June 2008

Remote Sensing Data Assimilation for a Prognostic Phenology Model

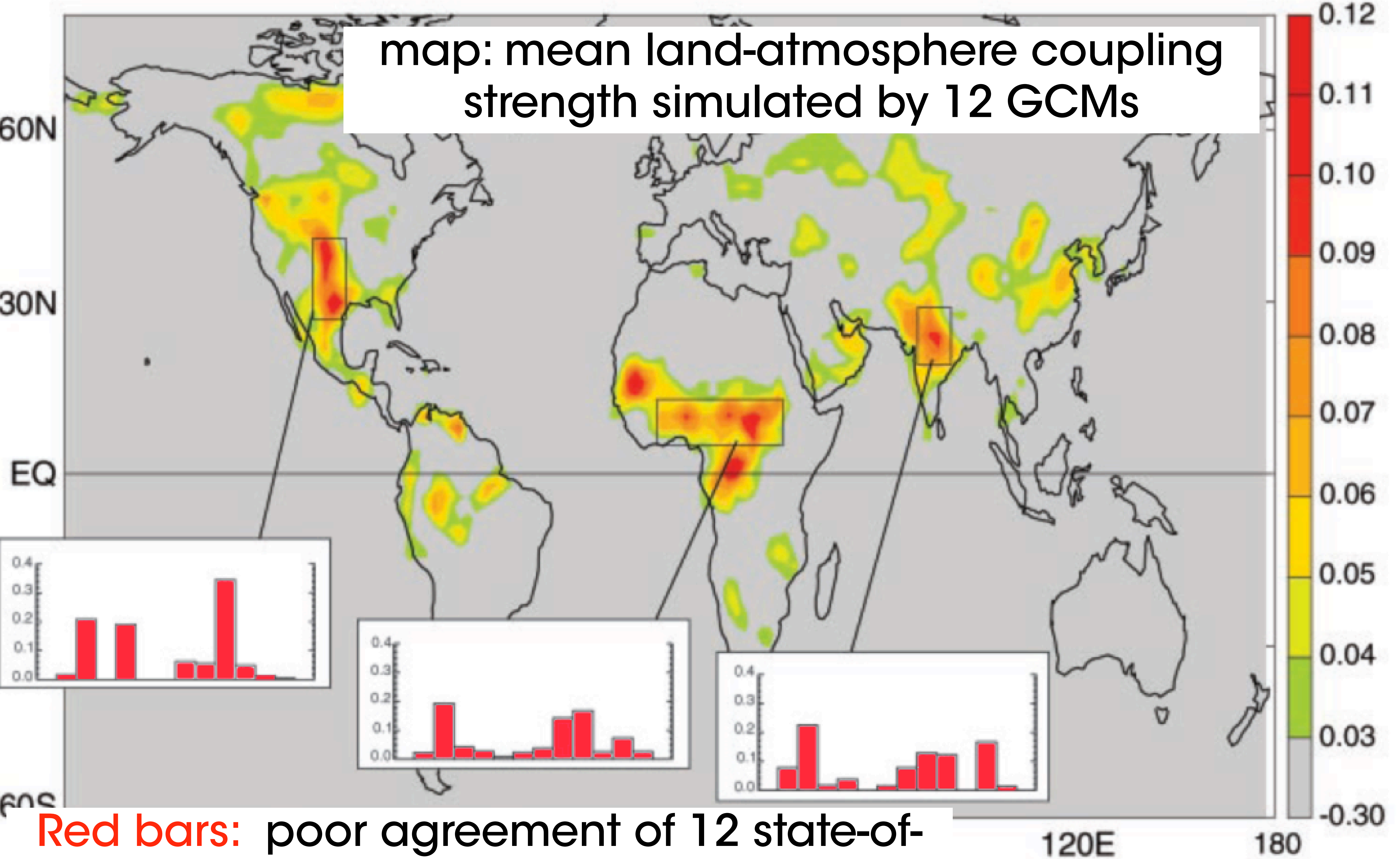
How to define global-scale empirical parameters?

Reto Stöckli[1,2] (stockli@atmos.colostate.edu)
Lixin Lu[1], Scott Denning[1] and Peter Thornton[3]
[1]Dept. of Atmospheric Science (CSU Fort Collins CO, USA)
[2]Climate Services (MeteoSwiss Zurich, Switzerland)
[3]Terrestrial Sciences Section (NCAR Boulder CO, USA)

Colorado State University
Knowledge to Go Places

NASA NEWS (NASA Energy and Water Cycle Study), Grant NNG06CG42G

Uncertainties in land - climate interactions



Red bars: poor agreement of 12 state-of-the-art GCMs for three key regions

Koster et al. (2004)

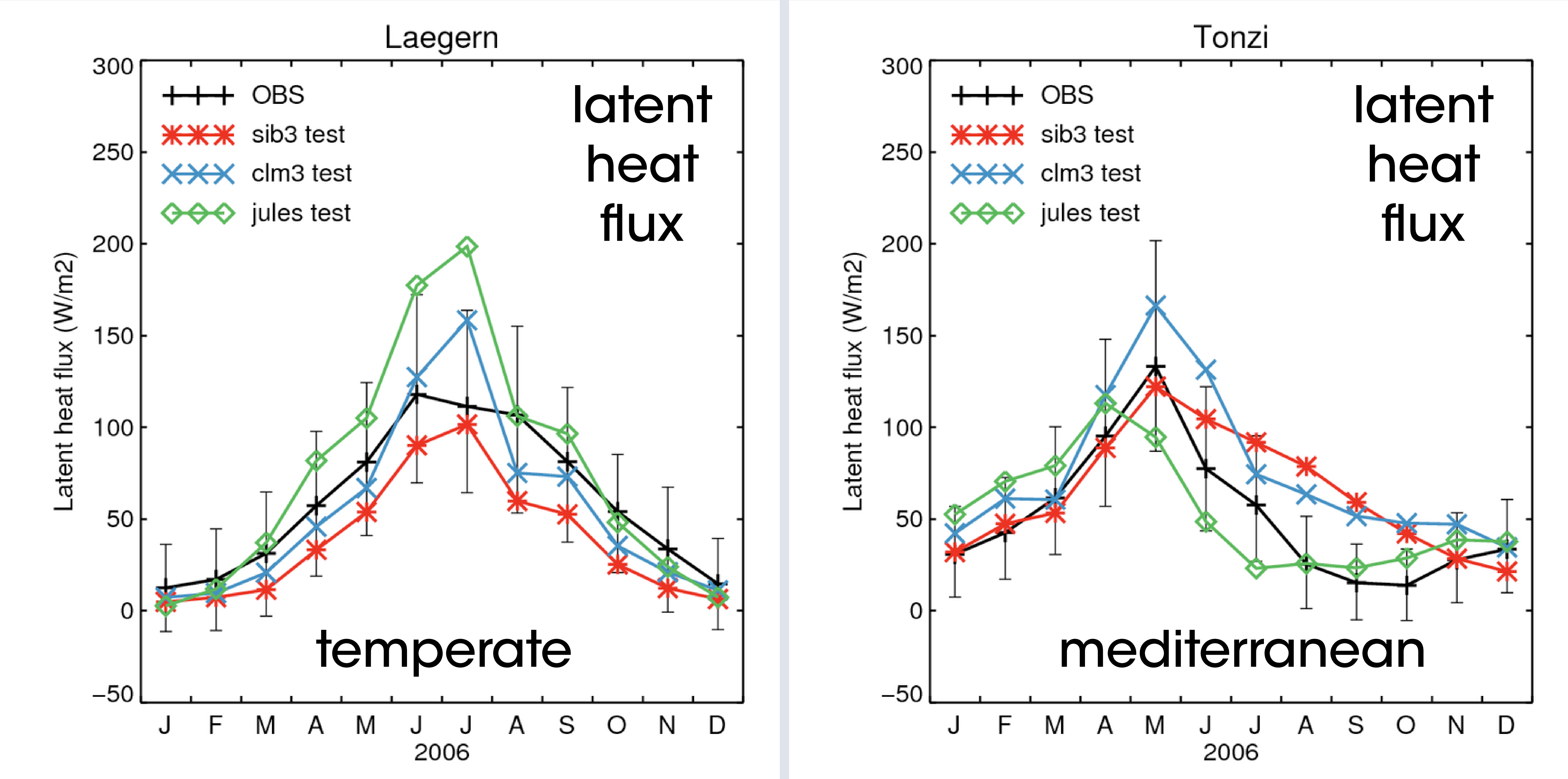
1

Improving mechanistic processes in a land model by use of land surface observations

Stöckli, R., Lawrence, D. M., Niu, G.-Y., Oleson, K. W., Thornton, P. E., Yang, Z.-L., Bonan, G. B., Denning, A. S., and Running, S. W. (2008). The use of FLUXNET in the community land model development. J. Geophysical Research-Biogeosciences, 113(G01025):doi: 10.1029/2007JG000562.

Oleson, K. W., Niu, G.-Y., Yang, Z.-L., Lawrence, D. M., Thornton, P. E., Lawrence, P. J., Stöckli, R., Dickinson, R. E., Bonan, G. B., and Levis, S. (2008). Improvements to the community land model and their impact on the hydrological cycle. J. Geophysical Research-Biogeosciences, 113(G01021):doi:10.1029/2007JG000563.

Problem: hydrologic cycle of current LSM's



LSMs: complex set of mechanistic processes

- little agreement of seasonal H, W, and C fluxes
- missing water cycle processes in LSMs?

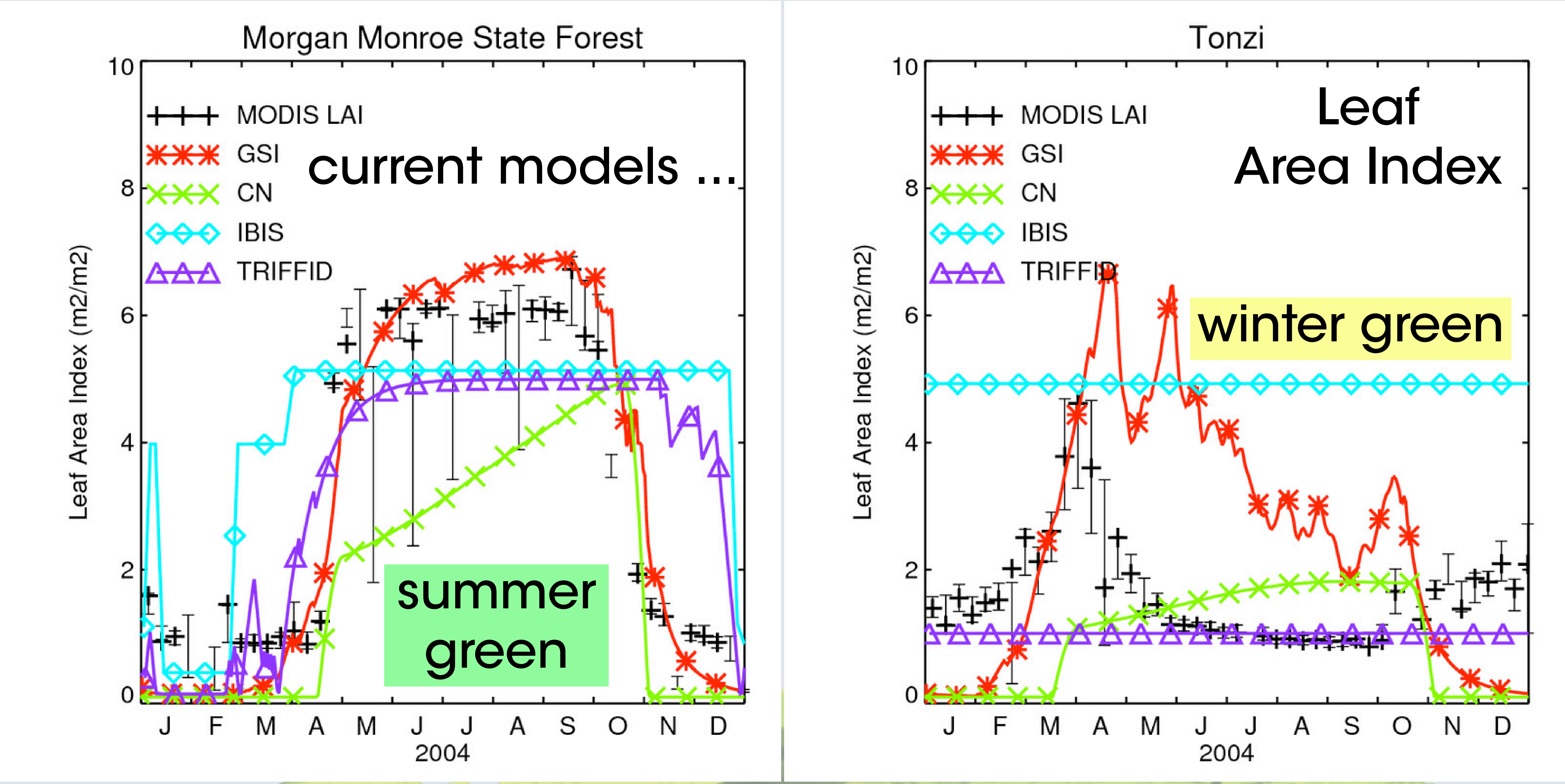
keyword: MODELFARM

2 Improving empirical parameters in a phenology model by use of satellite observations

Stöckli, R., Rutishauser, T., Dragoni, D., Keefe, J. O., Thornton, P. E., Jolly, M., Lu, L., and Denning, A. S. (submitted). Remote sensing data assimilation for a prognostic phenology model. J. Geophys. Res. - Biogeosciences.

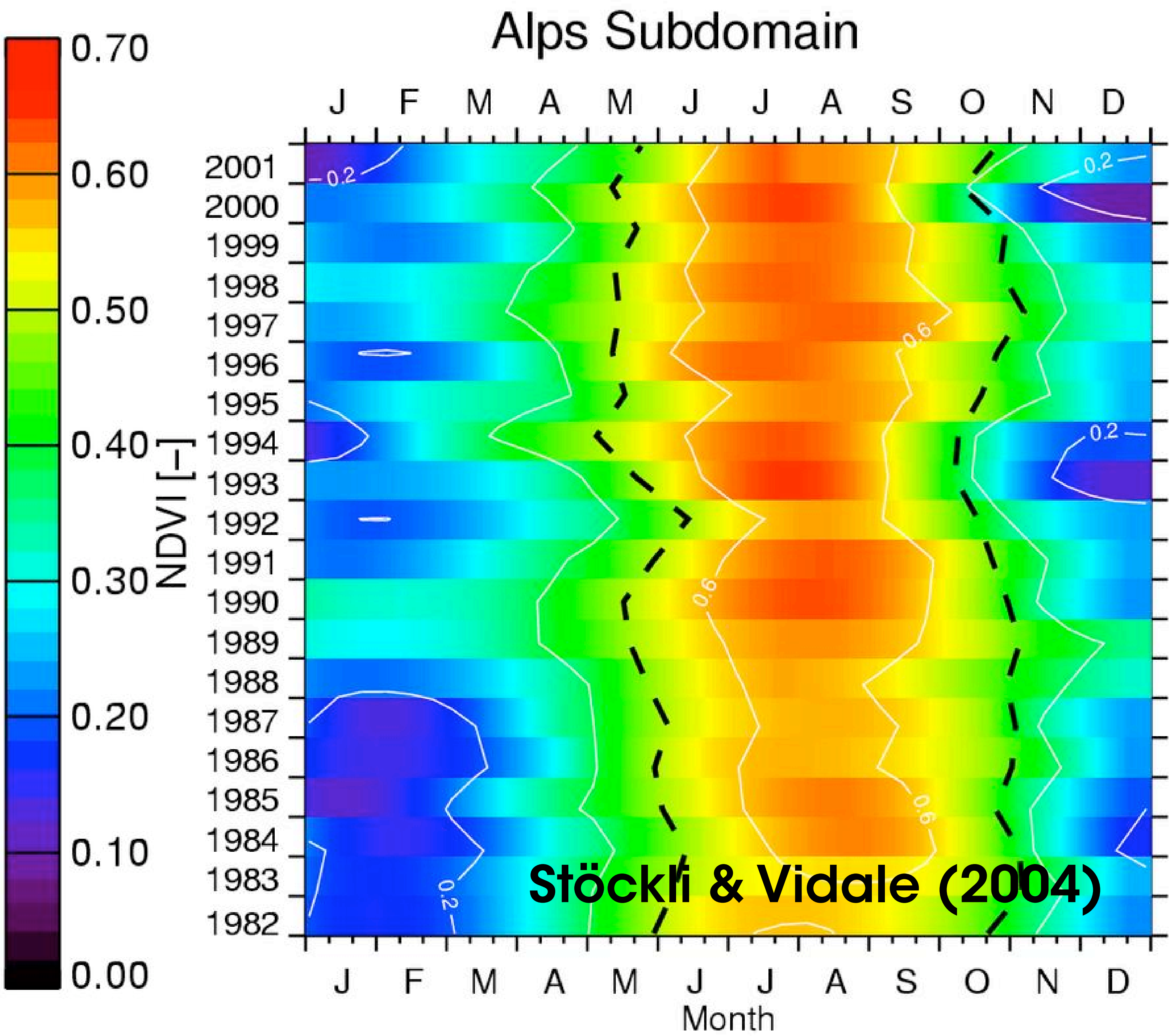
Problem: realism of phenology models

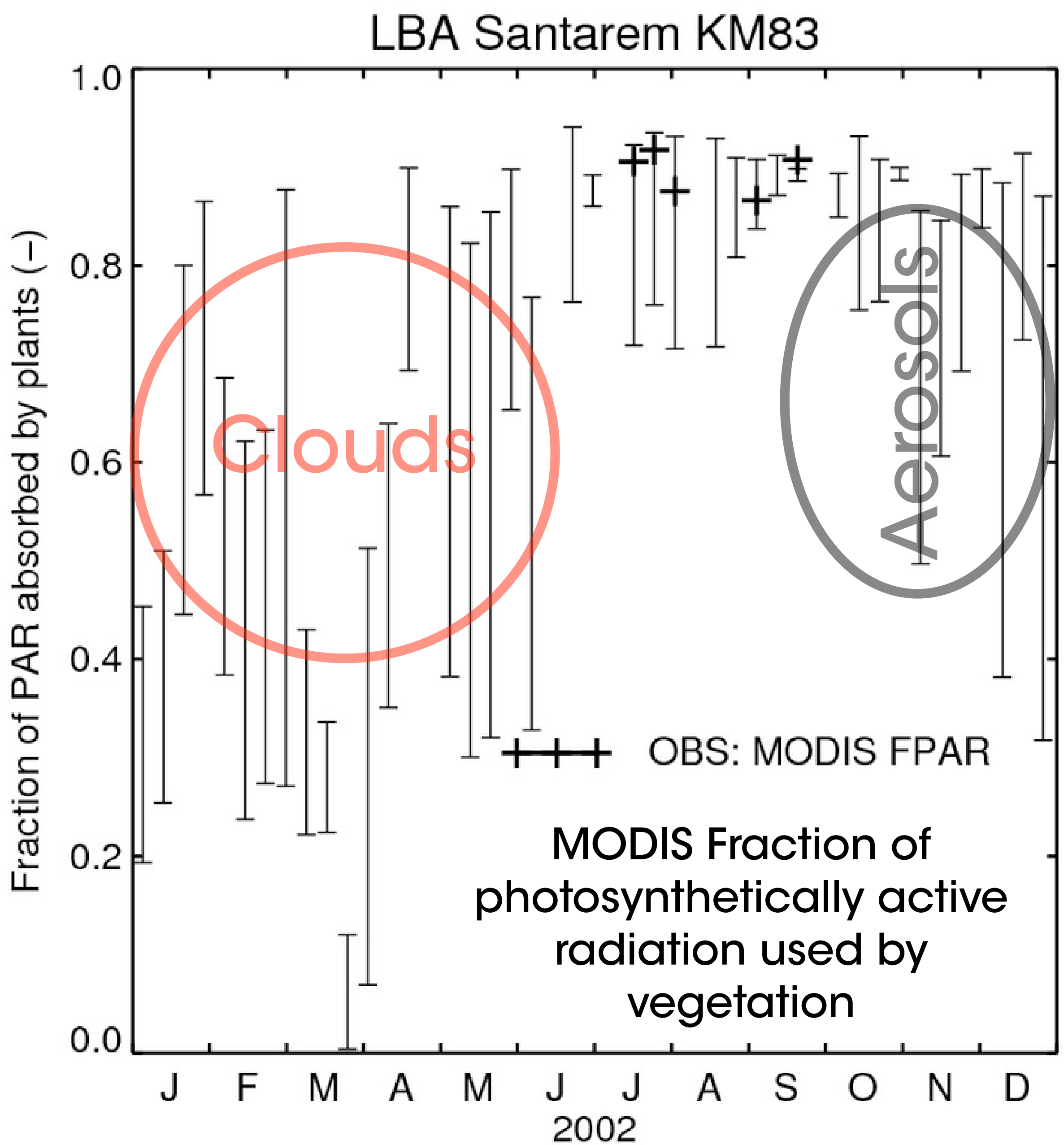
- Why care? CC impacts on C&W cycle (IPCC AR5)
- current models work well for temperate forests
- poor performance for drought deciduous veggie



Observations: satellite phenology

- seasonal & internnual variability
- global monitoring, 25+ years
- gaps from atmospheric disturbances
- diagnostic: no information about future





Use of Data Assimilation (EnKF)

Ensemble Kalman Filter (Evensen 2003)

$$\psi = f(x, u, \theta)$$

$$\mathbf{A} = (\psi_1, \psi_2, ..., \psi_N) \in \Re^{n \times N}$$

$$\mathbf{D} = (d_1, d_2, ..., d_N) \in \Re^{m \times N}$$

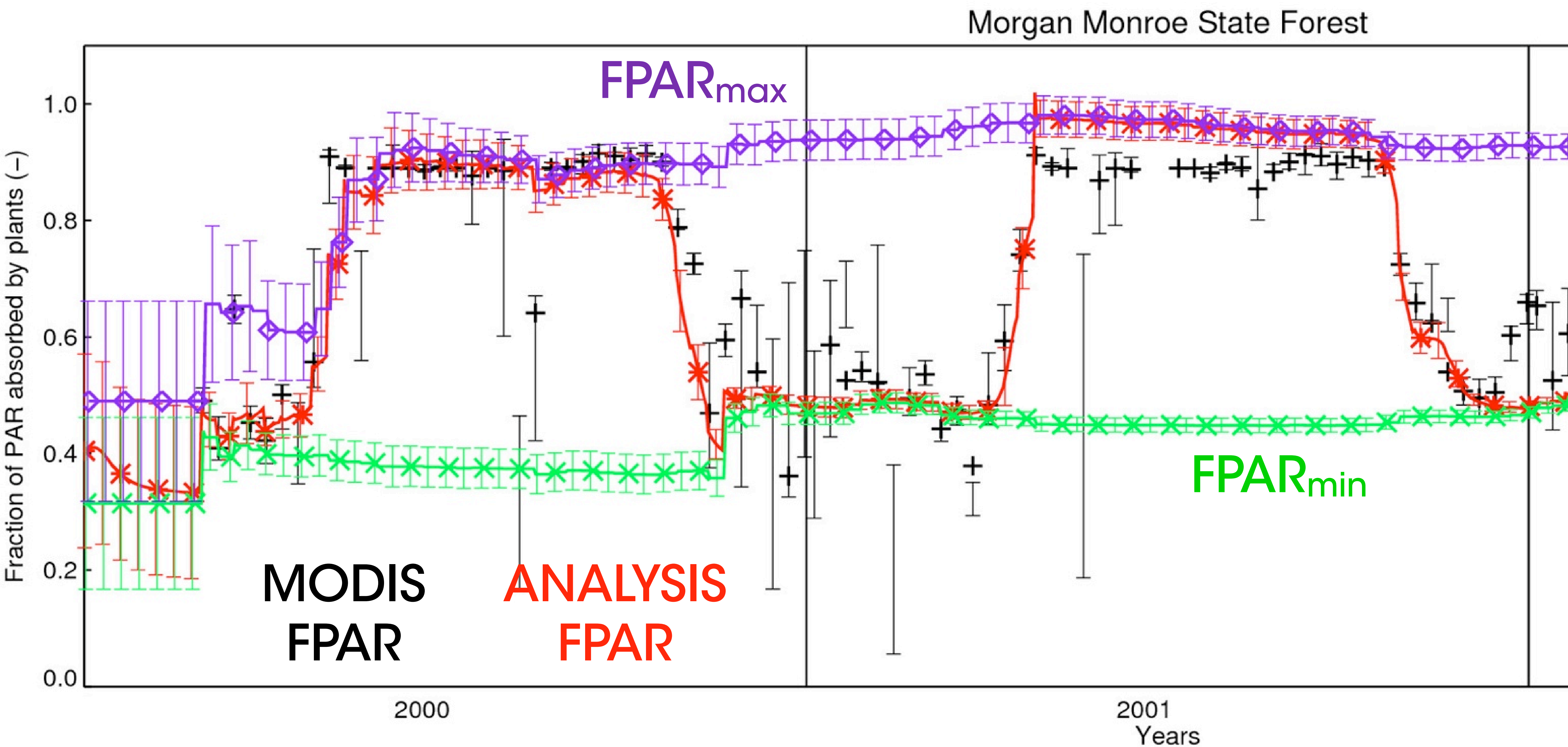
$$\mathbf{A}^a = \mathbf{A}^f + \mathbf{K}(\mathbf{D} - \mathbf{H}\mathbf{A}^f)$$

x	:	states (LAI, FPAR)
u	:	forcings (T, R_g, vpd)
θ	:	parameters $(T_{min}, ...)$
$\mathbf{A}$	:	states+parameters
$\mathbf{D}$	:	measurements
$\mathbf{H}$	:	measurement operator
$\mathbf{K}$	:	Kalman gain
N	:	no. ensembles (2000)
n	:	no. states (12)
m	:	no. observations (49)

Method: minimize observation-model difference

- **A**: model prognostic states + uncertainties
- **D**: satellite observations + uncertainties
- analyze ensembles of A+D and come up with a new set of model states+parameters which better fit observations

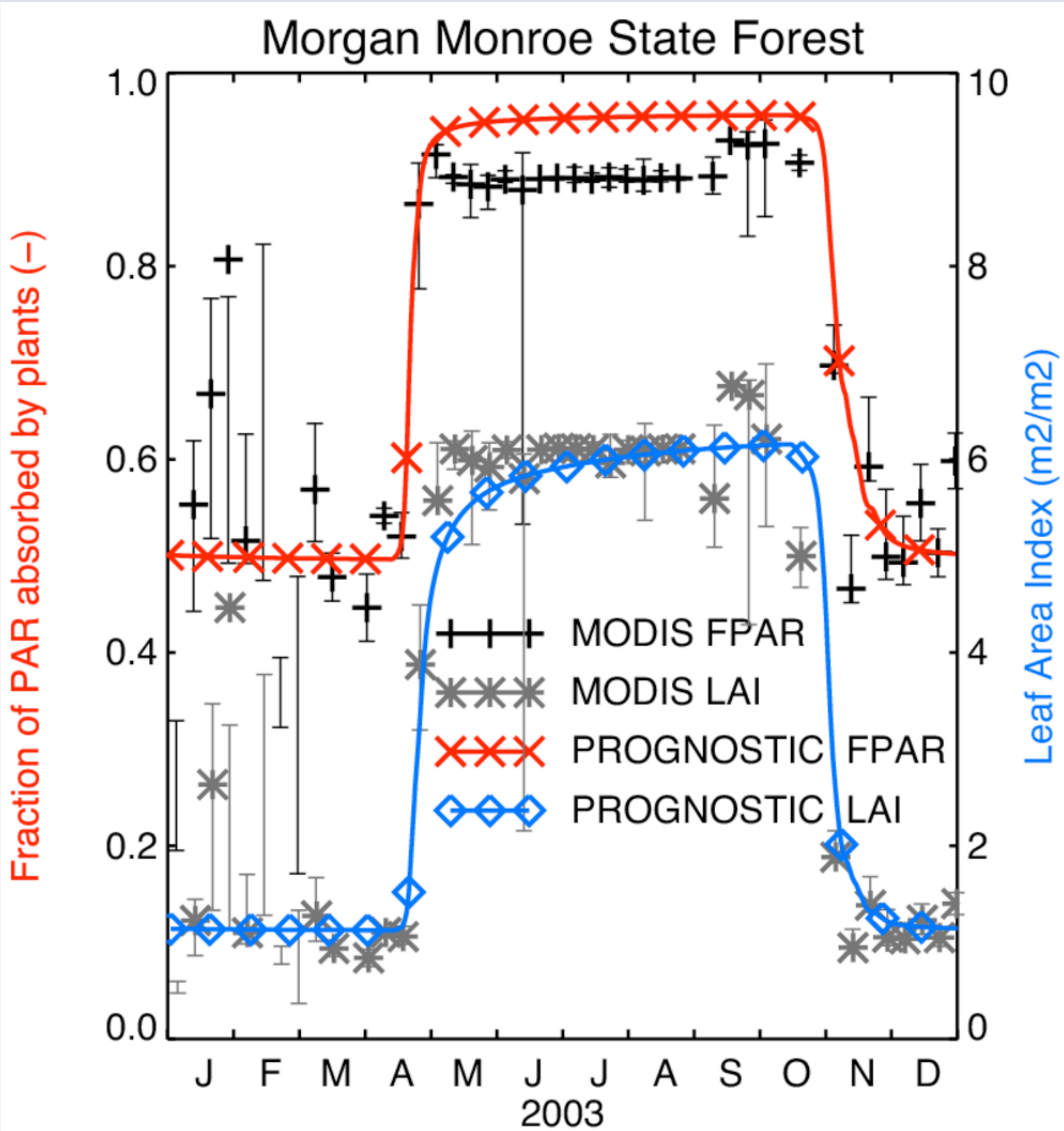
Joint state+parameter estimation

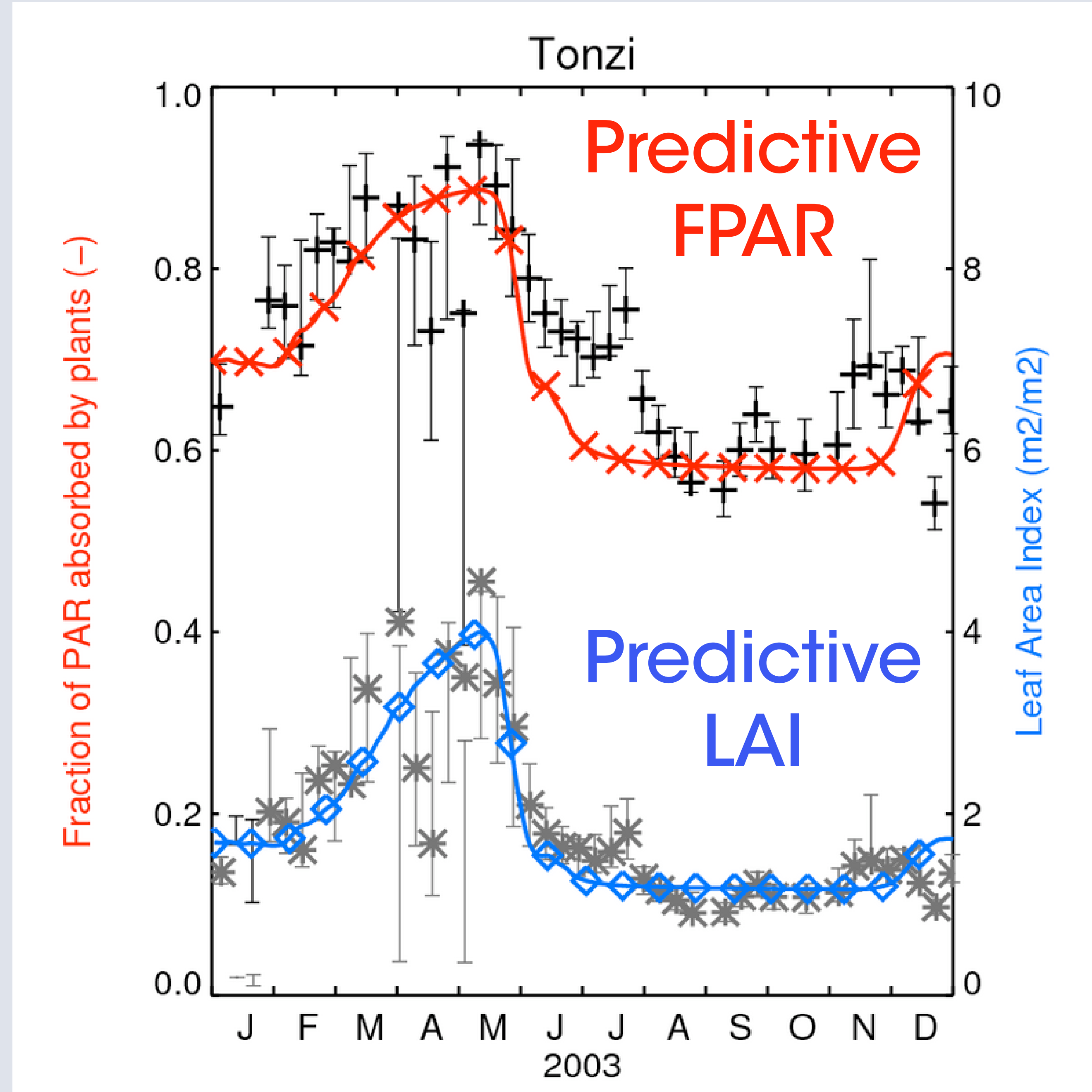


- empirical parameters constrained (sometimes!)
- proper treatment of MODIS uncertainties (QA!)

Stöckli et al., JGR-BGC (submitted)

1. Result: predict seasonal phenology





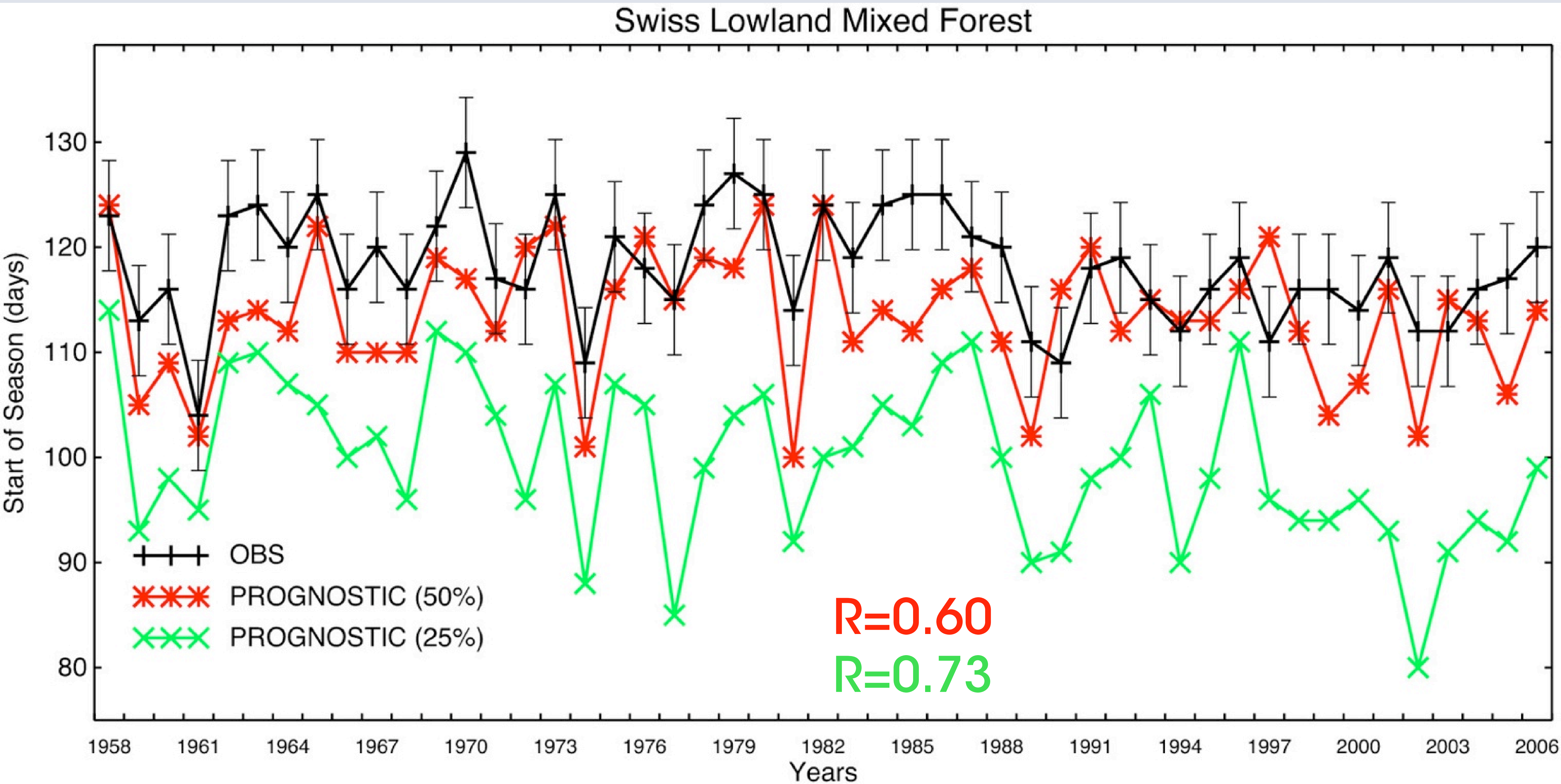
Temperate deciduous forest:

- spring: temperature; autumn: light

Drought deciduous: light + moisture

- vpd seems good surrogate for soil moisture

2. Result: predict interannual phenology

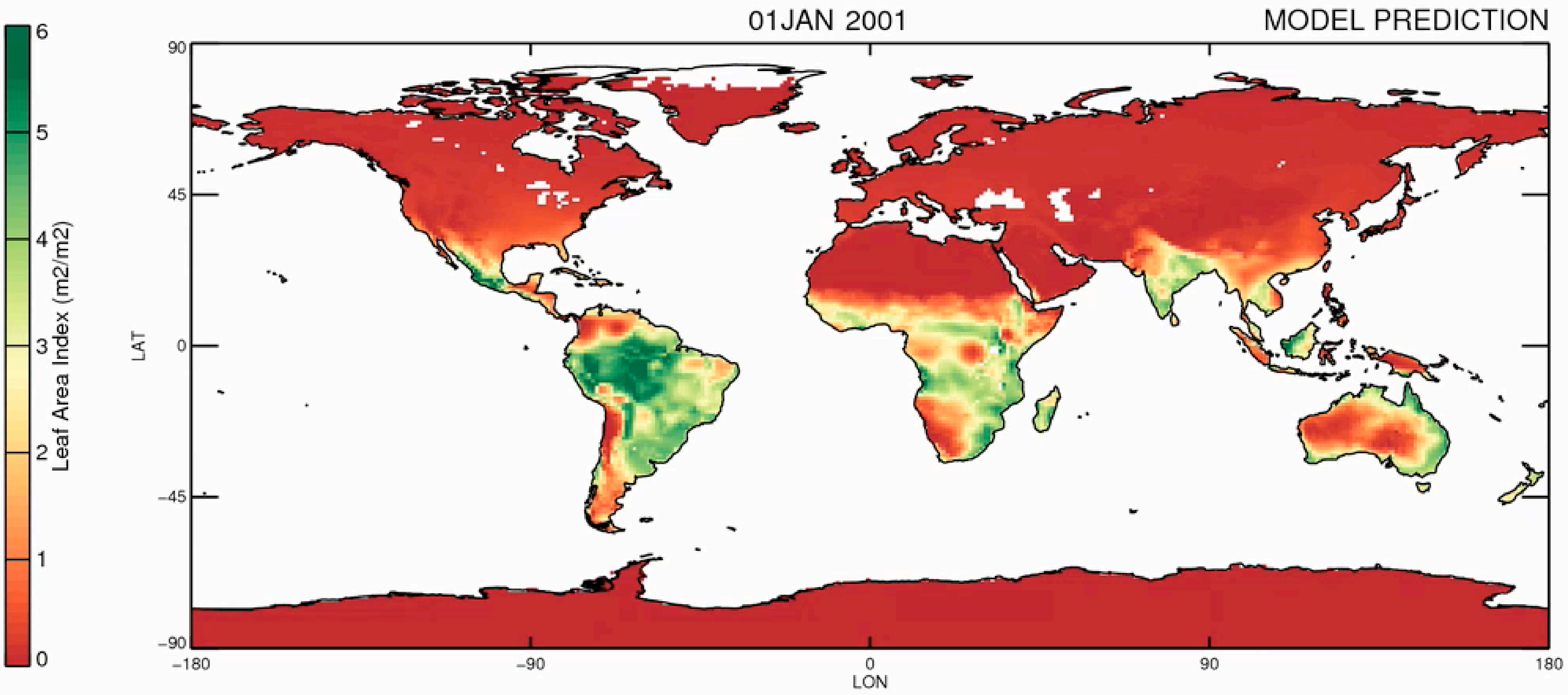


Comparison to "statistical plant" by T. Rutishauser

- model trained with only 7 years of satellite data
- interannual-decadal variability reproduced

Stöckli et al. , JGR-BGC (submitted)

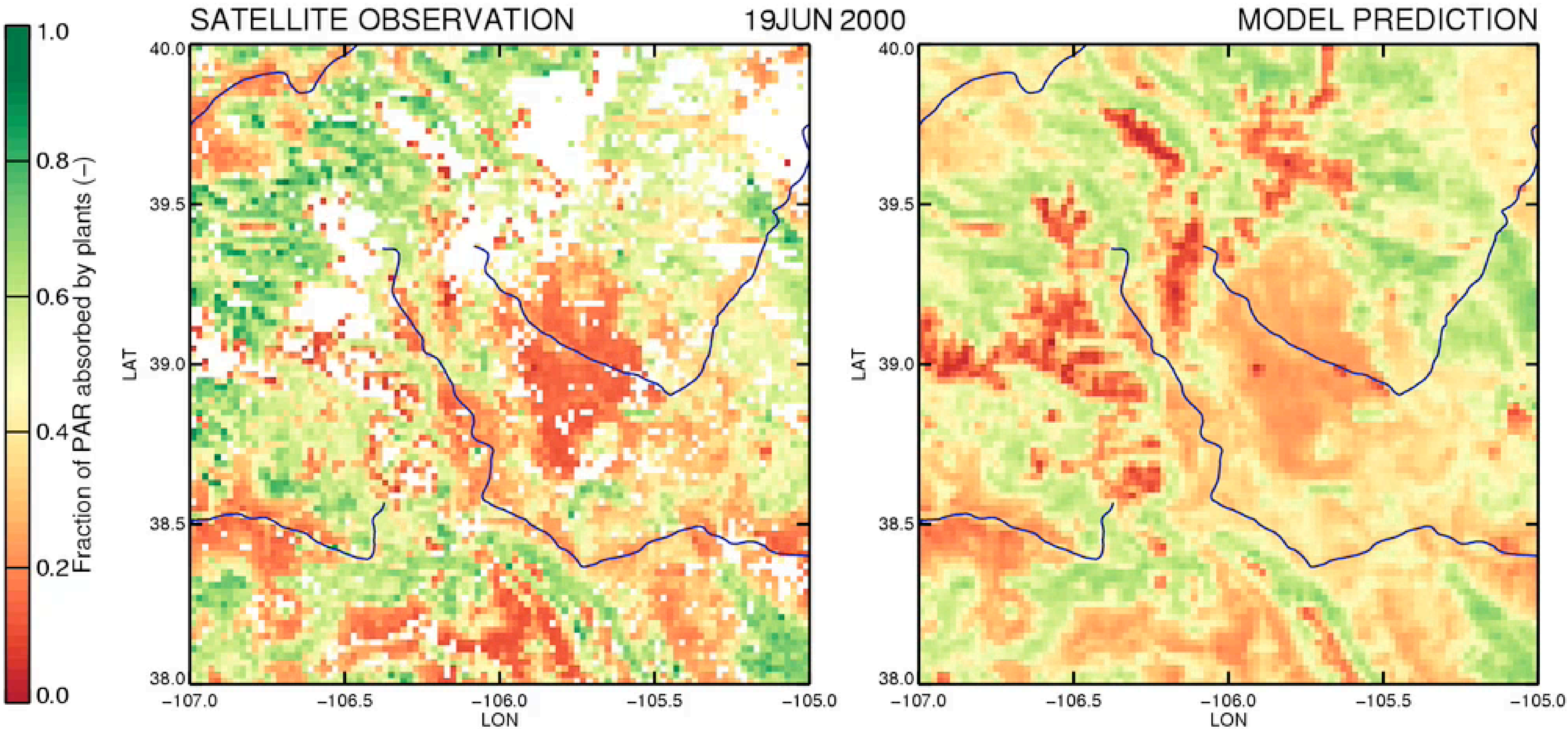
Next step: a global model of phenology



Global forward prediction of LAI using the GSI phenology model with standard parameters

- response to radiation, temperature, moisture
- not yet very realistic everywhere ...

Getting there: regional data assimilation



Detecting regional phenological variability

- subgrid-scale vegetation + topography
- aim: parameter set by vegetation type (pft)
- applicability: NWP + climate models

Conclusions

Finding missing processes (e.g. Hydrology)

- priority!

Constraining parameters (e.g. Phenology)

- data assimilation overcomes deficiencies of "messy" (satellite) data
- create a prognostic model which inherits statistics of diagnostic satellite data
- predictive power with realism of observations

Q&A: Reto Stöckli (stockli@atmos.colostate.edu)