Crop modelling:
Sirius wheat simulation model

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Sirius: wheat simulation model

- Initially developed by Peter Jamieson from Crop & Food Research, NZ; since 1992 development in collaboration with Mikhail Semenov at Rothamsted Research, UK

- Intensively tested in different environments and used in many countries ([www.rothamsted.bbsrc.ac.uk/mas-models/sirius.php](http://www.rothamsted.bbsrc.ac.uk/mas-models/sirius.php))

- Sirius is a part of the GCTE International Wheat Network
Sirius: wheat simulation model

Inputs
- Daily Weather
- Management
- Cultivar
- Soil

Outputs
- Grain yield
- Grain quality
- N leaching
- Water and N uptake
Sirius: a process-based model

- Radiation Use Efficiency and biomass accumulation
- Phenological development
- Canopy model
- Nitrogen uptake and redistribution
- Evapotranspiration and water limitation
- Soil model
Modelling growth: Radiation Use Efficiency

Radiation Use Efficiency

Biomass = RUE*R
R intercepted radiation

Beer's Law

P = 1 - exp(-k LAI)
P proportion of light intercepted
Modelling canopy

- Phenology is used to predict emergence times of individual leaves
- Deal with leaf “layers”
  - avoid consideration of tillers
  - avoid adding extra parameters for calibration
- Define genetic potential growth
Sirius grows a canopy (LAI) according to simple rules involving temperature, water and N supply; parameters (not rules) vary with cultivar.
Modelling phenology

- Pre-emergence and after anthesis calculations are based on thermal time
- Calculation of anthesis is based on the final leaf number and the value of phyllochron
- Calculation of the final leaf number includes vernalization and daylength responses
N Limitation

Green area contains 1.5 g N/m²; “non-green” biomass can store 1% labile N.

Daily N-demand is set by the increment of new GA and biomass.

Unsatisfied demand limits the GA increment and/or causes N release through premature GA senescence.
Calibration and validation

- Calibration – measuring (direct) or fitting (indirect) model parameters to observed data

- Validation – using independent (not use during calibration) observed data for testing model skills
Validation of Sirius: N experiments

FACE, Maricopa, 1996/97

Reading, 1999/2000 (M. Clarke)
Sirius: soil, evapotranspiration & water limitation

☞ Soil model is based on modified SLIM (UK) and DAISY (DENMARK) models

☞ ET is calculated as the sum of transpiration and soil evaporation after Ritchie (1972). The upper limit is given by the Penman potential ET rate or the Priestley&Taylor equation

☞ Water stress factor reduces leaf expansion and accelerate leaf senescence.
Validation: water-limited grain yield

Measured yield (t/ha) vs. Simulated yield (t/ha)

Y = X

Canterbury, NZ
Rothamsted, UK
Maricopa, H2O
Validation: N uptake
Free-Air CO$_2$ Enrichment Project (FACE)

USDA-ARS U.S. Water Conservation Laboratory, Maricopa, USA

\[ \text{RUE} = f(\text{CO}_2) \]
Model complexity

- Model complexity is related to a number of model parameters and model equations

- Hierarchy of complexity:
  - Meta-model (Brooks et al, 2001);
  - Sirius (Jamieson et al., 1998), AFRCWHEAT (Porter 1993), CERES-Wheat (Ritchie and Otter, 1985);
  - Ecosys (Grant, 1998).
Simplifying model

- Mimic model output by non-linear regression

Model response surface

Fitted approximation
Simplifying model

Simplify a model by analysing model structure, model processes and its interactions.
Comparison between Meta-model and Sirius
Rothamsted, UK, 1960-1990 (50% precipitation)
Simulation results, Andalucian region, Spain, 1988-1999

<table>
<thead>
<tr>
<th></th>
<th>Obs</th>
<th>Meta</th>
<th>Sirius</th>
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<td>Obs</td>
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The scatter plot shows the comparison between observed and simulated data. The line indicates perfect agreement. The symbols represent different models: Meta (◊) and Sirius (□).
Application
Prediction of wheat growth in real time
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Prediction of wheat growth in real time

Observed weather

Generated weather

Management

Soil

Sirius

AGRIDE MA Workshop, Vienna, 2005
Weather uncertainty in real-time predictions

Accumulated rainfall, mm
Grain prediction using mixture of observed and generated weather at Rothamsted, 1997

![Graph showing grain yield over time with observed and predicted weather data.](image-url)
Lead-time for predicting wheat growth at Rothamsted
Lead-time for predicting grain yield in diverse climates

Grain yield can be predicted with 0.9 probability:
in Toulouse 40 days and
in Tylstrup 65 days before maturity
Publications

- WWW: www.rothamsted.bbsrc.ac.uk/mas-model/sirius.html