

HOWGH

- an hourly weather generator for pests modeling in present and future climates

Martin Dubrovsky ⁽¹⁾, Martin Hirschi ⁽²⁾, Christoph Spirig ⁽²⁾

(1) Institute of Atmospheric Physics ASCR, Prague, Czech Republic (dub@ufa.cas.cz)

(2) Federal Office for Meteorology and Climatology MeteoSwiss, Zurich, Switzerland

Acknowledgements: The development of the weather generator is supported by the GAAV Grant Agency (project IAA300420806). Funding for the downscaling and pest simulation experiments was provided by COST Action 734 (CLIVAGRI) and the National Centre of Competence in Research on Climate (NCCR Climate) of the Swiss National Science Foundation.

1. Introduction

Agriculture is assumed to be largely affected by **indirect effects of climate change, such as changes in pest populations**. In the warmer climate, agricultural pests are generally expected to occur more frequently and possibly extend to previously unaffected regions. **To quantify impact** of the projected climate change on a specific pest in a specific site, **we may use a calibrated pest model** and compare the outputs obtained with site-specific weather data representing present vs. future climates. This contribution focuses on the **HOWGH weather generator**, which produces synthetic hourly weather data required by a **dynamic pest model SOPRA** simulating the development of codling moth.

2. Hourly weather generator HOWGH

- is based on a **combination of parametric and non-parametric statistical methods**
- allows to generate **optional number of weather variables**
- here it is used to generate hourly series of three weather variables required by SOPRA pest model:
 - solar radiation, temperature, precipitation

The **algorithm consists of three steps** (*see the scheme below*):

(i) Generating daily values by M&Rfi weather generator, which is based mostly on parametric modelling:

- precipitation occurrence ~ Markov model
- PREC amount ~ Gamma distribution
- SRAD + 2 temperature variables [(SRAD, TMAX, TMIN) or (SRAD, TAVG, DTR) or (SRAD, TMID, DTR)] ~ 1st-order AutoRegressive model]

(ii) For each single day generated by M&Rfi, the hourly values are sampled from the observational hourly database

(iii) The sampled hourly values are fitted to driving daily values generated by M&Rfi

HOWGH – scheme:

observed hourly series
 1981-01-01:00 [SRAD, TAVG, PREC]
 1981-01-01:02 [SRAD, TAVG, PREC]
 ...
 2009-12-31:22 [SRAD, TAVG, PREC]
 2009-12-31:23 [SRAD, TAVG, PREC]

daily series:
 1981-01-01: [SRAD, TAVG, PREC]
 1981-01-02: [SRAD, TAVG, PREC]
 ...
 2009-12-31: [SRAD, TAVG, PREC]

**calibrated M&Rfi WG
 = WG parameters:**
 PREC occurrence: Markov chain
 PREC amount: Gamma distribution
 (SRAD, TMAX, TMIN) ~ AR(1)

learning series consisting
 of **daily** values + **hourly** values

1981-01-01: [SRAD, TAVG, PREC], [SRAD, TAVG, PREC]_{i=0..23}
 1981-01-02: [SRAD, TAVG, PREC], [SRAD, TAVG, PREC]_{i=0..23}
 1981-01-03: [SRAD, TAVG, PREC], [SRAD, TAVG, PREC]_{i=0..23}
 1981-01-04: [SRAD, TAVG, PREC], [SRAD, TAVG, PREC]_{i=0..23}
 1981-01-05: [SRAD, TAVG, PREC], [SRAD, TAVG, PREC]_{i=0..23}
 1981-01-06: [SRAD, TAVG, PREC], [SRAD, TAVG, PREC]_{i=0..23}
 ...
 ...

synthetic daily series
 1981-01-01: [SRAD TAVG PREC]
 1981-01-02: [SRAD TAVG PREC]
 ...
 2009-12-31: [SRAD TAVG PREC]

2. sampling

...
 ...
 2009-12-30: [SRAD TAVG PREC], [SRAD TAVG PREC]_{i=0..23}
 2009-12-31: [SRAD TAVG PREC], [SRAD TAVG PREC]_{i=0..23}
 2009-12-30: [SRAD TAVG PREC], [SRAD TAVG PREC]_{i=0..23}
 2009-12-31: [SRAD TAVG PREC], [SRAD TAVG PREC]_{i=0..23}
 2009-12-30: [SRAD TAVG PREC], [SRAD TAVG PREC]_{i=0..23}
 2009-12-31: [SRAD TAVG PREC], [SRAD TAVG PREC]_{i=0..23}

2. synthetic daily + hourly series
 1981-01-01: [SRAD TAVG PREC], [SRAD TAVG PREC]_{i=0..23}
 1981-01-02: [SRAD TAVG PREC], [SRAD TAVG PREC]_{i=0..23}
 1981-01-03: [SRAD TAVG PREC], [SRAD TAVG PREC]_{i=0..23}
 ...
 ...
 2009-12-30: [SRAD TAVG PREC], [SRAD TAVG PREC]_{i=0..23}
 2009-12-31: [SRAD TAVG PREC], [SRAD TAVG PREC]_{i=0..23}

3. adjusting
 hourlies to dailies

synthetic hourly series
 1981-01-01: [SRAD TAVG PREC]_{i=0..23}
 1981-01-02: [SRAD TAVG PREC]_{i=0..23}
 1981-01-03: [SRAD TAVG PREC]_{i=0..23}
 ...
 ...
 2009-12-30: [SRAD TAVG PREC]_{i=0..23}
 2009-12-31: [SRAD TAVG PREC]_{i=0..23}

3. Finetuning the weather generator

The performance of the whole algorithm may be adjusted through:

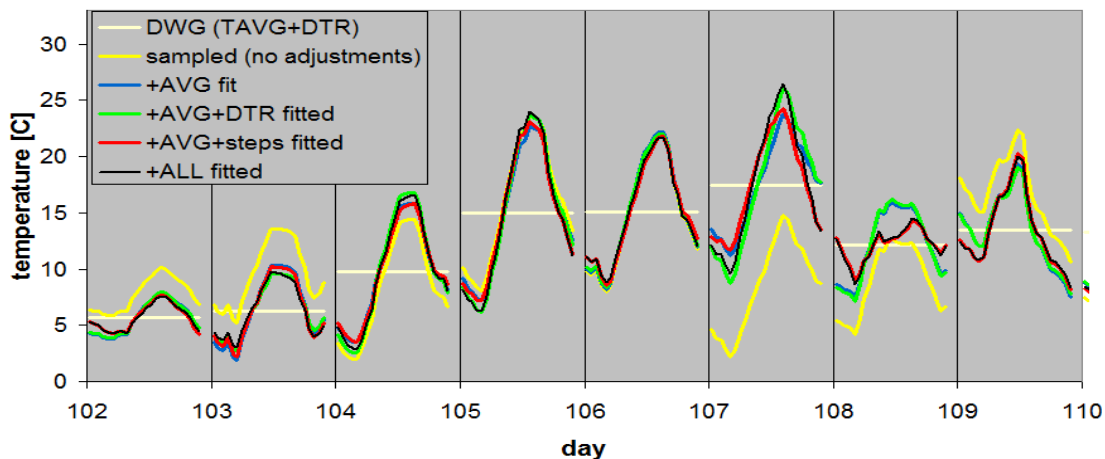
- (i) settings of the driving daily WG M&Rfi, e.g.:
 - order of the Markov chain (1 - 3)
 - representation of temperature: TAVG+DTR vs TMAX+TMIN vs. TMID+DTR
- (ii) settings of the resampling procedure (e.g. definition of the distance)
- (iii) adjusting hourly to dailies (see Fig. 1)

The present experiments focus on [shown in Figs.2a-b]:

- (i) the effect of representing temperature in daily WG
- (ii) effect of the hourly-to-daily adjustments

Fig.1: Fitting sampled hourly TEMP values to driving daily values

motivation: Daily averages/sums of the sampled hourly values do not fit values produced by daily WG. In result, the statistical structure of the daily series aggregated from the hourly series is misreproduced. The fitting procedure may be used to reproduce the features of daily series.



DWG: daily temperatures generated by daily WG (DTR \neq TMAX-TMIN/ values are also generated but not shown here)

sampled: sampled hourly series with no fittings applied

+ AVG fit: hourly values are additively modified to fit TAVG(DWG)

+ AVG + DTR fit: both averages and daily temperature range is fitted

+ AVG + steps: daily averages are fitted and interdiurnal steps and reduced

- ALL fitted: AVG + DTR are fitted and interdiurnal steps are reduced

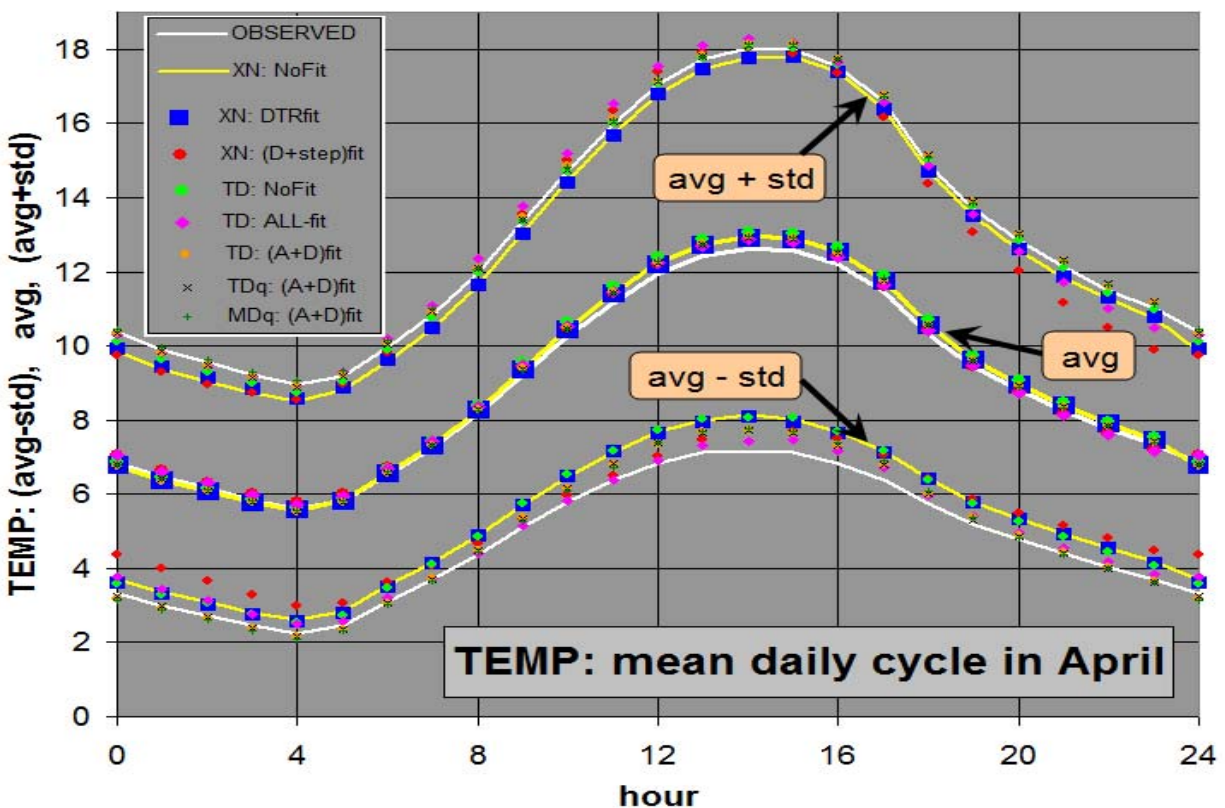
Figs. 2a-b: Effect of the WG settings on mean daily cycle of PREC and TEMP [data = Wädenswil, Switzerland; 1981-2009]

a) temperature

- **XN**: TMAX and TMIN are used in daily WG
- **TD, TDq**: TAVG and DTR are used in daily WG (DTR = TMAX-TMIN; *Dq indicates “normalized” DTR, which is transformed by quantile mapping)
- **MD, MDq**: TMID and DTR are used in daily WG [TMID = (TMAX+TMIN)/2]
- **NoFit**: hourly values are NOT fitted to daily values
- **DTR-fit**: only DTR is fitted
- **(A+D)-fit**: (AVG + DTR + steps) fitted
- **ALL-fit**: (AVG + DTR + steps) fitted

b) precipitation

- **NoFit**: hourly values are NOT fitted to daily values
 - **A-fit**: $P'(h) = P(h) * k$...[adjustment is proportional to $P(h)$]
 - **C-fit**: $P'(h) = P(h) + k_2 * P_{clim}(h)$...[adjustment is proportional to $P_{clim}(h)$]
 - **Q-fit**: $P'(h) = P(h) * [1 + k_3 * P_{clim}(h)]$...[adjustment is proportional to $P(h) * P_{clim}(h)$]
- where: $P(h)$ and $P'(h)$ is hourly precipitation before and after adjustment
 $P_{clim}(h)$ is mean climatological value of the hourly precipitation



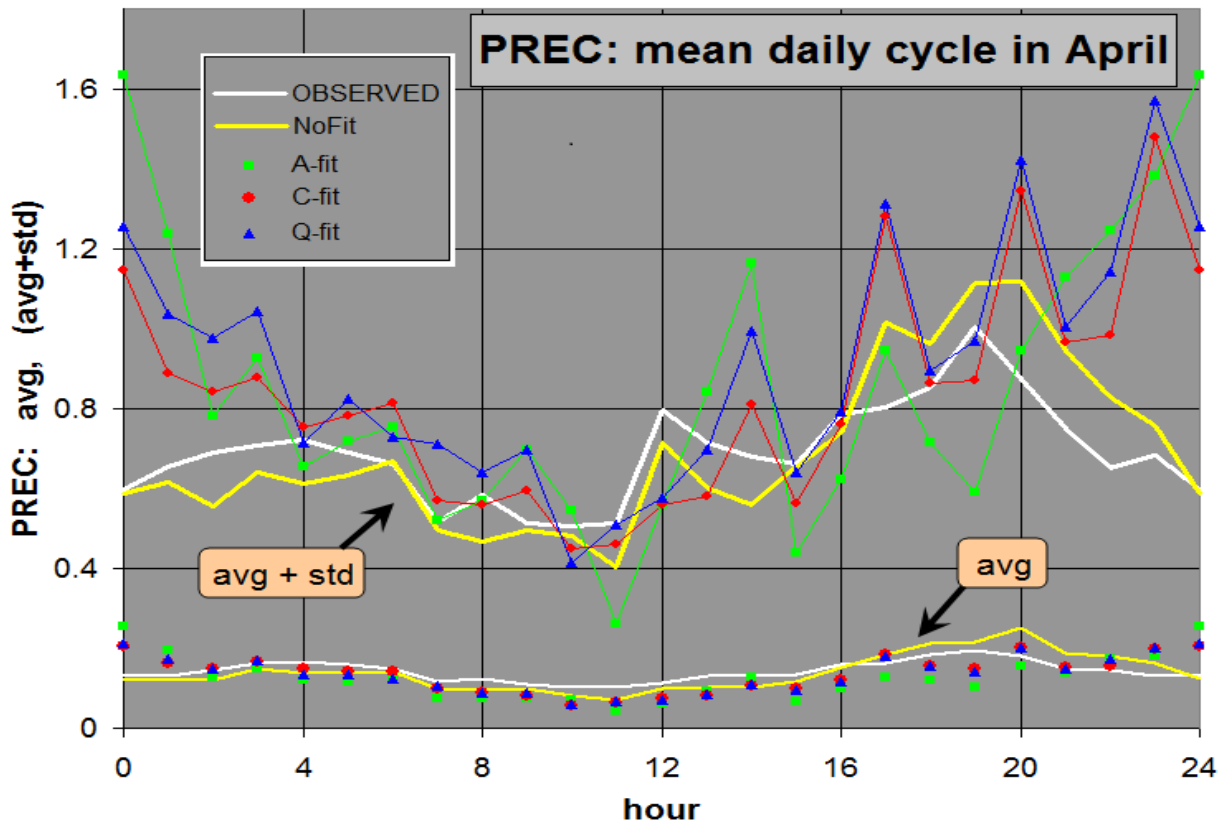
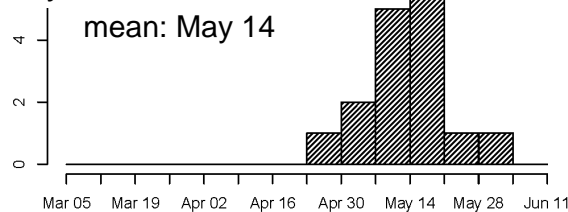
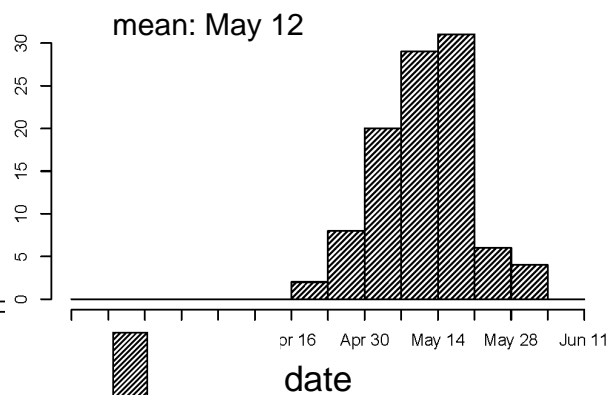
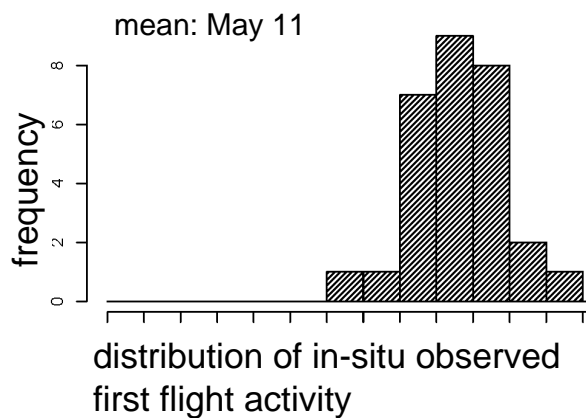


Fig.3a: Indirect validation of HOWGH via Flight start of codling moth modelled by pest model

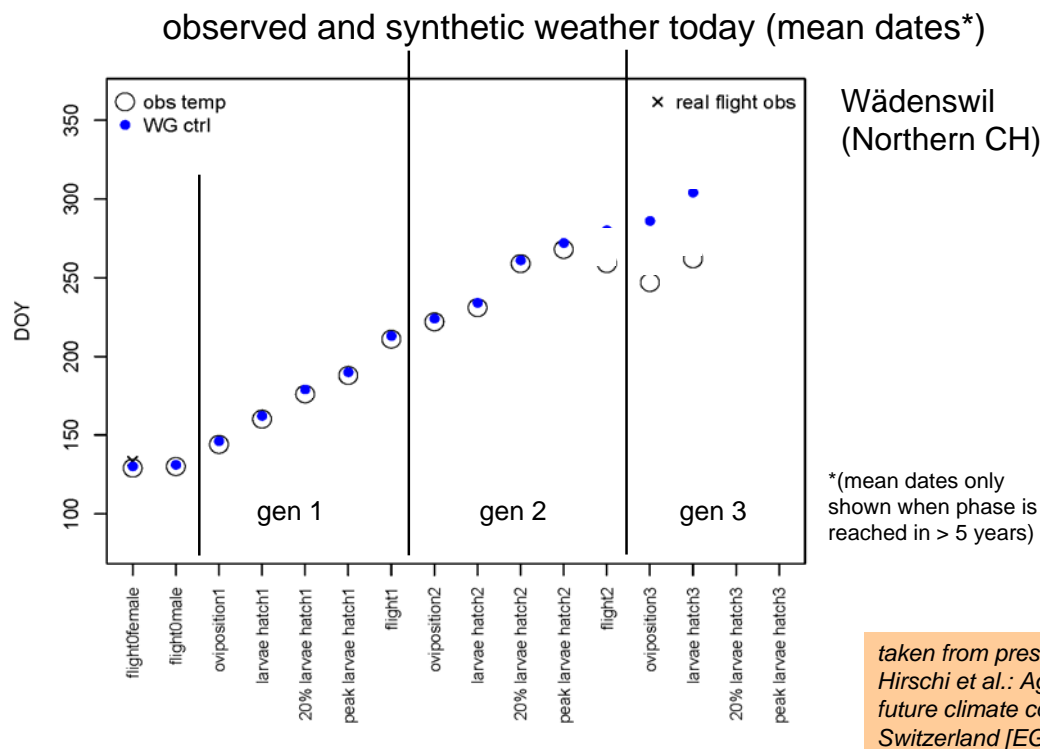
input weather = **observed**
(Wädenswil, 1981-2009)

input weather = **100-year synthetic**
weather produced by HOWGH



taken from presentation by Martin Hirschi et al.: Agricultural pests under future climate conditions in Switzerland [EGU2011-6063]

Fig.3b: Indirect validation of HOWGH in terms of Codling moth life phases modelled by pest model



Conclusions

- **This poster presents the new hourly weather generator HOWGH** designed to produce meteorological inputs to pest models.
- **The poster focuses on effect of representing temperature in daily WG and on hourly-to-daily adjustments step** [Fig.1], which serves to fit sampled hourly values to driving daily values produced by parameteric daily weather generator M&Rfi. The results show [Figs.2a-b], that this fitting may slightly deteriorate the reproduction of the daily cycle of the hourly weather characteristics. The question stands, what is the effect on climatic characteristics and output from the pest model (*will be studied in our further experiments*).
- **The experiments made with the pest model** run with the synthetic weather series produced by HOWGH generator show good reproduction pest model output obtained with observed vs. synthetic weather series [Figs. 3a-b]
- **Our future work** will focus on more detailed validation in terms of multiple climatic characteristics and using more stations and possibly further improvements of the weather generator.