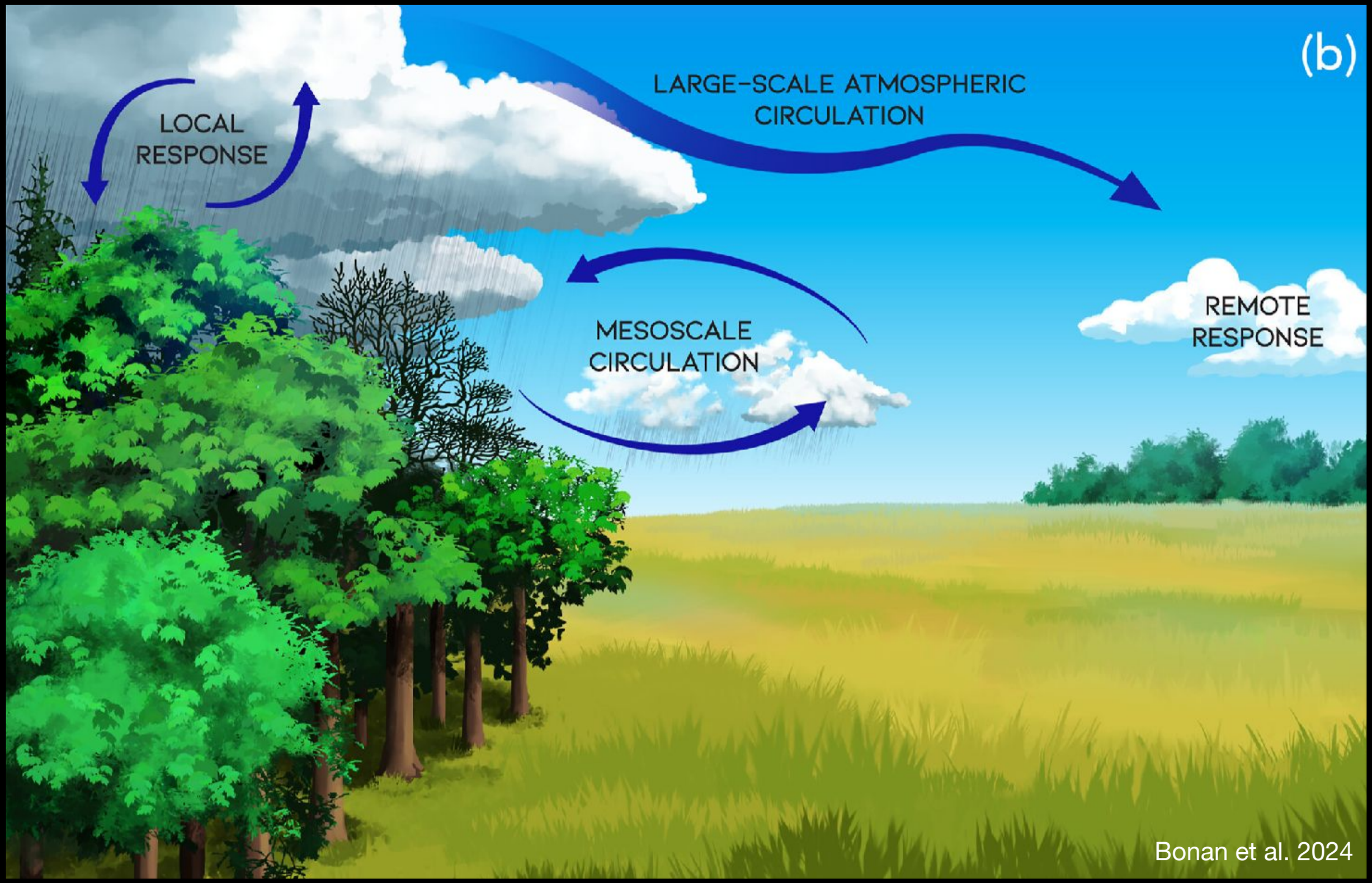
Representing Agriculture in CLM



Danica Lombardozzi & Sam Rabin

Land influences climate on local to global scales

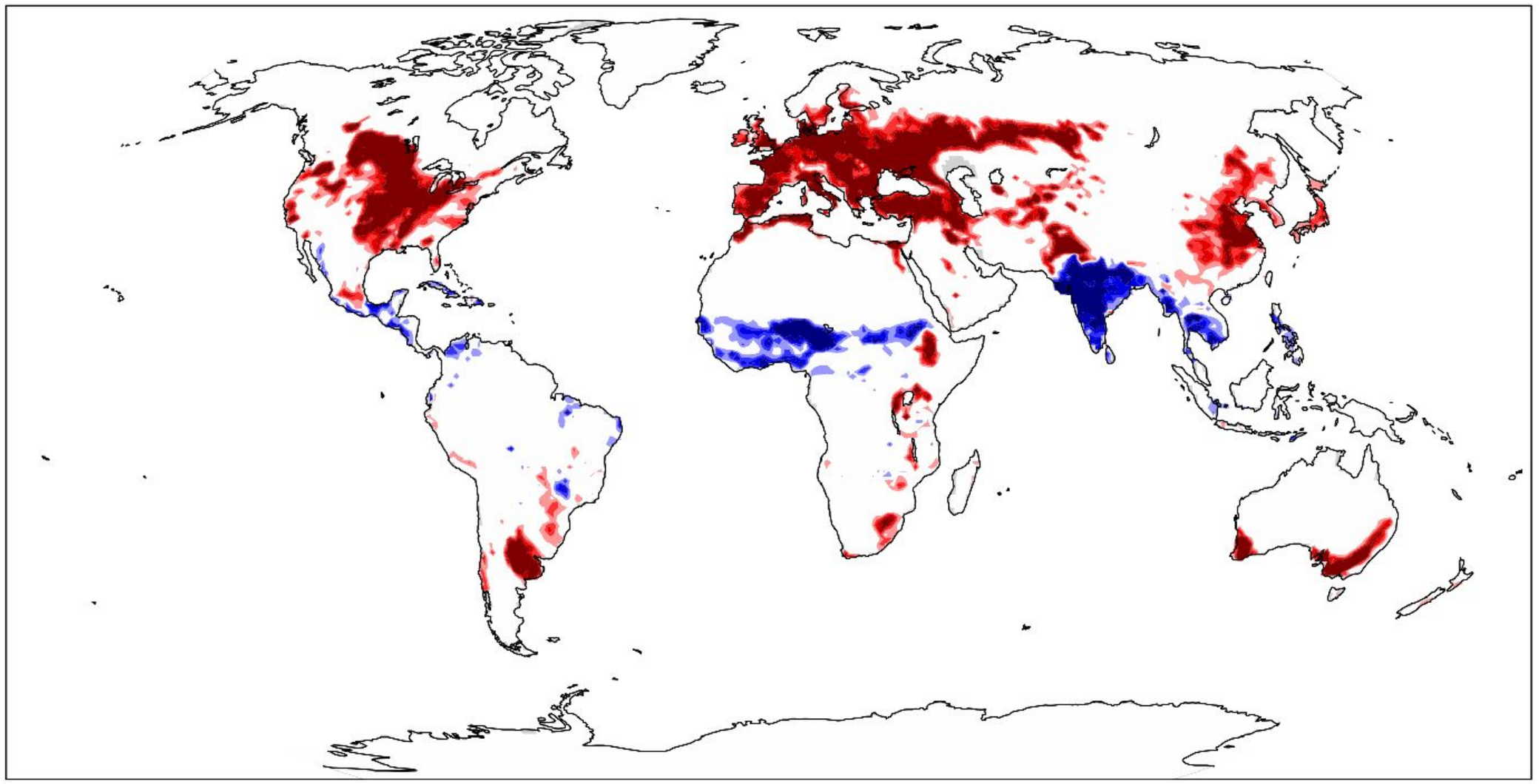




1991-2010 Average

Impact of Simulated Managed Crops

(relative to simulating generic crops)





Change in Annual Maximum **Gross Primary Productivity** (g C m^{-2} day^{-1})

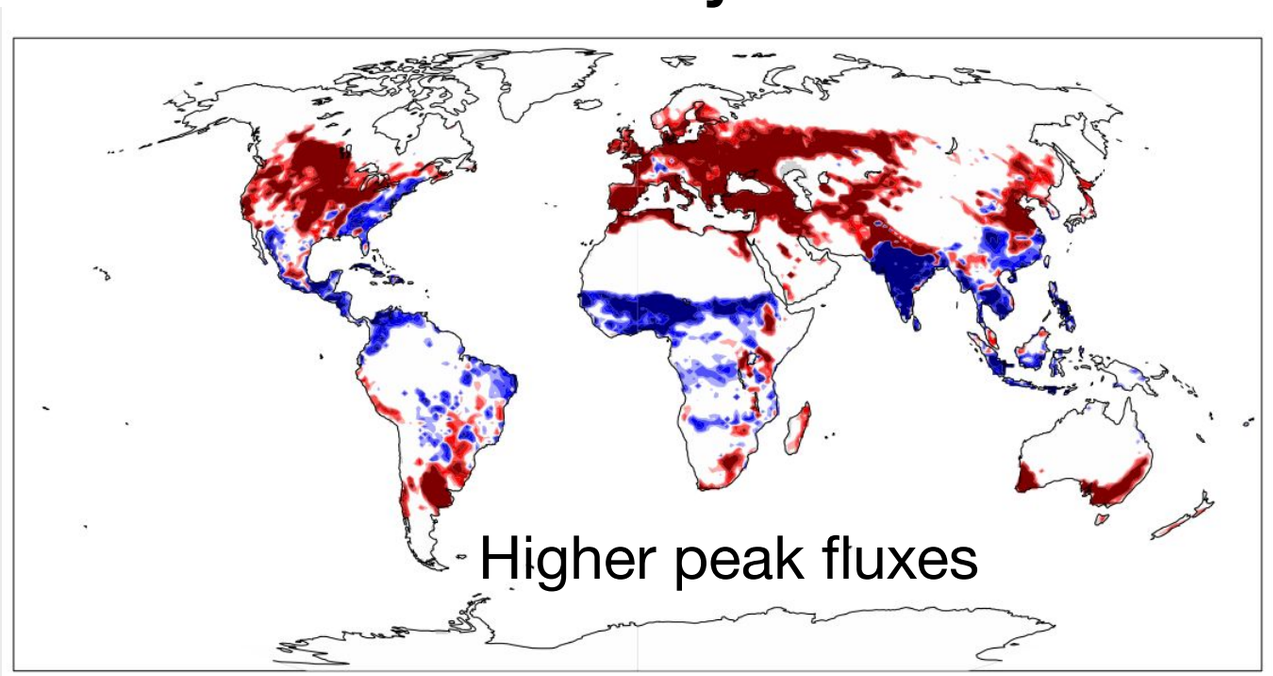
Lombardozzi et al., 2020

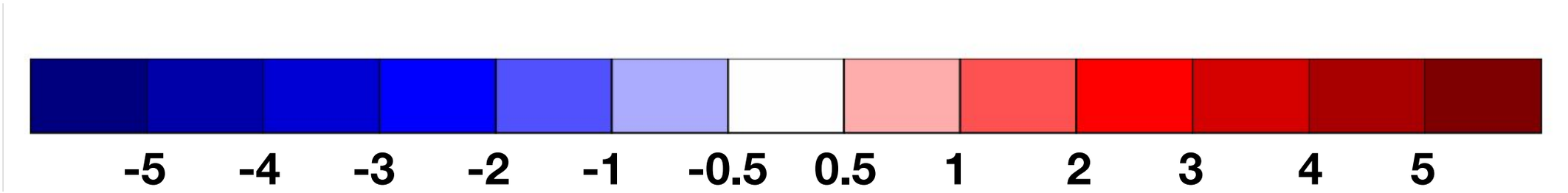
1991-2010 Average

Impact of Simulated Managed Crops

(relative to simulating generic crops)

Annual Monthly Maximum





Change in Latent Heat Flux (W m^{-2})

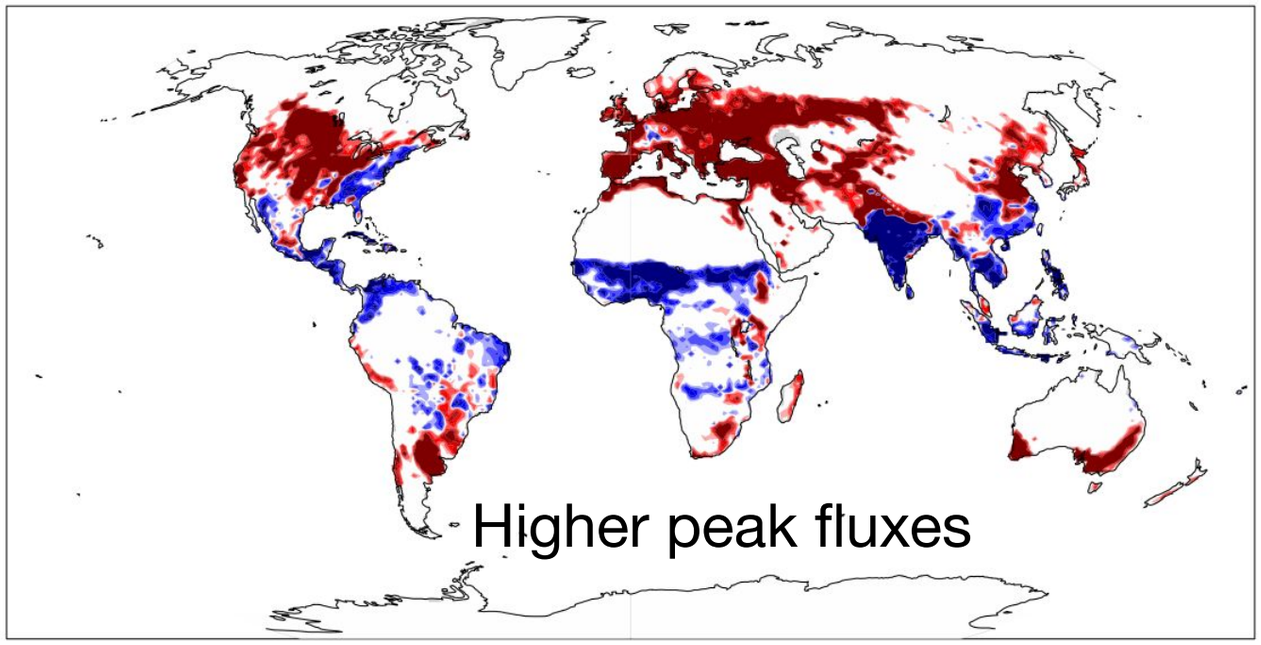
Lombardozzi et al., 2020

1991-2010 Average

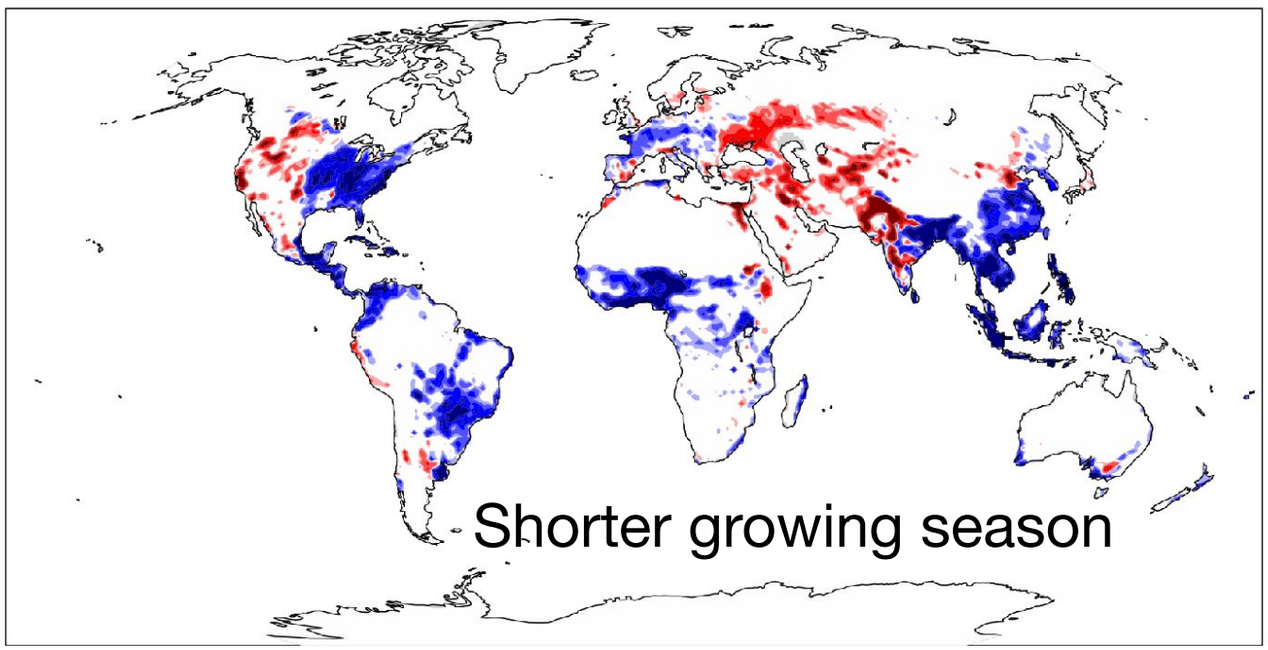
Impact of Simulated Managed Crops

(relative to simulating generic crops)

Annual Monthly Maximum



Annual Average



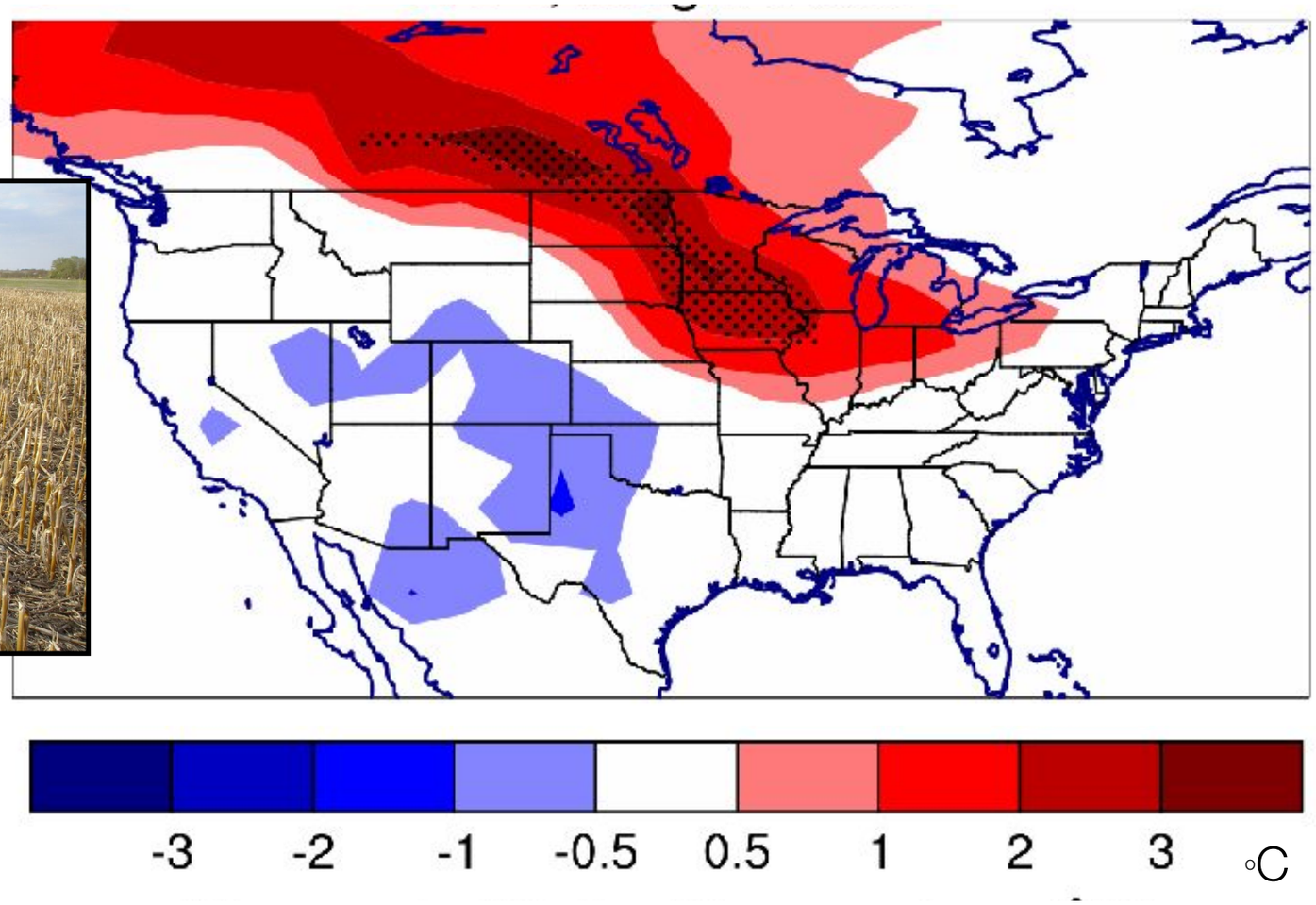


Change in Latent Heat Flux (W m^{-2})

Lombardozzi et al., 2020

Change in Winter* Temperature (°C)



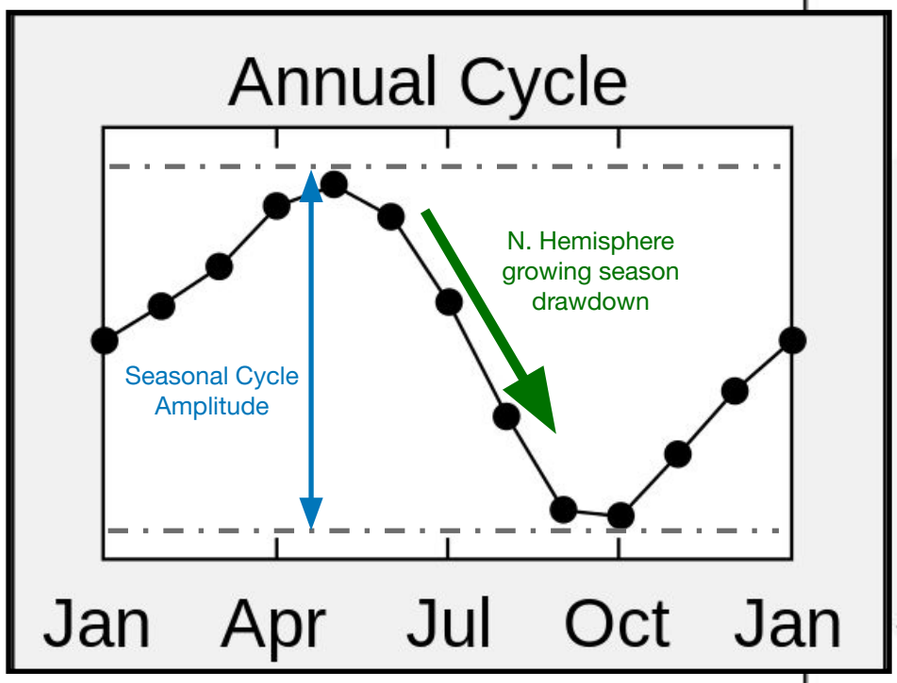


Cover crops may increase winter temperature in snowy regions

* December - January - February

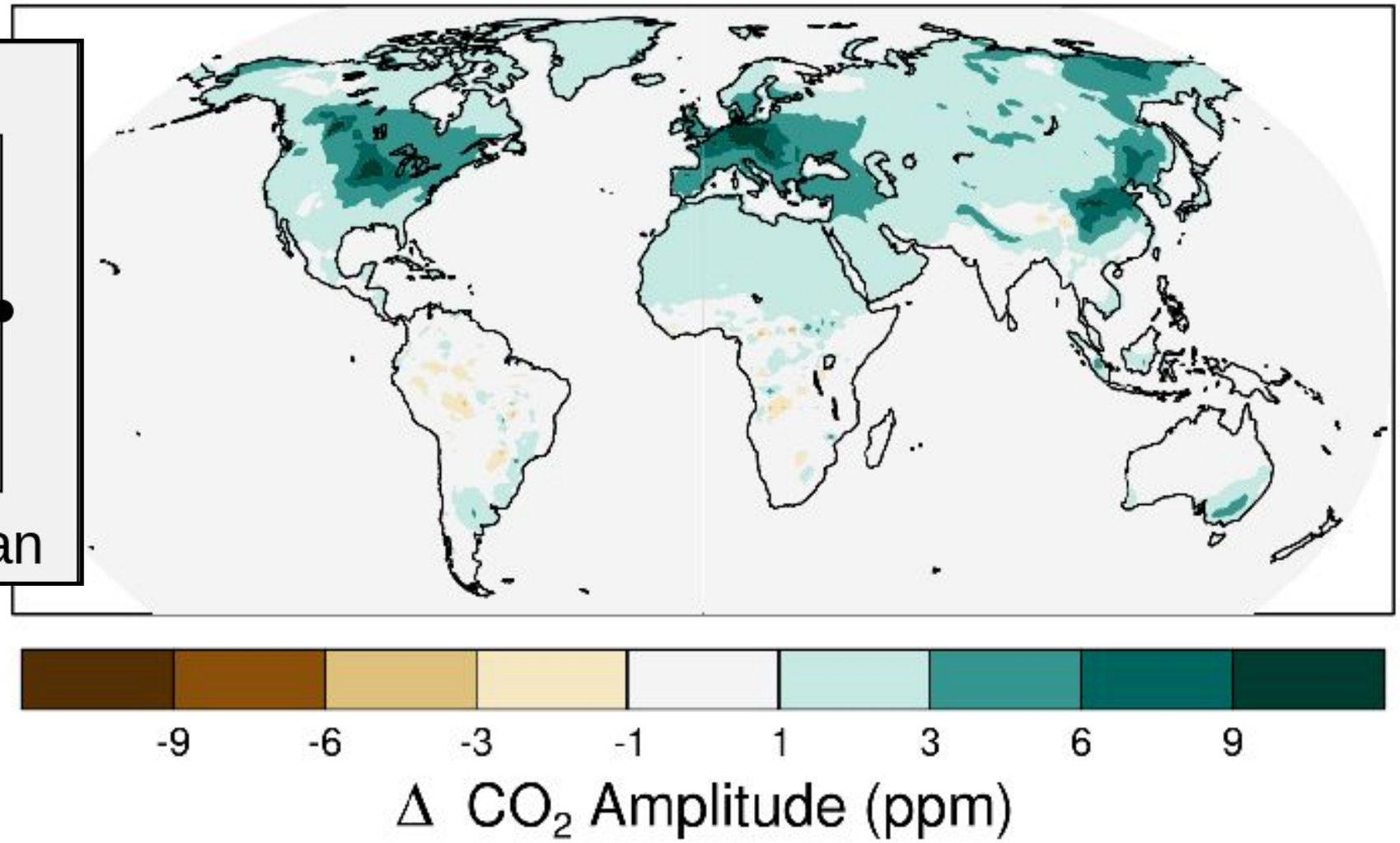
Lombardozzi et al. 2018

Impact of Agricultural N Fertilizer



CESM2

1995-2015



Lombardozzi et al. 2025

Crop Model Features

1) Crop types and distributions
2) Crop phenology
3) Allocation in crops
4) Management options
5) Crop Yields

1) Crop Types & Distributions

Crop Types

Corn*





Soy*

Sugarcane





Cotton

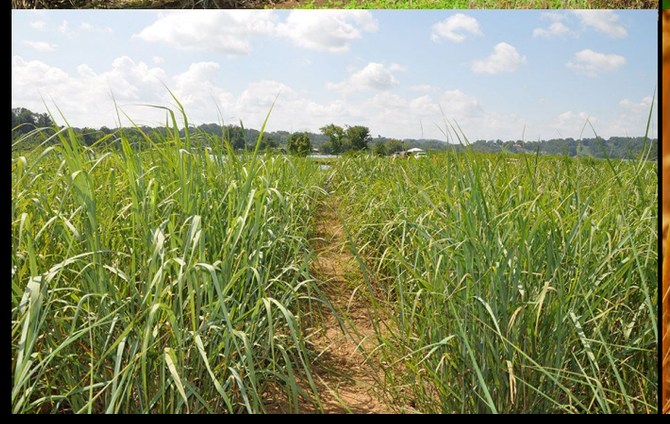
Miscanthus†Ω





Rice

Switchgrass†Ω





Wheat§Ω

* *Temperate and tropical varieties*

† *Biofuel crops*

§ *Spring and winter varieties*

Ω *Distributions not yet on land use and surface datasets*

Additional Crops: Placeholders

barley
winter barley
rye
winter rye
cassava
citrus
cocoa
coffee
date palm
fodder grass
grapes
groundnuts
millet
oil palm
potatoes
pulses
rapeseed
sorghum
sugarbeet
sunflower

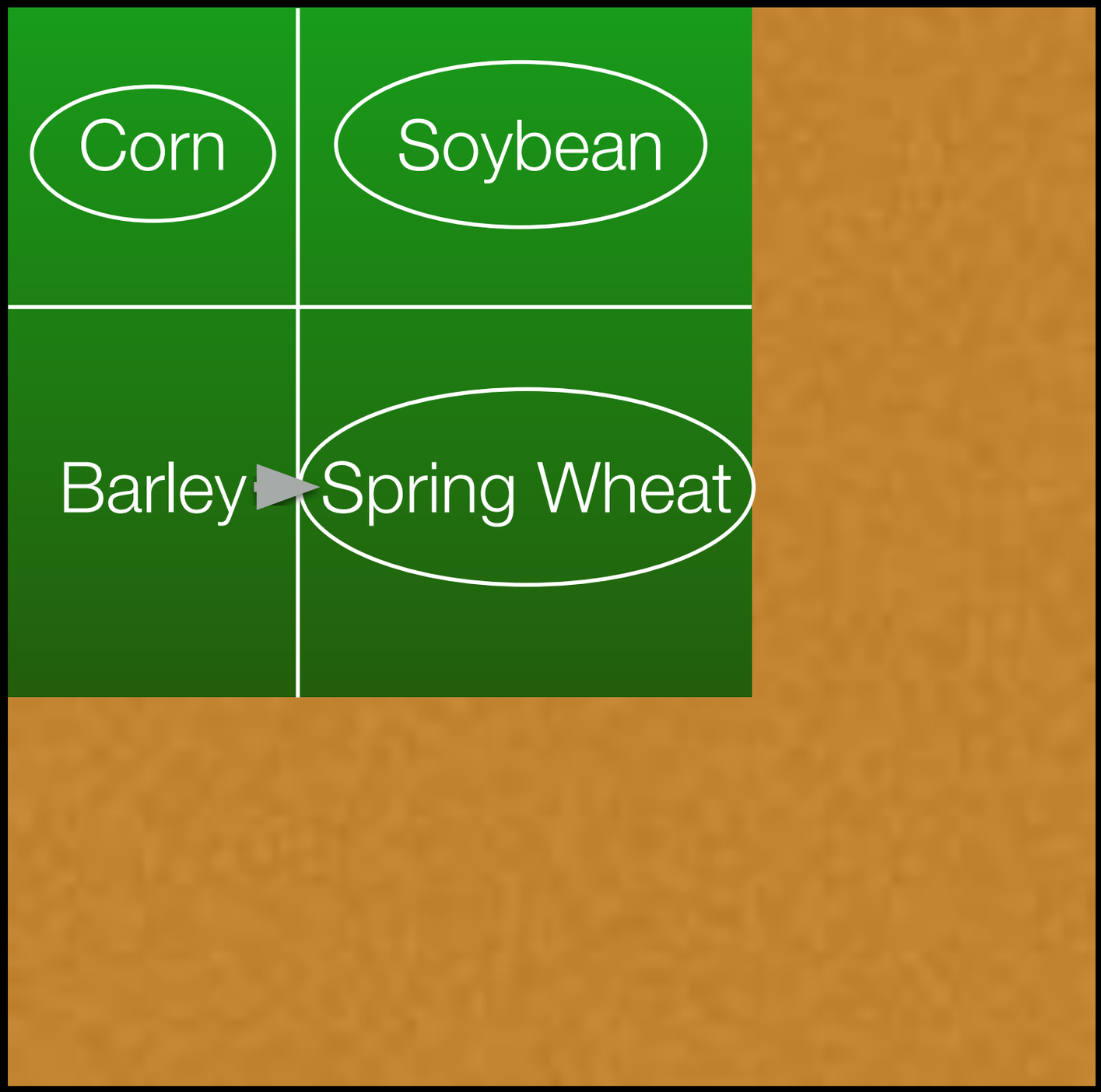
The surface dataset includes distributions for these crops, but we do not have the required parameters to represent them.

Pull request for CLM5-FruitTree, which will improve representation of tree crops (Dombrowski et al. 2022)

Note that there are irrigated and rain-fed PFTs for each crop type. When crops are active, the surface dataset has 78 (instead of 16) PFTs.

All crop area is represented as managed cropland

Even crops without active parameterizations



Crops without parameters are merged with an active crop type

Yields can be calculated for 31 crop types

Assumption that inactive crops have same growing triggers & allocation as the active crop

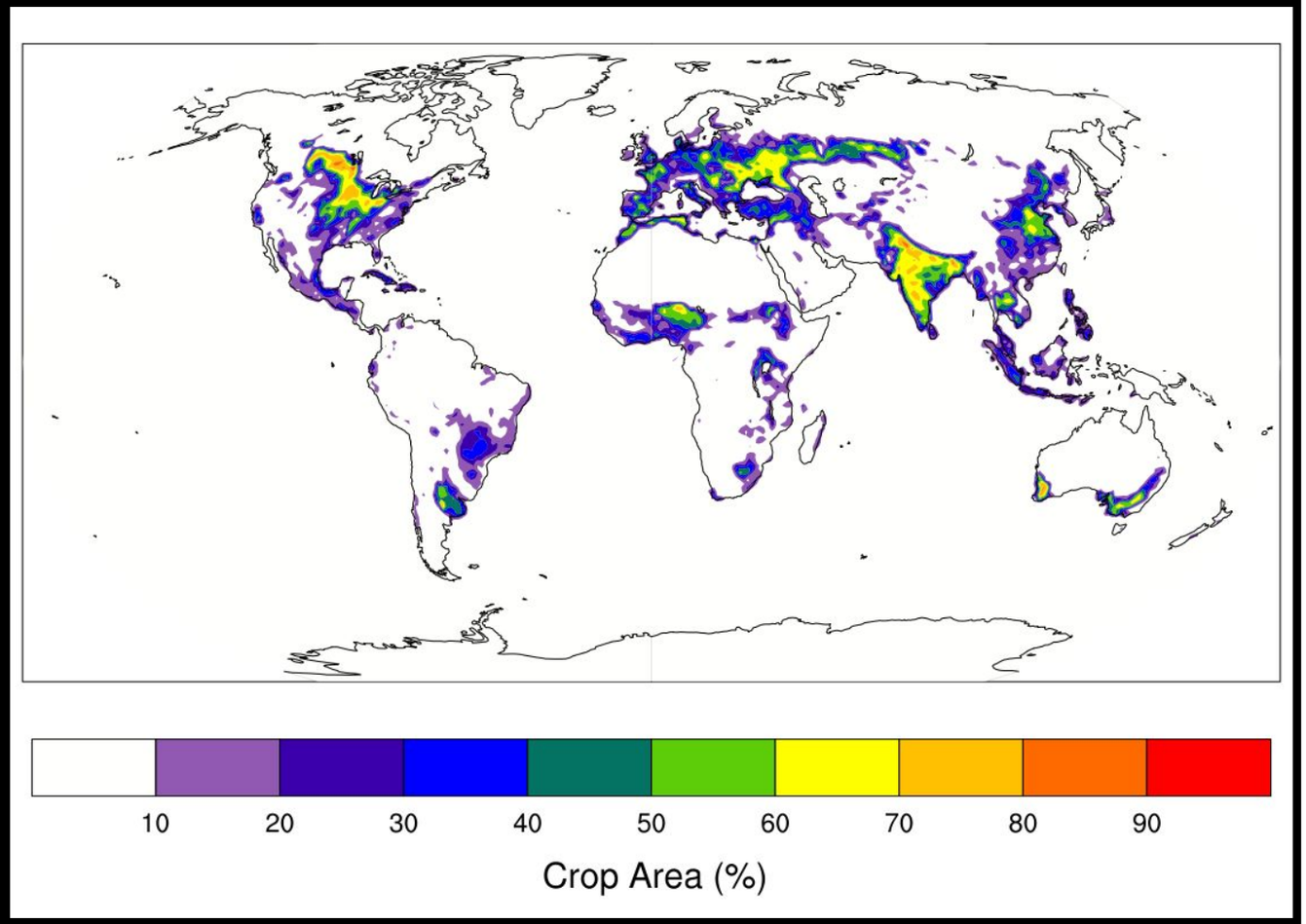
Need to use surface dataset for remapping during analysis

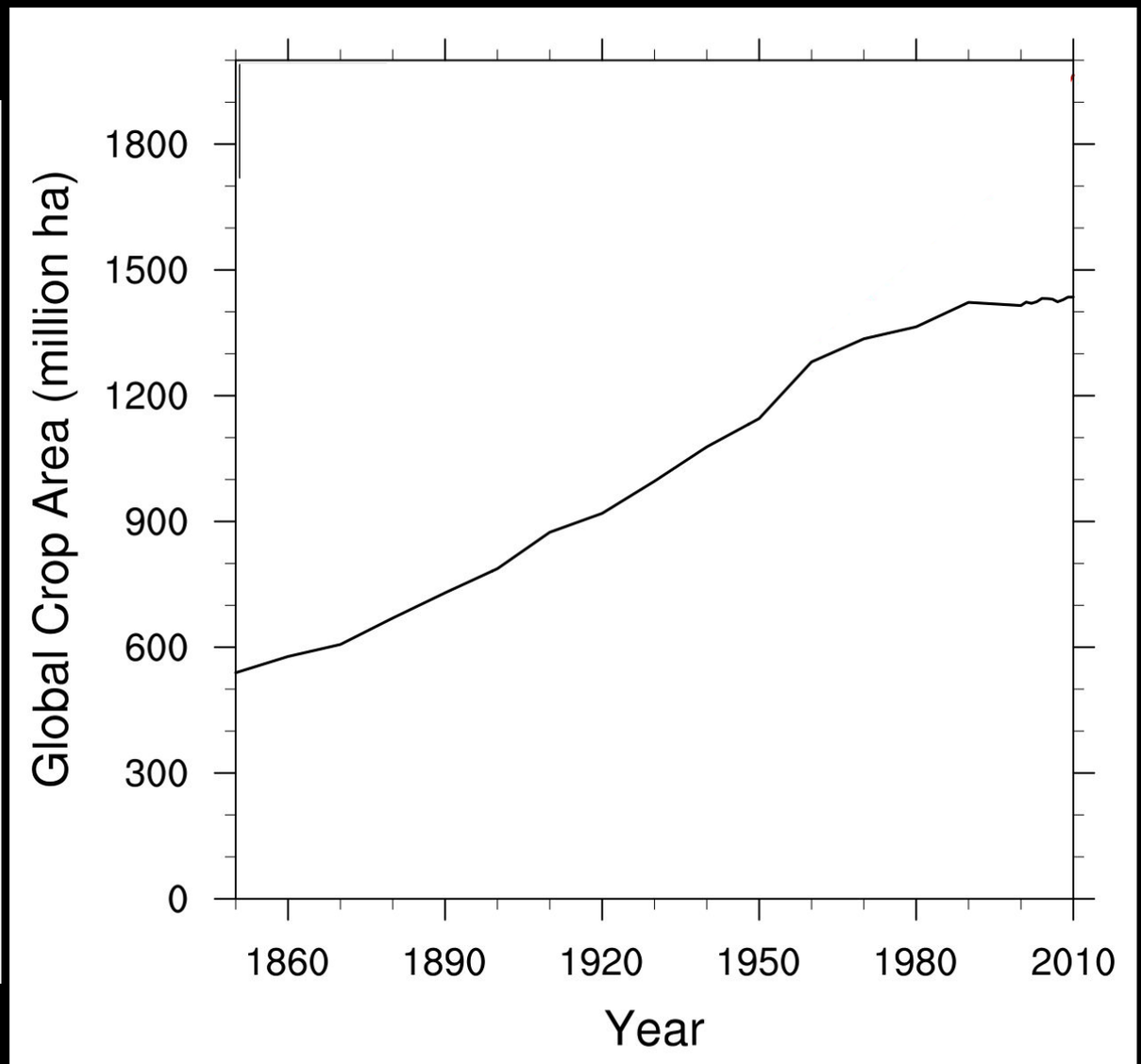


A full list of which parameters are used for each crop type is included in the CLM Tech Note

Crop Distributions

1991-2010 Crop Area





Crop distributions are found on the surface dataset (‘fsurdat’ in the clm namelist)

2) Crop Phenology

CNPhenology.F90

Phenology







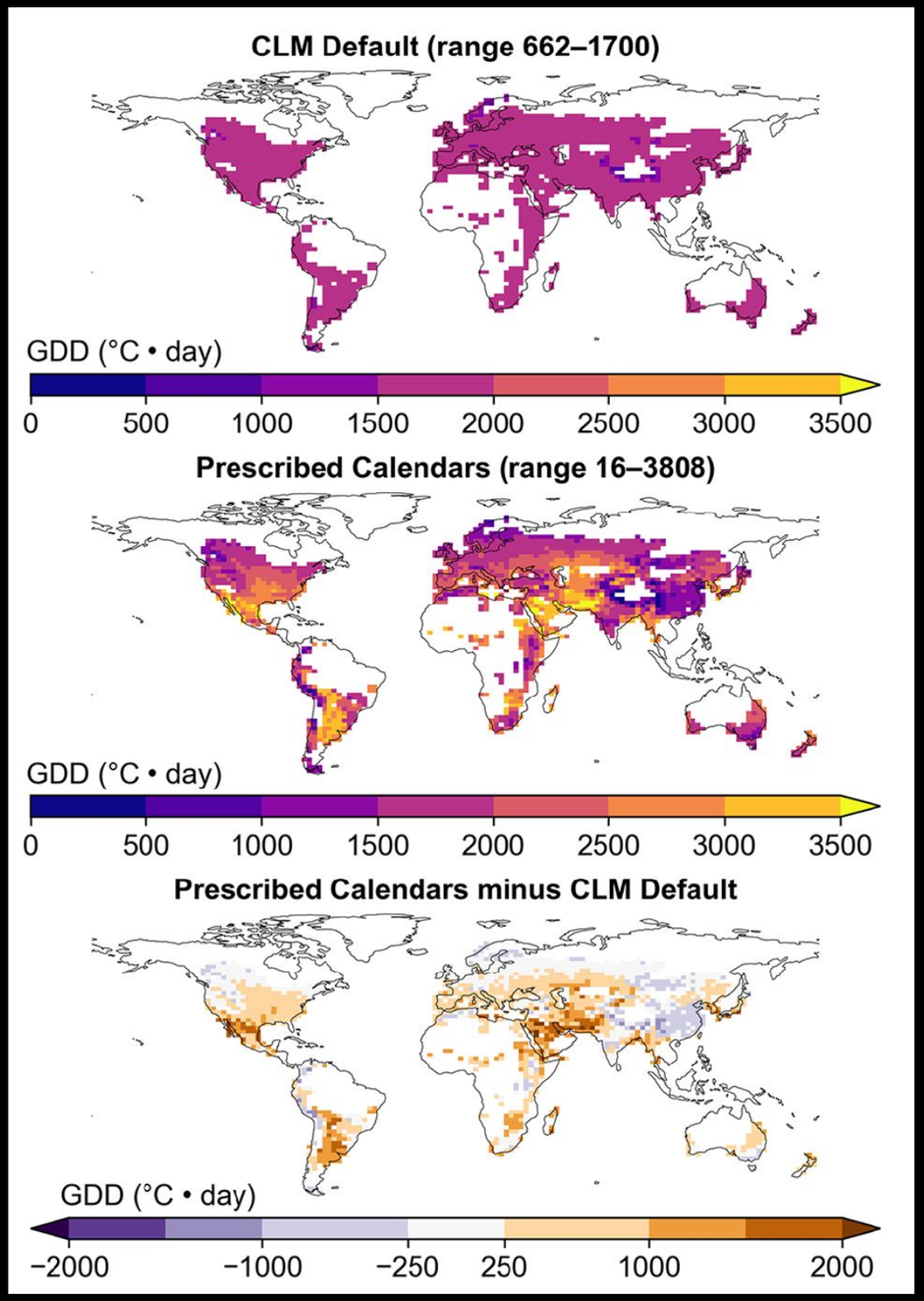


*All phenology phases are triggered by **<u>temperature</u>**.*

Option: Prescribed Crop Calendars

Observation-based crop calendars for **sowing dates** and **maturity requirements**

Rabin et al. 2023



Spring Wheat Maturity Requirements

More realistic for historical & present-day simulations

Better comparison with observations

Not prognostic, limiting changes for future climate projections

3) Allocation

Allocation

2) Leaf Emergence



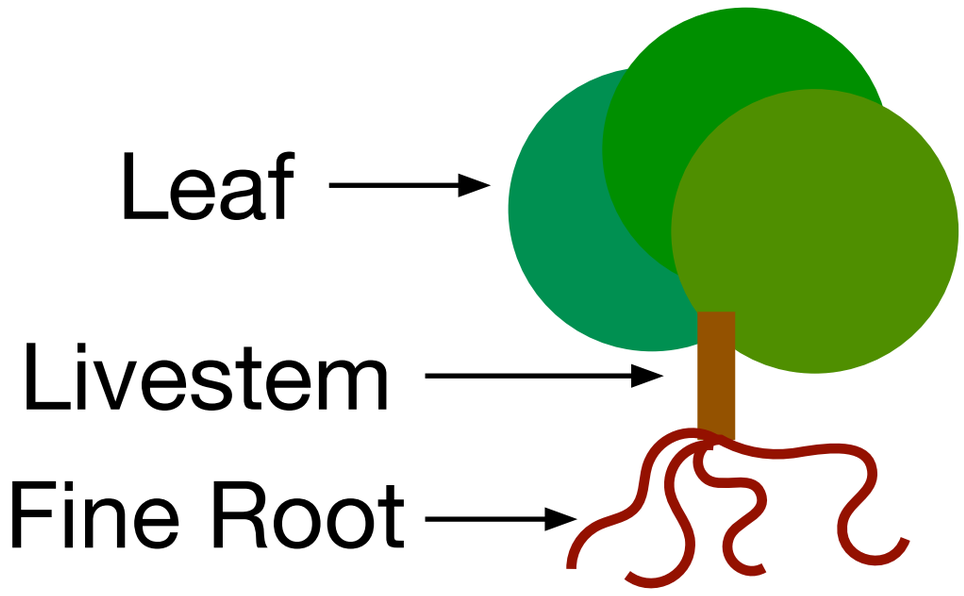
3) Grain Fill



Allocation changes depending on which phenological phase the crop is in. Allocation parameters also vary by crop type

During Leaf Emergence (Phenological Phase 2)

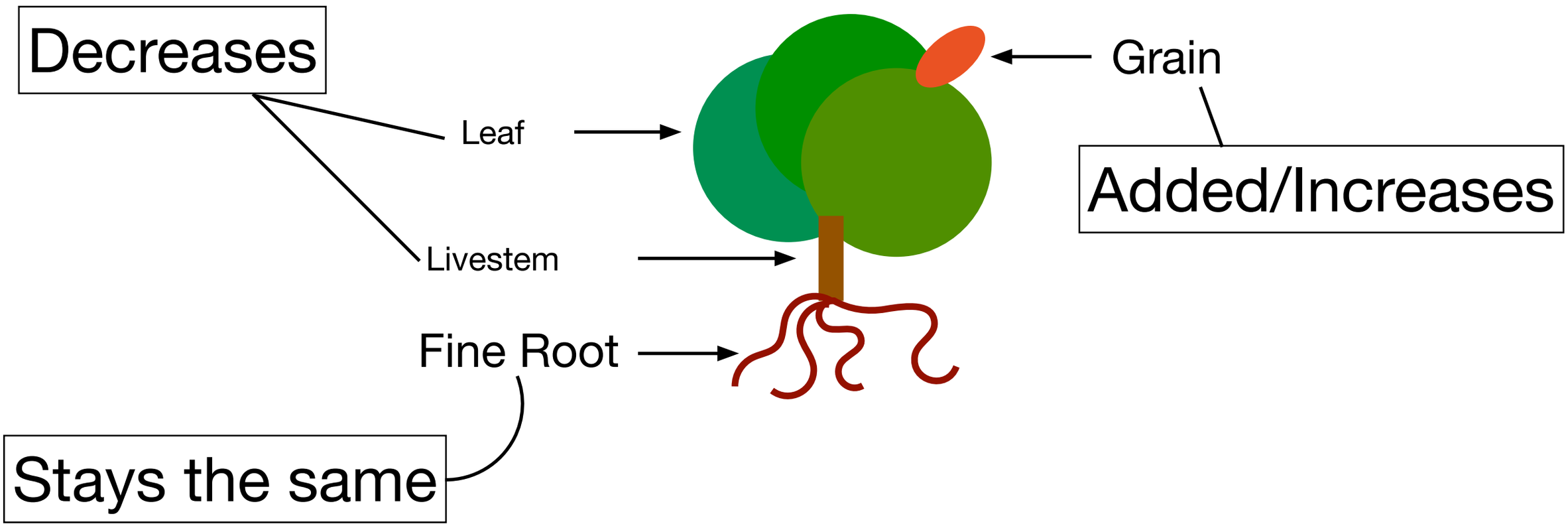
Carbon and nitrogen are allocated to the following pools:



Allocation to these pools are based on crop-specific parameters

During Grain Fill (Phenological Phase 3)

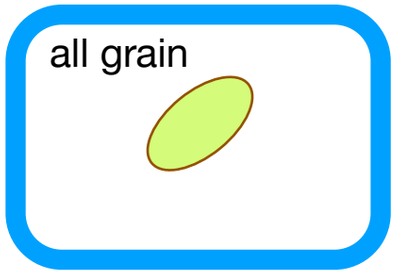
C and N allocation changes:



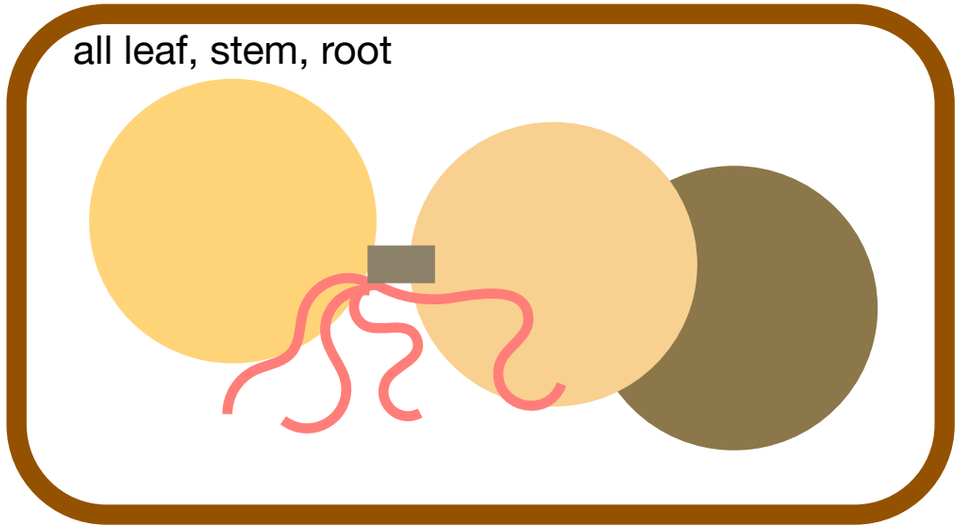
Allocation to these pools are based on crop-specific parameters

At harvest

Atmosphere



Litter



Stubble
(stem area index = 0.25)

Note: Options for residue removal. Biofuels remove a different fraction of residue

4) Management Options

Active Management

Fertilization



Manure: 2 g N m^{-2} yr^{-1}

Chemical fertilizer: prescribed by crop type, year, and country

Irrigation



Application methods

- **Drip** (default)
- Sprinkler
- Flood (development)

Water sources

- **Rivers/surface water** (default)
- Groundwater
- Reservoirs (development)



Fertilizer

Fertilization begins during leaf emergence and runs for 20 days

Note that the slow application minimizes N loss and limits N application to emergence phase

Fertilizer is applied as two sources:

Manure (manunitro)

Applied at a rate of 0.002 kg N m-2 yr-1

Industrial (FERTNITRO_CFT)

Based on LUMIP land use and land cover change time series (LUH2 and SSPs)

Prescribed by crop functional type

Varies spatially and temporally and specified on the land use time series

Note that for non-transient simulations, industrial fertilizer is constant and specified on the land surface dataset (CONST_FERTNITRO_CFT)

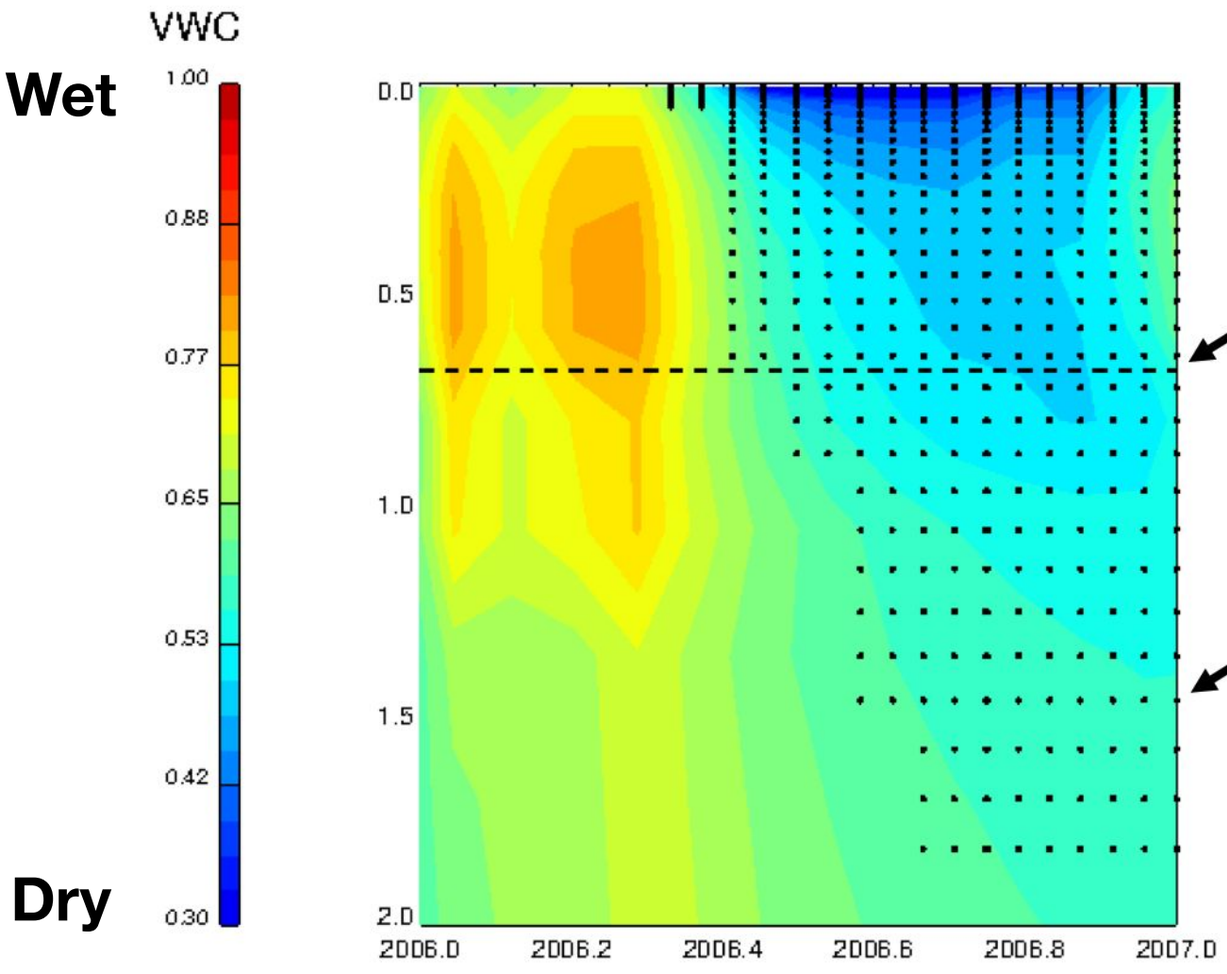
Irrigation

Irrigation is only applied to irrigated crop columns

Irrigation is triggered by the soil moisture state in the root zone

The amount of irrigation depends on three parameters: root zone depth, target soil moisture, and difference between actual and target soil moisture





S. Swenson

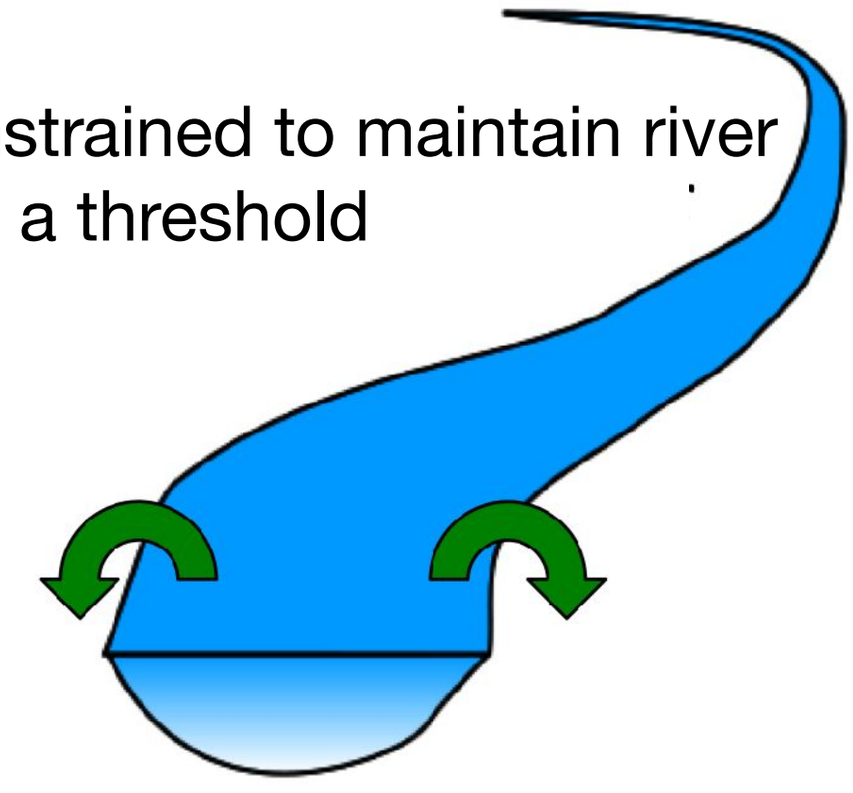
How is irrigation limited?

Irrigation demand is calculated independently of water availability, and irrigated water is removed from river water storage.

If river water is inadequate to meet irrigation demand:

1) additional water can be removed from the ocean

2) irrigation can be constrained to maintain river water storage above a threshold



Irrigation name list options:

- irrig_depth
- irrig_length
- irrig_method_default
- irrig_min_lai
- irrig_river_volume_threshold
- irrig_start_time
- irrig_target_smp
- irrig_threshold_fraction
- irrigate
- limit_irrigation_if_rof_enabled
- mksrf_firrig
- use_groundwater_irrigation

S. Swenson

Other Available Management Options

Soil Tillage



High & Low Intensity options

Residue Management



Option to set fraction of residue removal

5) Crop Yields

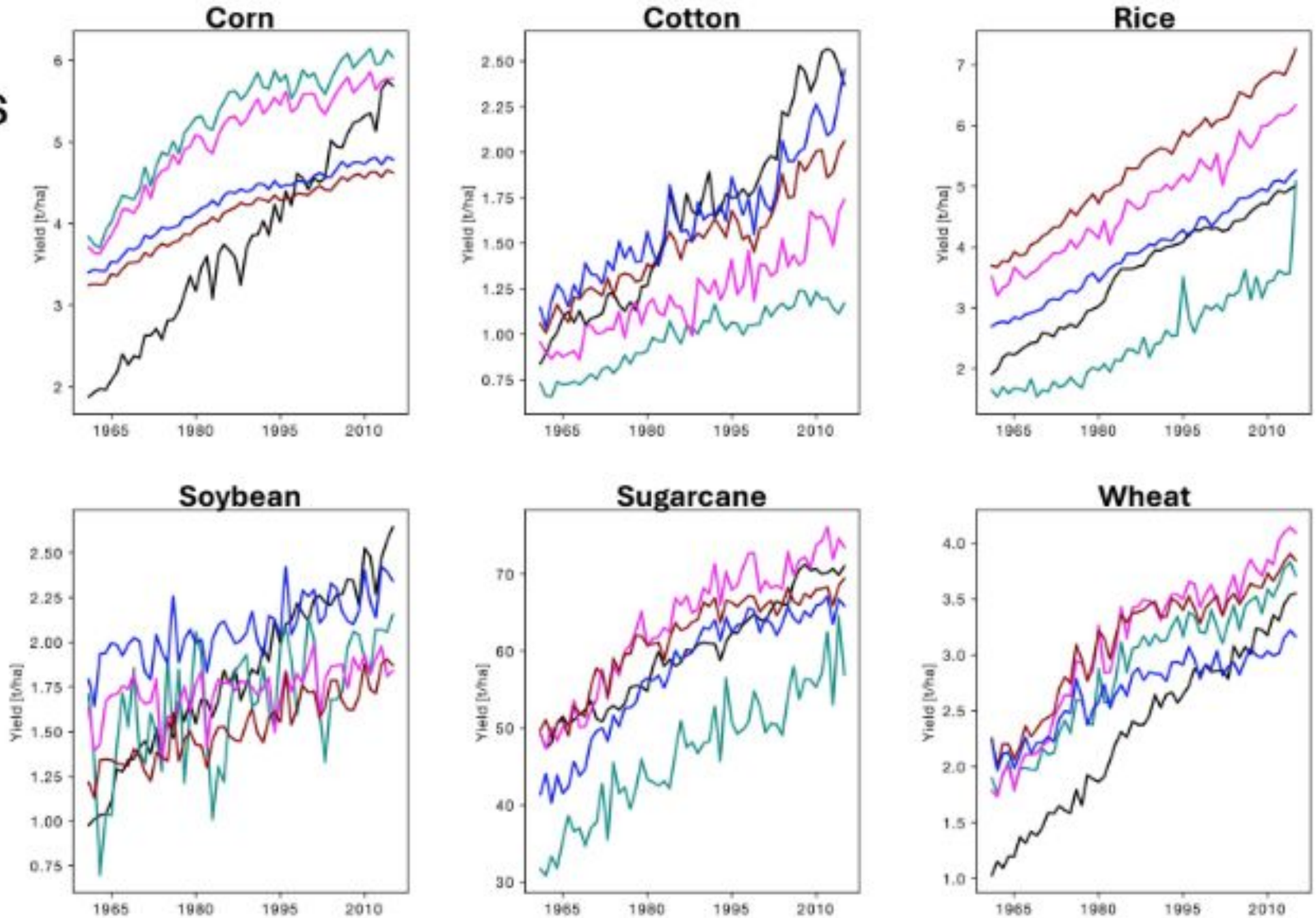
Updates to parameter values improve yields

Also, new atmospheric forcing & prescribed crop calendars

Yield: New params

- FAO-ES (obs.)
- Original
- + New cals
- + CRU-JRA
- + New params

All improved!



Slide courtesy of S. Rabin

Crop Model Features

1) Crop types and distributions
2) Crop phenology
3) Allocation in crops
4) Management options
5) Crop Yields

Questions?