BIOMATH

Department of Applied Mathematics, Biometrics and Process Control

Global and long-term calibration methodology of ASMs for full-scale WWTPs

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Friday 24 February, 2006

Overview of the presentation

- Introduction
- The Haaren WWTP
- Development of a global calibration approach
  - Local and Short-term calibration
  - Global and Long-term calibration
  - Global and periodic calibration
- Conclusions/perspectives

Introduction

- ASMs application to full-scale WWTP
  - Complex
  - Over-parameterised
  - Calibration is not simple: heuristic approaches and requiring exhaustive expert knowledge
  - Tedious and time consuming
  - Reliability or uncertainty of model extrapolations?

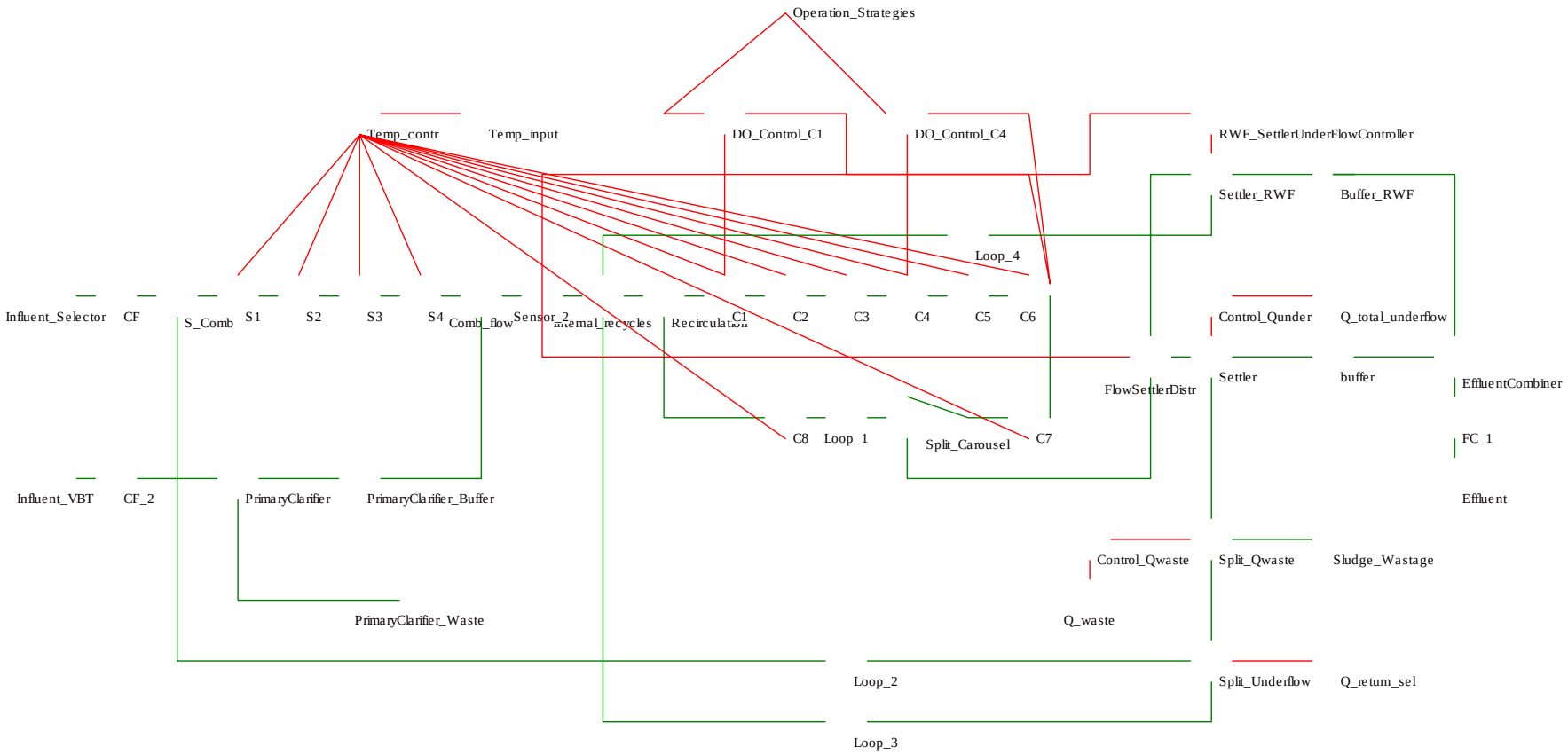
Introduction

- Motivation:
  - Develop a calibration methodology that is efficient and produces reliable models for WWTPs
  - Ultimate aim: use the model to optimise and advice the plant opertion (e.g. develop or test different DO control algorithms)
  - Emphasis: Automate calibration by developing software making use of advanced mathematical/statistical approaches

The Haaren WWTP

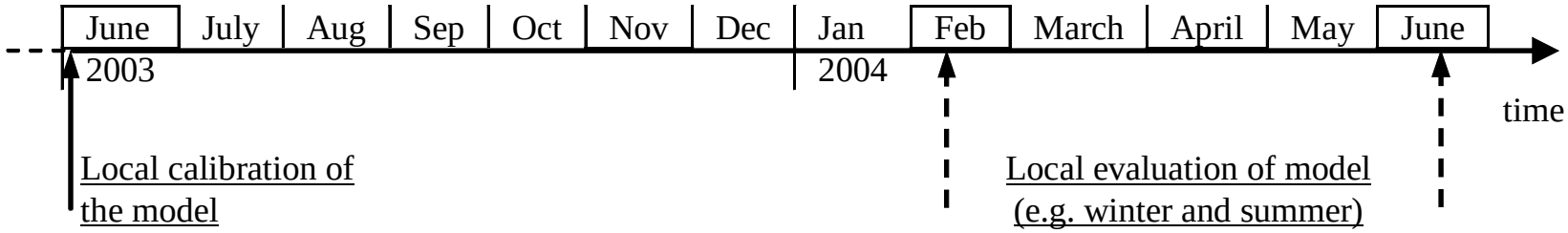
- Located in Haaren, The Netherlands
- 50,000 PE
- Domestic/partially industrial wastewater
- Oxidation ditch system (USA): Carrousel (EU) wwtp with anaerobic selector ➔
  - SRT ~ 22 days
  - Biological phosphorus and nitrogen removal
  - Qave = 1200 m^3/h & Qrain = 2450 m^3/h

The Haaren WWTP



Local & short-term calibration

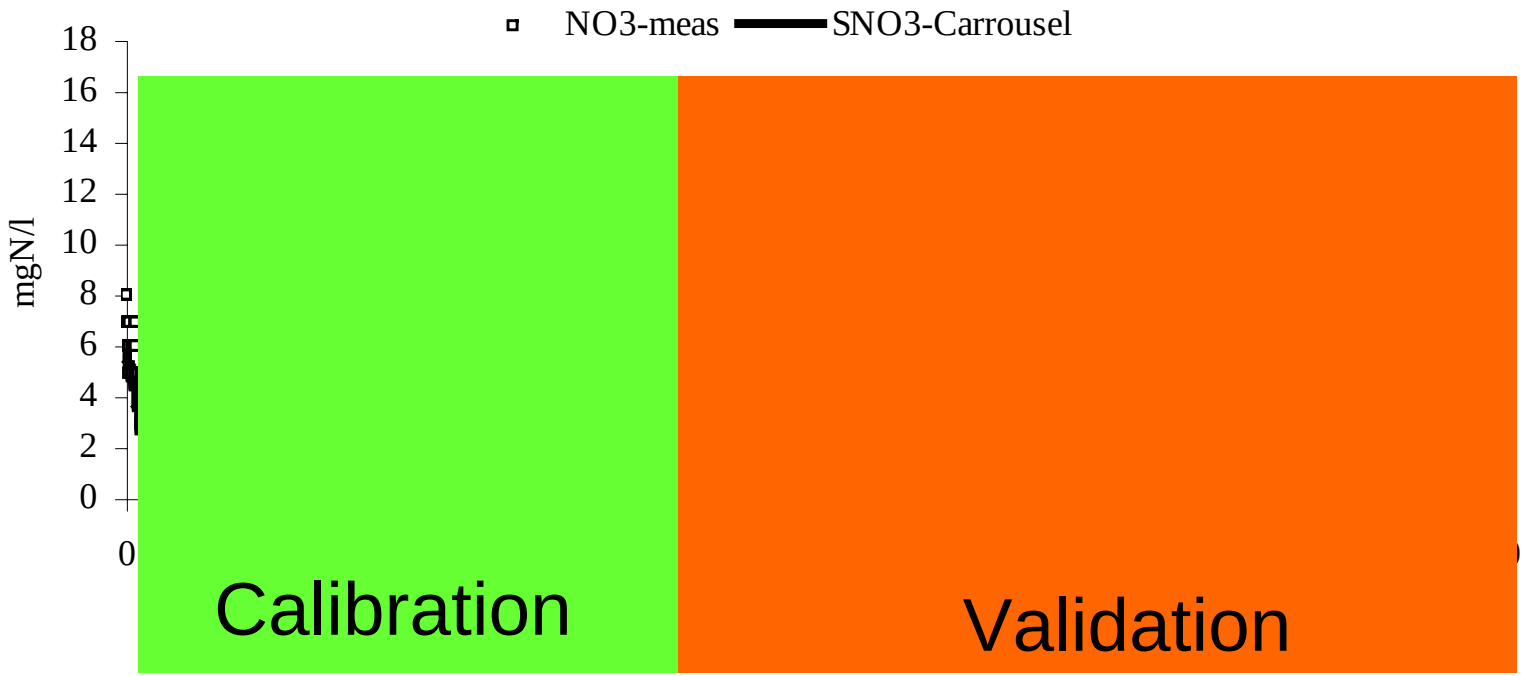
- Definition
  - Global/local: method of parameter calibration
  - Long-term/short-term/periodic: duration of data used for calibration



- Calibration: 4 days of intensive measurement campaign data in June 2003

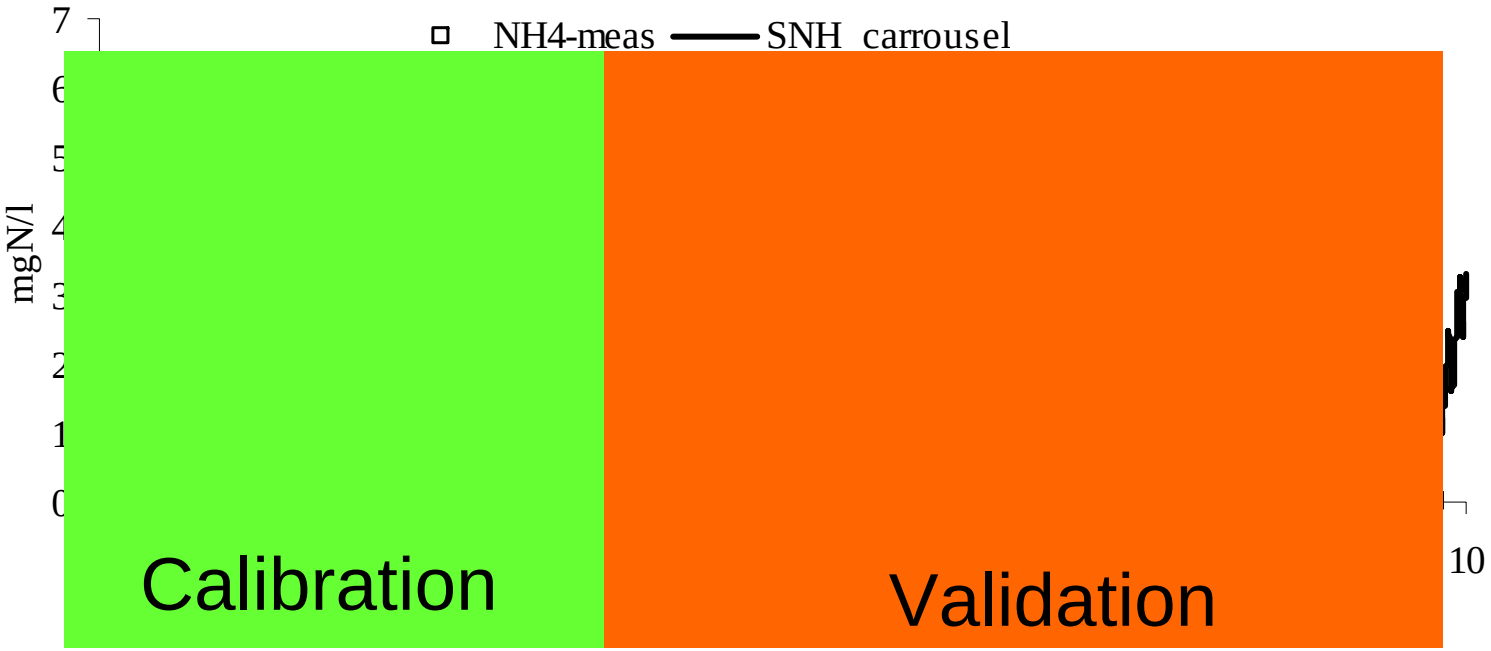
Local & short-term calibration (2)

- June 2003 calibrated model: NO_3-N fit



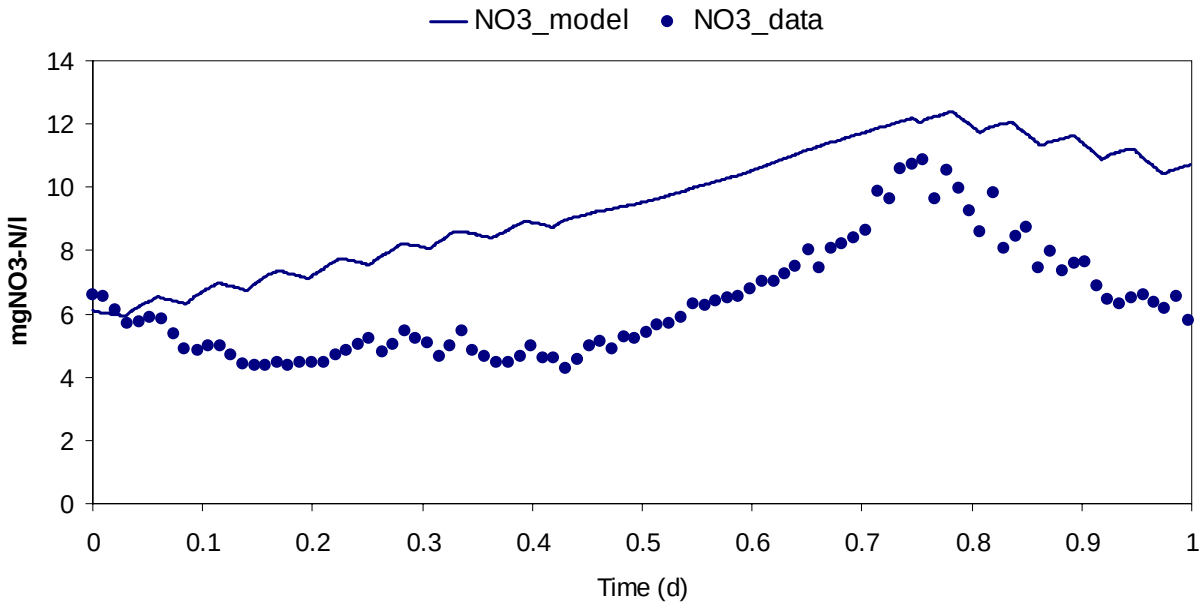
Local & short-term calibration (3)

- June 2003 calibrated model: NH_4-N fit



Local & short-term calibration: Evaluation

- Model evaluation in February 2004 (temp = 10 ^{0}C)
  - Model prediction of NO_3-N



Local & short-term calibration: Evaluation (2)

- Model evaluation in February 2004 (temp = 10 ^{0}C)
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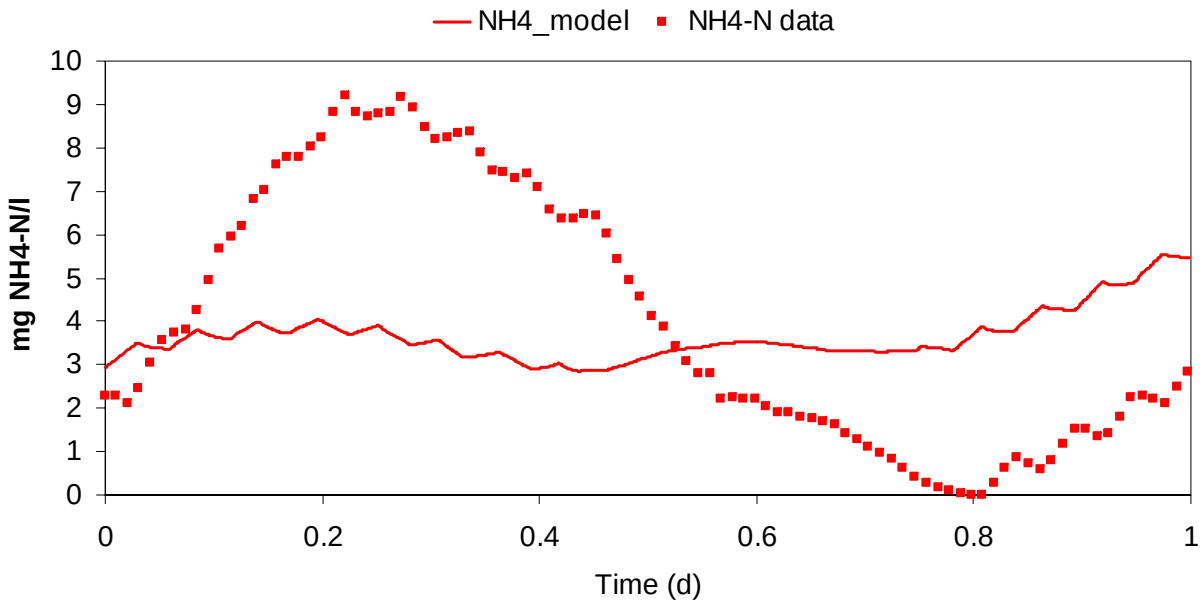


Local & short-term calibration: summary

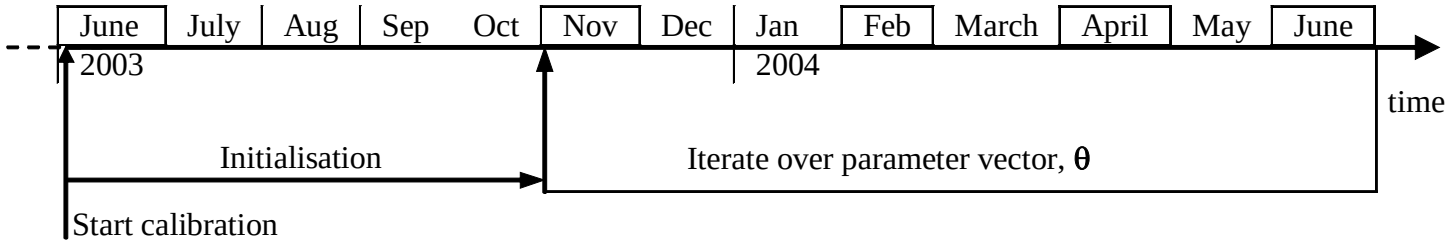
- In short, the model evaluations show:
  - Nitrification & denitrification underestimated in winter!
  - Nitrification overestimated in summer (results not shown)
- Possible reasons?
  - The model calibrated in June (Summer) captures summer dynamics but not winter dynamics, i.e. locally valid!
  - Initial conditions, e.g. biomass concentrations, will most probably be different

How to improve the model?

- A fundamentally different thinking / approach:
  move from local to global!

Global and Long-term calibration approach

- Overview of global calibration approach
  - History of the plant is integrated over the course of model calibration/evaluation

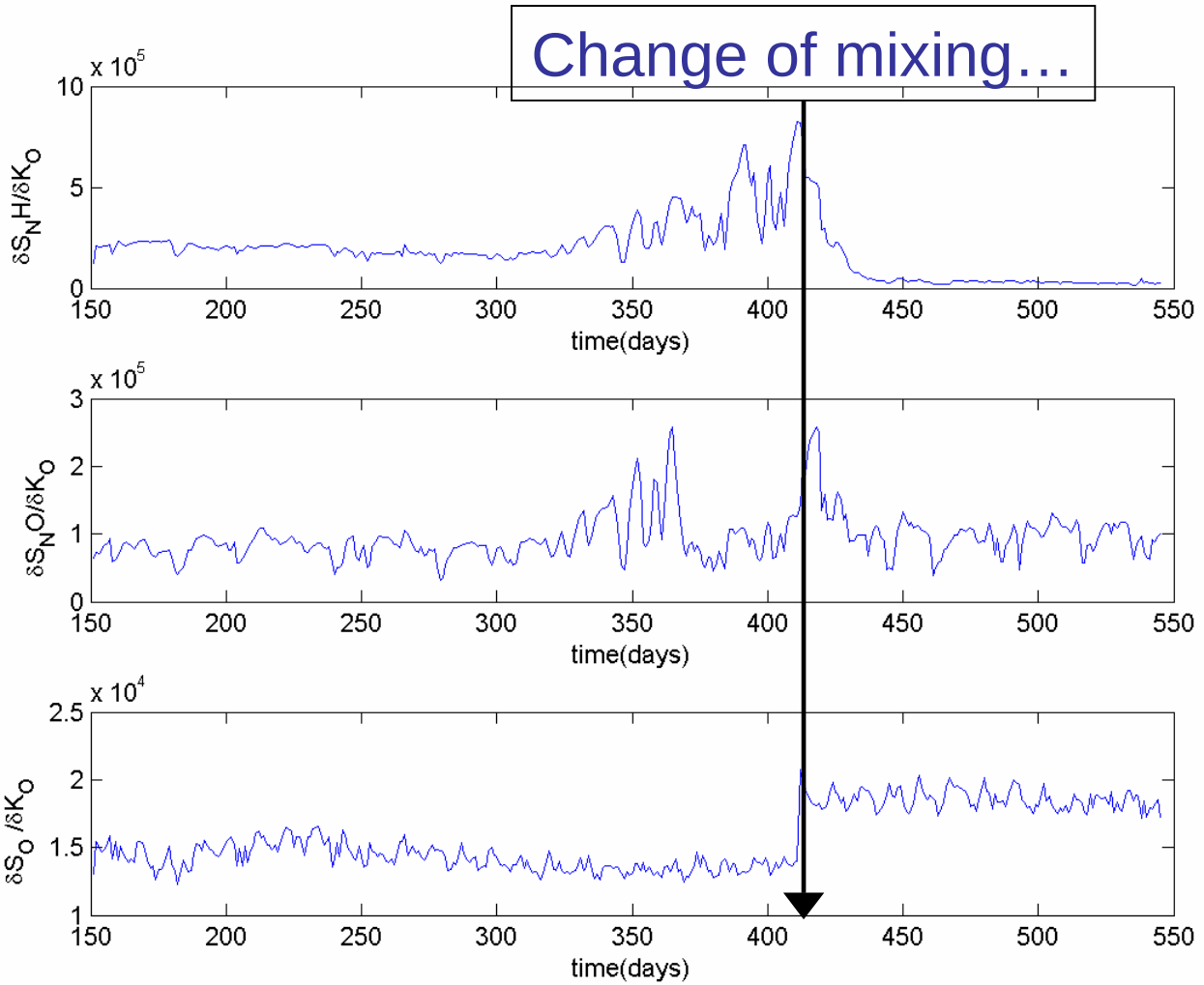


1. Find the parameter set, θ
2. Latin Hypercube Sampling (LHS) of parameter space, e.g. 500 different combinations of parameters
3. Simulate 500 different θ
4. Pick up the best fitting simulation(s) among the 500!

Global and Long-term calibration approach

- Which parameter set to calibrate?
  - (practical) identifiability analysis
    - Several methodologies available, yet NOT STRAIGHTFORWARD
    - The model is complex (large number of parameters and outputs) ➔ computationally demanding
    - Need for development of feasible identifiability methodology (on-going)
  - use expert-knowledge plus sensitivity analysis

Preliminary sensitivity analysis:, e.g. K_O



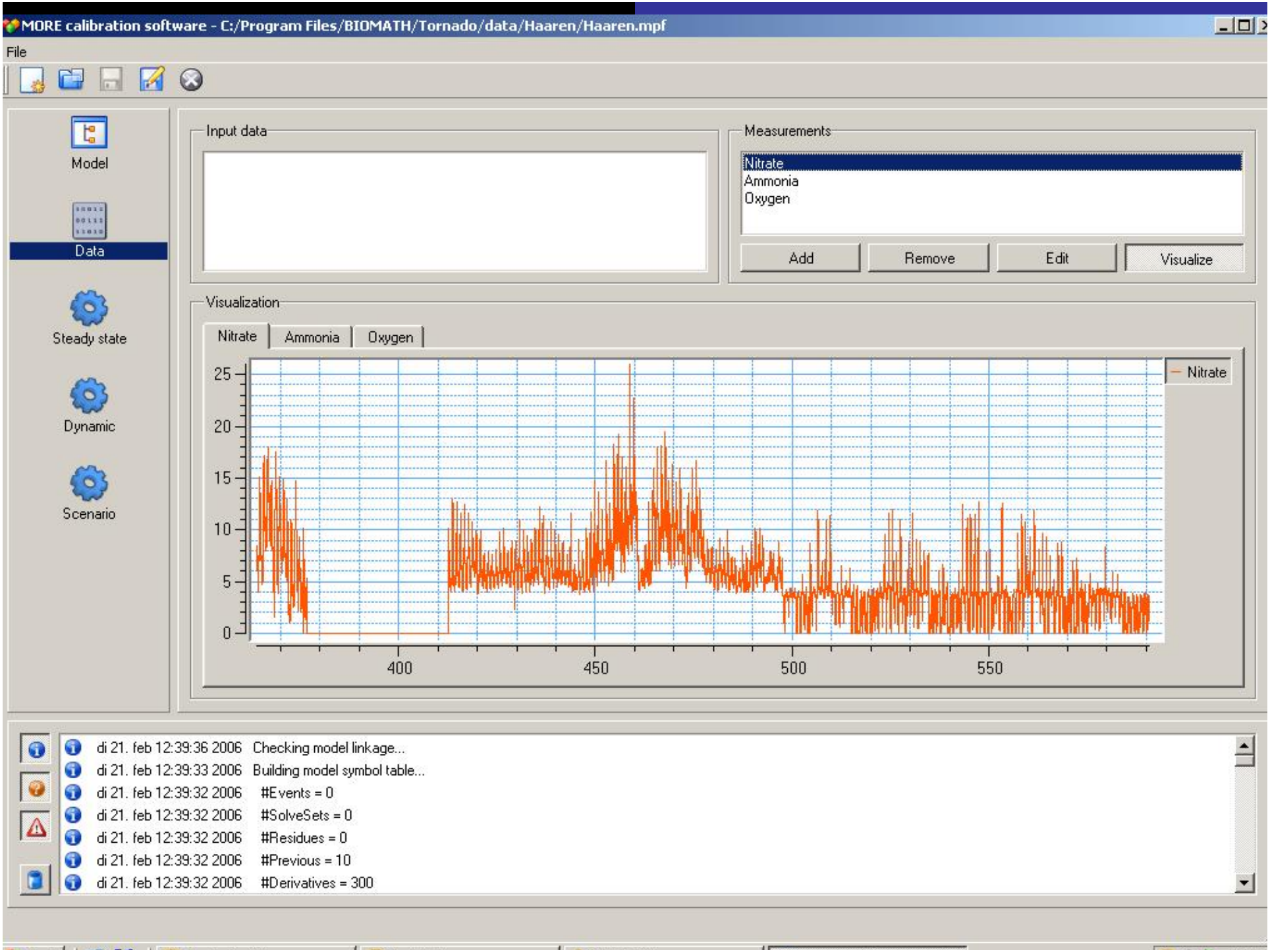
The parameter set chosen for calibration…

- Parameter set to calibrate (with upper and lower range required for generating LHS samples)

	μ_{AUT}	$K_{O,AUT}$	K_O	η_g	k_h	b_{PAO}	η_{fe}	K_La_{max}	K_La_{min}
Reference	1	0.4	0.3	0.6	3	0.12	0.2	300	50
Lower	0.8	0.1	0.1	0.5	2	0.1	0	200	30
Upper	2	1	1	1	4	0.4	1	350	70

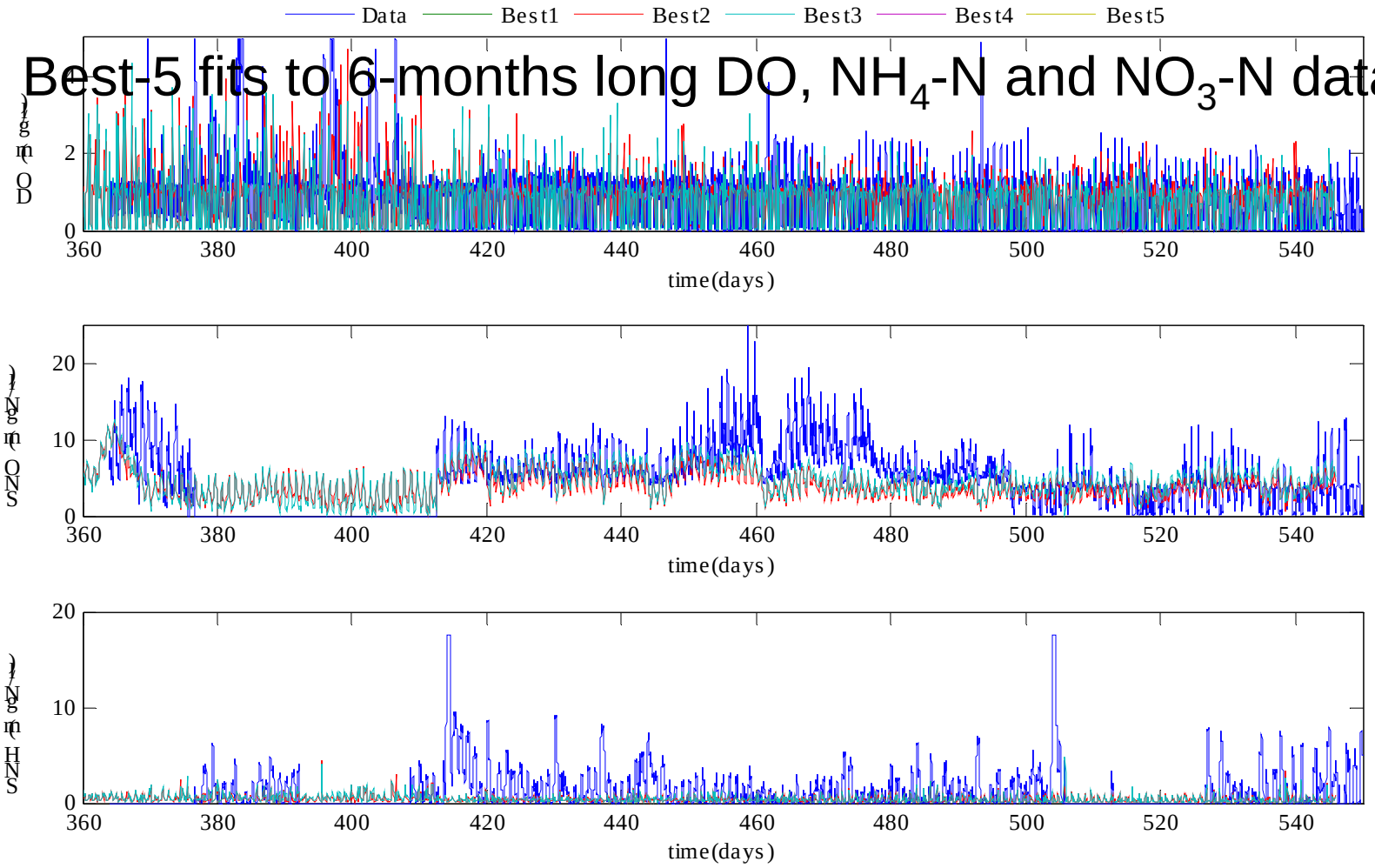
Global and Long-term calibration approach

- Implementation of such approach requires software: MORE
  - it is being developed as a user interface that uses the WEST simulation engine to carry out different jobs (simulation, optimisation, Monte-Carlo simulation, scenario, etc)


MORE calibration software - C:/Program Files/BIOMATH/Tornado/data/Haaren/Haaren.mpf
File
Model
Data
Steady state
Dynamic
Scenario
Input data
Measurements
Nitrate
Ammonia
Oxygen
Add
Remove
Edit
Visualize
Visualization
Nitrate
Ammonia
Oxygen
25
20
15
10
5
0
400
450
500
550
Nitrate
di 21. feb 12:39:36 2006 Checking model linkage...
di 21. feb 12:39:33 2006 Building model symbol table...
di 21. feb 12:39:32 2006 #Events = 0
di 21. feb 12:39:32 2006 #SolveSets = 0
di 21. feb 12:39:32 2006 #Residues = 0
di 21. feb 12:39:32 2006 #Previous = 10
di 21. feb 12:39:32 2006 #Derivatives = 300

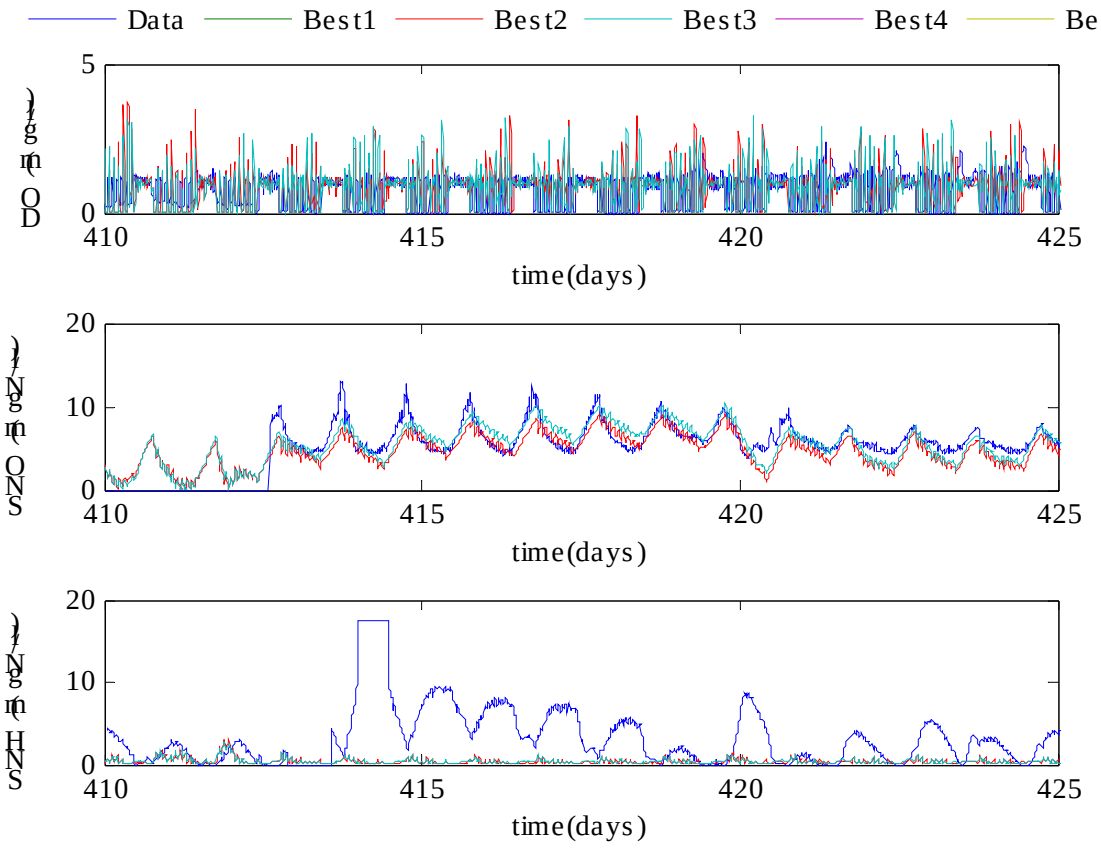
Global and Long-term calibration approach

- Best-5 fits to 6-months long DO, NH_4-N and NO_3-N data



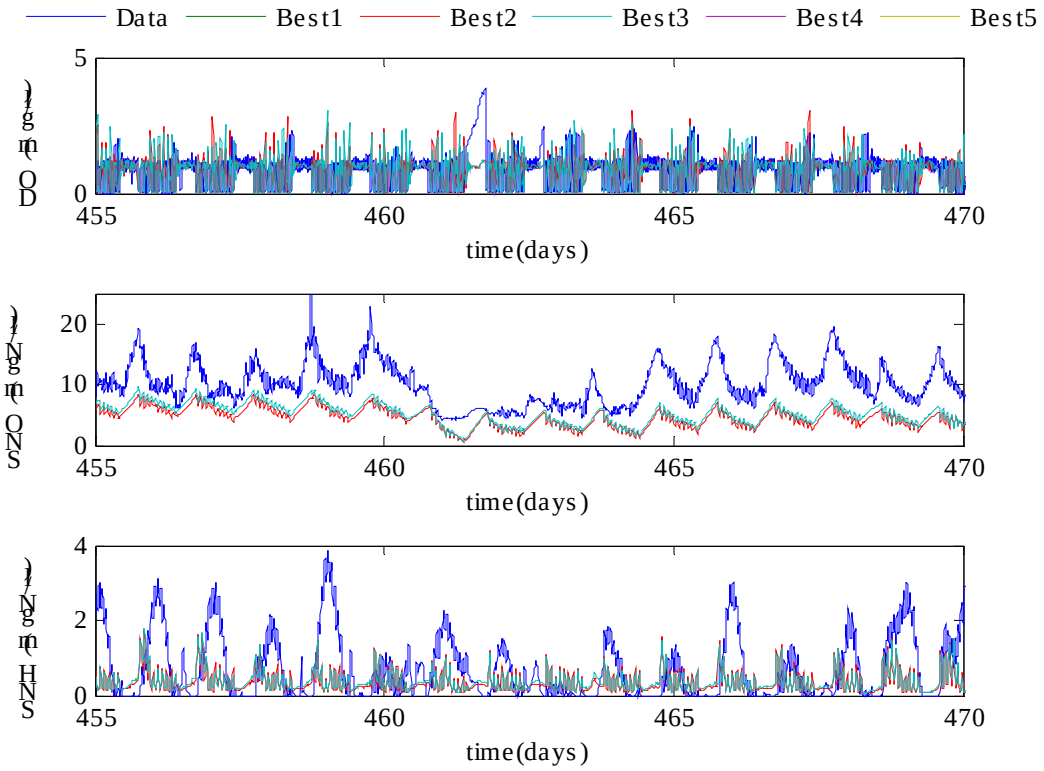
Global and Long-term calibration approach

- Zoom into February month: NO_3-N fit is good NH_4-N not!



Global and Long-term calibration approach

- Zoom into April month: NO_3-N fit is not good



Global and Long-term calibration approach

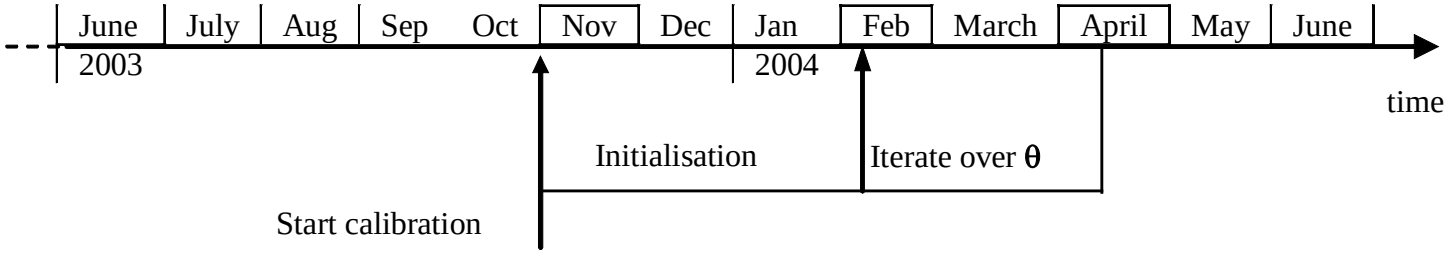
- In general:
  - The results of the global methodology are encouraging
  - Still there is room for improvement desired
- In particular:
  - One can see some model fits are good in February while they are not in the other months
  - Maybe the process behaviour has changed…
  - Let us test this hypothesis!

Global and periodic calibration approach

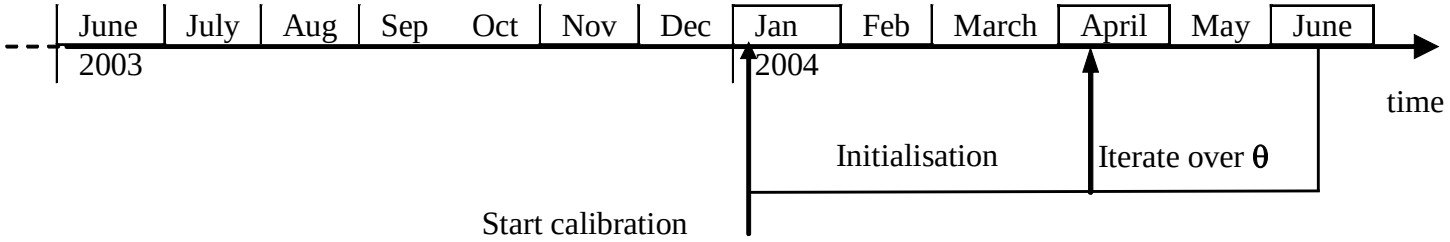
- Now we will narrow our focus from global to periodic model fits using the same procedure
- We defined three periods according to known operational changes:
  - Period 1: 16th February 2004 – 11th April 2004 (impeller installed; IA 18:00 -10:00)
  - Period 2: 12th April 2004 – 19th of June 2004 (DO control: IA 14:00 -06:00)
  - Period 3: 20th of June 2004 – 15th of July 2004 (DO control: IA 10:00 -02:00)

Progress in calibration: (2) December 2005

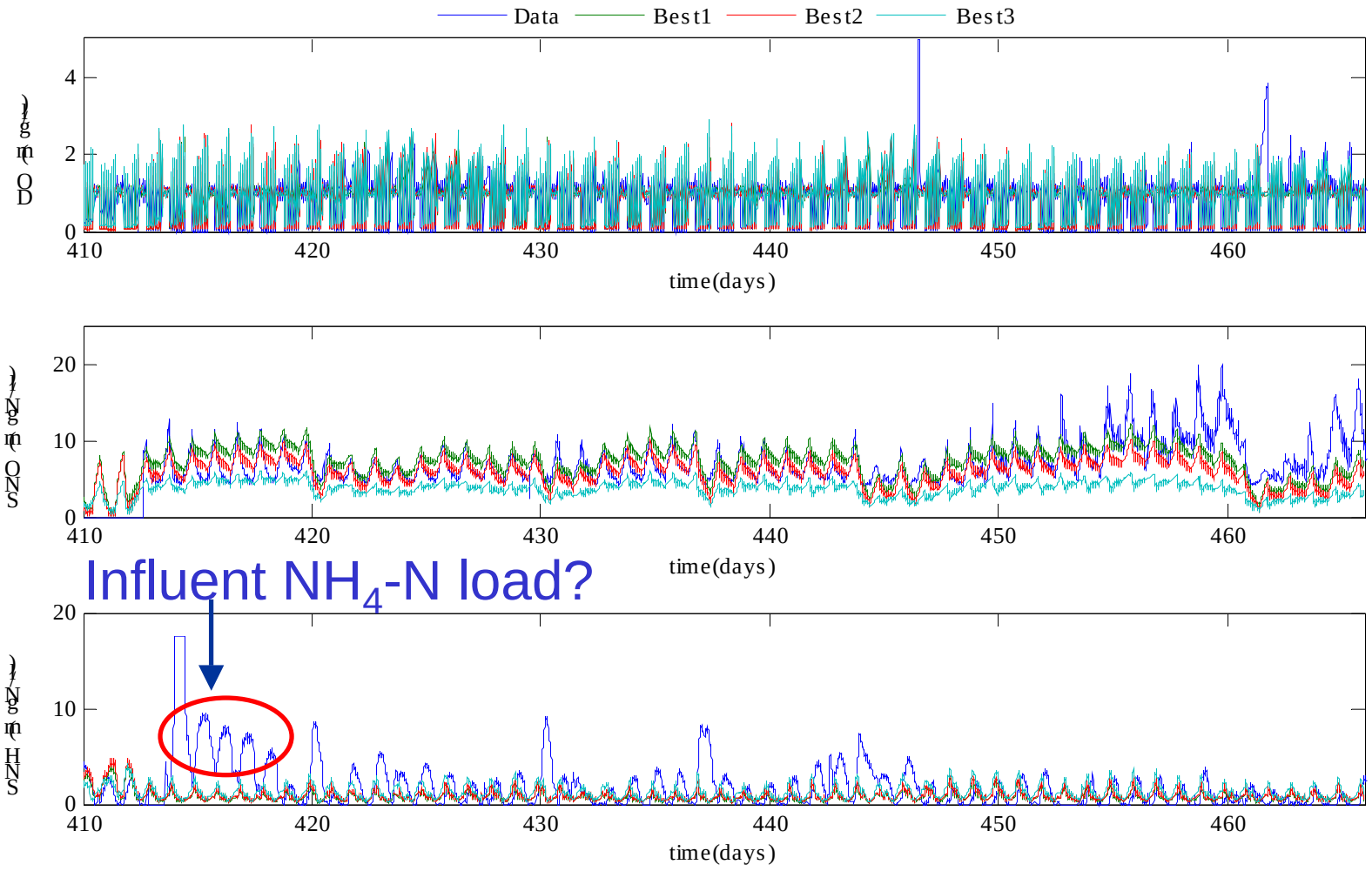
- Period 1: 16th February 2004 – 11th April 2004



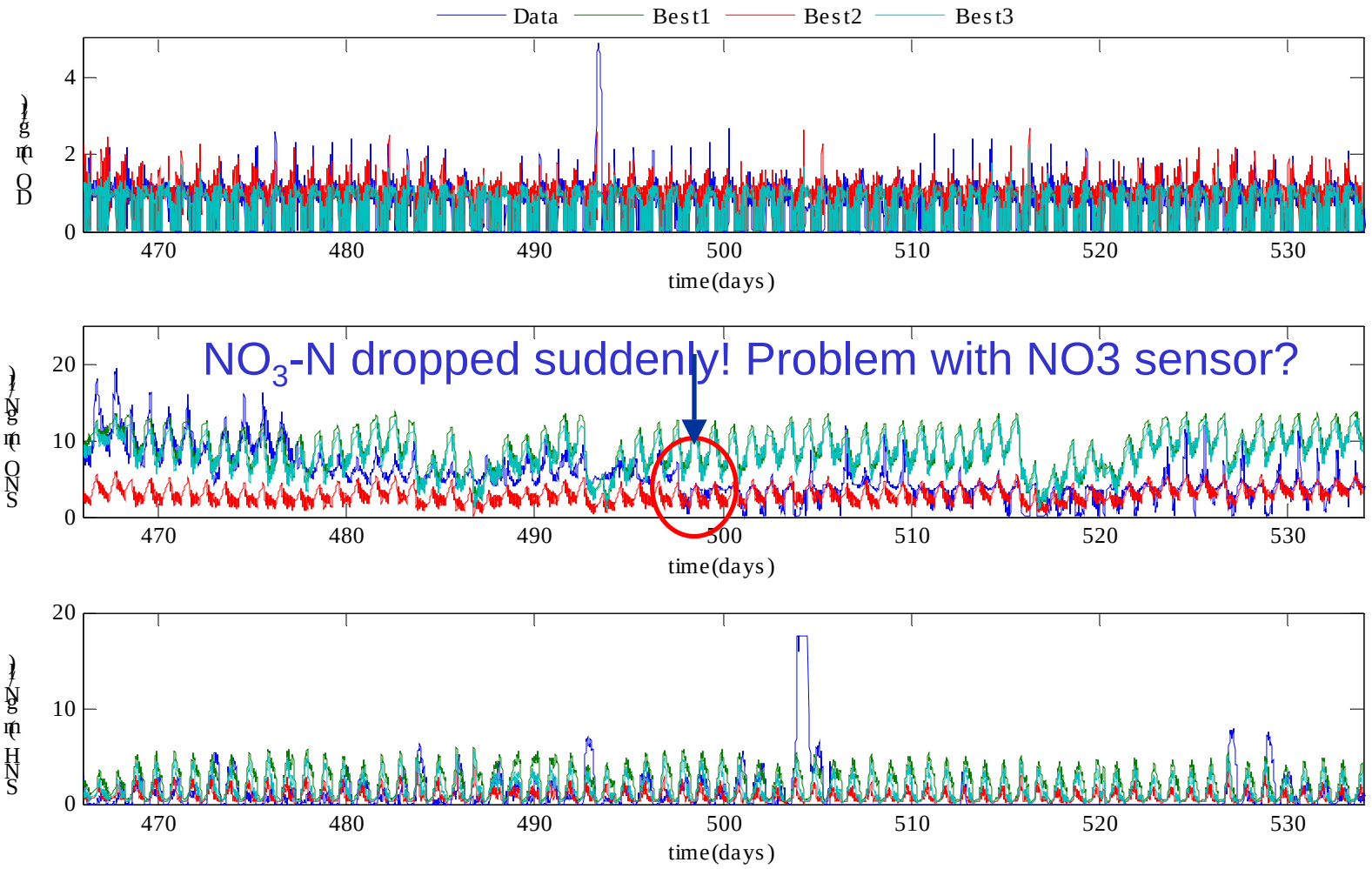
- Period 2: 12th April 2004 – 19th June 2004



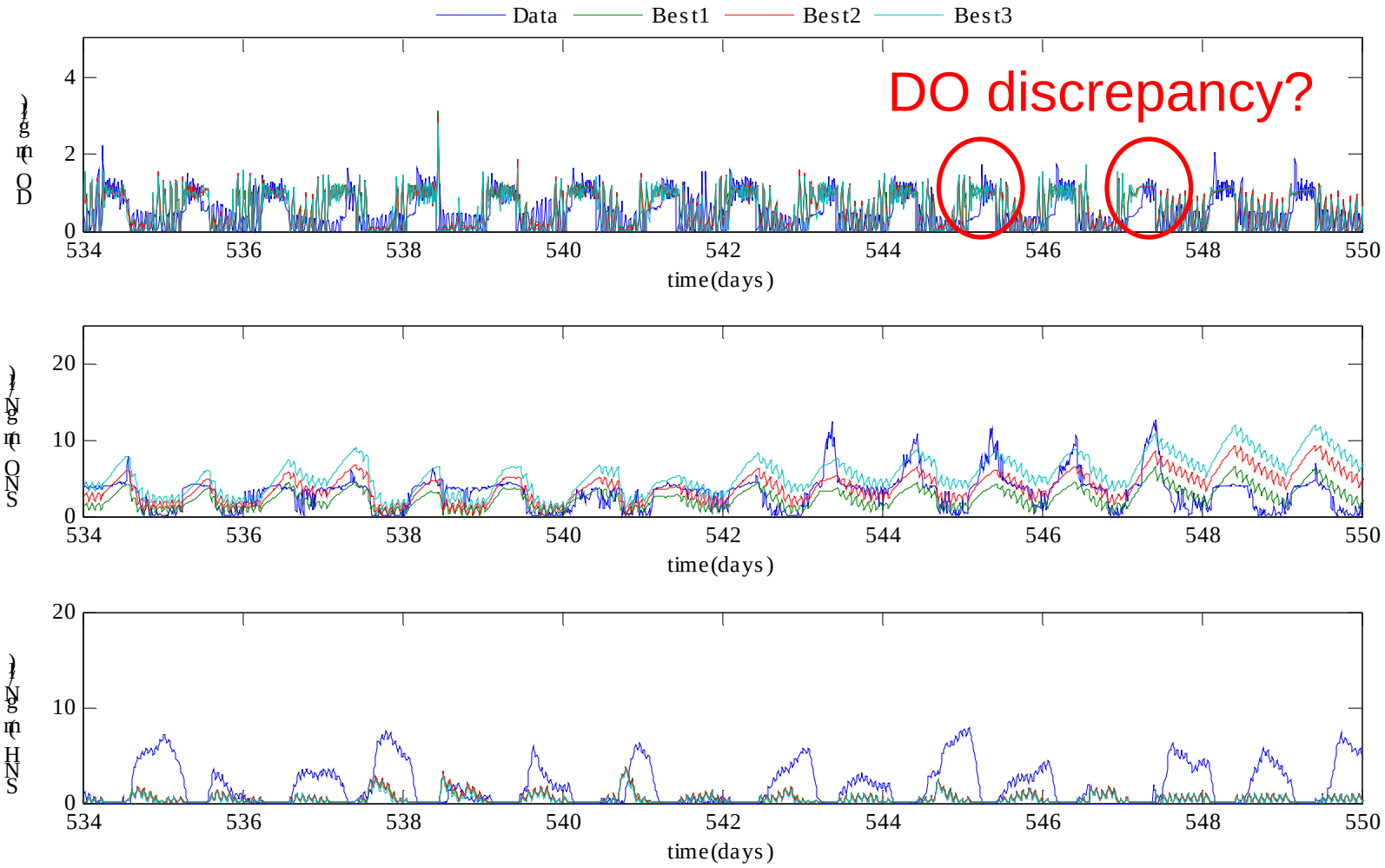
Period 1: 3-best model fits to DO, NH_4-N and NO_3-N



Period 2: 3-best model fits to DO, NH_4-N and NO_3-N



Period 3: 3-best model fits to DO, NH_4-N and NO_3-N



Global and periodic calibration: summary

- In general:

  improved model fits to the data could be obtained

- At this stage, the methodology provides good fits/predictions on 15 minute-scale which is quite remarkable knowing that ASMs are usually used for daily average predictions…

Conclusions

What we have achieved:

- We have improved the calibration methodology to a sufficiently good level.
- It provides effective results and is efficient to use thanks to the MORE software.
- The computer does the work;

  the expert process/control engineer does the interpretations!
- However!

Still challenges ahead…

- What caused NH_4-N peaks in Feb-04?
  - Probably due to influent load (currently it is estimated from the available 52 measurements/year using spline-interpolation)
  - measure the influent load!
- What caused the NO_3-N sudden drop in May?
  - Sensor failure or sudden change in process behaviour?
  - first check the sensor with off-line lab measurements!
- DO discrepancy in June 2004?
  - High influent load or high endogenous respiration?
  - Measure influent load & measure endogenous-respiration!

Still challenges ahead…

- Different criteria (e.g. SSE_NO_3; SSE_DO and SSE_NH_4) led to different choices of best fits
  - How to resolve it? How to choose a best fit that is equally best for all the variables under study? Is it possible?
  - Are LHS 500 shots enough to represent the global parameter space? Are the chosen fits **the globally best fit?**
- Is the model sufficiently good for the purpose of developing DO control strategies?
  - Validate the model using the 2005 data
  - Check the uncertainty of model predictions (Monte-Carlo simulations)