadCM3l
GISS-E2-R





Wetland CH_4 emissions
+ fire CH_4 emissions
+ fire other emissions
+ atmospheric warming
+ humidity change
+ BVOCs emissions (isoprene, monoterpene)



IPSL
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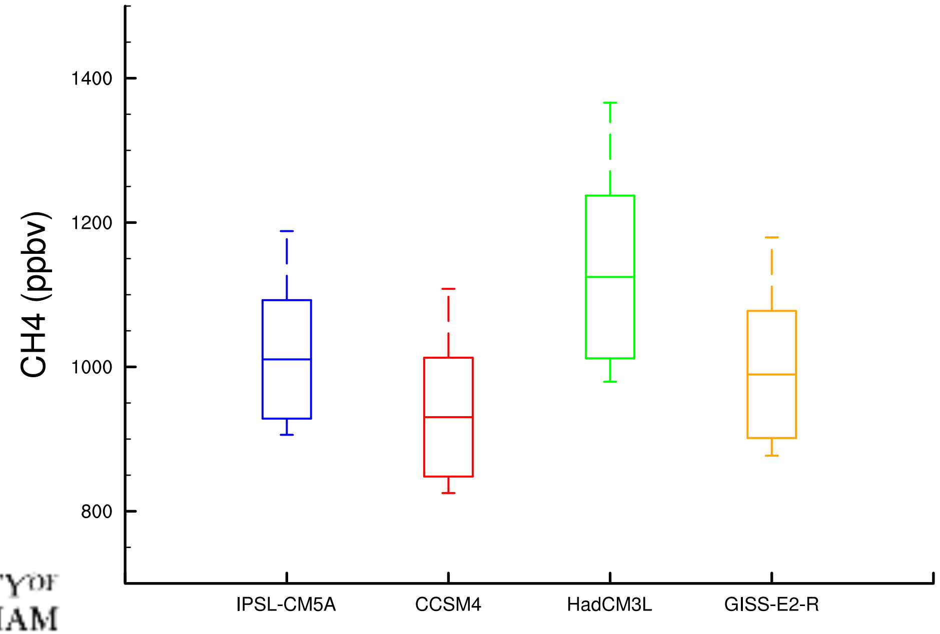

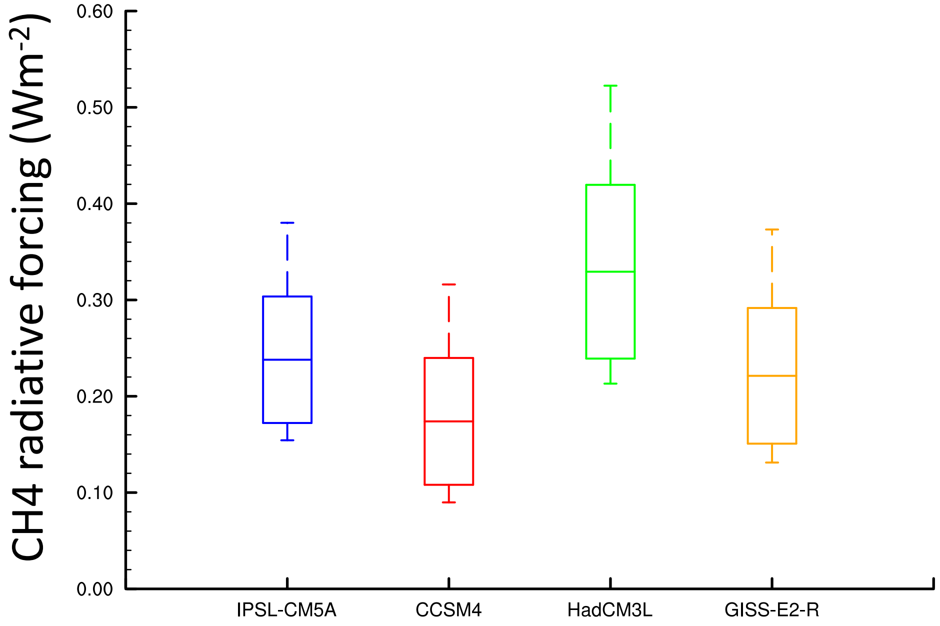

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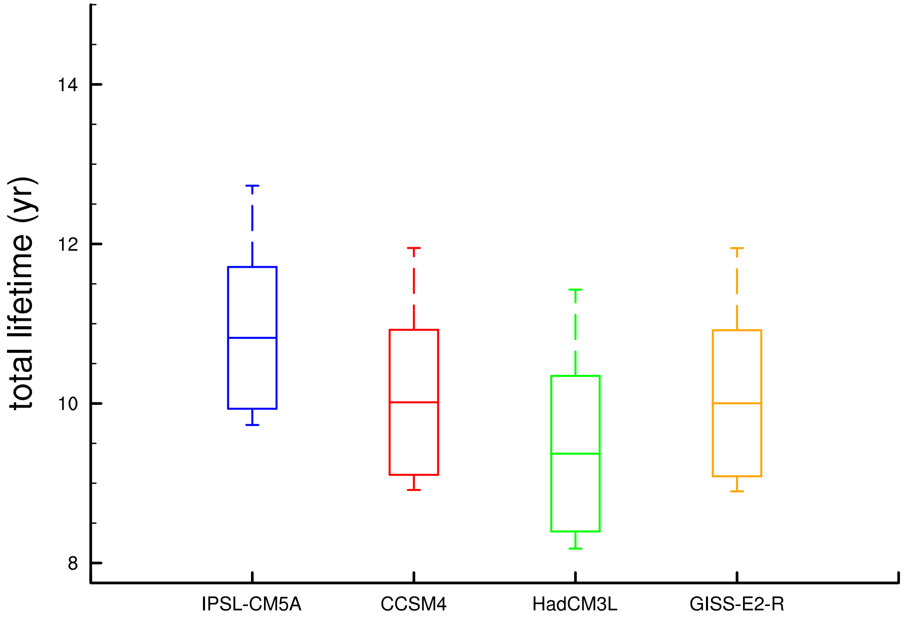
Wetland CH_4 emissions
+ fire CH_4 emissions
+ fire other emissions
+ atmospheric warming
+ humidity change
+ BVOCs emissions
+ soil NO_x emissions



IPSL
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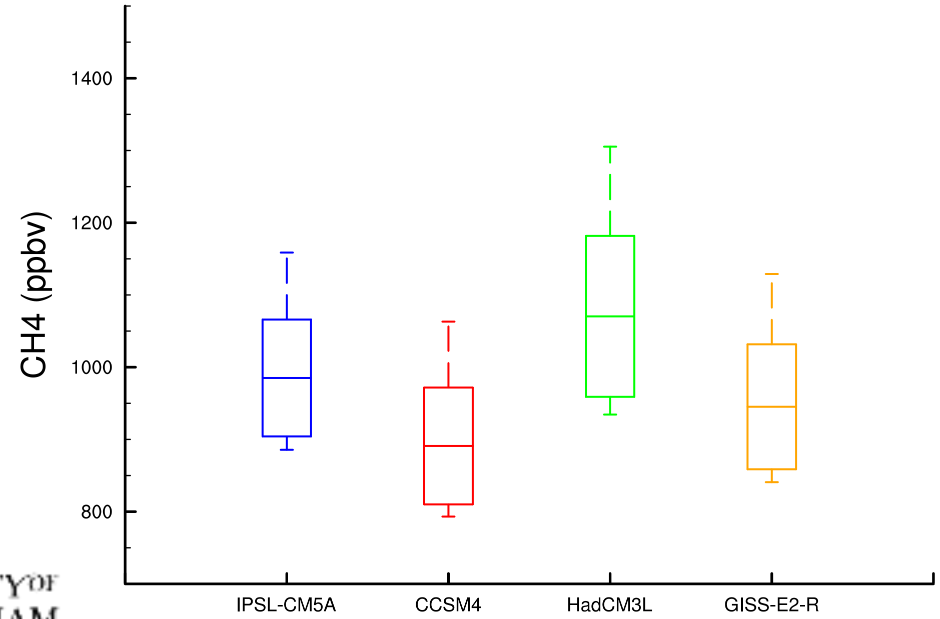
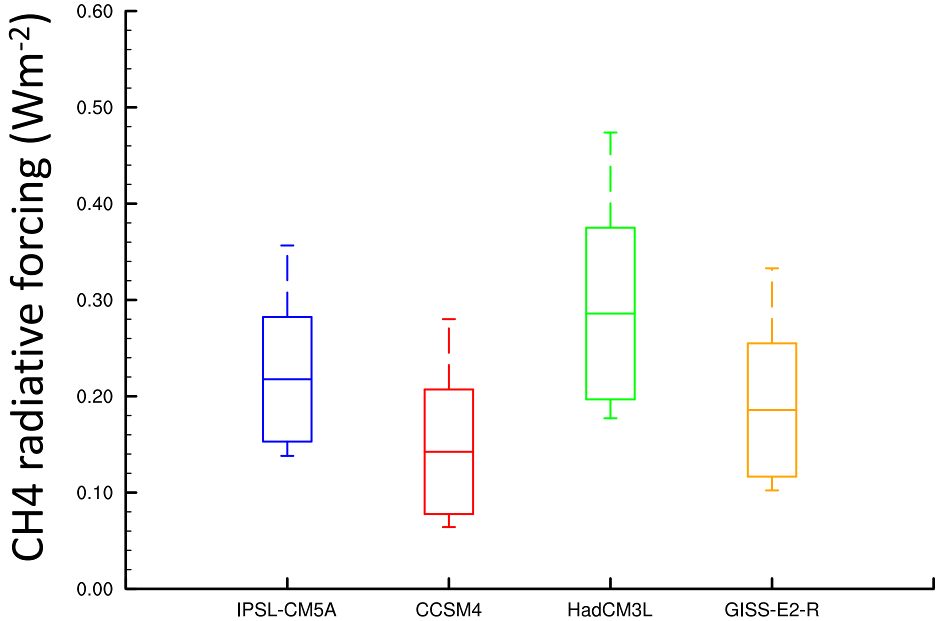
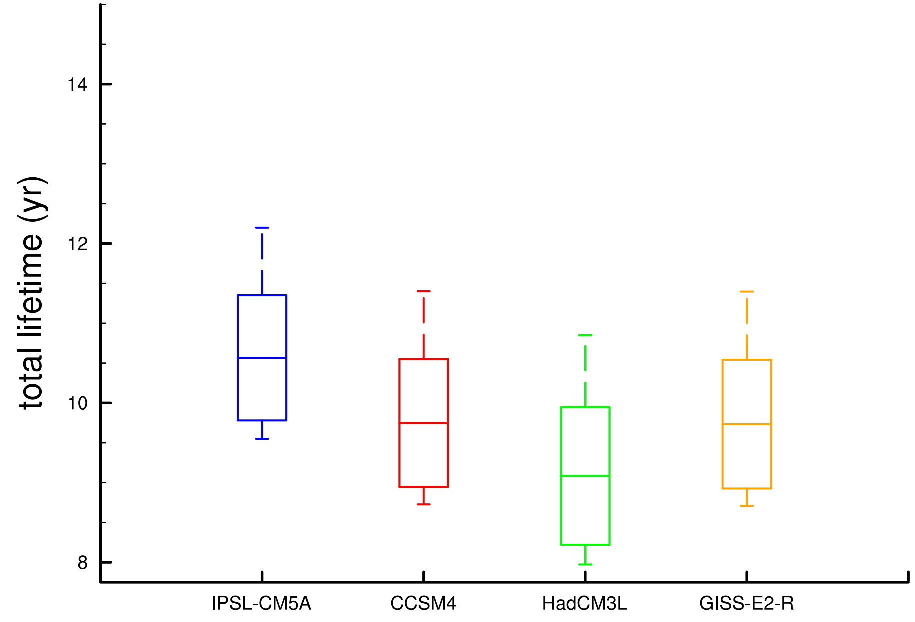




Wetland CH_4 emissions
+ fire CH_4 emissions
+ fire other emissions
+ atmospheric warming
+ humidity change
+ BVOCs emissions
+ soil NO_x emissions
+ lightning NO_x emissions



IPSL
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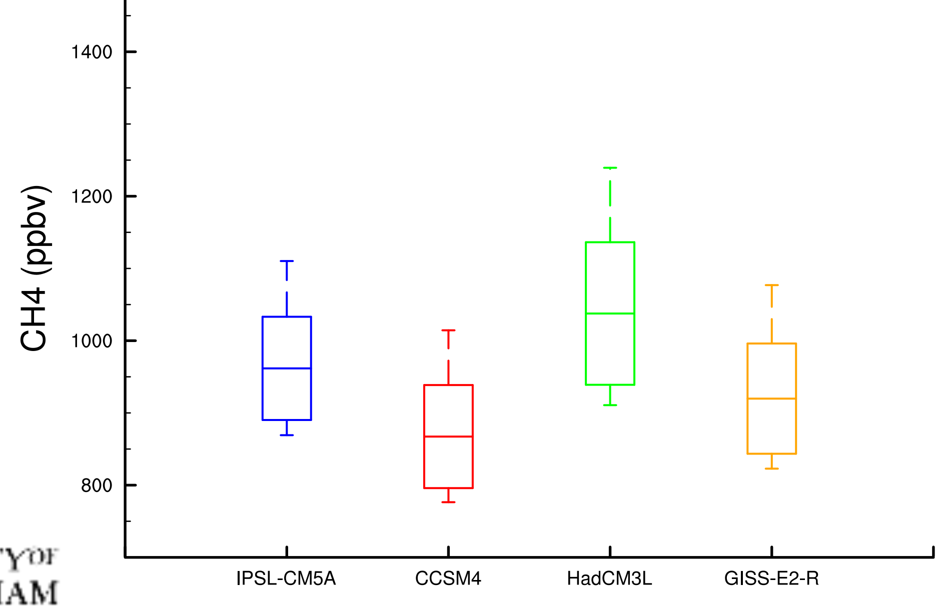

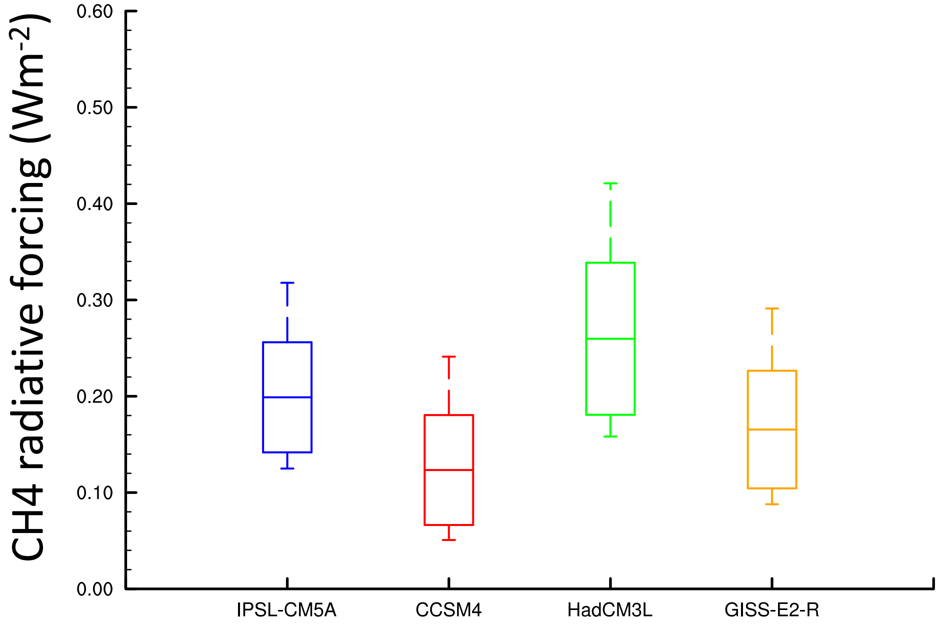

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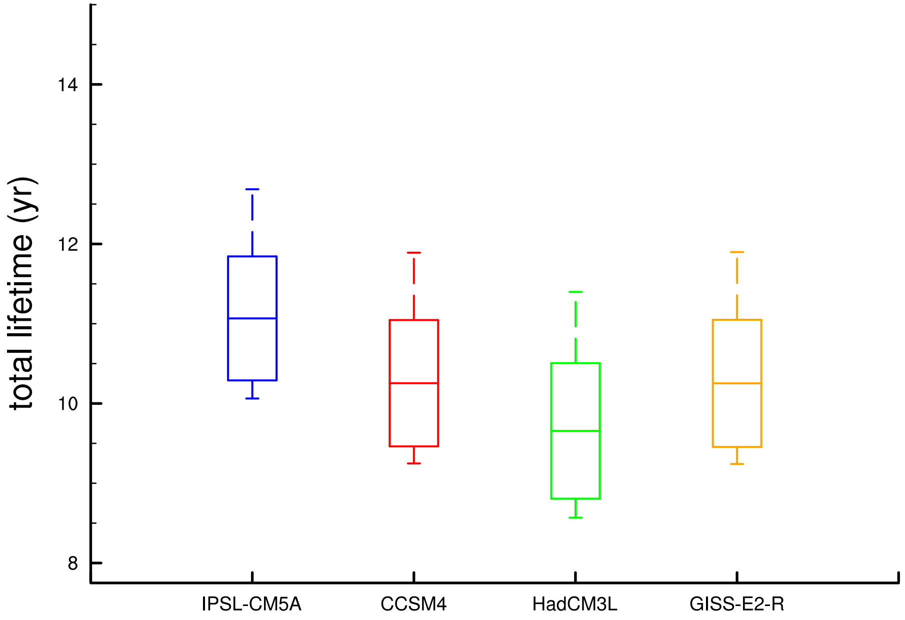
Wetland CH_4 emissions
+ fire CH_4 emissions
+ fire other emissions
+ atmospheric warming
+ humidity change
+ BVOCs emissions
+ soil NO_x emissions
+ lightning NO_x emissions
+ tropospheric O_3 change



IPSL
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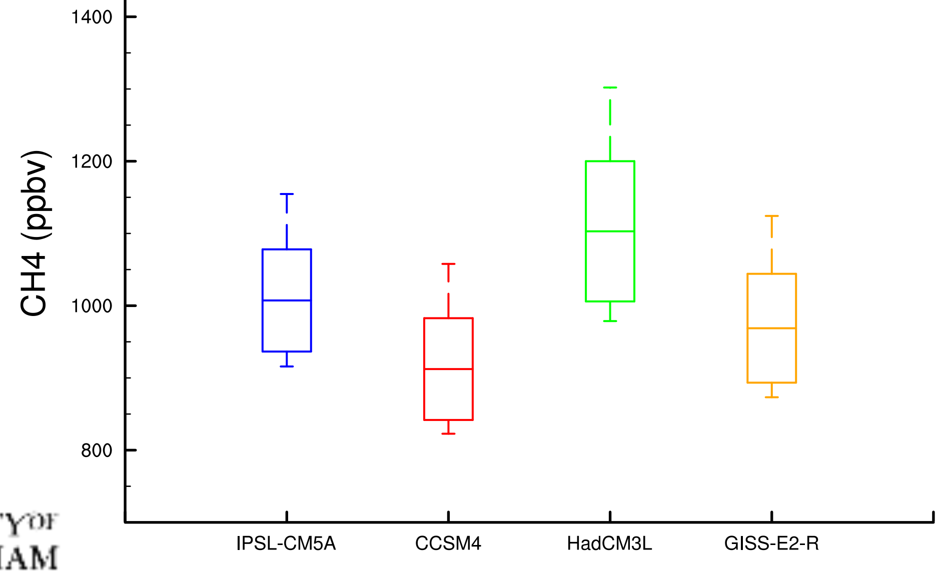

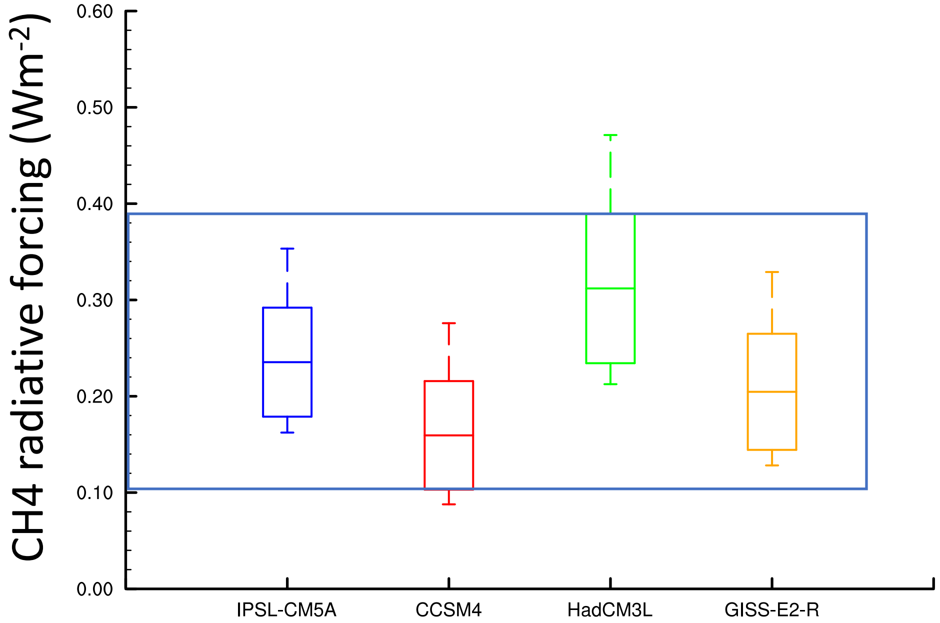

CO_2e
370->
400 ppm

Summary

- CH_4 cycling sensitive to natural climate oscillations over Quaternary
- Not directly considered in Pliocene simulations to date

Conclusions

- CH_4 probably not major driver of Pliocene warmth
- Fire and soil NO_x do show very strong increases
- No ‘**warm and wet**’ model in our ensemble … yet.

Caveats

- Wetland models underestimate change at LGM (Hopcroft *et al* 2017, 2018).
- Tropical precipitation response in GCMs divergent.

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Thanks for listening

Thanks to Linda Sohl (Colombia) for providing GISS-E2-R model output.

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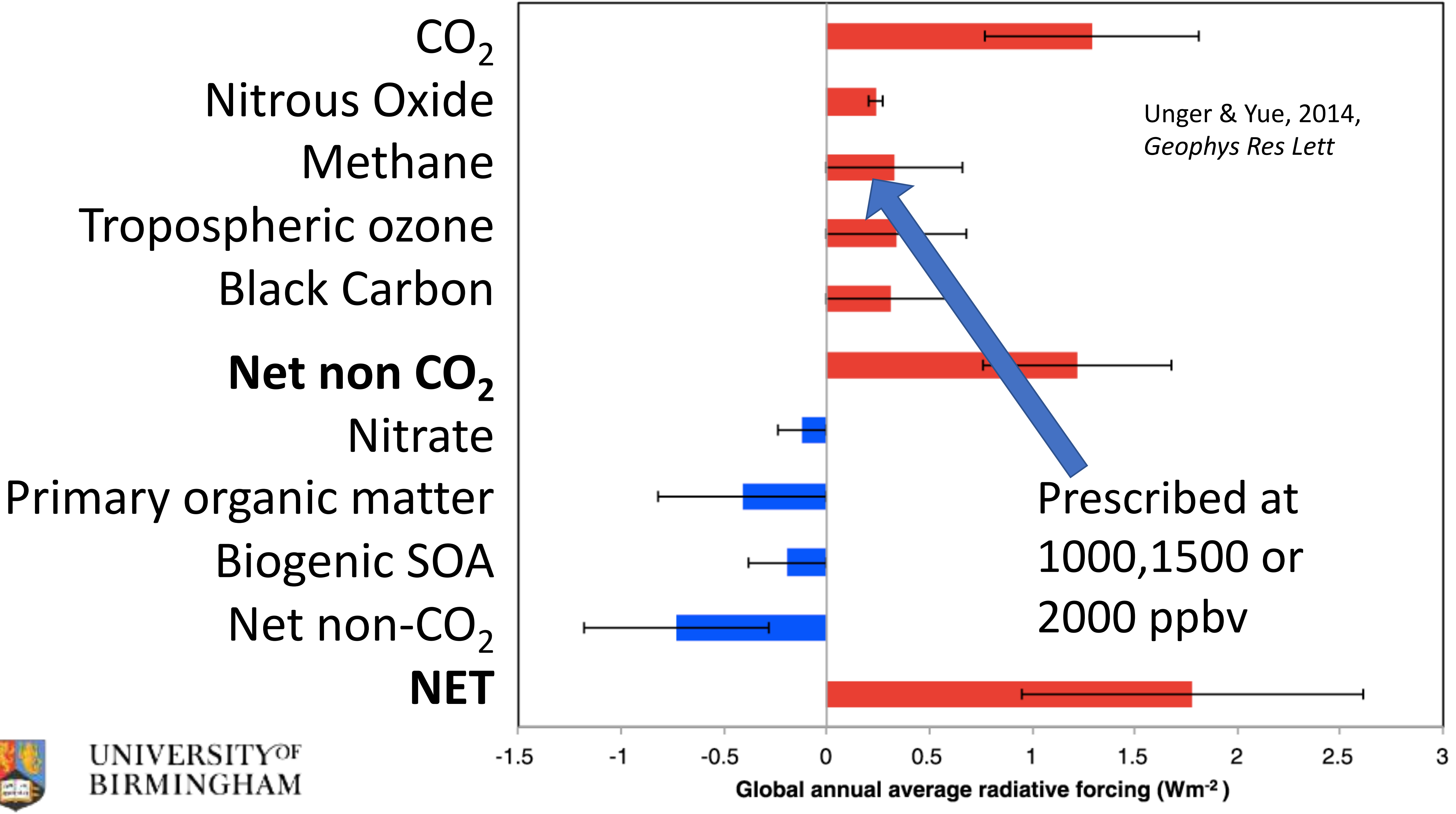
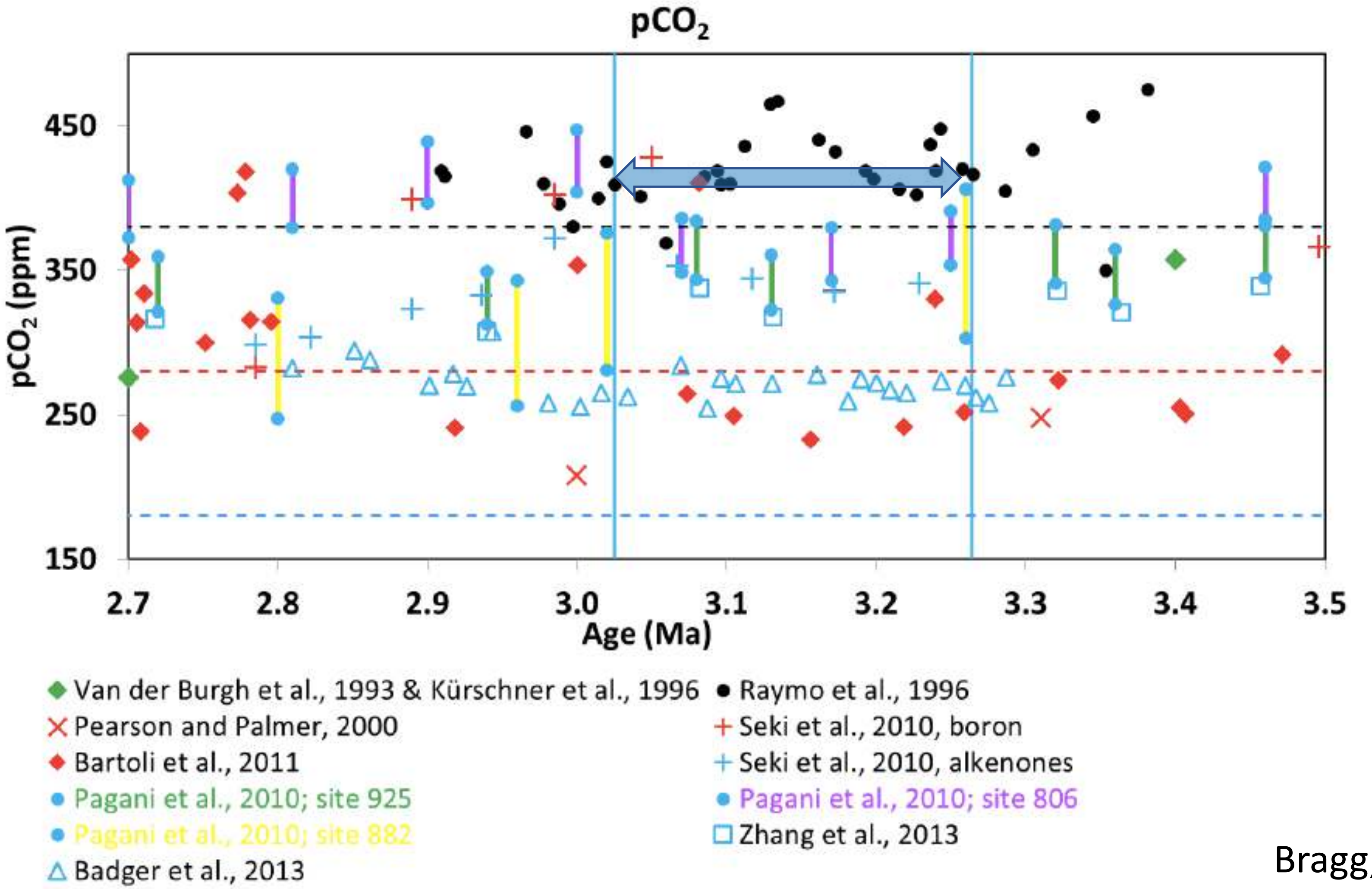

CO_2
Nitrous Oxide
Methane
Tropospheric ozone
Black Carbon
Net non CO_2
Nitrate
Primary organic matter
Biogenic SOA
Net non-CO_2
NET
Unger & Yue, 2014, *Geophys Res Lett*
Prescribed at 1000,1500 or 2000 ppbv
-1.5 -1 -0.5 0 0.5 1 1.5 2 2.5 3
Global annual average radiative forcing (Wm^{-2})



Bragg, PhD Thesis, 2014

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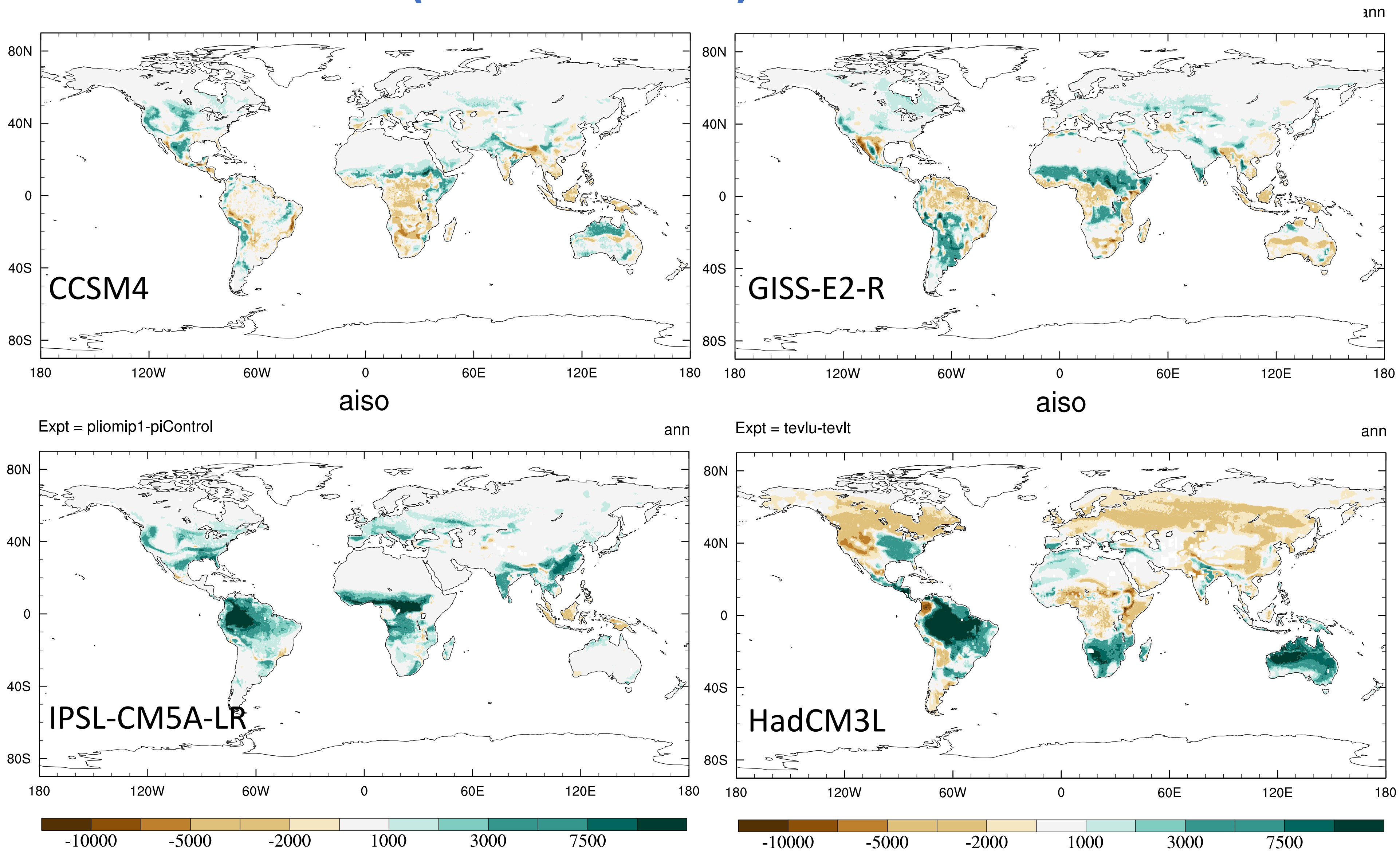
Isoprene emissions (LPJ-GUESS)



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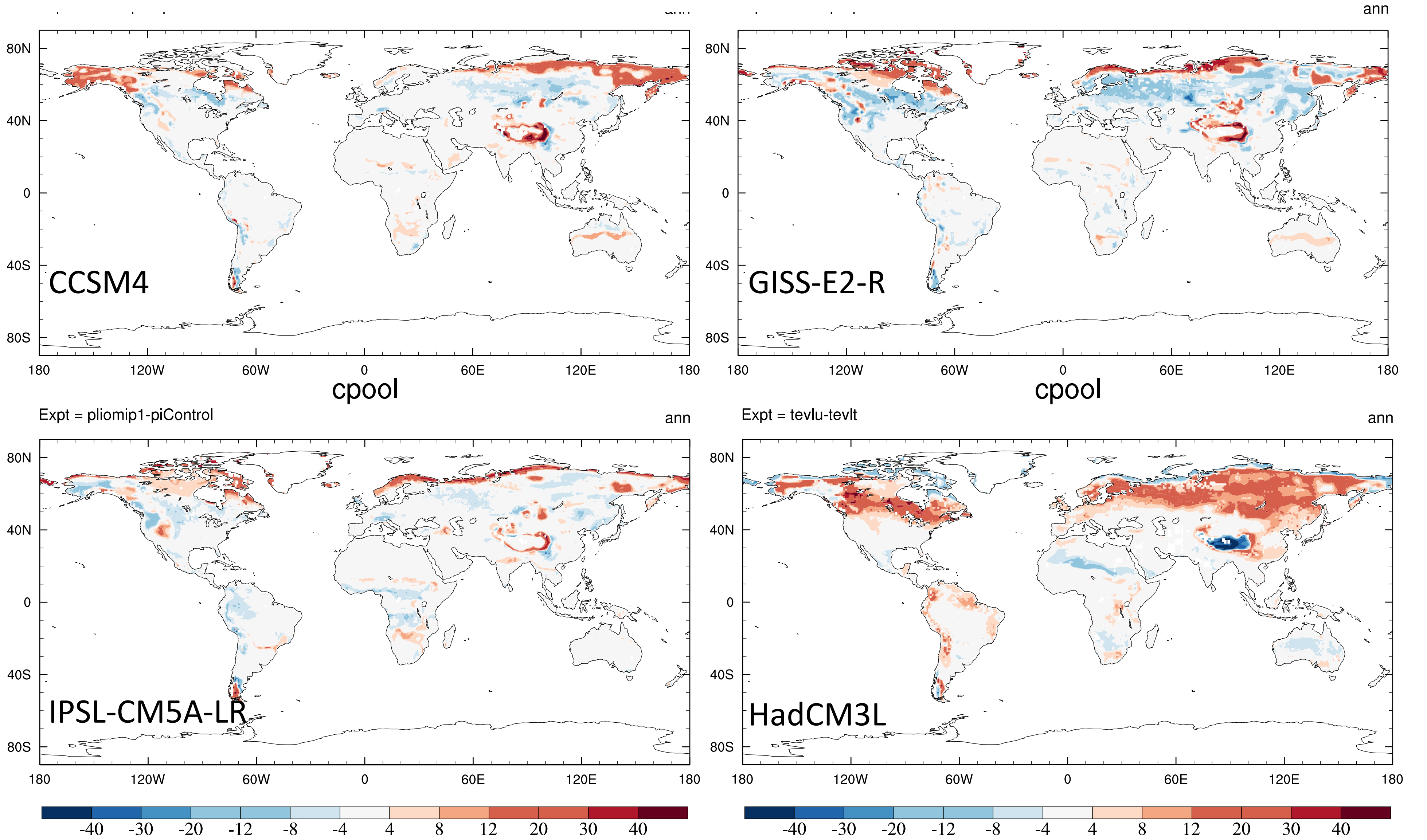
Soil carbon pool (LPJ-GUESS)



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Terrestrial carbon cycle model: LPJ-GUESS

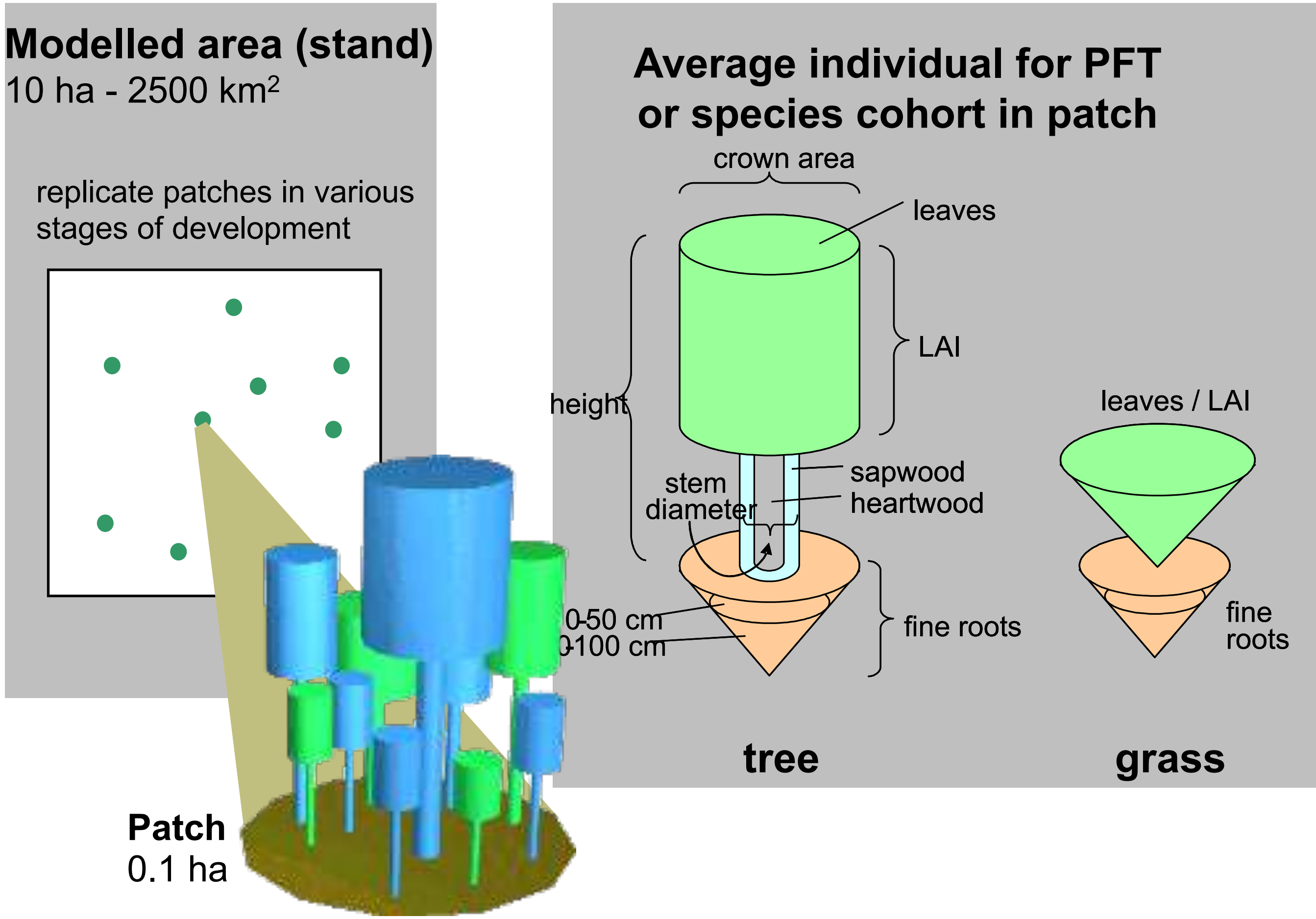
Vegetation dynamics (Smith et al 2001, Hickler et al 2004)

Nitrogen limitation (Smith et al., 2014)

Fire (Thonicke et al 2001)

Isoprene emissions (Arneth et al 2007)

Monoterpene emissions (Schurgers et al 2008)



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