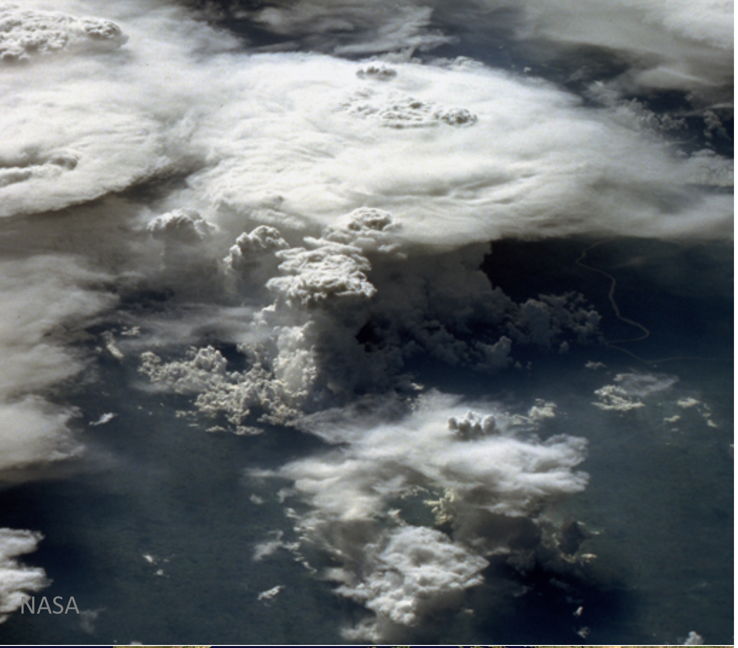

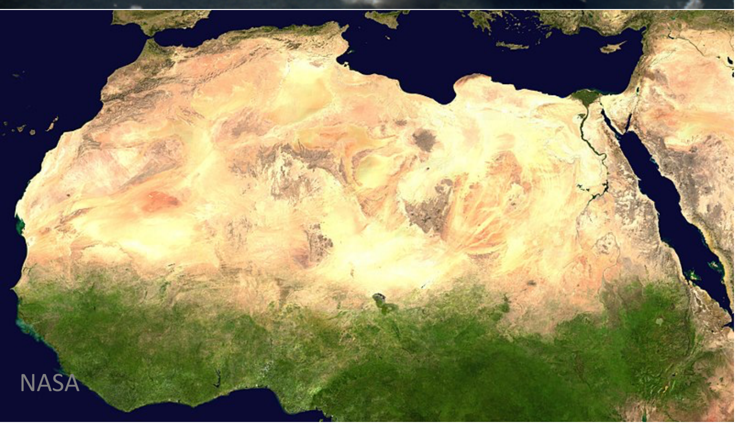

Probing parametric uncertainty in the rainfall response to mid-Holocene conditions for North Africa

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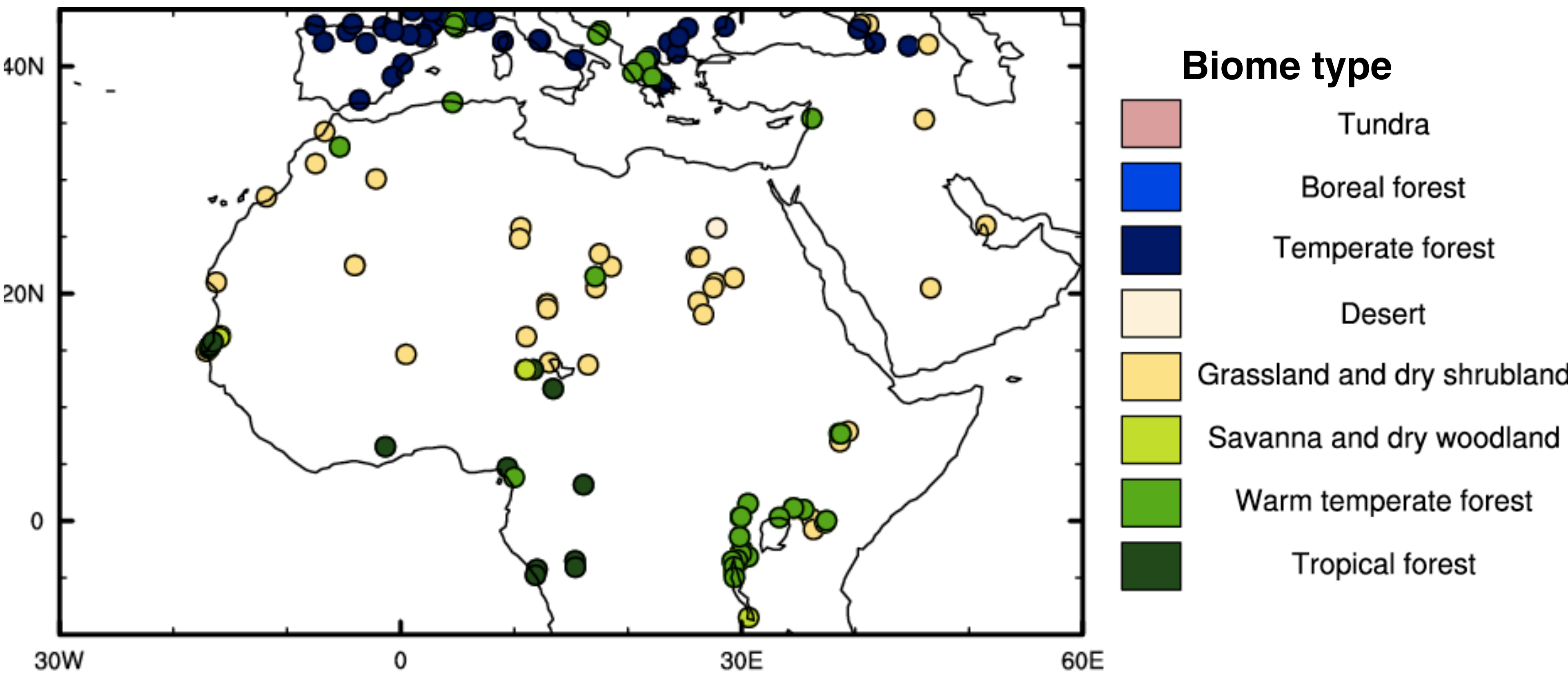
Paul Valdes University of Bristol

William Ingram University of Oxford

Evidence for a ‘Green’ Sahara 9000-5000 years ago

Pollen



Prentice et al 2000

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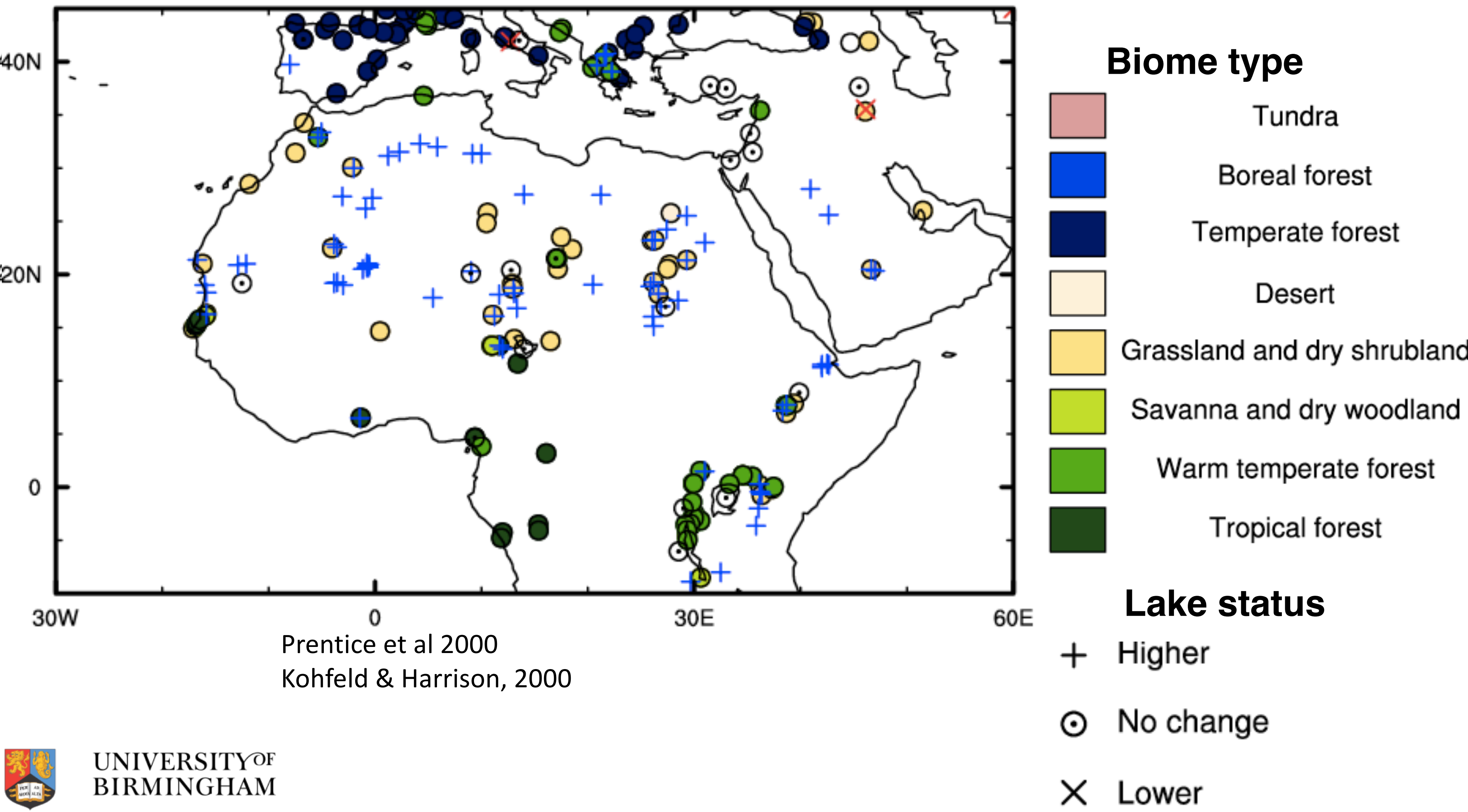
Evidence for a 'Green' Sahara 9000-5000 years ago

Pollen + Lake levels



Prentice et al 2000
Kohfeld & Harrison, 2000

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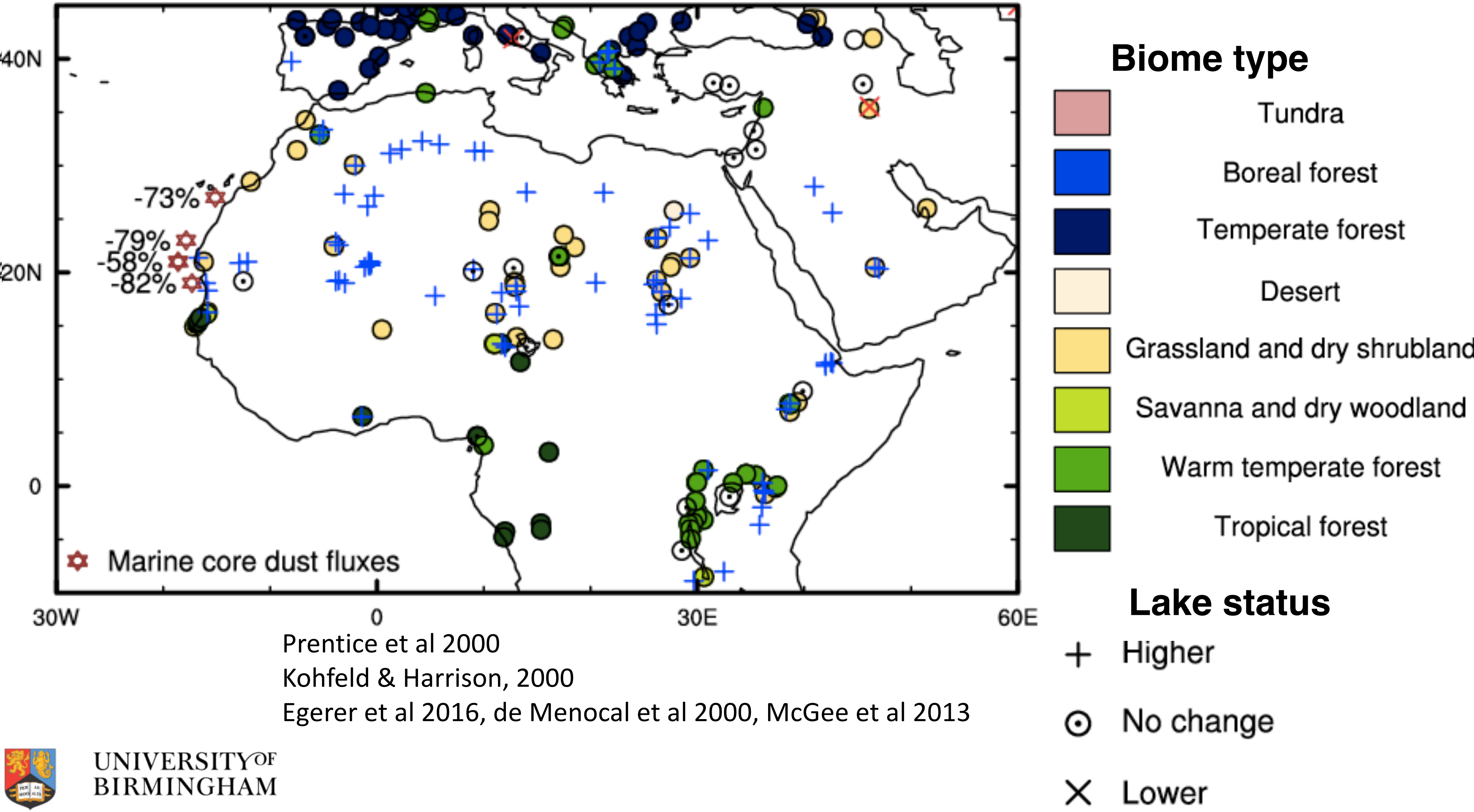
Evidence for a 'Green' Sahara 9000-5000 years ago

Pollen + Lake levels + Dust flux



Prentice et al 2000
Kohfeld & Harrison, 2000
Egerer et al 2016, de Menocal et al 2000, McGee et al 2013

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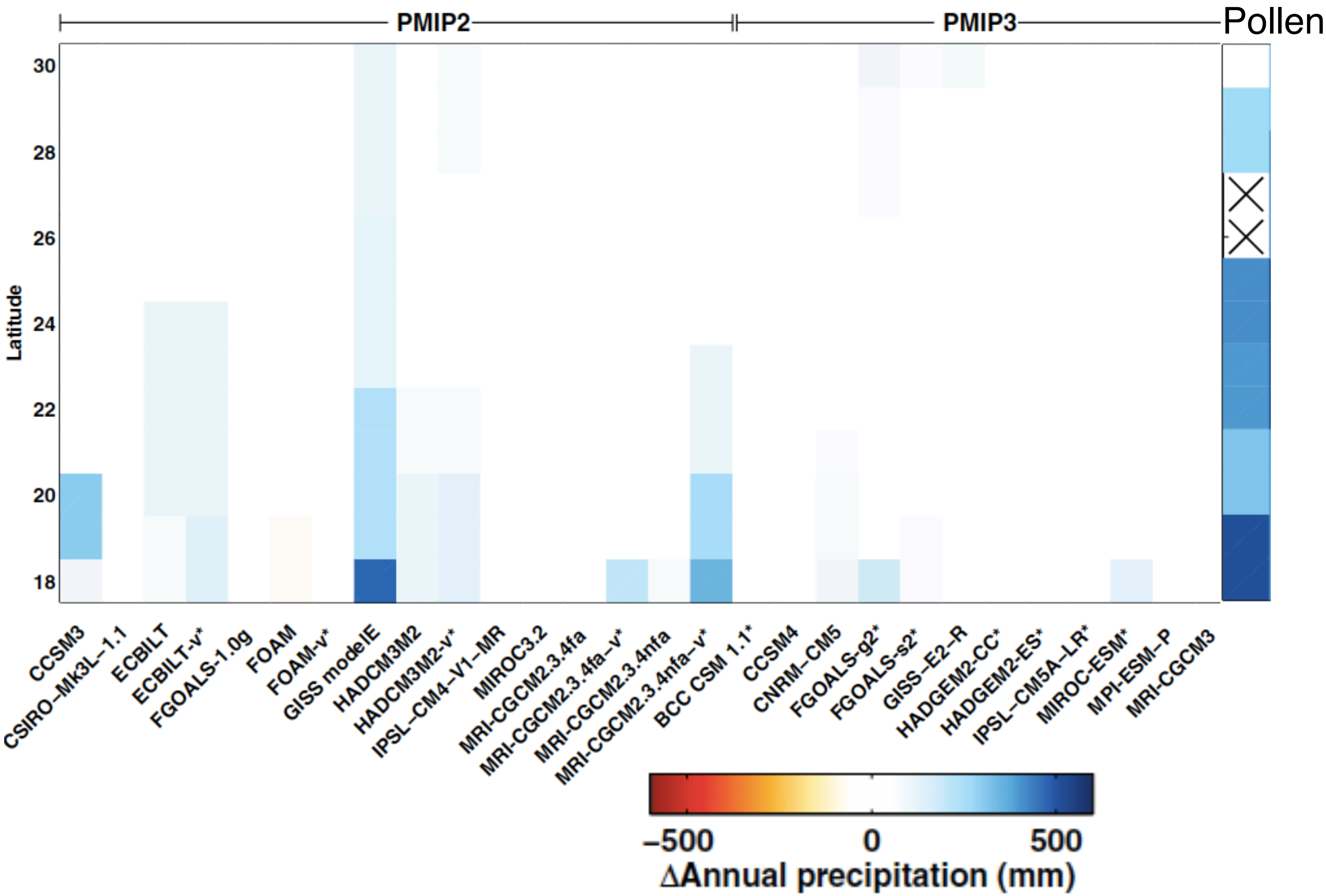
Modelling the rainfall increase



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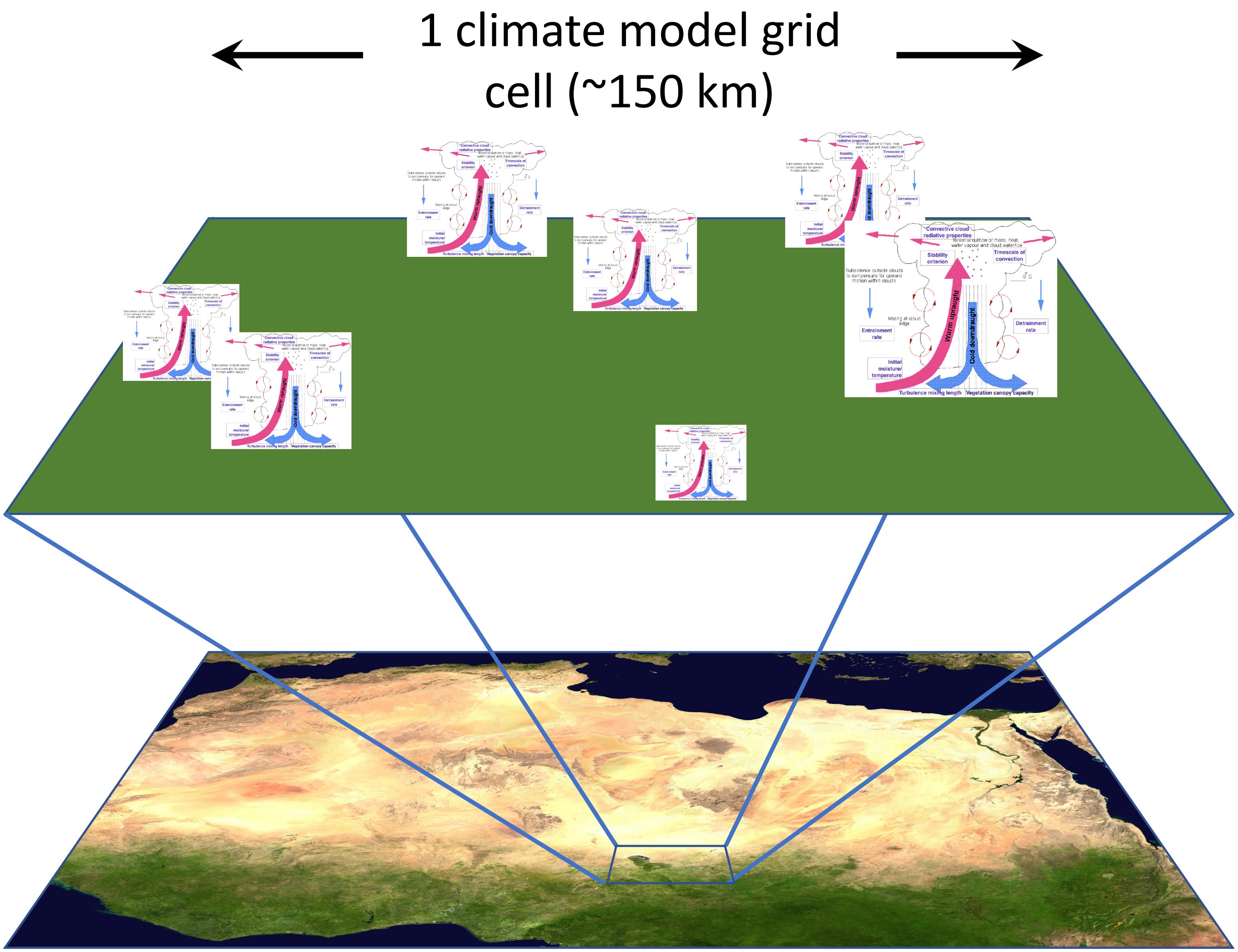
Modified from Tierney et al 2017, *Science Advances*

Representing moist convection



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Sampling uncertainty in convection

HadAM3 - 3.75° x 2.5° x 19 levels (Pope et al 2000, Valdes et al 2017)
MOSES 2.1 land surface model (Essery et al 2003)
Mass-flux convection scheme (Gregory & Rowntree, 1990, Gregory et al 1997)

	Parameter	Description	default	range
1	E	Controls vertical profile of entrainment/detrainment	0	-0.5, 0.35
2	F	Controls the magnitude of entrainment/detrainment	1	0.75, 1.5
3	α_{det}	Sensitivity to relative humidity in mixing detrainment	3	0.5, 5
4	r_{det}	The sensitivity to vertical buoyancy gradient in forced detrainment	0.8	0.1, 1
5	xsbmin	Minimum excess buoyancy to continue parcel ascent (K)	0.2	0.1, 2.0
6	t_initial	Excess parcel initial temperature (K)	0.2	0.2, 2.0
7	q_initial	Excess parcel initial moisture ($kgkg^{-1}$)	0.0	0, 5e-4
8	z0ofsea	Free convective roughness length over sea (m)	$1.3x10^{-3}$	$2x10^{-4}$, $5x10^{-3}$
9	τ_{CAPE}	Time for destruction of CAPE (s)	7200	3600, 14400
10	vf1	Ice fall speed (ms^{-1})	1	0.5, 2.0
11	ct	Accretion constant (s^{-1})	2.0x10-4	0.5x10-4, 4.0x10-4

150 member ensemble

Simulation setup

Present day

- CO_2 =280 ppm
- CH_4 =700 ppb
- Vegetation from IGBP observations
- SSTs/sea-ice: HadISST 1981-2010 climatology

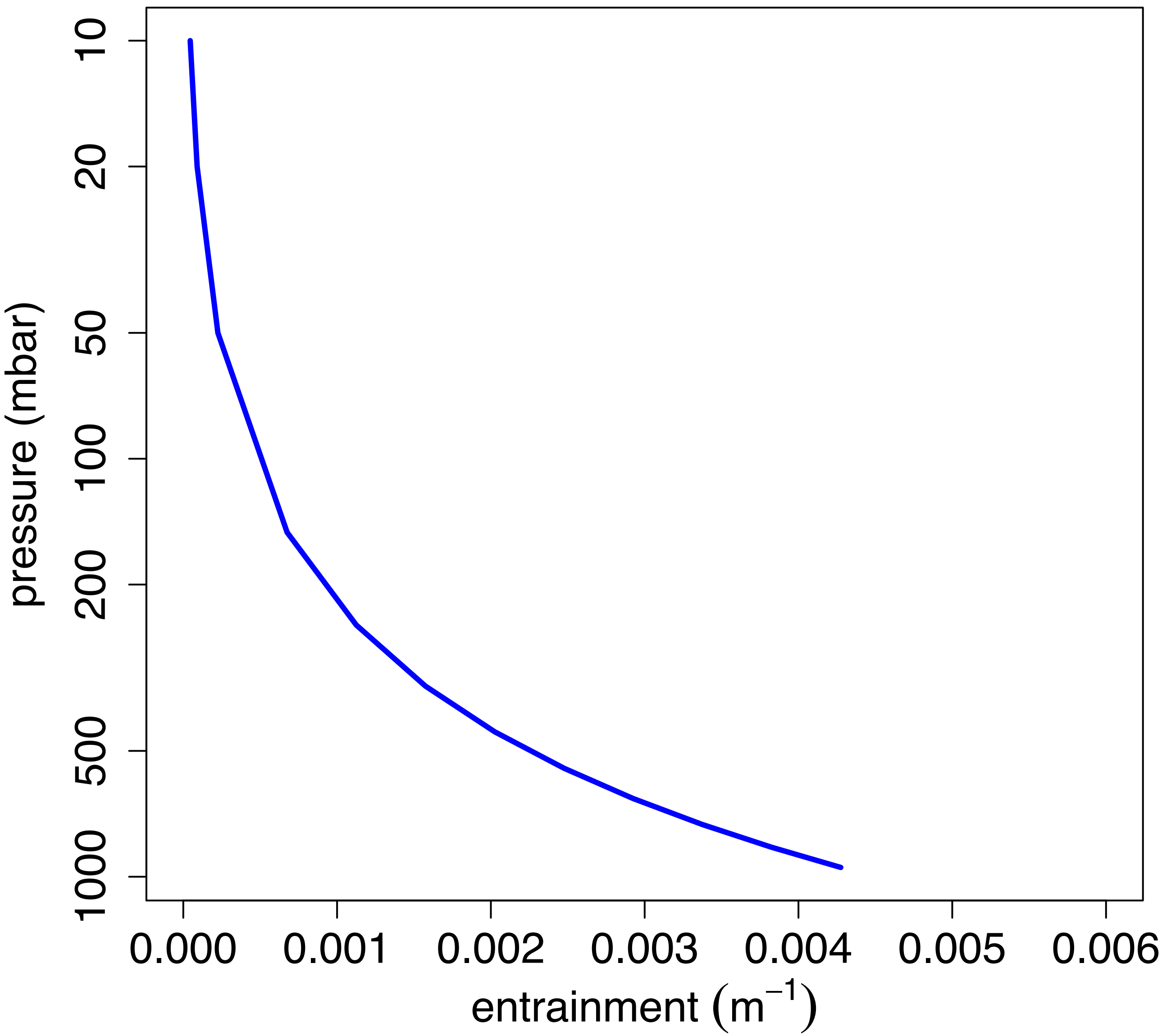
Mid-Holocene

- 6kyr orbital parameters
- 50% grass/shrub in North Africa over Sahara
- SSTs/sea-ice: as present day + 6kyr anomalies from coupled (AOGCM) simulations

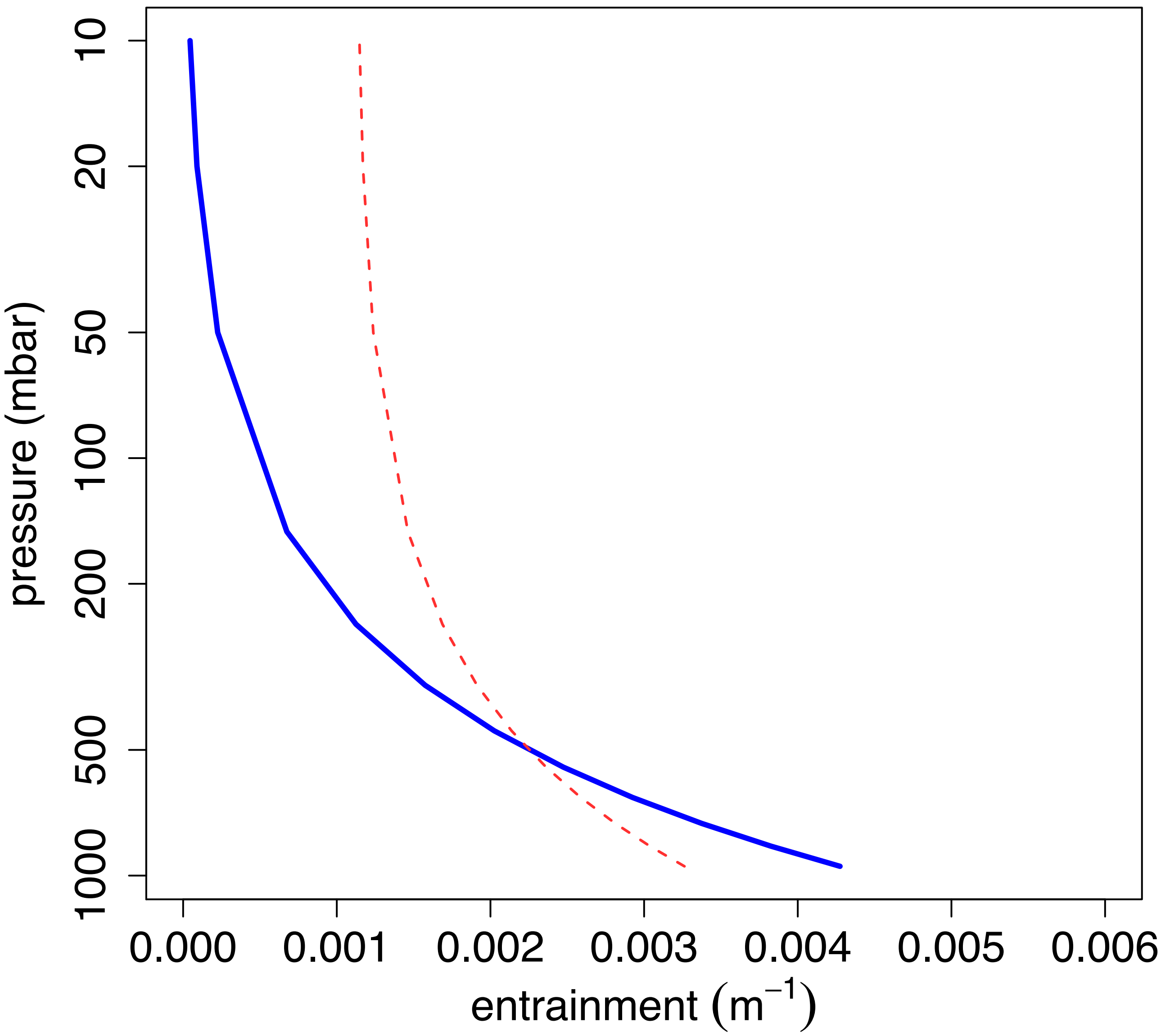
2xCO_2

- CO_2 =560 ppm
- SSTs/ice: as present day + 2xCO_2 anomalies from coupled simulations

Sampling entrainment (parameters *E* and *F*)



Sampling entrainment (parameters *E* and *F*)



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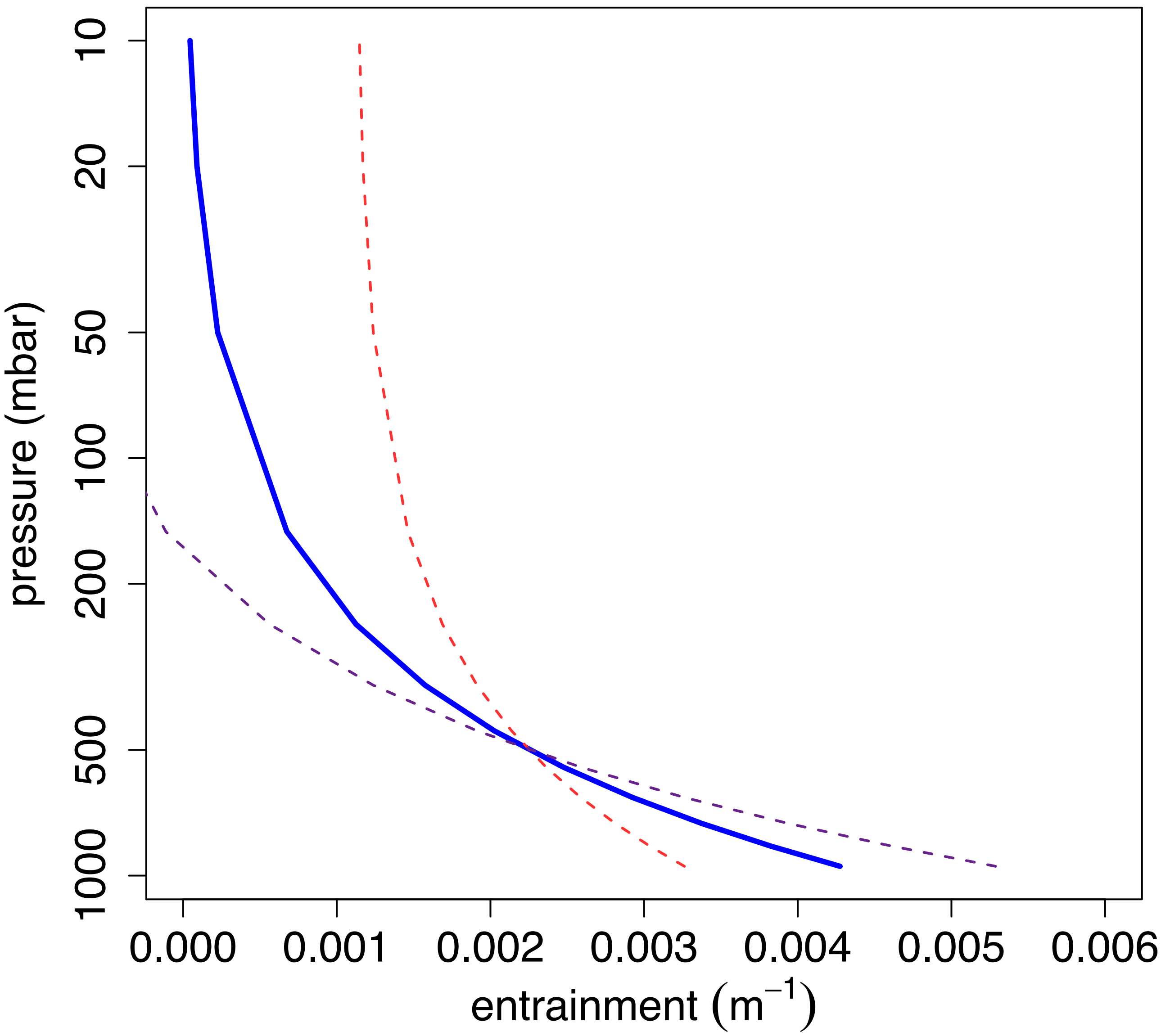

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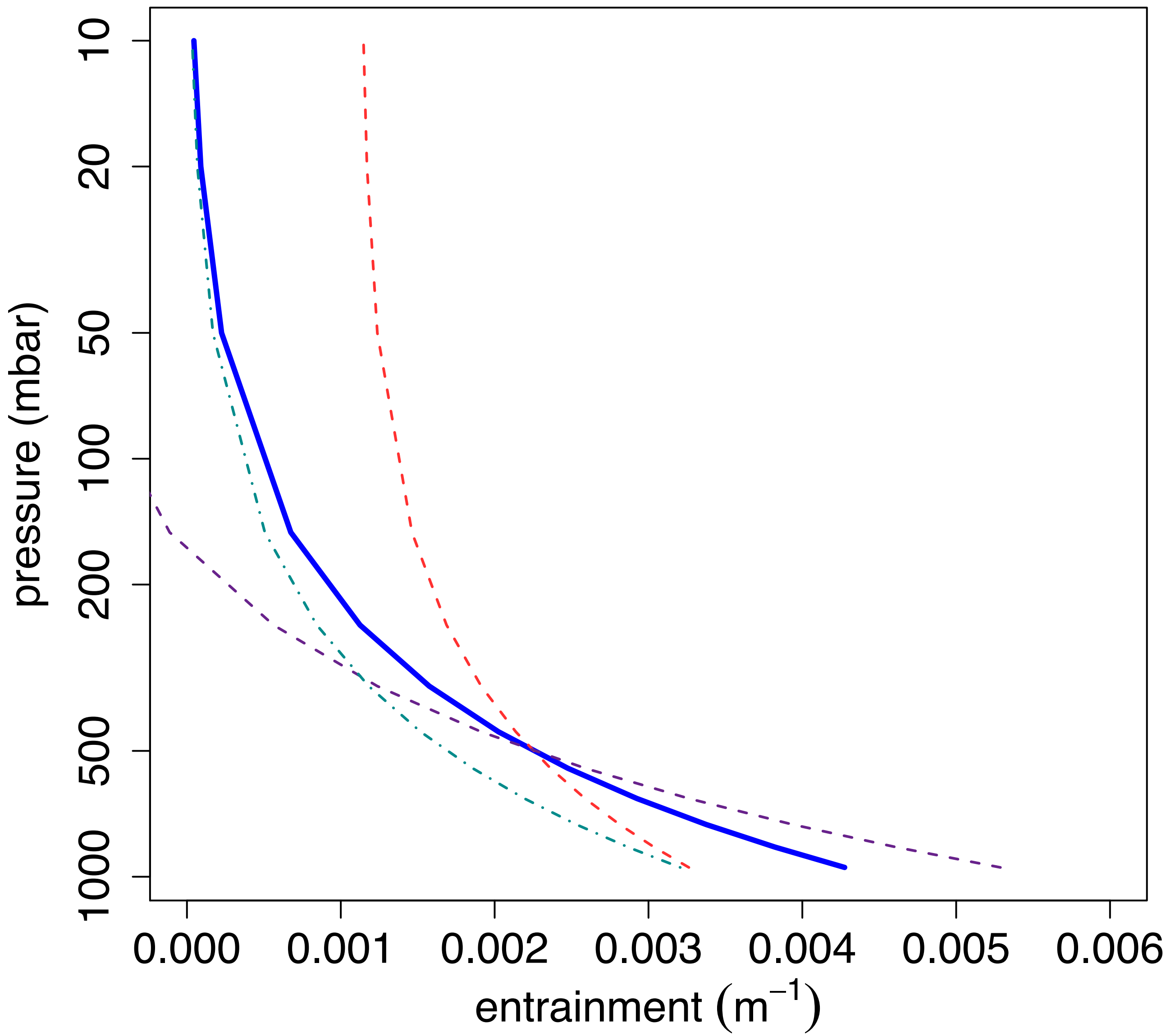
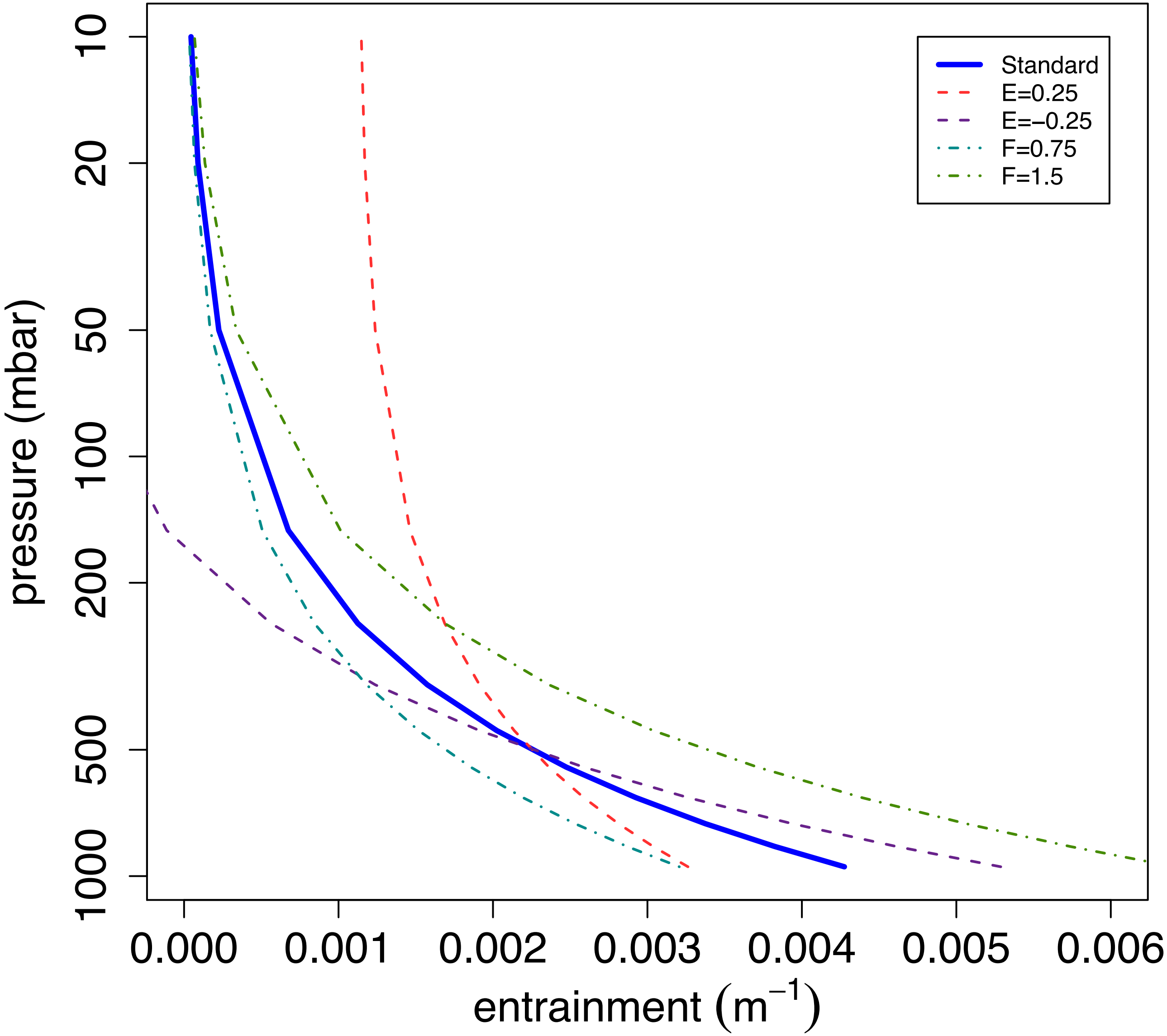
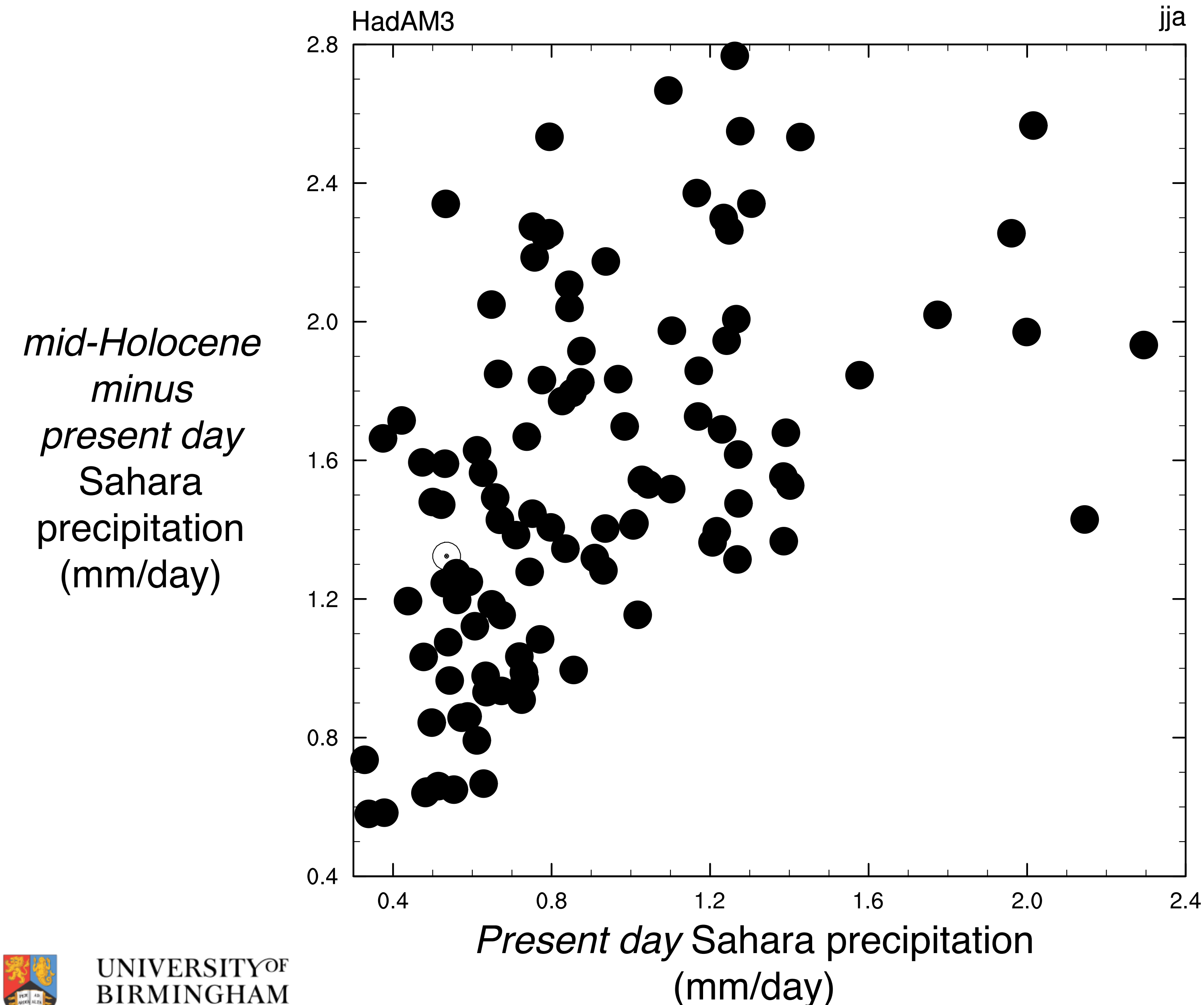
Sampling entrainment (parameters *E* and *F*)



Sampling entrainment (parameters *E* and *F*)



Results: rainfall over North Africa



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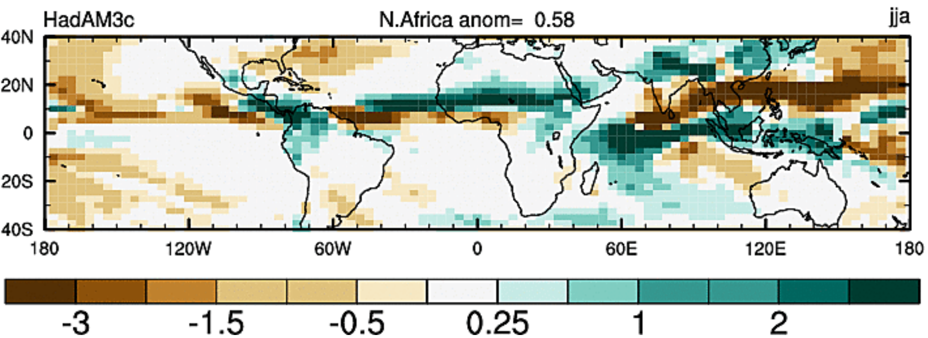
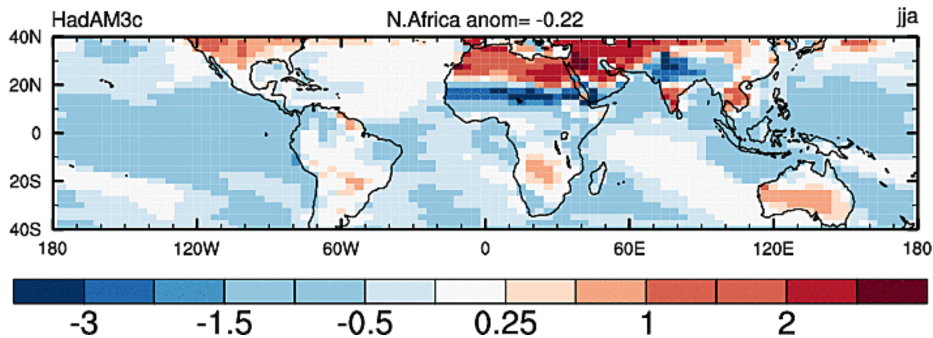
Mid-Holocene climate anomalies

Mid-Holocene minus present day over North Africa (15-25°N)

Sorted by ascending magnitude of precipitation anomaly



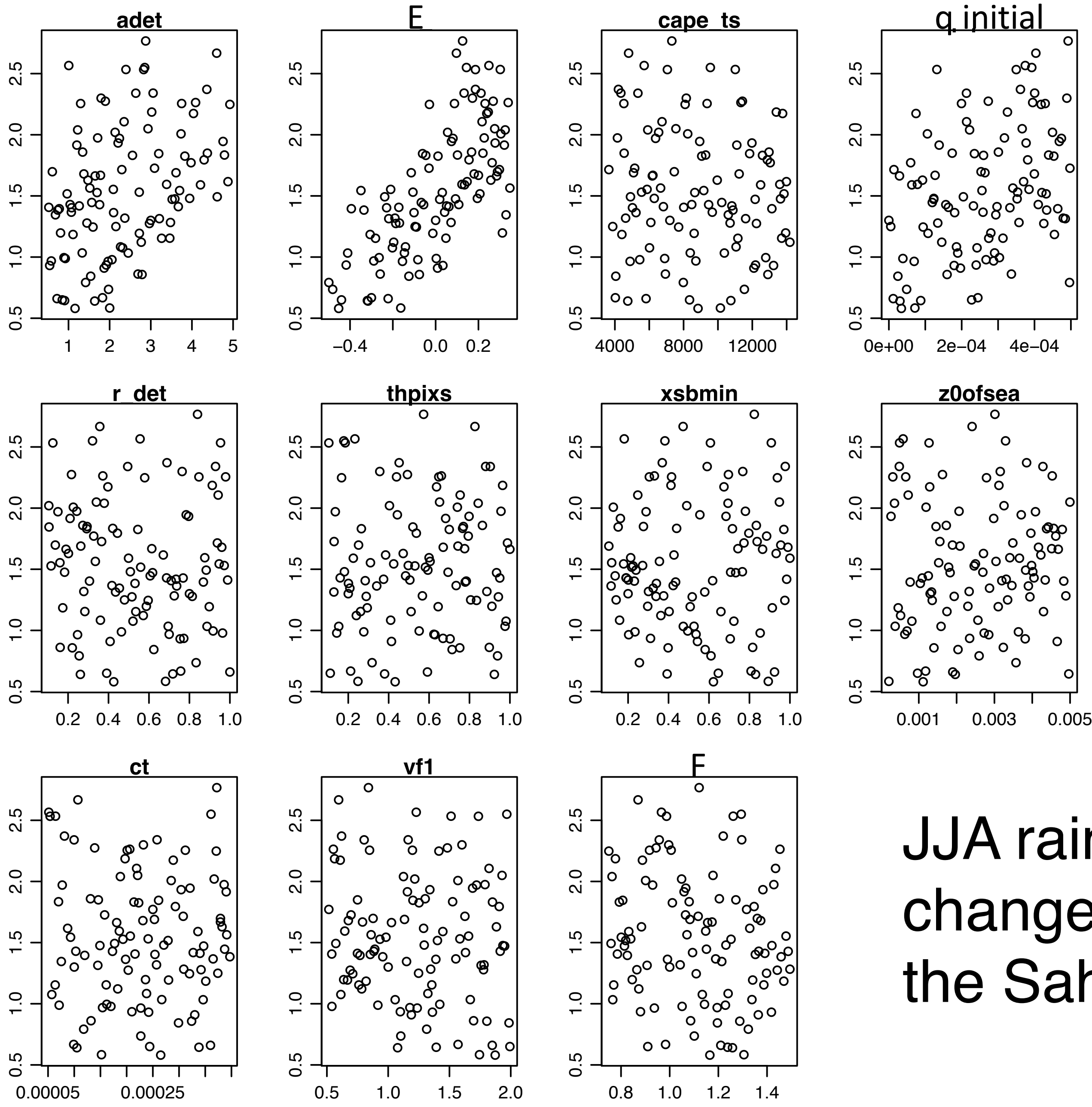
Δ precipitation (mm/day)



Δ surface air temperature (K)

Rainfall range:
0.58 – 2.77 mm/day
Control:
1.3 mm/day

Ensemble results: anomalies



mid-Holocene minus present day Sahara precipitation (mm/day)

JJA rainfall change over the Sahara

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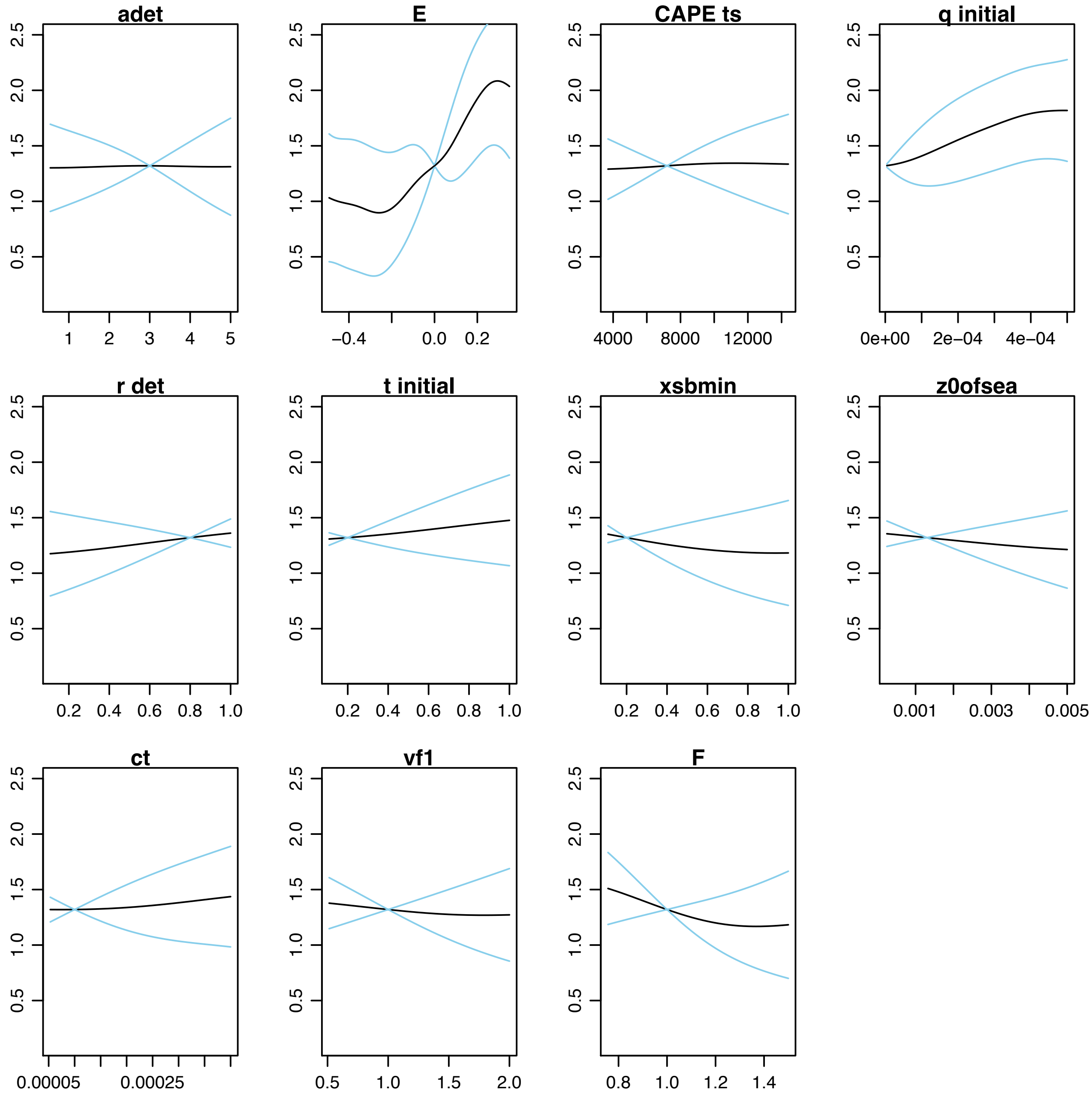
Emulator prediction: anomalies

mid-Holocene minus present day
Sahara precipitation (mm/day)



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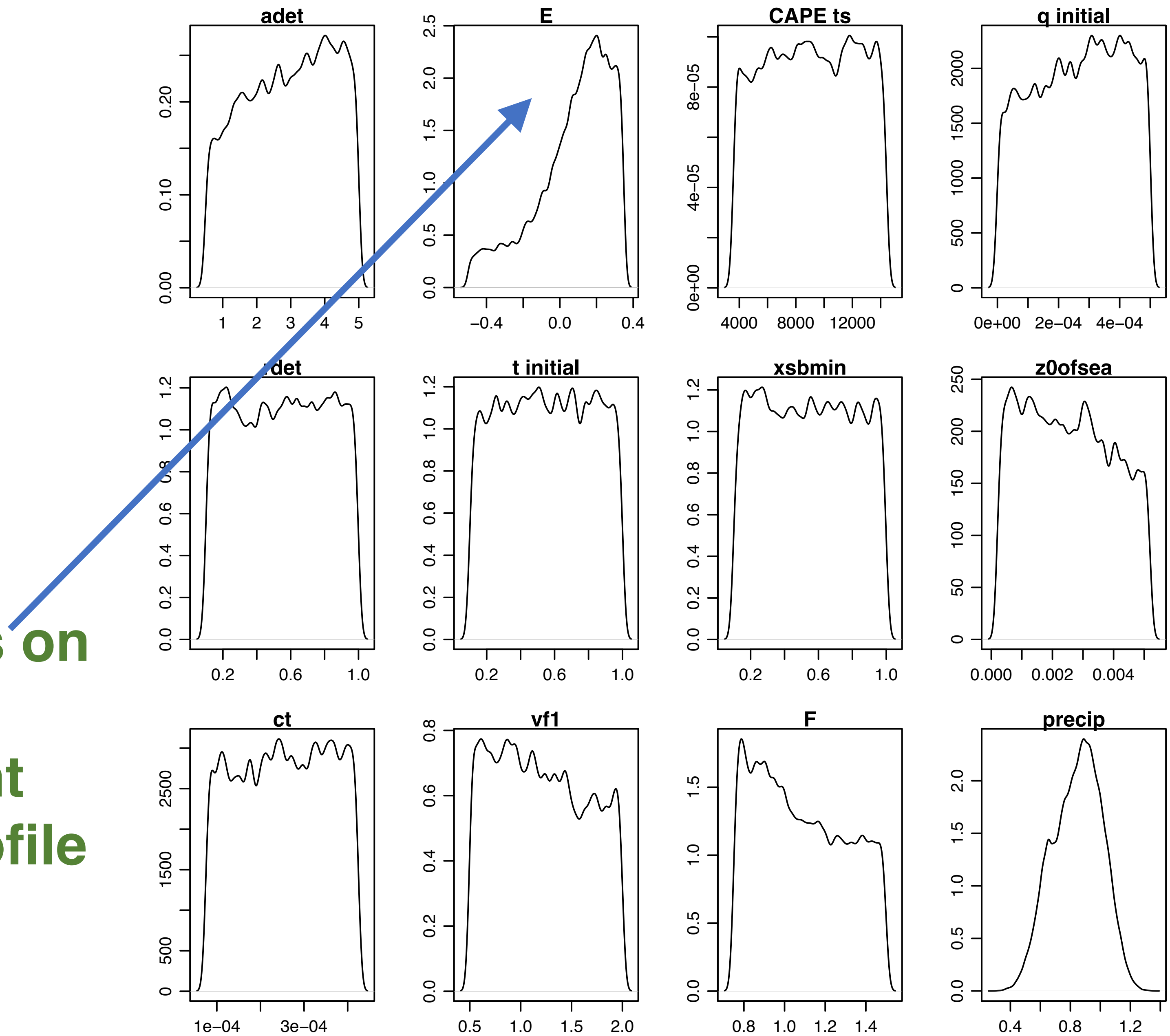
Tuning the model parameters



Strongest constraints on the entrainment vertical profile parameter

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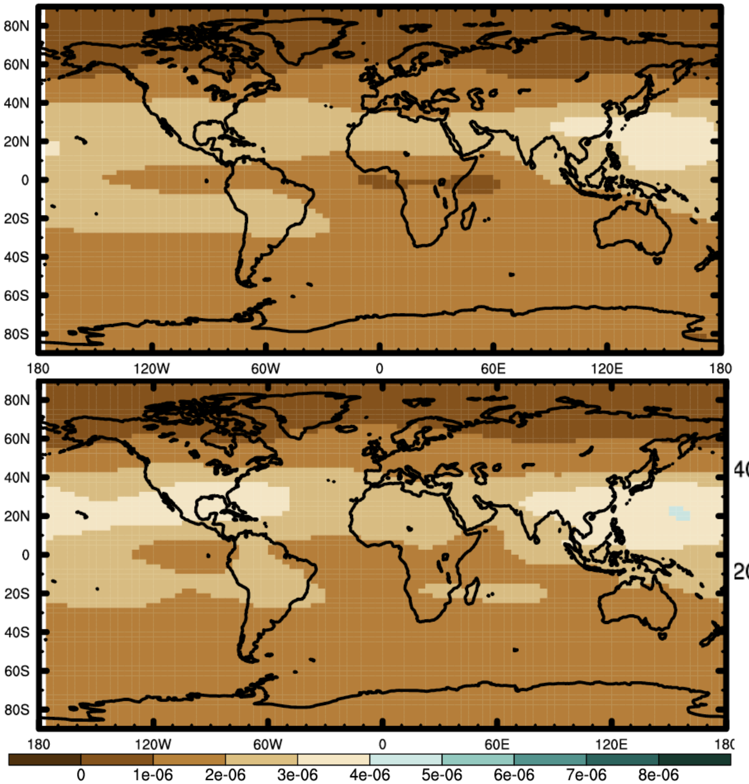
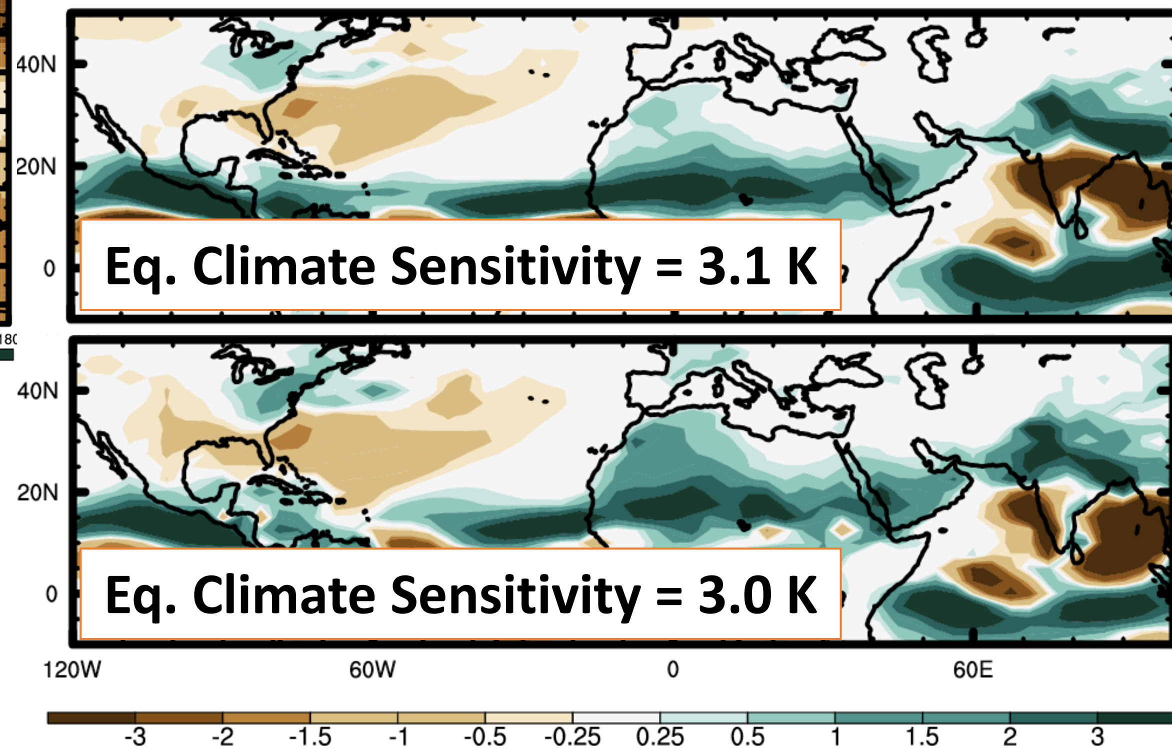
Tuning the model parameters

Stratospheric water vapour (ppbv) at 110mbar



Rainfall anomalies

Control	**Optimised**
JJA mean: 20-30 °N	
133 mm/day	322 mm/day (+ 140 %)
Annual mean: 20-30 °N	
112 mm/day	188 mm/day (+ 54 %)



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Conclusions and next steps

- Possible to reconcile 'Green' Sahara rainfall by tuning the convection scheme in a GCM
- Reduced gradient of entrainment vertical dependence is key
- Must take care of stratospheric water vapour and possibly the impact on climate sensitivity

Future steps

- Include other metrics in tuning (e.g. present day stratospheric water vapour)
- Understand dependence of monsoon intensity versus spatial extent and duration