Delivering local-scale climate scenarios for impact assessments

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Outline

• Nonlinear responses of impact models
• Downscaling with WGs
• ELPIS: a dataset of local-scale climate scenarios
• Example
Importance of climatic variability

Rate of photosynthesis as a function of temperature and light intensity.
Importance of extremes

- Heat shock at flowering can decrease the grain number (Mitchell et al, 1995; Wheeler et al 1996)

- Heat shock shortly after flowering can decrease the potential grain size (Wardlaw et al 1989)
Requirements for climate scenarios for impact assessments

• Should include the full set of climate variables required by impacts models
• Should be daily site-specific and be able to reproduce climatic variability and extremes
• Should contain an adequate number of years for risk analysis
• Should incorporate predicted changes in mean climate and climate variability
Coarse spatial resolution of GCM means that sub-grid scale processes, such as precipitation, are not adequately resolved.

GCM/RCM outputs are biased.
Downscaling techniques

Dynamic downscaling
A regional climate model is nested within GCM and run over a region using boundary conditions from GCM

Statistical downscaling
Derives statistical relationships between observed small-scale variables and larger (comparable to GCM) scale variables, using various techniques (circulation patterns, regression analysis, or neural network)

Weather generator
WGAs as a downscaling tool

1. Baseline: estimate WG parameters of the distributions for climatic variables for a site using observed daily weather

2. Derived from GCM/RCM $\Delta$-changes for climatic means and variability between baseline and future predictions

3. Adjust WG distributions for a site with $\Delta$-changes

4. Using adjusted WG parameters for a site generate local-scale climate scenarios
ELPIS: a dataset of local-scale climate scenarios for Europe

• Underlying observed daily weather from the European Crop Growth Monitoring System (CGMS) meteorological dataset from the EC JRC

• Climate projections from multi-model ensembles, including CMIP3 and EU-ENSEmbles (CMIP5 is coming)

• LARS-WG weather generator

(Semenov et al., 2010)
CGMS meteorological dataset

• Daily data for precipitation, temperature and radiation from ~3000 stations for 1982-2009 have been interpolated to a regular 25-km grid over Europe

• Interpolated daily data represents daily weather at a typical site from the grid used for agricultural production

• CGMS is used for various agricultural assessments for the EC in conjunction with agricultural models
Multi-model ensembles incorporated in ELPIS

<table>
<thead>
<tr>
<th></th>
<th>CMIP3</th>
<th>EU-ENSEMBLES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Climate models</strong></td>
<td>15 GCMs</td>
<td>9 RCMs embedded into 9 GCMs</td>
</tr>
<tr>
<td><strong>Spatial resolutions</strong></td>
<td>1.9° × 1.9° to 4° × 5°</td>
<td>25 km or 50 km</td>
</tr>
<tr>
<td><strong>Emission scenarios</strong></td>
<td>SRES-A1B, B1 (some for A2)</td>
<td>A1B</td>
</tr>
<tr>
<td><strong>Regions</strong></td>
<td>global</td>
<td>Europe</td>
</tr>
<tr>
<td><strong>Future projections</strong></td>
<td>2011-2030, 2046-2065 and 2081-2100</td>
<td>2011-2030, 2030-2050</td>
</tr>
</tbody>
</table>
LARS-WG weather generator

- Generates precipitation, min and max temperature, radiation and potential evapotranspiration
- Modelling of precipitation event is based on wet/dry series
- Semi-empirical distributions are used for distribution of climatic variables
- Temperature and radiation are conditioned on the wet/dry status of a day and auto- and cross-correlated
- LARS-WG was extensively tested in diverse climates and is used in more than 65 countries for research and in several Universities as an educational tool
- LARS-WG is available for academic, governmental and non-profit organizations from http://www.rothamsted.ac.uk/mas-models/larswg.php
Fitted distributions

• **Parametric** (WGEN, Richardson & Write, 1984)
  small set of parameters, prior assumptions on distributions

• **Semi-parametric** (LARS-WG, Semenov et al 1998)
  small set of parameters, no prior assumptions on distributions

• **Resampling** (Resampling, Lall & Sharma, 1996)
  Original dataset used to resample time-series
Skills of WGs in diverse climates

<table>
<thead>
<tr>
<th>Site</th>
<th>Series</th>
<th>Rain</th>
<th>Month mean</th>
<th>Month var</th>
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<tr>
<td>Athens</td>
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<td>0</td>
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<td>Bismarck</td>
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<td>Boise</td>
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<td>0</td>
<td>2</td>
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<td>1</td>
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<td>Caribou</td>
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<td>Jokioinen</td>
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<td>Tucson</td>
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<td>Verhojansk</td>
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<td>Wageningen</td>
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<td>5</td>
</tr>
</tbody>
</table>

(Semenov et al, 1998)
Overdispersion in WGs

WG's often fail to capture interannual variability

Monthly temperature

Daily temperature
Simulation of extreme events by LARS-WG

<table>
<thead>
<tr>
<th>Precipitation</th>
<th>Maximum temperature</th>
<th>Heat waves</th>
</tr>
</thead>
</table>

![Graph showing Observed vs. Model Returns for Precipitation](image1)

![Graph showing Observed vs. Model Returns for Maximum Temperature](image2)

![Graph showing Observed vs. Model Returns for Heat Waves](image3)

(Semenov, Climate Research, 2008)
Performance of LARS-WG at CGMS dataset

Proportion of CGMS grids with the number of significant test results at the significance level $\alpha = 0.01$
Test results for mean temperature
Test results for radiation means
Validation of ELPIS using ECA&D dataset
Validation of ELPIS using ECA&D dataset
ELPIS: open architecture

GCM/RCMs ensembles

Baseline parameters for regions

Local-scale climate scenarios
ELPIS-JP: a dataset of local-scale climate scenarios for Japan

(lizumi et al, Phil. Trans. R. Soc. A, 2012)
Impact on wheat: identifying future threats

Maximum temperature and precipitation at SL, Spain and RR, UK for 2050 as predicted by CMIP3 compared with baseline 1960-1990
Yield losses from drought stress decreased

Soil water deficit at anthesis and 95-percentiles of DSI (drought stress index) for baseline and for 2050 (A1B)

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>1960-90</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avalon</td>
<td>Maturity</td>
<td>8 Aug</td>
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</tbody>
</table>

(Semenov & Shewry, Sci Reports, 2011)
Probability of heat stress at flowering increased

Probability of maximum temperature exceeding 27°C within 3 days of anthesis or consecutively at and after anthesis for baseline and for 2050 (A1B)

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>1960-90</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mercia</td>
<td>Flowering</td>
<td>19 June</td>
</tr>
<tr>
<td>Tmax at flowering, °C</td>
<td>19.36</td>
<td>20.42</td>
</tr>
</tbody>
</table>


Semenov MA & Shewry PR Modelling predicts that heat stress, not drought, will increase vulnerability of wheat in Europe. (2011) Scientific Reports, 1:66

Wilks DS (2009) A gridded multisite weather generator and synchronization to observed weather data. Water Resources Research 45

WWW: www.rothamsted.bbsrc.ac.uk/mas-model/larswg.php