The impact of droughts on interannual variability in terrestrial carbon-13 discrimination

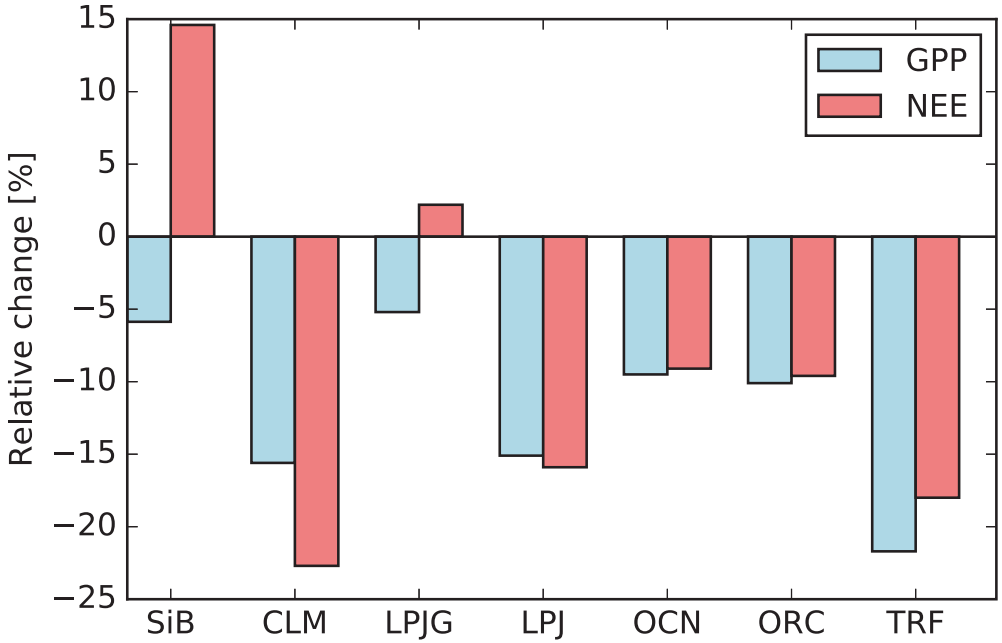
Erik van Schaik
Wageningen University and Research

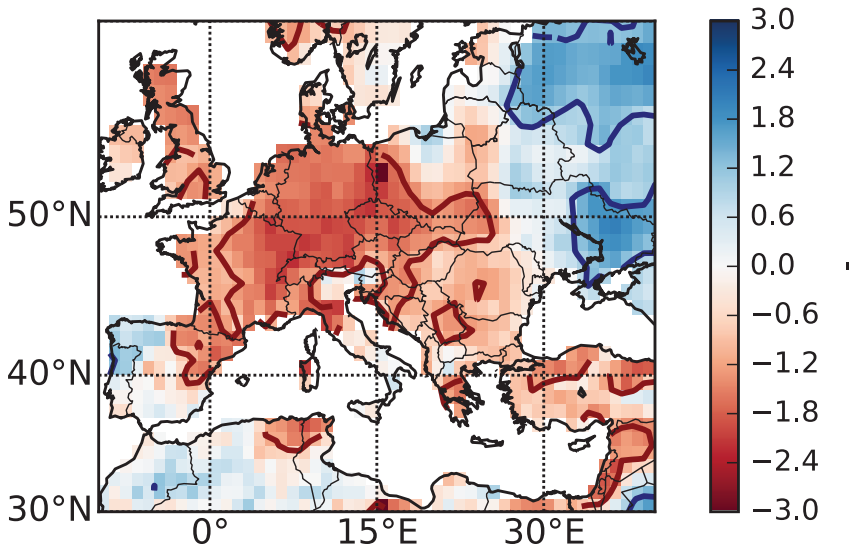
W. Peters, I. R. van der Velde, M. K. van der Molen, J. B. Miller, P. P. Tans, B. Vaughn, J. C. White, K. Schaefer

WAGENINGEN
UNIVERSITY & RESEARCH

ICOS
INTEGRATED CARBON OBSERVATION SYSTEM
SCIENCE CONFERENCE
HELSINKI 2016
27-29 SEPT

Model estimations of carbon fluxes during the European drought of 2003





TRENDY data from
Sitch et al., 2008

WAGENINGEN
UNIVERSITY & RESEARCH

Water – Vegetation coupling

Drought

$$iWUE = \frac{GPP}{g_s}$$

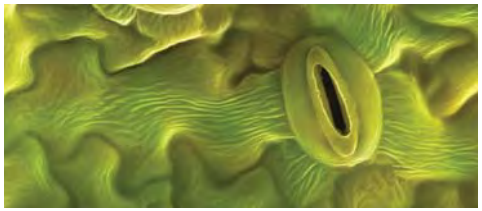
Vapour Pressure

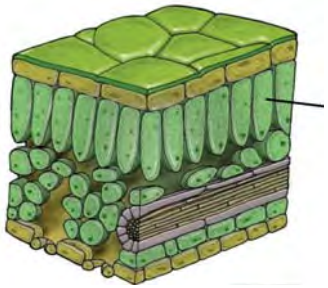
Soil moisture

Stomatal conductance

Biochemical capacity

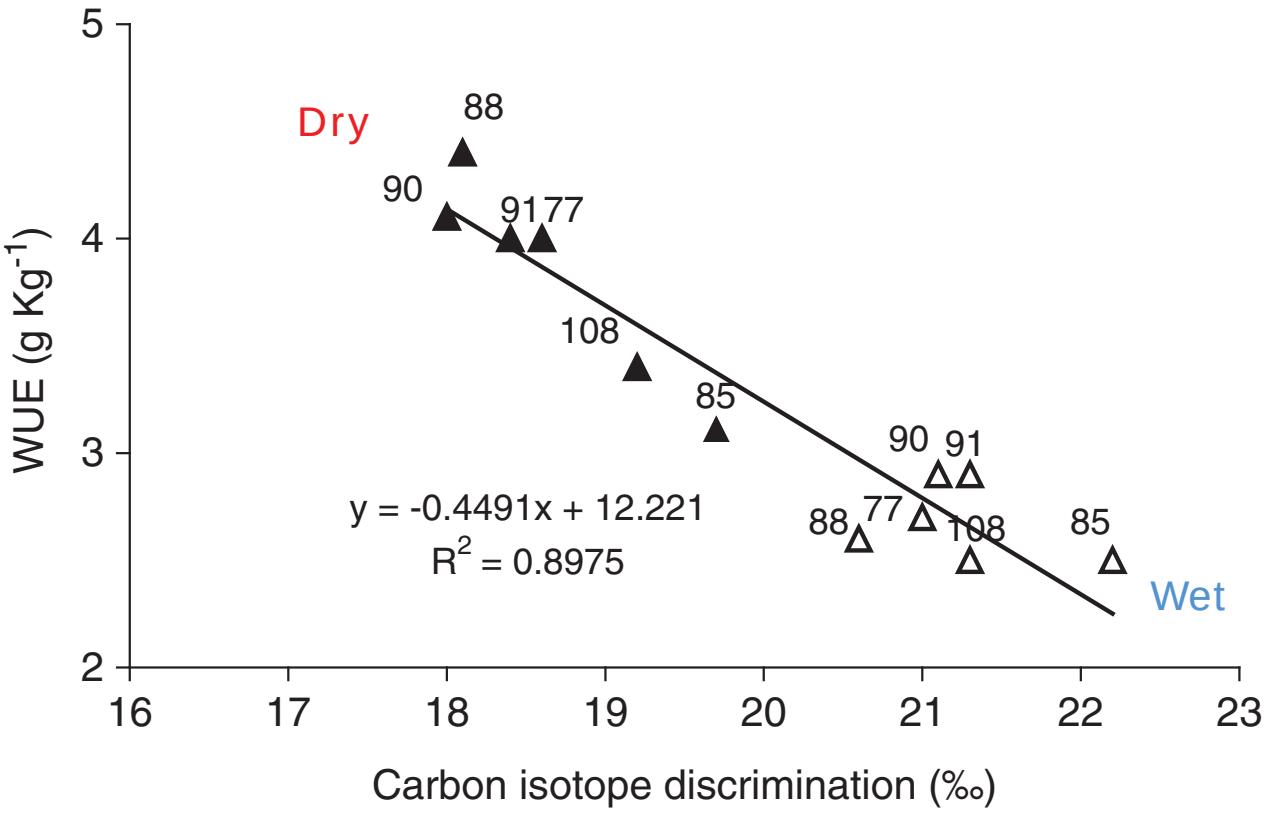
Mesophyllic conductance





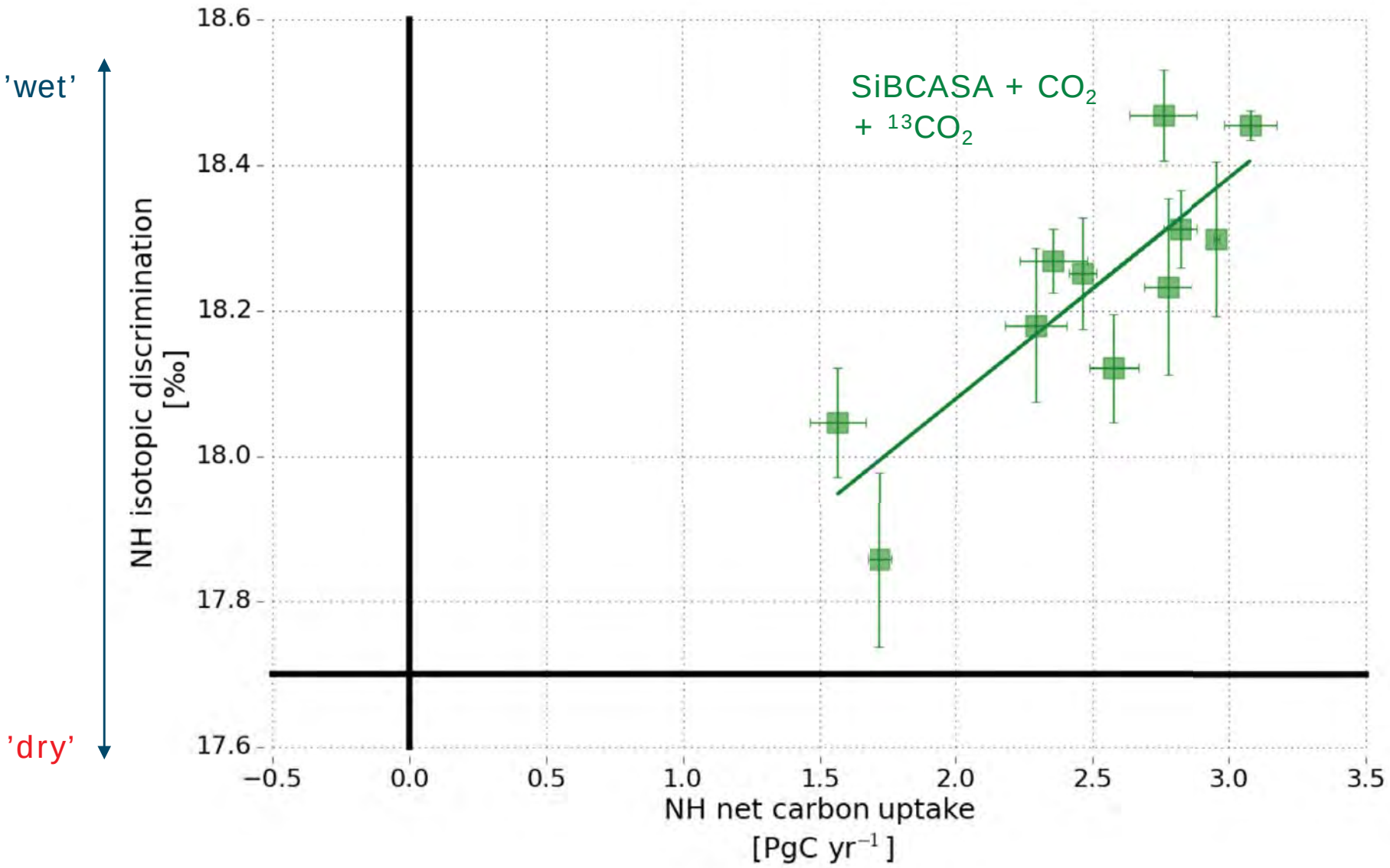
WAGENINGEN
UNIVERSITY & RESEARCH

Observed Water Use Efficiency (WUE)



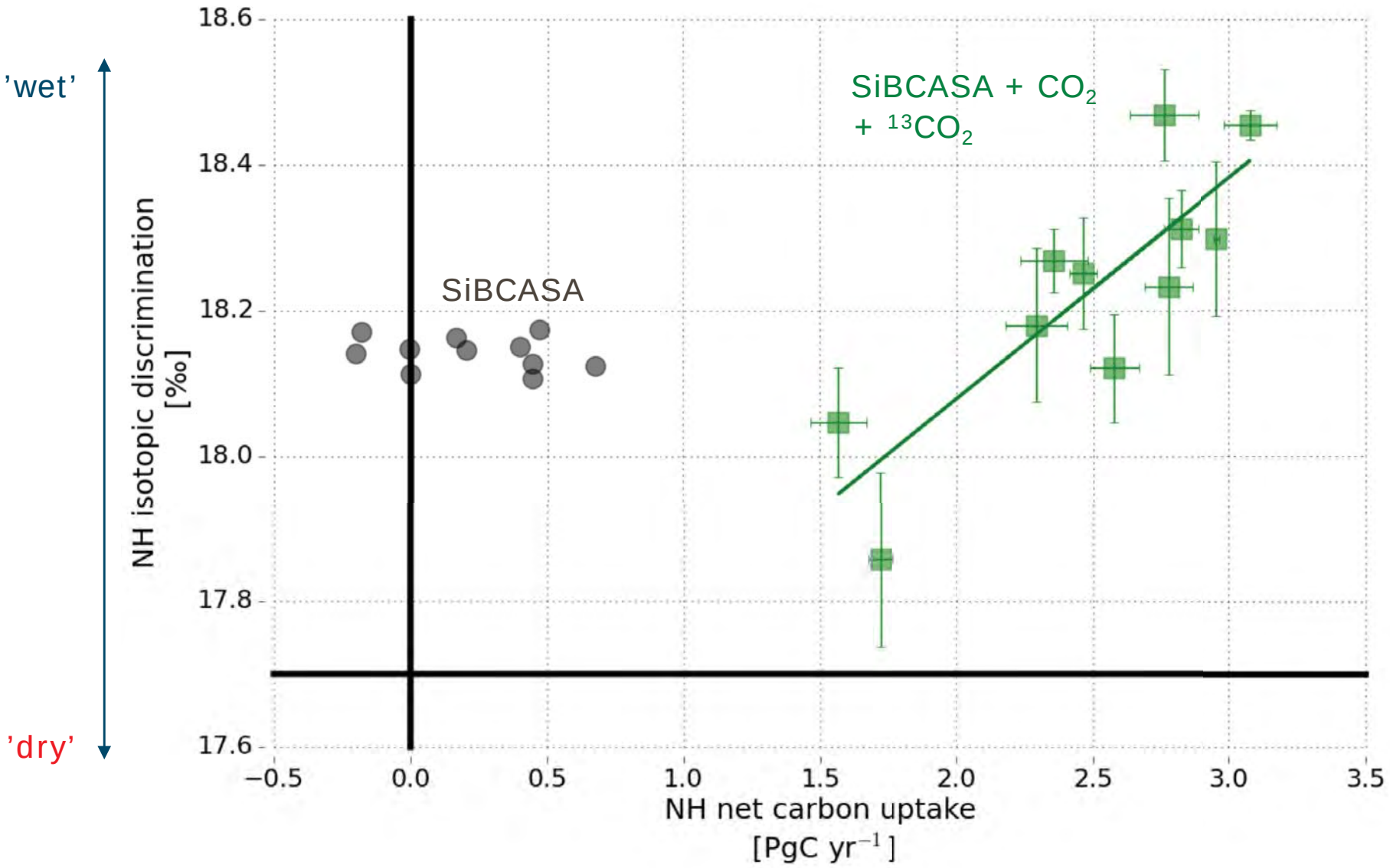
Anyia et al. (2007)

Variations in iWUE at the largest scale from $\delta^{13}C$



Van der Velde (2015)

Variations in iWUE at the largest scale from $\delta^{13}C$



Van der Velde (2015)

Water – Vegetation coupling

SiBCASA

Sellers et al., 1996
Baker et al., 2008

Drought

Vapour Pressure

Soil moisture

Stomatal conductance
g_s

Biochemical capacity
V_{max}, J_{max}

Mesophyllic conductance
g_m

Included

Not included

Water – Vegetation coupling

CLM / JULES ORCHIDEE VISIT

Oleson et al., 2010
Anav et al., 2015
Krinner et al., 2005
Ito and Oikawa, 2002

Drought

Vapour Pressure

Soil moisture

Stomatal conductance
g_s

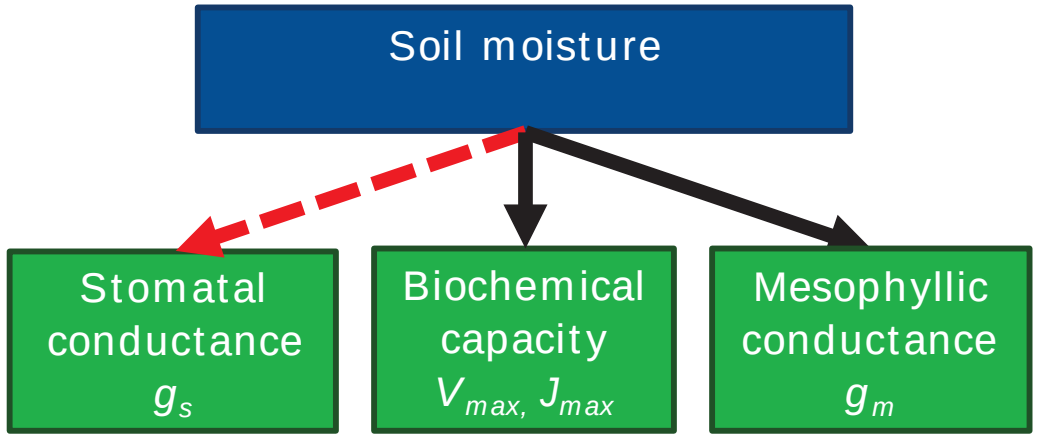
Biochemical capacity
V_{max}, J_{max}

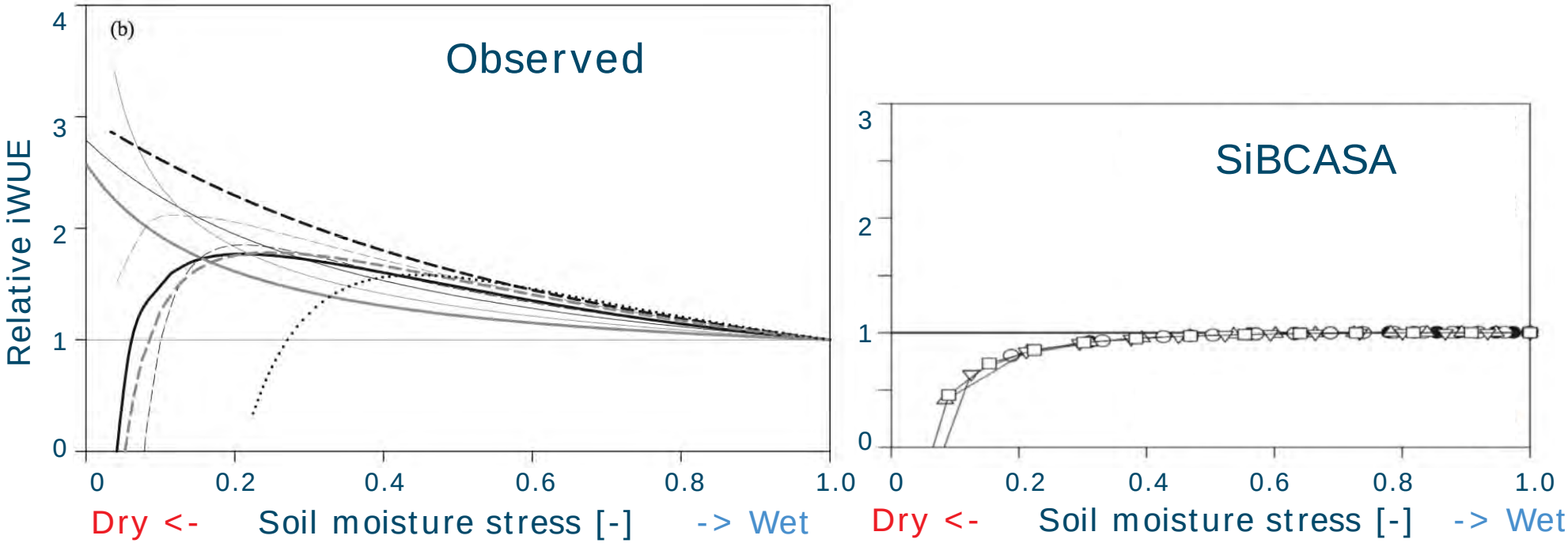
Mesophyllic conductance
g_m

Included
Not included

Moisture stress enhances WUE

- SiBCASA (and many other models) do not capture this response in iWUE.

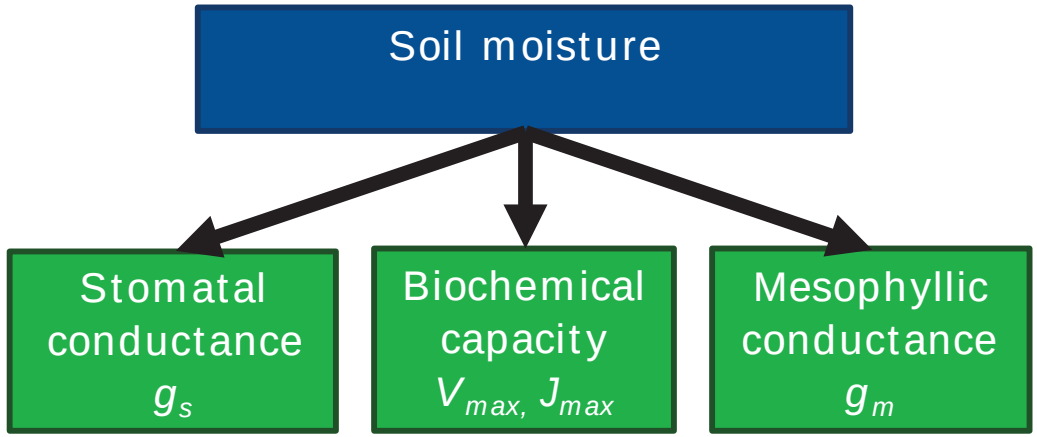


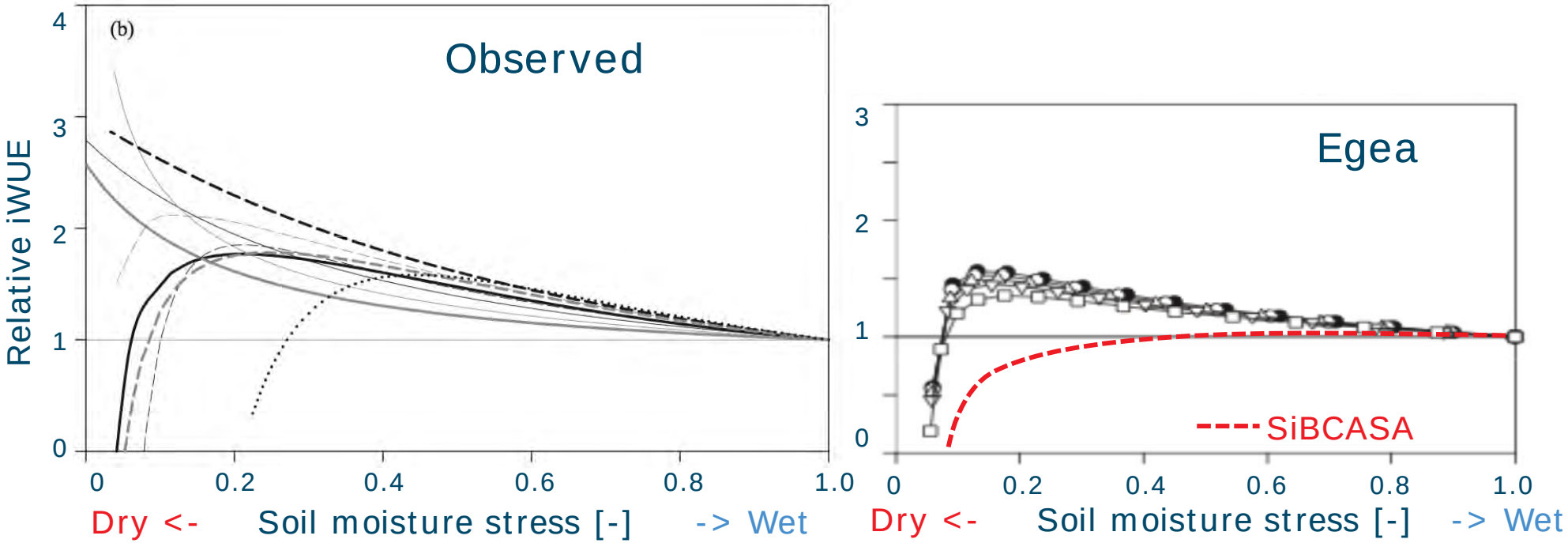


Egea et al. (2011)

Moisture stress enhances WUE

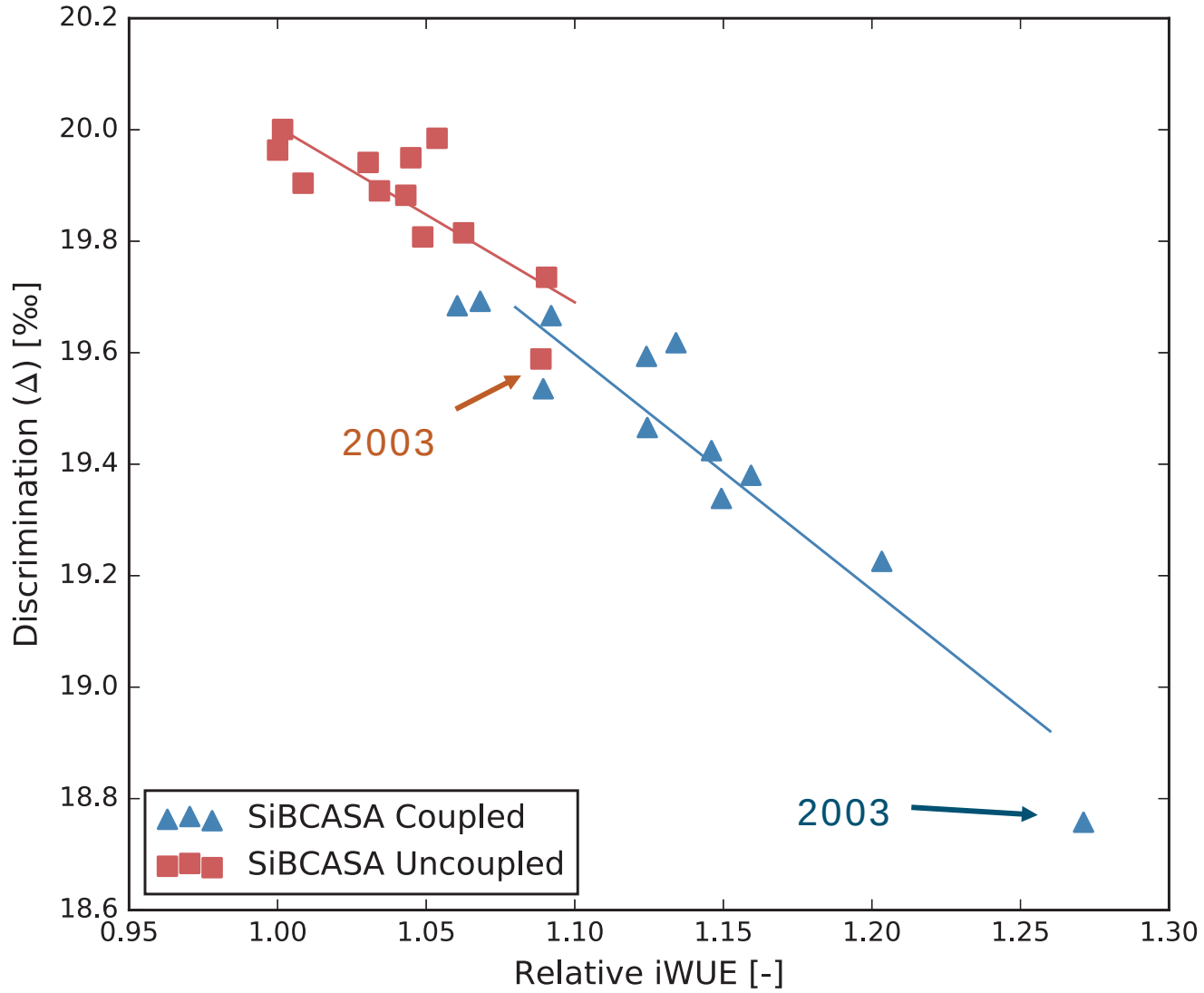
- Soil moisture needs to be explicitly coupled to all three processes



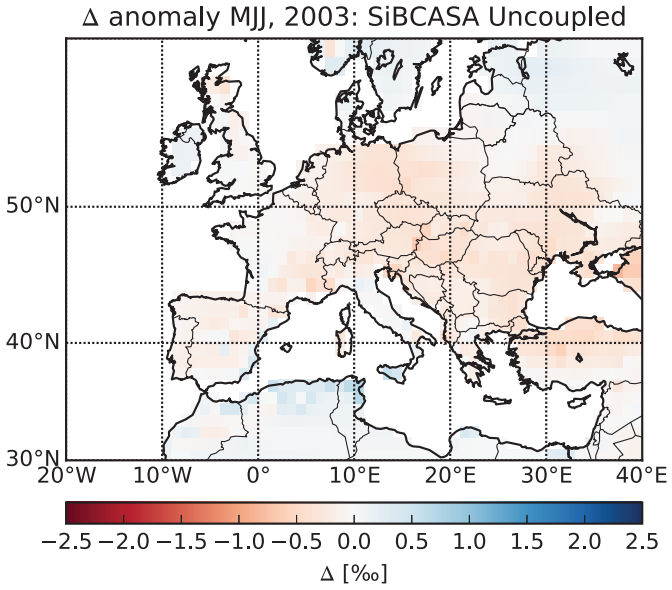


Egea et al. (2011)

WUE – Discrimination for Europe (2000-2011)



Discrimination during 2003 drought in Europe

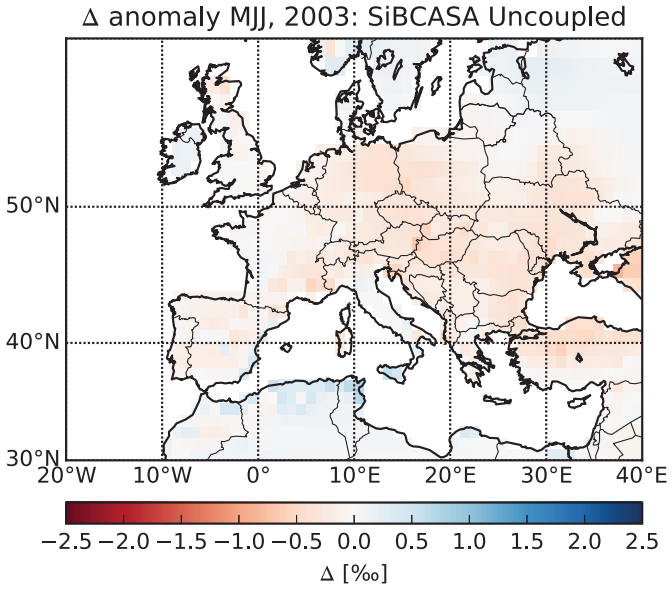


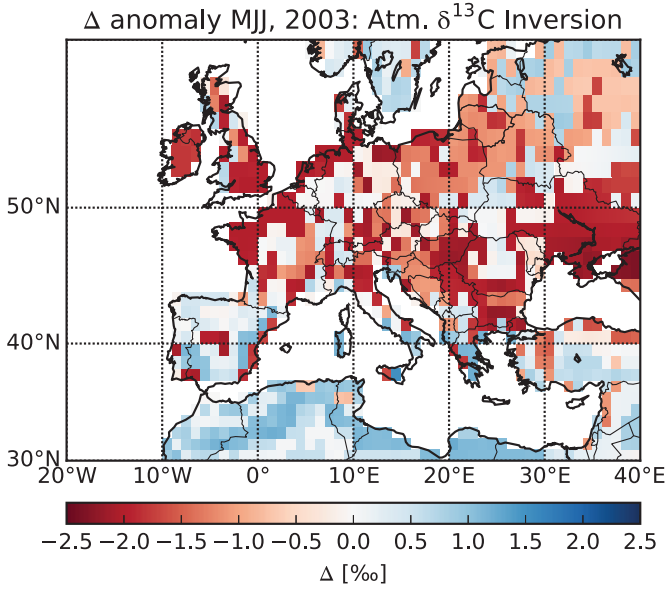
Months May-June-July

Δ anomaly : -0.21 ‰
NEE anomaly: 0.03 TgC

WAGENINGEN
UNIVERSITY & RESEARCH

Discrimination during 2003 drought in Europe





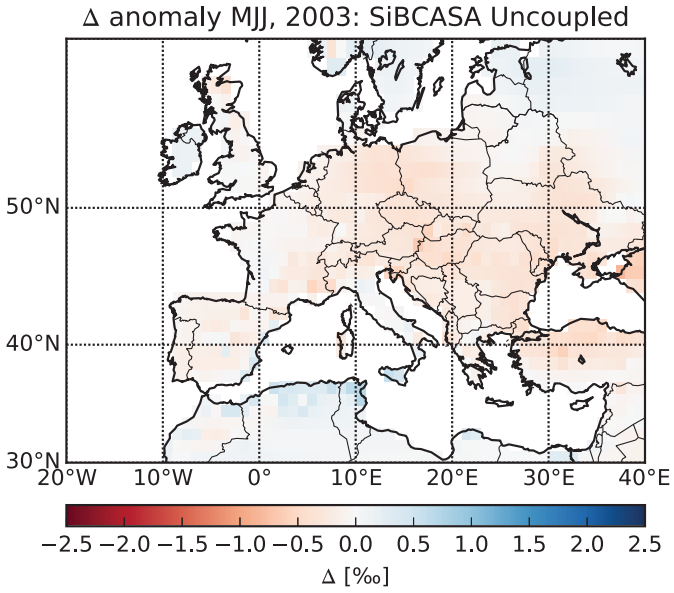
Months May-June-July

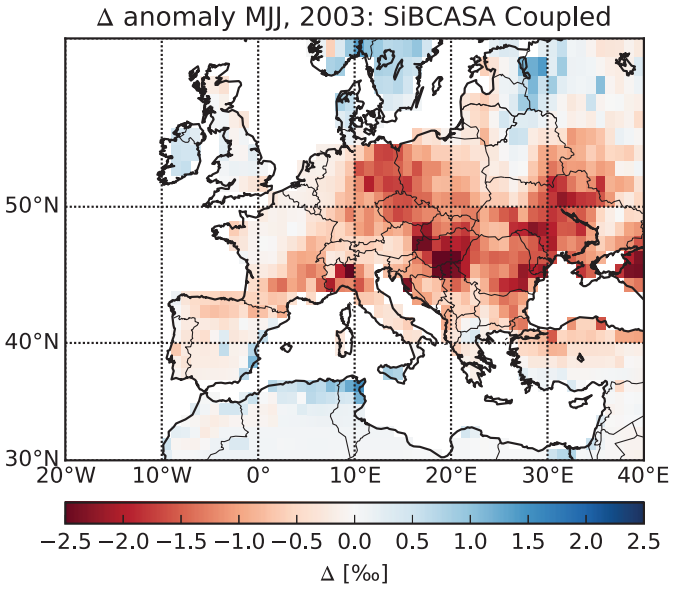
Δ anomaly : -0.21 ‰
NEE anomaly: 0.03 TgC

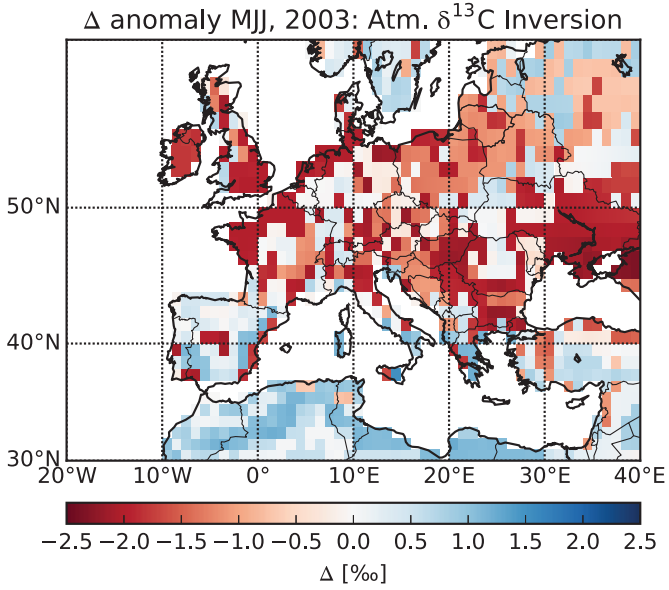
Δ anomaly : -1.04 ‰
NEE anomaly: -0.06 TgC

WAGENINGEN
UNIVERSITY & RESEARCH

Discrimination during 2003 drought in Europe







Months May-June-July

Δ anomaly : -0.21 ‰
NEE anomaly: 0.03 TgC

Δ anomaly : -0.94 ‰
NEE anomaly: -0.24 TgC

Δ anomaly : -1.04 ‰
NEE anomaly: -0.06 TgC

WAGENINGEN
UNIVERSITY & RESEARCH

Summary

- Measurements of atmospheric $\delta^{13}C$ can provide unique insight in plant functioning on regional to continental scales
- Many biosphere models are not able to simulate changes in iWUE under water-stressed conditions.
- iWUE can be a valuable metric to assess the performance of biosphere models.

References

- Anav, Alessandro, Pierre Friedlingstein, Christian Beer, Philippe Ciais, Anna Harper, Chris Jones, Guillermo Murray-Tortarolo, et al. 2015. "Spatiotemporal Patterns of Terrestrial Gross Primary Production: A Review: GPP Spatiotemporal Patterns." Reviews of Geophysics 53 (3): 785–818. doi:10.1002/2015RG000483.
- Anyia, A. O., J. J Slaski, J. M. Nyachiro, D. J. Archambault, and P. Juskiw. 2007. "Relationship of Carbon Isotope Discrimination to Water Use Efficiency and Productivity of Barley Under Field and Greenhouse Conditions." *Journal of Agronomy and Crop Science* 193 (5): 313–23. doi:10.1111/j.1439-037X.2007.00274.x.
- Baker, I. T., L. Prihodko, A. S. Denning, M. Goulden, S. Miller, and H. R. da Rocha. 2008. "Seasonal Drought Stress in the Amazon: Reconciling Models and Observations." Journal of Geophysical Research 113 (July). doi:10.1029/2007JG000644.
- Egea, Gregorio, Anne Verhoef, and Pier Luigi Vidale. 2011. "Towards an Improved and More Flexible Representation of Water Stress in Coupled Photosynthesis–stomatal Conductance Models." Agricultural and Forest Meteorology 151 (10): 1370–84. doi:10.1016/j.agrformet.2011.05.019.
- Ito, Akihiko, and Takehisa Oikawa. 2002. "A Simulation Model of the Carbon Cycle in Land Ecosystems (Sim-CYCLE): A Description Based on Dry-Matter Production Theory and Plot-Scale Validation." Ecological Modelling 151 (2-3): 143–76. doi:10.1016/S0304-3800(01)00473-2.
- Krinner, G., Nicolas Viovy, Nathalie de Noblet-Ducoudré, Jérôme Ogée, Jan Polcher, Pierre Friedlingstein, Philippe Ciais, Stephen Sitch, and I. Colin Prentice. 2005. "A Dynamic Global Vegetation Model for Studies of the Coupled Atmosphere-Biosphere System: DVGM FOR COUPLED CLIMATE STUDIES." *Global Biogeochemical Cycles* 19 (1). doi:10.1029/2003GB002199.
- Oleson, Keith, David Lawrence, Gordon Bonan, Mark Flanner, Erik Kluzek, Peter Lawrence, Samuel Levis, et al. 2010. "Technical Description of Version 4.0 of the Community Land Model (CLM)." doi:10.5065/D6FB50WZ.
- Sellers, P.J., D.A. Randall, G.J. Collatz, J.A. Berry, C.B. Field, D.A. Dazlich, C. Zhang, G.D. Collelo, and L. Bounoua. 1996. "A Revised Land Surface Parameterization (SiB2) for Atmospheric GCMS. Part I: Model Formulation." Journal of Climate 9 (4): 676–705. doi:10.1175/1520-0442(1996)009<0676:ARLSPF>2.0.CO;2.
- Sitch, S., C. Huntingford, N. Gedney, P. E. Levy, M. Lomas, S. L. Piao, R. Betts, et al. 2008. "Evaluation of the Terrestrial Carbon Cycle, Future Plant Geography and Climate-Carbon Cycle Feedbacks Using Five Dynamic Global Vegetation Models (DGVMs)." *Global Change Biology* 14 (9): 2015–39. doi:10.1111/j.1365-2486.2008.01626.x.
- van der Molen, M. K., R. A. M. de Jeu, W. Wagner, I. R. van der Velde, P. Kolari, J. Kurbatova, A. Varlagin, et al. 2015. "The Effect of Assimilating Satellite Derived Soil Moisture in SiBCASA on Simulated Carbon Fluxes in Boreal Eurasia." Hydrology and Earth System Sciences Discussions 12 (9): 9003–54. doi:10.5194/hessd-12-9003-2015.
- van der Velde, I. R. 2015. Studying Biosphere-Atmosphere Exchange of CO2 through Carbon-13 Stable Isotopes. Wageningen: Wageningen University.