Tools developed to analyze chilling requirements & phasic development of the olive tree

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Introduction

- There are some aspects in the prediction of olive phenology that are still controversial.
- One of such aspects is the method of prediction of flowering occurrence.
- Prediction of flowering of olive trees should account for chilling requirements (Rallo et al., 1991).
- Prediction of the time of flowering involves two phases: 1) a chilling accumulation phase; and 2) a forcing (heat accumulation) phase.

Introduction (cont.)

- Chilling accumulation phase
  - Chill model (De Melo e Abreu et al., 2004) (Fig. 1):
    -

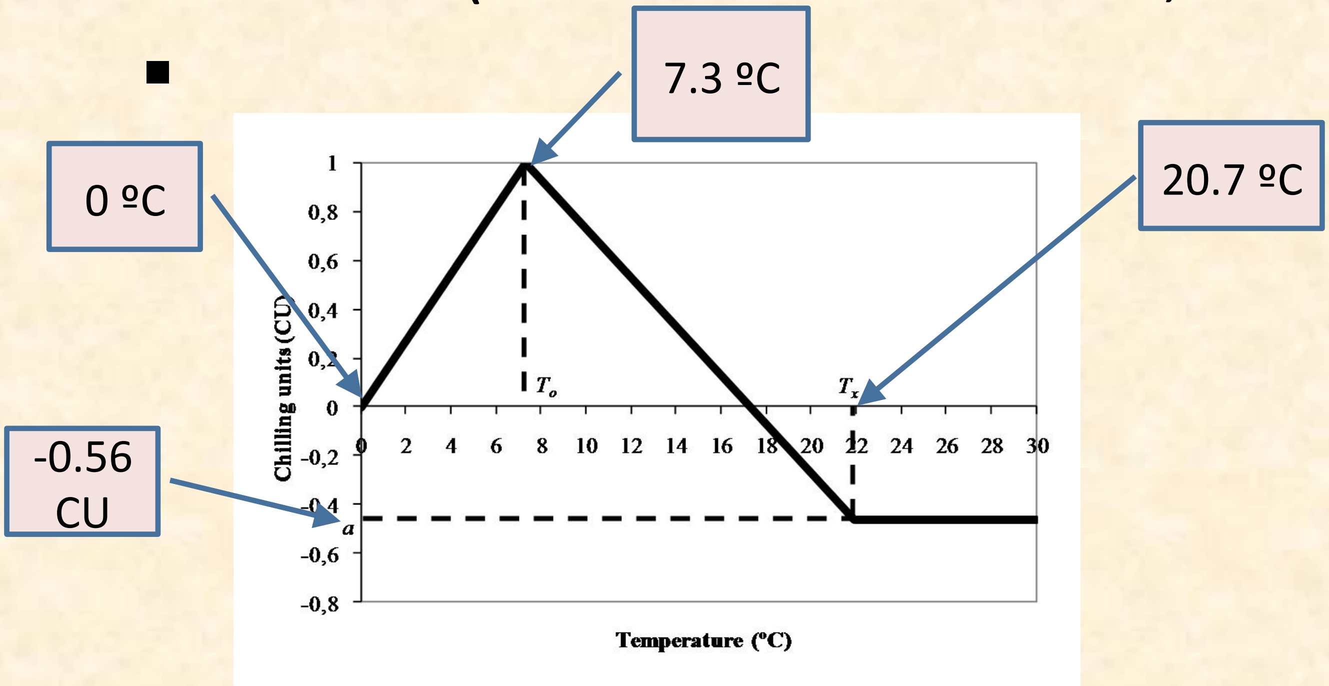


Figure 1

Chilling unit in response to an hour at different air temperatures (ºC)

Introduction (cont.)

- Forcing phase
  - Accumulation of temperature above a base temperature (Tb)
  - We calculated Tb = 9.1ºC, averaged over ten cultivars.

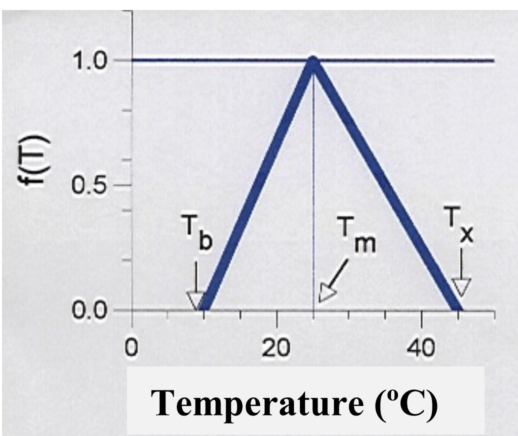
Introduction (cont.)

- In the original publication, the model has parameters valid at species level and others that must be determined for each cultivar.
- The parameters of the chill unit model and the base temperature (Tb) for heat accumulation were considered valid for the species.
- The amount of chilling units necessary to release dormancy and the accumulation of temperature in the forcing phase were calculated for each cultivar.

Introduction (cont.)

- After flowering, phasic development is simulated using thermal time
- A popular method consists upon considering a saw-tooth model:

Saw-tooth model (Garcia-Huidobro *et al.*, 1982)



$$f(T) = \begin{cases} \dfrac{T - T_b}{T_m - T_b} & \text{with} \quad T_b \le T < T_m\,, \\[2ex] \dfrac{T_X - T}{T_X - T_m} & \quad\quad\;\; T_m \le T \le T_X\,, \\[2ex] 0 & \quad\quad\;\; \text{other cases} \end{cases}$$

Tasks and tools

- calibration of model for flower date prediction

- The old Pascal algorithm was replaced by a VBA application in Excel.
- The new application (FlowerCalib) may calculate all the parameters in the sequential model or only a subset.
- In general, only the parameters for the cultivar are adjusted.
- Data and parameters may be found for daily or hourly temperatures.
- Multiple locations and related weather data may be input.
- Parameters may be fitted across cultivars

Tasks and tools
- Use of FlowerCalib

Enter cultivar, site, dates of flowering

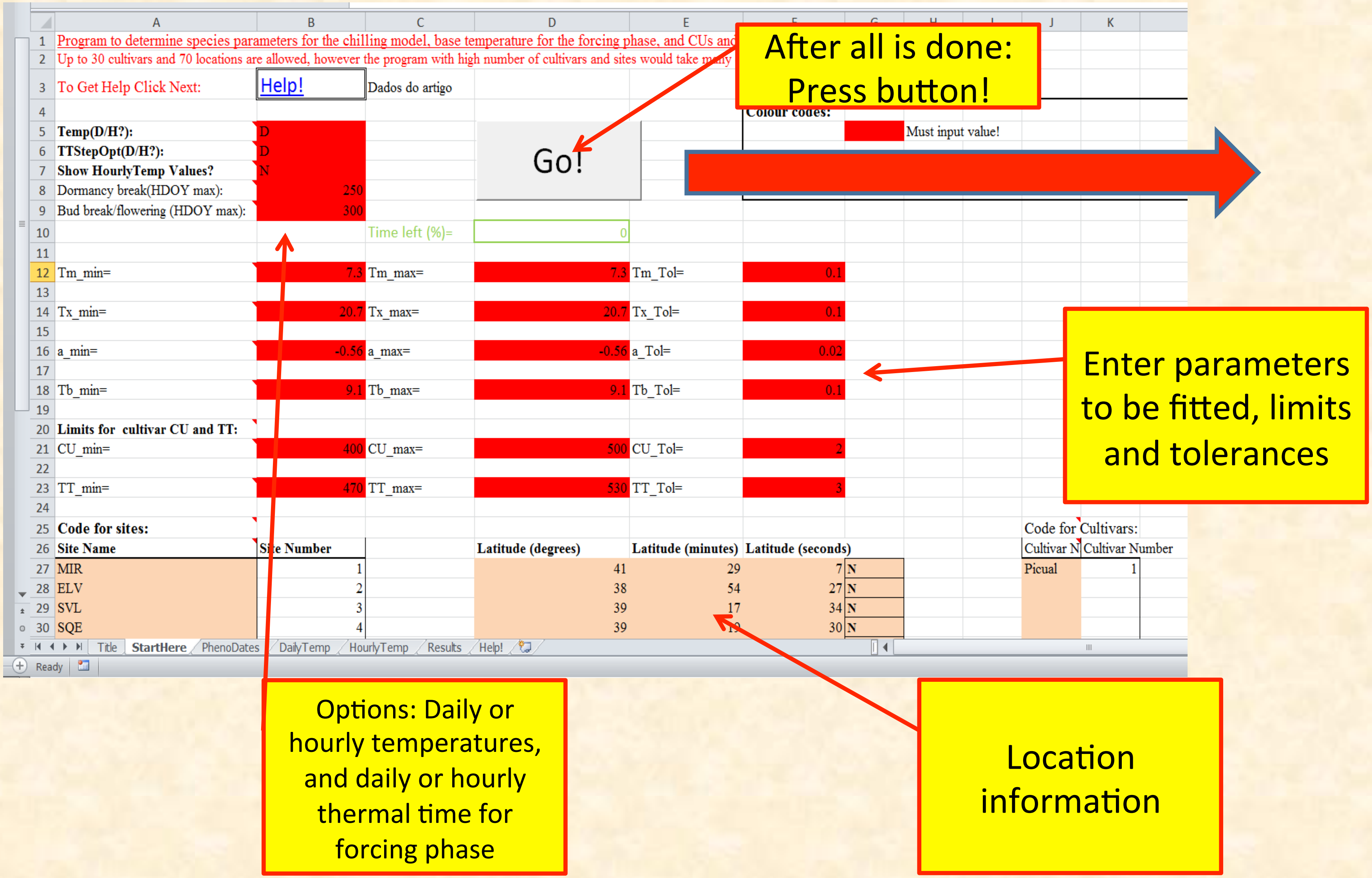
Cultivar	Site (Nb)	Event HYear	Event HDOY
1	2	1998	224
1	2	1999	224
1	2	2000	234
1	2	2001	228
1	2	2002	226
1	2	2005	228
1	2	2006	226
1	2	2007	231
1	2	2010	232
1	2	2011	218
1	2	2012	234
1	5	2011	210
1	5	2012	227
1	7	1999	230
1	7	2000	227
1	7	2001	221
1	7	2002	222
1	8	1976	235
1	8	1977	212
1	8	1978	227
1	8	1982	219

Enter maximum and minimum temperatures or hourly temperatures

Site (Nb)	HYear	HDOY	Tmin	Tmax
1	2011	1	9.64	25.75
1	2011	2	9.31	24.15
1	2011	3	14.47	19.59
1	2011	4	12.06	21.72
1	2011	5	8.88	24.01
1	2011	6	14.54	17.89
1	2011	7	13.01	25.38
1	2011	8	15.45	22.09
1	2011	9	12.23	[illegible]
1	2011	10	9.17	[illegible]
1	2011	11	9.98	23.71
1	2011	12	11.97	23.37
1	2011	13	11.57	24.13
1	2011	14	9.20	23.56
1	2011	15	10.23	20.39
1	2011	16	7.06	18.26
1	2011	17	5.09	19.11
1	2011	18	5.45	18.25
1	2011	19	2.90	19.03

Tasks and tools

- Use of FlowerCalib (cont.)



Tasks and tools
- Use of FlowerCalib (cont.)

RMSE in days

RMSE:	5.650051						
Variety	T0	Tm	Tx	Parm *a*	Tb	CU	TT
Picual	0	7.3	20.7	-0.56	9.1	469	495

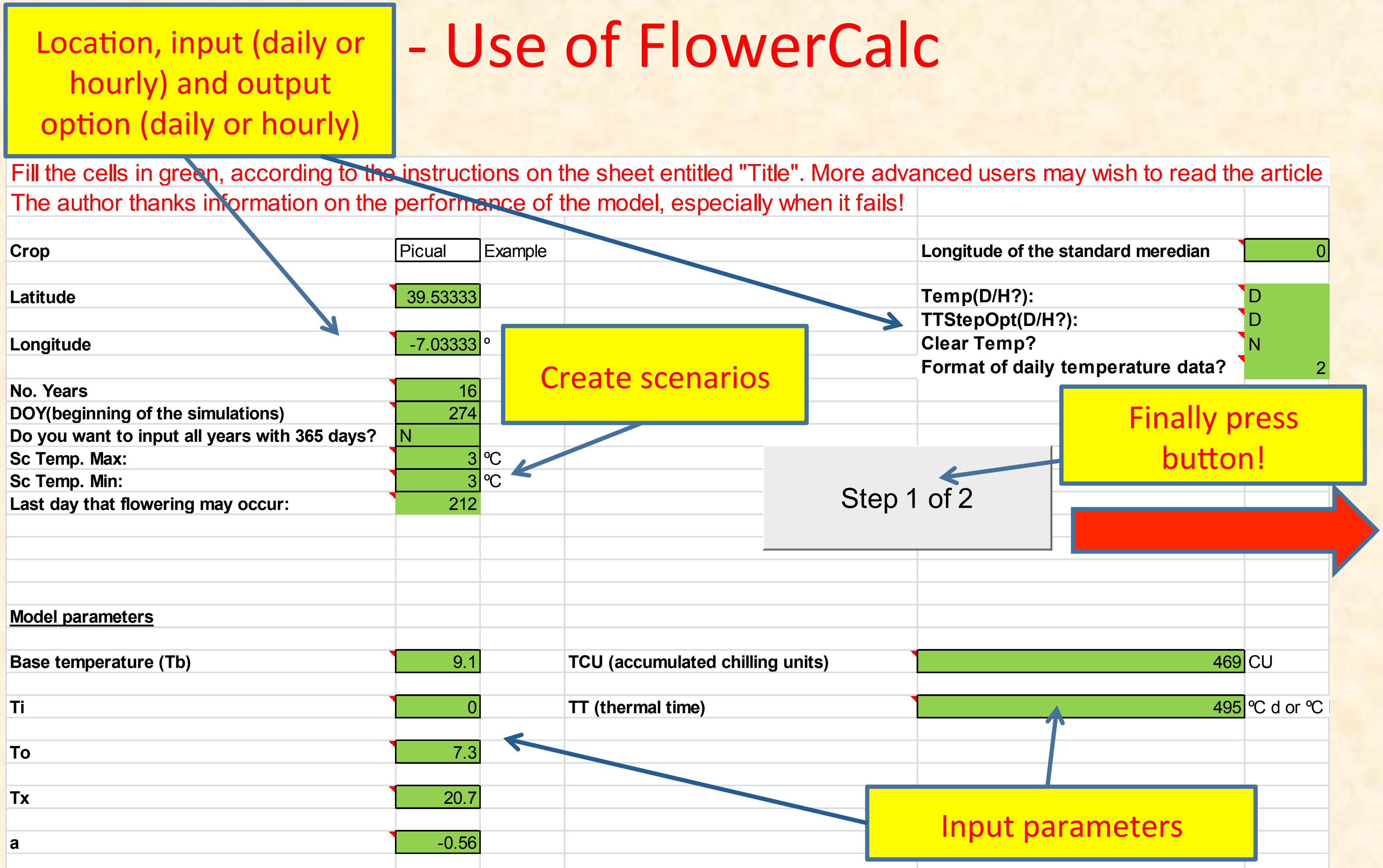
Chilling hours (phase 1)

Thermal time (phase 2)

Tasks and tools
- simulations with the model after calibration

- Once calibration is done, the model is ready for use.
- Application “FlowerCalc” is designed to perform simulations of flowering occurrence for up to 100 years of weather data.
- FlowerCalc is also prepared for considering global warming scenarios

Tasks and tools - Use of FlowerCalc



Tasks and tools

- Use of FlowerCalc (cont.)

Enter temperature (daily or hourly)

Finally, press button

Step 2 of 2

Ano	DOY	Tmin	Tmax
2001	274	11.3	17.8
2001	275	11.3	20.6
2001	276	14.4	24.7
[illegible]	277	10.9	28.6
[illegible]	278	14	30.8
[illegible]	279	13.8	28
2001	280	13	27.8
2001	281	14.5	26.5
2001	282	13.8	26.7
2001	283	12.3	27.1
2001	284	13	21.7
2001	285	11	22.2
2001	286	10.4	15.8
2001	287	8	15.9
2001	288	5.2	16.6
2001	289	7.6	15.4
2001	290	11	19.2
2001	291	8.9	21.6
2001	292	10.9	22.7
2001	293	10.7	24

Results (worksheet)

ºC added to Tmax.:	3	
ºC added to Tmin:	3	
Year	Day of Flowering (DOY)	Day of Dormancy Break(DOY)
2001	99	366
2002	102	354
2003	114	7
2004	109	1
2005	115	363
2006	108	357
2007	113	8
2008	96	364
2009	106	346
2010	113	11
2011	104	356
2012	120	4
2013	115	8
2014	104	361
2015	110	9
2016	129	48

Case study
Flowering in Jaén under different scenarios

- Cultivar: **Picual**
- 3 **scenarios of global warming by 2100** (Castro et al., 2005):

    A: + 2 ºC

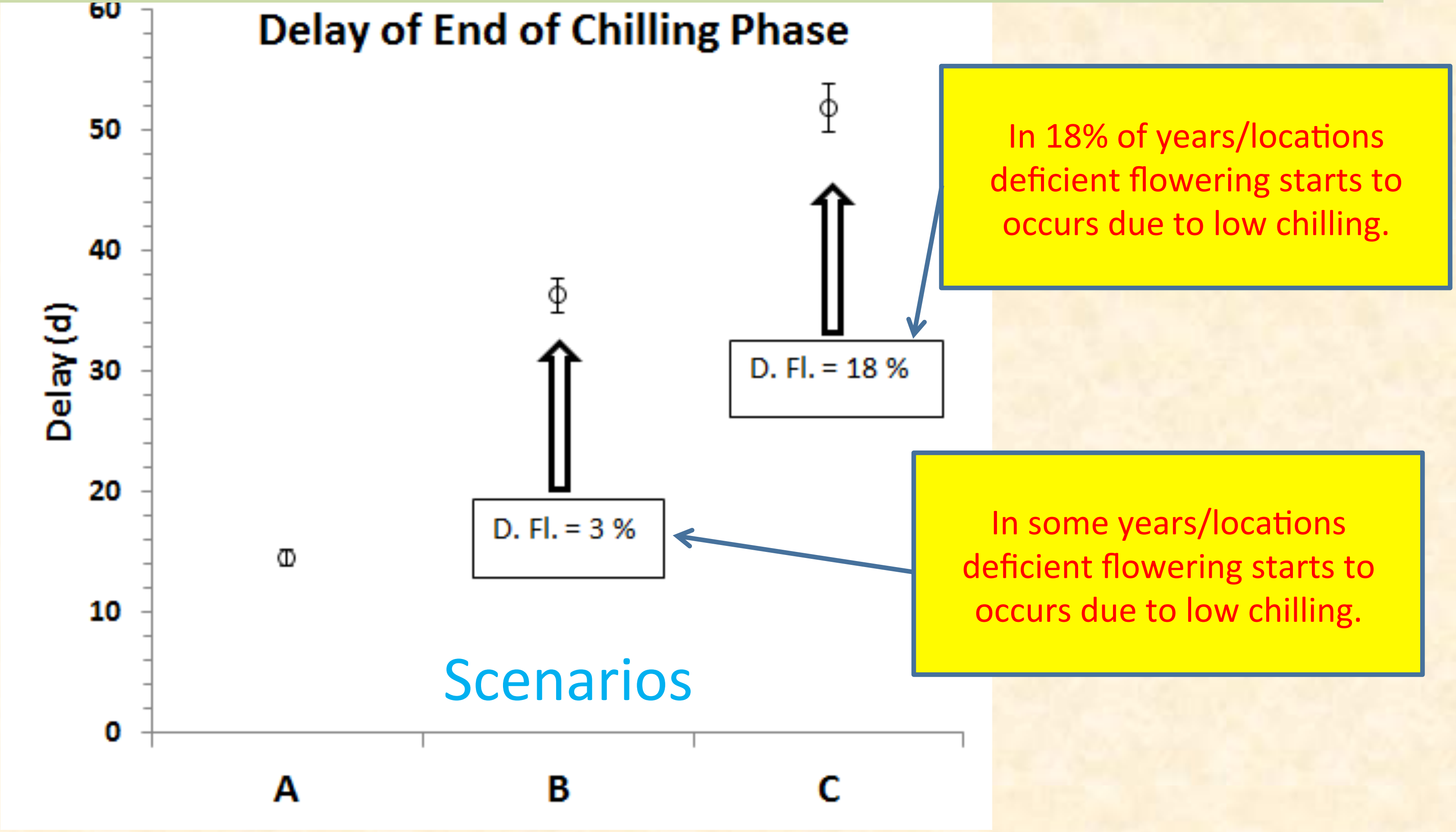
    B: +4 ºC

    C: +5 ºC (upper limit for winter-spring)
- Data from 5 **weather stations in Jaén** :
  - Locations: 1. *Chiclana de Segura*; 2. *Linares*; 3. *Mancha Real*; 4. *San José de los Proprios*; 5. *San Tomé*.

Case study (cont.)

Flowering in Jaén under different scenarios (cont.)

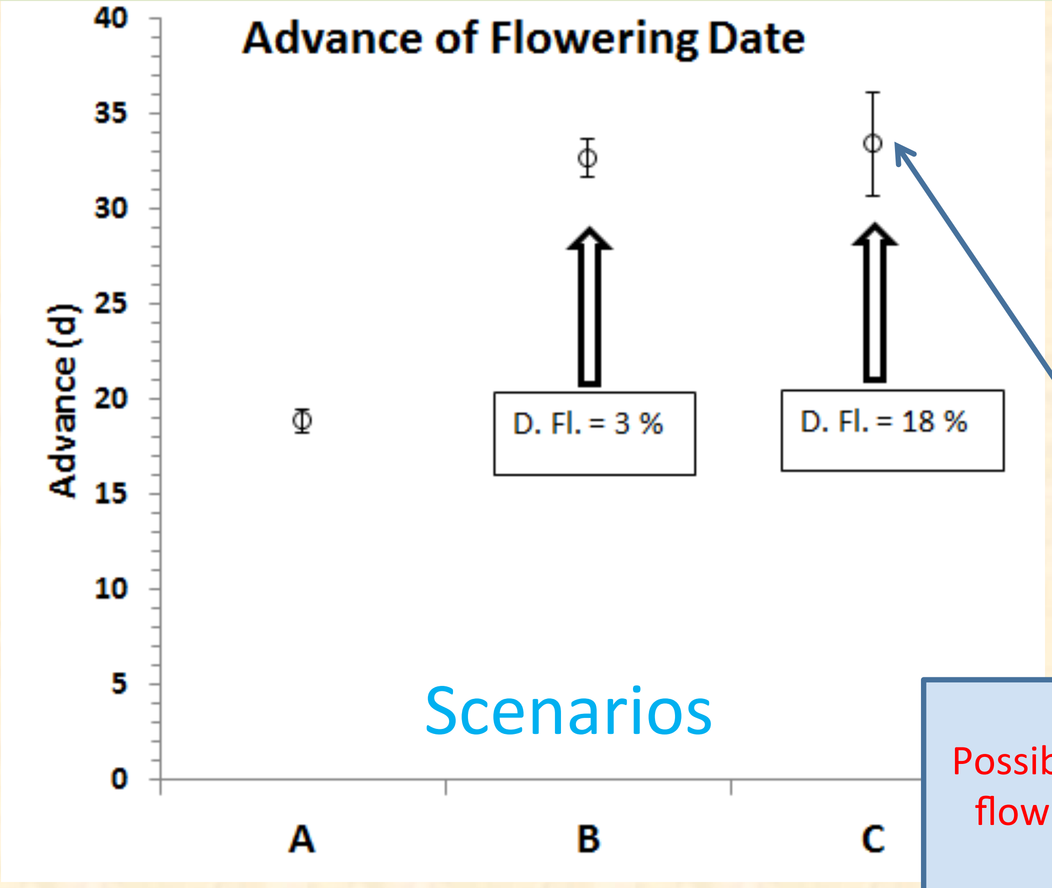
Average and SE (5 locations x 16 years) of delays of end of chilling phase
in relation to scenarios A, B & C



Case study (cont.)

Flowering in Jaén under different scenarios (cont.)

Average and SE (5 locations x 16 years) of advances of flowering date
in relation to scenarios A, B & C



Higher variability!!

Possible explanation for longer flowering periods under low chilling?

Conclusion of these simulations

- At least until the 2100, ‘Picual’ in Jaén is likely to have little problems due to low chilling.
- The known increases of the period of flowering, under low chilling conditions, may be due to small differences in temperature within the canopies and their amplified effect on the date of flowering of the floral buds.
- This result may be useful to detect varieties that have high chilling requirements. Hence, these varieties would show abnormally long flowerings periods after warmer winters.

Tasks and tools
- Calibration of saw-tooth model

- Applications BiodevDly and BiodevHly use a VBA program that fits the parameters of the saw-tooth model.
- These applications may use data of various locations and fix some of the parameters and let the others be adjusted.

Tasks and tools

- Use of BiodevDly

- ***Example: Determination of the cardinal temperatures for phase full flowering to endocarp hardening***

In “PhenoData” enter day of full flowering and day of endocarp hardening

In “DlyTemp” enter maximum and minimum temperatures

1993	127	193
1994	125	181
1995	111	181
2001	114	182
2002	122	185
2003	126	181
2004	125	194
2005	127	183
2011	118	190
2012	135	206

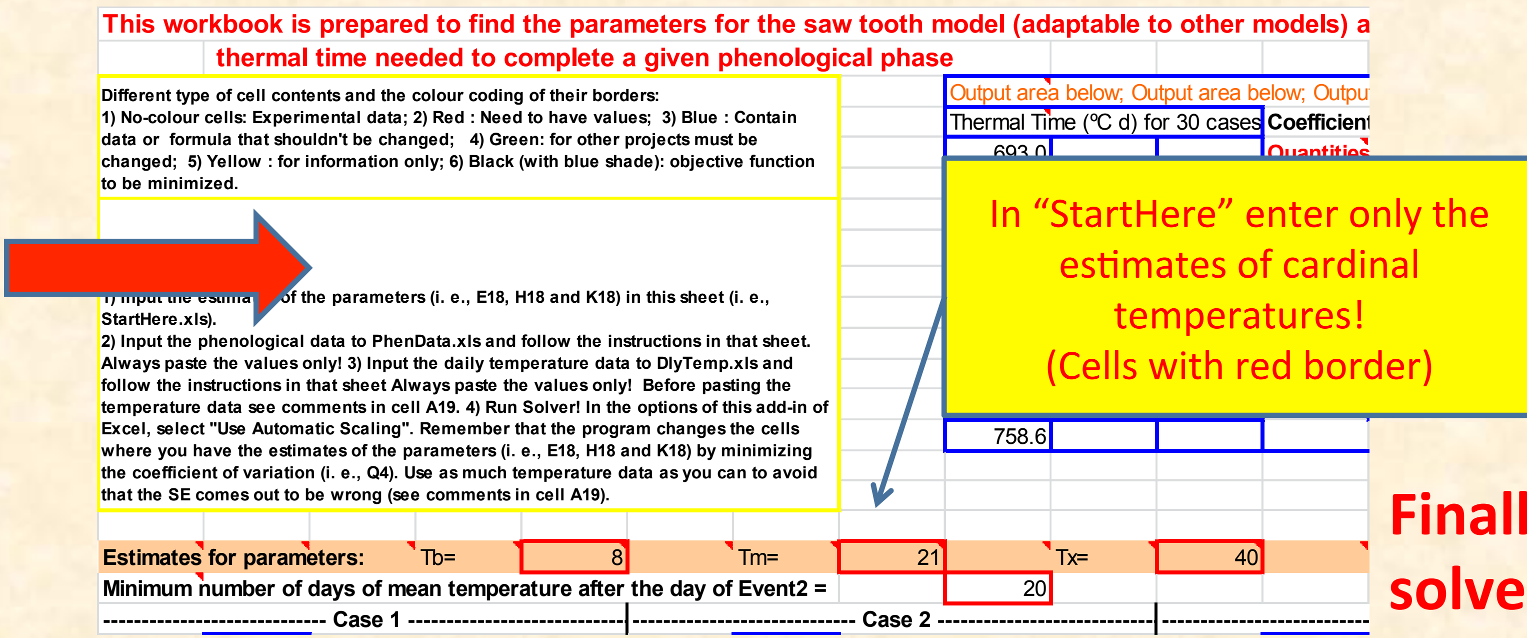
For each case you need to have three columns with YEAR , DOY and daily mean temperature (ºC); three column

1993	1	8.453547	1994	1	10.80468	1995	1	13.10427	2001
1993	2	7.254355	1994	2	9.655253	1995	2	7.755452	2001
1993	3	5.605305	1994	3	6.704762	1995	3	8.203356	2001
1993	4	4.405476	1994	4	7.553029	1995	4	6.804681	2001
[illegible]	5	7.203819	1994	5	4.804781	1995	5	8.603848	2001
[illegible]	6	7.004313	1994	6	9.301825	1995	6	10.55384	2001
[illegible]	7	7.154617	1994	7	6.953052	1995	7	9.054461	2001
1993	8	8.155043	1994	8	5.35284	1995	8	6.953868	2001
1993	9	8.554795	1994	9	9.969975	1995	9	[illegible]	[illegible]
1993	10	8.403916	1994	10	8.851714	1995	10	[illegible]	[illegible]
1993	11	6.453818	1994	11	6.951695	1995	11	8.70339	2001
1993	12	11.30208	1994	12	12.40034	1995	12	8.853274	2001
1993	13	10.85263	1994	13	9.20232	1995	13	6.552835	2001
1993	14	10.45264	1994	14	10.00162	1995	14	6.902283	2001
1993	15	9.602602	1994	15	9.501333	1995	15	8.902204	2001
1993	16	9.502302	1994	16	6.25128	1995	16	8.202077	2001
1993	17	9.301919	1994	17	5.95096	1995	17	10.10105	2001
1993	18	9.101555	1994	18	5.850897	1995	18	12.57639	2001
1993	19	8.401361	1994	19	7.450664	1995	19	10.2009	2001
1993	20	8.401065	1994	20	5.700782	1995	20	9.647051	2001
1993	21	9.950771	1994	21	5.000627	1995	21	8.550601	2001
1993	22	7.550683	1994	22	6.90042	1995	22	9.400502	2001

Tasks and tools

- Use of BiodevDly

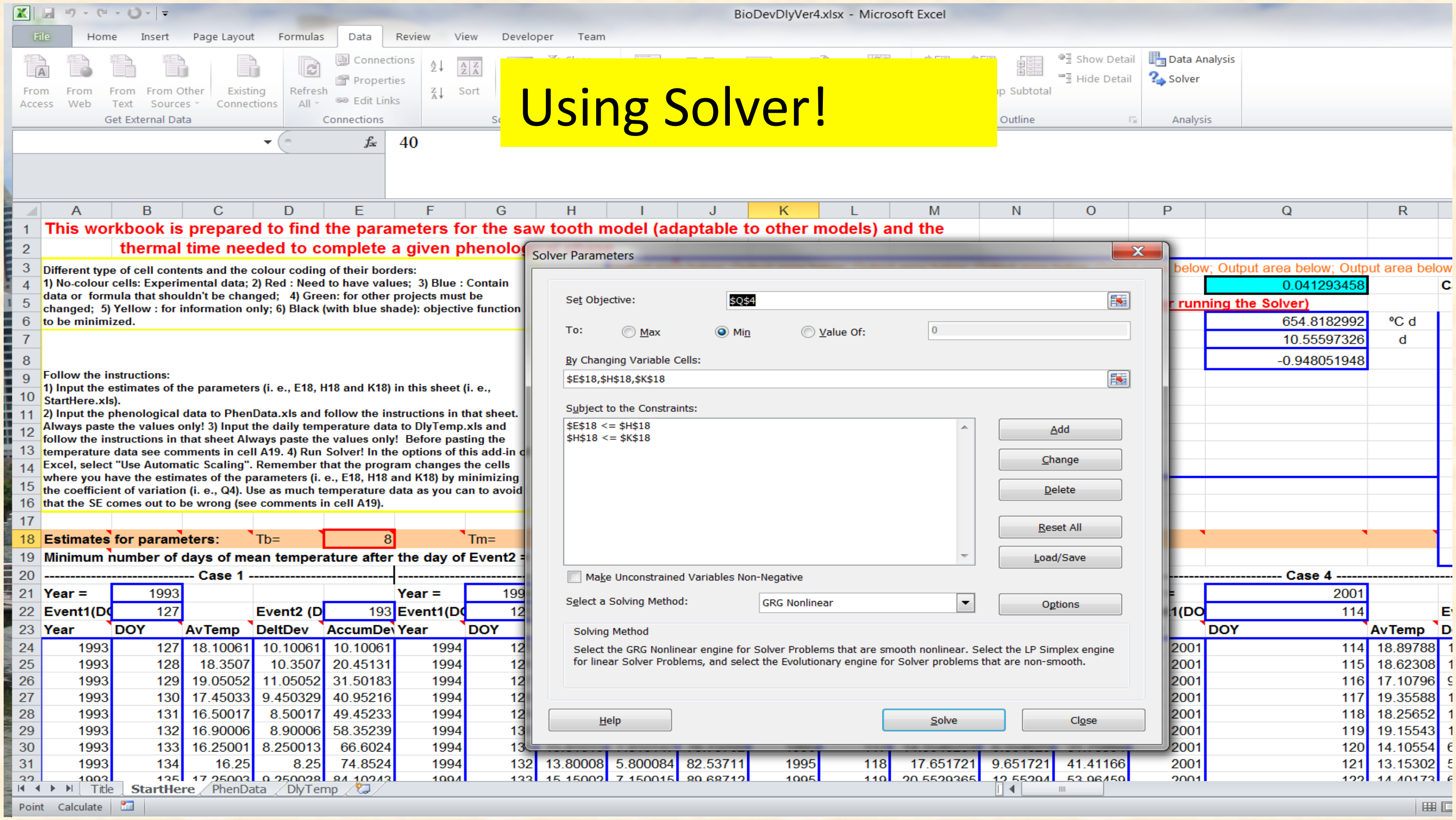
- ***Example: Determination of the cardinal temperatures for phase full-flowering to endocarp hardening***



Finally use solver!

Tasks and tools
- Use of BiodevDly

- ***Example: Determination of the cardinal temperatures for phase full-flowering to endocarp hardening***



Tasks and tools

- Use of BiodevDly

RESULTS: Fitted parameters

RESULTS: Thermal time for the phase

Output area below; Output area below; Output area below; Output area below; Output area below; Output area below; Output area belo

Thermal Time (ºC d) for 30 cases			Coefficient of Variation = function to be minimized:				0.024918736	
824.6			Quantities & fitted parameters (below, but only after running the Solver)					
726.9			Thermal time for the phase:				833.9994059	ºC d
966.0			Standard Error of the Regression Estimate:				5.250850271	d
870.7			R^2 =	0.5		ME =	0.517982018	
811.7			Tb =	8.21551517	ºC			
780.8								
888.6			Tm =	25.0524079	ºC			
789.7								
849.9			Tx =	44.0074932	ºC			
830.9								

Tasks and tools
- Use of BiodevDly

- Using *Biodev* we have had success in simulating all phases until endocarp hardening.
- However, prediction of date of maturity, presented many problems. This may be due to the fact that the accumulation of oil is affected by many other factor besides temperature.

Access to tools

- All these tools (and many more) are in my web page:
  - www.isa.utl.pt/~jpabreu

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Doubts?!!

END

Qu[illegible]s?!!

Suggestions?!!