Fully integrated assessments of the interactions between crops and climate

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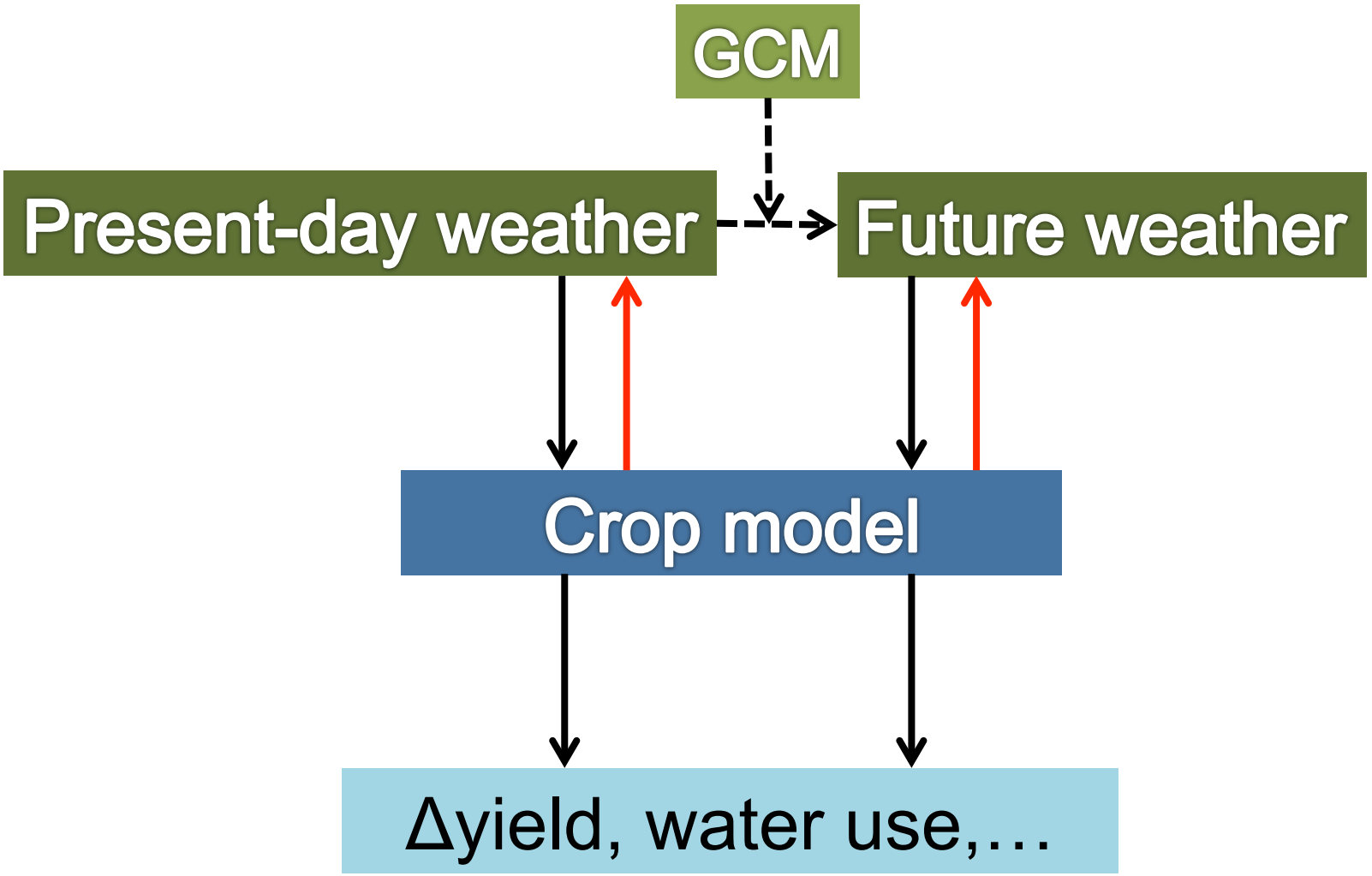
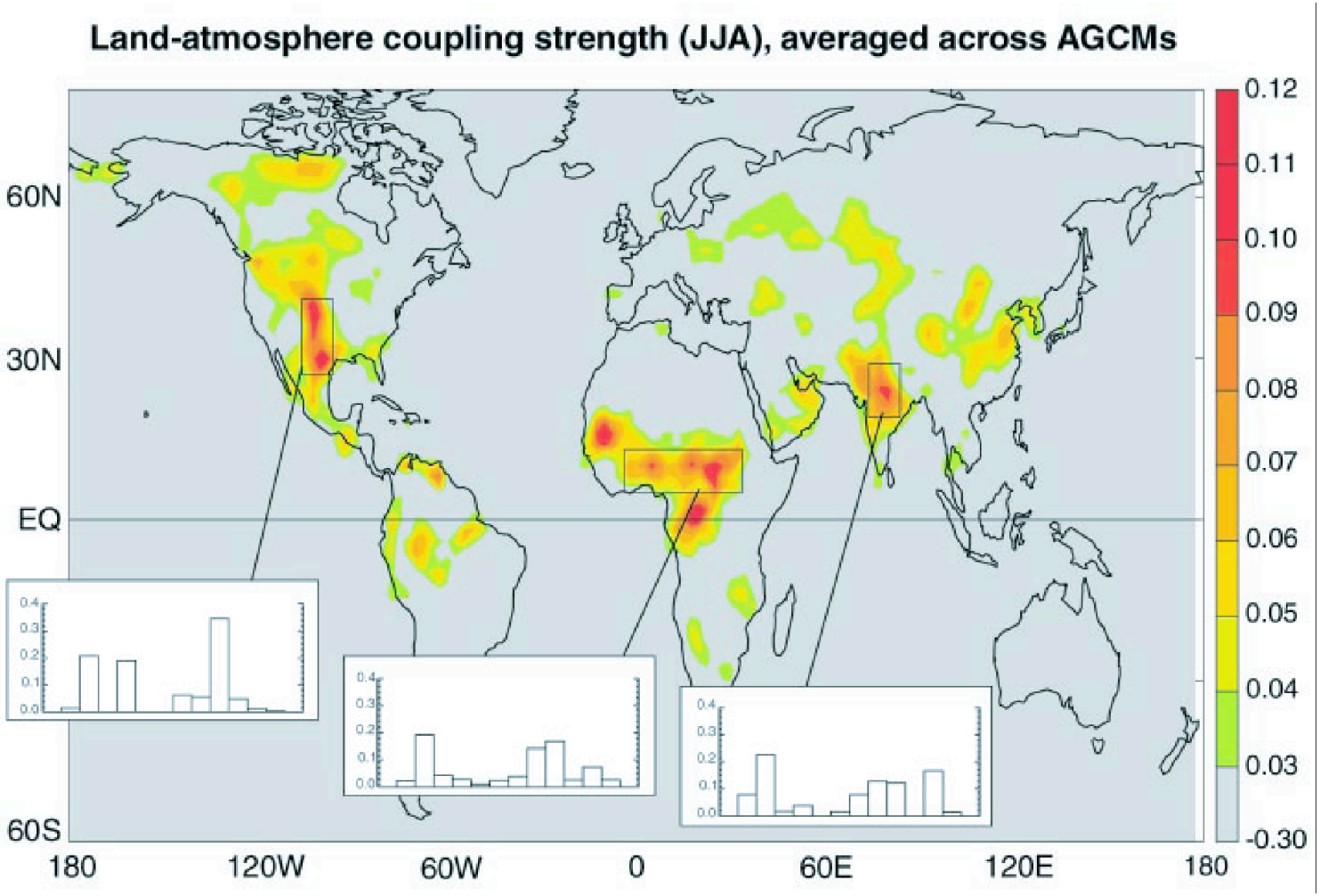
Typical crop impact assessments

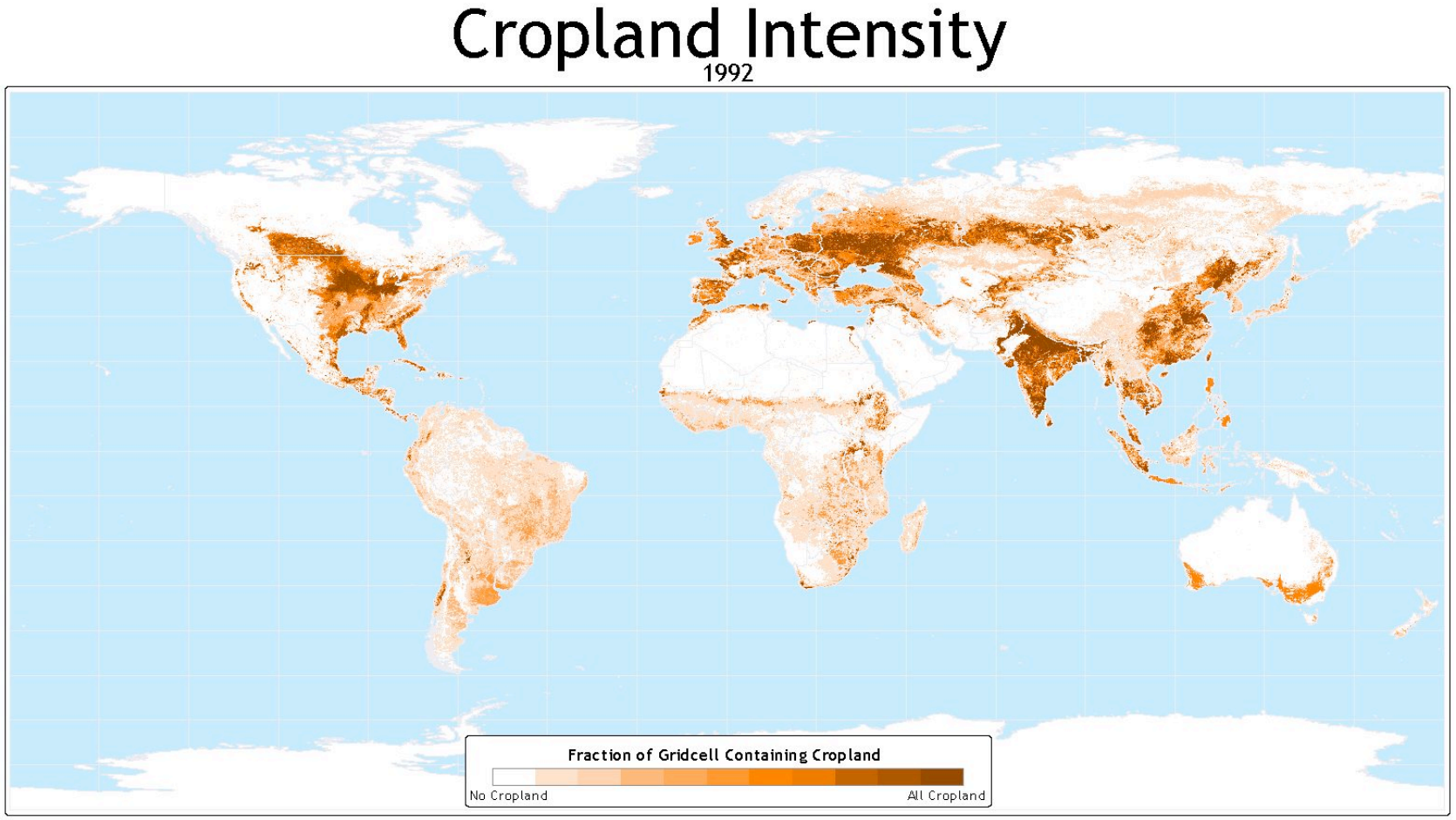


Land surface can affect climate.



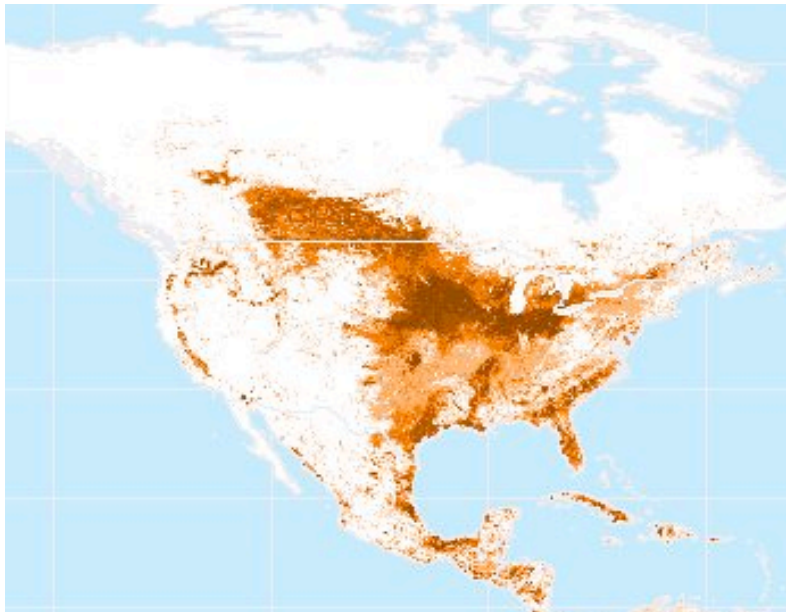
Koster *et al* (2004)

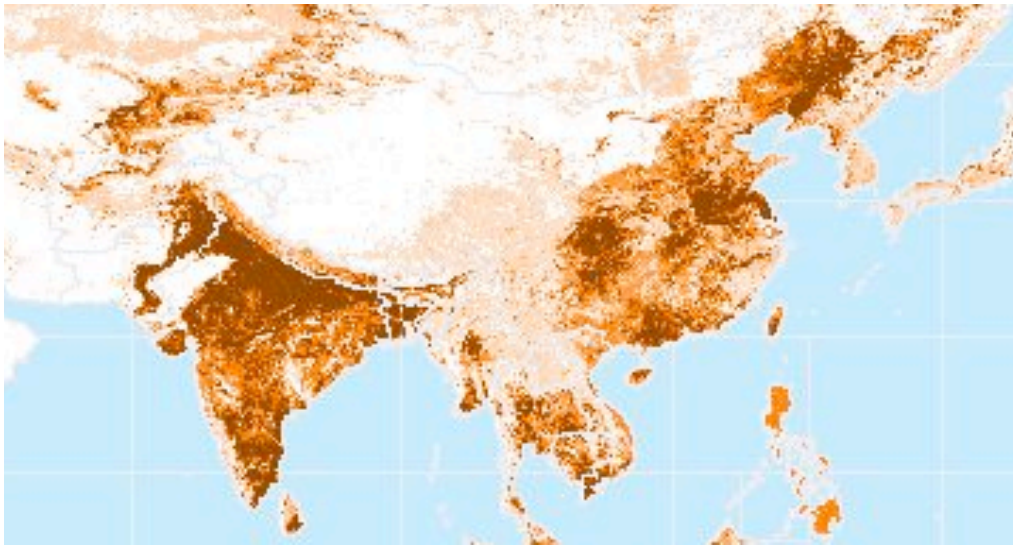
Crops now a significant component of land surface



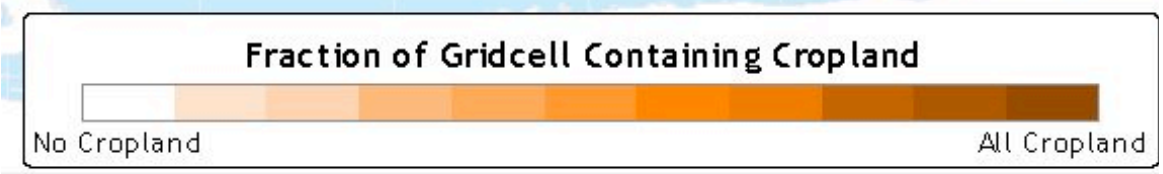
Ramankutty and Foley (1999)

Especially so in particular regions

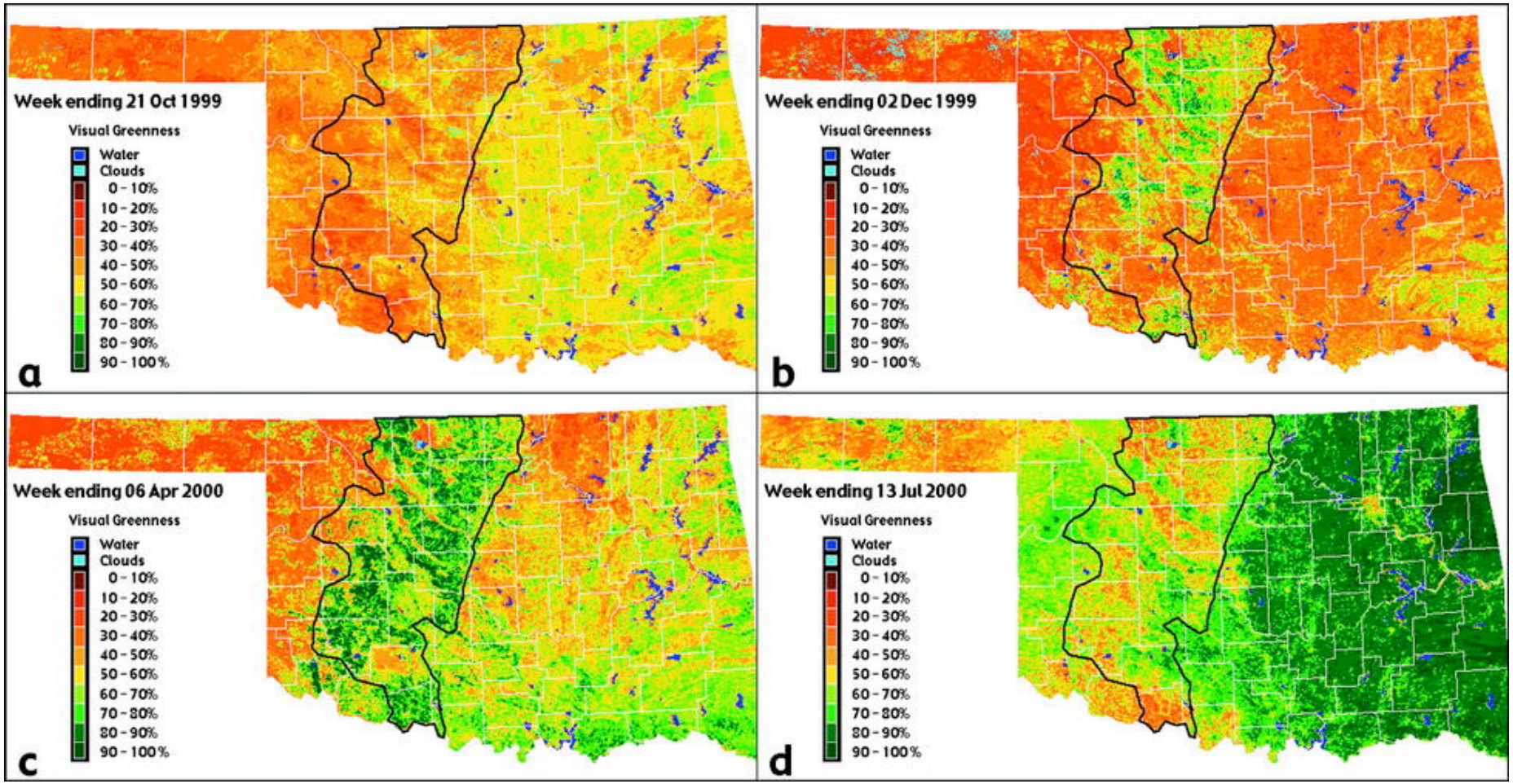




Ramankutty and Foley (1999)

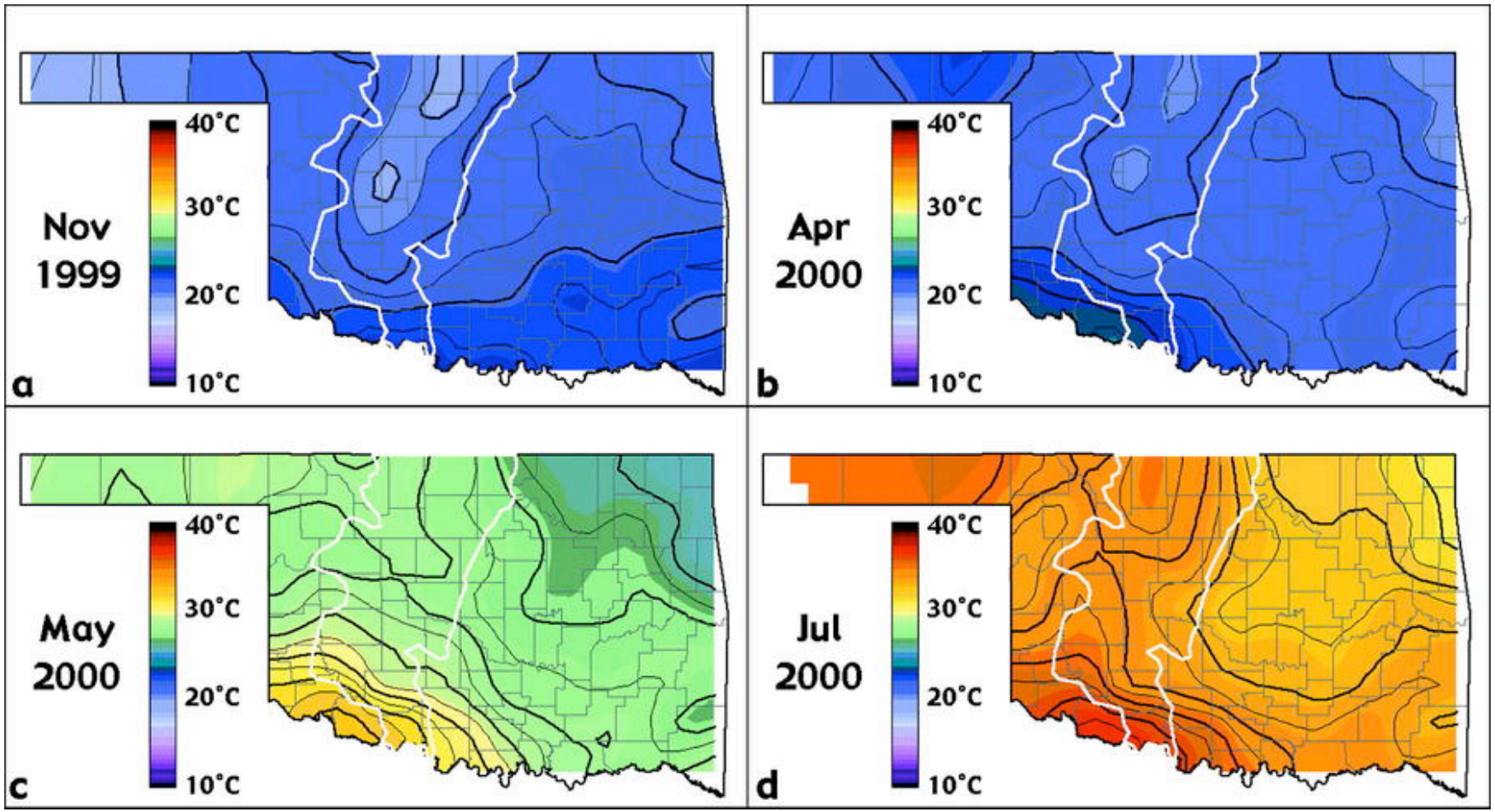


Crops differ to “natural” vegetation …



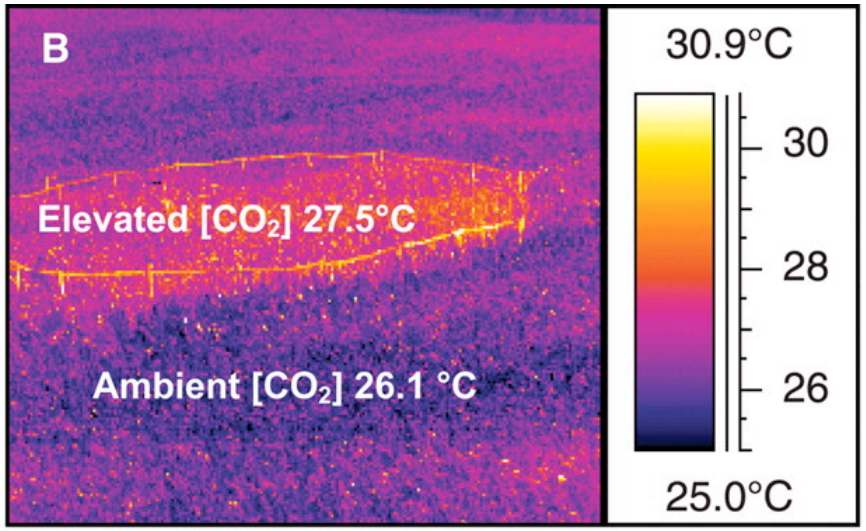
McPherson *et al.* (2004)

… leading to differences in near-surface climate (e.g. max daily air temperature)



McPherson *et al.* (2004)

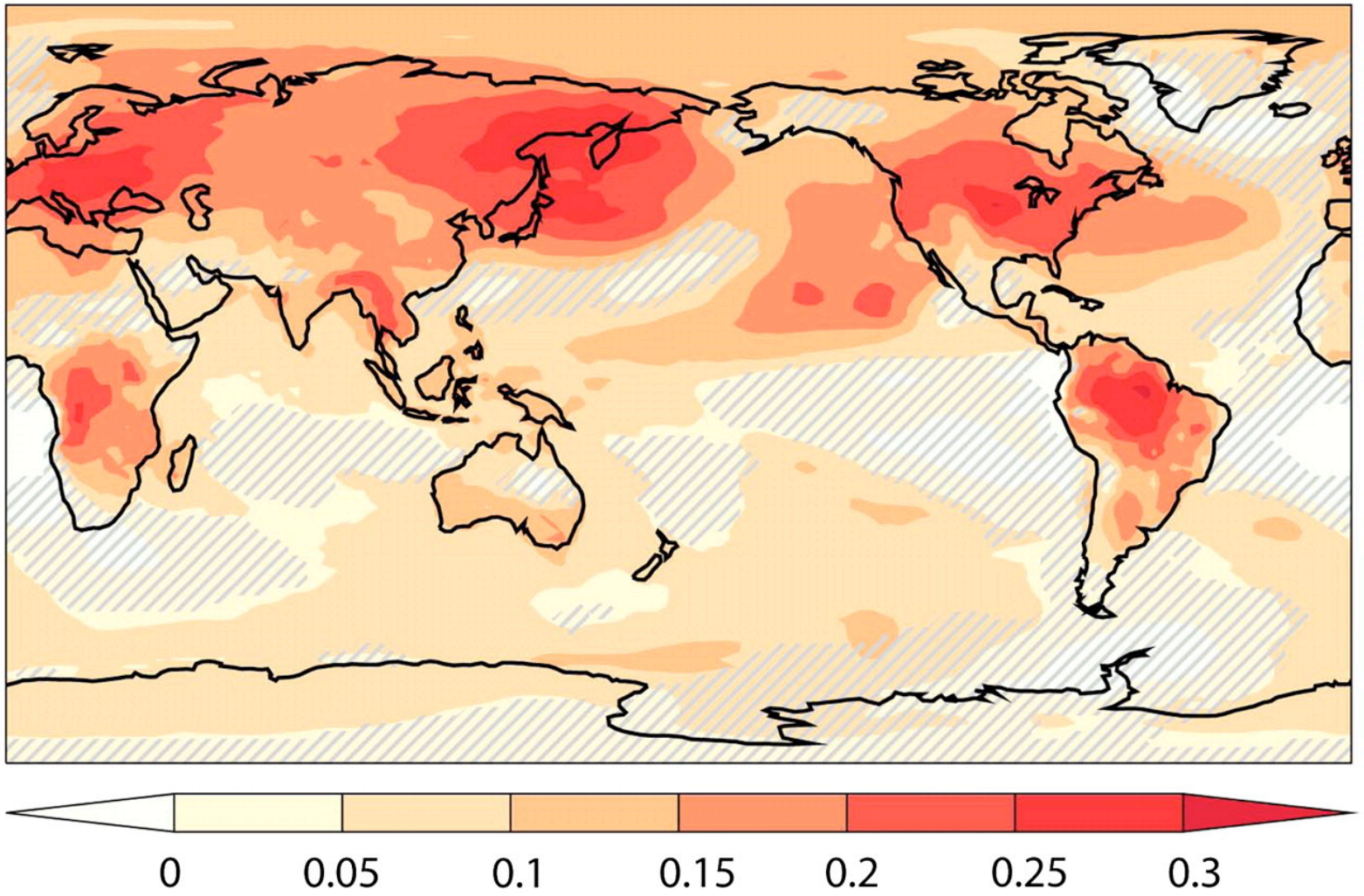
Response of vegetation to environment can affect climate.



FACE: Free Air CO_2 enrichment

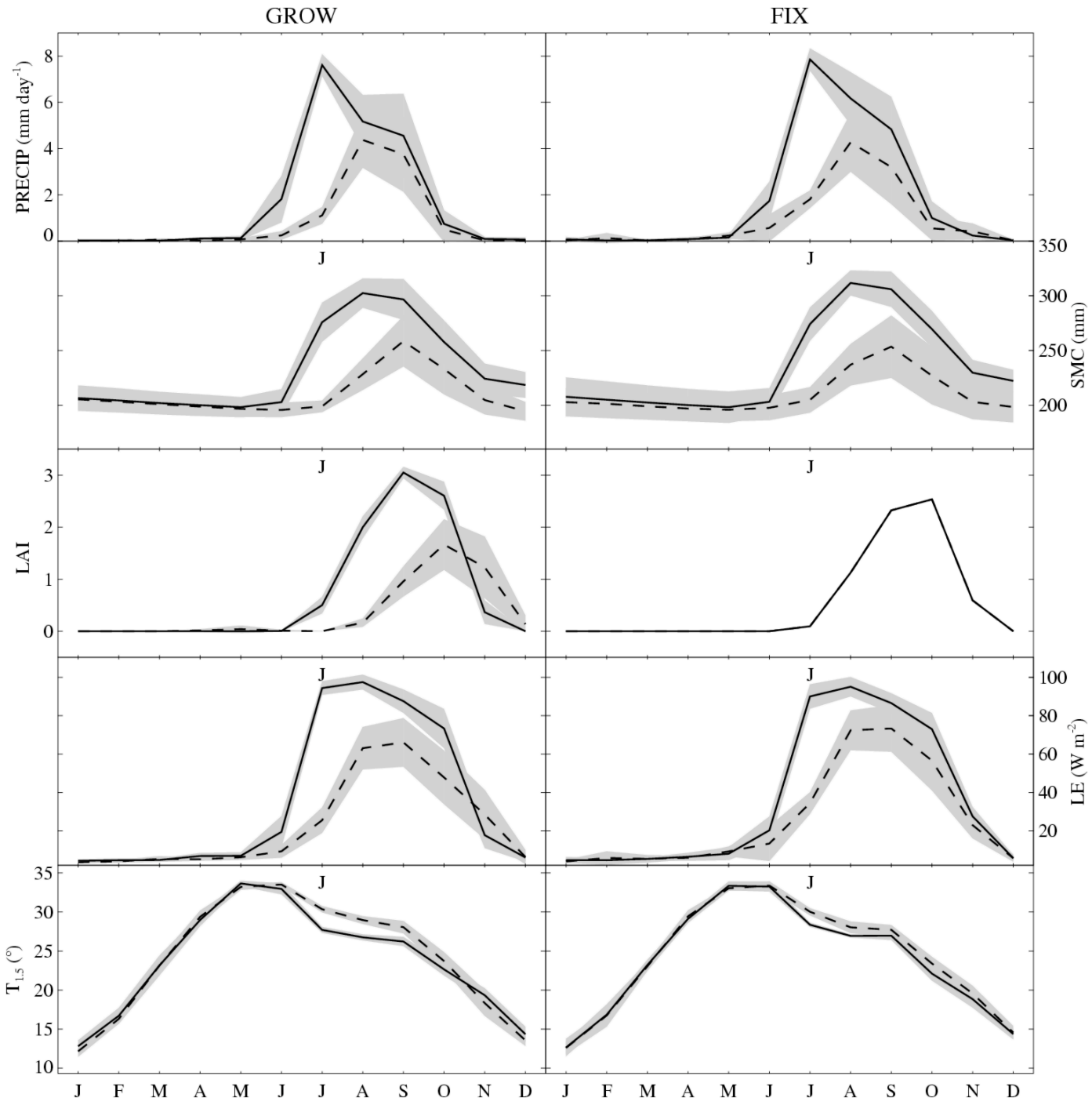
Long *et al* (2006)

Fraction of total surface warming (warming caused by the combined CO2-radiative and physiological effects) associated with the physiological forcing of CO2.



Cao L et al. PNAS 2010;107:9513-9518

Growing crops in a climate model can feedback on to simulated climate variability.



NW India

Wet

Dry

CI (5,95)

Osborne *et al* (2009)

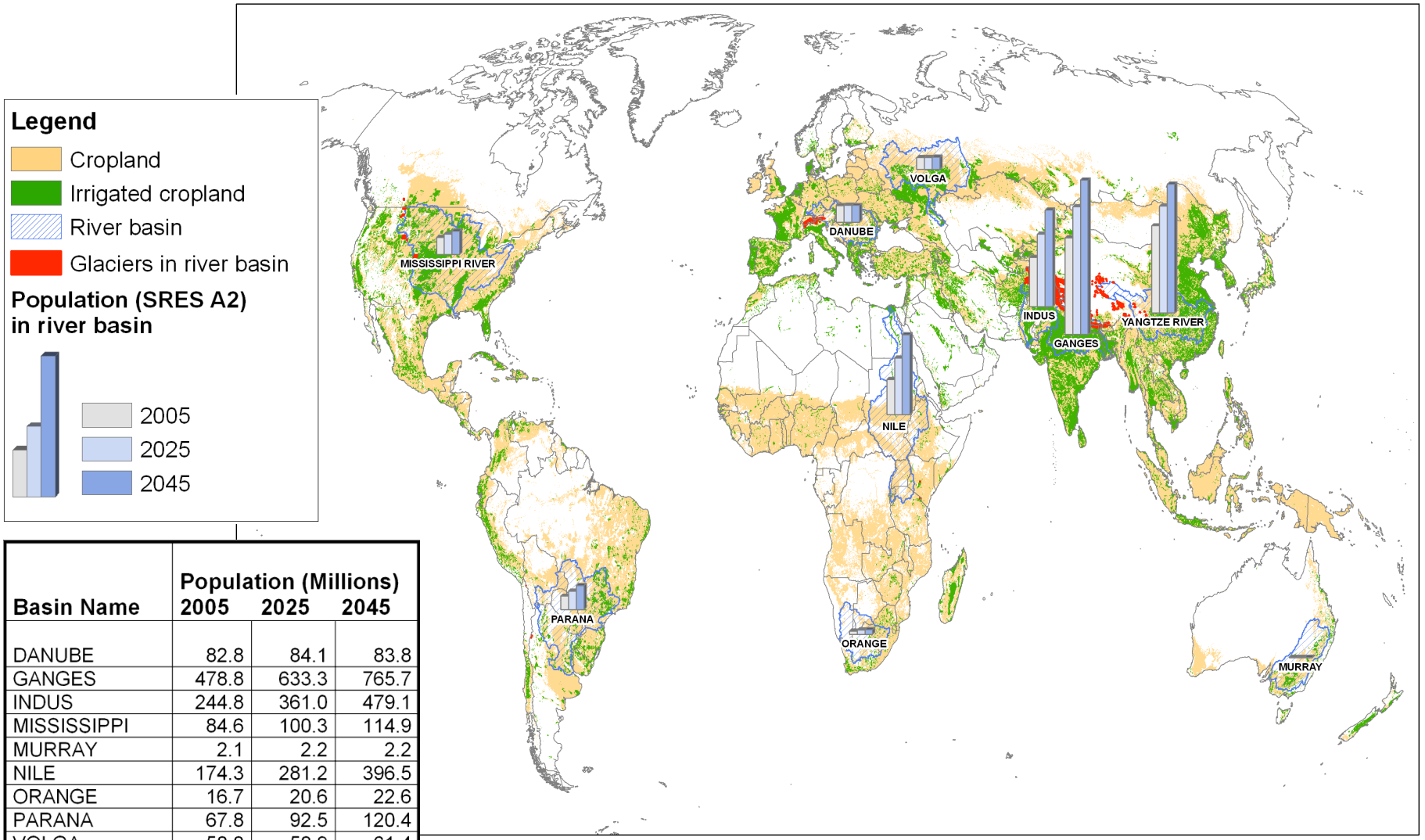
Development of JULES*-crop

Aims:

1) Improved representation of land surface in cropped regions.
2) Physically consistent prediction of crop yields under variable environmental conditions.

*Joint UK Land Environment Simulator (Best *et al,* 2011Geosci. Model Dev, 4, 677-699)

Integrated impacts modelling:
Joint UK Land Environment Simulator (JULES)



Basin Name	Population (Millions) 2005	2025	2045
DANUBE	82.8	84.1	83.8
GANGES	478.8	633.3	765.7
INDUS	244.8	361.0	479.1
MISSISSIPPI	84.6	100.3	114.9
MURRAY	2.1	2.2	2.2
NILE	174.3	281.2	396.5
ORANGE	16.7	20.6	22.6
PARANA	67.8	92.5	120.4
VOLGA	58.8	58.9	61.4
YANGTZE	432.2	531.2	639.3

Courtesy: Andy Wiltshire, UK Met Office

Development of JULES*-crop

Aims:

1) Improved representation of land surface in cropped regions.
2) Physically consistent prediction of crop yields under variable environmental conditions.

Challenges:

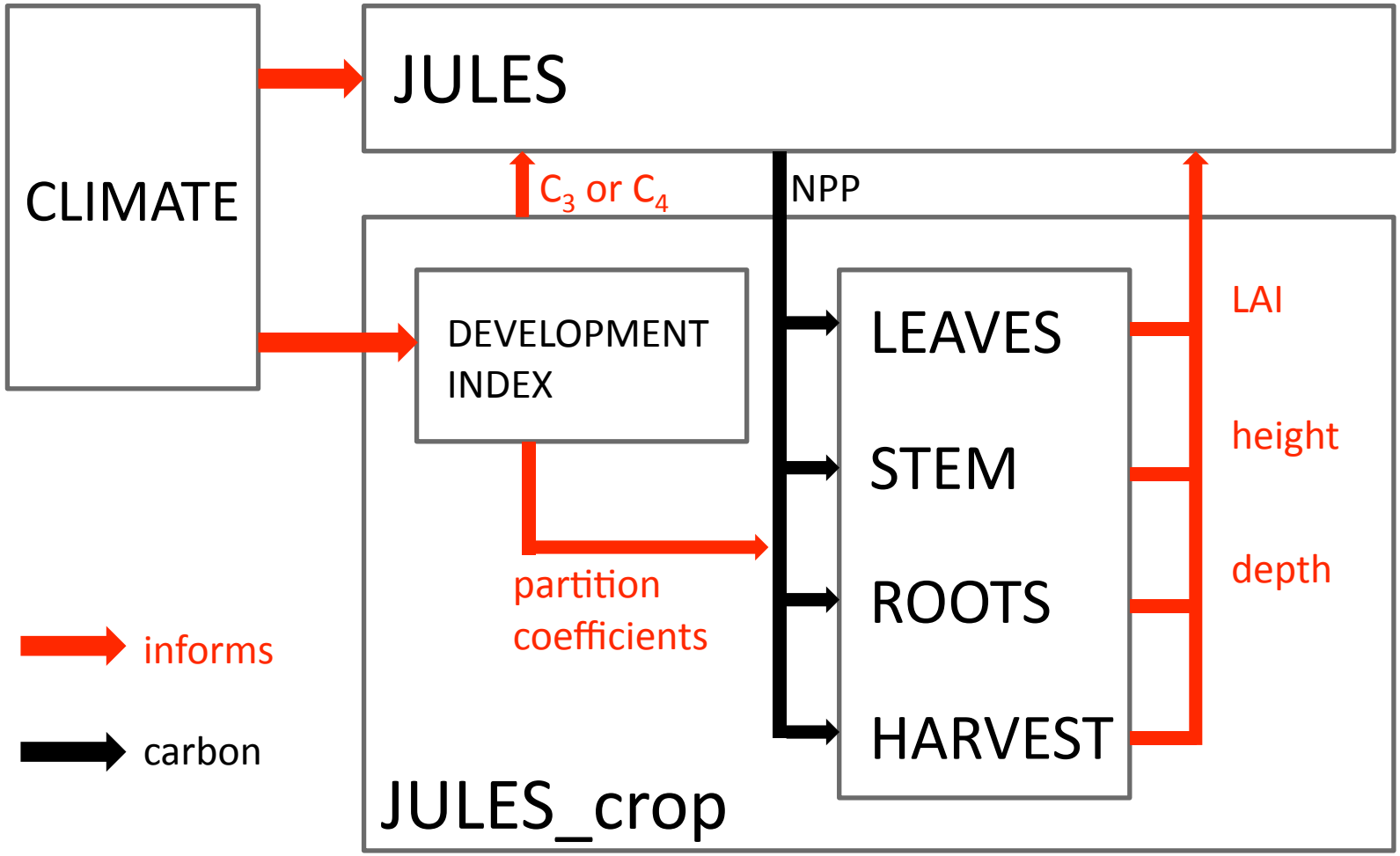
1) Representing the wide variety (175, Monfreda *et al*) of crops
   – Crop Functional Types.
2) Generic parameterisation suitable for all crop types.
3) Parameterisation of management (non-climatic influences)

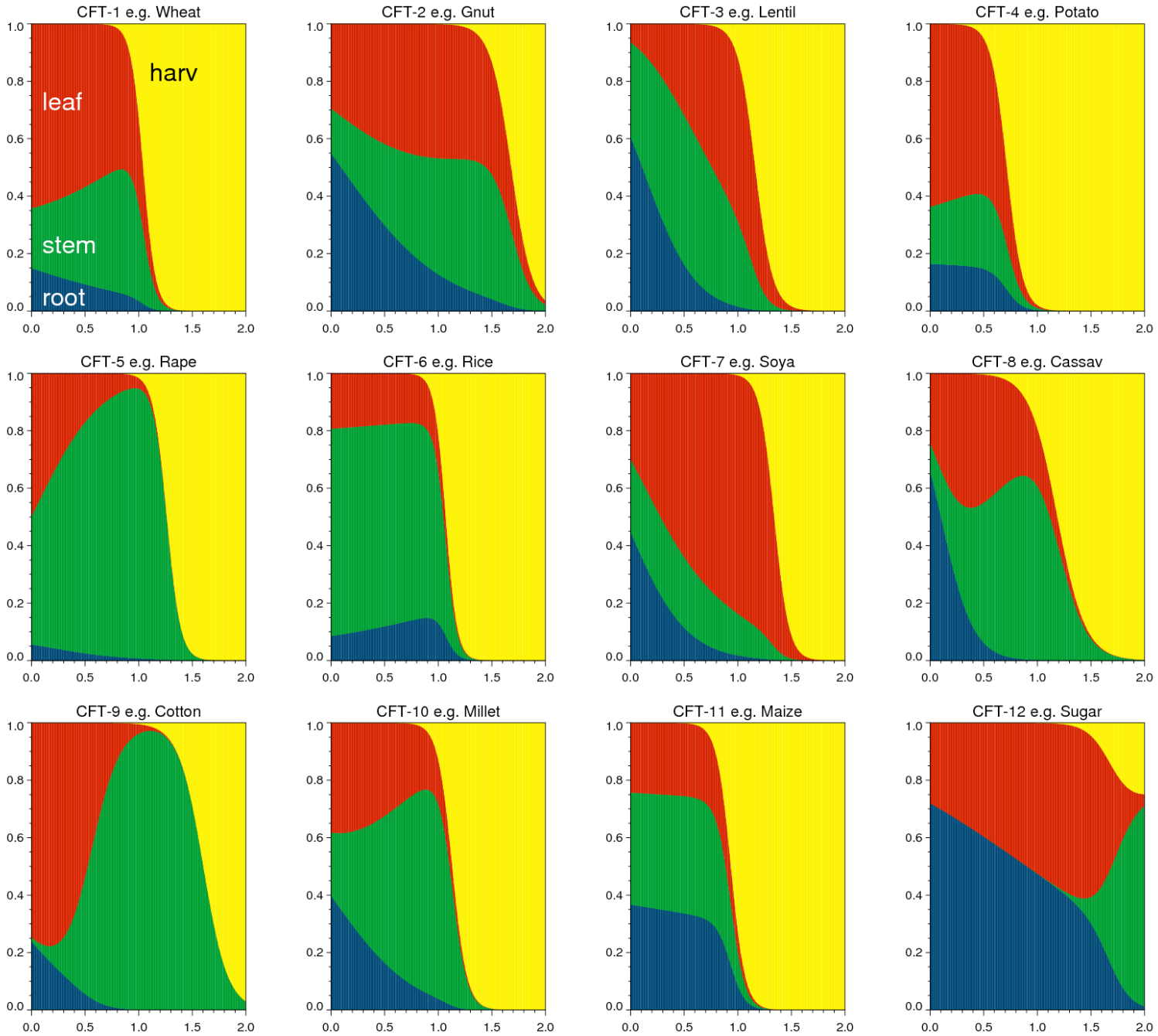
*Joint UK Land Environment Simulator (Best *et al,* 2011Geosci. Model Dev, 4, 677-699)

Crop Functional Types

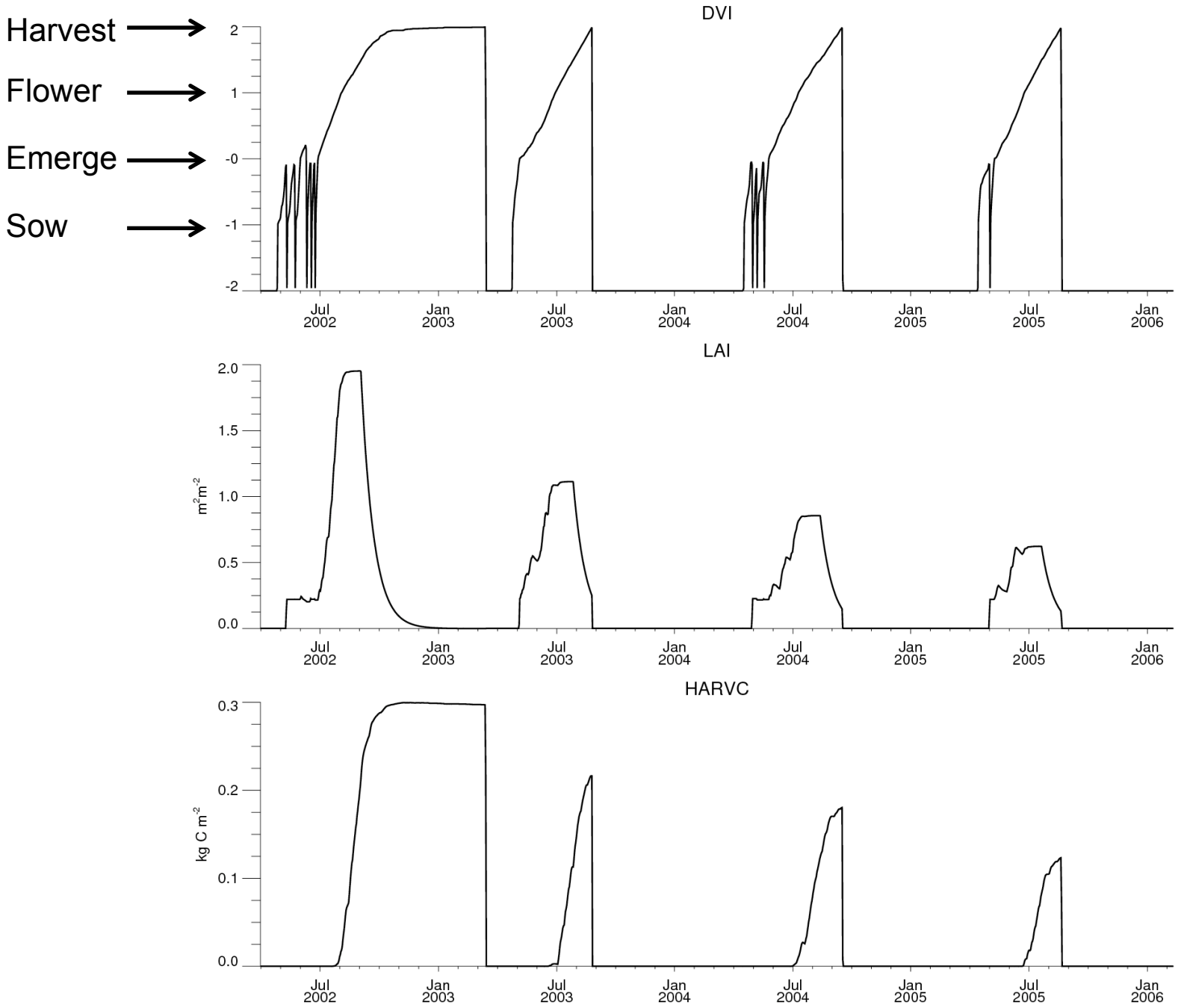
PHOTO SYNTHESIS	PHOTO SENSITIVITY	C / L / O	OTHER	CFT	EXAMPLE
C_3	LONG DAY SENSITIVE	CEREAL	----------	1	WHEAT, BARLEY, RYE, OAT
		LEGUME	OILSEED	2	GROUNDNUT
			NOT	3	LENTIL, CHICKPEA, DRYBEAN
		OTHER	ROOT / TUBER	4	POTATO, SUGARBEET
			NOT	5	RAPE
	SHORT DAY SENSITIVE	CEREAL	----------	6	RICE
		LEGUME	----------	7	SOYBEAN
		OTHER	ROOT / TUBER	8	CASSAVA, SWEET POTATO
			NOT	9	COTTON
C_4	----------	CEREAL	SMALL GRAIN	10	SORGHUM, MILLET
			LARGE GRAIN	11	MAIZE
		OTHER	----------	12	SUGARCANE

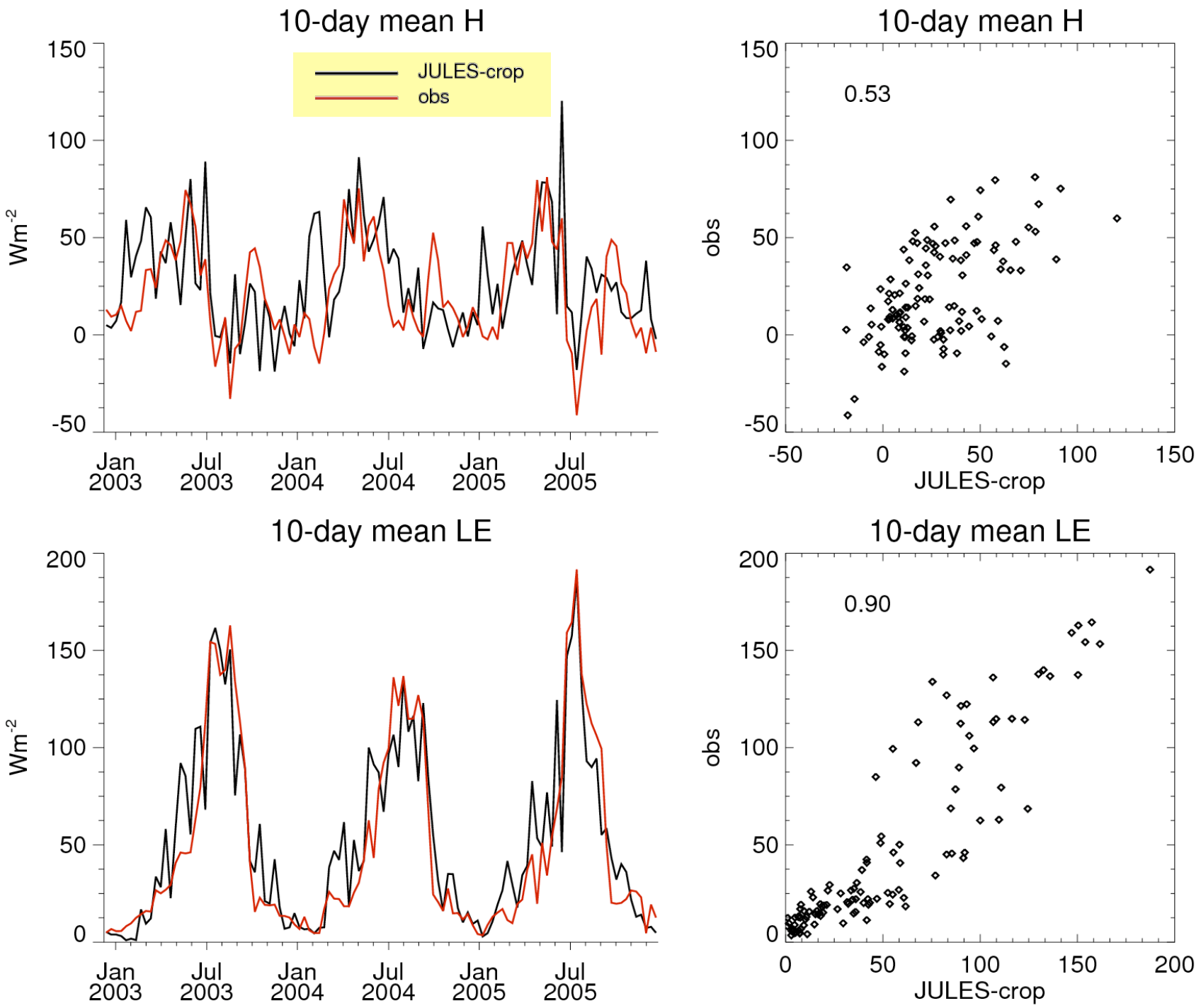
Generic parameterisation

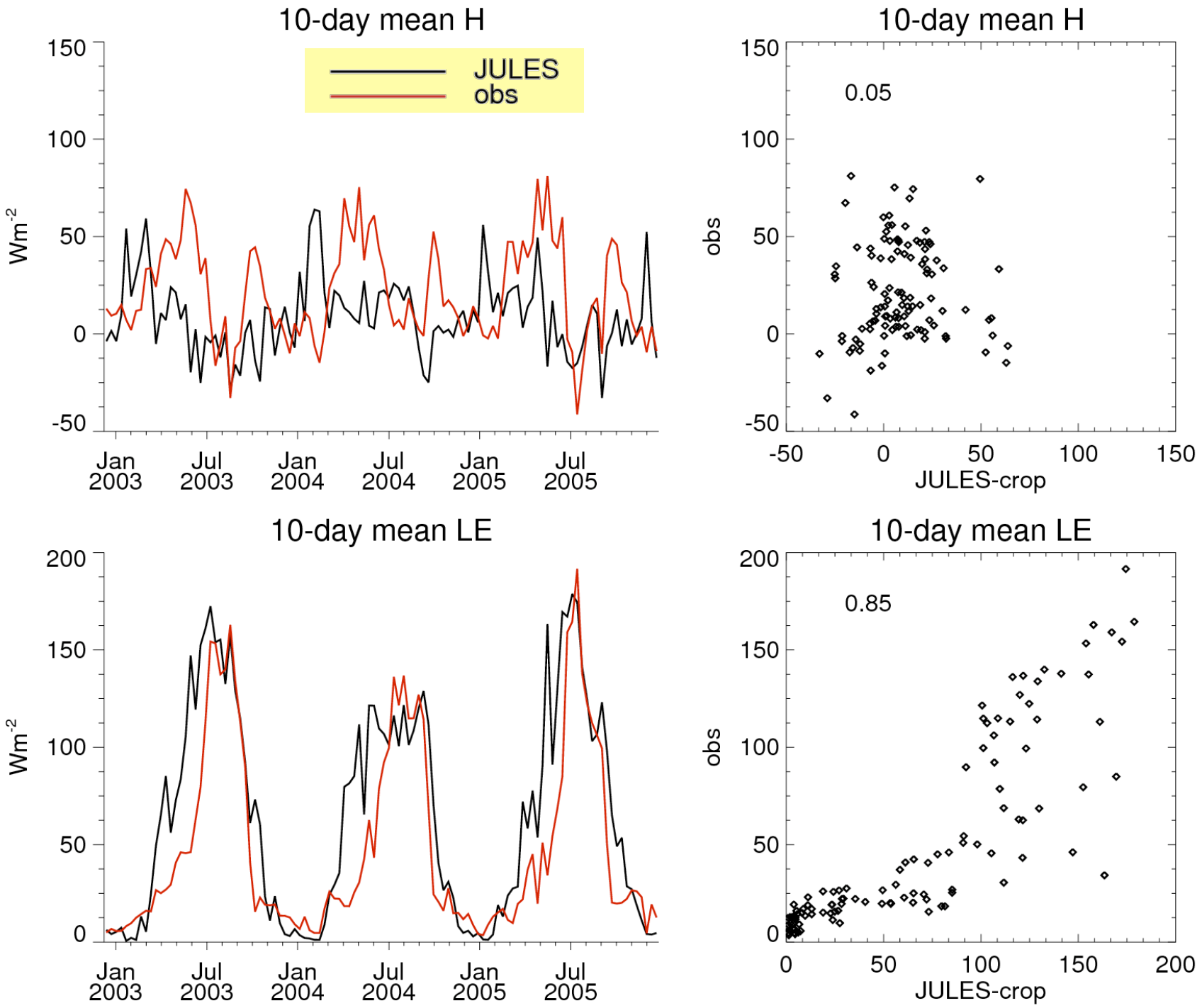



CFT-1 e.g. Wheat
CFT-2 e.g. Gnut
CFT-3 e.g. Lentil
CFT-4 e.g. Potato
CFT-5 e.g. Rape
CFT-6 e.g. Rice
CFT-7 e.g. Soya
CFT-8 e.g. Cassav
CFT-9 e.g. Cotton
CFT-10 e.g. Millet
CFT-11 e.g. Maize
CFT-12 e.g. Sugar
harv
leaf
stem
root
0.0
0.2
0.4
0.6
0.8
1.0
0.0
0.5
1.0
1.5
2.0

Site evaluation: Mead, NE

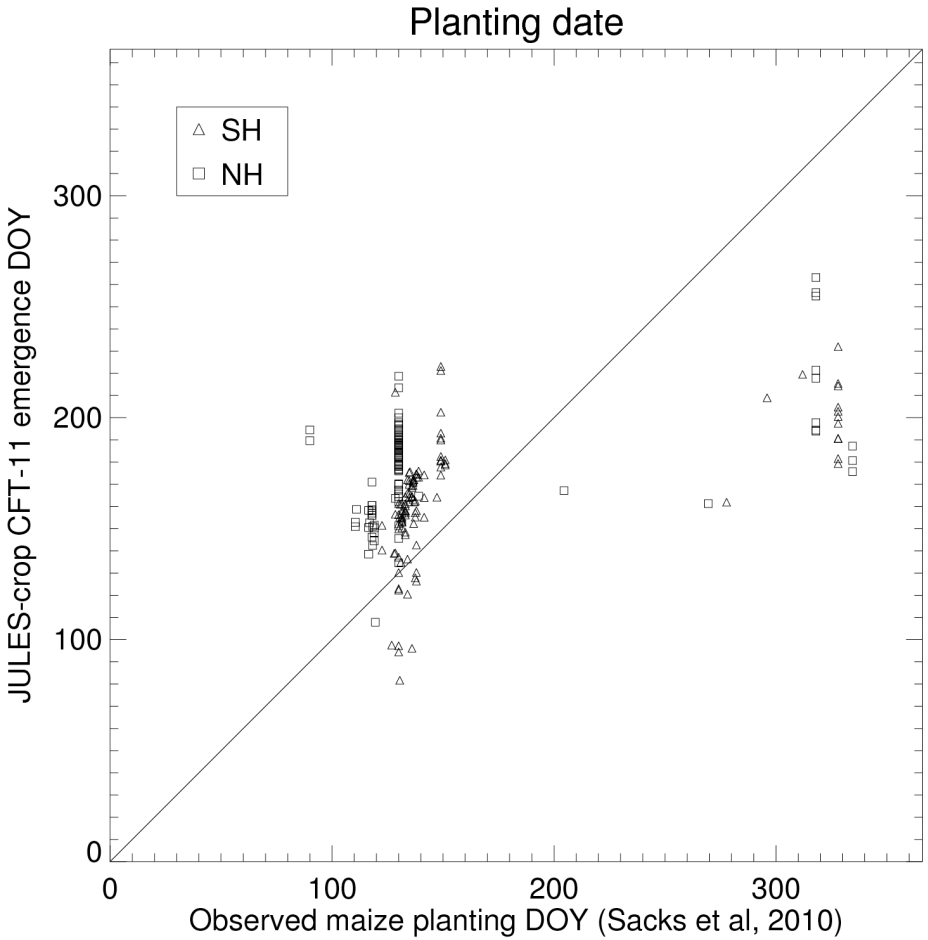

Harvest
Flower
Emerge
Sow
DVI
2
1
-0
-1
-2
LAI
2.0
1.5
1.0
0.5
0.0
m2m-2
HARVC
0.3
0.2
0.1
0.0
kg C m-2
Jul 2002
Jan 2003
Jul 2003
Jan 2004
Jul 2004
Jan 2005
Jul 2005
Jan 2006


10-day mean H
JULES-crop
obs
Wm-2
150
100
50
0
-50
Jan 2003
Jul 2003
Jan 2004
Jul 2004
Jan 2005
Jul 2005
10-day mean H
0.53
obs
JULES-crop
10-day mean LE
200
150
100
50
0
10-day mean LE
0.90
obs
JULES-crop

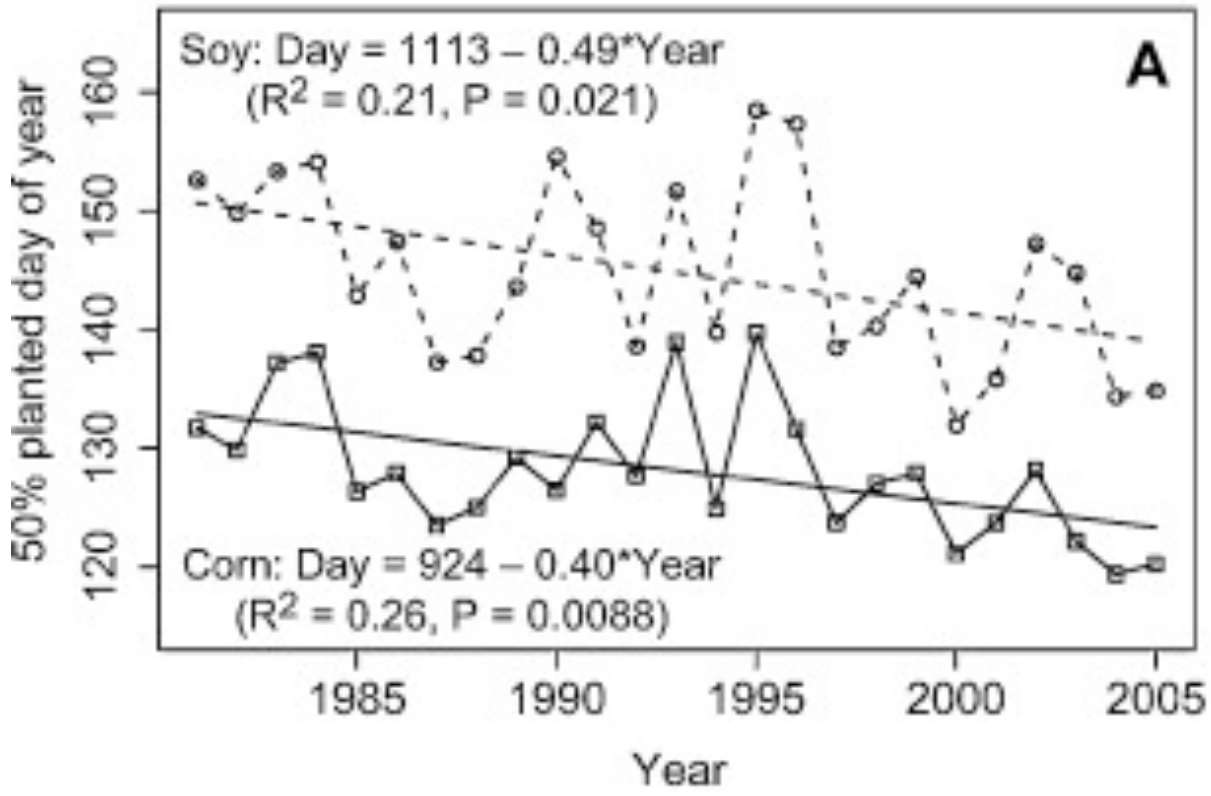

10-day mean H
JULES
obs
Wm-2
150
100
50
0
-50
Jan 2003
Jul 2003
Jan 2004
Jul 2004
Jan 2005
Jul 2005
10-day mean H
0.05
obs
JULES-crop
10-day mean LE
0.85
200
150
100
50
0

Spatially distributed simulations

200 grid cells with largest fractional coverage in Monfreda et al dataset.



Earlier planting of crops in US: part climate, part technology



Sacks and Kucharik (2011)

- Current assessments of the impacts of climatic change on crop productivity assume that croplands do not effect the overlying atmosphere.
- The potential for the state of the land surface to impact subsequent weather and climate, at least at local scales, and the differences in growth characteristics of crops from natural vegetation, suggests that this should be examined.
- To do so requires the addition of explicit parameterisations of crops in climate model land surface schemes.
- JULES-crop has been developed and shown to capture temporal variation in surface fluxes, and spatial variation in planting date.

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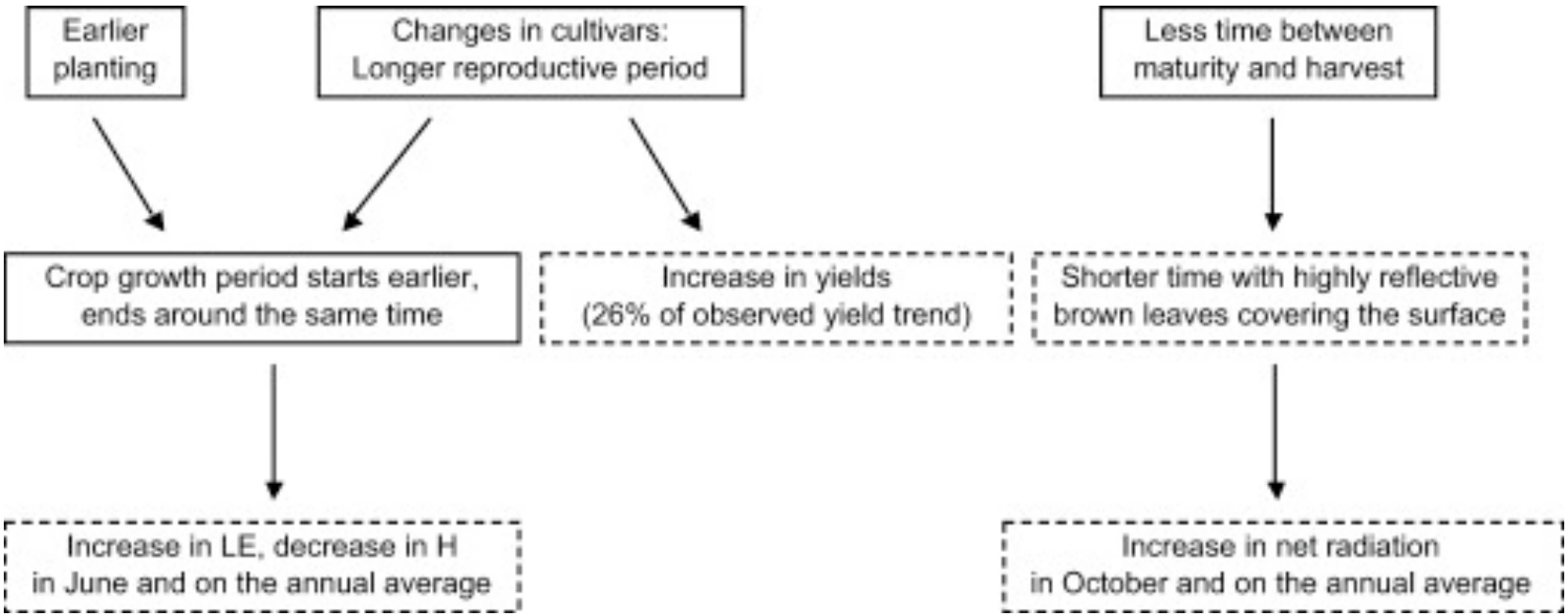
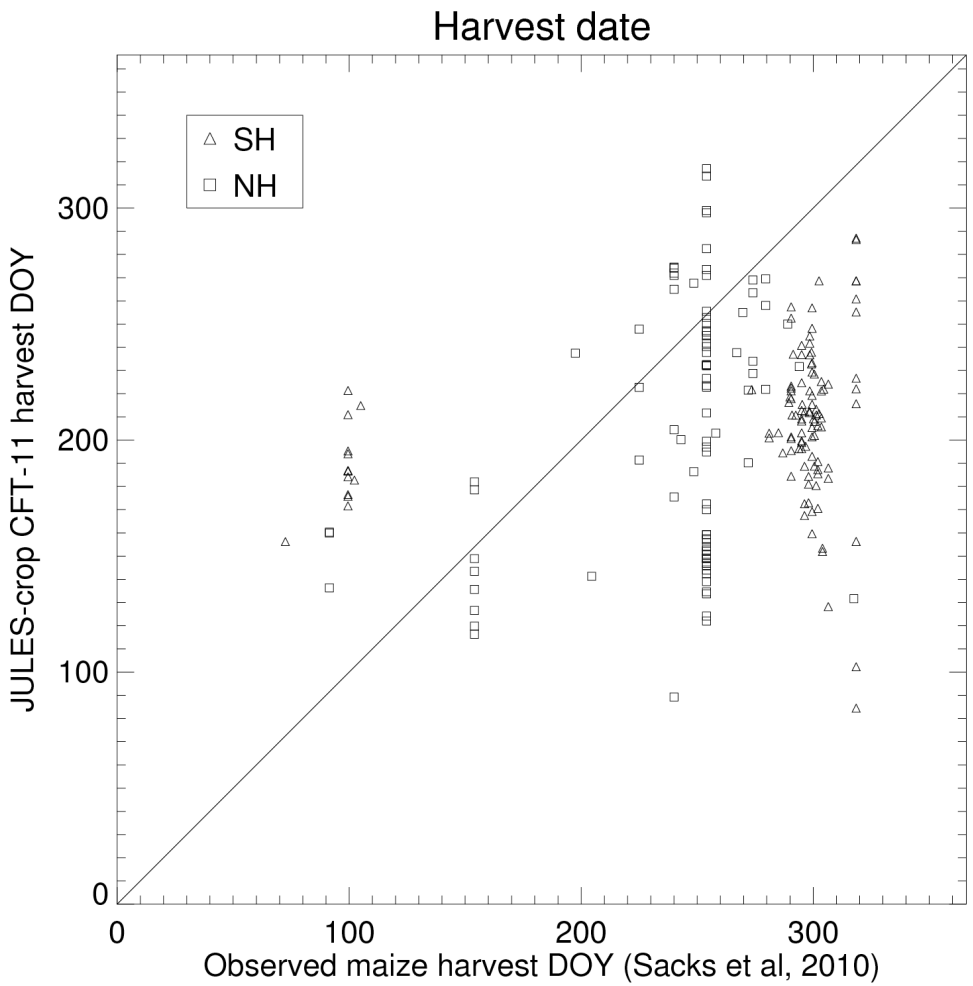

Earlier planting
Changes in cultivars: Longer reproductive period
Less time between maturity and harvest
Crop growth period starts earlier, ends around the same time
Increase in yields (26% of observed yield trend)
Shorter time with highly reflective brown leaves covering the surface
Increase in LE, decrease in H in June and on the annual average
Increase in net radiation in October and on the annual average


Harvest date
SH
NH
JULES-crop CFT-11 harvest DOY
Observed maize harvest DOY (Sacks et al, 2010)
0
100
200
300

- Integrated assessments of crops and climate.
- High-level introduction.
  - Important to understand how cropping systems are and will be affected by climatic change.
  - Assessments (not predictions) of how climate change will impact on crop productivity are commonly produced by running crop models (process-based, occasionally empirical) with current and future weather conditions, and plotting the difference.
  - This design (of crop models) is that the atmosphere is outside of the system. i.e. weather variables are exogenous/ boundary conditions.
  - I am proposing that this assumption should be addressed. I will describe the evidence for integrated crop-climate modelling and introduce a new crop parameterisation for a GCM land surface scheme which we plan to use in the future to examine the fully coupled crop-climate system.
- Evidence for an integrated coupled crop-climate approach
  - Land surface can affect climate, especially near the land surface (Koster et al)
  - Crops occupy much of the land surface, especially in heavily cropped regions, (Ramankutty & Foley)
  - Crops grow differently to "natural" vegetation (McPherson) which is how they are parameterised

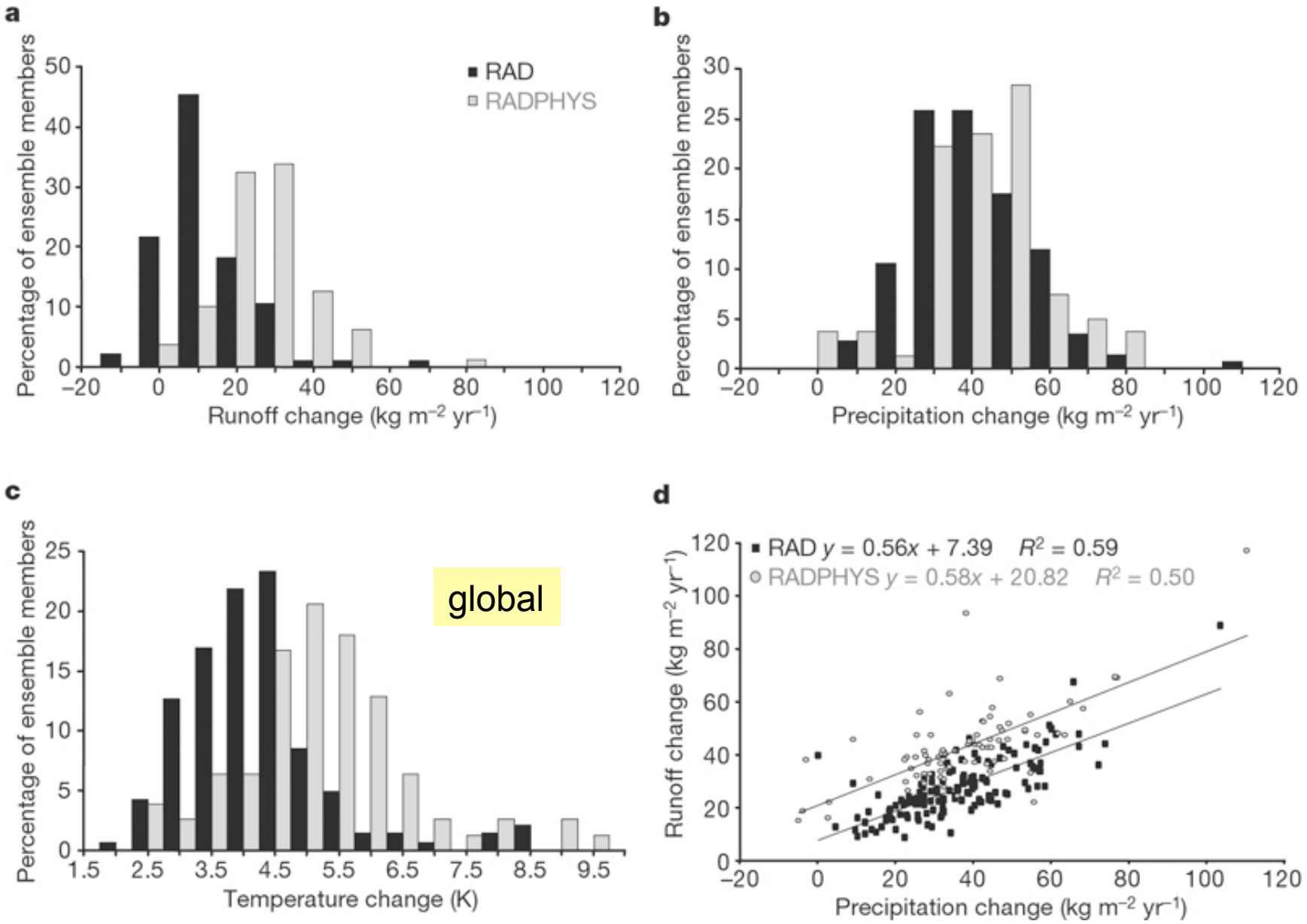
  Relevant examples,

  physiology can affect climate – e.g. CO2-gs temperature effects – local to regional effects
  - growing crops in climate model affects climate, affects crops,…, - interannual variability example
  - climate - glacier melt – irrigation – crops. Integrated impacts science.

Therefore, include crops in LSM for coupling to climate model

Challenges,

1. Representing many types (Monfreda, 175) of crop.
2. Representing in generic framework suitable for global LSS. (i.e. can't do separate model for potatoes, for wheat, for rice). E.g. DSSAT
3. Simulation of management (planting date, variety choice – Sacks)



Betts *et al* (2007)