Modelling the phenology and carbon budget of major crops at the field scale, supported by remote sensing data

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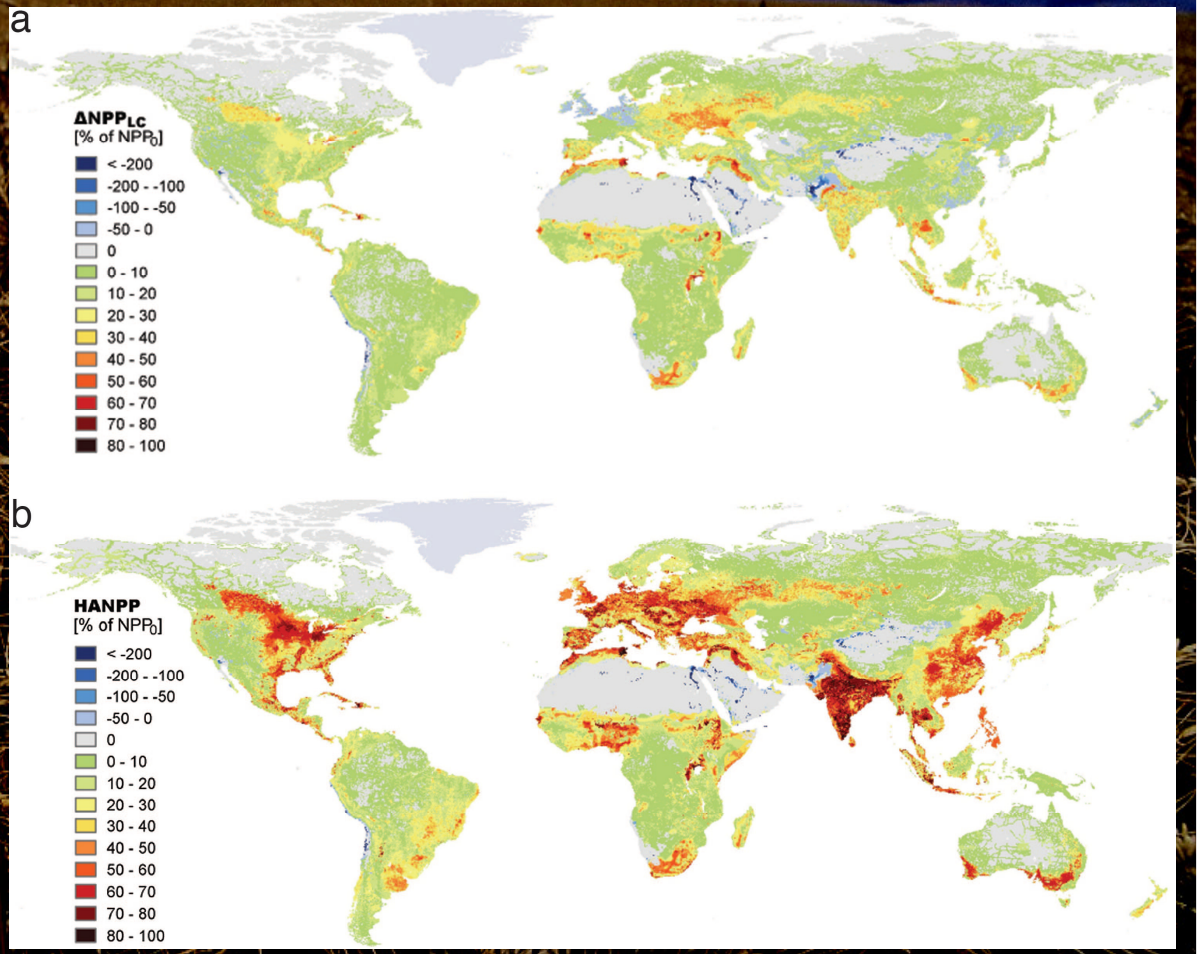
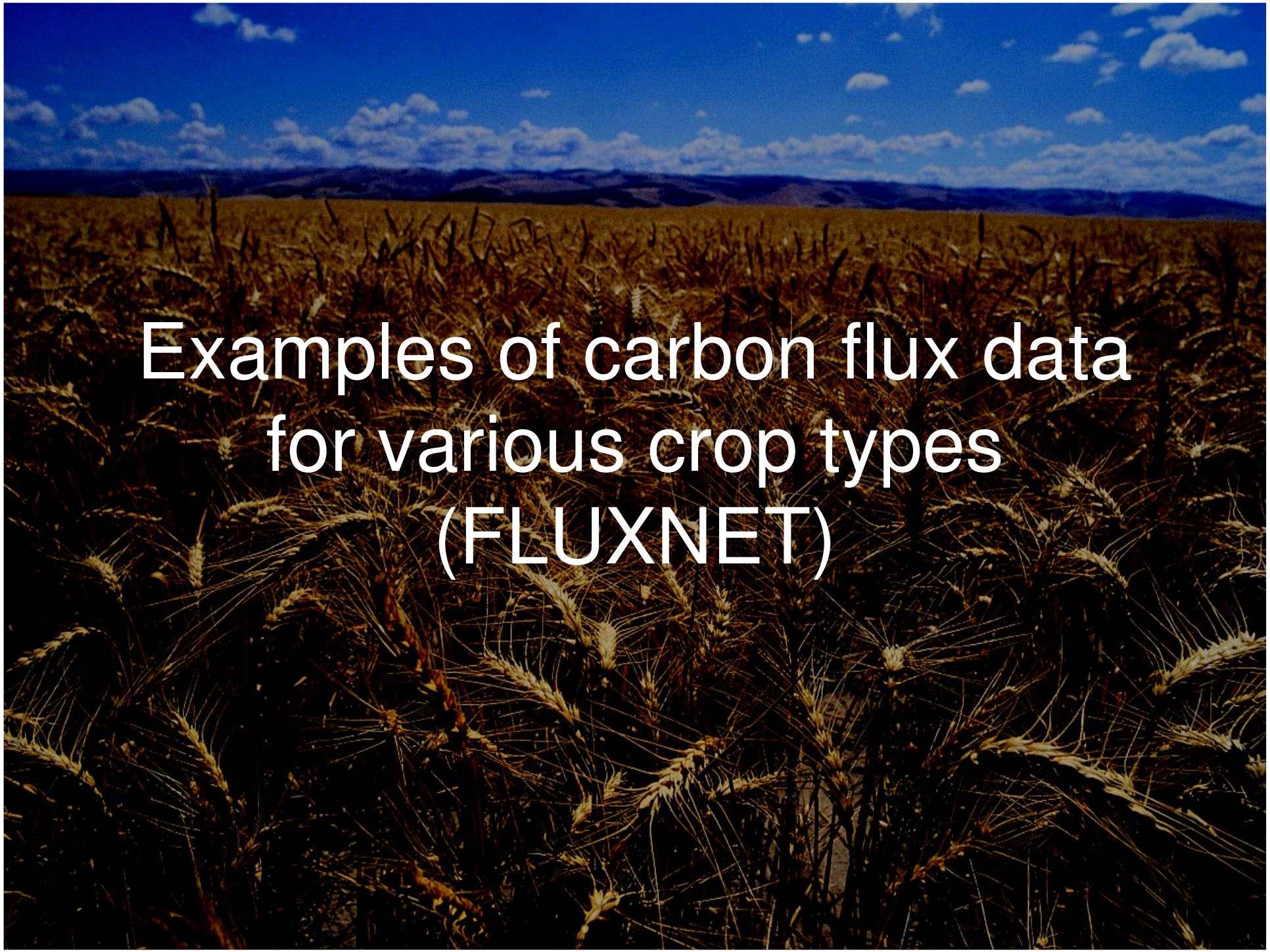
Content

- Introduction
- Examples of cropland carbon flux data
- Crop modelling – approach and results
- Remote sensing – data assimilation and time series analysis

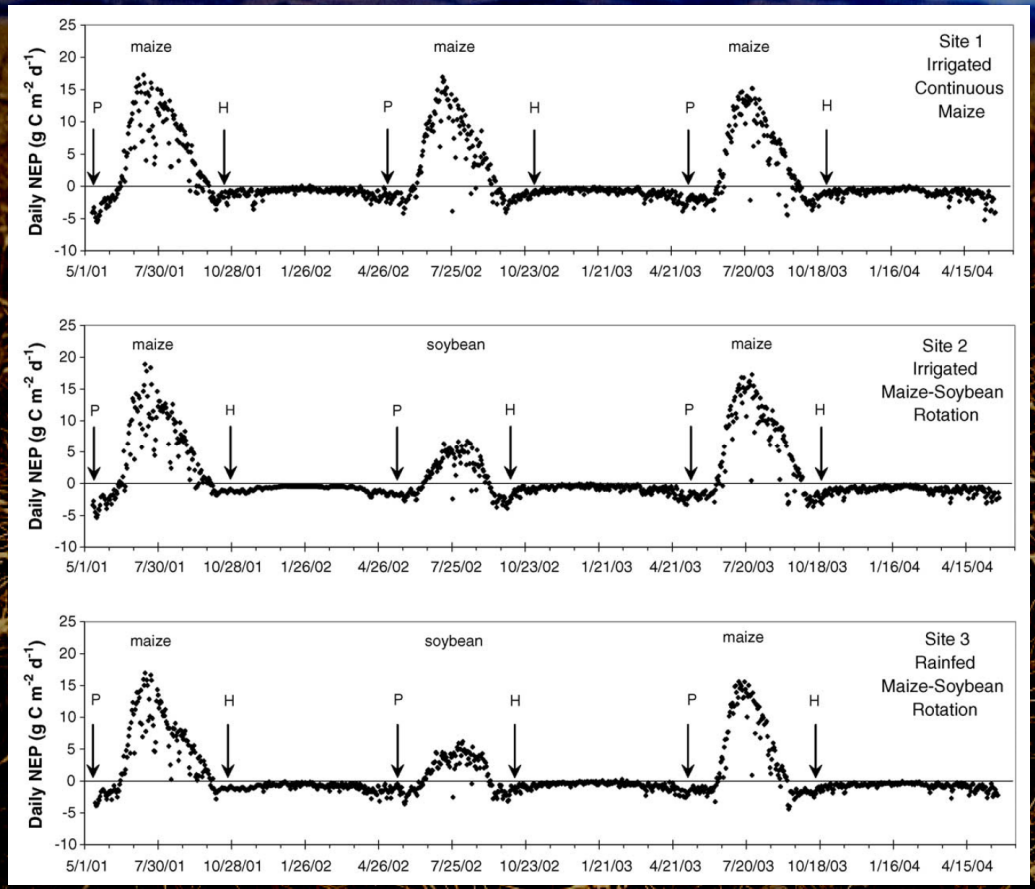
Haberl et al., 2007: The Human appropriation of NPP (HANPP) in Earth's terrestrial ecosystems for the year 2000

- HANPP: combined effect of harvest and productivity changes induced by land use on availability of NPP in ecosystems
- Globally: HANPP ~ 25% of potential NPP



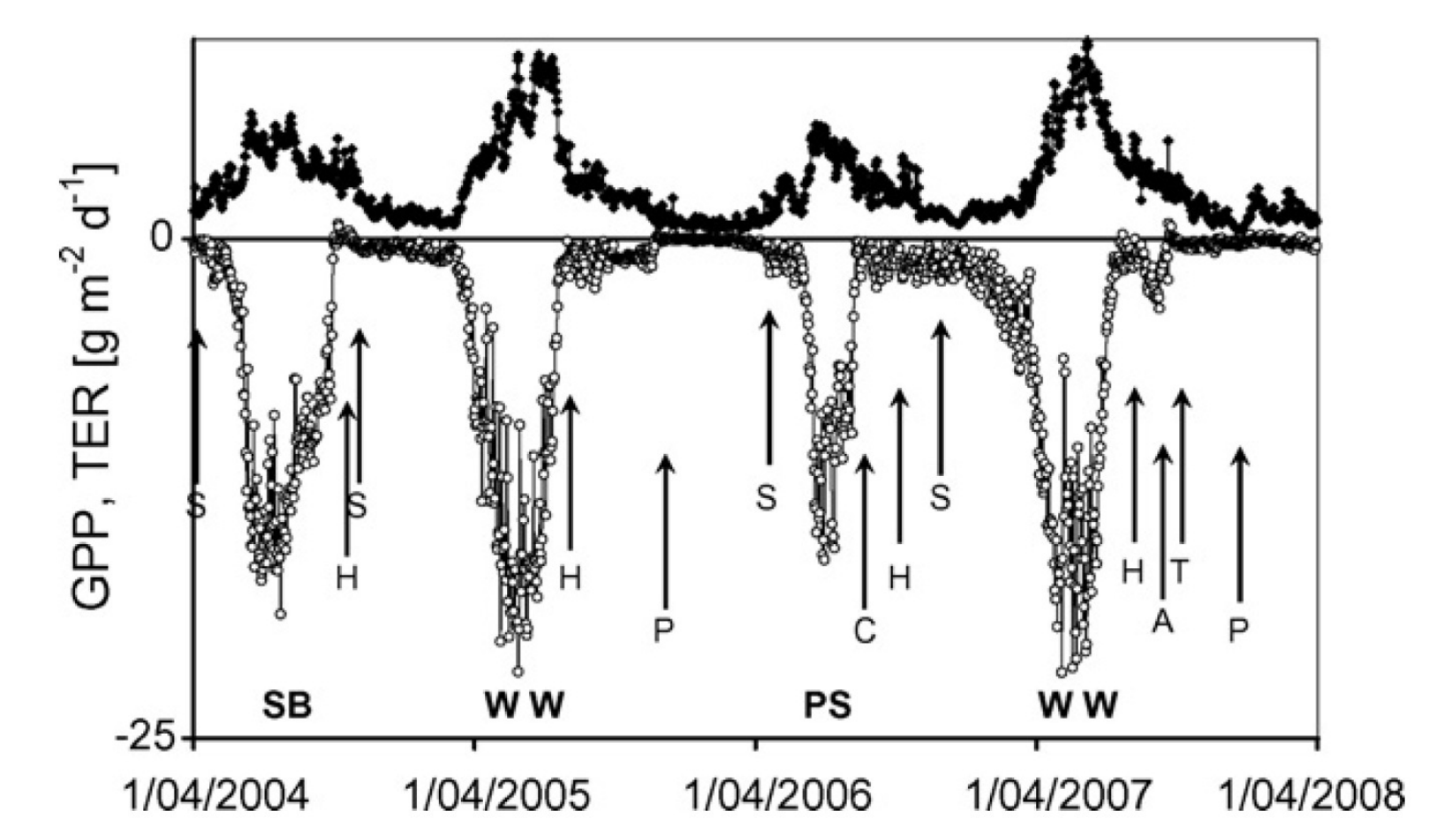

Examples of carbon flux data
for various crop types
(FLUXNET)

Example of observed NEE: maize and soybean in Nebraska (USA)



Verma et al., 2005

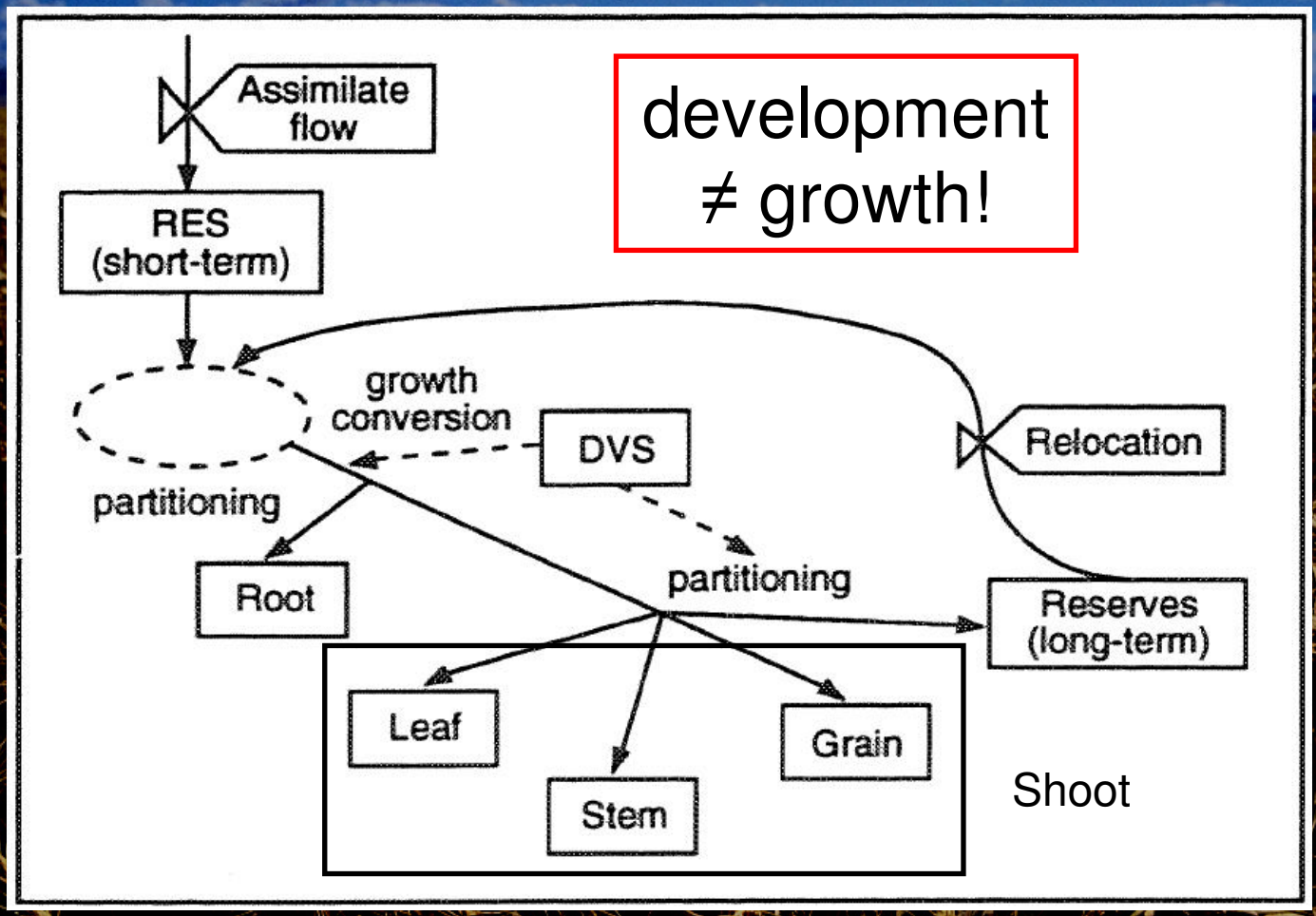
Aubinet et al., 2008: sugar beet, winter wheat, seed potato, winter wheat (Lonzée, Belgium)



Authors	Location	Crop	NEP ($gCm^{-2}y^{-1}$)	NBP ($gCm^{-2}y^{-1}$)
Hollinger et al., 2005	Illinois (USA)	Maize (rainfed/rotation)	+576.4	+184.4
		Soybean	+32.5	-124.1
Verma et al., 2005	Nebraska (USA)	Maize (irrigated)	+440	-57
		Maize (irrigated/ rotation)	+550	+22.5
		Soybean	-48	-231
		Maize (rainfed/rotation)	+454	+138
		Soybean	-18	-171
Anthoni et al., 2004	Germany	Winter wheat	+215	-75
Moureaux et al., 2008	Belgium	Winter wheat	+630	?
Moureaux et al., 2006	Belgium	Sugar beet	+610	?


The crop modelling approach
built into SPA

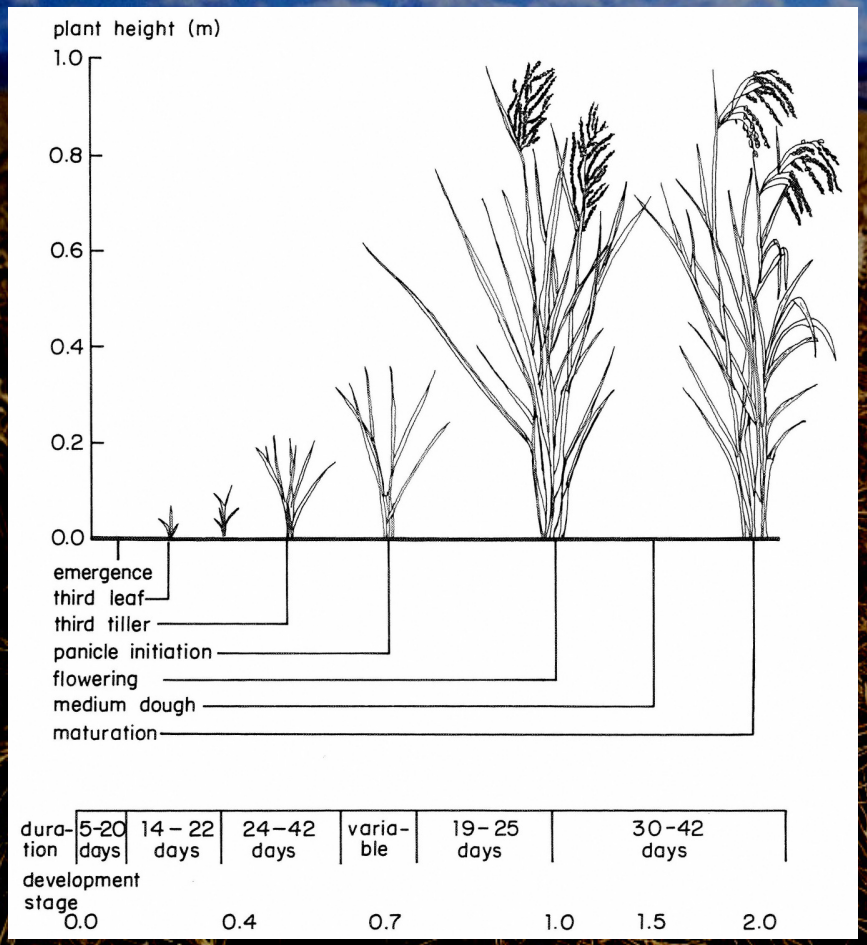
Distribution of crop assimilates



development ≠ growth!

Goudriaan & van Laar, 1994

Main phenology equations

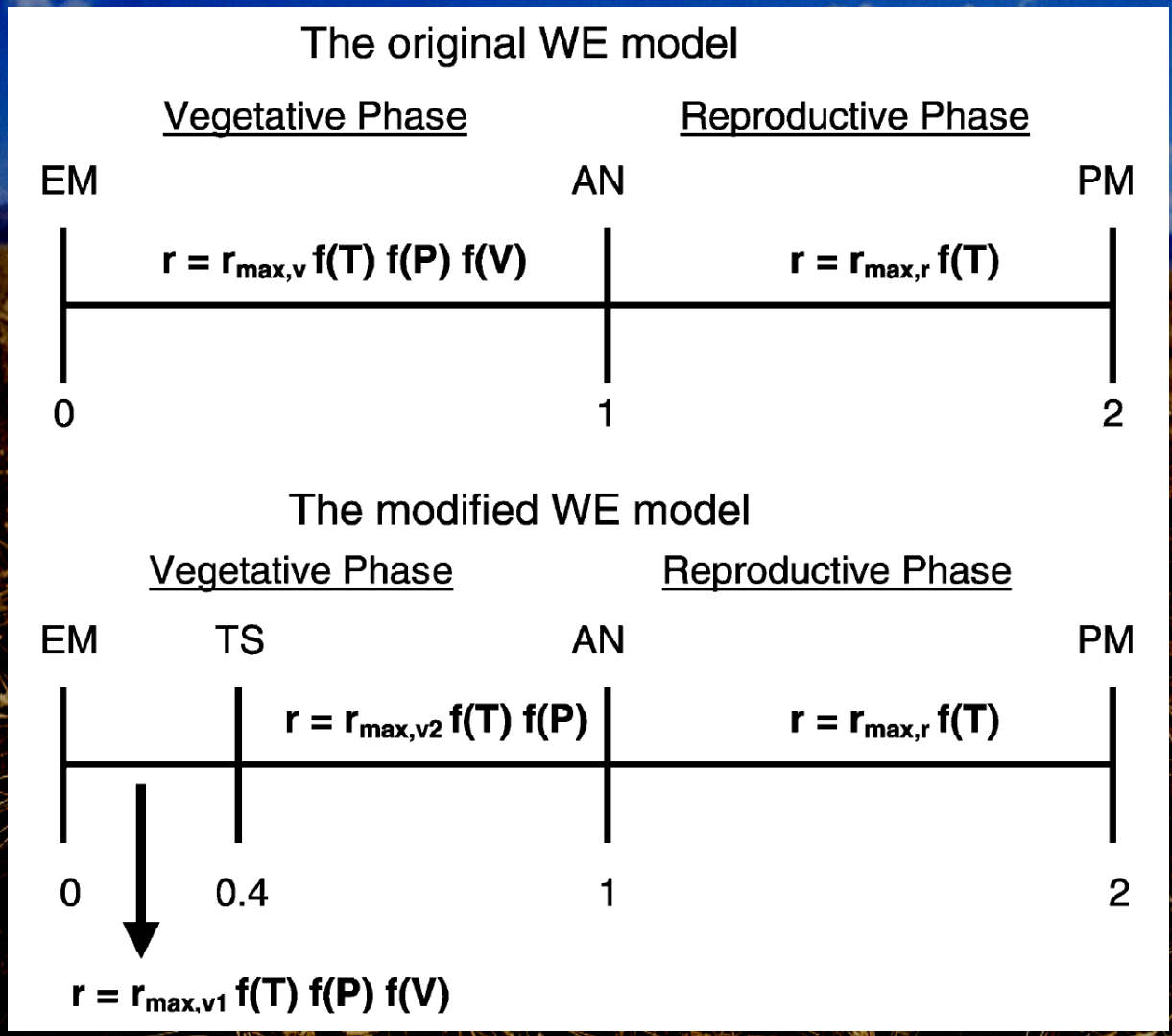


- Developmental stage
  - DS = ∑ DR
- Developmental rate
  - $DR = DR_{max} * f(T) * f(P) * f(V)$
- DR_{max} is different for each crop type and for the vegetative and reproductive phases

Penning de Vries et al., 1989

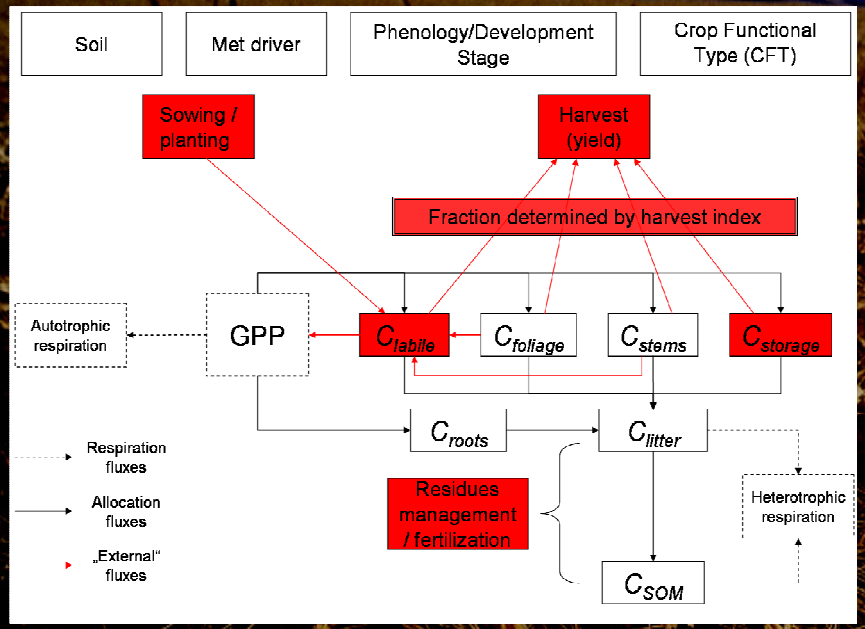
$DR = DR_{max} * f(T) * f(P) * f(V)$

- So there are three factors influencing developmental rate (DR):
  - f(T) = temperature function
  - f(P) = photoperiod (daylength) function
  - f(V) = vernalization function
- Basic inputs: cardinal temperatures, critical photoperiod and photoperiod sensitivity coefficient



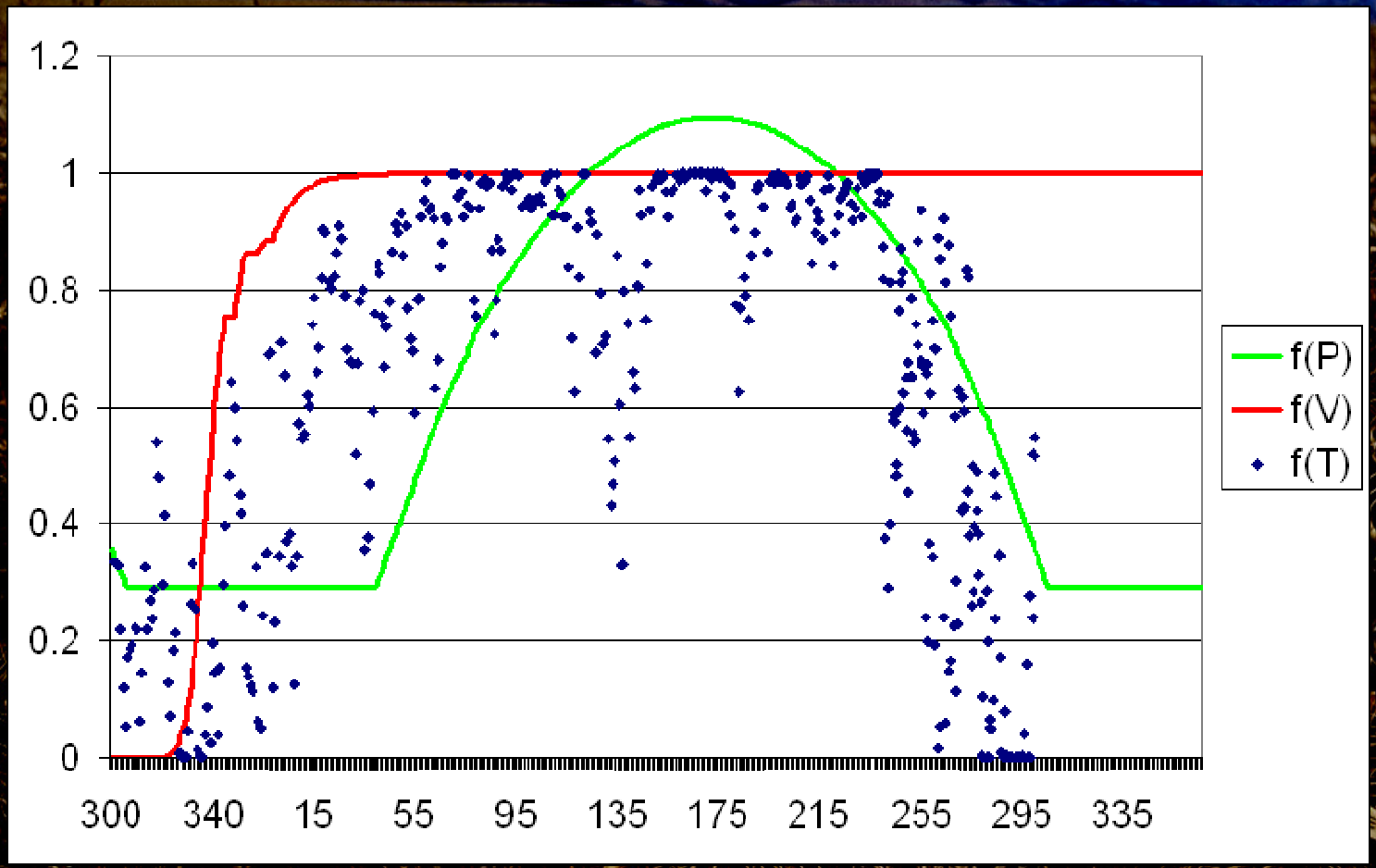
Streck et al., 2003

SPA - Soil–Plant–Atmosphere model

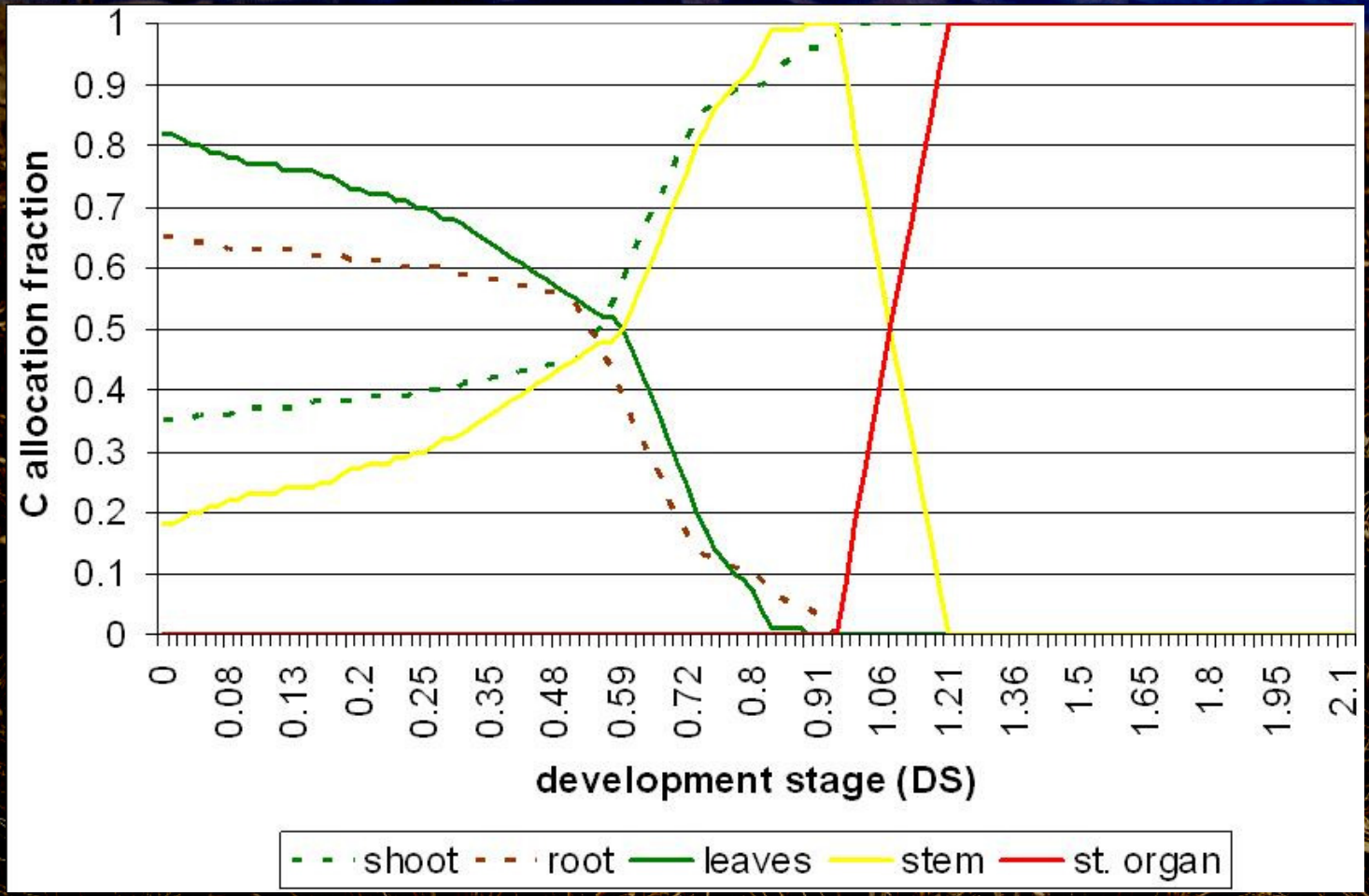


- Process-based model
- Photosynthesis and water balance
- Fine temporal/spatial scales, multiple canopy and soil layers
- Leaf-level parameter-ization and canopy level prediction →diagnoses eddy flux data and provides up-scaling

Example of values of phenological functions for winter wheat



Carbon allocation to various crop organs in SPA as a function of DS (here for spring barley)



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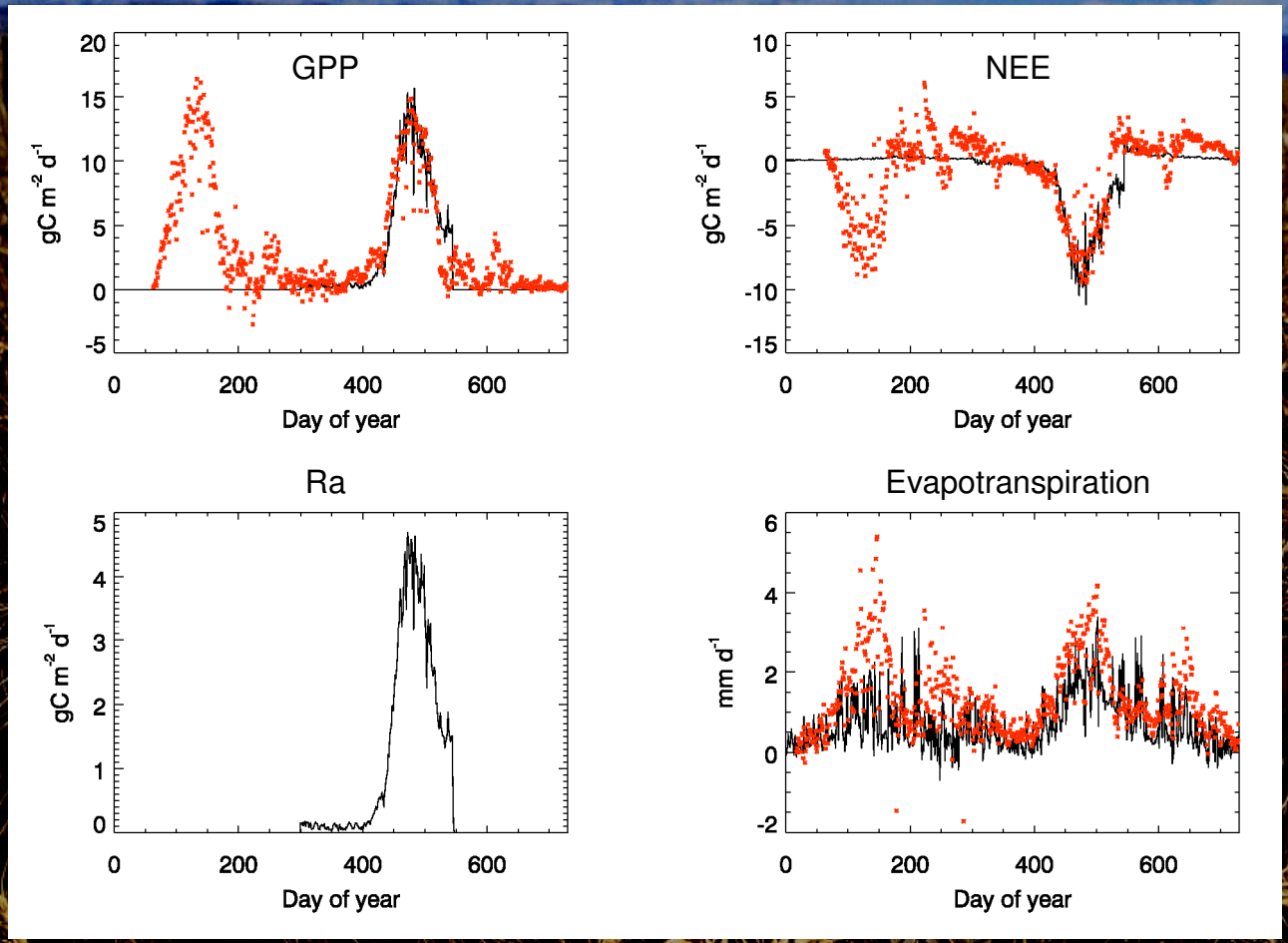
Winter wheat in Auradé, France (2005/06)



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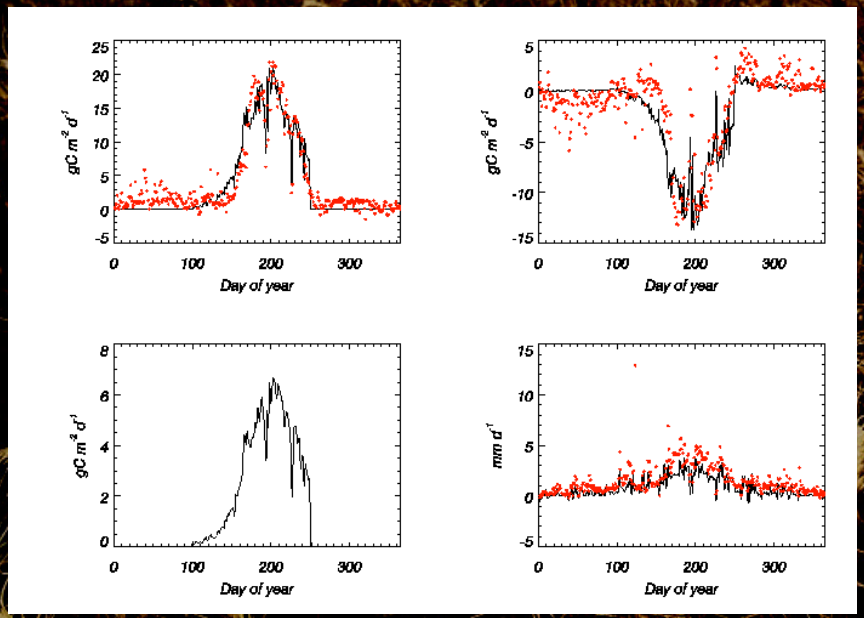
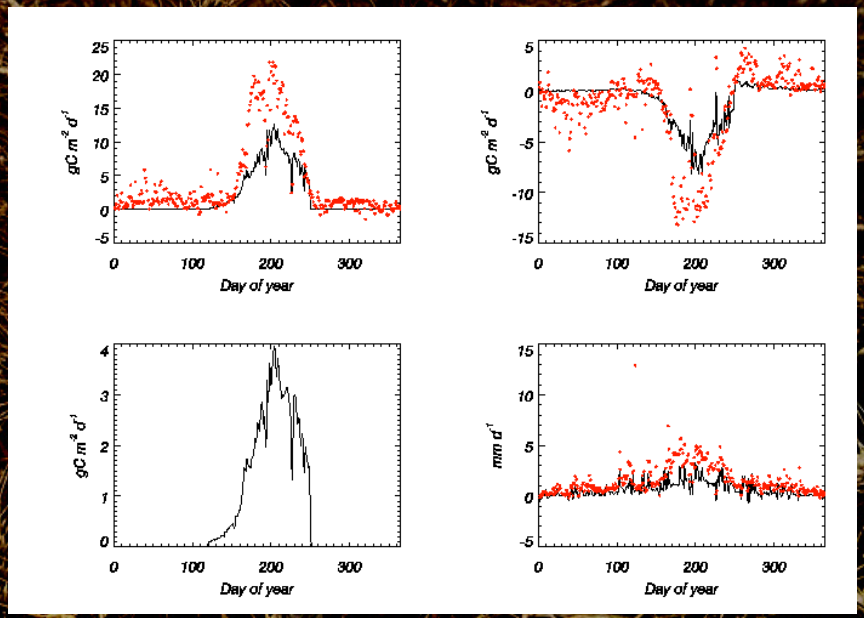
Effect of sowing date on NEE

- SPA results for maize in Bondville/Illinois (2005)

Sowing date: DOY 100



Sowing date: DOY 120



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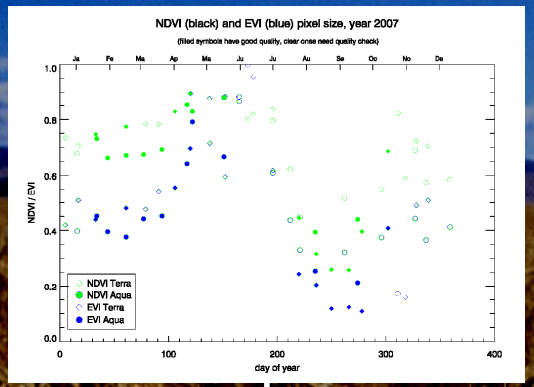
Plans

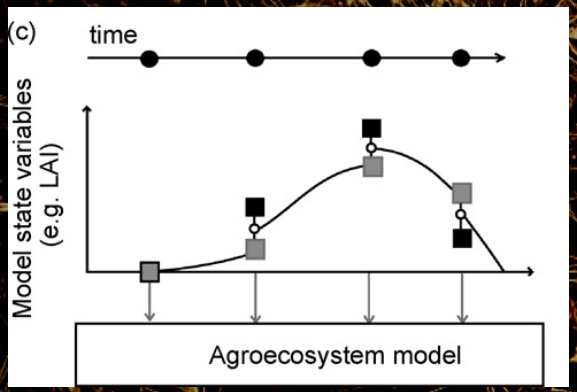
- SPA uses these functions to calculate the phenology of wheat, barley and maize
  → soybeans to come (Setiyono et al., 2007)
- Improvement of representation of senescence, addition of a standing dead biomass carbon pool
- Calibration: data assimilation modelling based on FLUXNET data (Ensemble Kalman Filter)
- Implementation of SPA crop phenology and carbon allocation routines into JULES


Remote Sensing

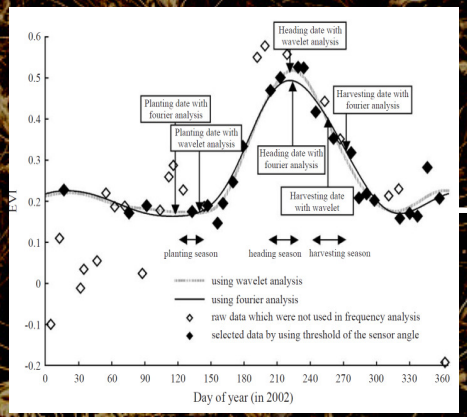
EO data time series

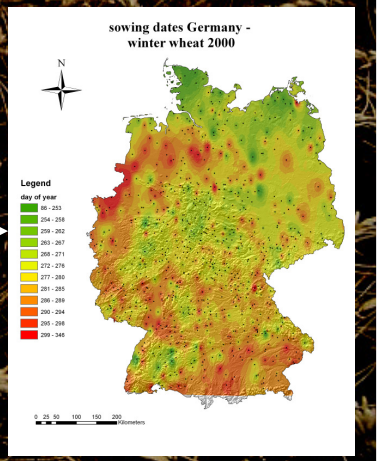


1. Data assimilation: calibration and updating



2. Extraction of land management dates





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MODIS 250m resolution pixel grid overlaying a 15m Landsat image and a field boundary vector layer at the CarboEurope flux tower site at Gebesee, Germany

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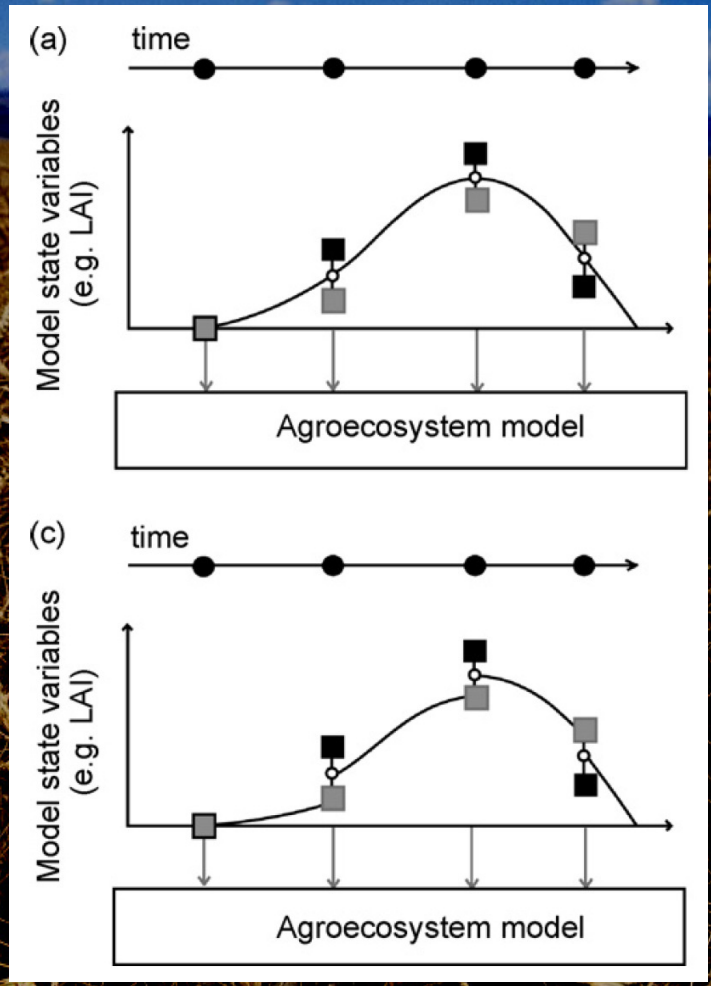
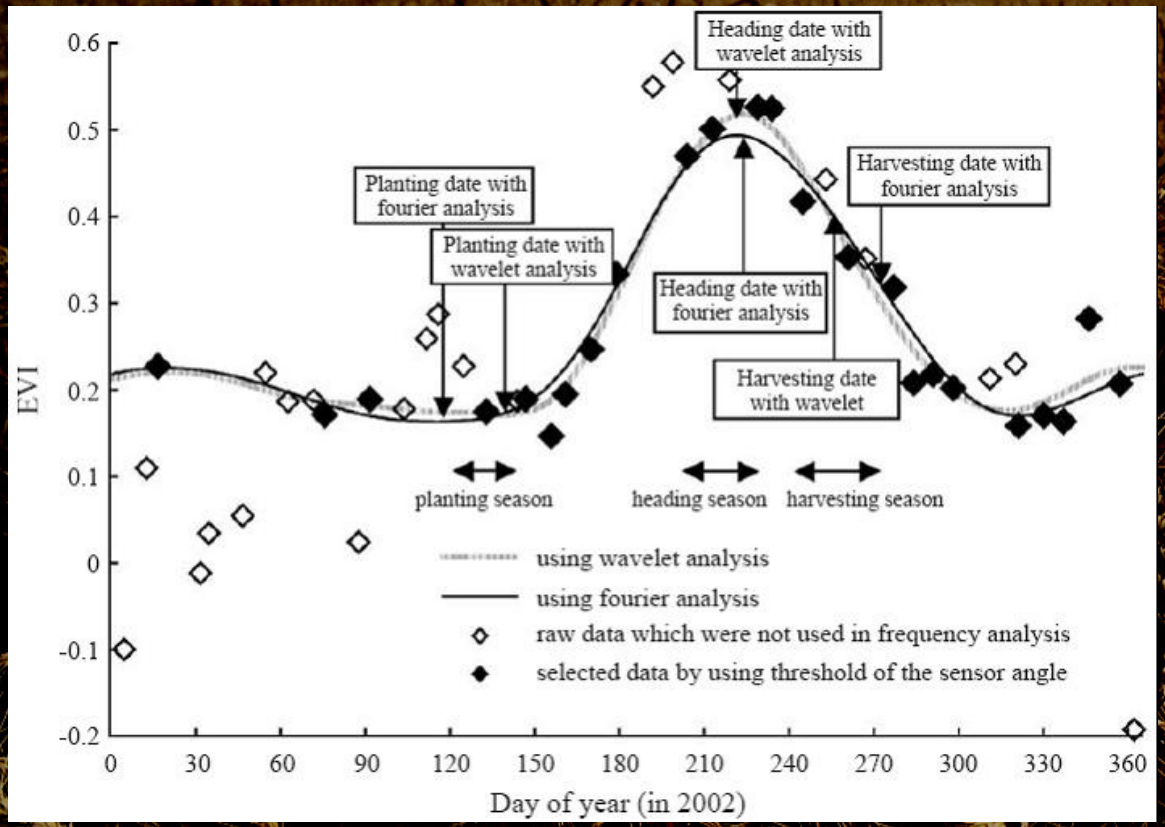
Data Assimilation

- Application of the Ensemble Kalman Filter to SPA “crop”
- Purpose: calibration and “updating”



Dorigo et al., 2007

Extraction of land management dates



Sakamoto et al., 2005

EVI: enhanced vegetation index

$$EVI = G^* [(\rho_{NIR} - \rho_{red}) / (\rho_{NIR} + C_1 * \rho_{red} - C_2 * \rho_{blue} + L)]$$

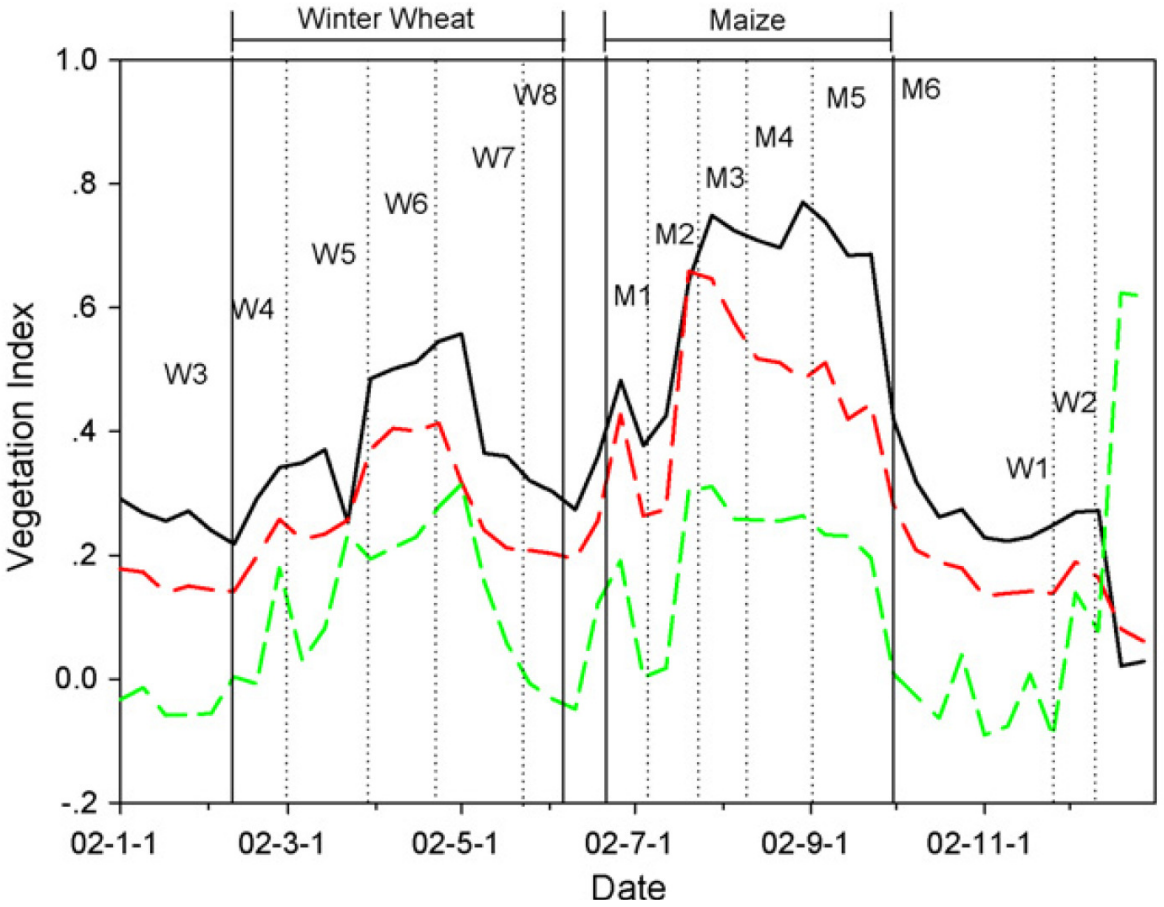


Fig. 3. Winter wheat–maize phenology and vegetation index in Yucheng. W1: winter wheat emergence; W2: winter wheat dormancy; W3: winter wheat recovery; W4: winter wheat tillering; W5: winter wheat jointing; W6: winter wheat heading; W7: winter wheat milking; W8: winter wheat maturity. M1: maize emergence; M2: maize–seven leaves; M3: maize jointing; M4: maize heading; M5: maize milking; M6: maize maturity.

Yan et al., 2008

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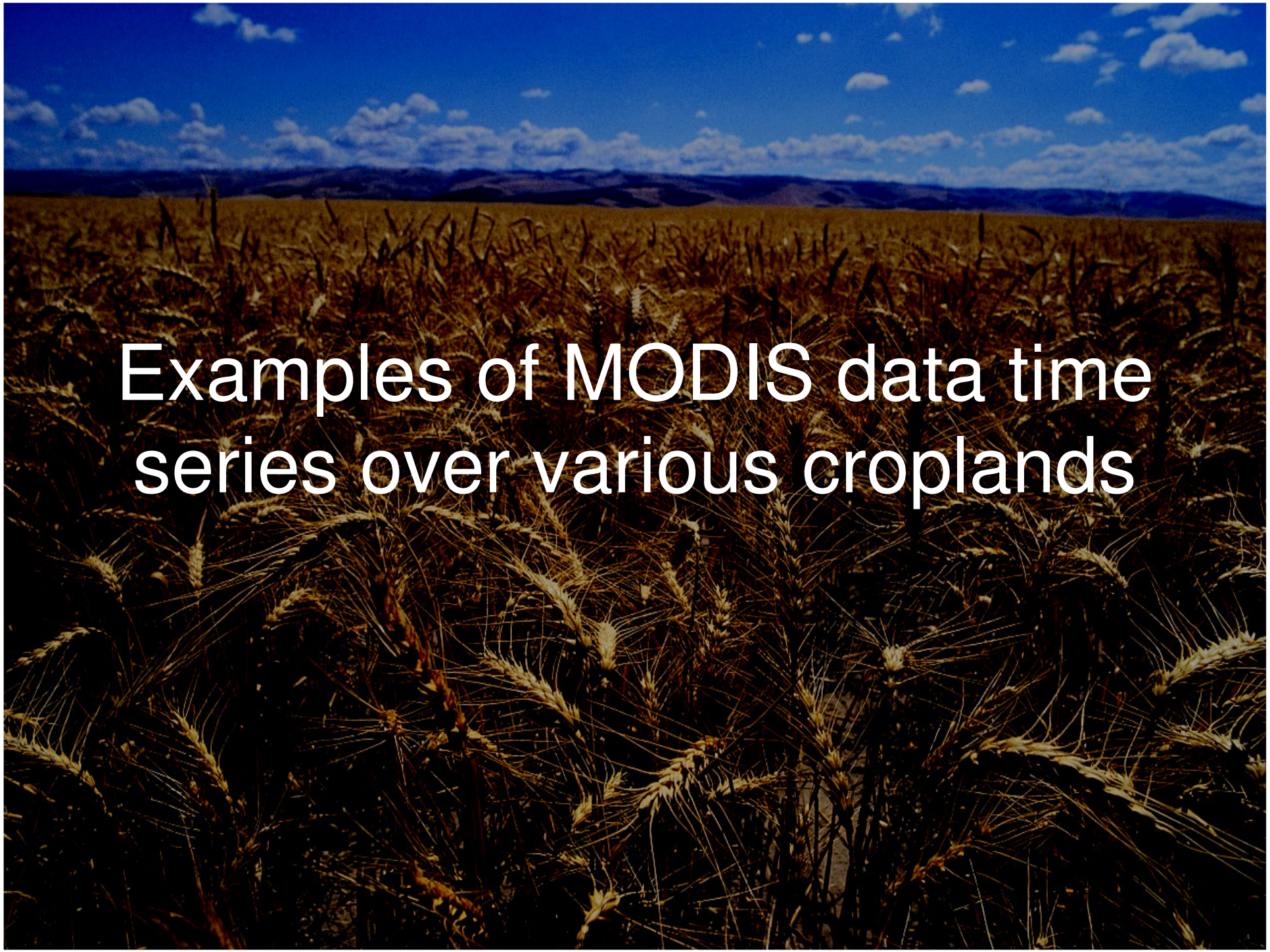
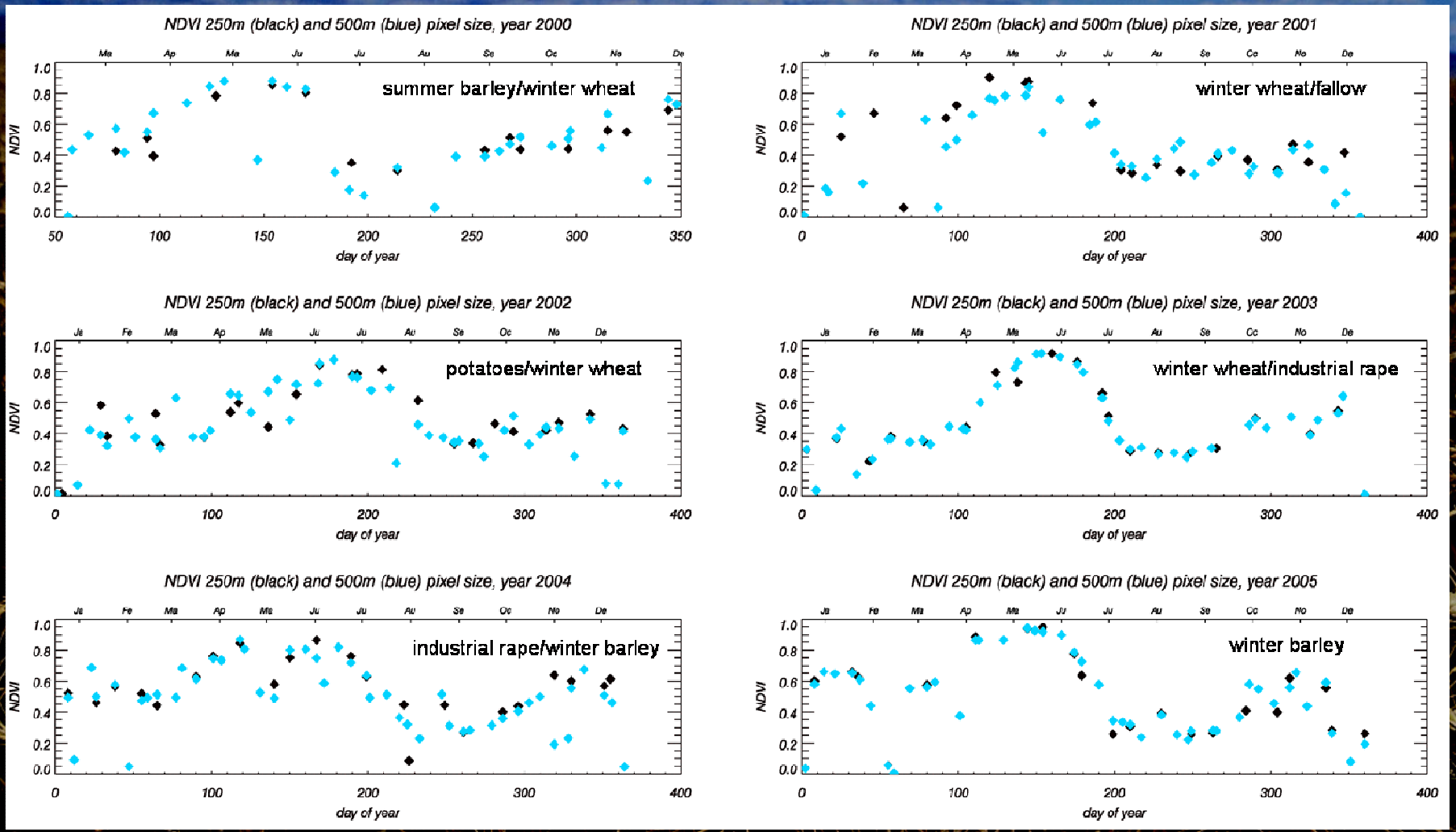

Examples of MODIS data time series over various croplands

MODIS Terra 250m (black) and 500m (blue) NDVI data over Gebesee, Germany



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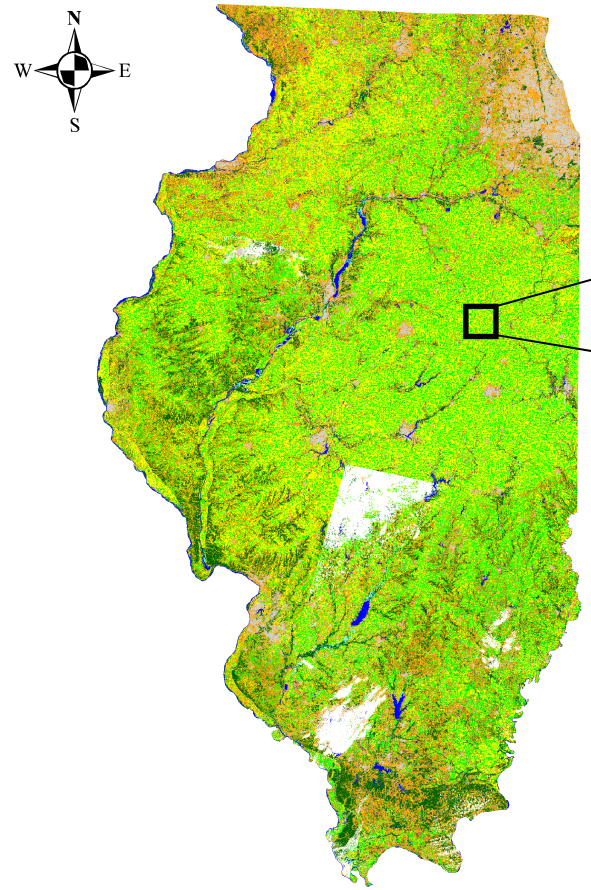
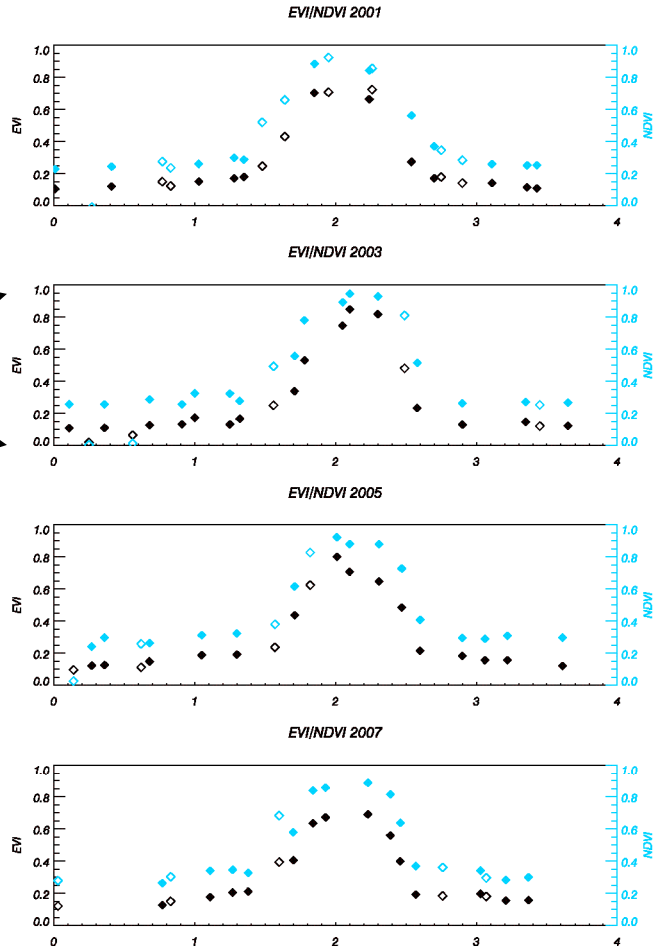
Bondville, Illinois: Maize/soybean rotation

Illinois crop classification map, 2005





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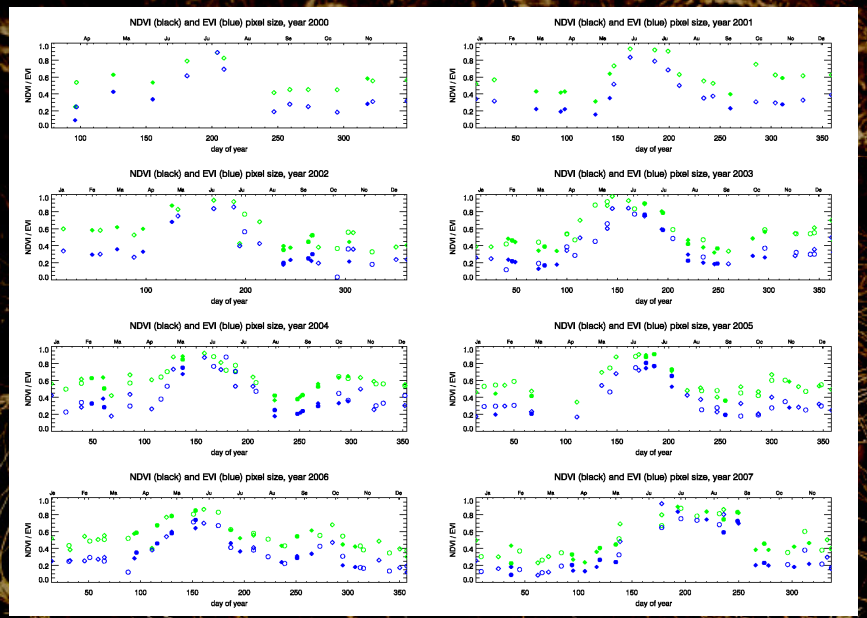
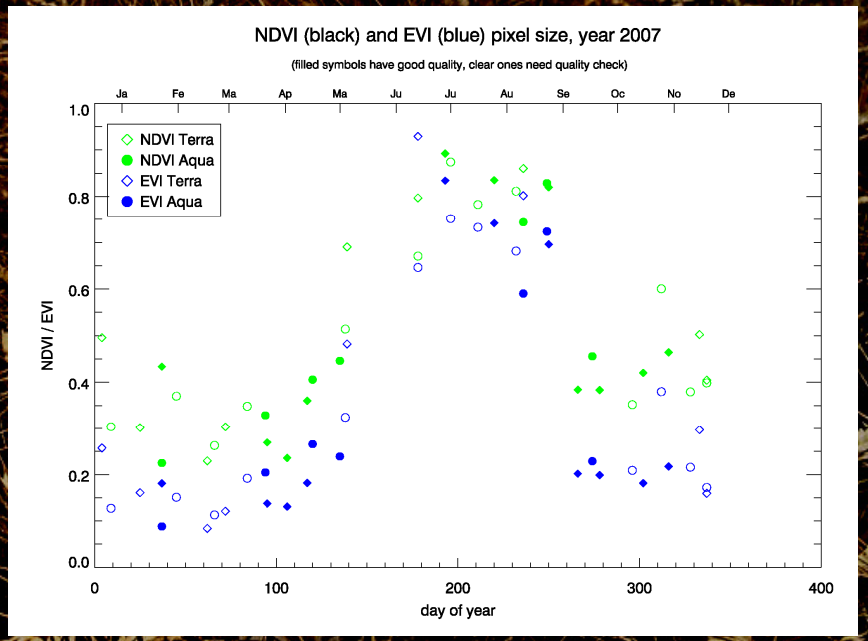
Scottish Crop Research Institute
(SCRI) field survey data…

Field 11A: 27ha, potato





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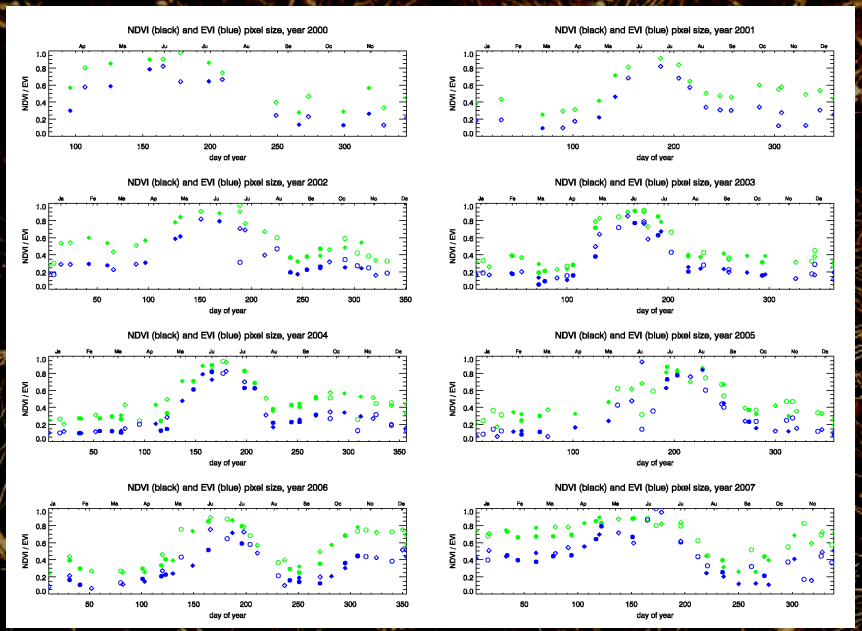
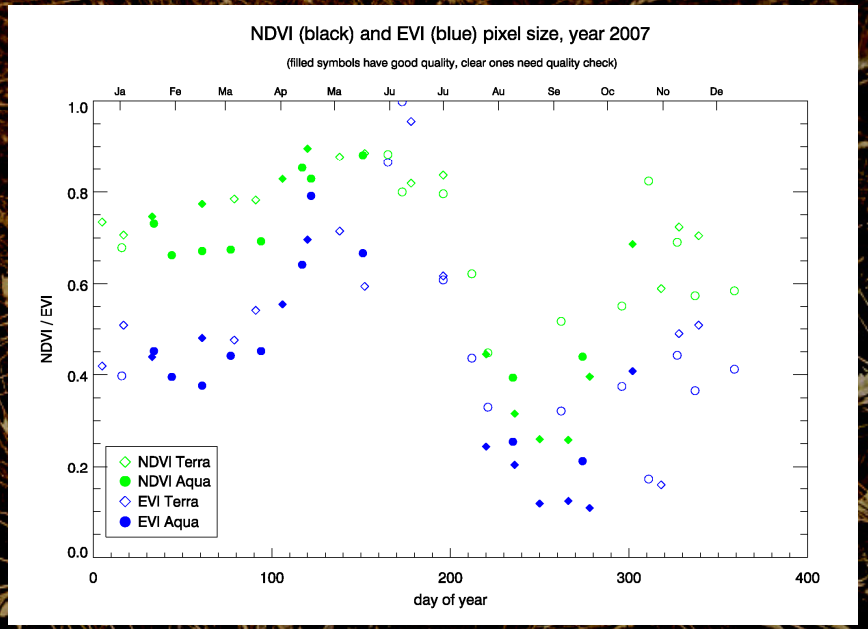
Field 53A: 28ha, winter oats





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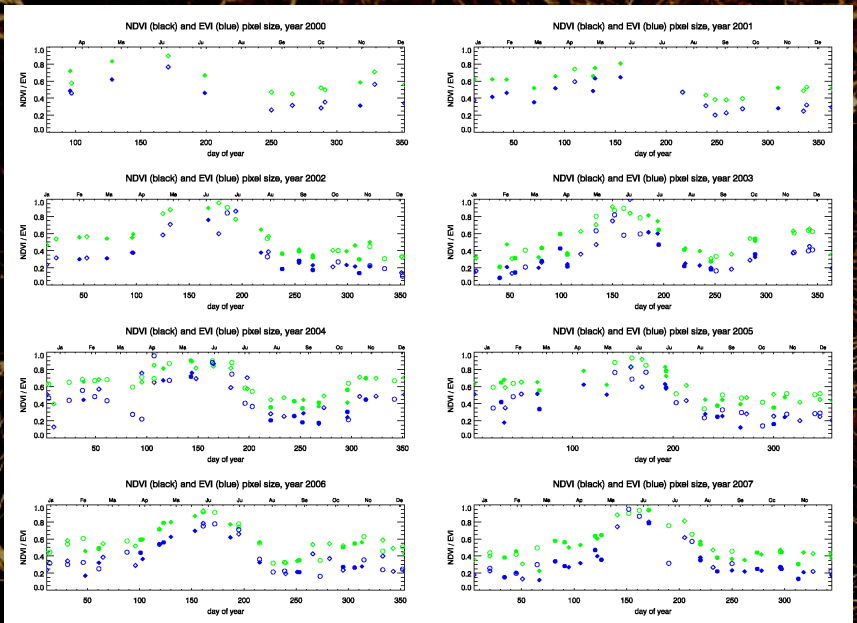
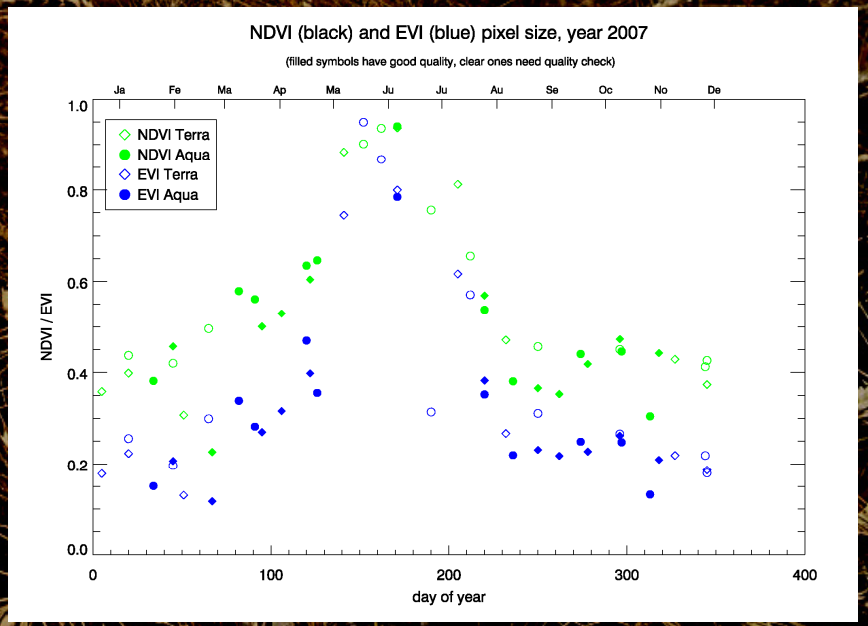
Field 42B: winter wheat, 5.7ha





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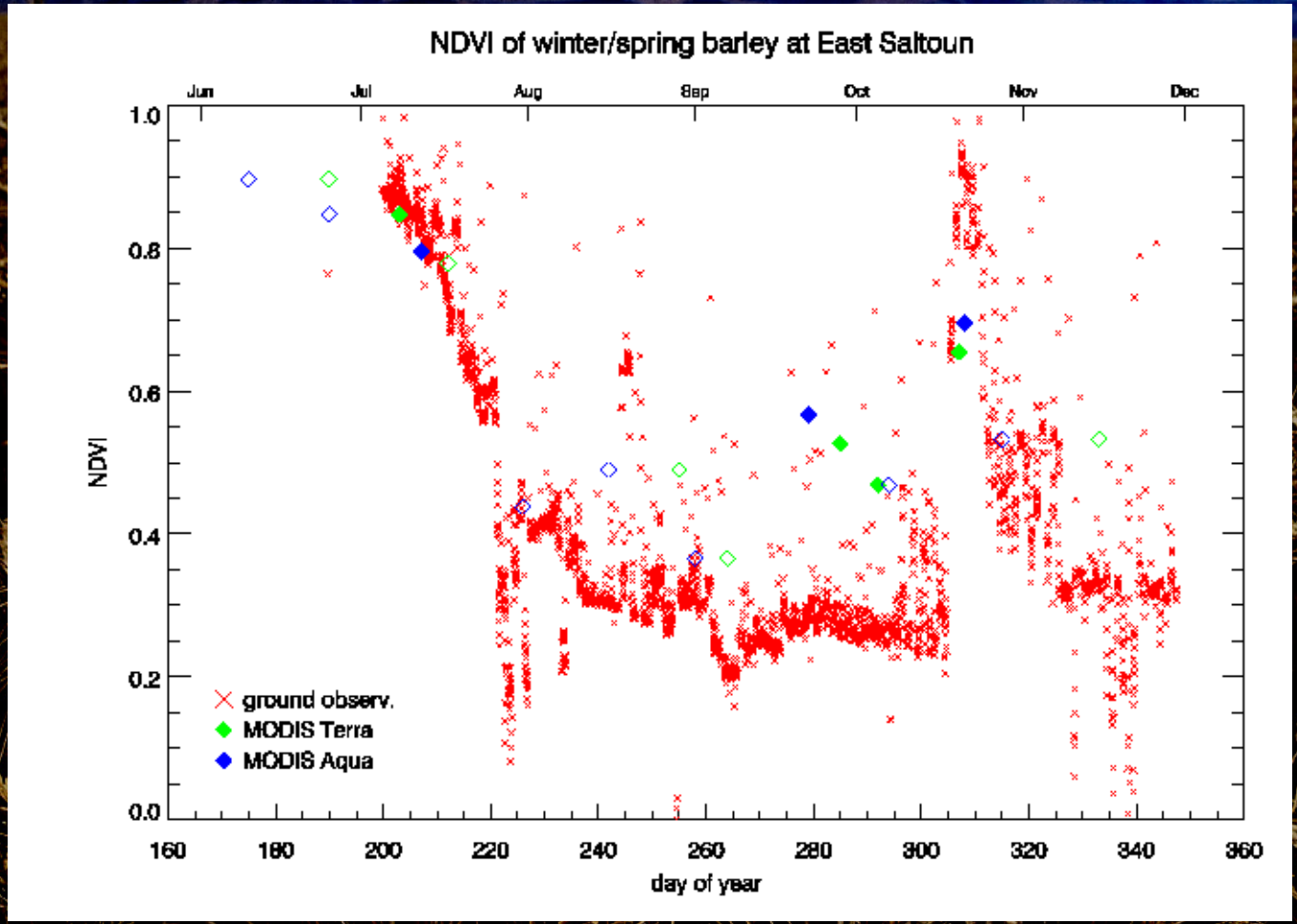
Ground truth data: NDVI of spring barley at the CarboEurope site East Saltoun



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Thank you