Linking the climate change scenarios and weather generators with agroclimatological models

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&

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part 1

Introduction
Thanks to…

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  – Pierpaolo Zara
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  – Valentina Mereu
  – ................................................ and others

• co-authors
  – Mirek Trnka
  – Zdenek Zalud
  – Daniela Semeradova
  – Petr Hlavinka
  – Eva Kocmankova
  – Lenka Bartosova

• Juergen Grieser & FAO
About this presentation

• This presentation is mostly based on conference contributions + some new slides which should link everything together

• It is divided into four parts:
  – introduction
  – scenarios
  – weather generators
  – applications
  … but sometimes I may mix it a little bit

• I am not a professional teacher, so excuse me
  – when I’ll be too long (going too much “into details”)
  – when I’ll be too short (giving you all unnecessary details)

• … and I am not an agriculturist

• interrupt me whenever you will need
  – more / less details
  – to ask me about anything
  – coffee, break, or anything else…. 
Introduction: Czech Republic (= Czechia)

- **Czechia** = Bohemia + Moravia
- **area**: 78866 km²
- **inhabitants**: 10 million
- **elevation**:
  - **MIN**: 115 m (Labe river exit to Germany)
  - **MAX**: 1602 m (Snezka mountain)
    - (skiing still popular in our country)
  - **AVG**: 430 m
  - (67% below 500 m)
Czechia - climate

- temperate continental climate, with
  - relatively hot summers (swimming season: June-August)
  - cold, cloudy and snowy winters (skiing season: December-March)
  - coldest / warmest month: January / July (July – January ~ 20°C)
  - Most rain falls during the summer

- distribution of the mountains plays an important role
  - Snezka mountain (1602 m): $T_{ann} \sim 0°C$
  - South Moravian lowlands: $T_{ann} \sim 10°C$

- Kőppen climate classification:
  - majority of CZ: Cfb, which changes to Dfb and Dfc with increasing altitude.
    - The Cfb climate implies at least 30 mm of precipitation each month, with the warmest month’s average temperature being below 22°C, but having at least 4 months with an average temperature above 10°C
    - Dfb and Dfc differ from Cfb by having lower temperatures.

source: Climate atlas of Czechia
Czech Republic - agriculture

- **arable land**: 2,568,000 ha (~33 % of the Czechia’s area)
- **permanent grassland**: 920,082 ha (~12%)

- **main crops**:
  - **Cereals** in total: 1,580,092 ha
    - Winter wheat: 760,399 ha
    - Spring barley (for beer😊): 341,220 ha
    - Grain maize: 113,777 ha

- **Technical crops**: 490,146 ha
  - Winter oil-seed rape: 356,924 ha
  - Poppy: 69,793 ha

- Fodder crops on arable land (maize for sillage, green oat, alfa-alfa, clover etc.): 400,283 ha
- Active **hop gardens**: 5,335 ha
- Yielding **vineyards**: 16,302 ha

- **Livestock**: since 1989 permanent decline
  - Cattle (3.5 mil in 1989 – 1.36 mil in 2009)
  - Pigs – 4.7 mil in 1989 – 1.97 mil in 2009
  - Poultry – 32.5 mil in 1989 – 26.5 mil in 2009
  - Sheep – 0.4 mil in 1989 – 0.18 mil in 2009
Czech Republic – products of agriculture

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Czechia: opportunities to study agriculture and meteorology & climate change impact studies

- **studying agriculture in Czechia:**
  - University of Agriculture and Forestry in Brno
  - Agricultural University in Prague

- **studying meteorology & climatology in Czechia:**
  - Charles University, Prague (Faculty of Mathematics and Physics)
  - Faculties of Natural Sciences in major universities (Charles Univ., Masaryk Univ. /Brno/, Palacky Univ. /Olomouc/)

- **1990:** National Climate Program founded in Czechoslovakia

- **1995:** „climate change studies boom“ started when our country has participated in the U.S. Country Studies Program sponsored by U.S. Environmental Protection Agency

- **also 1995:** our group established (as a result of U.S. Country Studies Program)
our group (present state)

• our “informal” group was founded in 1995 (Zdenek Zalud and Martin Dubrovsy)

Mendel Univ. of Agriculture and Forestry, Brno, Czech Rep. (MUAF):
• Zdenek Zalud
• Mirek Trnka
• Daniela Semeradova
• Petr Hlavinka
• Eva Kocmánková
• Lenka Bartošová

Inst. of Atmospheric Physics, Prague, Czech Rep. (IAP):
• Martin Dubrovsky

www.ufa.cas.cz/dub/crop/crop.htm
our group

• Mendel University of Agriculture and Forestry:
  – crop modelling (CERES-Wheat/Maize/Barley, WOFOST, STICS)
  – pest & diseases modelling (ECAMON, Climex, Dymex)
  – soil modelling (SoilClim)
  – modelling for agroclimatological indices (AgriClim), ….
  – model for snow cover: SnowMAUSE
  – phenology: observations & modelling (FenClim)

→ Demands on climate & weather data to run their models under present + changed climate

my role in our team:
  – construction of climate change scenarios (from GCM & RCM)
  – construction of input weather series representing “now” and “future” (using the weather generator)
  – linking the scenarios & WG with MZLU’s models
Crops

- **crop modelling** (= our first topic – since 1995 /CERES/)
  - CERES
  - WOFOST
  - STICS

- **crop yield forecasting:**
  - PERUN (based on WOFOST + Met&Rol)

- **impacts of climate change**
  - **sensitivity** to changes in stat. structure of inp. weather
  - **spatial assessments**
    - crop modelling + interpolation
    - or: interpolation of WG + simulation
  - **adaptation** through
    - different cultivars
    - shifting the sowing date
    - Increasing soil water reserves

- **references** ([www.ufa.cas.cz/dub/crop/crop.htm](http://www.ufa.cas.cz/dub/crop/crop.htm))
  - Dubrovsky et al., 2000
  - Zalud and Dubrovsky, 2002
  - Trnka et al. 2004a, 2004b
  + conference contributions
Pests and diseases

• **observations:**
  – MZLU’s observations (1961-2008); for some pests (diseases) archives reach back to late 19th century

• **trends and climate change impacts on**
  – Colorado potato beetle (……. figure:
  – European corn borer

• **modelling:**
  – **Climex:** climate matching software developed by CSIRO (Australia)
  – **Dymex:** modelling tool enabling easy custom-base development of own pest-disease models
  – **ECAMON:** model for estimating suitability of environmental conditions for European Corn Borer populations (developed by Trnká)

• **references:**
  – Trnká et al., 2007, Ecological Modelling 207, 61-84
  – Kocmánková et al., 2008, Plant Protection
  – Kocmankova et al., 2008, EMS
  – Kocmankova et al., 2009, EGU

Ecoclimatic Index [Climex model] of Colorado potato beetle in CZ (1961-90; 1991-2000; 2025; 2050) [Kocmankova et al., 2009, EGU]
Phenology

- **focus on:**
  - trends in phenophases
  - climate change impacts (via FenoClim model now being under development)

- **observations** (South Moravia, 1951-2009):
  - **Trees, shrubs and plants**: in natural reserves and agriculture systems (around 25 species) at 6 locations
  - **Birds**: 4 species (including information on the food chain)

- **references**:
  - Bartosova et al., 2008, EMS
  - Bartosova et al., 2009, EGU

Onset of phenological stages during individual decades within 1961-2007. [Bartosova et al., 2009, EGU]
Drought

- **since 2003** (together with NDMC in Lincoln, Nebraska)

- **focus on**
  - drought indices (SPI, PDSI, Z) (their use and modification)
  - projection of future drought conditions (CZ, Europe, globe)
  - development of soil model SoilClim (see next slide)
  - impacts on yields [Fig. ← ]

- **references:**
  - Trnka et al., 2007, *Plant Soil Environ.*
  + conference contributions

Statistical significance of relation between rZ and crop yields at district level [Hlavinka et al., 2007, EMS; Hlavinka et al, 2009, *Agric. For. Meteorol.*]
Soil modelling

**SoilClim** = model (by Trnka + collaboration with NDMC) based on Newhall model

**inputs:**
- **soil properties** affecting water movement and heat transfer
- **daily weather series** (SRAD, TMAX, TMIN, PREC, VAPO, WIND)

**modelled characteristics:**
- Soil hydric and thermic regimes
- "vegetation window"
- drought and wet events, etc.

**applications:**
- projections of future soil climate in Europe and U.S.

**references:**
- Trnka et al. 2008, AGU
- Hlavinka et al., 2009, EGU

Selected soil-climate characteristics for present (1985-2005) and future (2050; SRES-A2 * mid.clim.sens * 3GCMs). [Trnka et al., 2009, EGU]
• development of models:
  – **AgriClim** : model for Agroclimatic indices – presently being used in COST 734 study covering whole Europe
  – **SnowMaus** : snow cover model (anybody is interested in modelling snow cover in Sardinia?) [Trnka et al., submitted, Ecological modelling; Trnka et al., 2007, EMS; Trnka et al., 2008, EMS]
  – **GRAM** : grassland statistical model [Trnka et al., 2006, Grass and Forage Science 61 (3): 253-271]

• solar radiation, UV-B
  – estimating global solar radiation from proxies and consequent error propagation in crop models [Trnka et al., 2005, Agriculture and Forest Meteorology; Trnka et al., 2007, Sensors (open access journal)]
  – estimating UV-B from global radiation [Hlavinka et al., 2006, Meteorologische Zeitschrift]
international collaboration

• collaboration with institutes:
  – BOKU Wien
  – NDMC Lincoln-Nebraska
  – FAO (incl. Juergen Grieser)

• participation in projects:
  – NATO
  – AGRIDEMA
  – ADAGIO
  – Cecilia
  – COST-734
climate change impacts on crops - methodology

- multi-year simulation is made to assess mean and variability
- other models may be used instead of the crop model
- crop model is assumed to be calibrated and set to deal with variable climate conditions (e.g. "automatic" sowing day is used)
Q: How to get site-specific future-climate weather series?

• most methods use GCM outputs:
  – **direct use of GCM output?** No: GCM fails to fit both annual cycle, nor temporal structure
  – **dynamical downscaling?** (GCM → RCM): Regional Climate Models (RCMs) are more detailed than GCMs, but still not satisfactory (RCM-based series should be post-processed; *see next slides for RCM validation*)
  – **statistical downscaling?** (circulation / upper-air/ → surface weather)
  – **our approach:**
    - GCM-based climate change scenarios (derived from GCMs or RCMs)
    + Weather Generators

where:
- **climate change scenario** = changes in selected surface climatic characteristics (AVG, STD, …), typically for individual months
  a) **Delta approach**: \[ \Delta X = X(\text{future}) - X(\text{now}) \text{ or } \frac{X(\text{future})}{X(\text{now})} \]
  b) **pattern scaling**: \[ \Delta X = \Delta X^* \times \Delta T_G \] (*more details given later*)
RCM vs OBS: TMAX (July)

- **RCM**: Aladin driven by ERA-40
- **observations**: COST-734 database

RCM ~ OBS
RCM vs OBS: $\text{std}(\text{TMAX})$ [JUL]

- **RCM**: Aladin driven by ERA-40
- **observations**: COST-734 database

RCM < OBS ... RCM > OBS
RCM vs OBS: PREC(avg.daily sum) [JUL]

- **RCM**: Aladin driven by ERA-40
- **Observations**: COST-734 database
RCM vs OBS: \( \text{prob}(\text{PREC}>0) \) [JUL]

- **RCM**: Aladin driven by Reanalysis
- **observations**: COST-734 database

RCM >> OBS!
scheme of cc impacts study

GCM output

obs.wea.series (~15-30 years...)

WG (present climate)

CC scenario

WG (future climate)

info about
- plant genetics
- soil properties
- growing site
- management

synt.wea.series (present climate)

CC scenario

synt.wea.series (future climate)

CROP GROWTH MODEL

model “yields” (obs.wea.)

model “yields” (synt.wea: “presence”)

model “yields” (synt.wea.-”future”)

A: validation of crop model
B: validation of WG
C: indirect validation of WG
D: climate change impacts
   (comparison made in terms of means, variability, extremes)
TWO approaches to preparing Daily weather series for the Changed climate

a) direct modification of observed series:

pros:
- shape of distribution preserved
- limited length

cons:
- less control on other characteristics

x(t) = observed series
d(t) = climate change scenario
x'(t) = weather series representing present climate

b) stochastic wea. generator

pros:
- various characteristics may be modified
- arbitrary long
- may be interpolated!!!

cons:
- no WG model is perfect…

Ex = present “climate”
d(t) = climate change scenario (may include changes in AVG, VAR, …) [!!!]
Ex’ = future climate

Ex’ = future climate
a) Direct Modification (DM) approach

**Legend:**

- $\text{WO}^\prime(i) = \text{modified observed weather}$
- $\text{INP}(i) = \text{non-meteo input to crop model}$
- $\text{Y}, \text{Y}^\prime(i) = \text{crop yield}$
- $\text{WO}(i) = \text{observed weather (present)}$
- $i = \text{index of the year}$
b) **Weather Generator (WG) approach**

Legend:
- $WS(i)$ = synthetic weather (present)
- $WS'(i)$ = synthetic weather (future)
- $INP(R)$ = non-meteo input based on a representative year
- $Y(i)$, $Y'(i)$ = crop yield
- $i$ = index of the year
- $\text{avg}(Y)$, $\text{std}(Y)$, $\text{med}(Y)$, $Q25(Y)$, $Q75(Y)$, ... = statistical measures