energi SIMULATION

SUMMIT

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UNICAMP

MODEL-BASED AND DATA-DRIVEN RESERVOIR MANAGEMENT THROUGH DIGITAL FIELDS CONCEPTS

UNISIM

RESERVOIR SIMULATION & MANAGEMENT

OBJECTIVES

- Simulation
- Education
- Innovation
- Methodology
- Software

INTEGRATION WITH:

- Geosciences
- Production
- Economic Evaluation
- Data Science

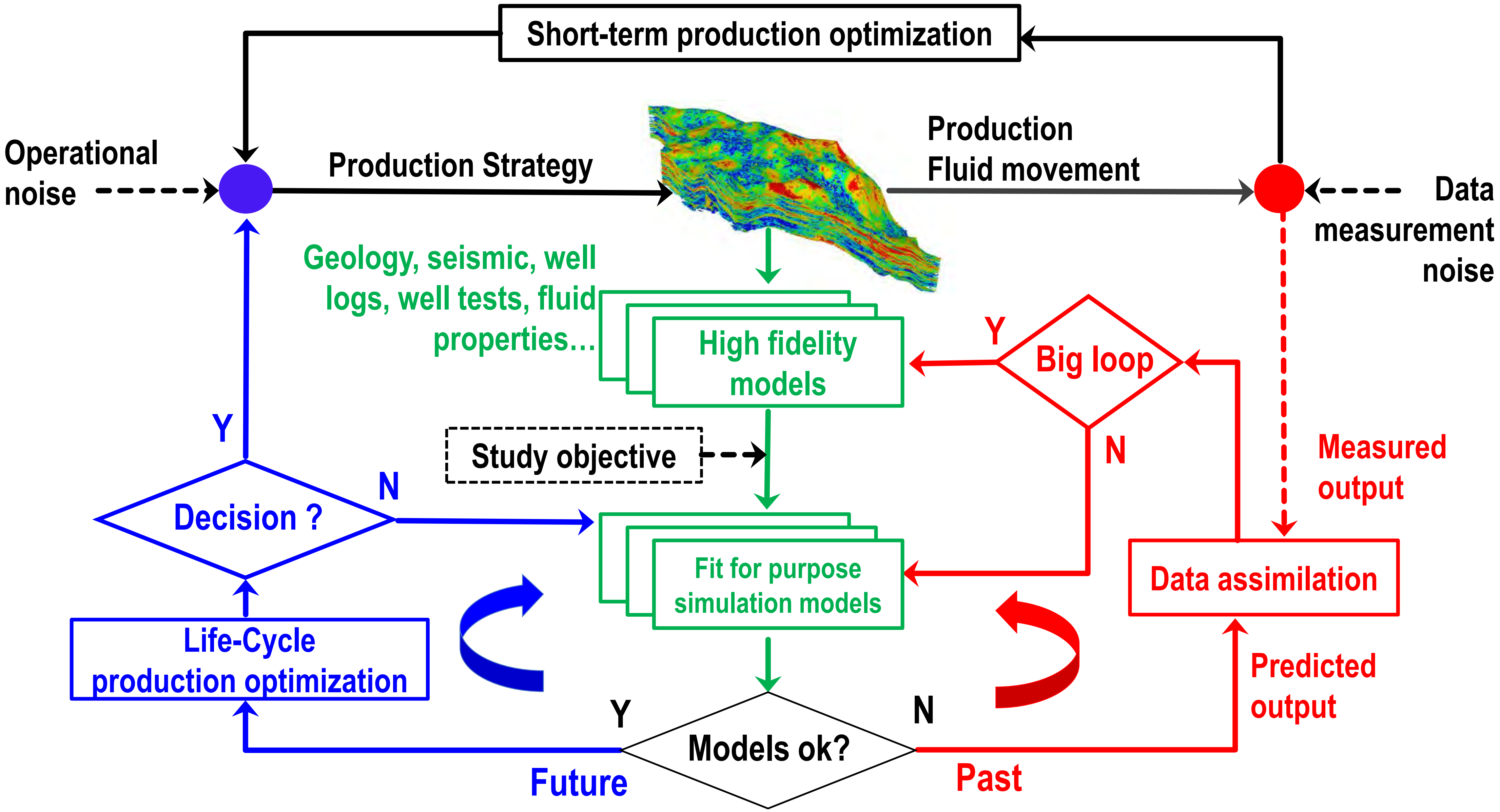
Introduction

- Improve decision making process using reservoir simulation models, data and special tools
- High investments, low flexibility, long-term projects (complex decisions)→ offshore and pre-salt fields
- Reliability and quality of studies
- Simulation (main tool) (high computational demand)
- High number of simulations (higher chances of better decisions)
- Multiple runs management – multi-fidelity approaches
- Techniques to speedup decisions
- Digital fields (life-cycle and short-term forecast and decisions)

CLFDM

Closed Loop Field Development and Management

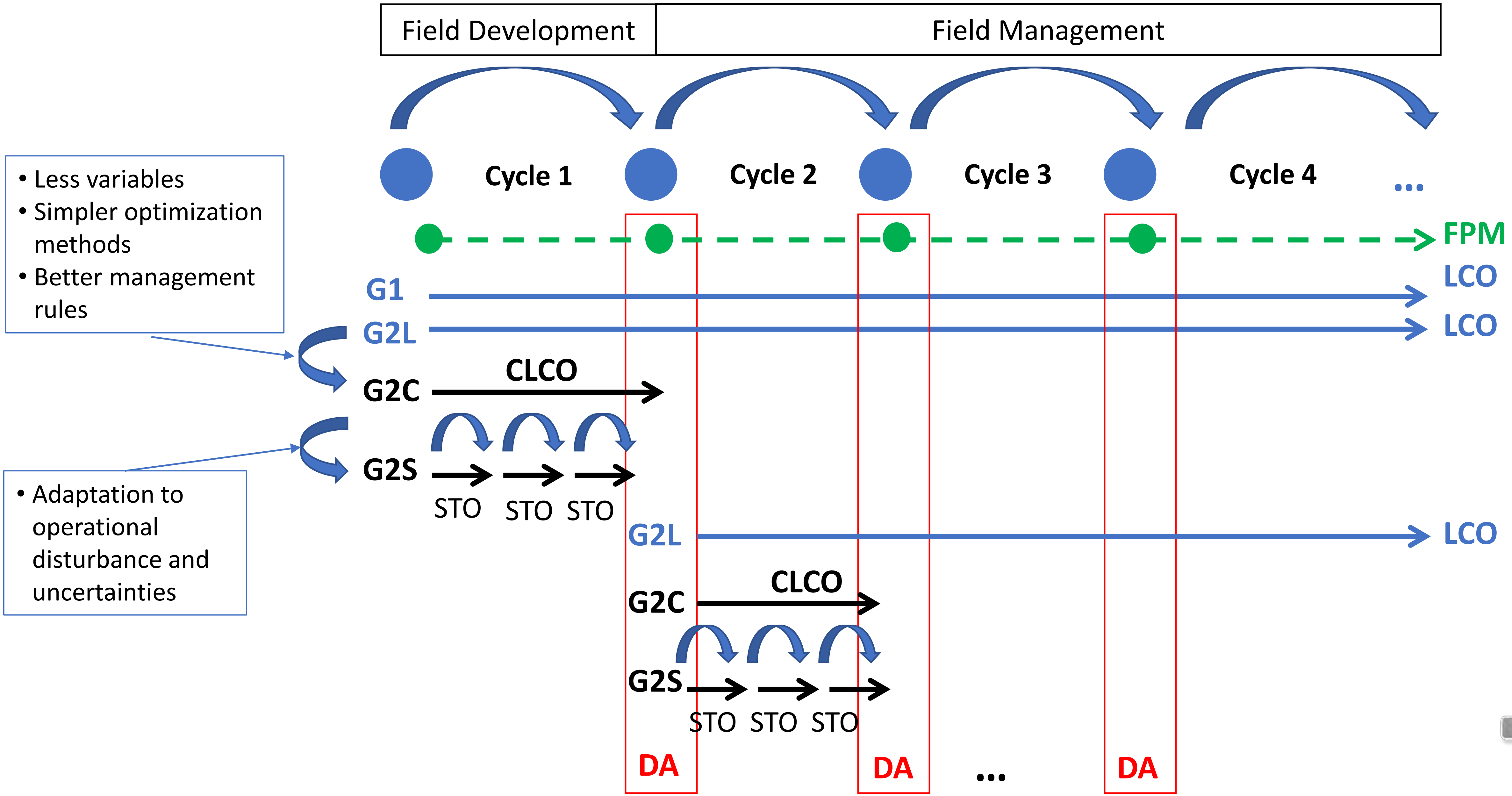
Model-based CLFDM



Black Step

- Focus of today´s presentation
- Final decision → implementation in the field field
  - Development (design) variables (group 1 – G1)
  - Management (control) variables (group 2 – G2)
    - G2L – lyfe-cycle rules selected in the blue steps
    - G2C – cycle variables
    - G2S – short-term → real time
  - Revitalization variables (group 3 - G3)
- Operational noise (delays, availability, …)

CL Cycles

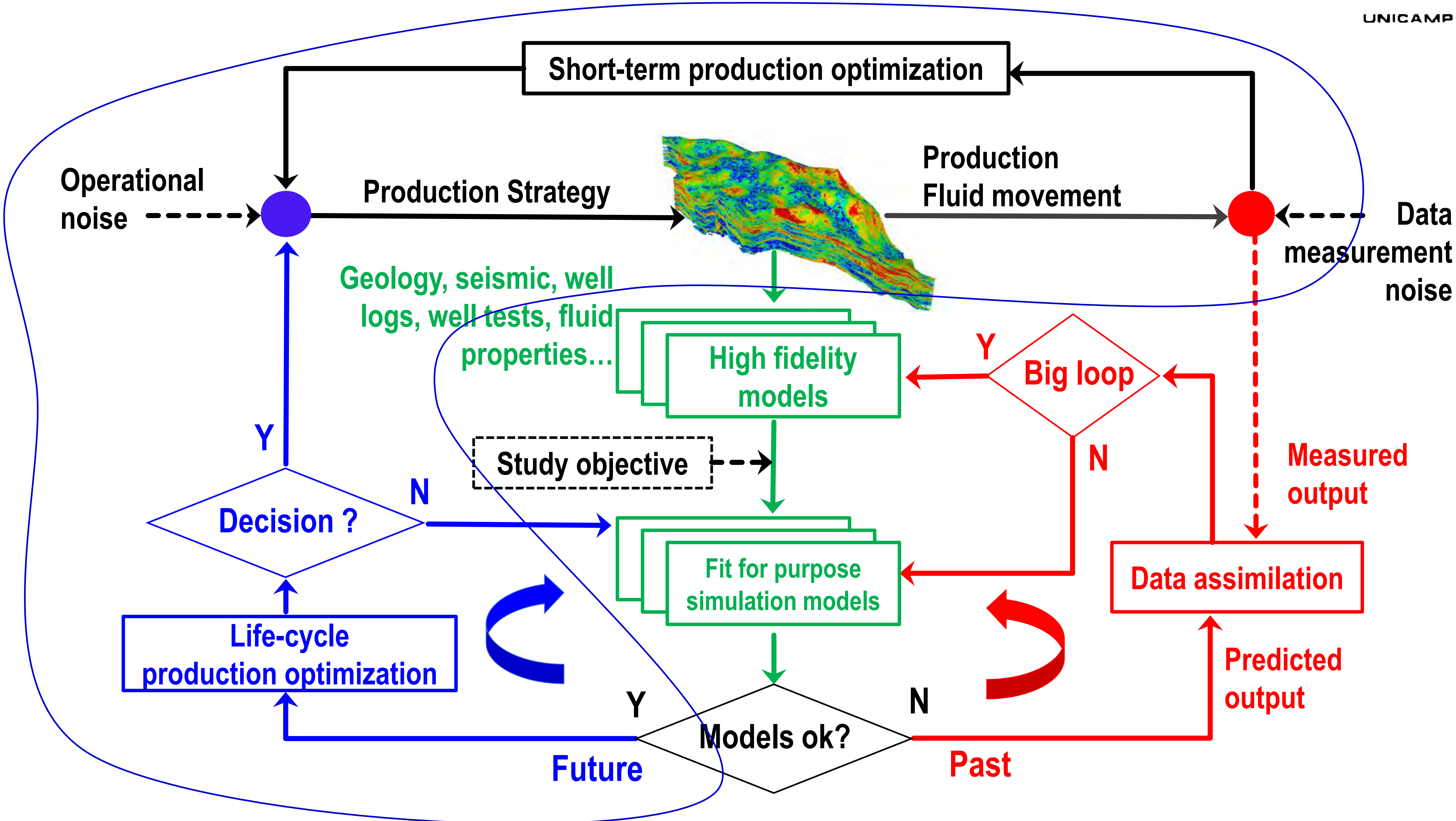


Field Development
Field Management
Cycle 1
Cycle 2
Cycle 3
Cycle 4
...
FPM
G1
LCO
G2L
LCO
CLCO
G2C
G2S
STO
STO
STO
G2L
LCO
CLCO
G2C
G2S
STO
STO
STO
DA
DA
...
DA
• Less variables
• Simpler optimization methods
• Better management rules
• Adaptation to operational disturbance and uncertainties

Current Energi Simulation Chair Preparation to Digital Field

Main motivation: simulation models are often used for life-cycle objectives but not often used to short-term, real-time applications → digital fields

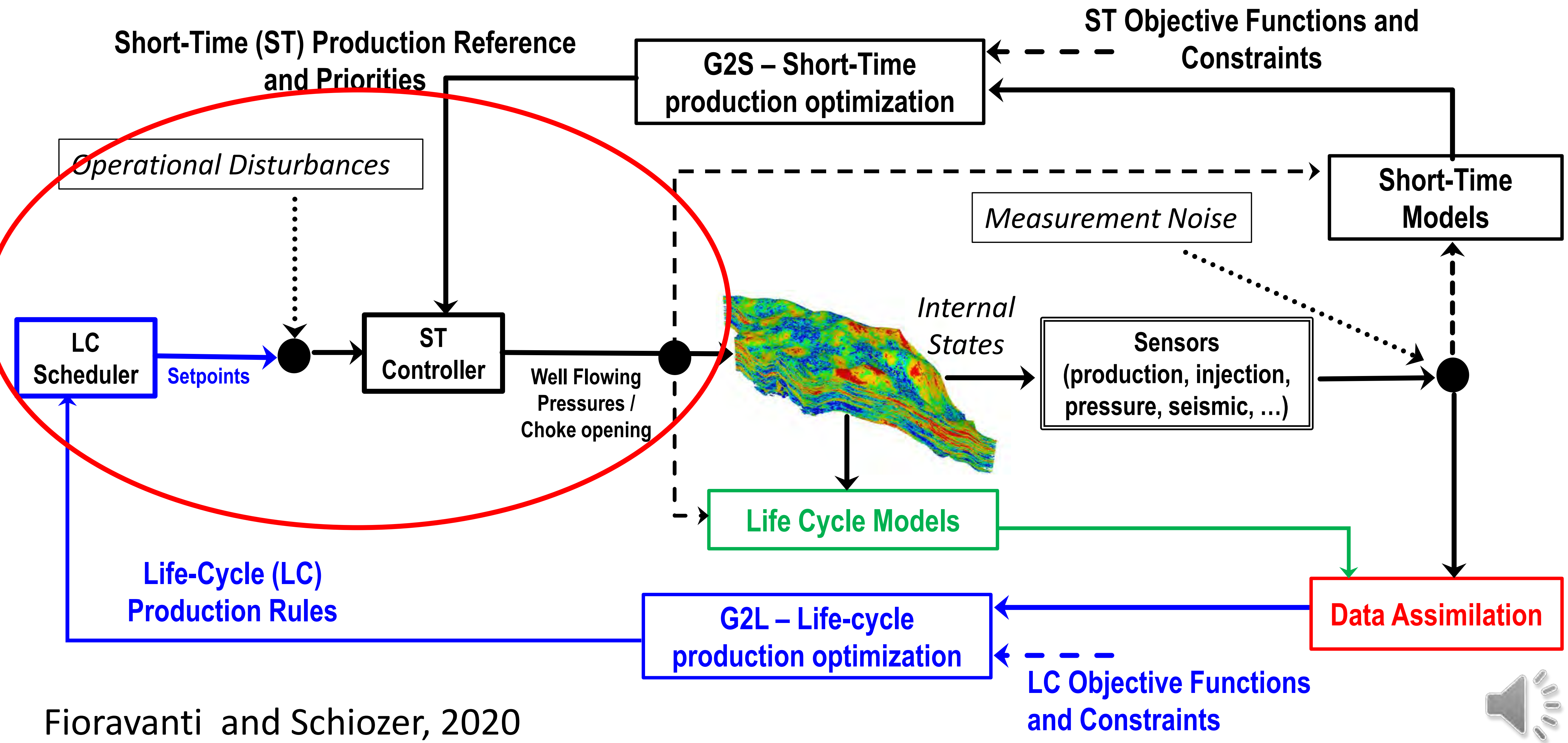
Model-based CLFDM



Steps towards digital fields → actions

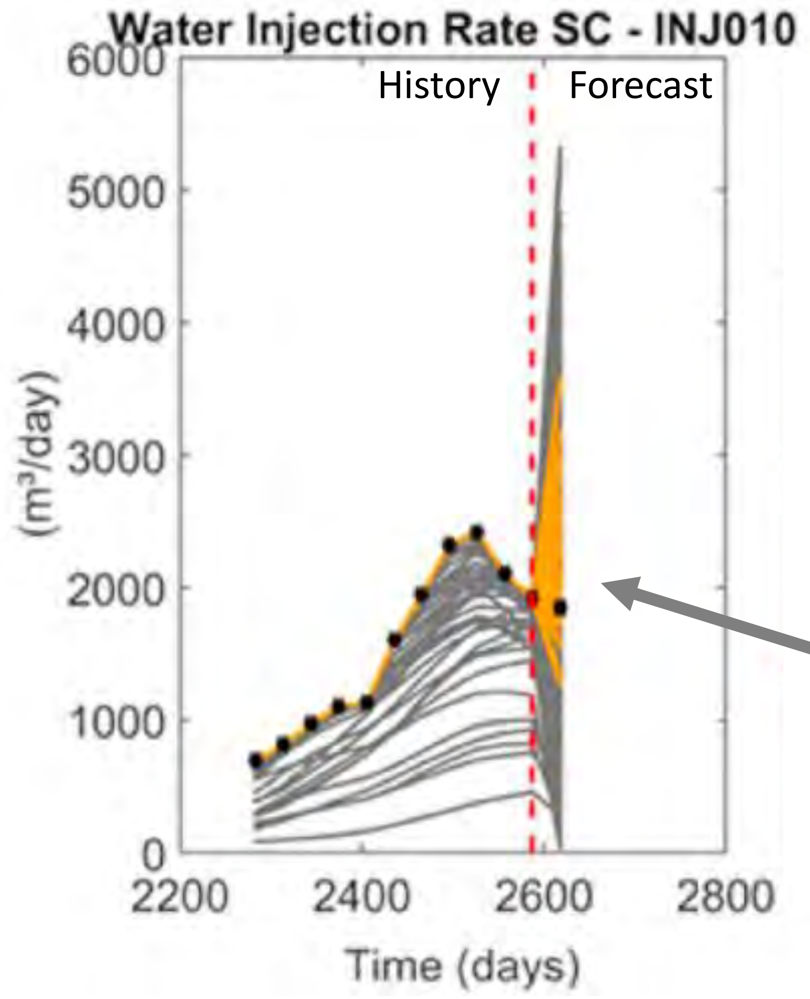
- Use of reservoir simulation models for shorter-term decisions
- Problems detected so far
  - Better transition “past-future” for simulation models
  - Integration with production facilities to improve short-term forecast
  - Better estimation of forecast conditions
  - Emphasize differences of control variables, physical restrictions, reservoir, management, operational problems, prorating, maintenance, etc.
- Future steps
  - Integration with data-driven approaches (machine learning techniques)
  - Reduce size of CL Cycle
- Model quality indicators → fit-for-purpose models to be used in short-term decisions may be different
  - Multi-fidelity models
- Probabilistic approaches (as we use in life-cycle) may have to change
  - Less influence of several uncertainties

CLFDM – cycle and short-term control



Fioravanti and Schiozer, 2020

Transition past → future



Almeida et al. (2020)

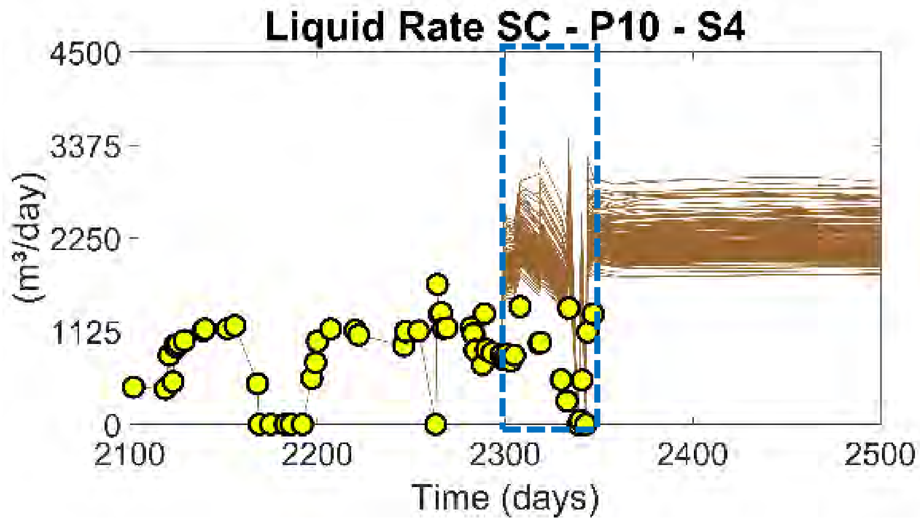
Example of multiple realization runs that honors the past but with a future behavior inconsistent with data

Long-term effects small because material balance over time will approximate solutions

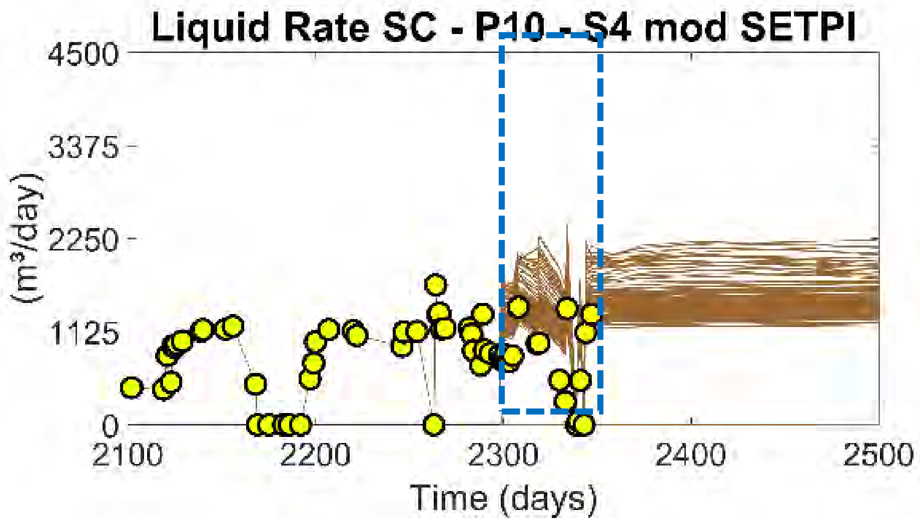
<u>Short-term effects very important</u>

Improvement of Data assimilation Process

- Example of problematic well (real field)



IP Corrections



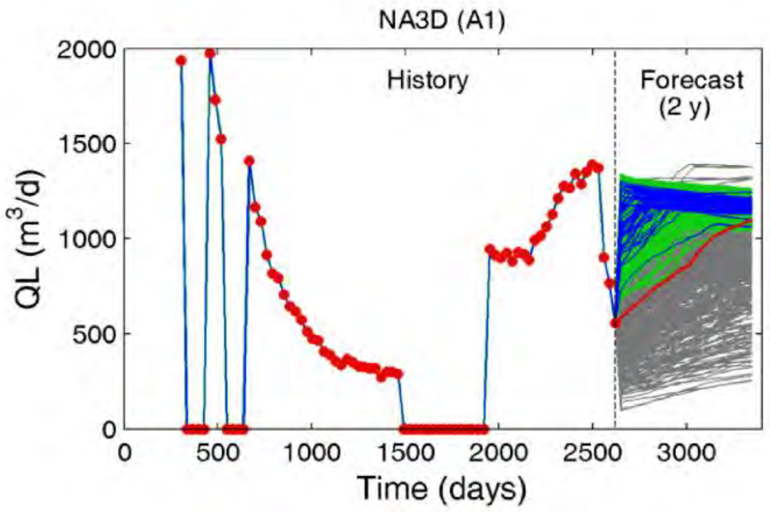
Validation period

Boundary conditions changed to forecast mode

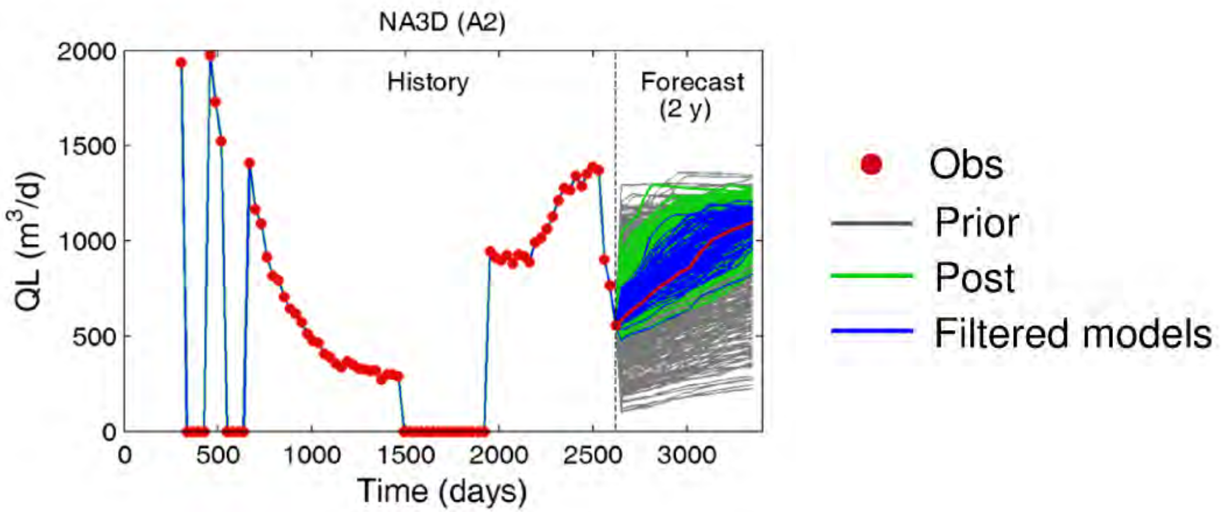
Reservoir and production system data assimilation

- Methodology for data assimilation comprising reservoir model and production system
- Main contribution: inclusion of Vertical Lift Performance (VLP) tables (resulting from the production system data assimilation) in the reservoir data assimilation process

Fixed VLP

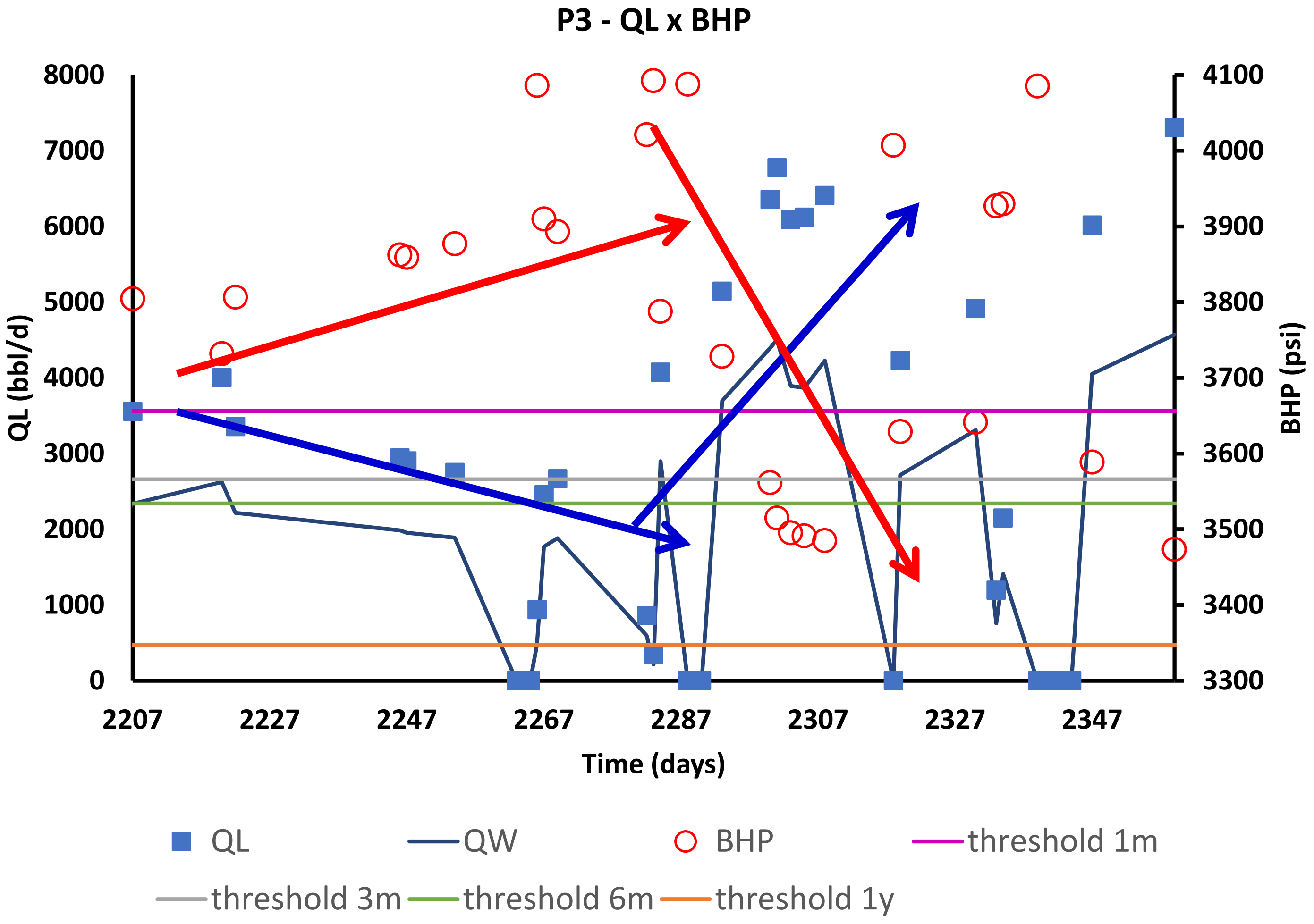


VLP as a uncertain parameter in data assimilation



Improvements in short-term production forecast

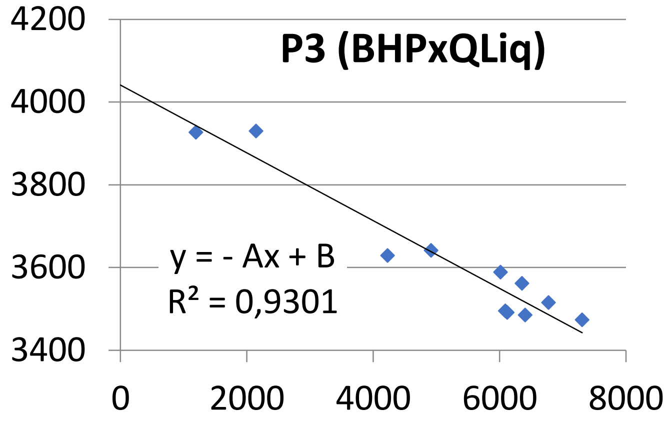
Example of well P3 forecast

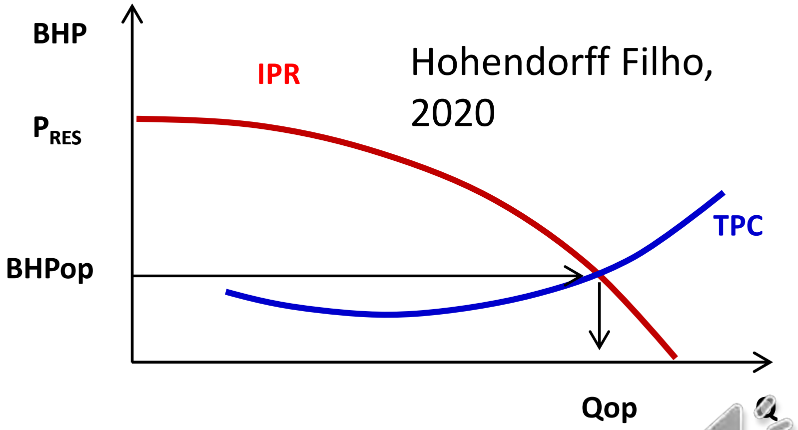


Casanova, 2020

BHP behavior

QL behavior

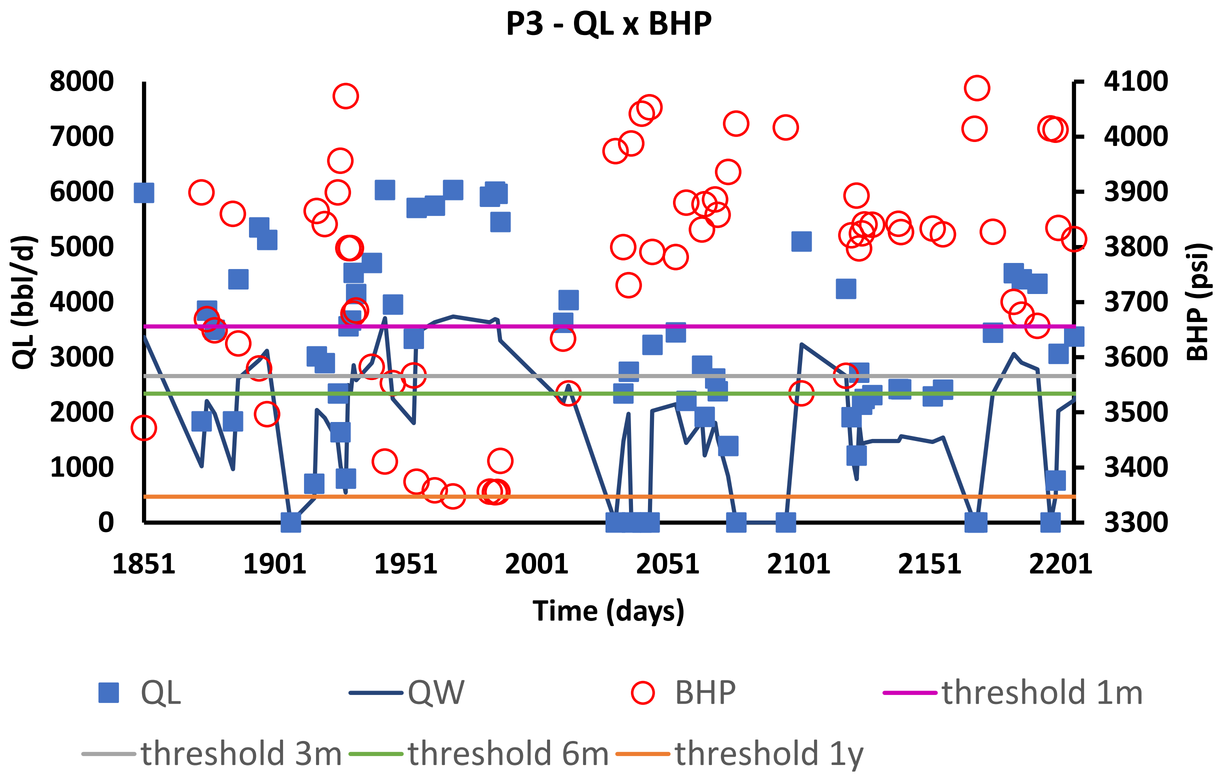




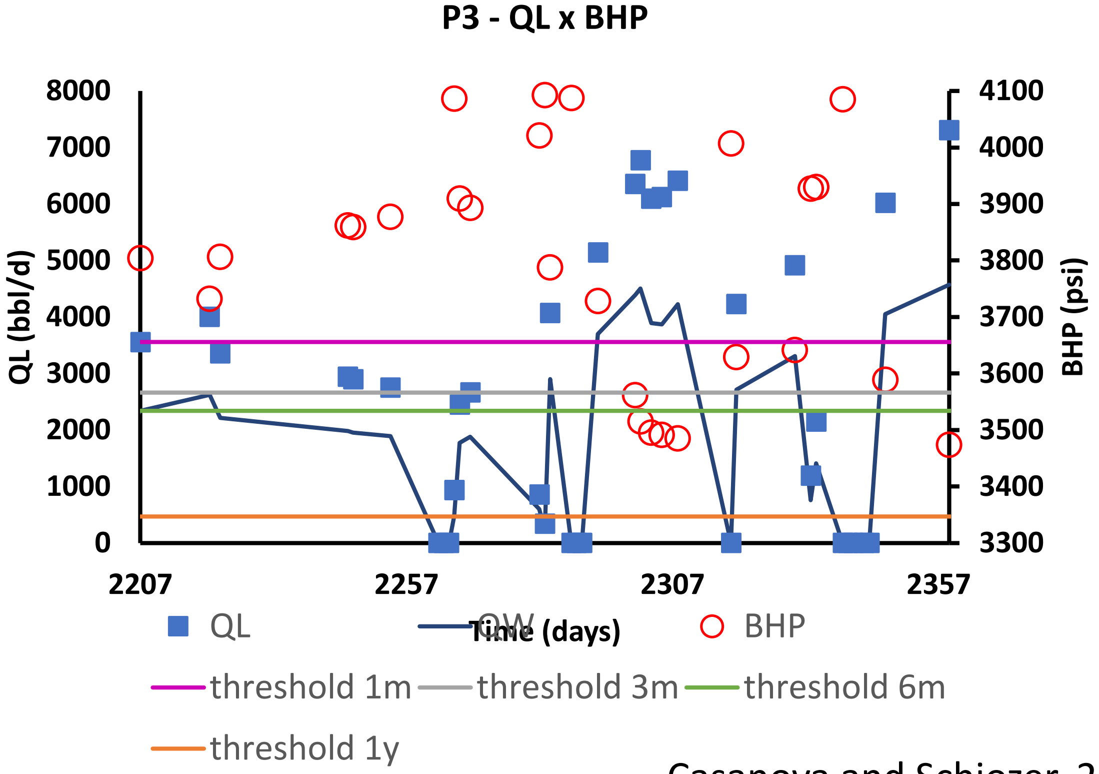
Hohendorff Filho, 2020

Application (P3) → future BHP ?

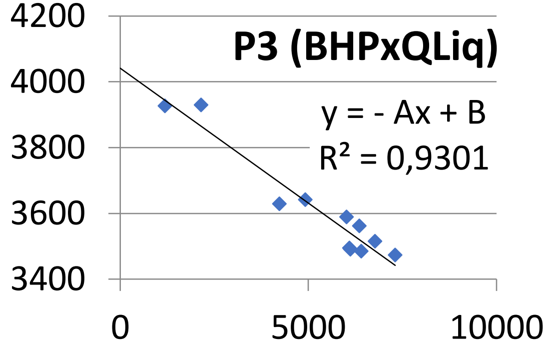
History

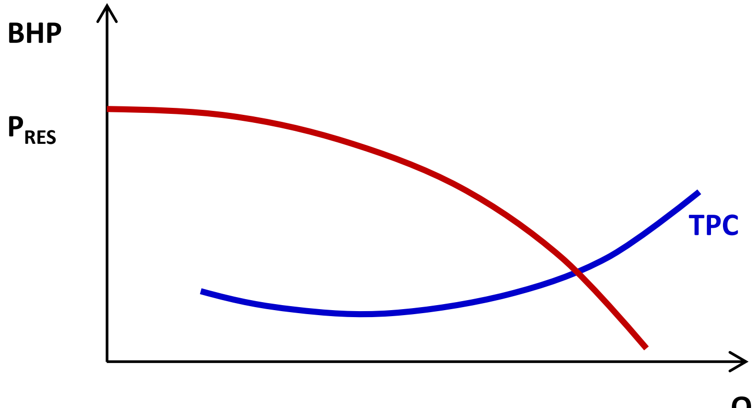


Forecast



Casanova and Schiozer, 2020





+ well reports + machine learning → short-term future behavior

Steps towards digital fields

Life-cycle

- Human-intervention-free forecast
  - Reservoir potential (reservoir pressure, fluids saturations)
  - Well: IP
  - Production facilities: pipes, pumps, valves, separators, ICV, …
- Facilities constraints (physical limits) – maximum capacities
- Field management: intentional controls to reach objectives

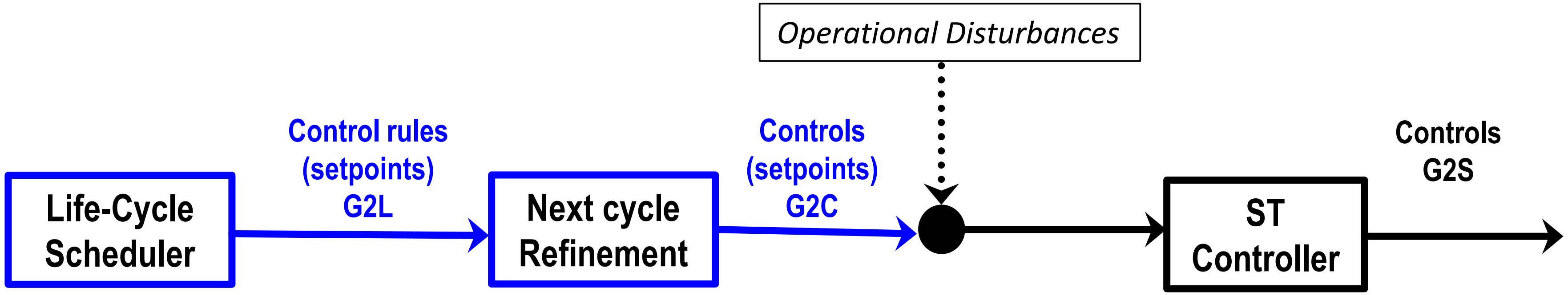
General control rules (setpoints) G2L

Next cycle

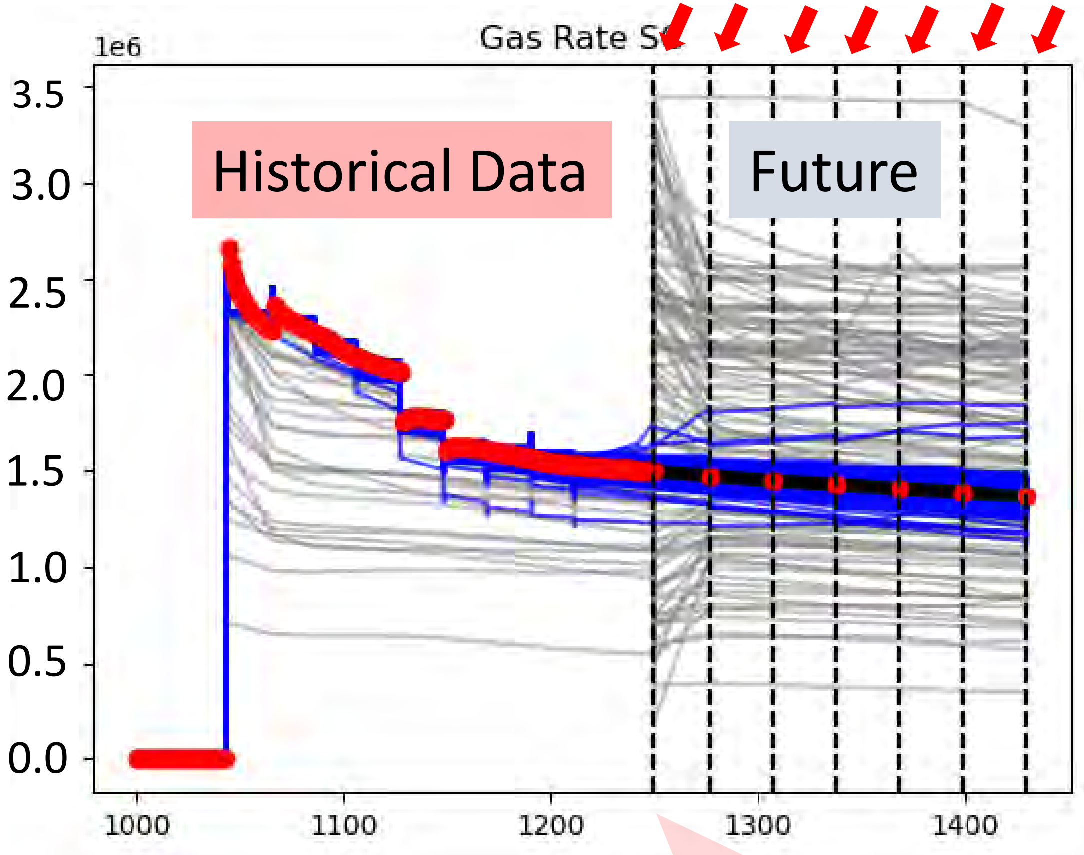
- Control of cycle parameters → G2C

Short-term

- MT / ST operational management: well tests, preventive maintenance, prorating stops, ...
- Operational problems: random problems that change production systems
- Not Mapped Uncertainties → not expected behavior in LC forecast

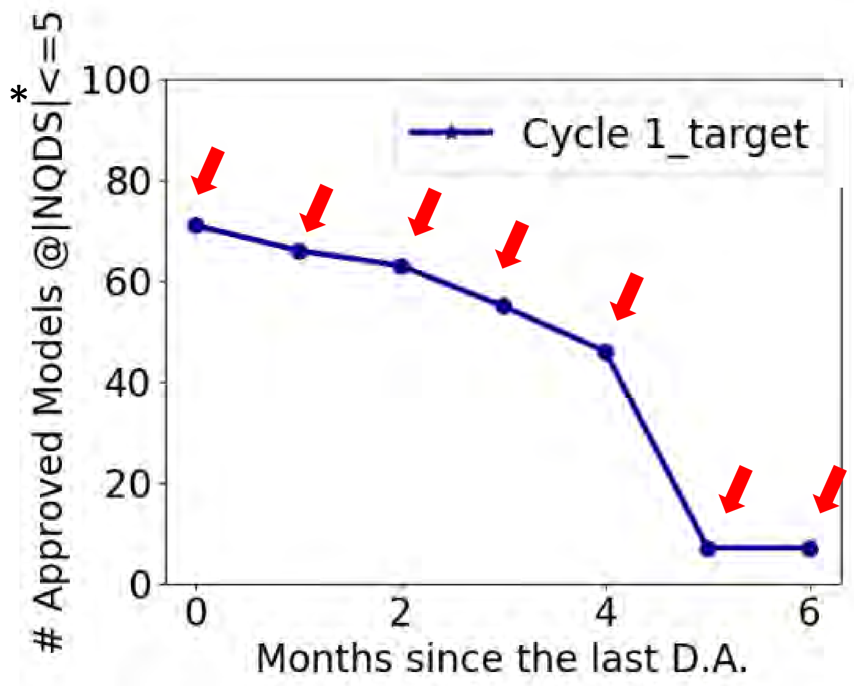


Quality over time (cycle)



Data assimilation

Tracking NQDS over time after Data Assimilation



** Considering all objective functions*

Model-based integration with data-driven

- Initial research lines (ST)
  - Data-driven (DD) approaches for short-term forecast (Other professors)
    - Data-driven (DD) to correct model-based short-term forecast
  - Model-based (MB) with uncertainties → boundary limits to DD forecast
  - Increase frequency of analysis in MB decisions (shorter cycles)
- Future
  - Real-time
  - Possible applications for digital transformation

Final considerations

- Additional focus in 4 main areas (4 colors)
  - Models for short-term analysis: multi-fidelity analysis
  - Data assimilation for reduction uncertainties of reservoir models
    - Improvements of trasition past-future behaviour
    - Modification in methods to ST analysis
  - Production forecast
    - Life-Cycle (G2L) → Cycle (G2C) → setpoints for ST controls (G2S)
    - Multi-fidelity approaches
  - Decision analysis : Cycle → ST → RT → Digital transformation
  - Probabilistic approaches used for MB Life-Cycle management → ST (less variability) (approaching deterministic ?)
- Preparation: digital field technology
- Application to pre-salt fields: giant carbonate fields with permanent 4D and intelligent completions – ICV, WAG-CO_2 injection, gas-driven optimization

Acknowledgments

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CEPETRO
CENTRO DE ESTUDOS DE PETRÓLEO

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epic Research & Education

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CAPES

anp Agência Nacional do Petróleo, Gás Natural e Biocombustíveis

CMG COMPUTER MODELLING GROUP LTD.

Schlumberger

TOTAL

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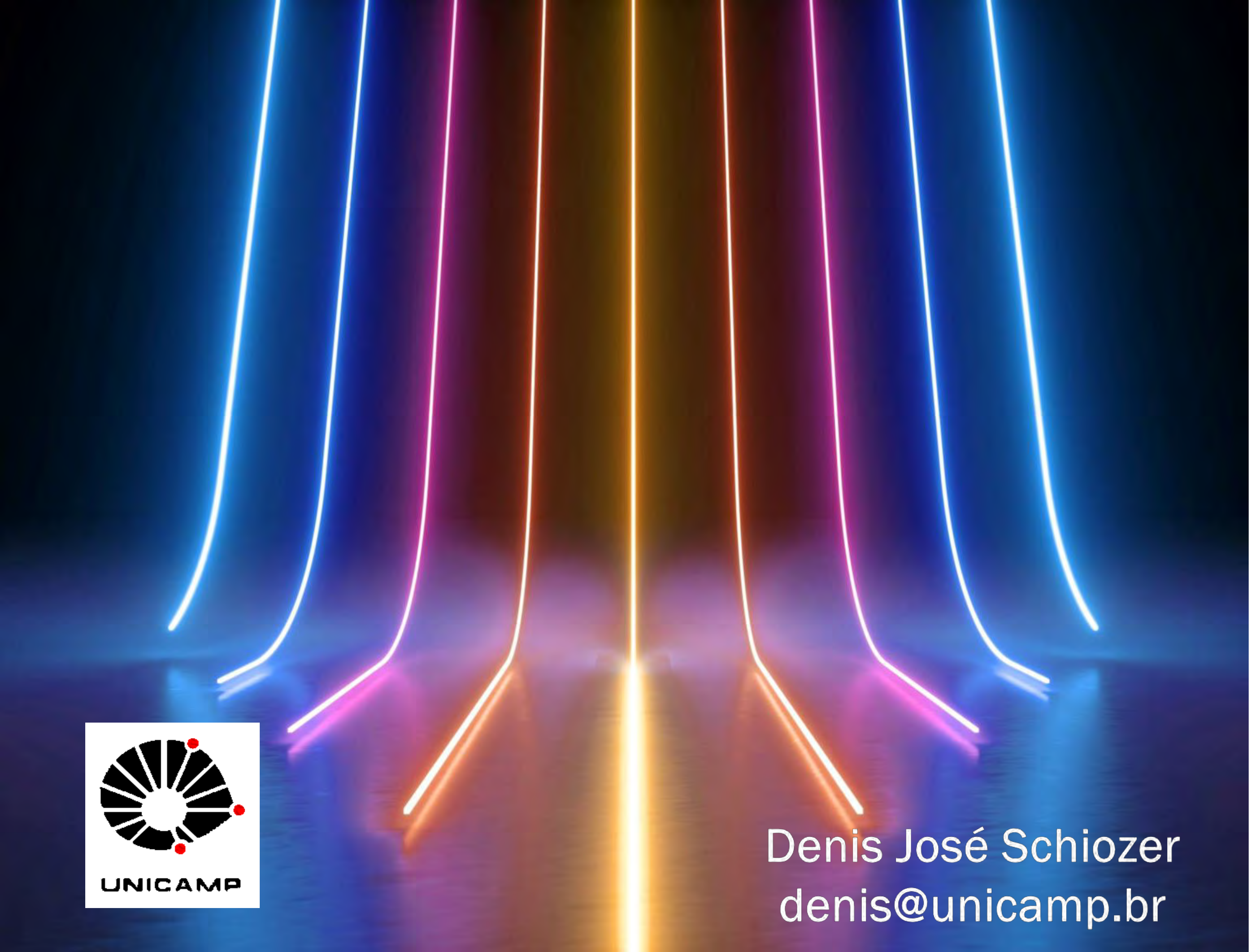
BeicipFranlab



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Extra Slides

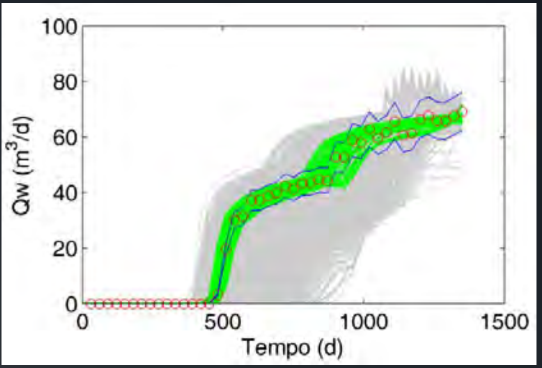
Green steps challenges

- Speed up studies of complex and/or giant field
- Representation of critical heterogeneities with low computational cost
  - Karst, vug, fracture flow modeling
- Near well upscaling
- LFM (low fidelity models), FOFE (fast objective function estimators) of petrophysical properties
- Integration/combination with FOFE → multi-fidelity
- Improve benchmarks: more realistic operational problems

> Internal Benchmarks:
> UNISIM-I (typical of Campus Basin offshore field)
> UNISIM-II (pre-salt carbonate reservoir)
> UNISIM-III (pre-salt giant oil field)
> https://www.unisim.cepetro.unicamp.br/benchmarks/en/

- Models for short-term behavior

Red steps challenges



- History matching → data assimilation to reduce uncertainties
- Reduction of uncertainties in petrophysical properties
  - ESMDA efficient HM method (EHM from Petrobras)
    - Collapse of models – excessive uncertainty reduction
  - Methods that integrate with geostatistical: good results – more complex to implement
- Integration with 4D seismic: quantitative solutions (SenRML)
- Model calibration to forecast short-term production (productivity deviation as new objective function)
- Fast procedures to apply in digital fields (→ short-term → real time)
- Data assimilation applied to production facilities

Blue Steps - Challenges

- Optimization techniques
- FOFE (emulators, proxies, …) and LFM
- Economic analysis / fiscal regimes
- Development plan (production strategies – G1 - design variables)
- Field management
  - Control variables (G2)
  - Revitalization variables (G3)
- Intelligent fields
- MIP (integration reservoir – facilities)
  - Multiple reservoirs - common production facilities
  - Flow assurance / subsea separation
- Improved recovery methods
  - Complex treatment of G2 for WAG-CO_2 with ICV options
- Preparation to digital transformation