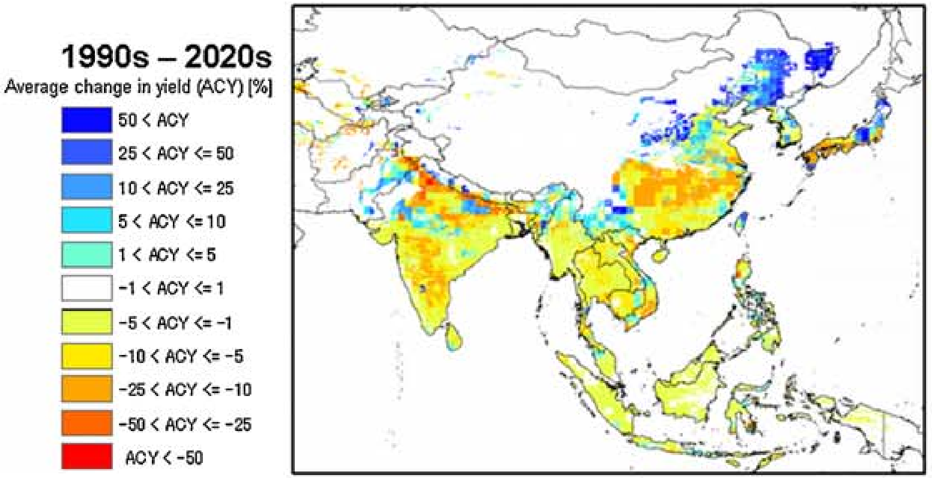
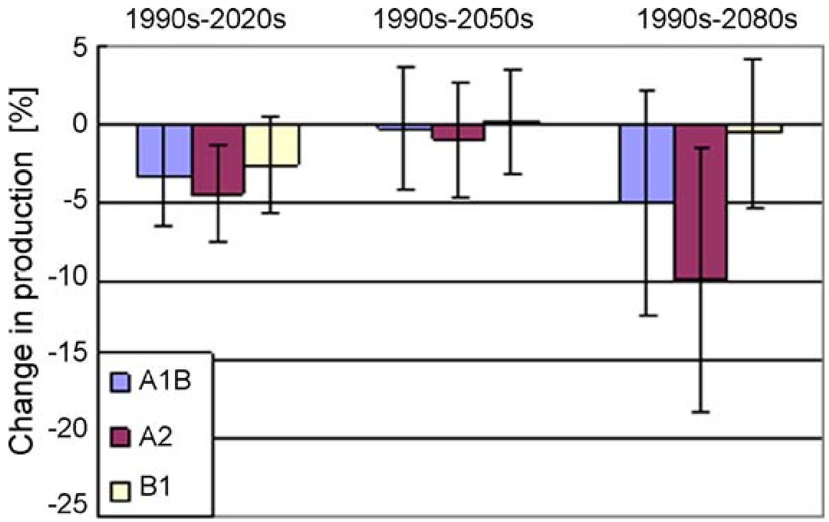
Development of a new type of crop model for impact assessment of global warming and air pollution (Ozone)

20th AIM WS@NIES
24 Jan. 2015

Yuji Masutomi
College of Agriculture, Ibaraki Univ.

Impact of global warming on rice productivity



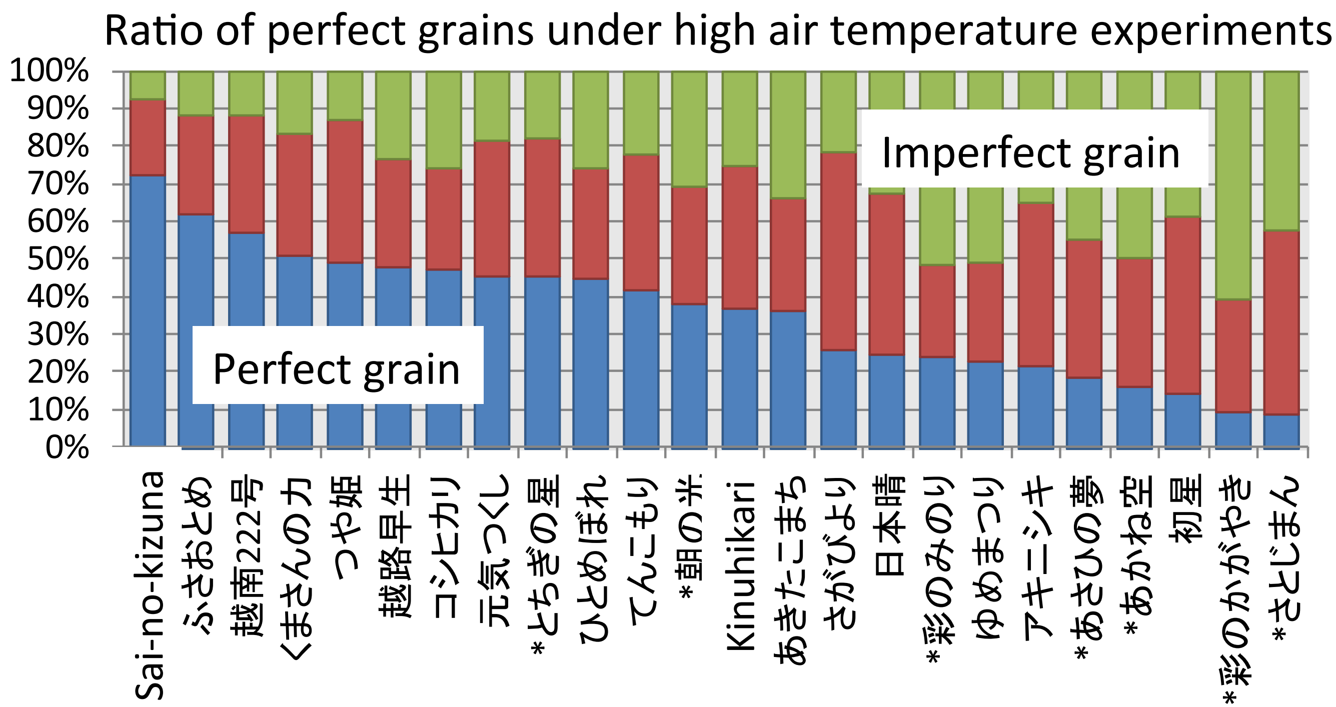


Masutomi et al. (2009)

Global warming will have significant impacts on rice productivity over Asia.

Next step is…

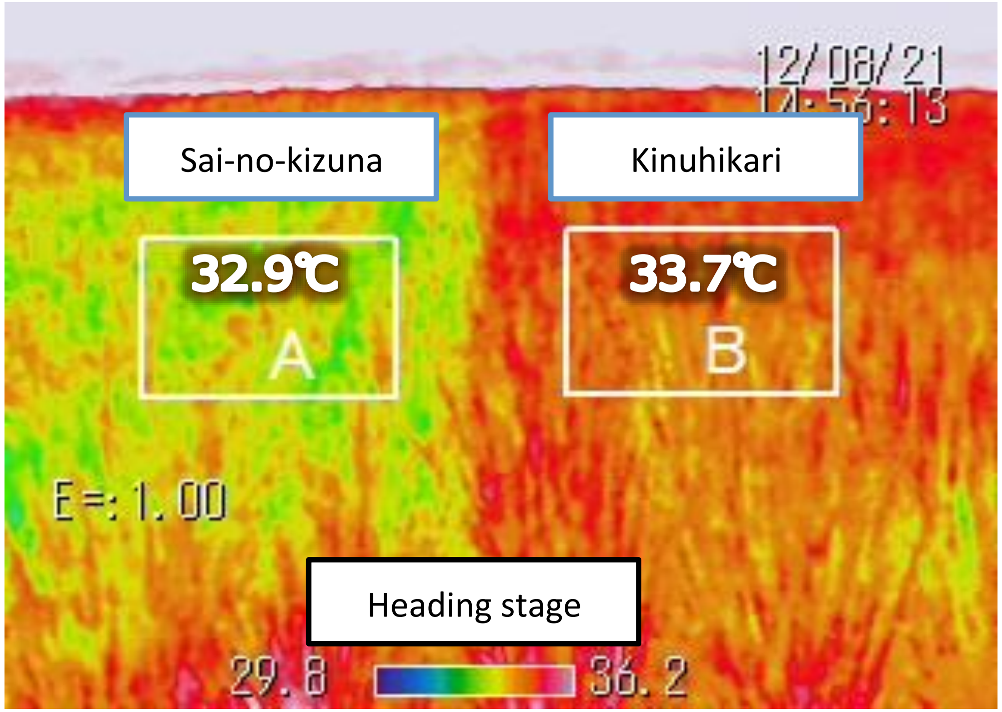
- How to adapt?
  - Local problem
    - We must consider local rice varieties.
    - Different rice varieties have different responses to high temperature.



Arakawa et al. (2014)

How to simulate the difference?

- Leaf temperature
  – is one of key factors for the different response



Arakawa et al. (2014)

Same conditions including weather, but different leaf temperature

How to simulate leaf temperature?

- Basically, temperature of any objects is determined by input and output of energy.

Leaf temperature can be simulated by energy balance of the crop.

Requirement #1

Energy balance is simulated
to determine leaf temperature

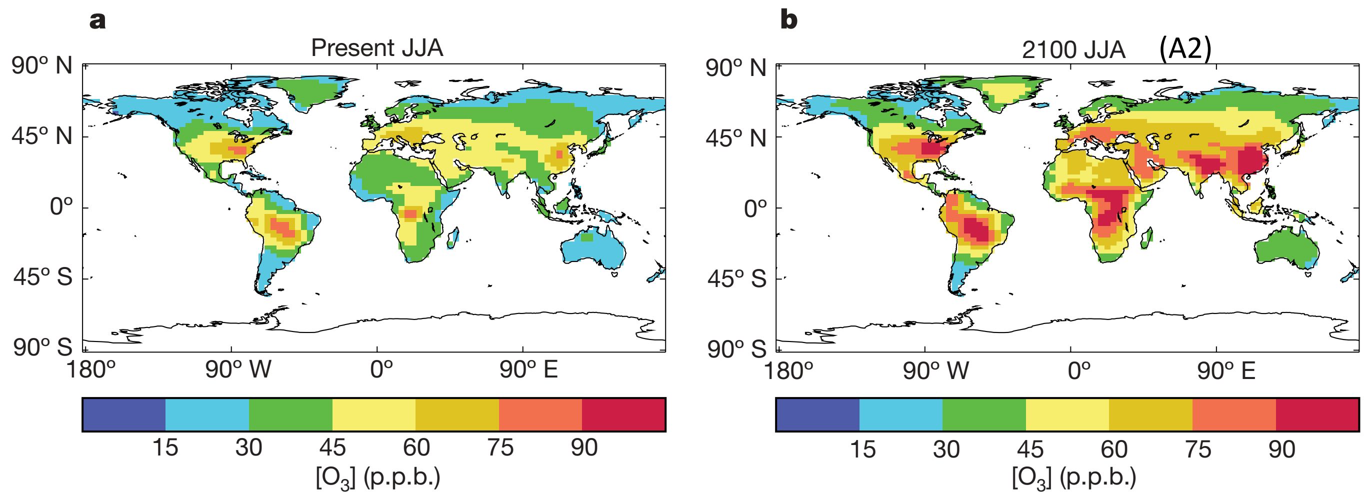
Impact of Ozone

2ppb << 36ppb

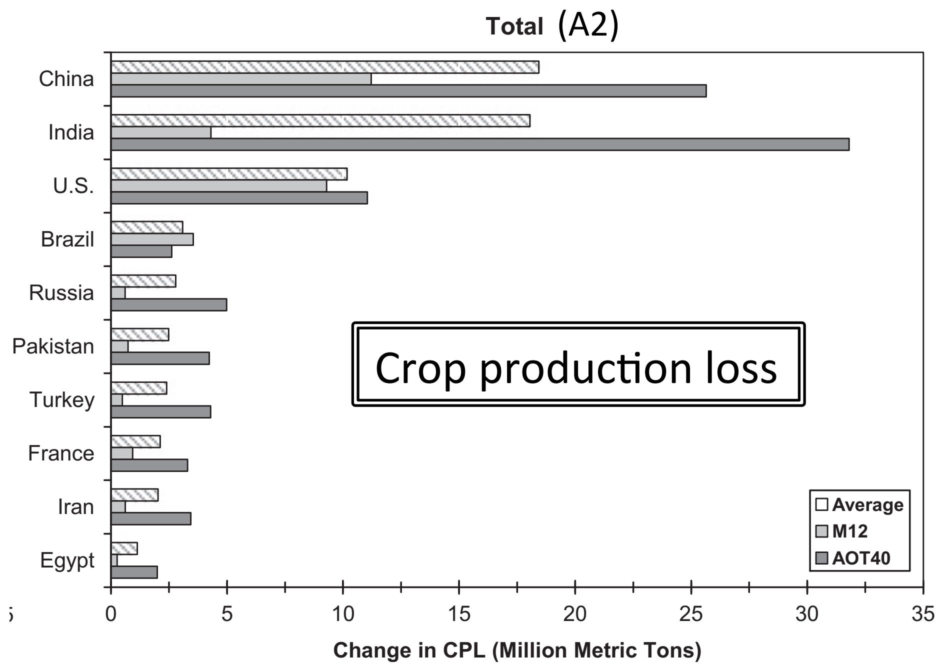
(Provided by Dr. Yonekura (CESS))

Ozone reduces crop productivity

Future impacts of Ozone



Sitch et al. (2007)



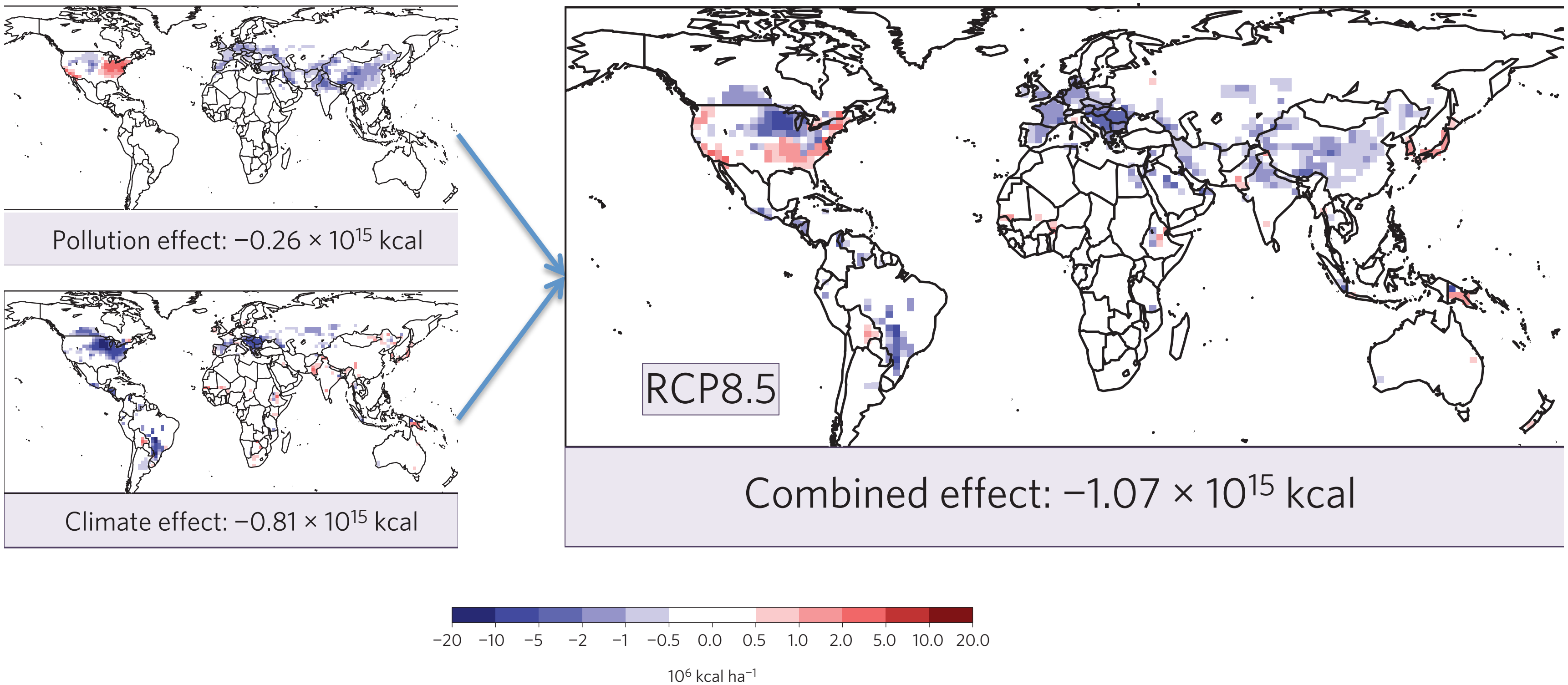
Avnery et al. (2011)

Combined effect of CC and Ozone

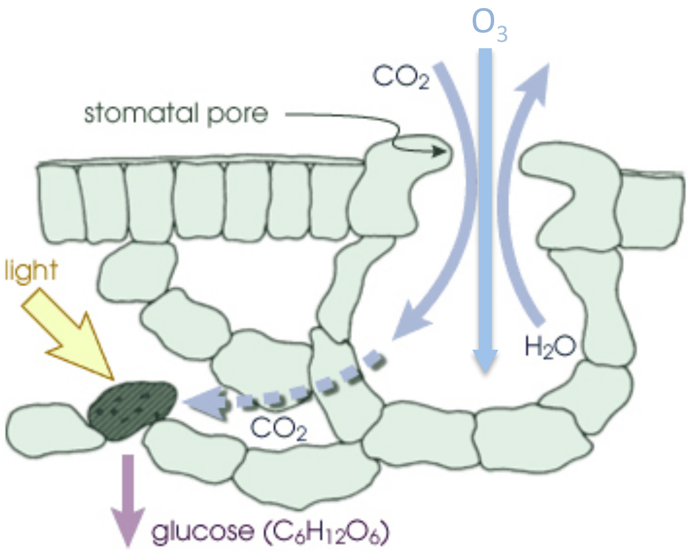
nature climate change
LETTERS
PUBLISHED ONLINE: 27 JULY 2014 | DOI: 10.1038/NCLIMATE2317

Threat to future global food security from climate change and ozone air pollution

Amos P. K. Tai[1*†], Maria Val Martin[2,3] and Colette L. Heald[1,4]



Crop physiological interaction



Both CO2 and O3 are taken up into leaf through stoma.

- High CO2 concentration tends to close stoma
  - O3 uptake will reduce → reduce ozone damage
- High O3 concentration tends to close stoma
  - CO2 uptake will reduce → reduce photosynthesis

What will happen under High CO2 and O3 concentration?

A stomatal response model should be included.

Requirement #2

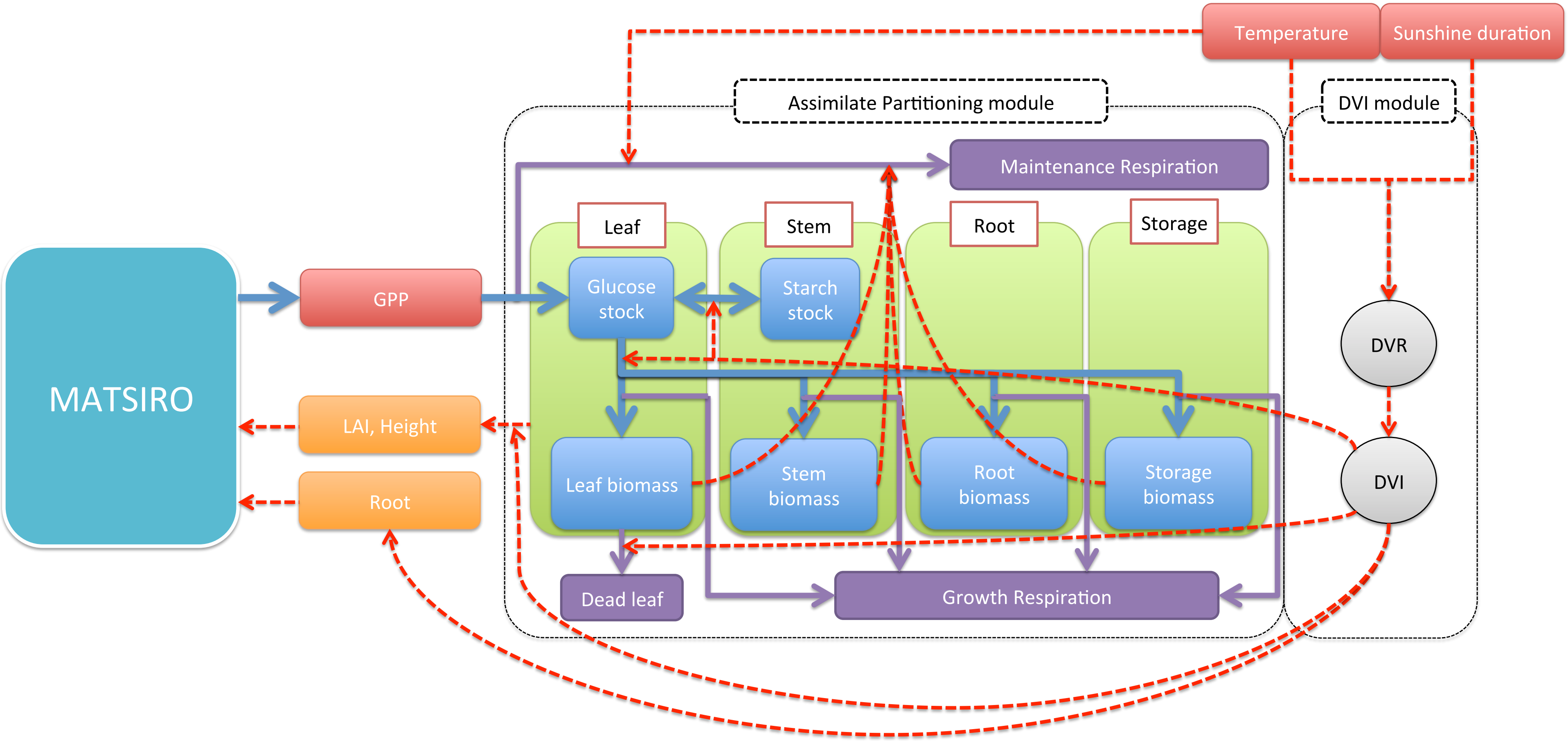
Stomatal response should be included

So, I am developing MATCRO…

- MATCRO has two components
  - Land surface model
    - Simulates heat and water fluxes (energy balance)
    - Includes a stomatal response model
    - is based on MATSIRO (Takata et al., 2003)
      - MATSIRO is a component of climate models
  - Crop model
    - Phenology and Partitioning models

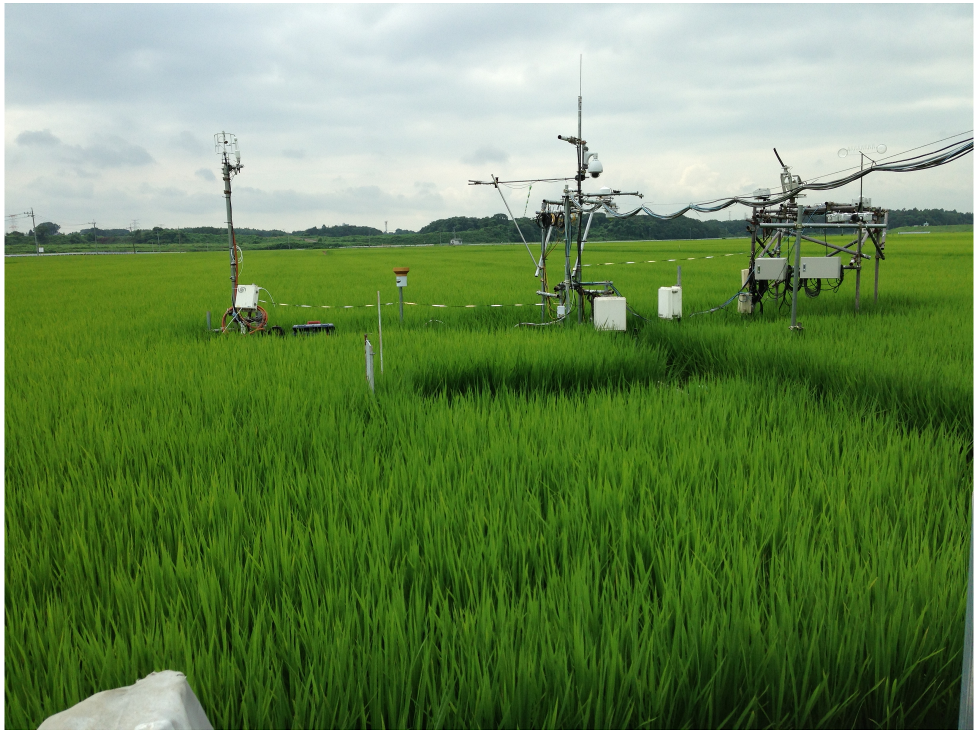
MATSIRO + Crop = MATCRO

Structure of MATCRO



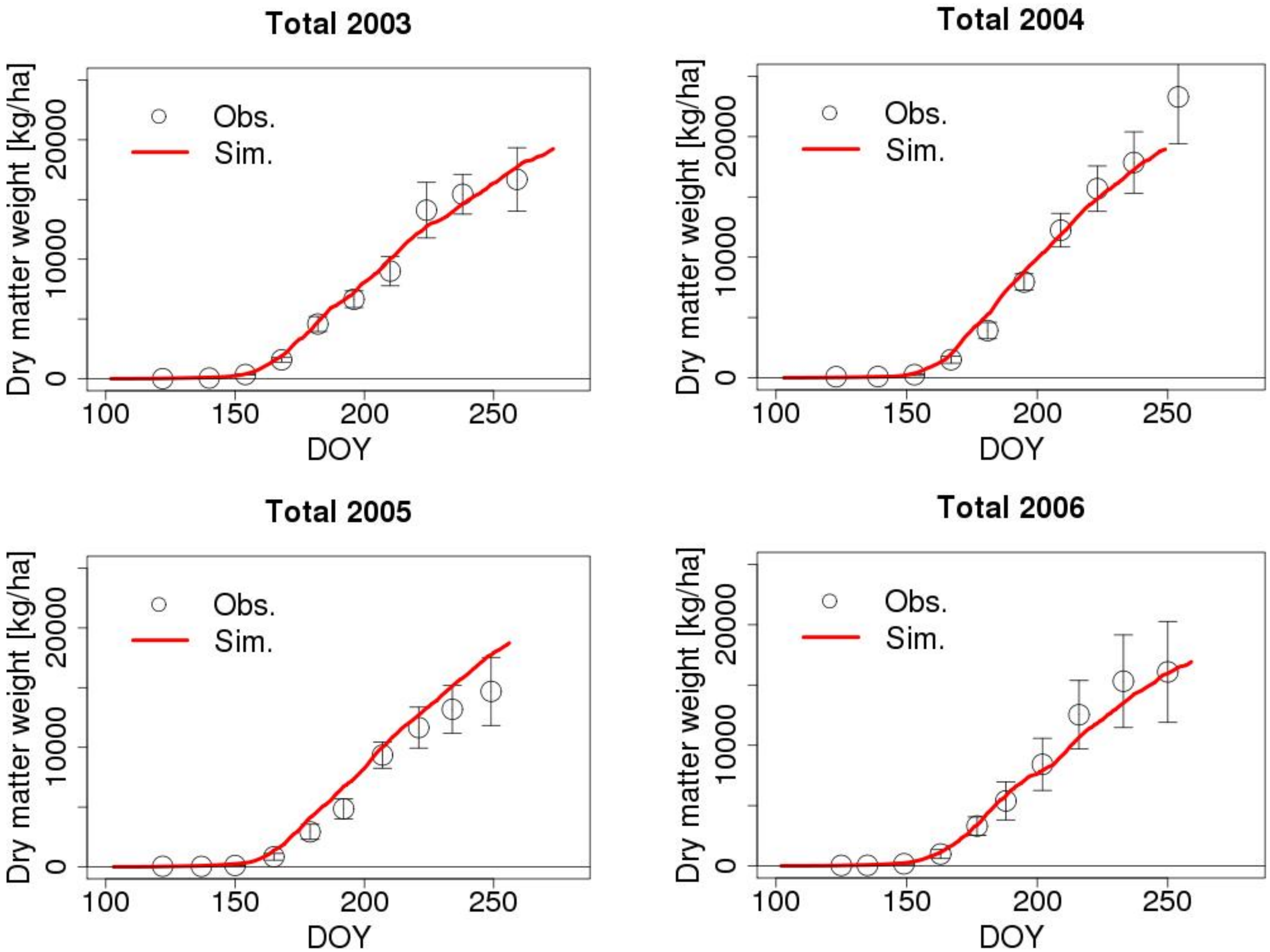
Simulation results

Model test site -Mase-

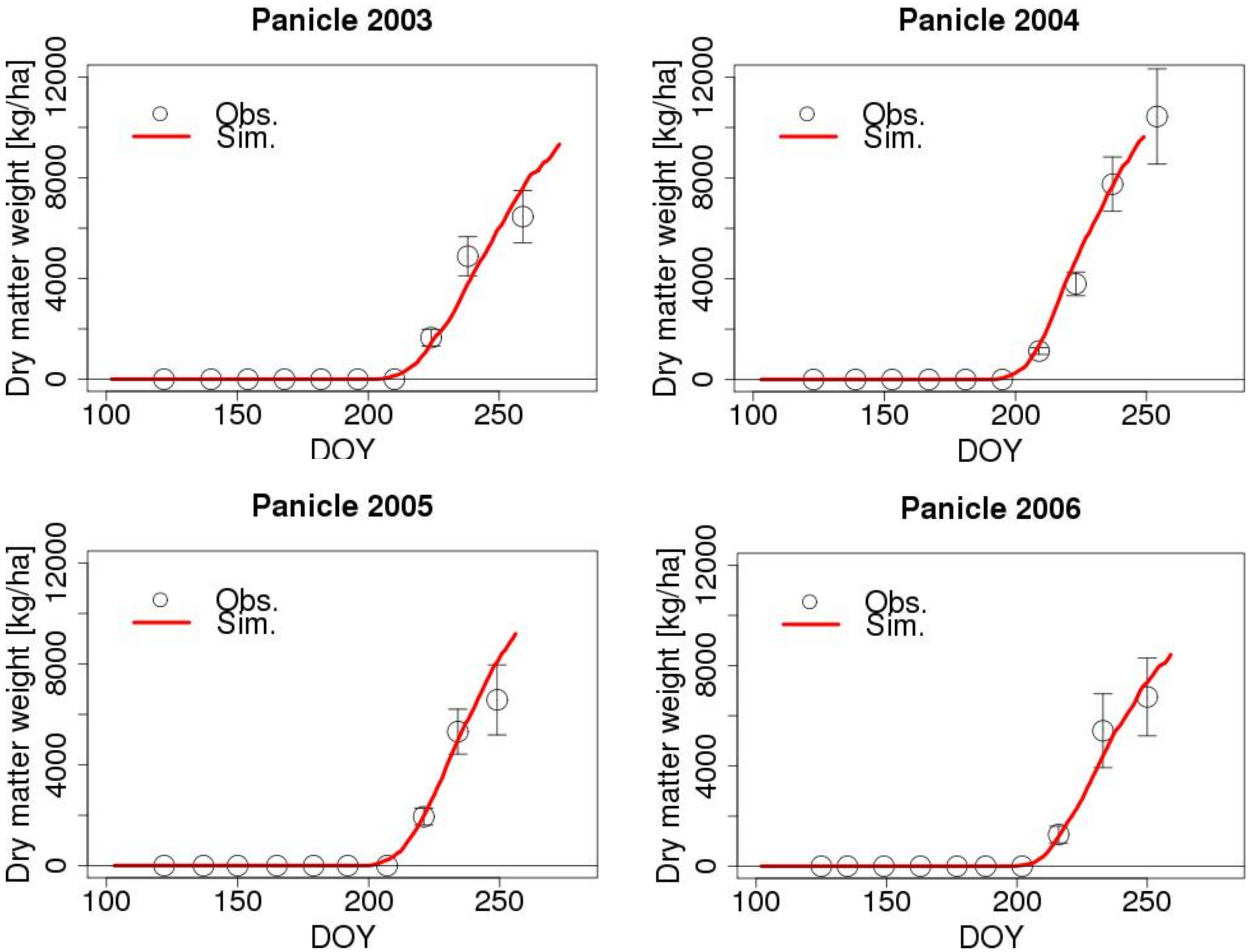


- Observation : climate variables, sensible and latent heat fluxes, CO_2 and CH_4 fluxes, biomass for each organ, LAI, etc..
- Variety: Koshihikari

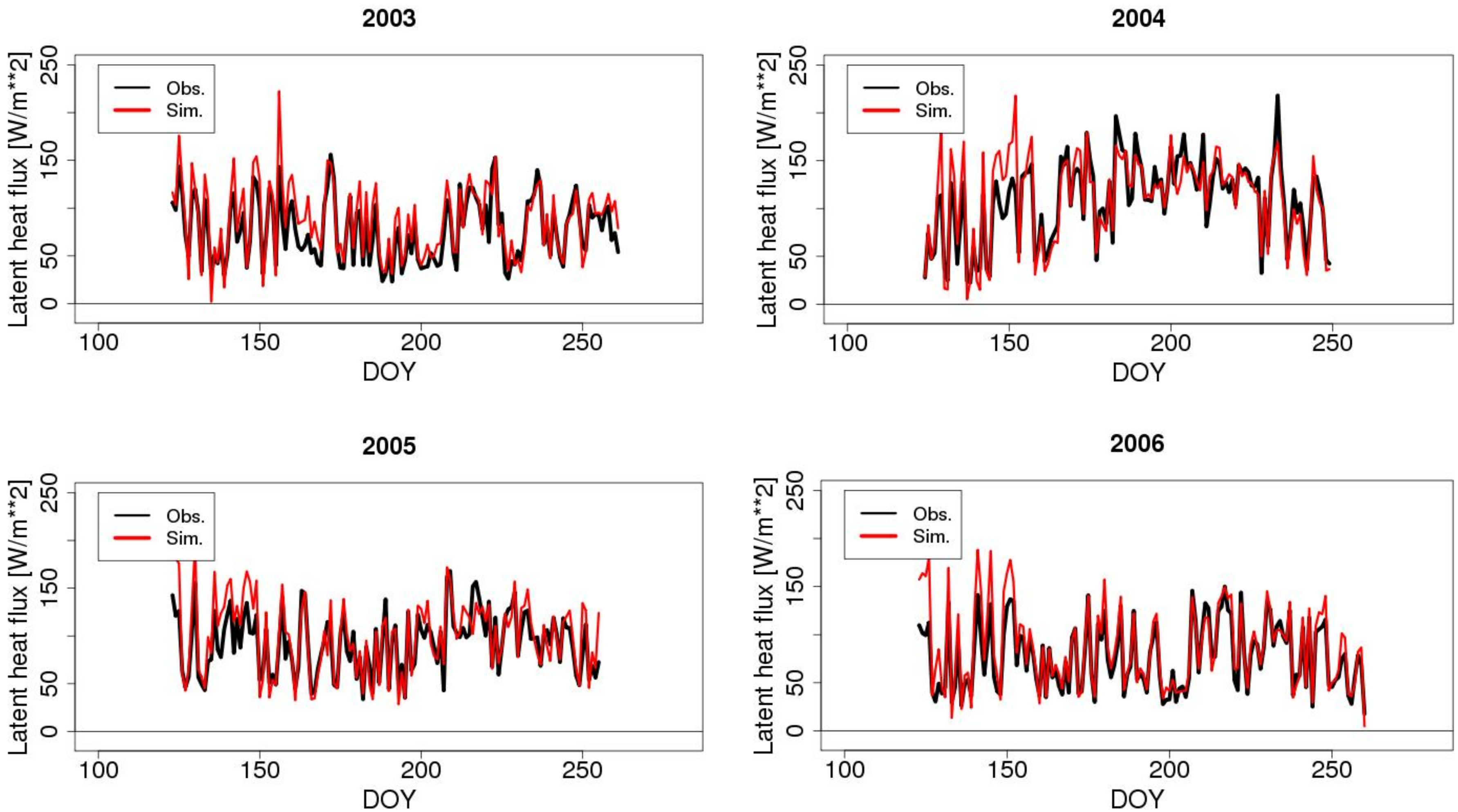
-Total Biomass-



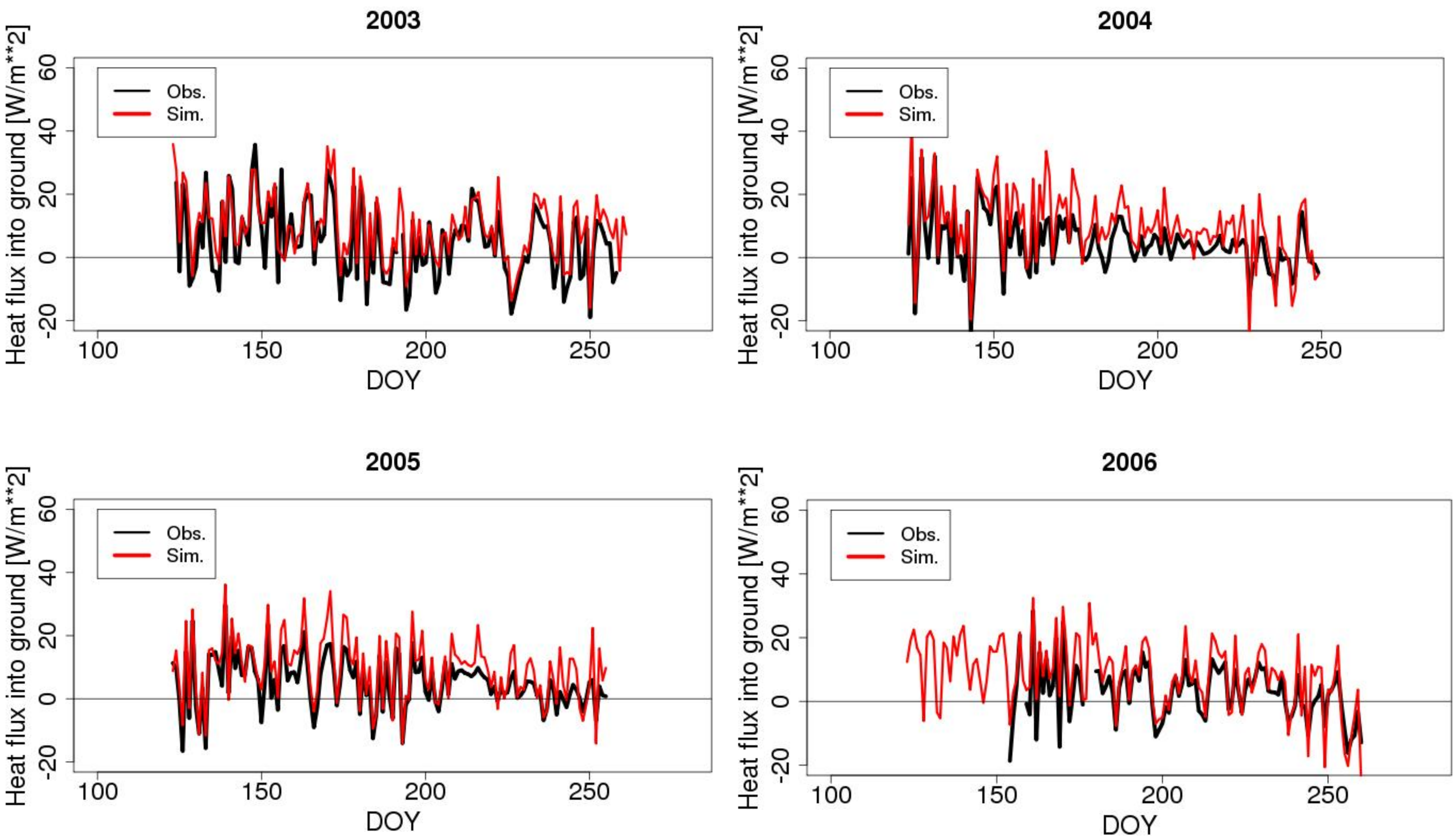
-Panicle (Yields) biomass-



-Latent heat flux-
(evaporation and transpiration)



Heat flux into ground



Summary

- A new type of crop model has been developed
  - MATCRO
    - is a LSM combined with a crop model
- MATCRO can reproduce well
  - Biomass
  - heat fluxes
    - Leaf temperature must be reproduced well

Challenges

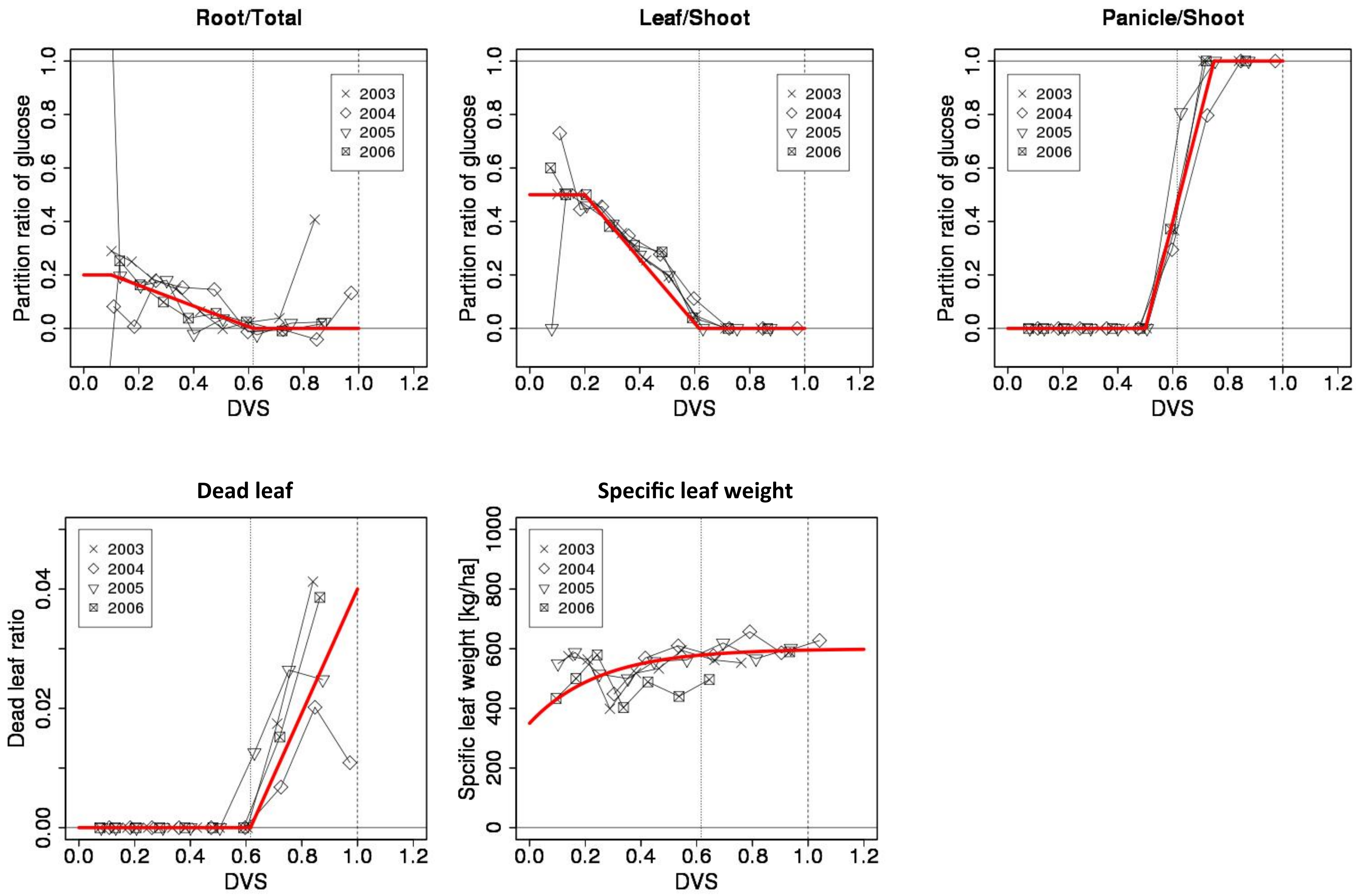
- Ozone response and interaction with CO_2

- Global application
  - Global parameterization
    - Phenology model and partitioning model

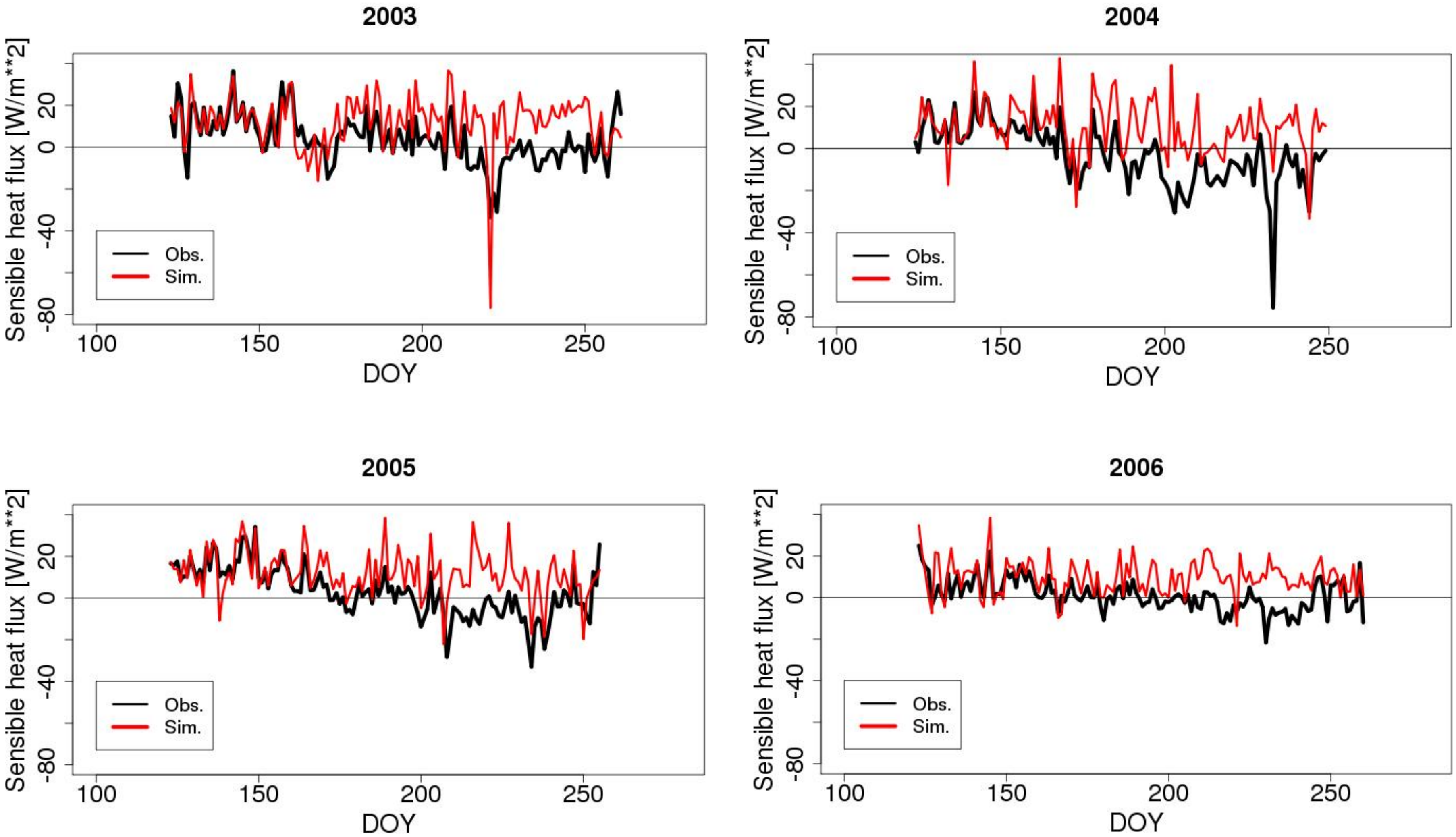
  - Nitrogen dynamics

Thank you for your attention!

Parameterization -Partitioning-



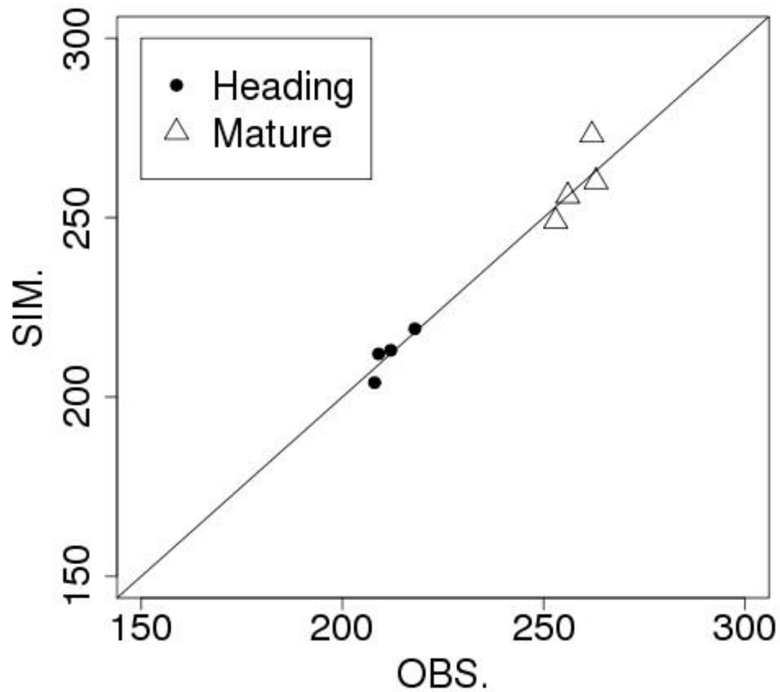
-Sensible heat flux-



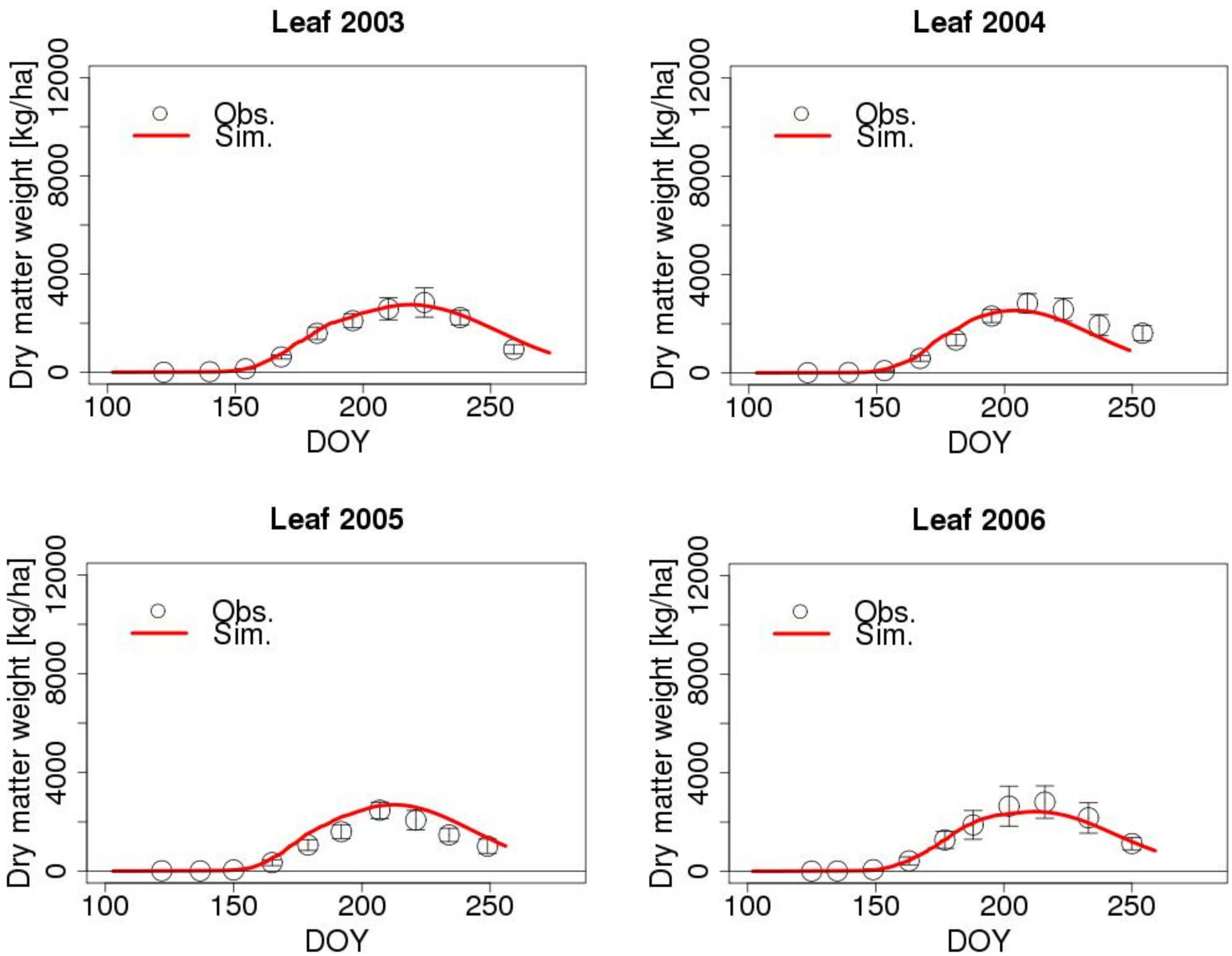
Parameterization

Parameterization I -Phenology-

- The method of Growing degree days(GDDs) is used.
  - GDDs are summation of air temperatures over growing periods



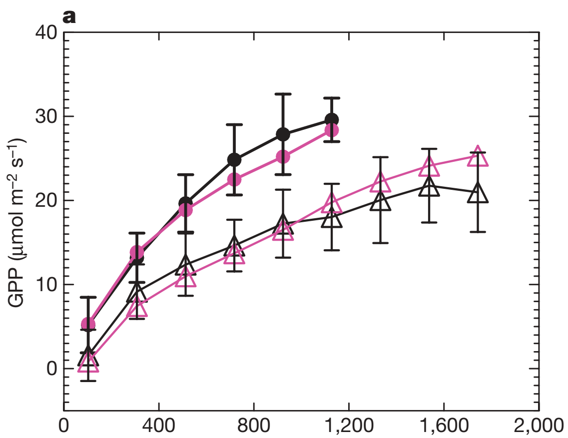
-Leaf biomass-



The impact of changes in diffuse radiation on crops

- Diffuse-radiation fertilization effect
  - Surface radiation has two components of Direct and Diffuse
  - Crops can use diffuse radiation more efficiently than direct radiation
  - Higher fraction of diffuse radiation increase crop productivity.

- High concentration of aerosols decrease total radiation but increase the fraction of diffuse radiation.



Diffuse

nature
Vol 458 | 23 April 2009 | **doi:10.1038/nature07949**

LETTERS

Impact of changes in diffuse radiation on the global land carbon sink

Lina M. Mercado[1], Nicolas Bellouin[2], Stephen Sitch[2], Olivier Boucher[2], Chris Huntingford[1], Martin Wild[3] & Peter M. Cox[4]