Chronological Modelling : some examples with ChronoModel

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ChronoModel software

- Tools for constructing chronologies
- Based on the Event model[1]
- Several dating methods : 14C, TL/OSL, Archaeomagnetism, typo-chronology, . . .
- A user-friendly interface
- Free and open-source cross-platform software (Mac, Windows, Linux)

www.chronomodel.fr

[1] Lanos and Philippe, 2016 to appear

The Event Model

The example of Lezoux

Medieval kiln of the potter's workshop in Lezoux (Auvergne, France)[2]

Aim : Dating the last firing of the kiln

[2] Menessier-Jouannet *et al.* 1995

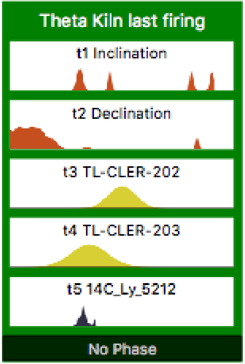
Lezoux - Modelling

- **Prior information** about the date of the last firing (θ) : any date between 0 and 2 000

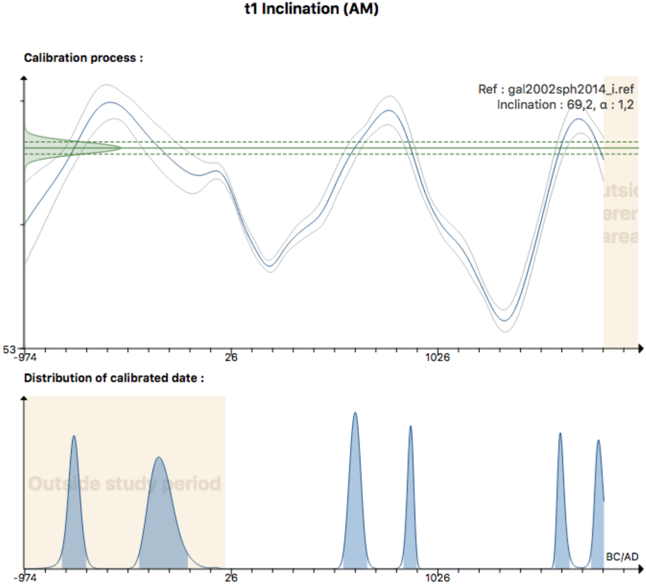
> Prior distribution, $\theta \sim U_{[0,2000]}$

- **Material found** :
  - baked clays dated by
    AM > *Estimation of the last time the temperature exceeded a critical point*
    TL > *Estimation of the last firing*
  - a charcoal
    14C > *Estimation of the felling of the tree*

=> **Assumption of contemporaneity** (Event model)

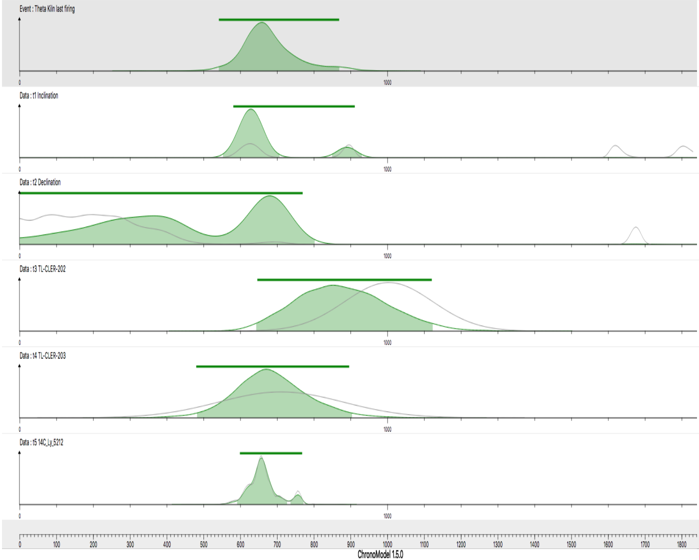


Lezoux - Calibration process

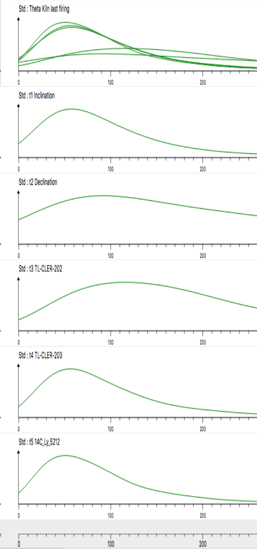


Lezoux - Posterior densities

Posterior densities : Event (θ) and dates (t_i)



Individual std (σ_i)



Lezoux - Comments

- Combination of data from different dating techniques using **different calibration curves**

- Assumption of **contemporaneity** of the dates related to the target event

- **Individual standard deviations** (σ_i) allow for **dating errors**
human mistakes, equipment malfunction or unknown and uncontrolled factors

Outlier data

The side effect of individual standard deviations (σ_i)

A toy example - Modelling

- **Prior information** about θ :

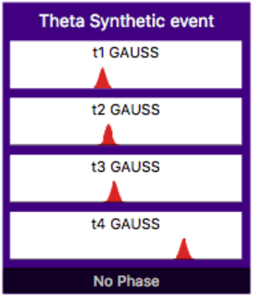
Any date between 0 and 2 000

- **Data included** :

4 Gaussian distributed measurements
M_i +/- s_i :

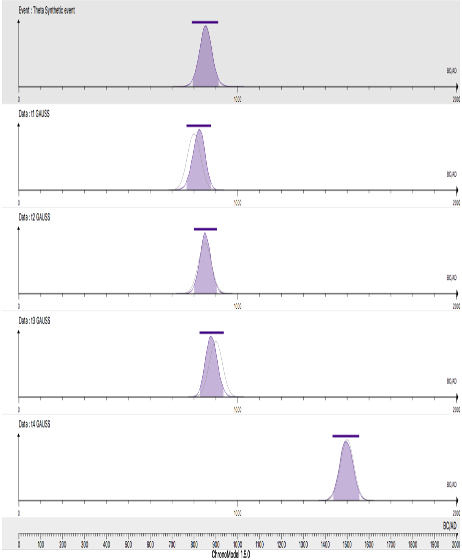
- t_1 = 800 +/- 30
- t_2 = 850 +/- 30
- t_3 = 900 +/- 30
- t_4 = 1500 +/- 30

=> **Assumption of contemporaneity**

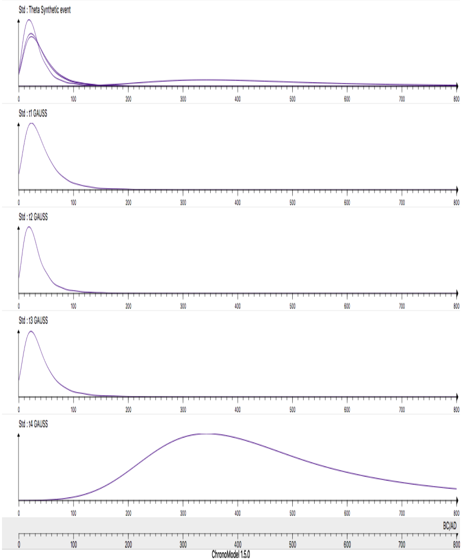


A toy example - Posterior densities

Event (θ) and dates (t_i)



Individual std (σ_i)



A toy example - Comments

- θ is not affected by the outlying date t4 ($M_4 = 1500$)
- σ_1 to σ_3 have a mean value about 40 whereas the mean of σ_4 reaches 500

=> **Robustness of the Event model**

- No detection and no modelling of outlier dates but there is no need for it !

Temporal order constraint between events

The example of stratification

The example of Tungurahua

Ecuador's Tungurahua volcano[3]

Aim : Dating the succession of eruptions using a stratigraphic sequence of ashes deposits

[3] Collaboration with Jean-Luc Le Pennec (IRD, Université de Clermont-Ferrand)

Tungurahua - Modelling

θ : date of one eruption

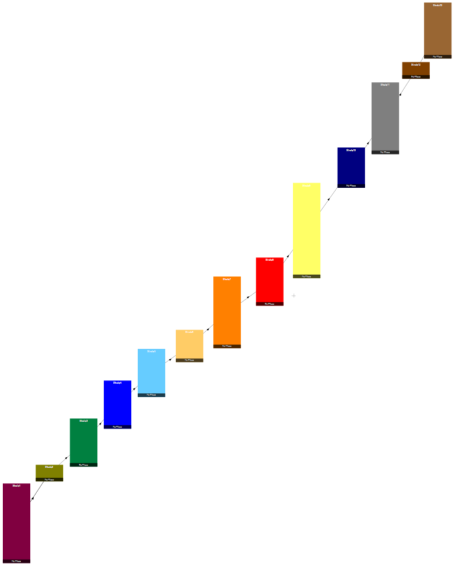
- **Prior information** about θ*s* :

Any date between -2 000 to 2 000
+
13 layers with stratigraphic constraints
+
Time elapsed during each eruption neglected

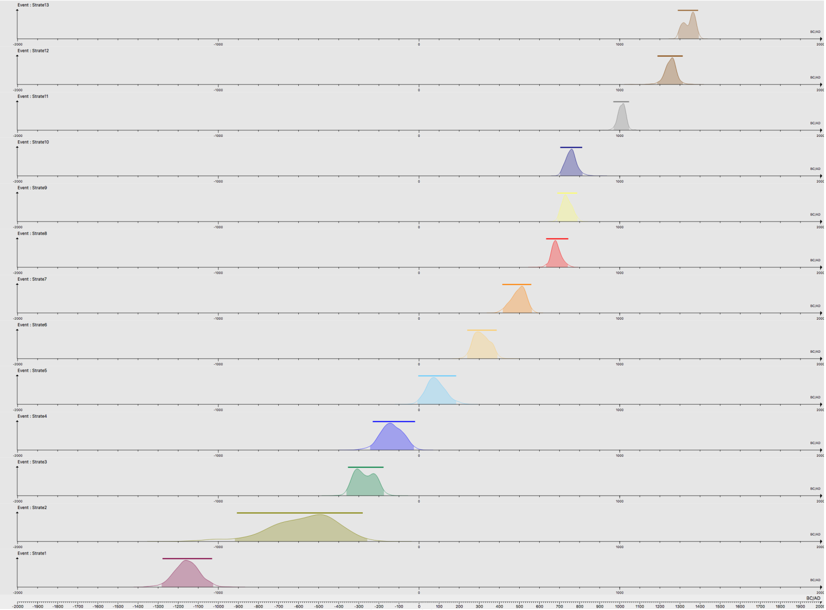
=> **Assumption of contemporaneity within each layer** (Event model)

- **Material found** :

Several organic samples dated by ^{14}C

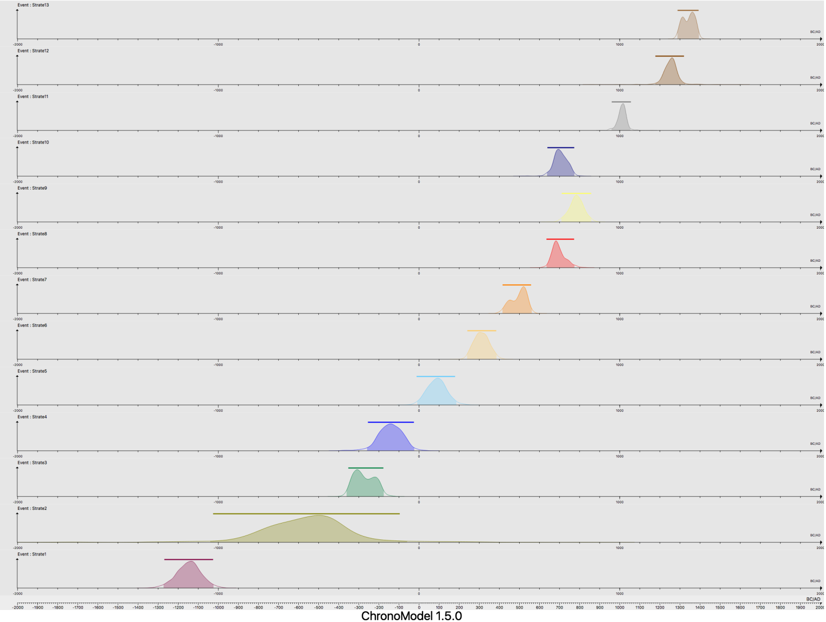


Tungurahua - Posterior densities



ChronoModel 1.5.0

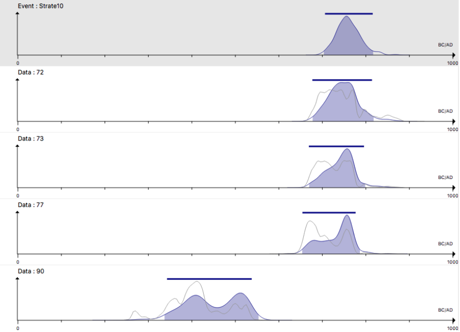
Tungurahua - Posterior densities without constraints



Tungurahua - Focus on layer 10

Marginal posterior densities of the event (θ) and the dates (t_i)

With constraints



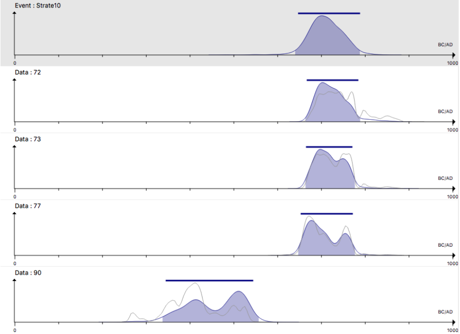
HPD Region (95%) in BC/AD

Layer 11 : [967, 1047]

Layer 10 : [706, 809]

Layer 9 : [690, 777]

Without constraints



HPD Region (95%) in BC/AD

Layer 11 : [973, 1049]

Layer 10 : [654, 782]

Layer 9 : [711, 853]

Tungurahua - Comments

Stratigraphic constraints or **temporal order constraints**

- Strong prior information

- Events are constraint, data are not

> Even if data does not satisfy the constraints, the posterior result for the events will still verifies them

> The opposite is not true

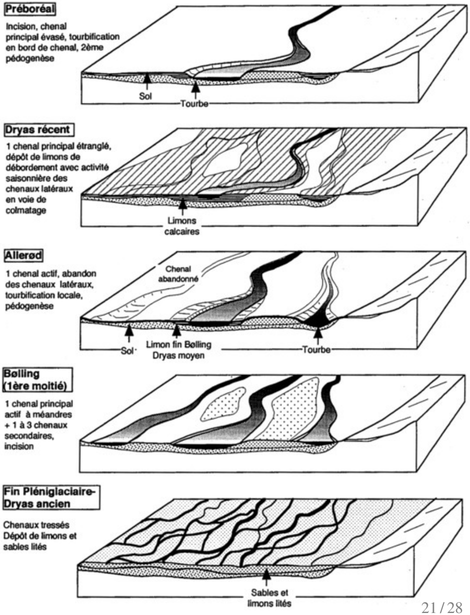
Groups of events or Phases

The example of Palynozones

Lateglacial pollen zones in the Paris basin[4]

Aim : Defining chronological transitions between 4 phases

Tgl 7 : the younger Dryas
Tgl 6 : the second part of Allerød
Tgl 5 : the first part of Allerød
Tgl 4 : the older Dryas



[4] Leroyer *et al.* 2011, 2014

Palynozones - Modelling (1)

- **Prior information** about θ*s* :

Any date between -18 000 and -5 000

+

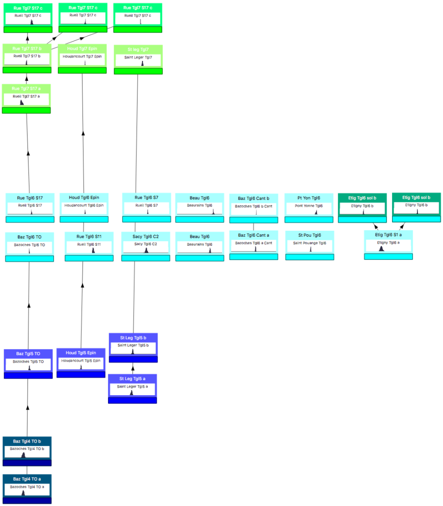
Stratigraphic constraints if any

- **Material found** :

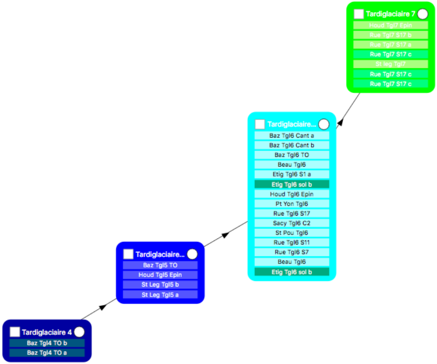
28 bulk sediment samples

dated by **C14**

> **One date per Event**



Palynozones - Modelling (2)



- **Prior information** about Phases :

Temporal order constraints

But no overlapping

$>$ **One Event belongs to only one Phase**

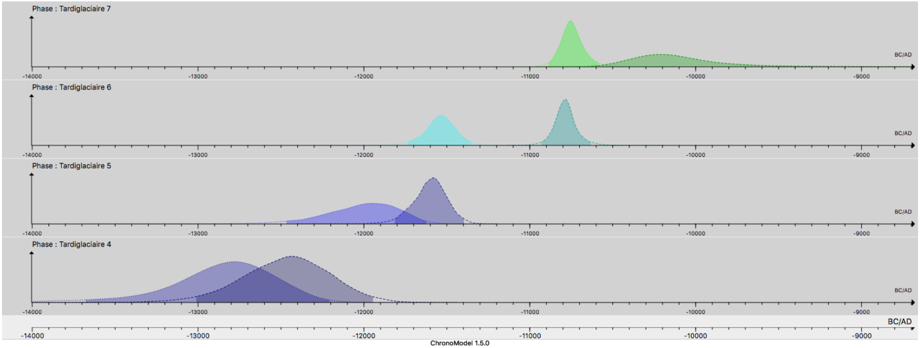
- **Marginal posterior information** about a phase :

Beginning : $\alpha = \min(\theta_{j,j=1\ldots r})$

End : $\beta = \max(\theta_{j,j=1\ldots r})$

Duration : $\tau = \beta - \alpha$

Palynozones - Posterior densities of the Phases



Palynozones - More information

- **Phase time range**

The shortest interval that covers α and β at 95%

The $100(1-\gamma)\%$ Phase time range is the shortest interval $[a,b] \subset T$ such that

$$P(a \leq \alpha \leq \beta \leq b \,|\, \mathcal{M}) = 1-\gamma \qquad (1)$$

- **Transition between two successive phases** (for P_1 older than P_2) :

The shortest interval that covers β_1 and α_2

The $100(1-\gamma)\%$ Phase transition is the shortest interval $[a,b] \subset T$ such that

$$P(a \leq \beta_1 \leq \alpha_2 \leq b \,|\, \mathcal{M}) = 1-\gamma \qquad (2)$$

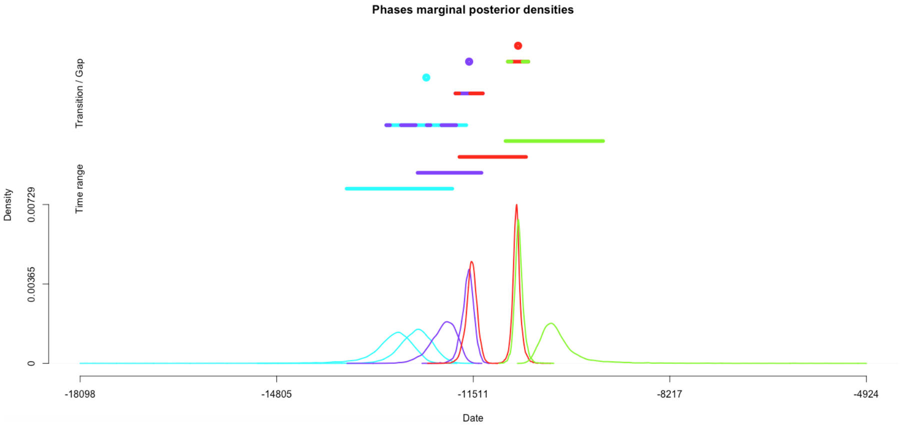
- **Test for existence of a Gap between successive two phases** :

If it exists, the longest interval included in β_1 and α_2.

The $100(1-\gamma)\%$ gap is the longest interval $[a,b] \subset T$ such that

$$P(\beta_1 \leq a \leq b \leq \alpha_2 \,|\, \mathcal{M}) = 1-\gamma \qquad (3)$$

Palynozones - RChronoModel



Phases - Comments

Phases

- Groups of Events on the basis of some criteria
- Reflect the information given by the Events included in it
- No prior information about the distribution of Events in a Phase

=> No modelling of the Phase

Posterior information

- **Phase** : Beginning / End, Duration, Time range
- **Succession of phases** : Phases Gap, Phases Transition

Softwares

- **ChronoModel version 1.5** but no Time range/ Phase Gap/ Phase Transition
- **RChronoModel package** available on CRAN for R users

www.chronomodel.fr

RChronoModel

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