



➤ Calibration of a complex population dynamics model: from its development to results validation

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Jocelyn Domange

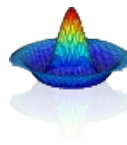
Laurent Beaulaton

Patrick Lambert

Stéphanie Mahévas

Victor Picheny

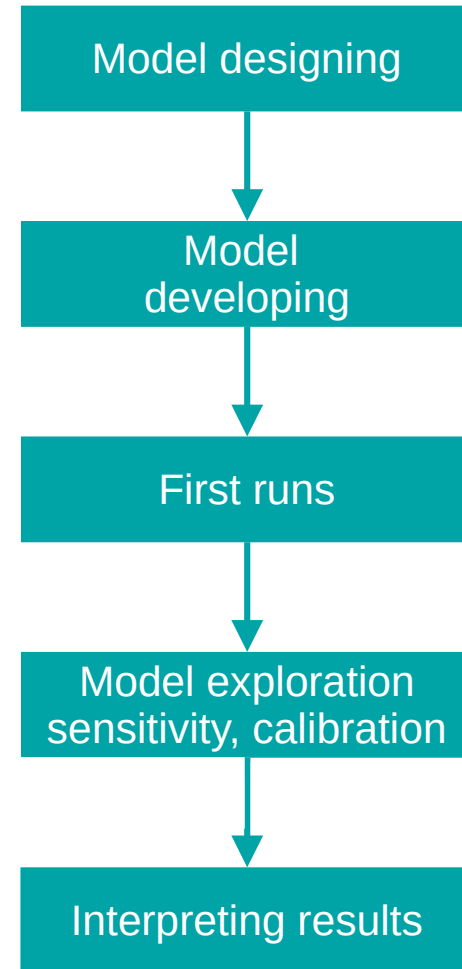
Robert Faivre



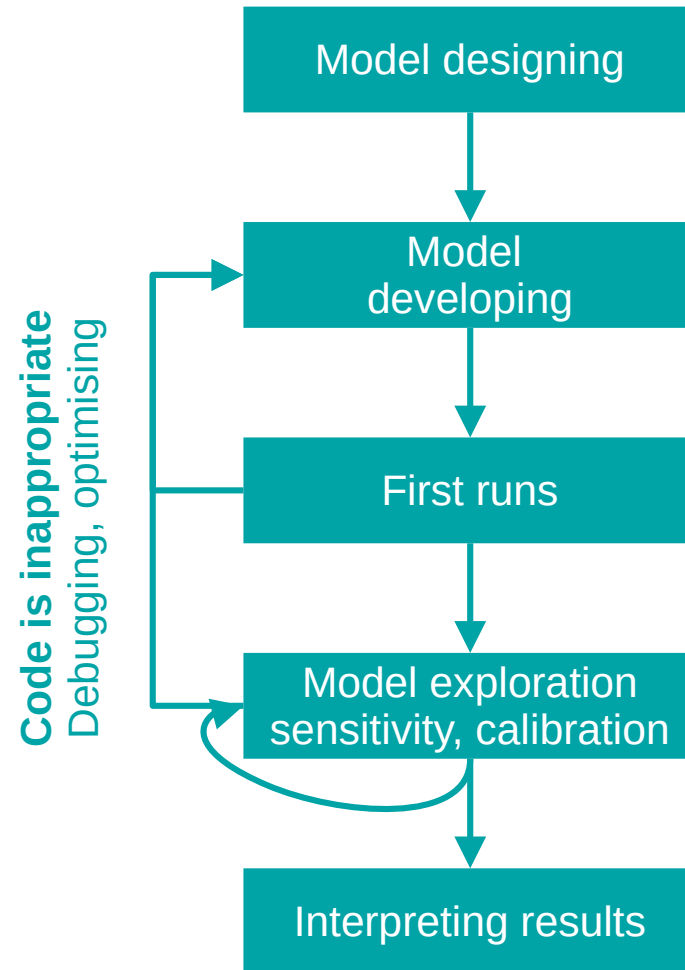
MEXICO
WEXICO



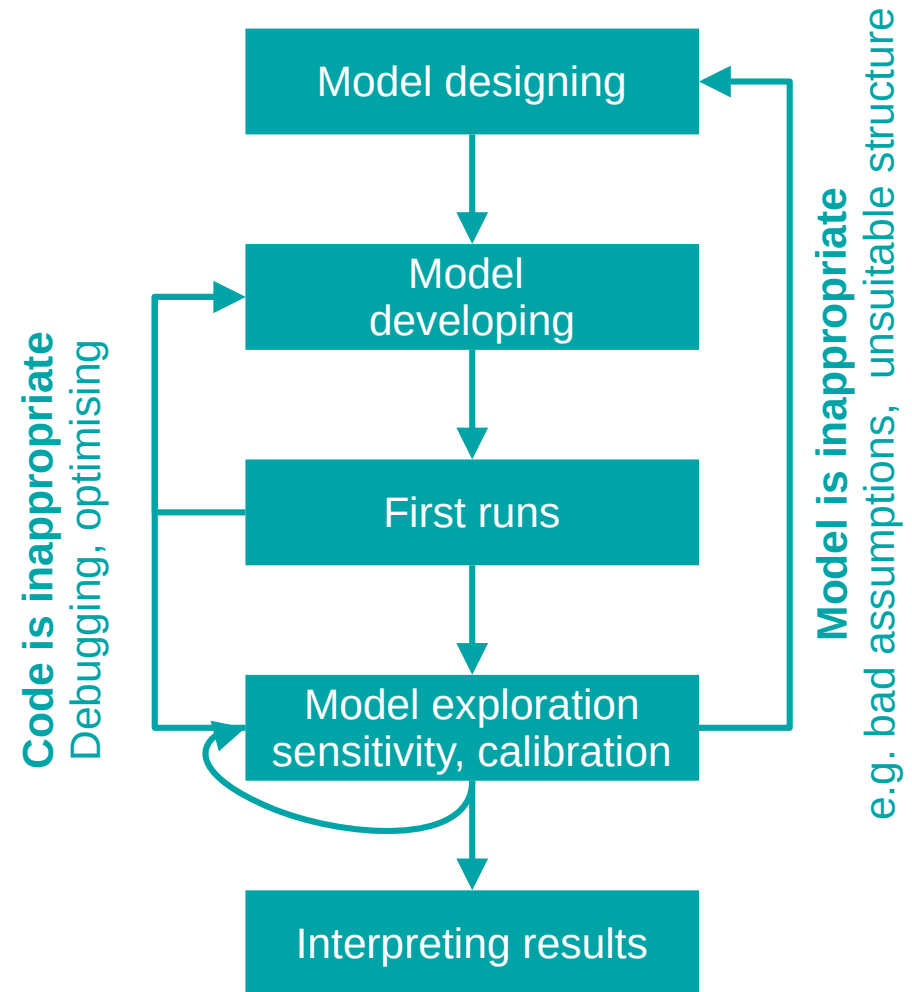
Calibration of a complex population dynamics model : a long process



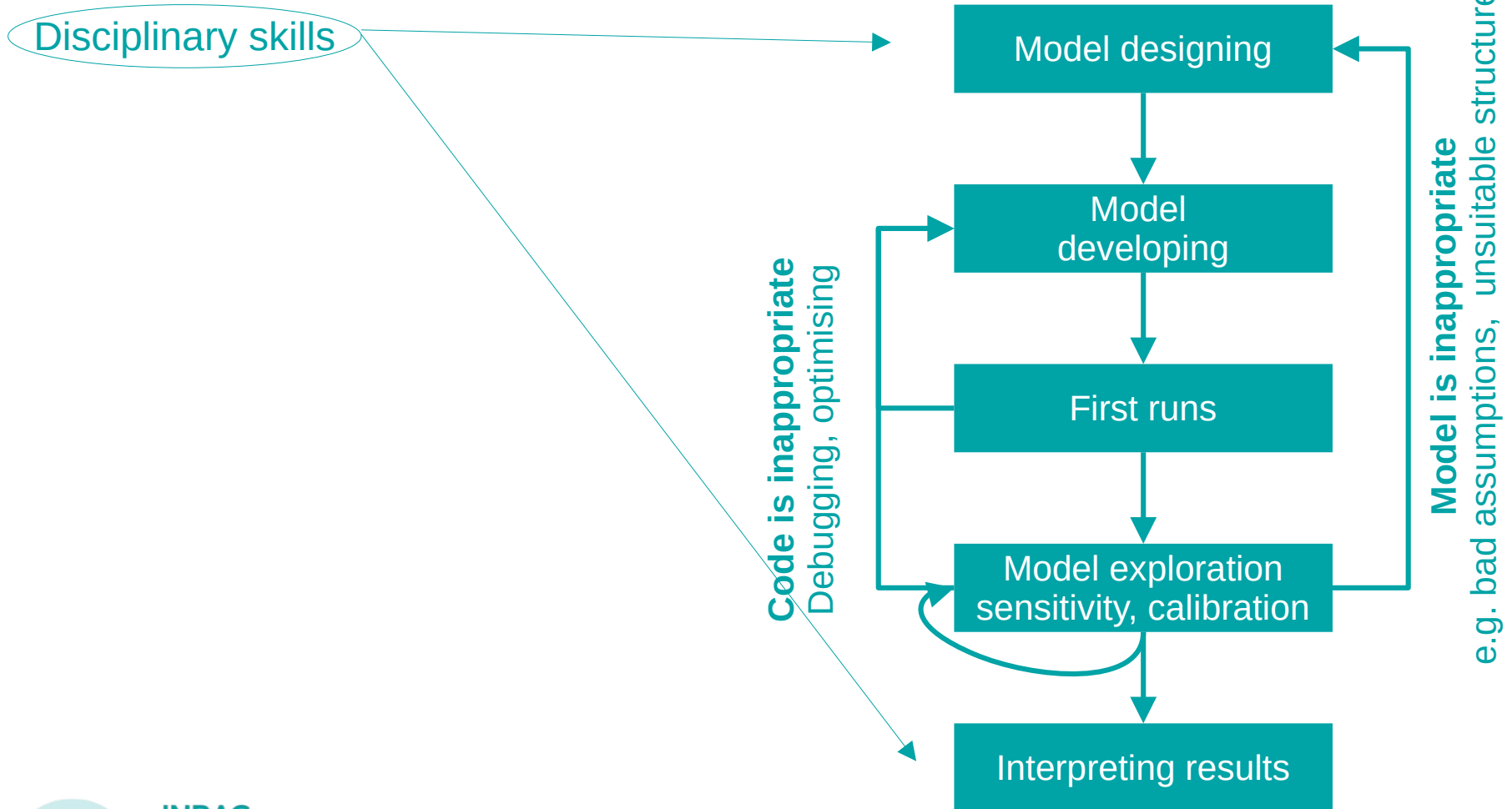
Calibration of a complex population dynamics model : a long process



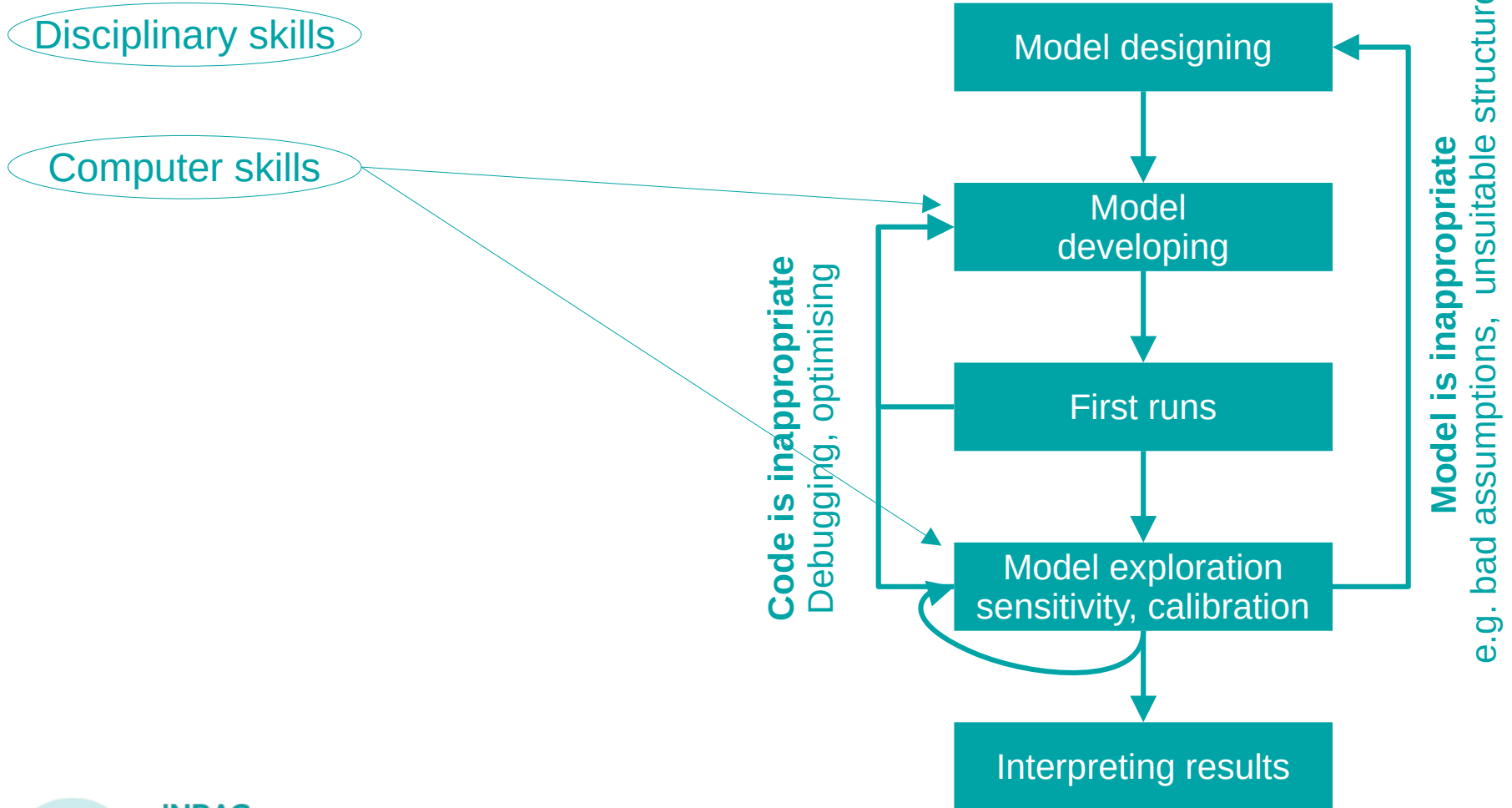
Calibration of a complex population dynamics model : a long process



Calibration of a complex population dynamics model : a long process

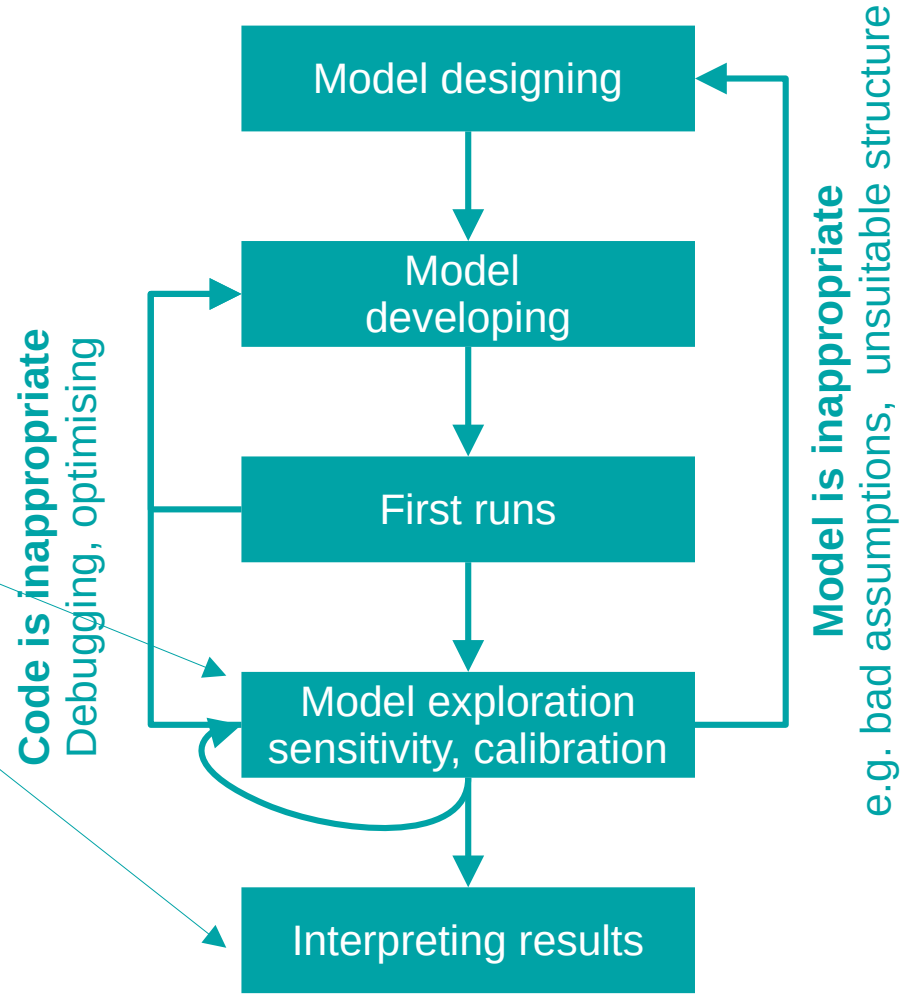


Calibration of a complex population dynamics model : a long process

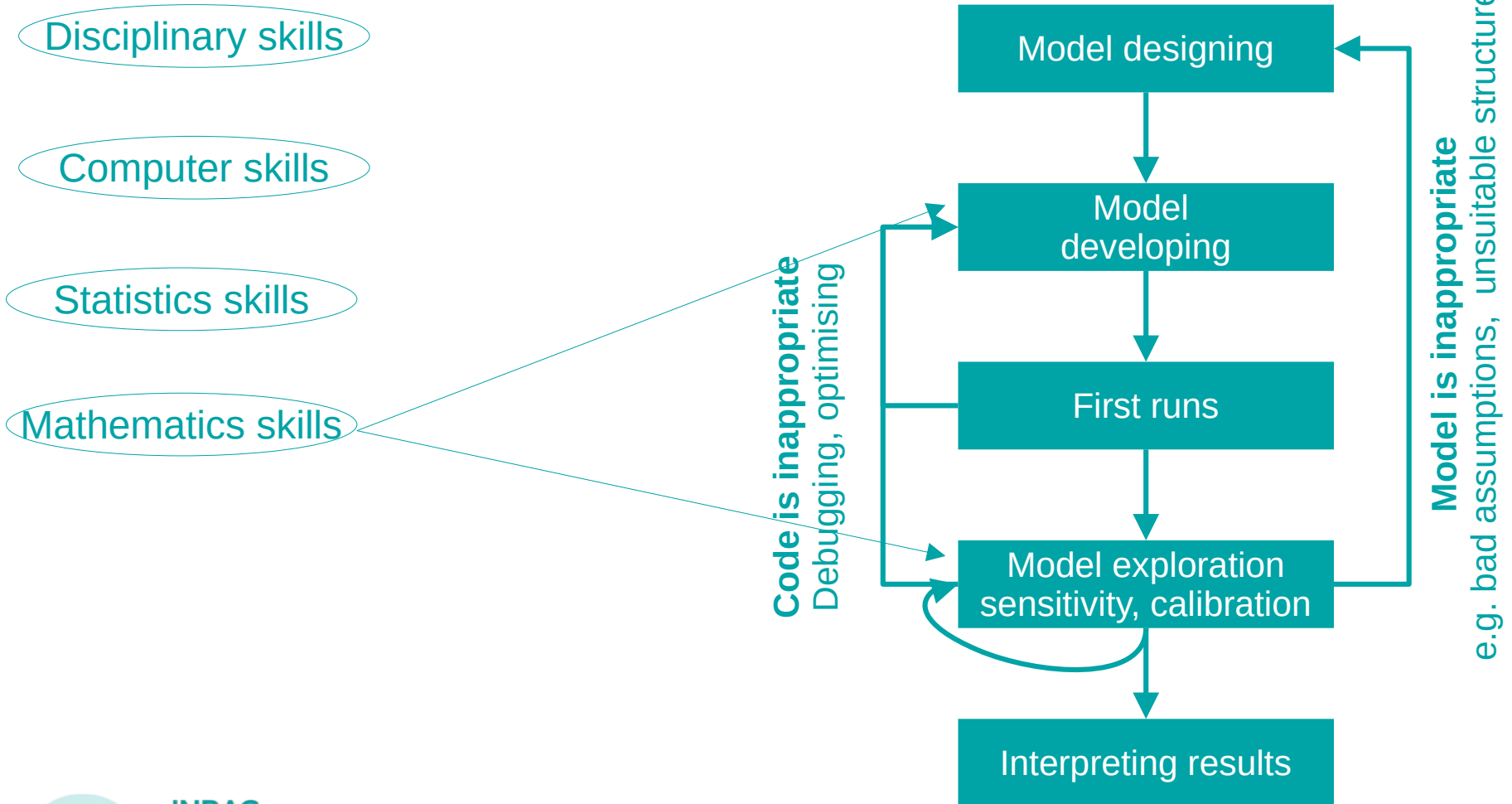


Calibration of a complex population dynamics model : a long process

- Disciplinary skills
- Computer skills
- Statistics skills



Calibration of a complex population dynamics model : a long process



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Calibration of a complex population dynamics model : a long process

Disciplinary skills

How to decrease the number of iterations?

Model designing

developing

runs

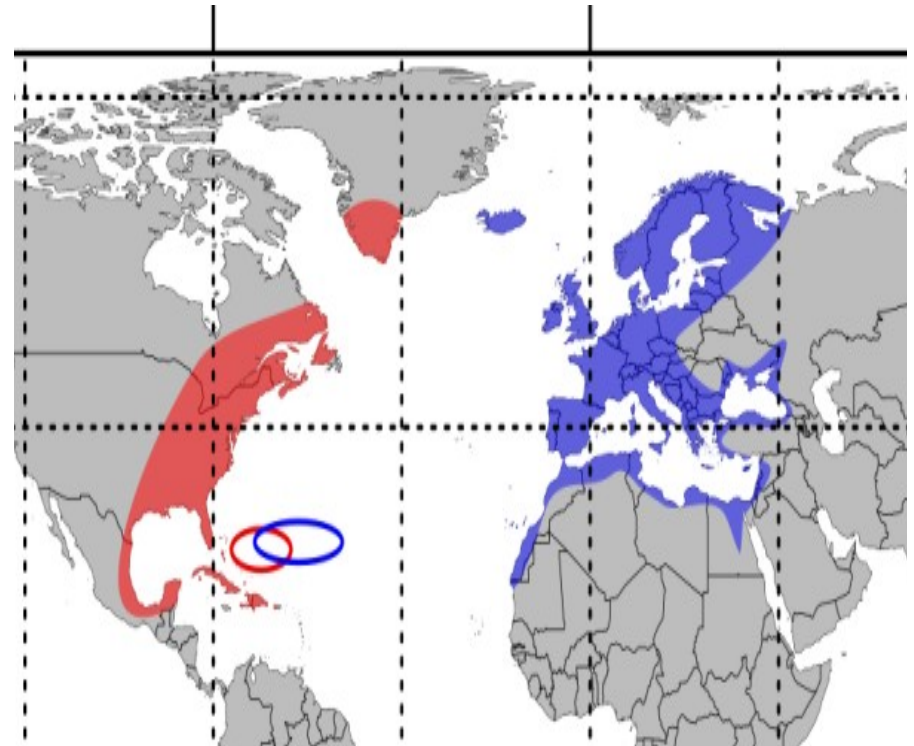
Code is
Debugging

Model exploration
sensitivity, calibration

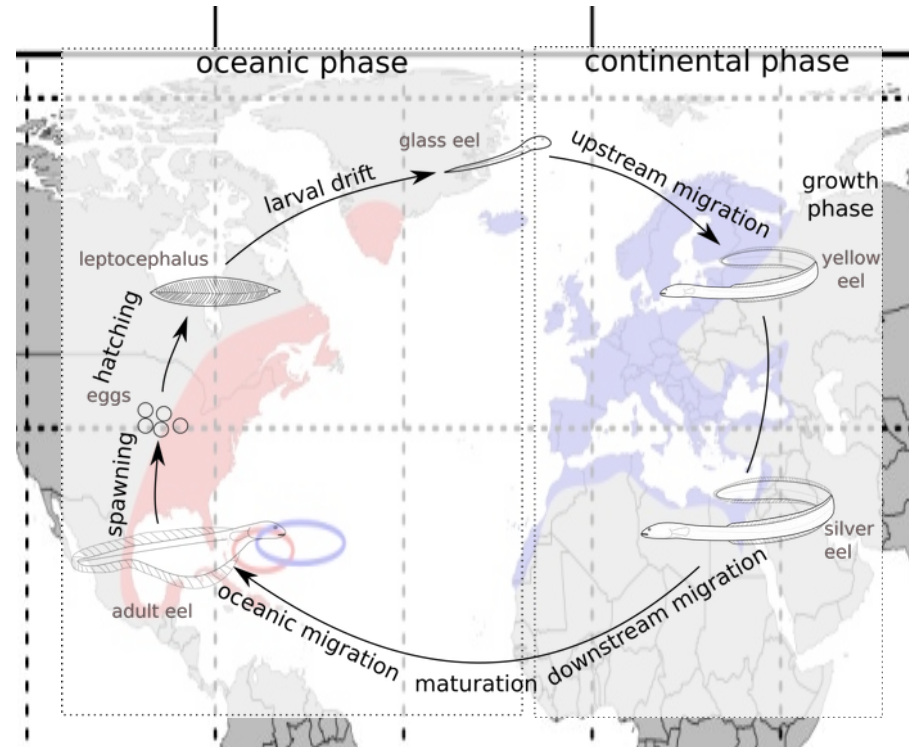
Interpreting results

Model is inappropriate
e.g. bad assumptions, unsuitable structure

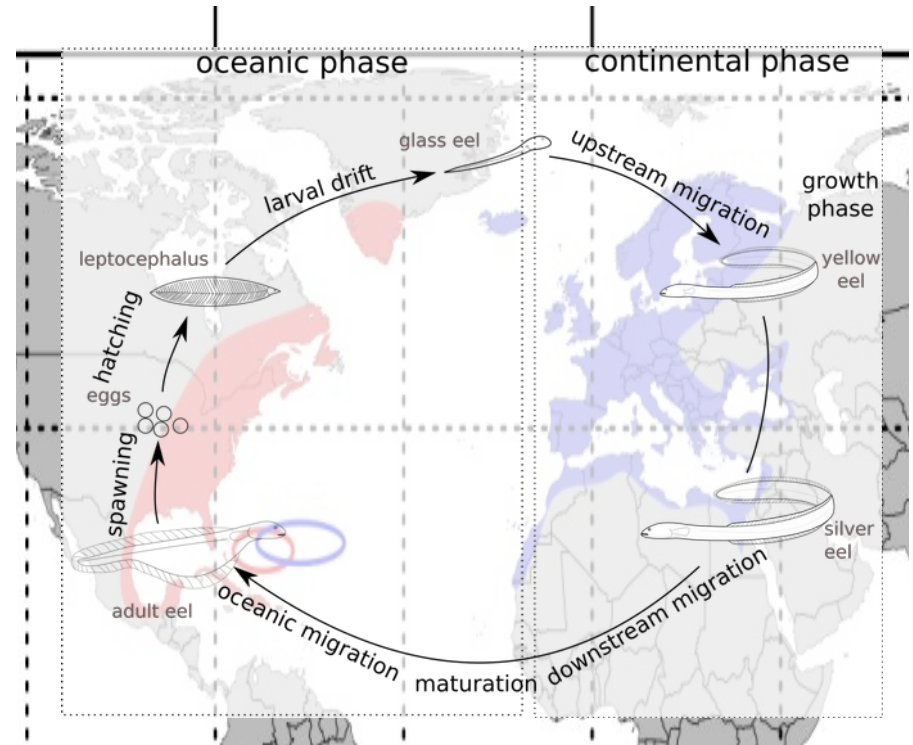
How many eels are killed by hydropower plant turbines in France ?



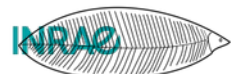
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How many eels are killed by hydropower plant turbines in France ?



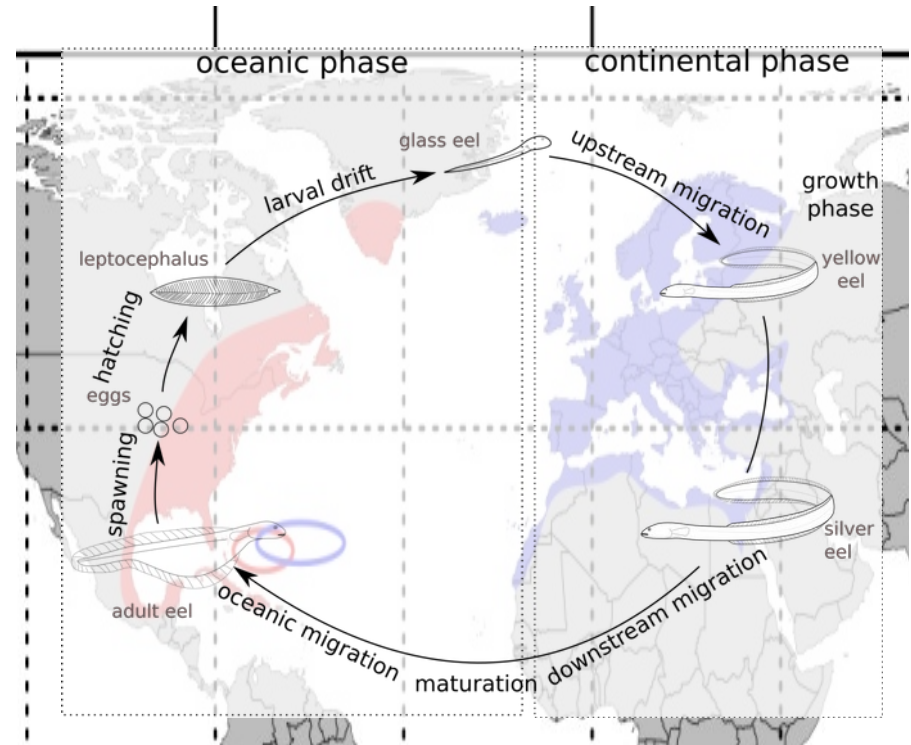
hungry... and lost!



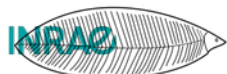
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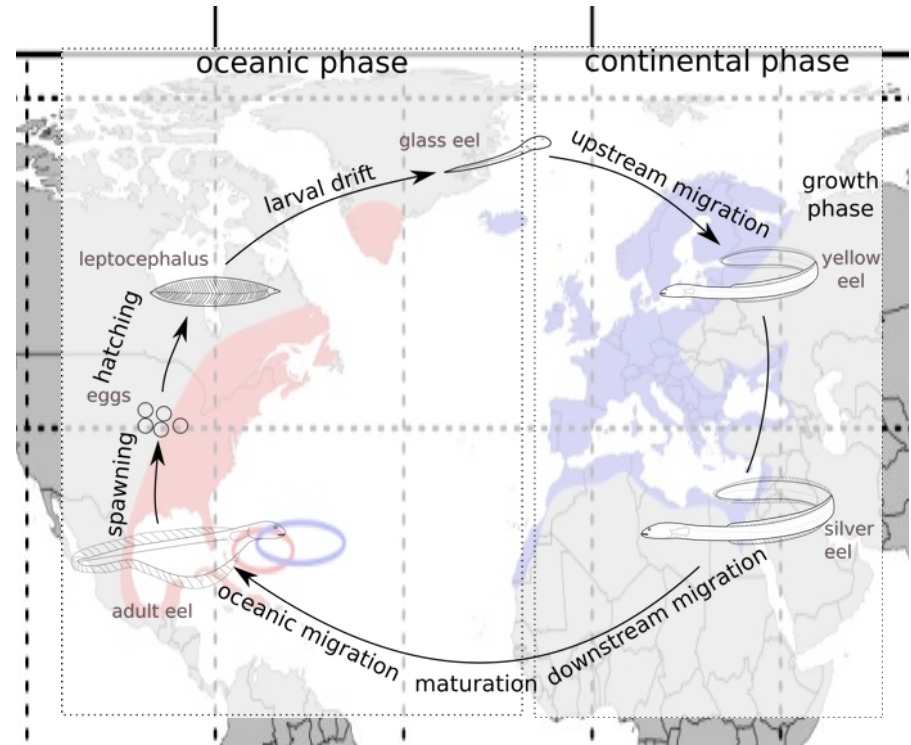
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How many eels are killed by hydropower plant turbines in France ?



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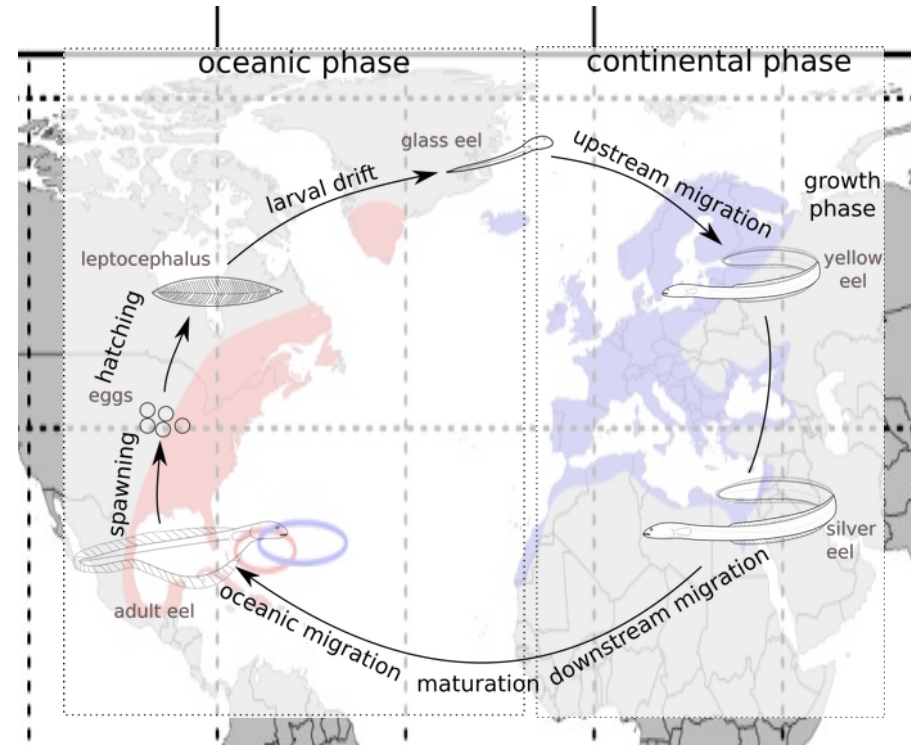
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hungry... and lost!

Groupement de Recherche
MASCOT-NUM
CIRIS



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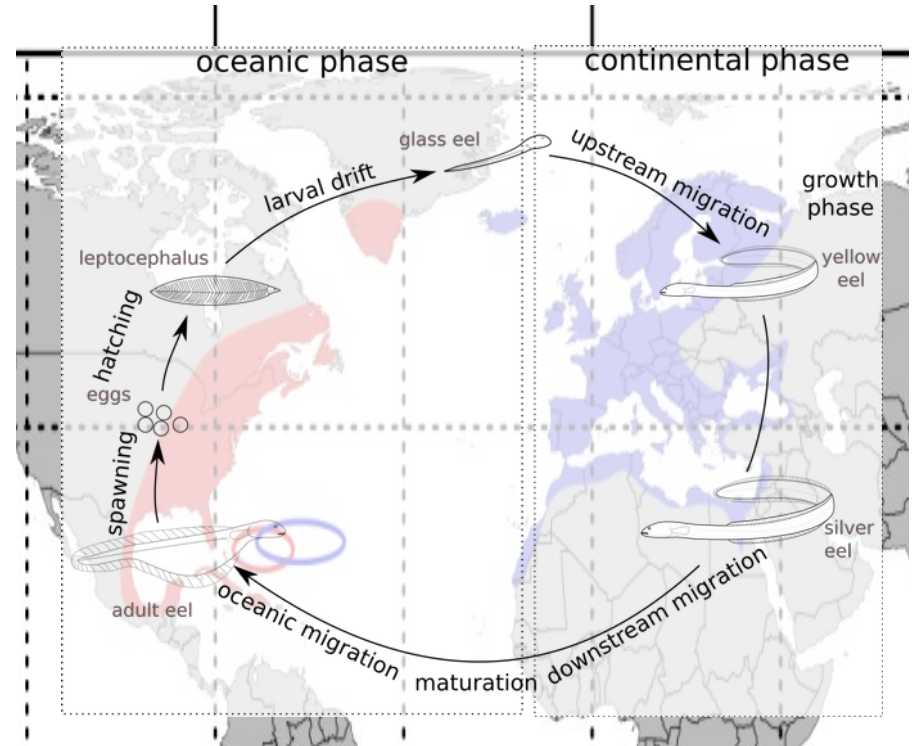
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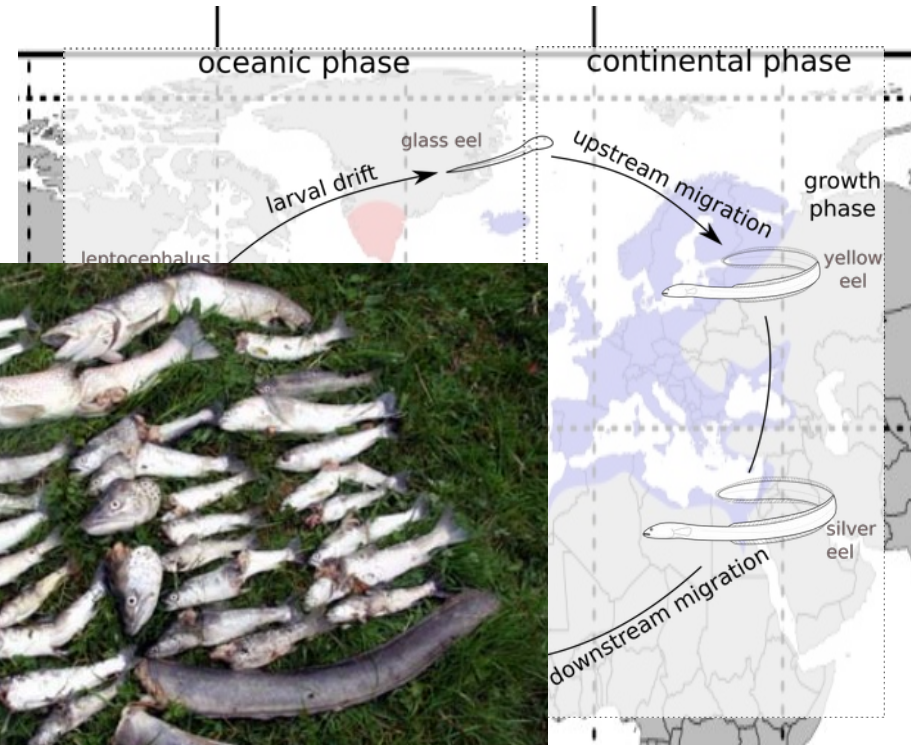
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How many eels are killed by hydropower plant turbines in France ?



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Anguilla anguilla

<http://dx.doi.org/10.2305/IUCN.UK.2014-1.RLTS.T60344A45833138.en>

Scope: Global
Language: English

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NOT EVALUATED	DATA DEFICIENT	LEAST CONCERN	NEAR THREATENED	VULNERABLE	ENDANGERED	CRITICALLY ENDANGERED	EXTINCT IN THE WILD	EXTINCT
NE	DD	LC	NT	VU	EN	CR	EW	EX

22.9.2007

FR

Journal officiel de l'Union européenne

L 248/17

RÈGLEMENT (CE) N° 1100/2007 DU CONSEIL

du 18 septembre 2007

instituant des mesures de reconstitution du stock d'anguilles européennes

How many eels are killed by hydropower plant turbines in France ?



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Anguilla anguilla

<http://dx.doi.org/10.2305/IU>

NOT EVALUATED	DATA DEFICIENT
NE	DD



How many????
Where????

CRITICALLY ENDANGERED
CR

EXTINCT IN THE WILD
EW

EXTINCT
EX

Scope: Global

Language: English

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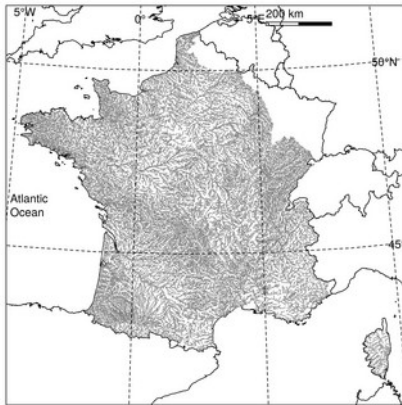
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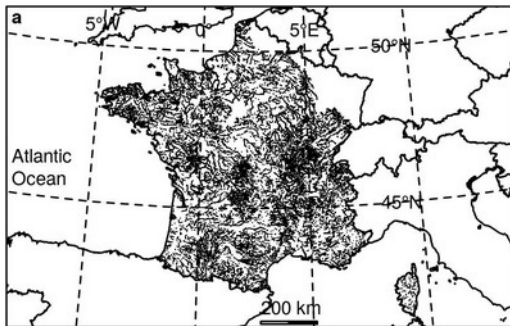


Hydrographic network:
>900 river basins
>280 000 km

How many eels are killed by hydropower plant turbines in France ?

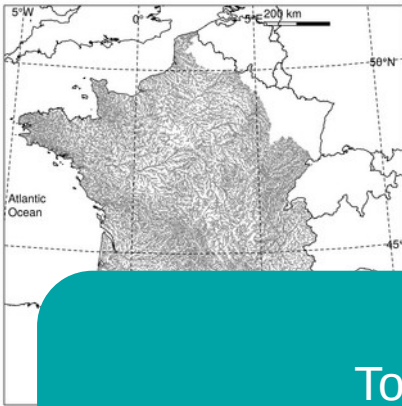


Hydrographic network:
>900 river basins
>280 000 km



>70 000 dams/weirs

How many eels are killed by hydropower plant turbines in France ?



Hydrographic network:
>900 river basins
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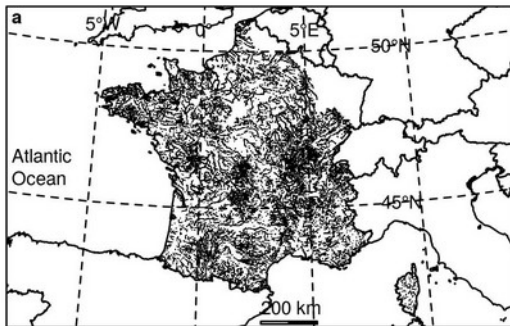
To know how many eels die, I need to know:
how many eels are in basins
where they are with respect to hydropower plants



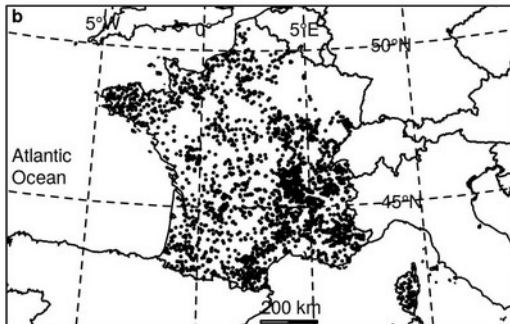
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Hydrographic network:
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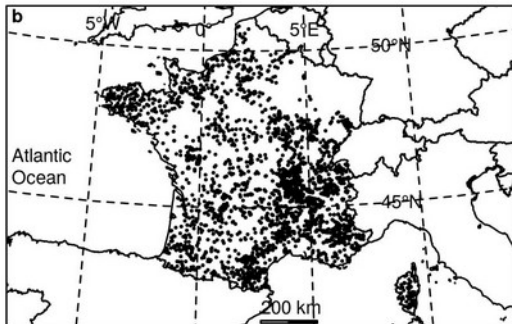
Abundance estimates + sd through
electrofishing monitoring
8531 operations
from 1990 to 2009

How many eels are killed by hydropower plant turbines in France ?



Hydrographic network:
>900 river basins
>280 000 km

Objective: Calibrate a model to estimate yearly abundance and location of eels using electrofishing data



Abundance estimates + sd through
electrofishing monitoring
8531 operations
from 1990 to 2009

Tabasco a random walk model

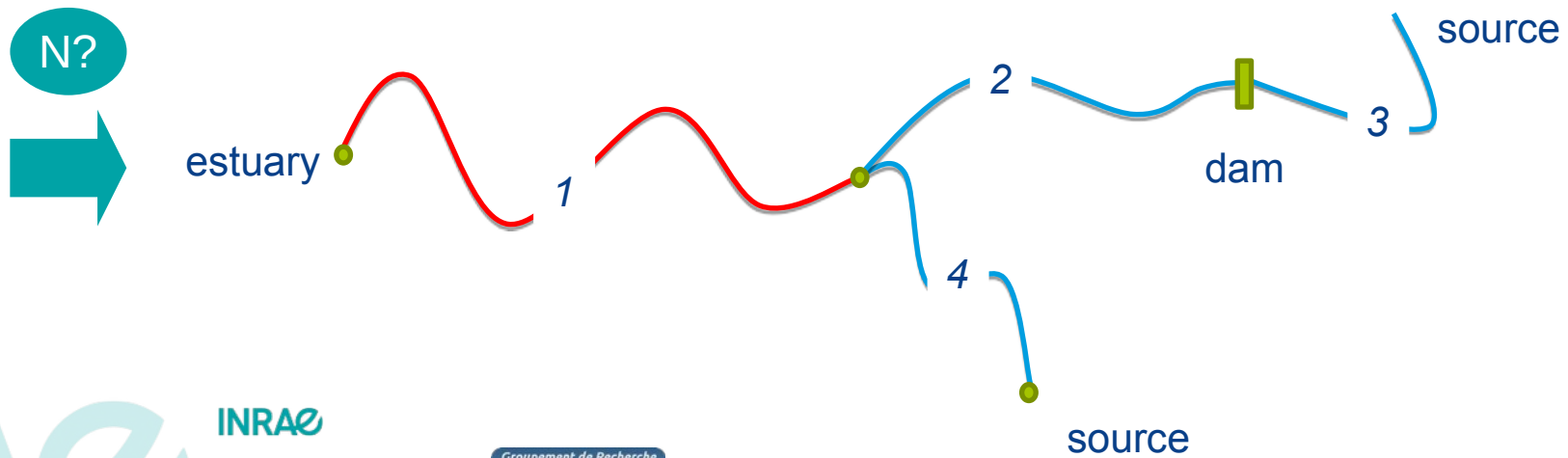


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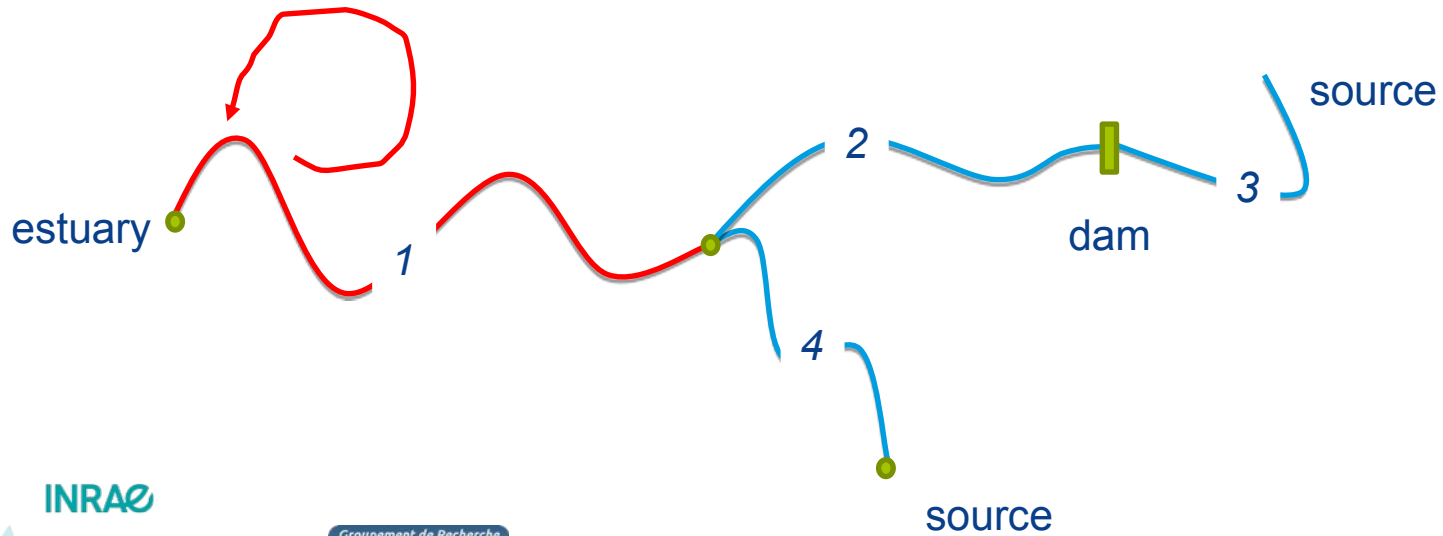
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Tabasco a random walk model



Tabasco a random walk model



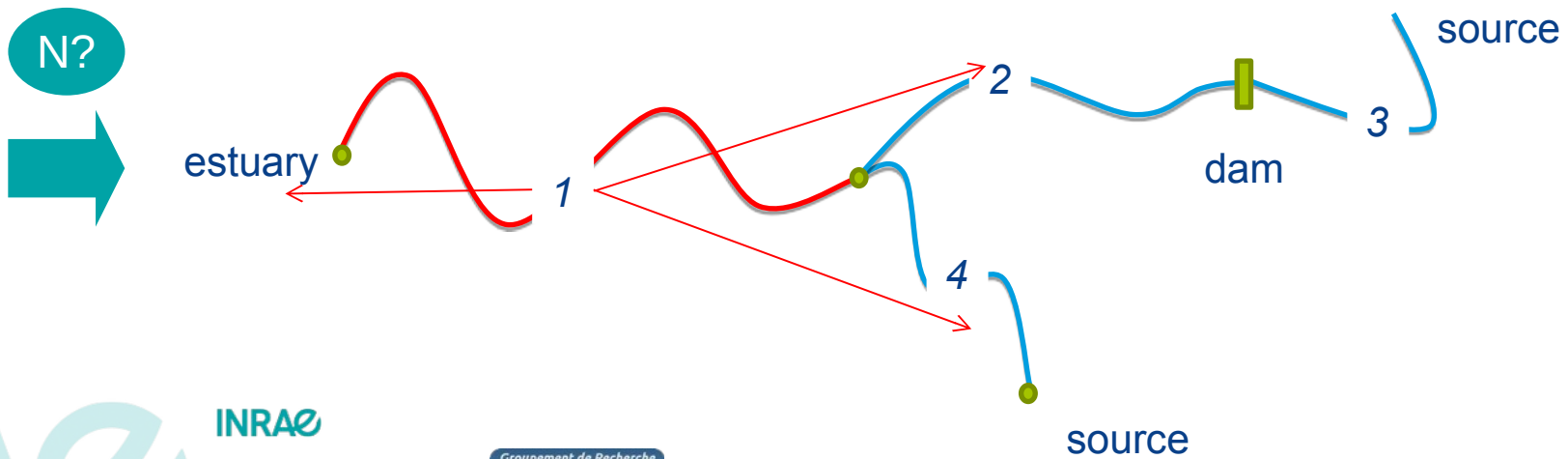
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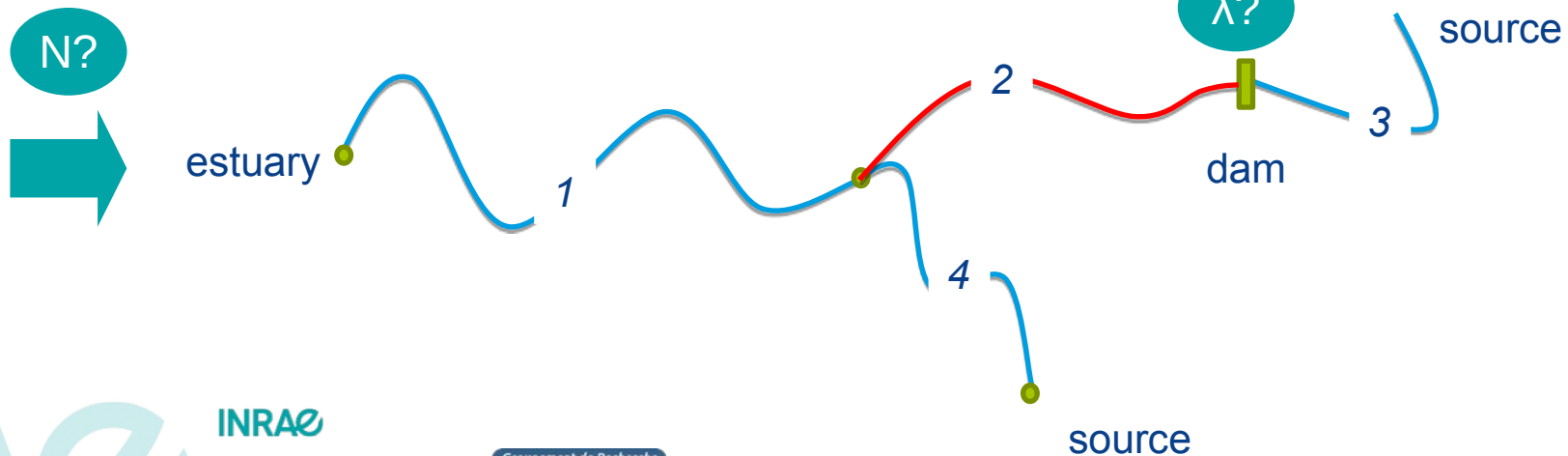
Tabasco a random walk model

$$\begin{bmatrix} 1/3 & 1/3 & 0 & 1/3 \end{bmatrix}$$



Tabasco a random walk model

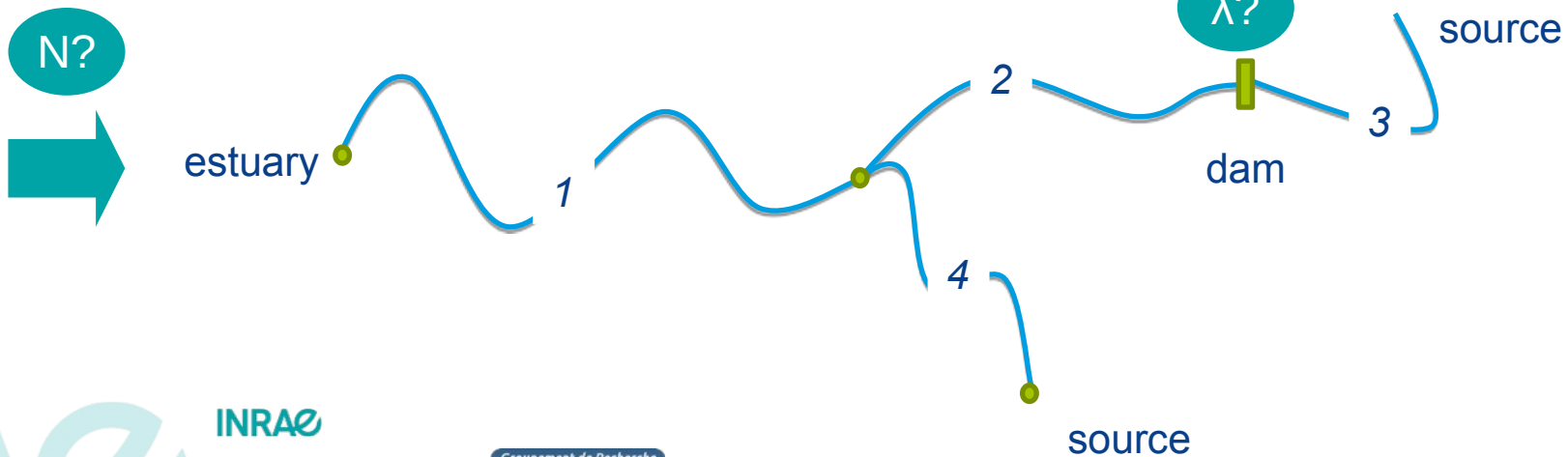
$$\begin{bmatrix} 1/3 & 1/3 & 0 & 1/3 \\ 1/3 & (1-\lambda) \cdot 1/3 & \lambda \cdot 1/3 & 1/3 \end{bmatrix}$$



Tabasco a random walk model

$$\begin{bmatrix} 1/3 & 1/3 & 0 & 1/3 \\ 1/3 & (1-\lambda)\cdot 1/3 & \lambda\cdot 1/3 & 1/3 \\ 0 & \lambda\cdot 1/2 & (1-\lambda)\cdot 1/2+1/2 & 0 \\ 1/3 & 1/3 & 0 & 1/3 \end{bmatrix}$$

b?



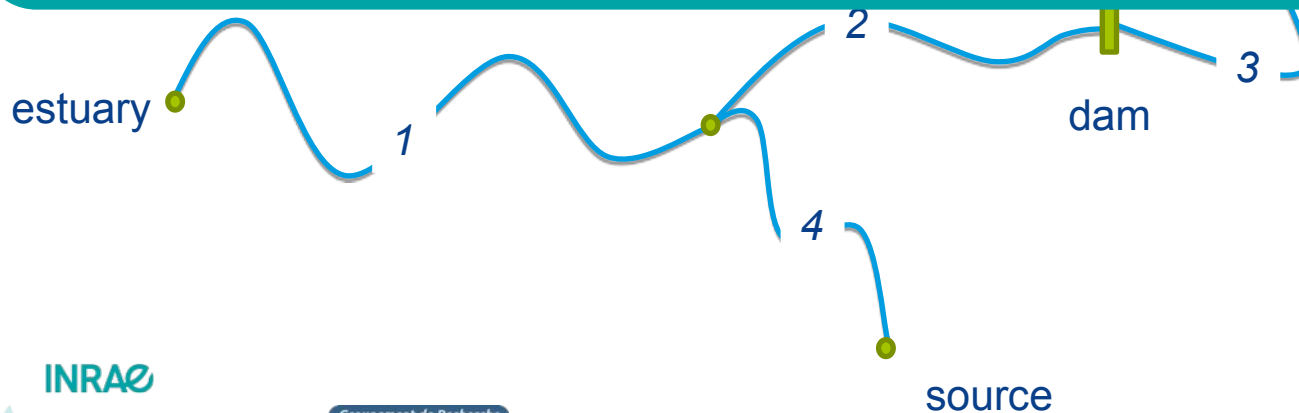
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b?

No way to compare how densities decreases when there is a dam to a situation when there is no dam =>
Impossible to estimate λ

N?

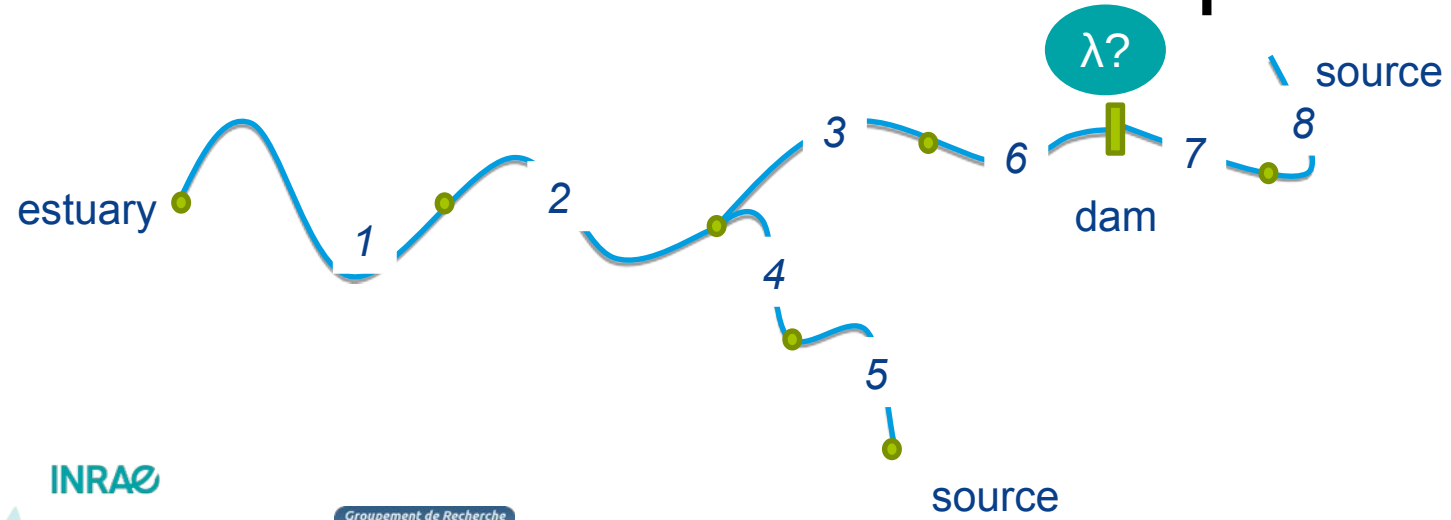


Tabasco a random walk model

$$\begin{bmatrix}
 1/2 & 1/2 & 0 & 0 & 0 & 0 & 0 & 0 \\
 1/3 & 0 & 1/3 & 1/3 & 0 & 0 & 0 & 0 \\
 0 & 1/3 & 0 & 1/3 & 0 & 1/3 & 0 & 0 \\
 0 & 1/3 & 1/3 & 0 & 1/3 & 0 & 0 & 0 \\
 0 & 0 & 0 & 1/2 & 1/2 & 0 & 0 & 0 \\
 0 & 0 & 1/2 & 0 & 0 & (1-\lambda)\cdot 1/2 & \lambda\cdot 1/2 & 0 \\
 0 & 0 & 0 & 0 & 0 & \lambda\cdot 1/2 & (1-\lambda)\cdot 1/2 & 1/2 \\
 0 & 0 & 0 & 0 & 0 & 0 & 1/2 & 1/2
 \end{bmatrix}$$

b?

N?



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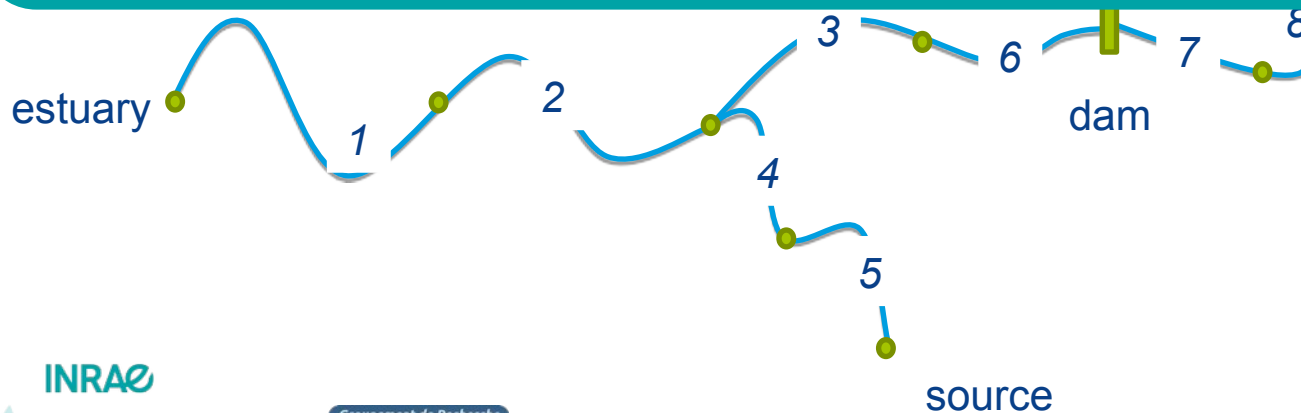
Tabasco a random walk model

1/2	1/2	0	0	0	0	0	0	0
1/3	0	1/3	1/3	0	0	0	0	0
0	1/3	0	1/3	0	1/3	0	0	0
0	1/3	1/3	0	1/3	0	0	0	0

b?

From 180 000 reaches to 225 000 => bigger matrices => large increase in computation time

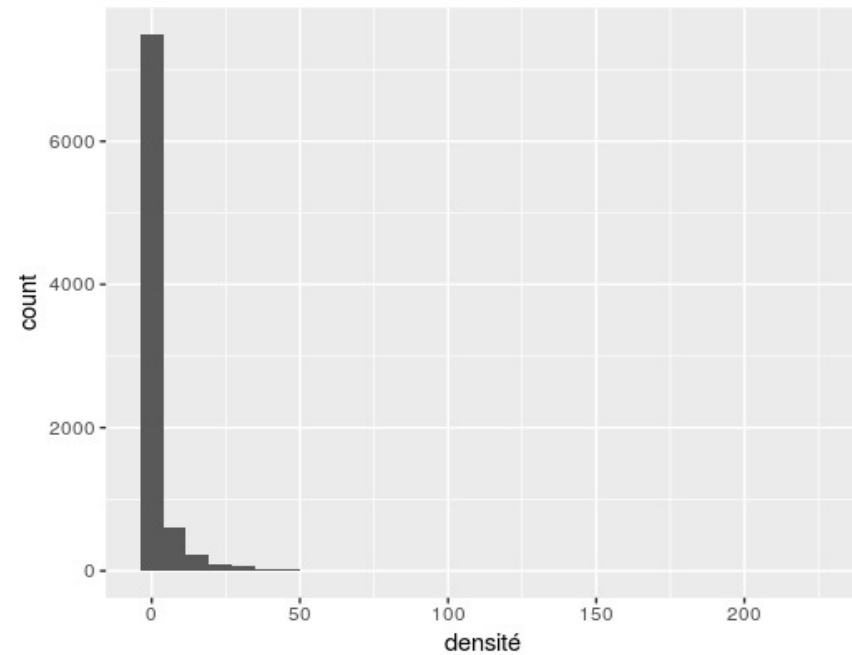
N?



Tabasco objective function

- Likelihood function

- $f(Y = 0) \sim \text{Binomial}(\theta)$
- $f(Y=x \mid Y>0) \sim \text{Gamma}(\theta)$
- $f(Y=0) = \text{PGamma}(1, \theta)$
- $f(Y=X \mid Y \geq 1) \sim \text{Gamma}(\theta)$
- $f(y=X) = \text{PGamma}(X+1.96 \text{ sd}) - \text{Pgamma}(X-1.96 \text{ sd})$



Tabasco - unknown parameters

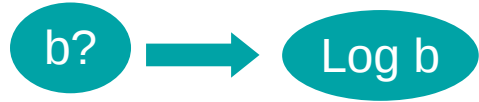
b?

IRAØ

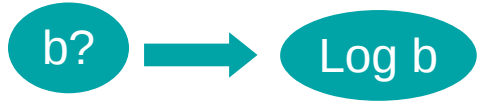
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Tabasco - unknown parameters

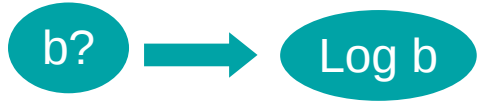


Tabasco - unknown parameters



6.2 ↔ 12

Tabasco - unknown parameters



6.2 ↔ 12

N?

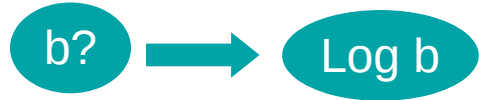


IRAØ

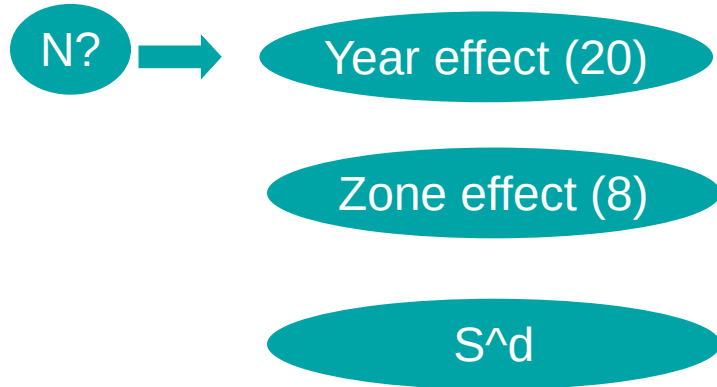
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Tabasco - unknown parameters



6.2 ↔ 12



Tabasco - unknown parameters

b?



Log b

6.2 ↔ 12

N?



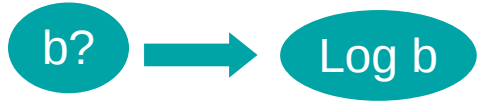
Year effect (20)

$$N(y, z, bv) = Z(z) \cdot Y(y) \cdot S_{bv}^b$$

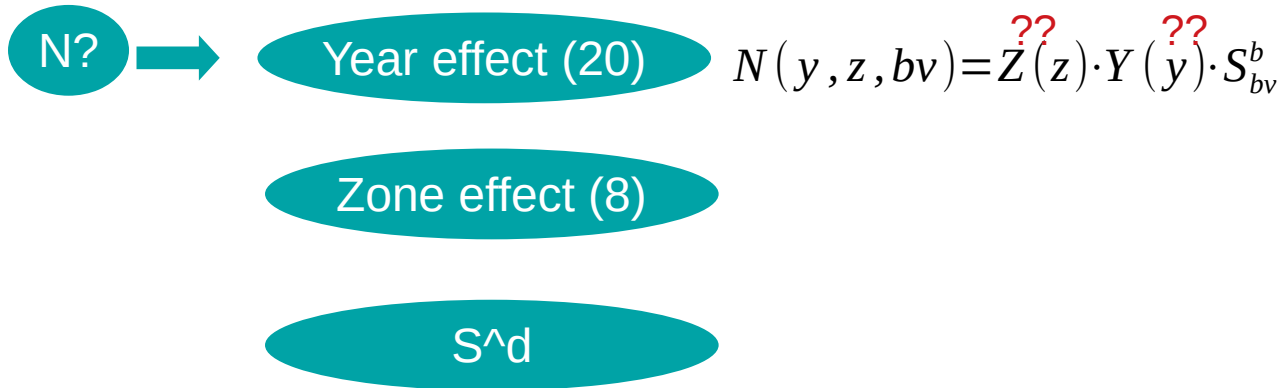
Zone effect (8)

S^d

Tabasco - unknown parameters



6.2 ↔ 12



Tabasco - unknown parameters

b?



Log b

6.2 ↔ 12

N?



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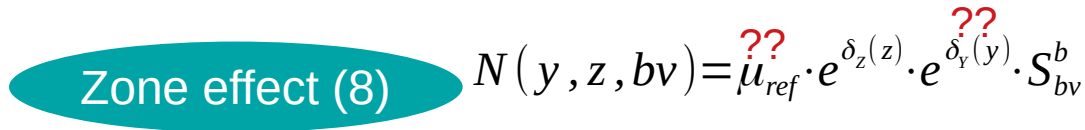
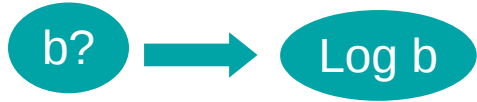
Zone effect (8)

$$N(y, z, bv) = \mu_{ref} \cdot e^{\delta_z(z)} \cdot e^{\delta_y(y)} \cdot S_{bv}^b$$

S^d

Tabasco - unknown parameters

6.2 ↔ 12



Tabasco - unknown parameters

b?



Log b

6.2 ↔ 12

N?



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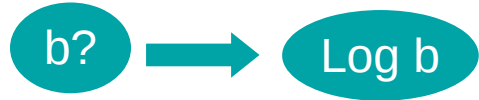
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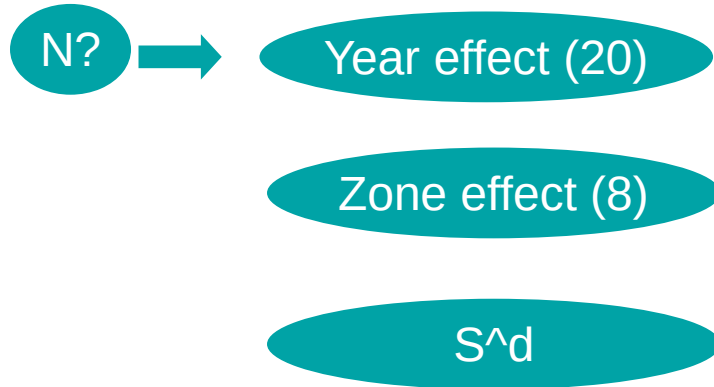
$$N(y, z, bv) = e^{\mu_{ref}} \cdot e^{\delta_z(z)} \cdot e^{\delta_y(y)} \cdot S_{bv}^b \cdot N(y-1, z, bv)$$

S^d

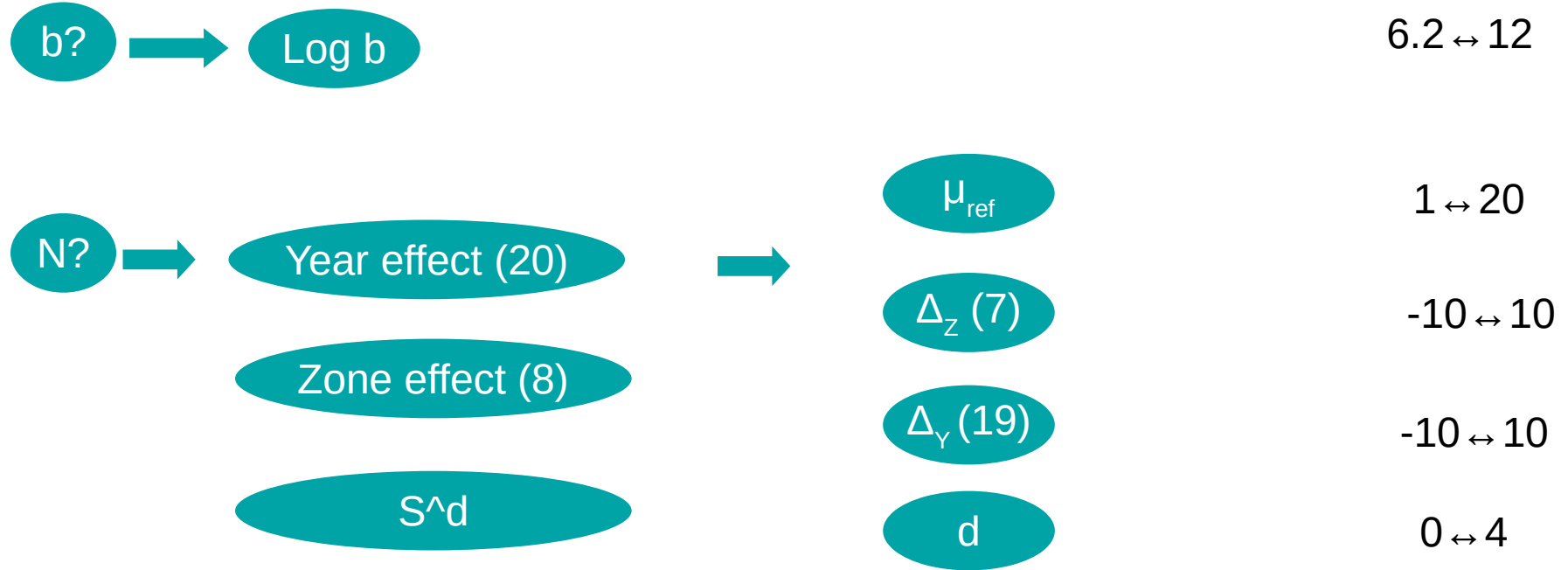
Tabasco - unknown parameters



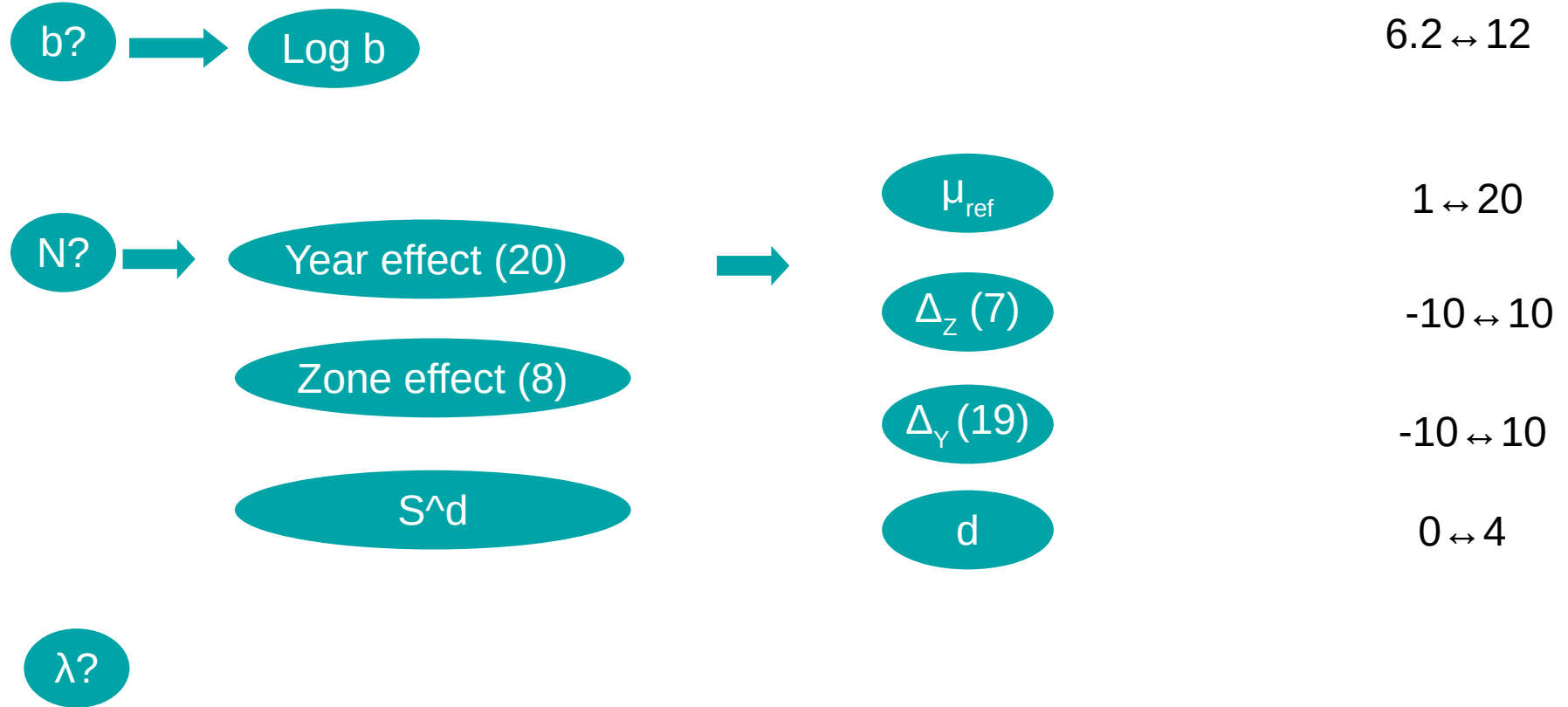
6.2 ↔ 12



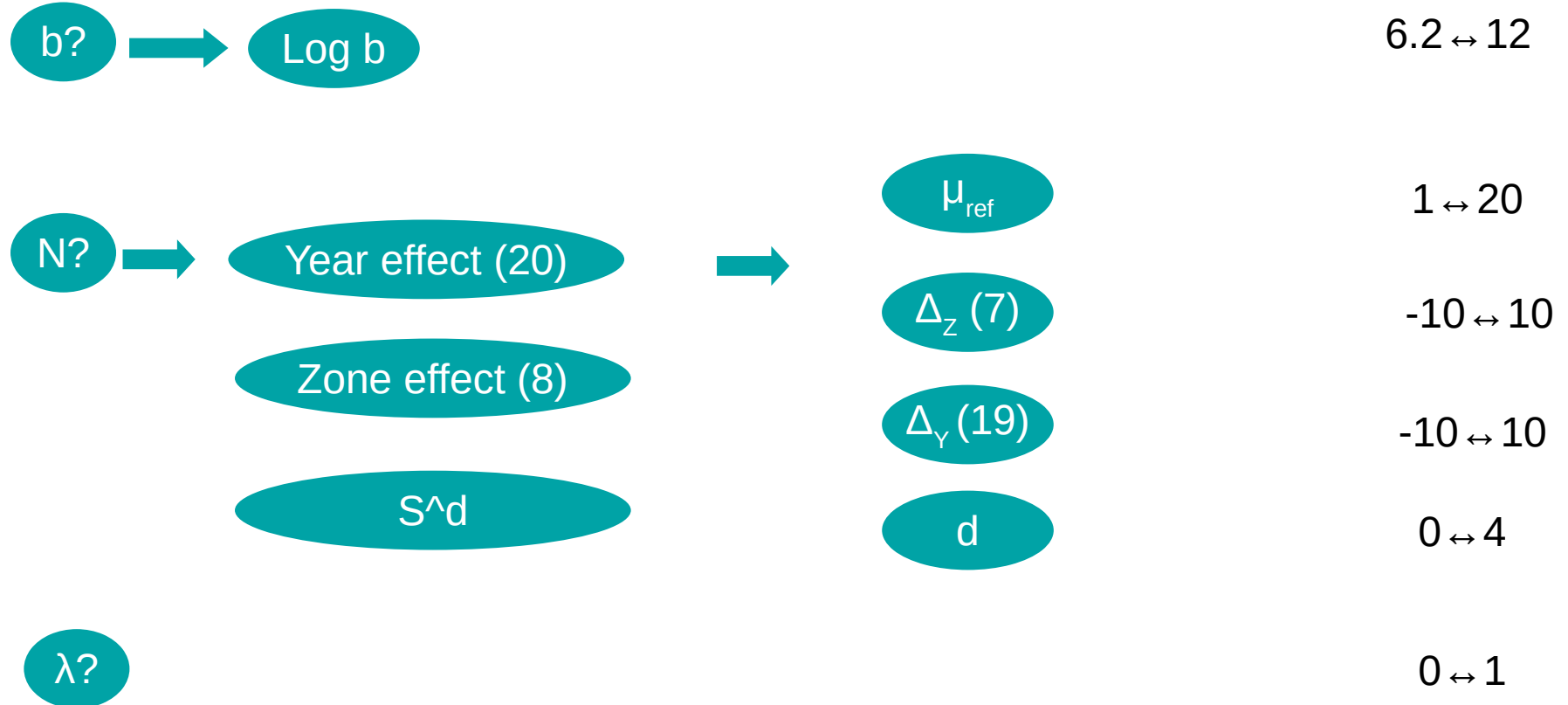
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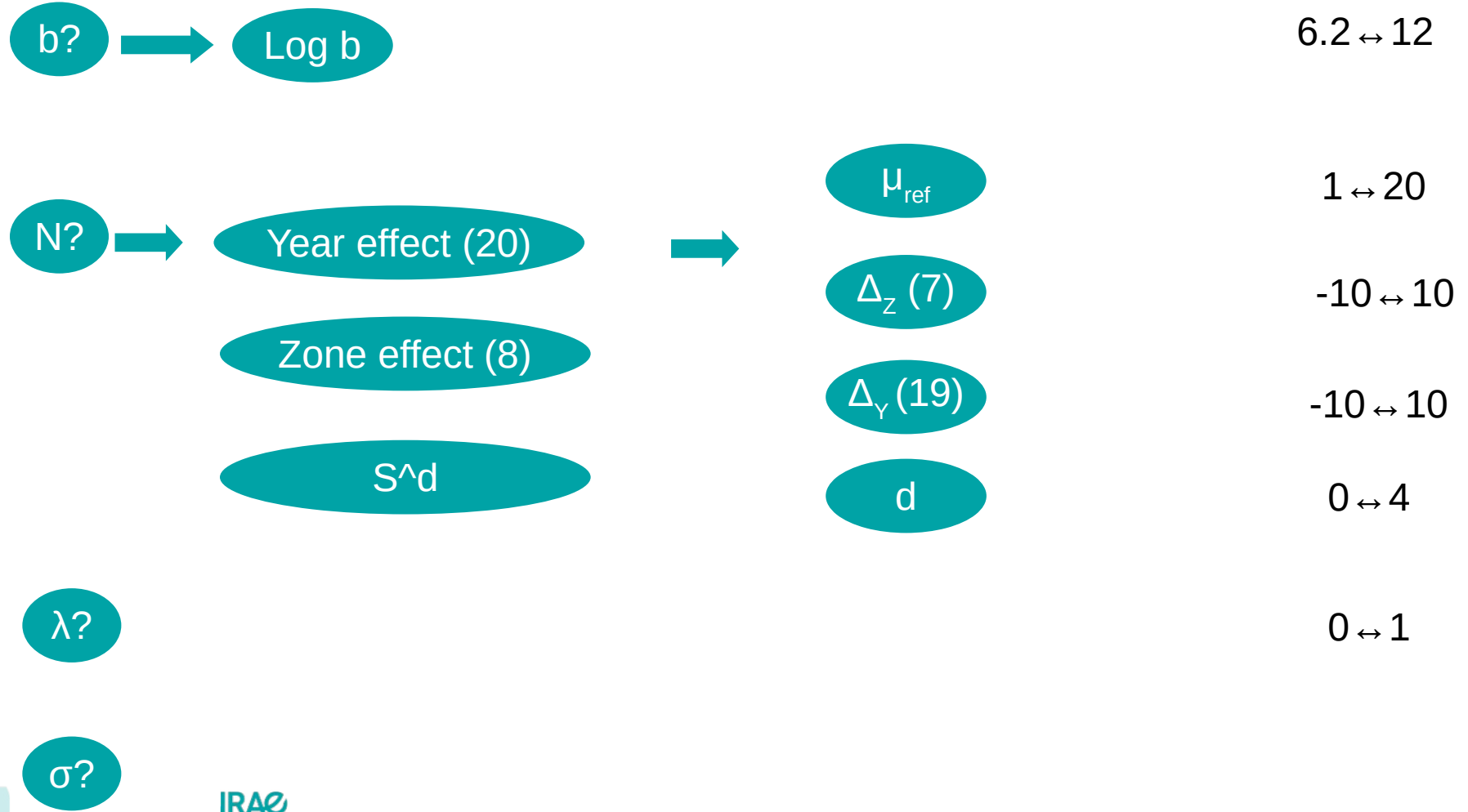
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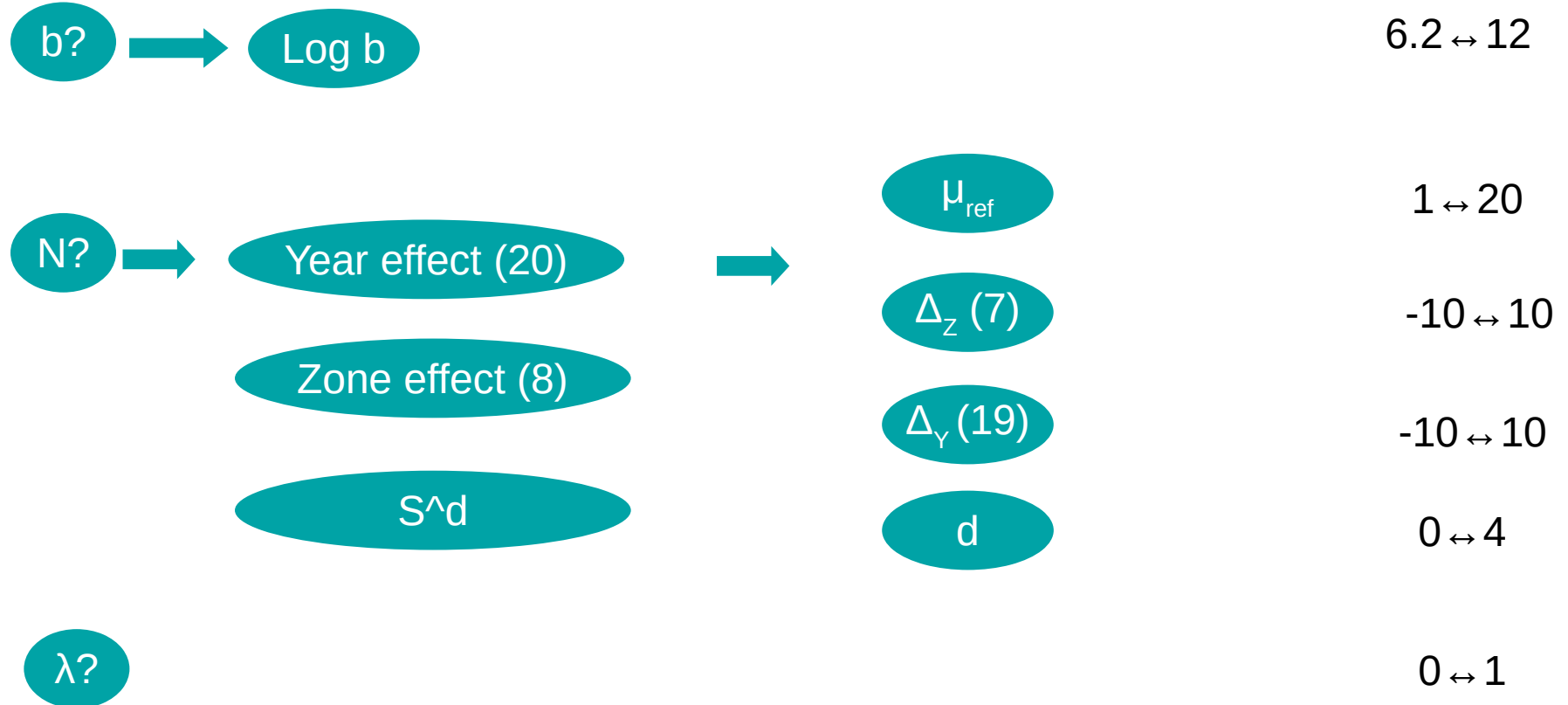
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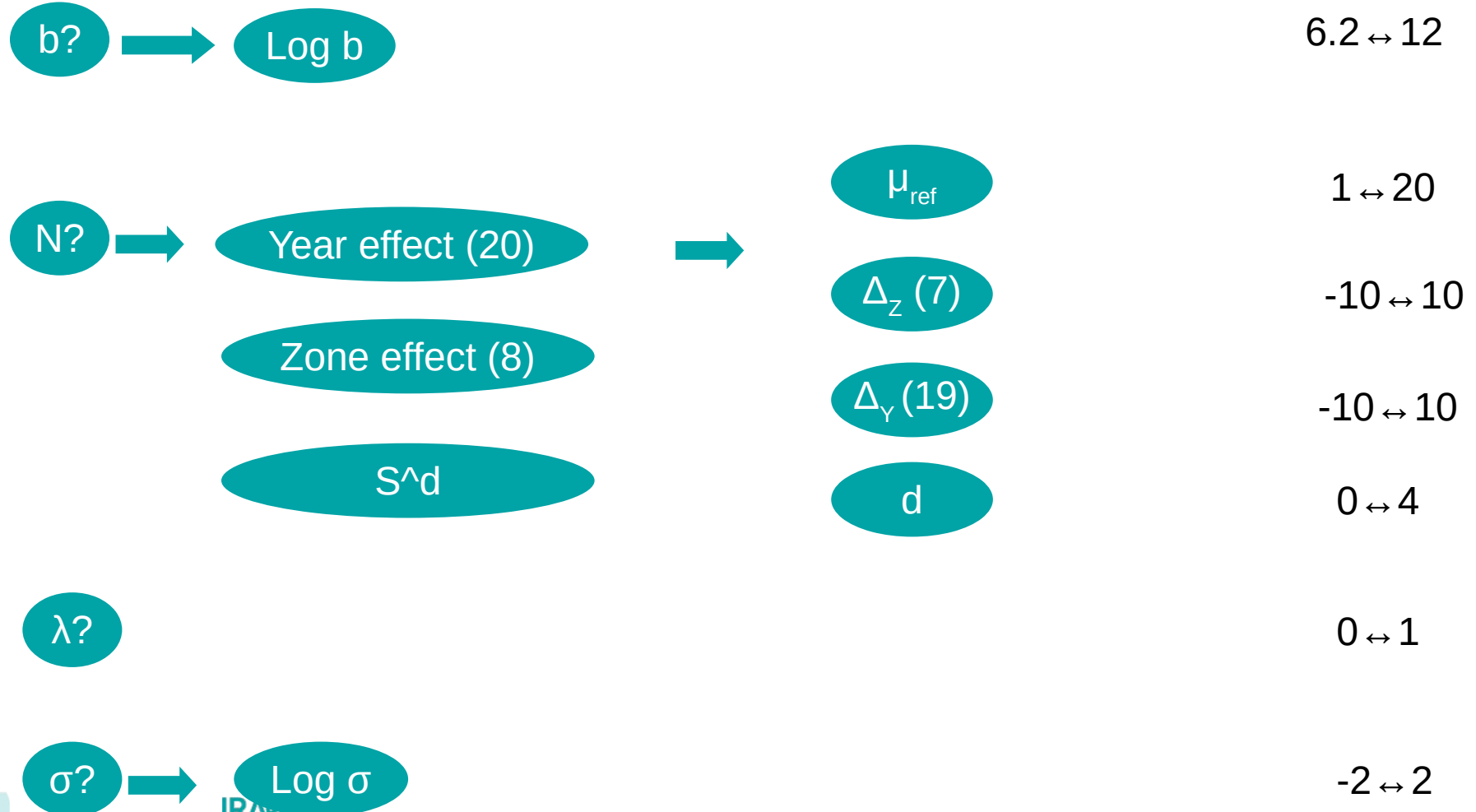
Tabasco - unknown parameters



Tabasco - unknown parameters



Tabasco - unknown parameters



IRAD

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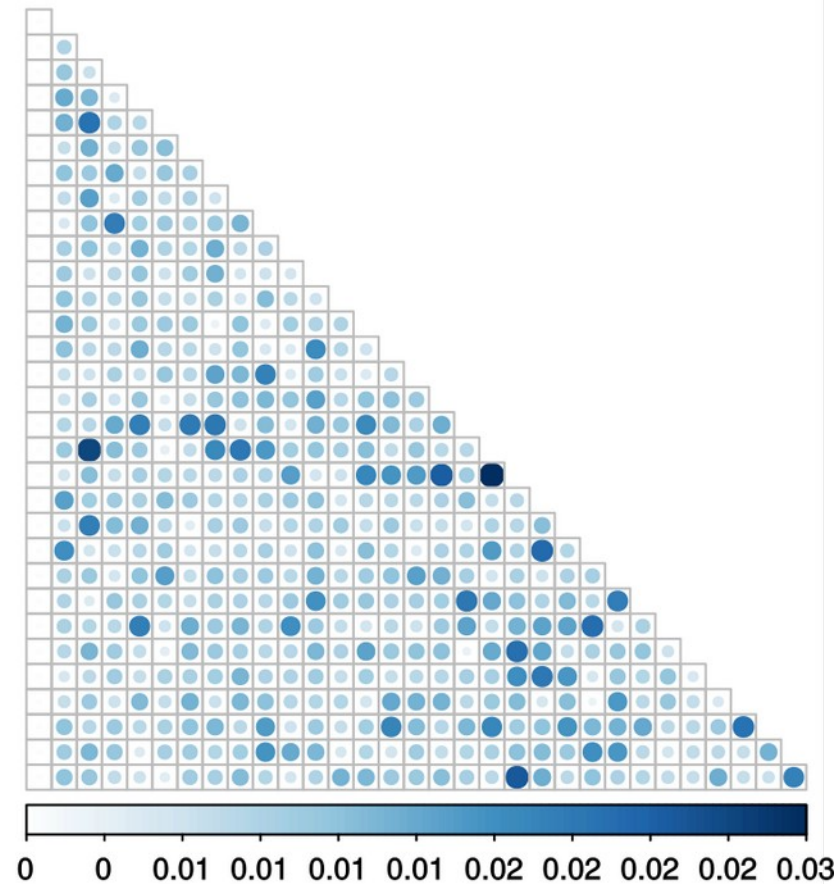
Tabasco objective function

- Model in C++
 - Computation time depends on b !!!!
 - Largest sparse matrices 55893×55893 ... impossible to decompose?
- Parallel computation
 - By river basin :
 - Not ideal since there are large basins (Loire River) and very small basin => most cores are not working waiting for large basins
 - By simulation :
 - Not ideal since computation time depend on b => many cores wait for simulations with large b



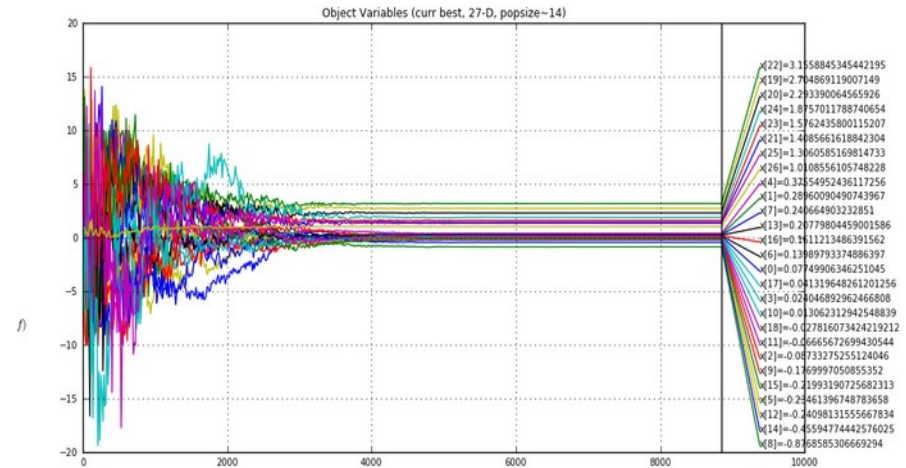
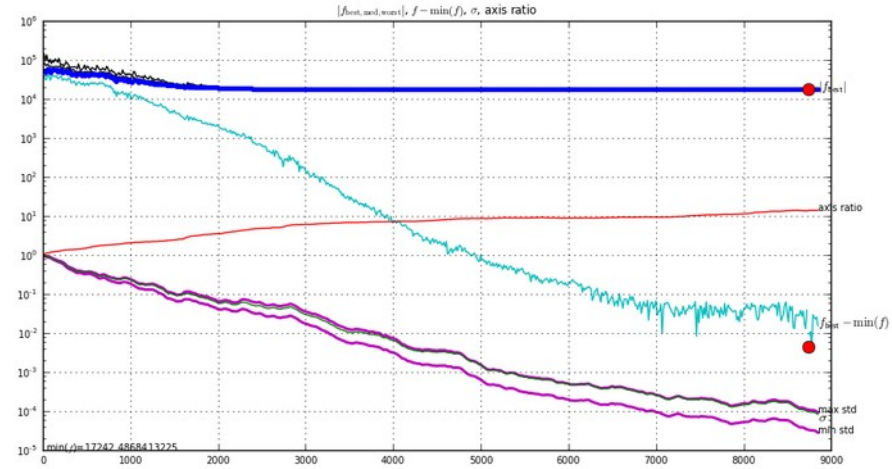
Tabasco exploration

- LHS
 - 31 parameters
 - 1000 simulations
- GAM model to
 - Quantify the sensitivity to parameters => choosing year 1998 and Rhone as intercept
 - Choose plausible initial values
 - Check concavity



Tabasco calibration

- First tests with BOBYQA
 - Local search through quadratic approximation
 - No need of derivatives
 - Fast... but sensitive to starting point



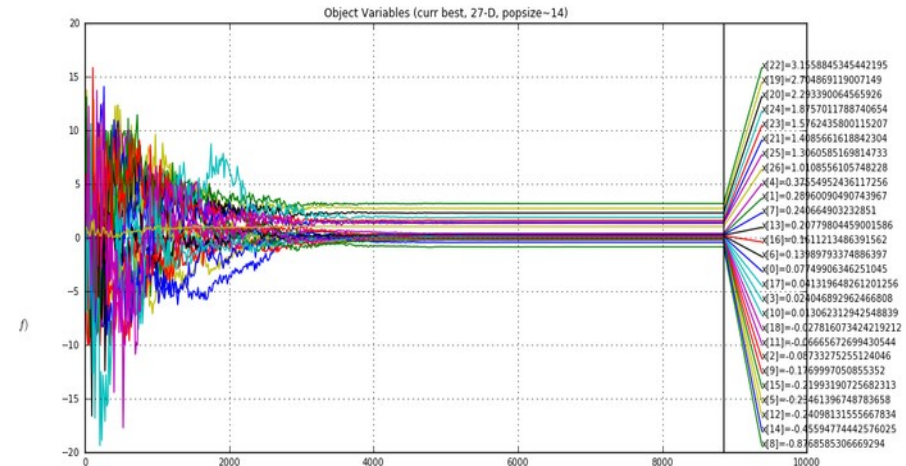
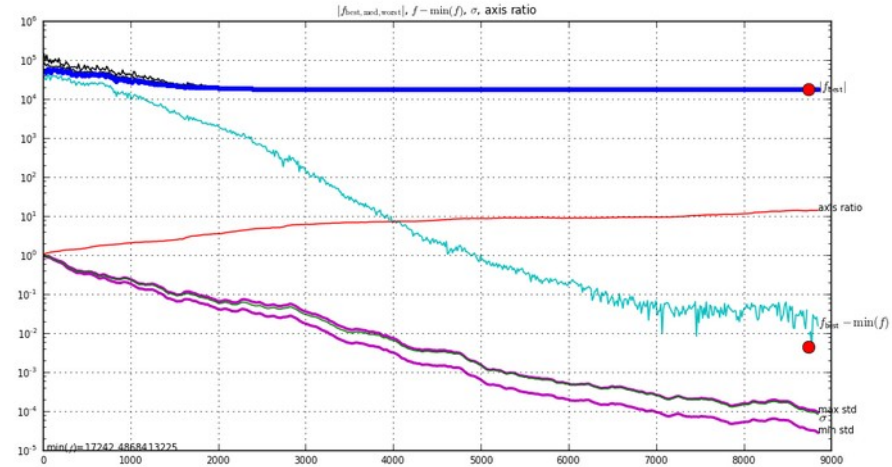
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Tabasco calibration

- First tests with BOBYQA
 - Local search through quadratic approximation
 - No need of derivatives
 - Fast... but sensitive to starting points
- CMA-ES (Hansen, 2006) - python
 - Metaheuristic local sampling
 - Several tests
 - Modifications of starting points
 - Size of population CMA-ES
 - Converge (almost always to the same solution)



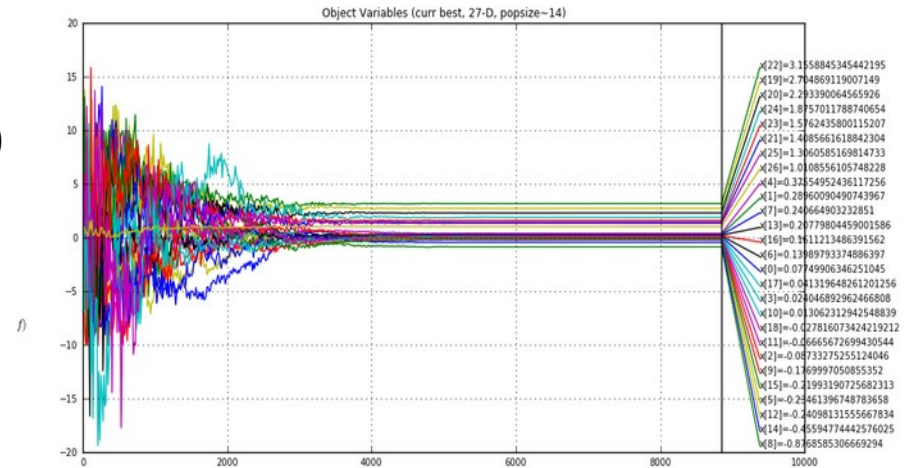
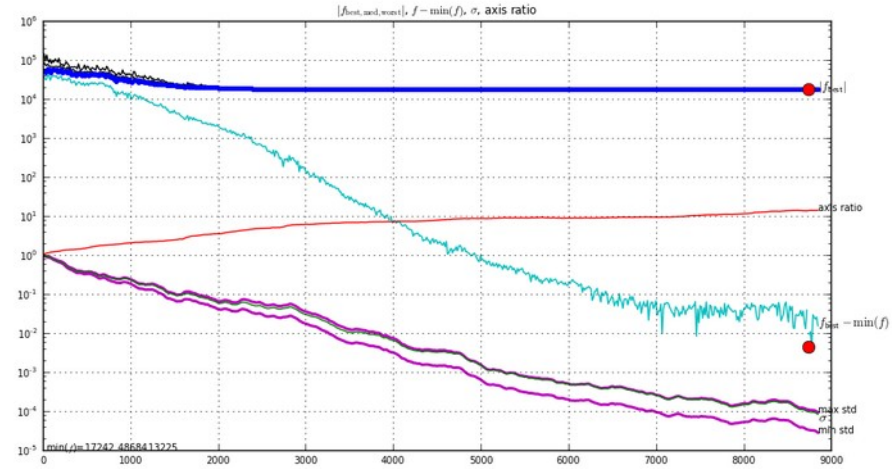
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Tabasco calibration

- First tests with BOBYQA
 - Local search through quadratic approximation
 - No need of derivatives
 - Fast... but sensitive to starting points
- CMA-ES (Hansen, 2006) - python
 - Metaheuristic local sampling
 - Several tests
 - Modifications of starting points
 - Size of population CMA-ES
 - Converge (almost always to the same solution)
- Coupling with Autodif



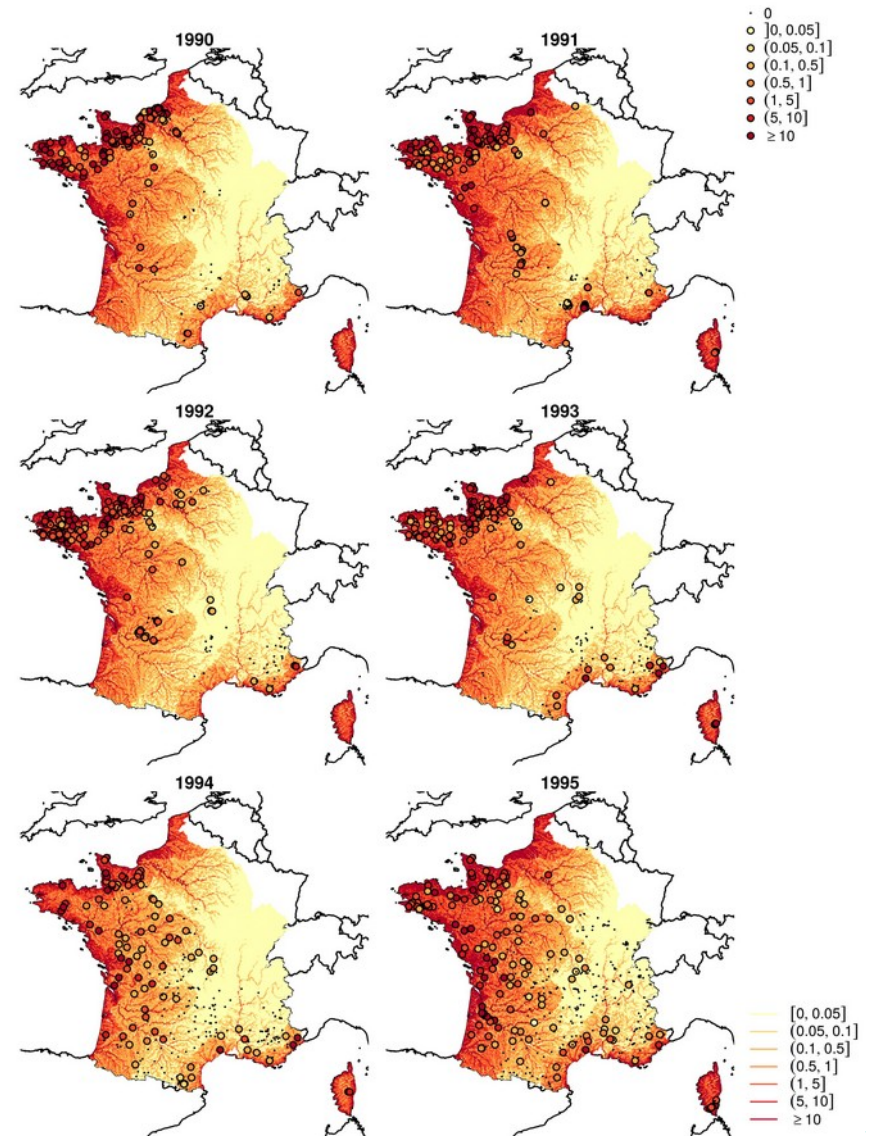
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Tabasco postcalibration

- Check traces of CMA-ES



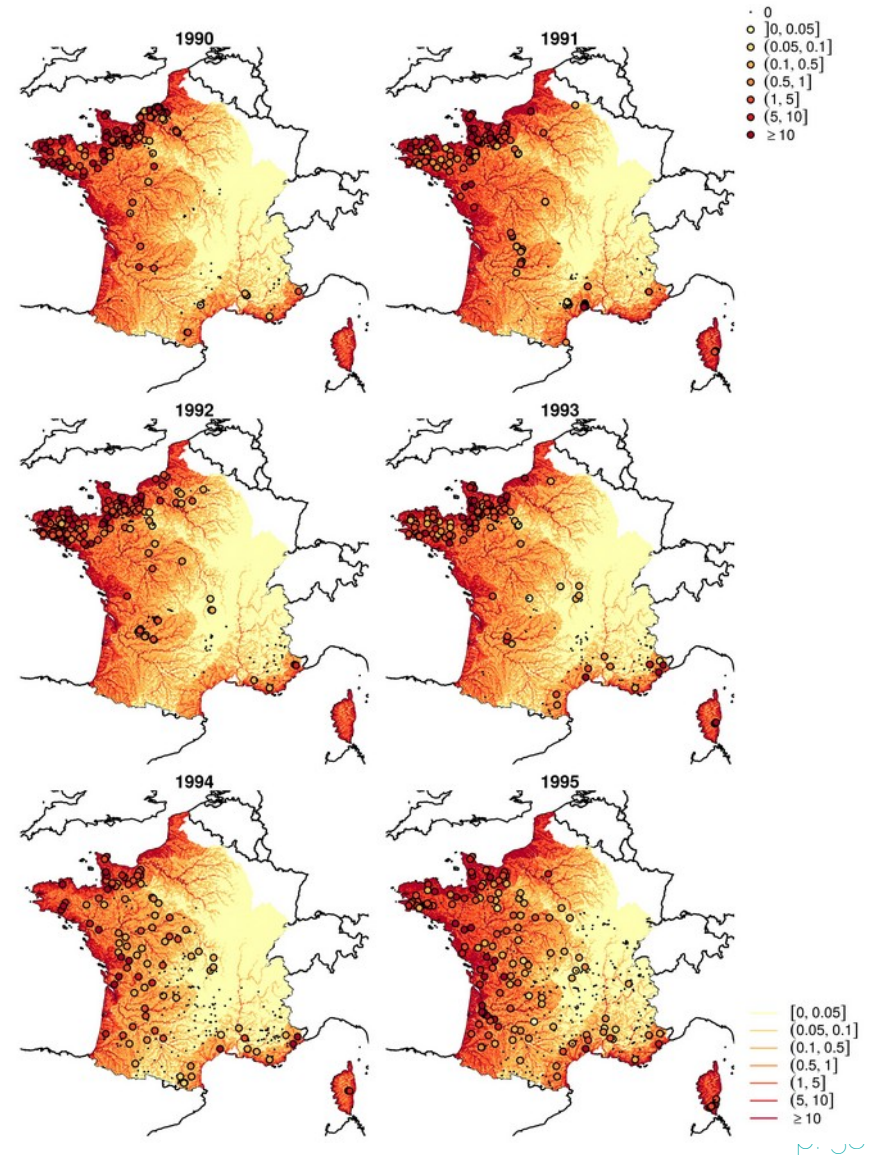
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Tabasco postcalibration

- Check traces of CMA-ES
- Check Hessian matrix from Autodif



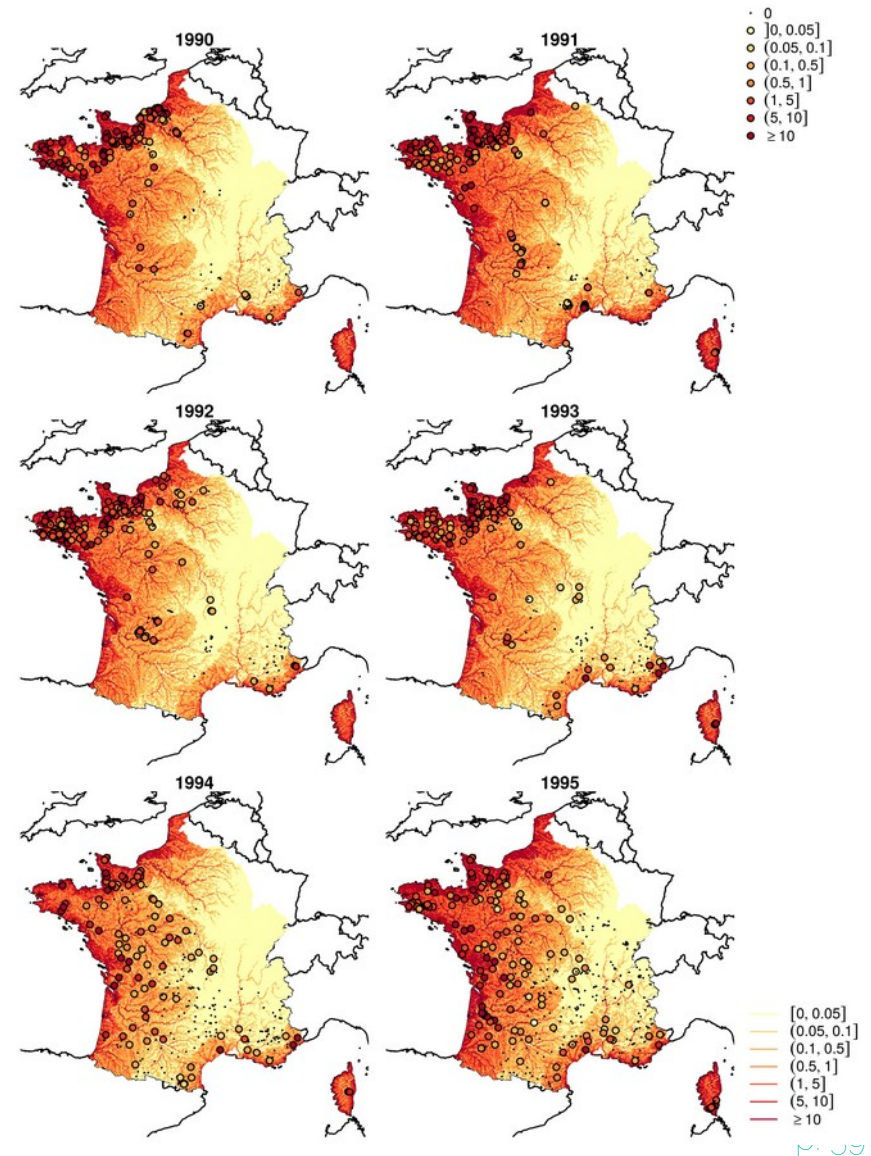
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Tabasco postcalibration

- Check traces of CMA-ES
- Check Hessian matrix from Autodif
- Check patterns in outputs => selection of most relevant model structure



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Groupement de Recherche
MASCOT-NUM
Méthodes d'Analyse Globale pour les Modèles de Traitement Numérique
GDR

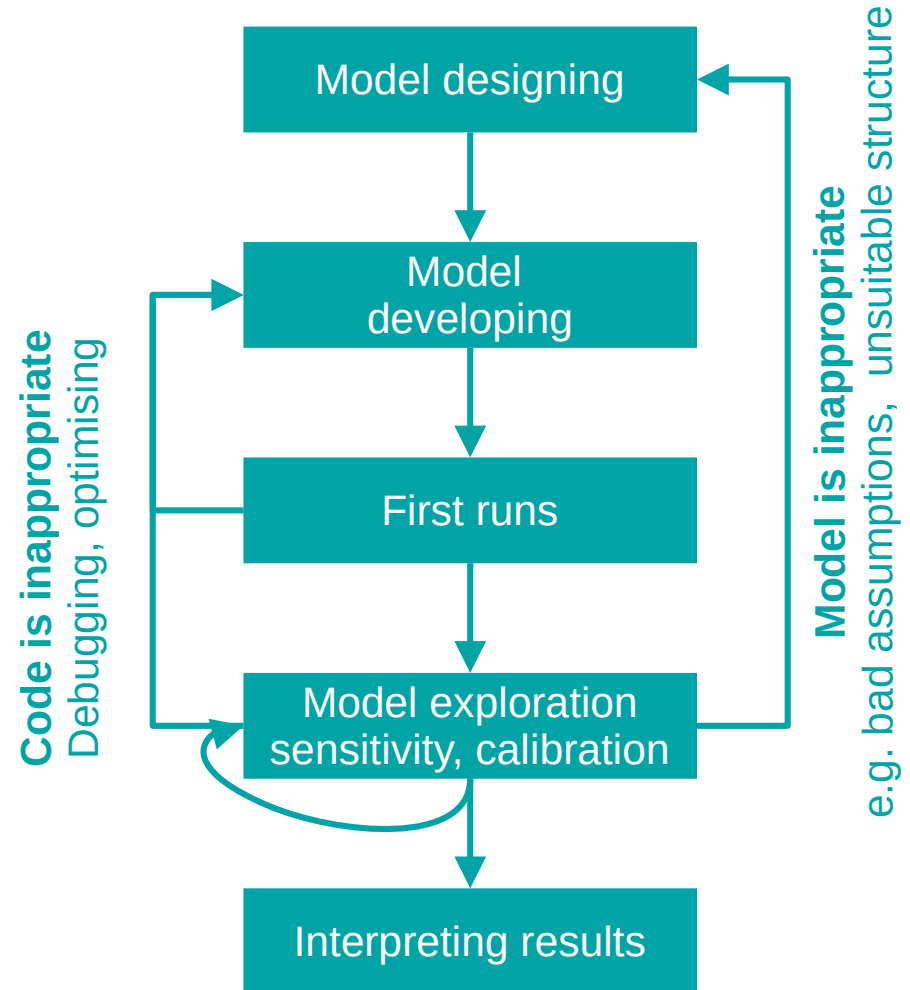
Repeatability? Transferring?

Disciplinary skills

Computer skills

Statistics skills

Mathematics skills



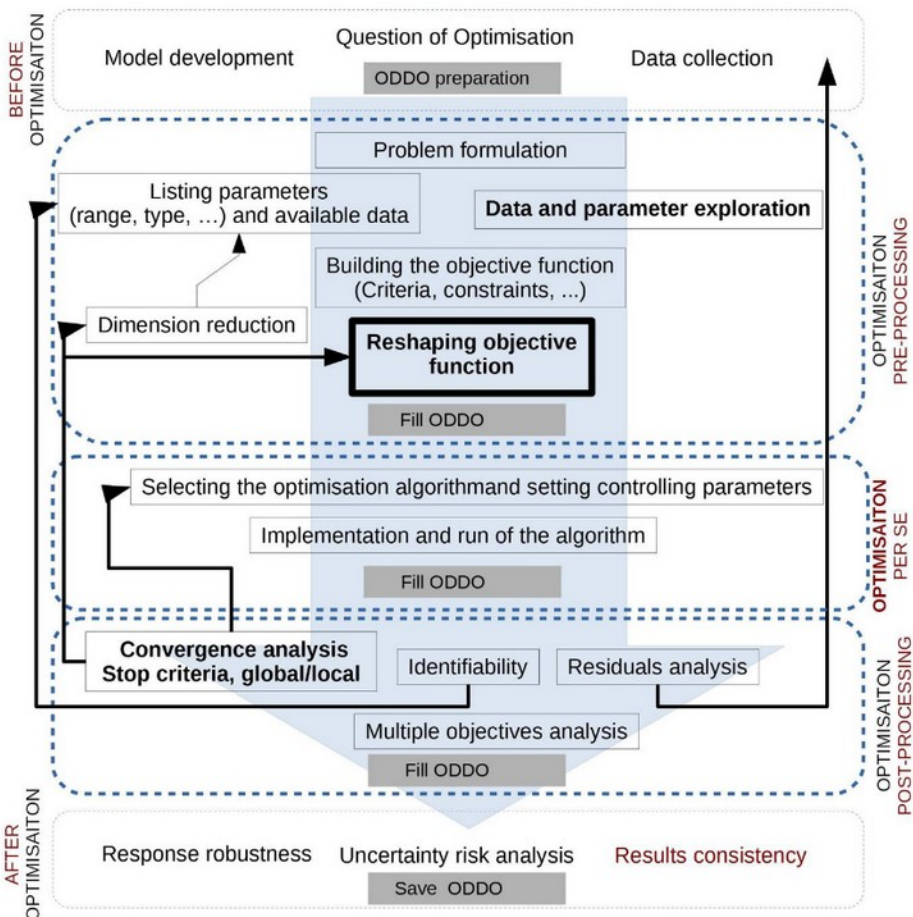
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Mexico: ODDO and decision trees

Mahévas, S., Picheny, V., Lambert, P., Dumoulin, N., Rouan, L., Soulié, J.-C., Brockhoff, D., et al. 2019, December 19. A Practical Guide for Conducting Calibration and Decision-Making Optimisation with Complex Ecological Models. Preprints.
<https://www.preprints.org/manuscript/201912.0249/v1>



Model	Performance	Time per model run	
	Development	parallelisation	
		language	
		Implementation of the optimisation algorithm	

Pre-processing	Problem Formulation	Model	
		Question	
		Data	
Parameters Bounds&constraints			
		Uncertainty (process and data)	
		Initial objective function	
	Objective Function	building	
		reshaping	
		final	
	Exploratory Analysis	data	
		Reduction dimension	

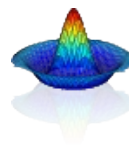
Algorithm	Family	
	Description-Justification	
	Changes in the algorithm	
	Settings	

Post-processing	Convergence	
	Optimum properties including Identifiability	
	Residual analysis	
	Multicriteria	

Comment	Number of simulations required	
	Duration	
	Reached stopping criteria	

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