Phenology

Estimation of growing season (SGS to EGS); using i. observations, ii. fixed time (latitude) and iii. Thermal time (oC Days).

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# Old Documentation

Old documentation from Documentation of DO3SEmodel\_Ver15.doc

## Phenology (SGS, EGS and fphen) and Canopy Structure (LAI and SAI)

A key driver of O3 deposition to vegetated surfaces and stomatal O3 flux is seasonality (i.e. the timing of the physiologically active growth period); this will primarily depend on geographical location but will also be influenced by land-cover type and species. Add an extra introductory descriptive para with a schematic that describes how SGS/EGS, F/fphen and LAI are all part of one approach accounting for seasonality of flux; also describe the difference between SGS/EGS and Astart/Aend

### Estimation of length of growth period (SGS and EGS) this chapter has to be updated – define what is of importance for interface

#### Forest Trees

For forest trees the EMEP latitude model was developed to identify the timing of the growing season of the “generic” deciduous tree species (UNECE, 2004). This model gave good agreement with observed phenological data for a range of deciduous species (e.g. birch, beech and oak; see also Fig x), with measurements of carbon flux from CarboEurope (<http://www.carboeurope.org/>) which were used to identify the initiation and cessation of physiological activity, and was also able to describe the onset of forest green-up and dormancy as determined from European remotely sensed data (Zhang et al. 2004); see UNECE (2004) for additional details.

**Fig x Comparison of observational phenological data with the EMEP latitude model. The black lines show the SGS and EGS determined with the EMEP latitude model. The green and orange lines show the onset of green-up and dormancy described by remotely sensed data for the year 2001 (Zhang et al. 2004) and the vertical red lines show the variation in observed SGS and EGS dates for sites at specific latitudes for a number of different years.**



The EMEP forest latitude model for the estimation of SGS and EGS is given below.

SGS occurs at year day 105 at latitude 50oN. SGS will alter by 1.5 day per degree latitude earlier on moving south and later on moving north.

EGS occurs at year day 297 at latitude 50oN. EGS will alter by 2 days per degree latitude earlier on moving north and later on moving south.

The effect of altitude on phenology is incorporated by assuming a later SGS and earlier EGS by 10 days for every 1000 m a.s.l.

It is useful to define the physiologically active growth period using the terms SGS and EGS. SGS is defined as the date of leaf unfolding (deciduous & broadleaved evergreen species) or the start of leaf/needle physiological activity (coniferous and evergreen species). For the “real” species, SGS is estimated by the EMEP latitude model with the exception of temperate conifers south of ~55oN, where SGS is defined by prevailing environmental conditions (using the ftemp function), and for Mediterranean trees where a year round growth period is assumed. EGS is defined as the onset of dormancy; the EMEP latitude model is used to identify EGS, again with the exception of temperate conifers south of ~55oN where EGS is defined by prevailing environmental conditions (using the ftemp function) and for Mediterranean trees where a year round growth period is assumed. Table x summarises the methods used to derive SGS and EGS for different real species by forest type.

#### Crops

The EMEP Crop latitude model uses a simple function :-

SGS occurs at year day 105 at latitude 50oN. SGS will alter by 3.0 days per degree latitude earlier on moving south and later on moving north.

**Table (x) Default deposition land-cover and species class methods/values for estimation of the start (SGS) and end (EGS) of the growing season.**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Land-cover type & Species** | **Climate region** | **SGS** | **EGS** | **Reference** |
|  |  |  |  |  |
| **Coniferous Forests (CF)** |  | EMEP Forest Latitude model | EMEP Forest Latitude model | UNECE (2004) |
| Norway spruce  (*Picea abies*) | Northern Europe | EMEP Forest Latitude model | EMEP Forest Latitude model | UNECE (2004) |
| Scots Pine  (*Pinus sylvestris*) | Atlantic Central Europe | ftemp | ftemp | UNECE (2004) |
| Norway Spruce  (*Picea abies*) | Continental Central Europe | ftemp | ftemp | UNECE (2004) |
| **Deciduous Forests**  **(DF)** |  | EMEP Forest Latitude model | EMEP Forest Latitude model | UNECE (2004) |
| ***Generic Deciduous*** | ***All Europe*** | EMEP Forest Latitude model | EMEP Forest Latitude model | ***UNECE (2004)*** |
| Silver birch  (*Betula pendula*) | Northern Europe | EMEP Forest Latitude model | EMEP Forest Latitude model | UNECE (2004) |
| Beech  (*Fagus sylvatica*) | Atlantic Central Europe | EMEP Forest Latitude model | EMEP Forest Latitude model | UNECE (2004) |
| Oak  (*Quercus petraea & robur*) | Atlantic Central Europe | EMEP Forest Latitude model | EMEP Forest Latitude model | UNECE (2004) |
| Beech  (*Fagus sylvatica*) | Continental Central European | EMEP Forest Latitude model | EMEP Forest Latitude model | UNECE (2004) |
| Beech  (*Fagus sylvatica*) | Mediterranean Europe | EMEP Forest Latitude model | EMEP Forest Latitude model | UNECE (2004) |
| **Needleleaf Forests**  **(NF)** |  | ***Year round growth*** | ***Year round growth*** | UNECE (2004) |
| Aleppo Pine  *(Pinus halepensis)* | Mediterranean Europe | Year round growth | Year round growth | UNECE (2004) |
| **Broadleaf Forests**  **(BF)** |  | Year round growth | Year round growth | UNECE (2004) |
| ***Generic Evergreen Mediterranean*** | ***All Europe*** | ***Year round growth*** | ***Year round growth*** | ***UNECE (2004)*** |
| Holm Oak  (*Quercus ilex*) | Mediterranean Europe | Year round growth | Year round growth | UNECE (2004) |
| **Temperate crops**  **(TC)** |  | EMEP Crop Latitude model | = SGS + 90 | Simpson et al. (2003) |
| ***Generic crop*** | ***All Europe*** | ***= (2.57 \* latitude + 40) - 50*** | ***= SGS + 90*** | ***UNECE (2004)*** |
| Wheat  (*Triticum aestivum*) | All Europe | = (2.57 \* latitude + 40) - 50 | = SGS + 92 | UNECE (2004); |
| **Mediterranean crops**  **(MC)** |  | EMEP Crop Latitude model | = SGS + 92 | Simpson et al. (2003) |
| Maize  *(Zea mays)* | All Europe | 130 | 250 | ICP Vegetation contract report (2006); |
| Sunflower  *(Helianthus annuus)* | All Europe | 150 | 250 | ICP Vegetation contract report (2006); |
| Tomato  *(Solanum lycopersicum)* | All Europe | 180 | 300 | ICP Vegetation contract report (2006); |
| Grape vine  *(Vitis vinifera)* | All Europe | 105 | 270 | ICP Vegetation contract report (2006); |
| **Root crops**  **(RC)** |  | 146 | 216 | Simpson et al. (2003); UNECE (2004) |
| Potato  (*Solanuum tuberosum*) | All Europe | 146 | 266 | UNECE (2004); Simpson et al. (2003) |
| **Semi-Natural / Moorland**  **(SNL)** |  | 1 | 365 | Simpson et al. (2003) |
| **Grassland**  **(GR)** |  | 1 | 365 | Simpson et al. (2003) |
| Perennial rye grass  (*Lolium perenne*) | All Europe | 1 | 365 | Simpson et al. (2003) |
| Clover  (Trifolium repens) | All Europe | 1 | 365 | Simpson et al. (2003) |
| **Mediterranean scrub** |  | 1 | 365 | Simpson et al. (2003) |

#### Estimation of canopy and leaf level gsto during the growth period (Fphen and fphen)

### Canopy level Fphen

#### Forest trees

##### Coniferous and deciduous forest species

For the “Coniferous” and “Deciduous” forests species the Fphen parameterisation is based on data describing the increase and reduction in gsto with the onset and end of physiological activity (coniferous species) and the green growth period (deciduous species) respectively. The minimum length of these respective periods (see Tables V.A1 to V.A4) has been used in the parameterisation to ensure that periods when forests are potentially experiencing higher ozone uptake are incorporated in the risk assessment.

For the beginning of the growing season the increase in gsto to gmax will begin on the year day defined as SGS. The time to reach gmax is defined by fphen\_e. For the end of the growing season, the decrease in gsto from gmax is defined by fphen\_f and assumed to occur on the year day defined as EGS. Would be good to add schematic here....

##### Mediterranean evergreen forest species are updates available here?

For Mediterranean forests, the Fphen value would ideally be set equal to 1 and the reduction in gsto that is frequently observed during the summer period would be estimated as a function of soil water status. However, if tested methods to determine soil water content for the “real” species and conditions are not available, it is recommended to default to the Fphen relationship used previously for Mediterranean evergreen “generic” species (see notes for Table V.A4). This function acts as a surrogate for soil water stress and may also incorporate phenological limitations to gsto that have been suggested to occur during the summer. For example, a depletion in gsto for Holm Oak was found during summer even under apparent non-drought stress conditions (Alonso et al., 2008) suggesting both the Fphen and fSWP terms may be required to estimate gsto. In conclusion it is recognised that further work is needed to improve methods to understand the influence of drought on gsto and hence O3 uptake; for example, ideally, the onset of soil water stress would determine the timing and extent of leaf flushing avoiding inconsistencies that currently exist between assumed fixed periods of stress and leaf flushing.

#### Crops

…add text….

A generic formulation for the canopy gsto relationship with canopy age (Fphen) is given by the equations provided below. This allows the use of a consistent formulation irrespective of whether there is a mid-season dip in Fphen (as is required to model Fphen for some Mediterranean species in the absence of methods to simulate the effect of water stress on gsto) check equations:-

Fphen = 0

when dd ≤ SGS

Fphen = ((1-Fphen\_a)\*((dd-SGS)/fphen1)+fphen\_a)

when SGS < dd ≤ fphen1+SGS

Fphen = Fphen\_b

when fphen1+SGS < dd ≤ Fphen\_limA

Fphen = (1-fphen\_c) \* (((fphen2 + Fphen\_limA) - (Fphen\_limA + (dd-Fphen\_limA))) /fphen2) + fphen\_c

when Fphen\_limA < dd < Fphen\_limA + fphen2

Fphen = Fphen\_c

when Fphen\_limA + fphen2 ≤ dd ≤ Fphen\_limB - fphen3

Fphen = (1-fphen\_c) \* ((dd-(Fphen\_limB - fphen3))/fphen3) + fphen\_c

when Fphen\_limB - Fphen3 < dd < Fphen\_limB

Fphen = Fphen\_d

when Fphen\_limB ≤ dd ≤ EGS - fphen4

Fphen = (1-fphen\_e) \* ((EGS-dd) / fphen4) + fphen\_e

when EGS - fphen4 < dd < EGS

Fphen = 0

When dd ≥ EGS

Fig x. Generic function for Fphen relationship.



Table (x) Default deposition land-cover and species class values for fphen parameters.

Problem that Fphen2 and Fphen3 may not work if the growth period is in the wrong place i.e. for crops where the SGS starts later but the growth period is only short (i.e. for approx 100 days). Will work if can use SGS but not sure this is possible in the code???

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Land-cover type & Species** | **Climate region** | **Fphen\_a** | **Fphen\_b** | **Fphen\_c** | **Fphen\_d** | **Fphen\_e** | **Fphen1** | **Fphen2** | **Fphen3** | **Fphen4** | **Fphen\_limA** | **Fphen\_limB** | **Reference** |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **Coniferous Forests (CF)** |  | 0 | - (1) | 1 | - (1) | 0 | 30 | - (200) | - (200) | 35 | - (0) | - (0) |  |
| Norway spruce  (*Picea abies*) | Northern Europe | 0 | - (1) | 1 | - (1) | 0 | 20 | - (200) | - (200) | 30 | - (0) | - (0) | UNECE (2004) |
| Scots Pine  (*Pinus sylvestris*) | Atlantic Central Europe | 0.8 | - (1) | 1 | - (1) | 0.8 | 40 | - (200) | - (200) | 40 | - (0) | - (0) | UNECE (2004) |
| Norway Spruce  (*Picea abies*) | Continental Central Europe | 0 | - (1) | 1 | - (1) | 0 | 0 | - (200) | - (200) | 0 | - (0) | - (0) | UNECE (2004) |
| **Deciduous Forests**  **(DF)** |  | 0 | - (1) | 1 | - (1) | 0 | 20 | - (200) | - (200) | 30 | - (0) | - (0) |  |
| ***Generic Deciduous*** | ***All Europe*** | 0 | - (1) | 1 | - (1) | 0 | 15 | - (200) | - (200) | 20 | - (0) | - (0) | ***UNECE (2004)*** |
| Silver birch  (*Betula pendula*) | Northern Europe | 0 | - (1) | 1 | - (1) | 0 | 20 | - (200) | - (200) | 30 | - (0) | - (0) | UNECE (2004) |
| Beech  (*Fagus sylvatica*) | Atlantic Central Europe |  |  |  |  |  |  |  |  |  |  |  | UNECE (2004) |
| Oak  (*Quercus petraea & robur*) | Atlantic Central Europe | 0 | - (1) | 1 | - (1) | 0 | 20 | - (200) | - (200) | 30 | - (0) | - (0) | UNECE (2004) |
| Beech  (*Fagus sylvatica*) | Continental Central European | 0 | - (1) | 1 | - (1) | 0.4 | 20 | - (200) | - (200) | 20 | - (0) | - (0) | UNECE (2004) |
| Beech  (*Fagus sylvatica*) | Mediterranean Europe | 0 | - (1) | 1 | - (1) | 0 | 15 | - (200) | - (200) | 20 | - (0) | - (0) | UNECE (2004) |
| **Needleleaf Forests**  **(NF)** |  | 1 | 1 | 0.3 | 1 | 1 | - (0) | 130 | 60 | - (0) | 80 | 320 |  |
| Aleppo Pine  *(Pinus halepensis)* | Mediterranean Europe | 1 | 1 | 0.3 | 1 | 1 | - (0) | 130 | 60 | - (0) | 80 | 320 | UNECE (2004); |
| **Broadleaf Forests**  **(BF)** |  | 1 | 1 | 0.1 | 1 | 1 | - (0) | 130 | 60 | - (0) | 80 | 320 |  |
| ***Generic Evergreen Mediterranean*** | ***All Europe*** | ***1*** | ***1*** | ***0.1*** | ***1*** | ***1*** | ***- (0)*** | ***130*** | ***60*** | ***- (0)*** | ***80*** | ***320*** | ***UNECE (2004)*** |
| Holm Oak  (*Quercus ilex*) | Mediterranean Europe | 1 | 1 | 0.1 | 1 | 1 | - (0) | 130 | 60 | - (0) | 80 | 320 | UNECE (2004) |
| **Temperate crops**  **(TC)** |  | 0.1 | - (1) | 1 | - (1) | 0.1 | 0 | - (SGS) | - (200) | 45 | - (0) | - (0) | Simpson et al. (2003) |
| ***Generic crop*** | ***All Europe*** | 0.1 | - (1) | 1 | - (1) | 0.1 | 0 | - (SGS) | - (200) | 45 | - (0) | - (0) | ***UNECE (2004)*** |
| Wheat  (*Triticum aestivum*) | All Europe | 0.1 | - (1) | 1 | - (1) | 0.1 | 0 | - (SGS) | - (200) | 45 | - (0) | - (0) | UNECE (2004); |
| **Mediterranean crops**  **(MC)** |  | 0.1 | - (1) | 1 | - (1) | 0.1 | 0 | - (SGS) | - (200) | 45 | - (0) | - (0) | Simpson et al. (2003) |
| Maize  *(Zea mays)* | All Europe | 0.1 | - (1) | 1 | - (1) | 0.1 | 0 | - (SGS) | - (200) | 45 | - (0) | - (0) | Simpson et al. (2003) |
| Sunflower  *(Helianthus annuus)* | All Europe | 0.6 | - (1) | 1 | - (1) | 0.4 | 34 | - (200) | - (200) | 34 | - (0) | - (0) | ICP Vegetation contract report (2006); |
| Tomato  *(Solanum lycopersicum)* | All Europe | 0.1 | - (1) | 1 | - (1) | 0.1 | 0 | - (SGS) | - (200) | 45 | - (0) | - (0) | ICP Vegetation contract report (2006); |
| Grape vine  *(Vitis vinifera)* | All Europe | 0.2 | - (1) | 1 | - (1) | 0.2 | 60 | - (200) | - (200) | 45 | - (0) | - (0) | ICP Vegetation contract report (2006); |
| **Root crops**  **(RC)** |  | 0.2 | - (1) | 1 | - (1) | 0.2 | 20 | - (SGS) | - (200) | 45 | - (0) | - (0) | Simpson et al. (2003) |
| Potato  (*Solanuum tuberosum*) | All Europe | 0.2 | - (1) | 1 | - (1) | 0.2 | 20 | - (SGS) | - (200) | 45 | - (0) | - (0) | UNECE (2004); |
| **Semi-Natural / Moorland**  **(SNL)** |  | 0.1 | - (1) | 1 | - (1) | 0.1 | 0 | - (SGS) | - (200) | 45 | - (0) | - (0) | Simpson et al. (2003) |
| **Grassland**  **(GR)** |  | 1.0 | - (1) | - (1) | - (1) | 1.0 | - (0) | - (200) | - (200) | - (0) | - (0) | - (0) | Simpson et al. (2003) |
| Perennial rye grass  (*Lolium perenne*) | All Europe | 1.0 | - (1) | - (1) | - (1) | 1.0 | - (0) | - (200) | - (200) | - (0) | - (0) | - (0) | Simpson et al. (2003) |
| Clover  (Trifolium repens) | All Europe | 1.0 | - (1) | - (1) | - (1) | 1.0 | - (0) | - (200) | - (200) | - (0) | - (0) | - (0) | Simpson et al. (2003) |
| **Mediterranean scrub** |  | 0.2 | - (1) | 1 | - (1) | 0.2 | 130 | - (200) | - (200) | 130 | - (0) | - (0) | Simpson et al. (2003) |

#### Current and older needle classes for Coniferous forest species

However, coniferous forest species have rather complex canopies due to the presence of needles of different ages within the canopy that will have different maximum gs values. In addition, the proportion of needles of different ages will vary over the course of the year according to the phenological stage of the tree.

To accommodate this, the EMEP model divides the canopy LAI into two needle classes a) current needles and b) older needles. The variation over the course of the year in the respective ratio of these two classes is modelled according to data provided by Beadle et al. (1982) and the start of the growing season (SGS) as shown in equation x

Pc month = (Pc\_max-Pc\_min)\*((month-SGSmonth)/5)+Pc\_min x

When SGS month ≤ month ≤ SGS month+5

where Pc month is the canopy ratio of current to older needles for that specific month (1-12); Pc\_max is the maximum canopy ratio of current to older needles; Pc\_min is the minimum canopy ratio of current to older needles; SGSmonth is the month (1 to 12) in which the start of the growing season occurs. Pc\_max and Pc\_min are given values of 0.5 and 0.1 respectively after Beadle et al. (1982). Outside the growing season gphen for both current and older needles is assumed to be equal to gmin.

The stomatal conductance of current year needles (gphen) is influenced by age and modelled as described in Table 1. The stomatal conductance of older needles (gphen old) is assumed constant at 0.5 relative g. The phenological variation in canopy stomatal conductance (Gphen) is calculated according to equation x

Gphen = Pc \* gphen + (1-Pc) \* gphen old  x

The Gphen and GPFD values can then be substituted for gphen and gPFD in equation to provide estimates of canopy stomatal conductance (Gsto) rather than needle stomatal conductance (gsto).

#### Leaf level fphen

For **wheat and potato** the leaf-level fphen is different to the canopy level Fphen. The method for defining fphen has been revised in subsequent versions of the UNECE Mapping Manual. Initially a fixed day method was used whereby fphen ‘sat’ around the date of mid-anthesis which could, for example, be determined according to latitude (LRTAP Convention, 2004); this is described below under fphen\_v1. In later versions of the Manual an aditional method was introduced which estimated fphen according to thermal time rather than the fixed days used previously (LRTAP Convention, 2008); below this is referred to as fphen\_v2. Finally, the thermal time method from 2008 was updated with new parameterisations that accounted for a plateau in fphen around the time of anthesis (LRTAP Convention, 2010); the description of this method is given under fphen\_v3 below. **For all other species the leaf-level fphen is equal to the canopy level Fphen.**

For all methods the time period over which fphen is calculated defines the accumulation period for PODy where Astart and Aend are the start and end of the accumulation period respectively.

These parameters are also described by SGS (start of growing season) and EGS (end of growing season) respectively for receptors such as forest trees).

**fphen\_v1**

The phenology function can be based on either a fixed number of days or effective temperature sum accumulation and has the same shape for both approaches. However, use of the effective temperature sum is generally accepted to describe plant development more accurately than using a fixed time period since it allows for the influence of temperature on growth. fphen is calculated according to Equations 3.13a, b and c (when using a fixed number of days) and 3.14a, b and c (when using effective temperature sum accumulation). Each pair of equations gives fphen in relation to the accumulation period for AFstY where Astart and Aend are the start and end of the accumulation period respectively. The parameters fphen\_a and fphen\_b denote the maximum fraction of gmax that gsto takes at the start and end of the integration period for ozone flux. The start and end of the integration period are expressed as either number of days before (fphen\_c) and after (fphen\_d) anthesis and tuber initiation in wheat and potato (for equations 3.13a,b,c) or the temperature sum before (fphen\_e) and after (fphen\_f) anthesis and tuber initiation in wheat and potato (for equations 3.14 a,b,c).

where dd is the year day; Astart and Aend are the year days for the start and end of the ozone accumulation period respectively. Describe how Astart and Aend are set with reference to Table XX

Fig x. Generic function for leaf fphen relationship for wheat and potato.



Table XX

|  |  |  |
| --- | --- | --- |
| Parameter | Wheat | Potato |
| Astart | = (2.57 \* latitude + 40) - 15 | 146 |
| Aend | = Astart + 55 | 216 |
| fphen\_a | 0.8 | 0.4 |
| fphen\_b | 0.2 | 0.2 |
| fphen\_1 | 15 | 20 |
| fphen\_2 | 40 | 50 |

N.B. The interface will only use fixed day methods, used in conjunction with latitude models.

**fphen\_v2**

The parameters fphen\_a and fphen\_b denote the maximum fraction of gmax that gsto takes at the start and end of the accumulation period for ozone flux. fphen\_c to fphen-i are receptor-specific parameters describing the shape of the function within the accumulation period.

When Astart ≤ tt < (Astart + fphen\_e)

When (Astart + fphen\_e) ≤ tt ≤ (Aend – fphen\_f)

When (Aend – fphen\_d) < tt ≤ Aend

Where *tt* is the effective temperature sum in degree days using a base temperature of 0oC and Astart and Aend are the effective temperature sums (above a base temperature of 0oC at the start and end of the ozone accumulation period respectively. As such Astart will be equal to 0oC.

**fphen\_v3 (only for wheat)**

**[see version on R:\SEI-Y RESEARCH GROUPS\Theme 1 MES\Projects\DO3SE Documentation]**

* **Estimating the timing of mid-anthesis (and SGS, EGS, Astart, Aend)**

The Mappping Manual provides different methods for estimating mid-anthesis based on national crop statistics, thermal time phenological models or a latitude function. For this **fphen-v3** version calculation it would seem most consistent to use the thermal time models to estimate mid-anthesis.

Mid-anthesis is estimated to occur 1075oC days after plant emergence. Spring wheat and winter wheat (both common types of wheat grown across Europe) are sown at different times (winter wheat in the preceding autumn and spring wheat in the spring); therefore plant emergence will occur at different times of the year.

For winter wheat it is assumed the plant will overwinter and hence the plant will already have emerged by the start of the year. Therefore, mid-anthesis is estimated according to thermal time (1075oC days) accumulated from 1st January. For spring wheat, the thermal time should be accumulated from the time of plant emergence which occurs 75oC days after sowing (assuming a base temperature of 0oC for both); sowing varies by region with climate ranging from 10th Feb in Mediterranean Europe to 30th May in Northern Europe (see Table 1x).

**Table 1.x Observed sowing dates for spring wheat in Europe**

|  |  |  |
| --- | --- | --- |
| **Region** | **Range** | **Default** |
| **Northern Europe** |  |  |
| Finland | 1-30 May | 30 May |
| Norway | 1-20 May | 30 May |
| Sweden | 1-20 April | 20 Apr |
| Denmark | 1 Mar - 20 Apr | 20 Mar |
| **Continental Central Europe** |  |  |
| Poland | 1-20 Apr | 10 Apr |
| Czech Republic | 10-30 Apr | 20 Apr |
| Slovakia | 10-30 Apr | 20 Apr |
| Germany | 10 Mar – 10 Apr | 01 Apr |
| **Atlantic Central Europe** |  |  |
| UK | 20 Feb – 20 Mar | 10 Mar |
| The Netherlands | 1-30 Mar | 15 Mar |
| France | 1 Mar – 10 Apr | 20 Mar |
| **Meditterranean Europe** |  |  |
| Bulgaria |  |  |
| Portugal | 20 Jan-10 Mar | 10 Feb |
| Spain | 1-28 Feb | 10 Feb |

For regional scale DO3SE model runs (e.g. when using data from across Europe that cannot easily be assigned to particular country/climate regions) we run three versions of the model to account for the variation in sowing date of spring wheat i.e. one run using 10 Feb; one run using 1 April and one run using 1 May for all regions.

The estimates of SGS and EGS (which are intended to represent the period during which Fphen is greater than zero) need to be consistent with these thermal time estimates. Currently, the DO3SE model assumes that the full wheat growth period (from SGS to EGS) takes 92 days. To accommodate the new thermal time model we will now assume that for spring wheat SGS starts at plant emergence and ends at Aend. For winter wheat, where plant emergence occurs the preseeding year, we assume that SGS occurs when the thermal time reach70oC days after 1st Jan.

* **Estimating fphen**

The parameters fphen\_a and fphen\_b denote the maximum fraction of gmax that gsto takes at the start and end of the accumulation period for ozone flux. fphen\_c to fphen-i are receptor-specific parameters describing the shape of the function within the accumulation period.

When

When

When ()

Where *tt* is the effective temperature sum in degree days using a base temperature of 0oC and and are the effective temperature sums (above a base temperature of 0oC) at the start and end of the ozone accumulation period respectively. As such will be equal to 200oC days before (-200oC), to 0oC days, to 700oC days after . The total temperature sum thus being 900oC days.

|  |  |  |  |
| --- | --- | --- | --- |
| **Parameter** | **Units** | **Winter Wheat** | **Spring wheat** |
| SGS | oCdays | =75oC days accumulated from 1 Jan | =75oC days accumulated from sowing date |
| EGS | oCdays | =1775oC days accumulated from 1 Jan | =1775oC days accumulated from sowing date |
| Astart | oC days | =875oC days accumulated from 1 Jan | =950oC days accumulated from sowing date |
| Mid Anthesis | oC days | 1075oC accumulated from 1 Jan | 1075oC accumulated from SGS |
| fphen\_a | fraction | 0.3 | 0.3 |
| fphen\_b | fraction | 0.7 | 0.7 |
| fphen\_e | oC days | 200 | 200 |
| fphen\_f\* | oC days | 0 | 0 |
| fphen\_g | oC days | 100 | 100 |
| fphen\_h | oC days | 525 | 252 |
| fphen\_i | oC days | 700 | 700 |



### Canopy Structure

The modelling of LAI and Fphen needs to be consistent with the timing of SGS and EGS.

The development of both??? Leaf Area Index (LAI) within the growing season is modelled with the simple function given in equations [x]:

LAI = LAImin

when dd < SGS

LAI = (LAImax-LAImin)\*((dd-SGS)/LAIs) + LAImin

SGS ≤ dd < SGS+LAIs

LAI = LAImax

When SGS+Ls ≥ dd < EGS-LAIe

LAI = (LAImax-LAImin)\*((EGS-dd)/LAIe) + LAImin

When EGS-LAIe ≥ dd < EGS

LAI = LAImin

when dd ≥ EGS

where dd is the day of year, LAIs is the number of days to go from minimum (LAImin) to maximum (LAImax) LAI and LAIe is the number of days to go from maximum (LAImax) to minimum (LAImin) LAI.

SAI is simply set to LAI=1 for forests, or LAI for non-crop vegetation. A simplified version of the methodology of Tuovinen et al (2003), based upon the life cycle of wheat, is applied for this crop type :-

SAI = LAI + 

when SGS < dd < SGS+LAIs

LAI + 1.5

when SGS + LAIs < dd < EGS

where dd is the day number.

Out-side the growing season, SAI = LAI = 0 m2 m-2.

The structure of the LAI function for Holm Oak is based on data for that species from Ferretti & Bussotti (2007) as follows:

LAI = 0.35\*((LAIs-dd)/LAIs)+LAImin

when dd ≤ LAIs

LAI = (LAImax-LAImin)\*(dd-LAIs)/LAIs+LAImin

when LAIs < dd ≤ (366 – LAIe)

LAI = (LAImax-(LAImin+0.35))\*((366-dd)/LAIe)+(LAImin+0.35)

when dd > (366 – LAIe)

N.B. Aleppo pine and beech follow the original LAI function described in the Mapping Manual, LRTAP Convention, 2004.

LAI at SGS = 3.85

Second point LAI = 3.5

Third point LAI = 5

LAI at EGS is 3.85

Period from LAI\_a to LAI\_b = 100

Period from LAI\_b to LAI\_c = 100

Fig x. Generic function for LAI relationships over the course of the year…this needs to change to allow for Med evergreen…



**Table (x) Default deposition land-cover and species class values for LAI parameters.**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Land-cover type & Species** | **Climate region** | **LAImin** | **LAImax** | **LAIs** | **LAIe** | **Reference** |
|  |  |  |  |  |  |  |
| **Coniferous Forests (CF)** |  | **3.4** | **4.5** | **192** | **96** | **Simpson et al (2003)** |
| Norway spruce  (*Picea abies*) | Northern Europe | 6.5 | 6.5 | - | - | UNECE (2004); Schulze. (2000); Lagergren et al. (2002); Slovik et al. (1995); Nihlgardh. (1972) |
| Scots Pine  (*Pinus sylvestris*) | Atlantic Central Europe | 4.5 | 4.5 | - | - | UNECE (2004) |
| Norway Spruce  (*Picea abies*) | Continental Central Europe | 12 | 12 | - | - | UNECE (2004); Breuer et al. (2003); Schaub. (pers. comm); Braun. (pers. comm.) |
| **Deciduous Forests**  **(DF)** |  | **3.5** | **5.0** | **56** | **92** | **Simpson et al (2003)** |
| ***Generic Deciduous*** | ***All Europe*** |  |  |  |  | ***UNECE (2004)*** |
| Silver birch  (*Betula pendula*) | Northern Europe | 0.0 | 3.0 | 15 | 30 | UNECE (2004); Wang et al. (1995) |
| Beech  (*Fagus sylvatica*) | Atlantic Central Europe | 0.0 | 4.0 | 15 | 30 | UNECE (2004) |
| Oak  (*Quercus petraea & robur*) | Atlantic Central Europe | 0.0 | 4.0 | 20 | 30 | UNECE (2004) |
| Beech  (*Fagus sylvatica*) | Continental Central European | 0.0 | 5.0 | 15 | 20 | UNECE (2004) ; Bugman. (1994); Zierl. (2000); Brassel & Brandli. (1999) |
| Beech  (*Fagus sylvatica*) | Mediterranean Europe | 0.0 | 5.0 | 15 | 30 | UNECE (2004); Ferretti. (pers.comm.) |
| **Needleleaf Forests**  **(NF)** |  | **3.5** | **3.5** | **192** | **96** | **Simpson et al (2003)** |
| Aleppo Pine  *(Pinus halepensis)* | Mediterranean Europe | 5.0 | 5.0 | - | - | UNECE (2004); Gimeno. (pers.comm.) |
| **Broadleaf Forests**  **(BF)** |  | **3.5** | **3.5** | **192** | **96** | **Simpson et al (2003)** |
| ***Generic Evergreen Mediterranean*** | ***All Europe*** | ***5.0*** | ***5.0*** | ***-*** | ***-*** | ***UNECE (2004)*** |
| Holm Oak  (*Quercus ilex*) | Mediterranean Europe | 3.5 | 5.0 | 100 | 166 | UNECE (2004); Ferretti. (pers.comm.) |
| **Temperate crops**  **(TC)** |  | **0.0** | **3.5** | **70** | **22** | **Simpson et al. (2003)** |
| ***Generic crop*** | ***All Europe*** | ***0.0*** | ***3.5*** | ***70*** | ***22*** | **Simpson et al. (2003)** |
| Wheat  (*Triticum aestivum*) | All Europe | 0.0 | 3.5 | 70 | 22 | Simpson et al. (2003); |
| **Mediterranean crops**  **(MC)** |  | **0.0** | **3.0** | **70** | **44** | **Simpson et al. (2003)** |
| Maize  *(Zea mays)* | All Europe | 0.0 | 3.0 | 40 | 30 | ICP Vegetation contract report (2006); |
| Sunflower  *(Helianthus annuus)* | All Europe | 0.0 | 5.0 | 30 | 0.0 | ICP Vegetation contract report (2006); |
| Tomato  *(Solanum lycopersicum)* | All Europe | 0.0 | 4.5 | 90 | 0 | ICP Vegetation contract report (2006); |
| Grape vine  *(Vitis vinifera)* | All Europe | 0.0 | 3.0 | 20 | 20 | ICP Vegetation contract report (2006); |
| **Root crops**  **(RC)** |  | **0** | **4.2** | **35** | **65** | **Simpson et al. (2003); UNECE (2004)** |
| Potato  (*Solanuum tuberosum*) | All Europe |  |  |  |  | UNECE (2004); Simpson et al. (2003) |
| **Semi-Natural / Moorland**  **(SNL)** |  | **2.0** | **3.0** | **192** | **96** | **Simpson et al. (2003)** |
| **Grassland**  **(GR)** |  | **2.0** | **3.5** | **140** | **135** | **Simpson et al. (2003)** |
| Perennial rye grass  (*Lolium perenne*) | All Europe | 4.0 | 4.0 | - | - | Simpson et al. (2003) |
| Clover  (Trifolium repens) | All Europe | 4.0 | 4.0 | - | - | Simpson et al. (2003) |
| **Mediterranean scrub** |  | **2.5** | **2.5** | **1** | **1** | **Simpson et al. (2003)** |

# Glossary

|  |  |  |  |
| --- | --- | --- | --- |
| **Term** | **Description** | **Short name** |  |
|  |  |  |  |
|  |  |  |  |
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