

How to make more from your online & offline fermentation data

and speed up your biotech process development with statistical modelling

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what is precious to you?



Agenda

- Introduction to Clariant and sunliquid®
- Statistical analysis of fermentation data
 - Standard statistical modelling (Fit Model & Extrapolation Control)
 - Online data analysis with Functional Data Explorer platform
- Summary



Clariant – a global leader in specialty chemicals serving a broad industry



CARE CHEMICALS

Personal Care
Industrial Applications
Home Care
Crop Solutions
Food Ingredients
Encapsulation Technologies



CATALYSIS

Catalysts
Biofuels & Derivatives



NATURAL RESOURCES

Additives
Oil Services
Mining Solutions
Refinery Services
Functional Minerals

3 860 Sales 2020 (CHF m)
from continuing operations

15,0% EBITDA margin 2020
from continuing operations

13 235 Total staff 2020 (FTE) ¹

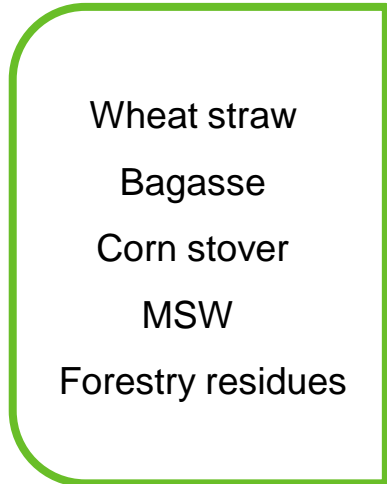
85 Production sites worldwide
in 2020 ^{1, 2}

¹ Total Group incl. discontinued operations (excl. Business Unit Masterbatches)

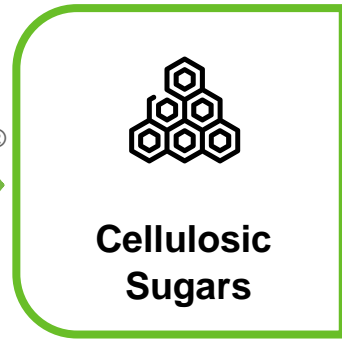
² Shared production sites with Business Unit Pigments are split as separate sites

sunliquid[®] - Beyond cellulosic ethanol

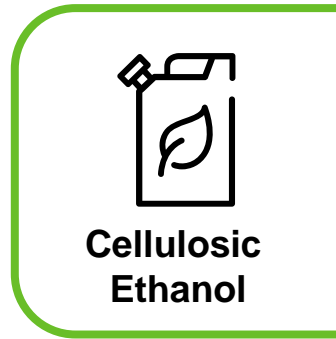
BIOMASS FEEDSTOCK (EXAMPLES)



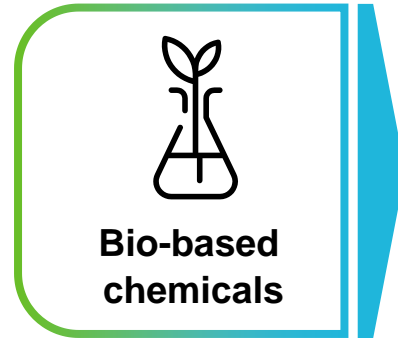
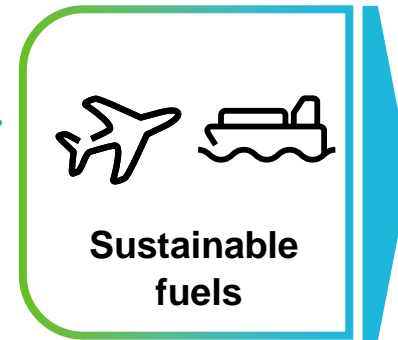
sunliquid[®]



sunliquid[®]



Catalytic
conversion

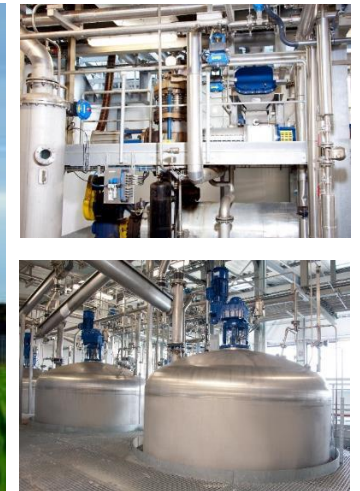
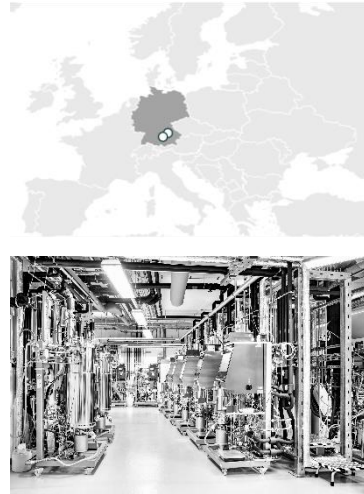


EXAMPLES

- Sustainable aviation fuels (SAF)
- Sustainable marine fuels

- Fatty acids
- Ethylene/ Ethylene oxide

Clariant's Biotech facilities - Developed in Bavaria, Applied in the World



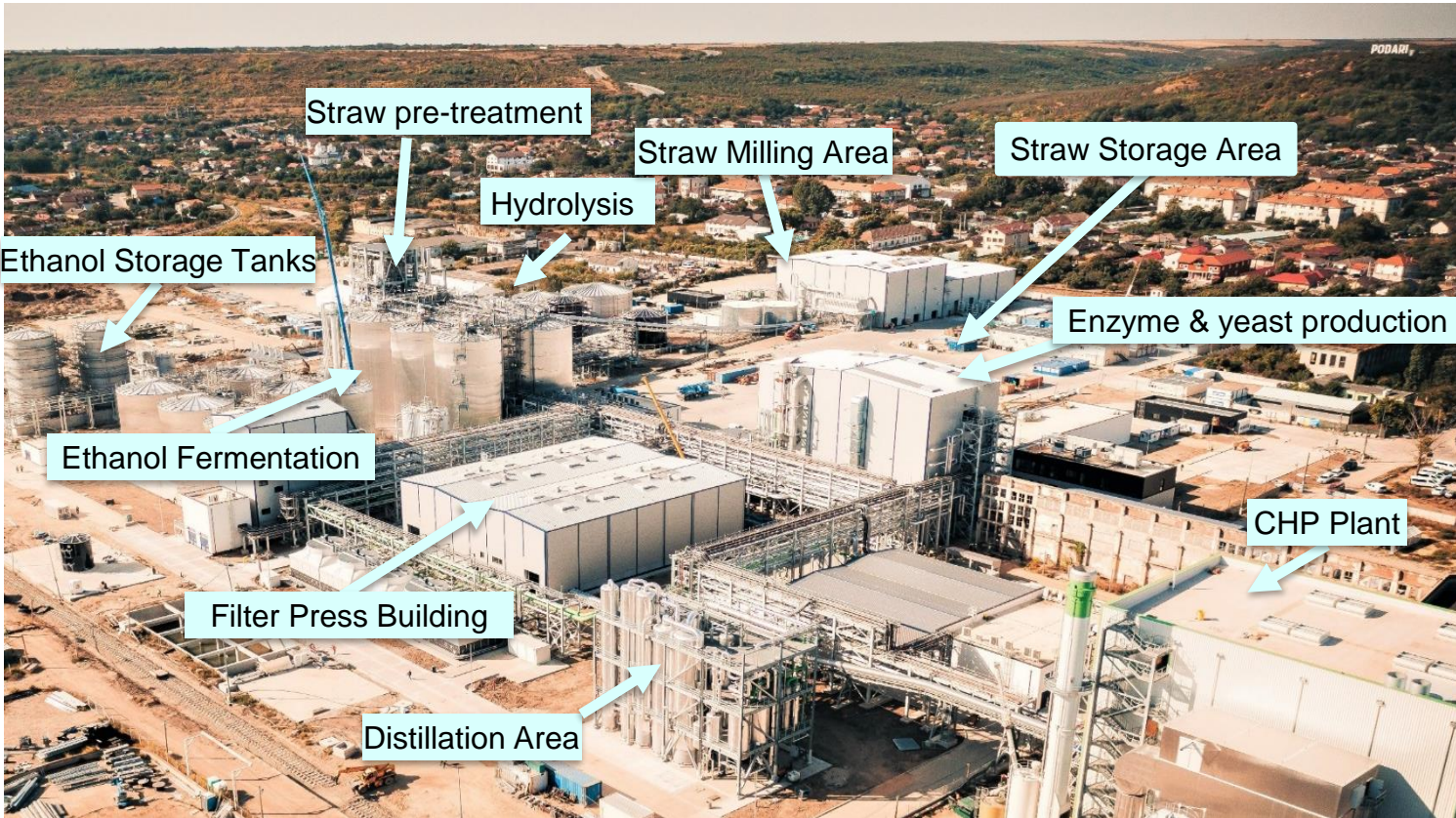
Biotechnology R&D Center (Planegg)

- Inaugurated in 2006
- Over 100 scientists & technician in the labs
- Competence fields: biofuels & derivatives, industrial enzymes, biobased chemicals
- Capabilities: e.g. protein engineering, strain evolution, high throughput screening, application, fermentation, downstream processing

sunliquid® pre-commercial plant (Straubing)

- Inaugurated in 2012
- 1,000 t/a EtOH; ~4,500 t/a feedstock with scaled-down commercial design reproducing all process steps
- Wide range of feedstocks tested, e.g. wheat straw, rice straw, corn stover, bagasse, sugar cane, miscanthus, woody residues

Construction of Clariant's sunliquid[®] plant in Podari (Status: Jan 2022)



KEY FACTS

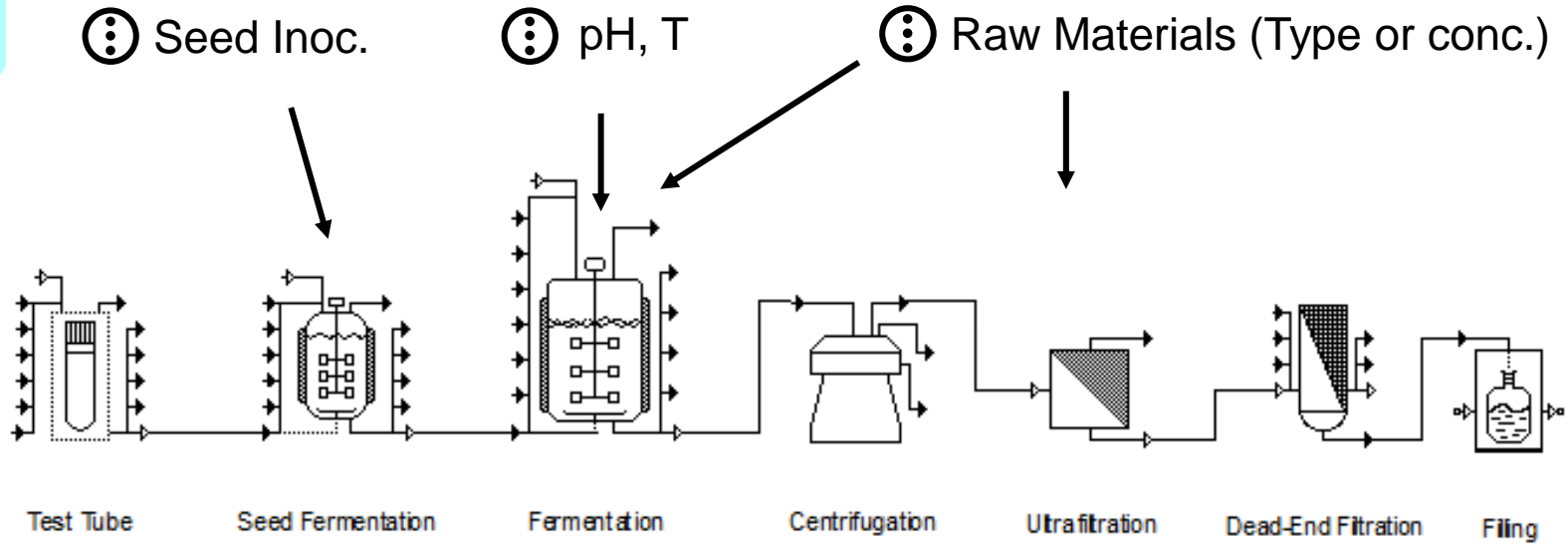
- Plant capacity: **17 mio gal / 50,000 TPY of cellulosic ethanol** by processing **250,000 TPY of straw** (locally sourced)
- **Mechanical construction** finished
- **Ethanol offtake secured** through multiyear agreement
- **Greenfield combined heat & power (CHP) plant** for energy independence by GETEC
- **Process by-products lignin & vinasse** will be fully utilized for **energy supply & as fertilizer**
- Plant will act as **training facility for customers**

Statistical analysis of fermentation data

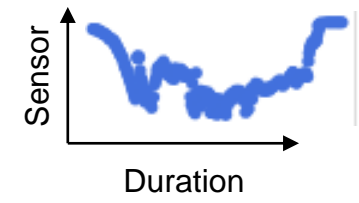


Fermentation + DSP Process

Factors



- ③ Constant factor/response
- ④ Functional data

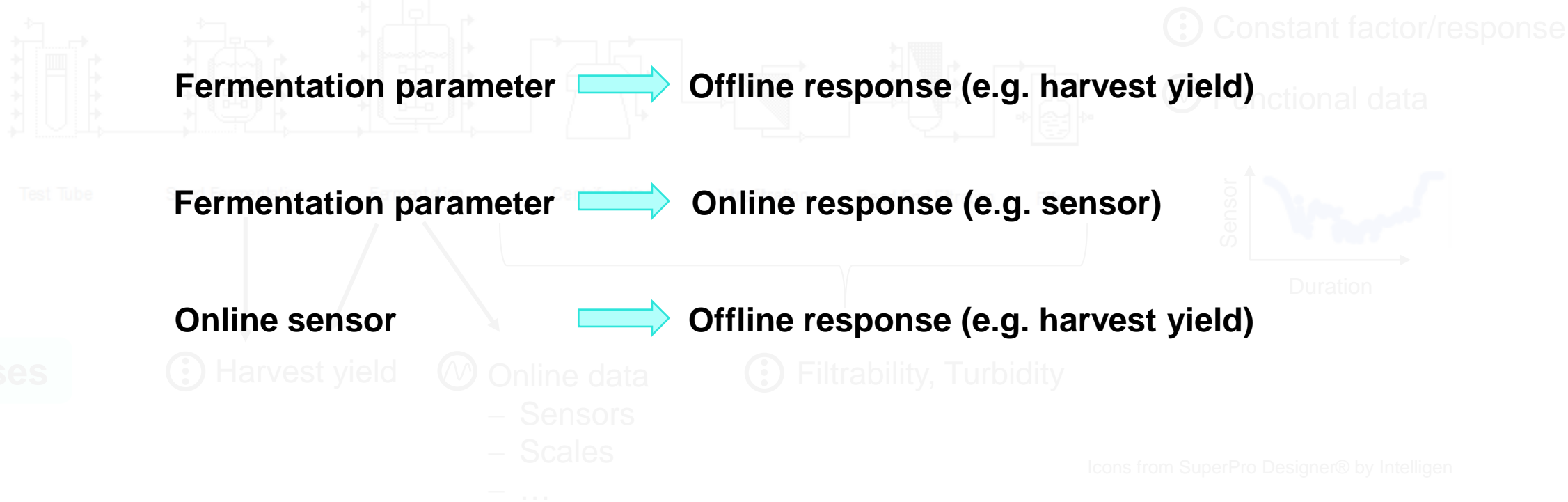


Responses

- ③ Harvest yield
- ④ Online data
 - Sensors
 - pH, T, p
 - Scales...
- ③ Filtrability, Turbidity


Fermentation + DSP Process

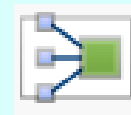
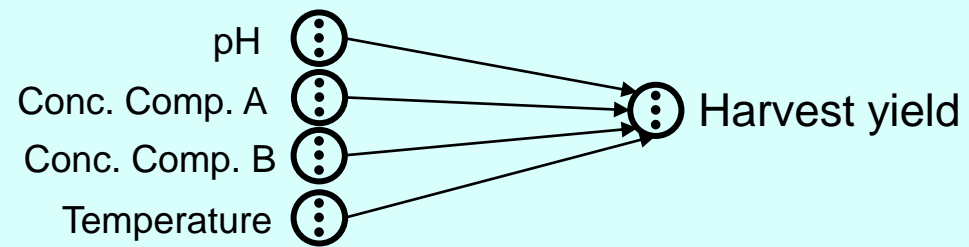
HOW IS ALL THE DATA INTERCONNECTED?



Responses

Standard statistical modelling (Fit Model & Extrapolation Control)

Fermentation parameter  Offline response



Standard statistical modelling (Fit Model & Extrapolation Control)

Goal:

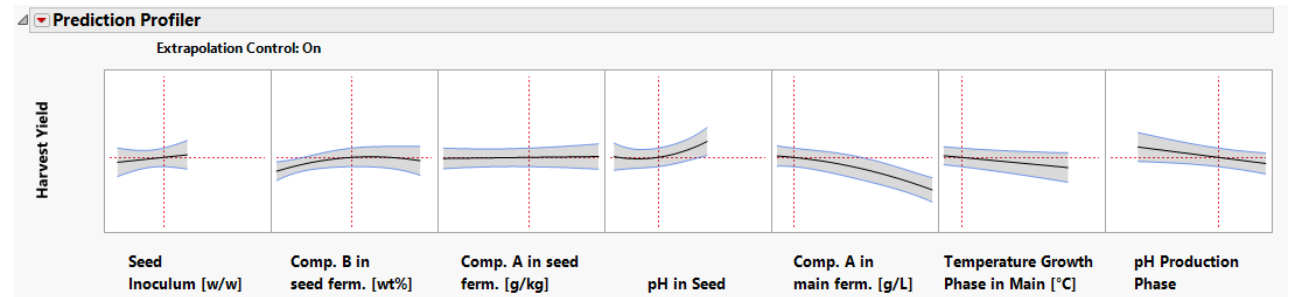
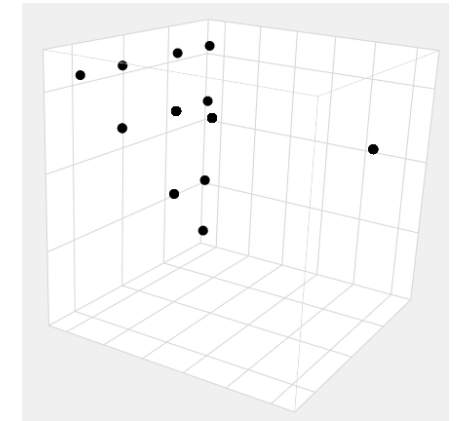
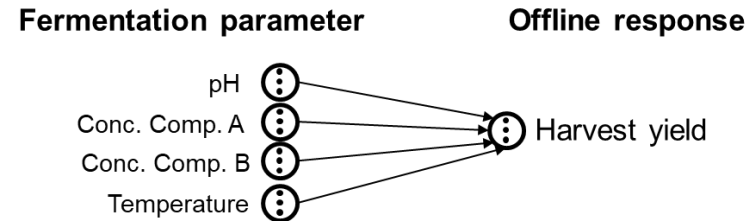
- What process parameter give a high harvest yield?
- Find an optimum in the design space
- Is this optimum stable?
- What parameters have interaction?
- What is the sensitivity of the parameters?

Analysis:

- Statistical Modelling in JMP with Fit Model platform
- Detailed evaluation by&with subject matter expert

Constraint:

- Experiment was not intended for statistical analysis (only „planned experiment“ not a DOE)
- Non optimal design space
- **JMP Live Demo** (with focus on extrapolation control)



Standard statistical modelling (Fit Model & Extrapolation Control) Evaluation for harvest yield

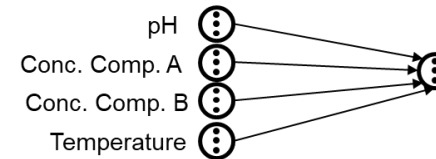
Analysis:

- Model shows expected and unexpected relations
- Extrapolation control very valuable for limited design space
- Find optimized parameters of model in design space
 - Identified potential parameters for higher harvest yield
- Interpret stability → simulator or contour profiler
 - Adding more responses enhances process understanding
 - E.g. DSP performances (can be dependend of fermentation!)

Limits:

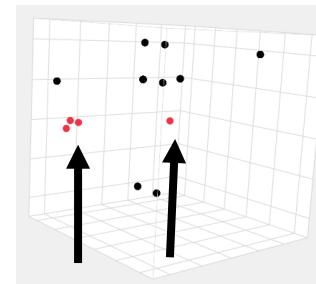
- Experiment had a non optimal design space
 - Chosen optima are on the design space limit of model
 - **Verify with additional experimental runs**

Fermentation parameter

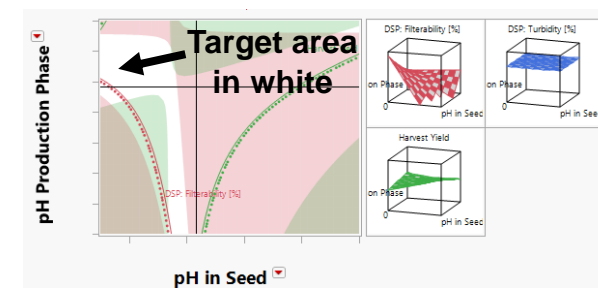


Offline responses

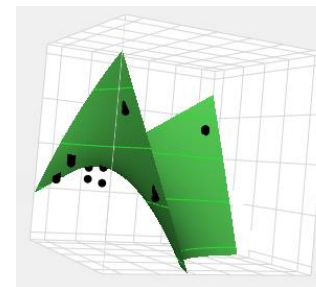
Optima from model



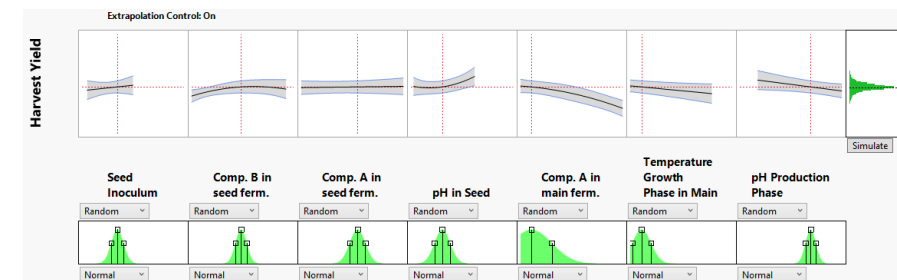
Contour plot (with multiple responses)



Surface plot



Profiler with simulator

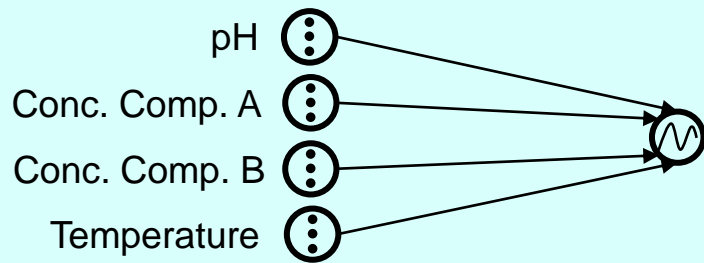


Online data analysis with Functional Data Explorer platform

Fermentation parameter



Online response



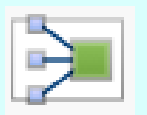
Functional data

- pO2
- pH



Offline response

- Harvest yield



what is precious to you?

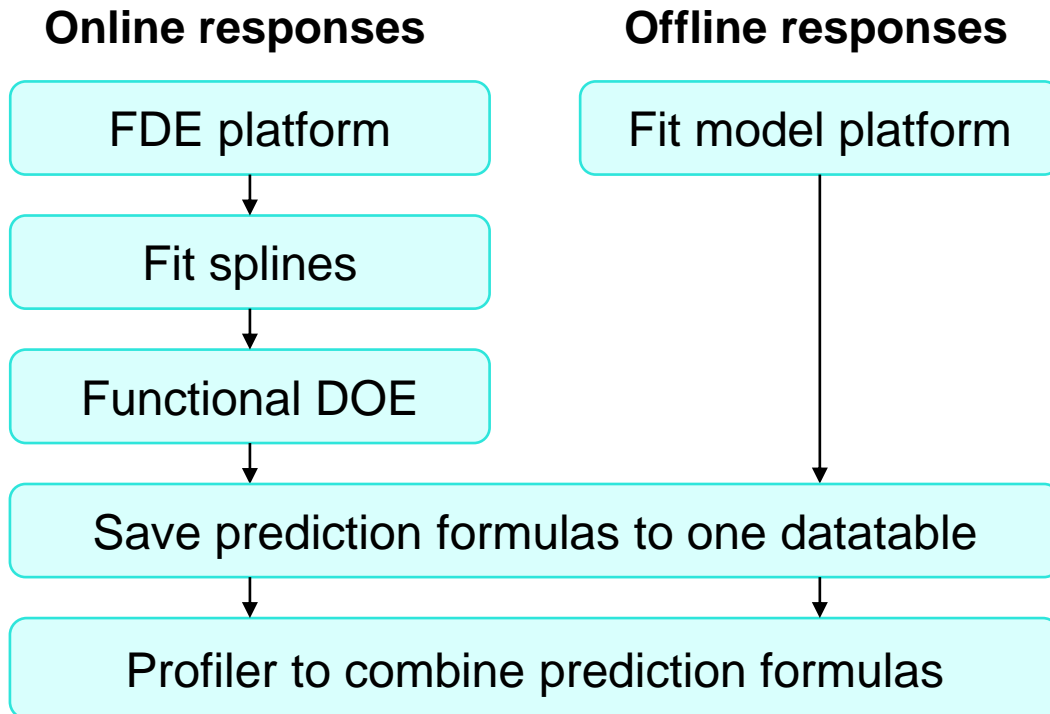


Online data analysis with functional data explorer platform

Goal:

- What set of parameters lead to which response curves?
- Fermentation online data: pO2 (solved oxygen in reactor)
- Add offline responses

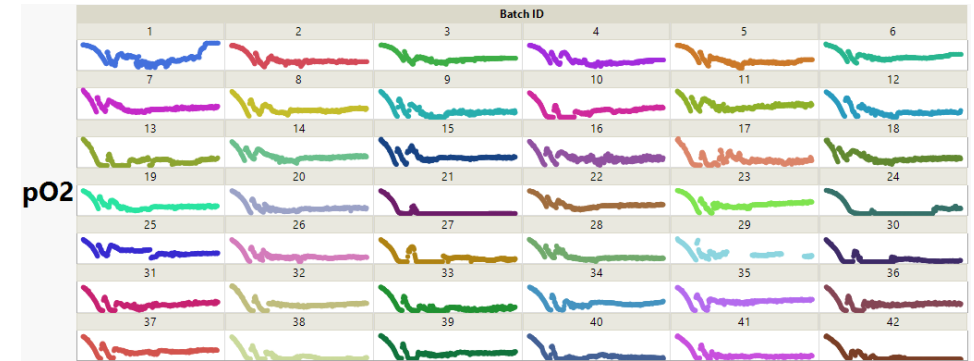
Analysis: → JMP Live Demo



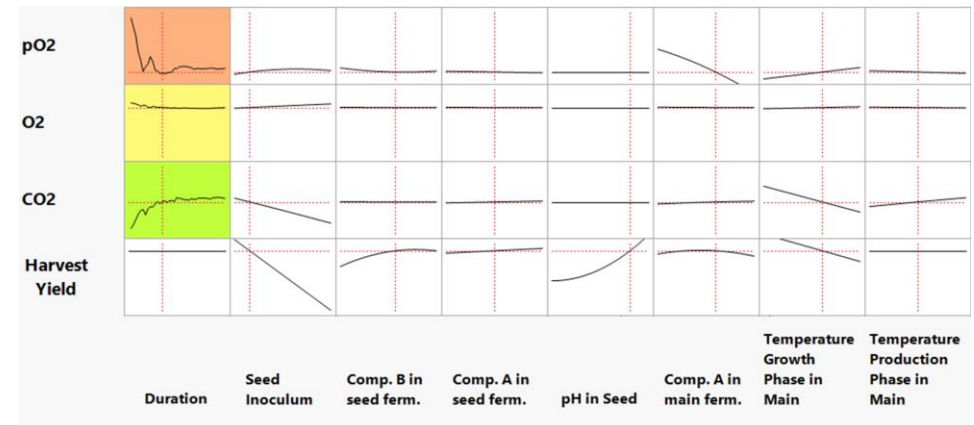
Fermentation parameter

- Conc. Comp. A ☺
- Conc. Comp. B ☺
- Temperature ☺
- pH ☺

Online pO2 responses



Profiler



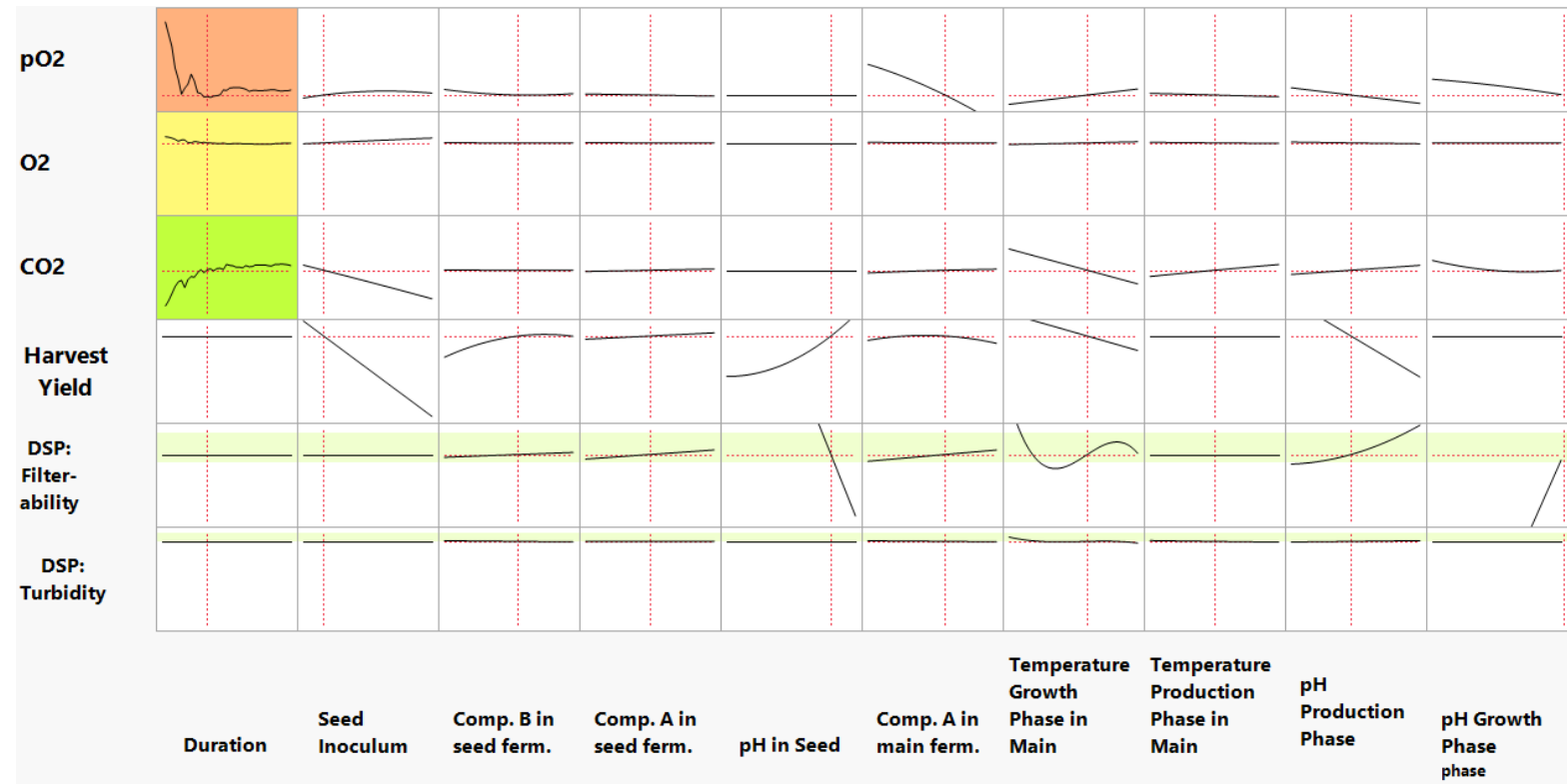


Online data analysis with functional data explorer platform

Apply parameter limits! → no extrapolation control here (different models)

Evaluation:

- See influence of parameters on functional and constant responses
- Be aware of limits of the model (no extrapolation control here)
- In detail by subject matter expert

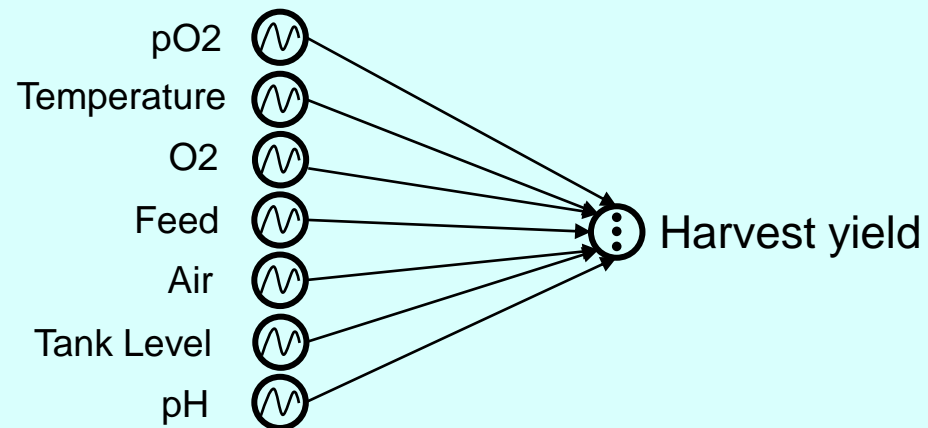


Online data analysis with Functional Data Explorer platform

Online data

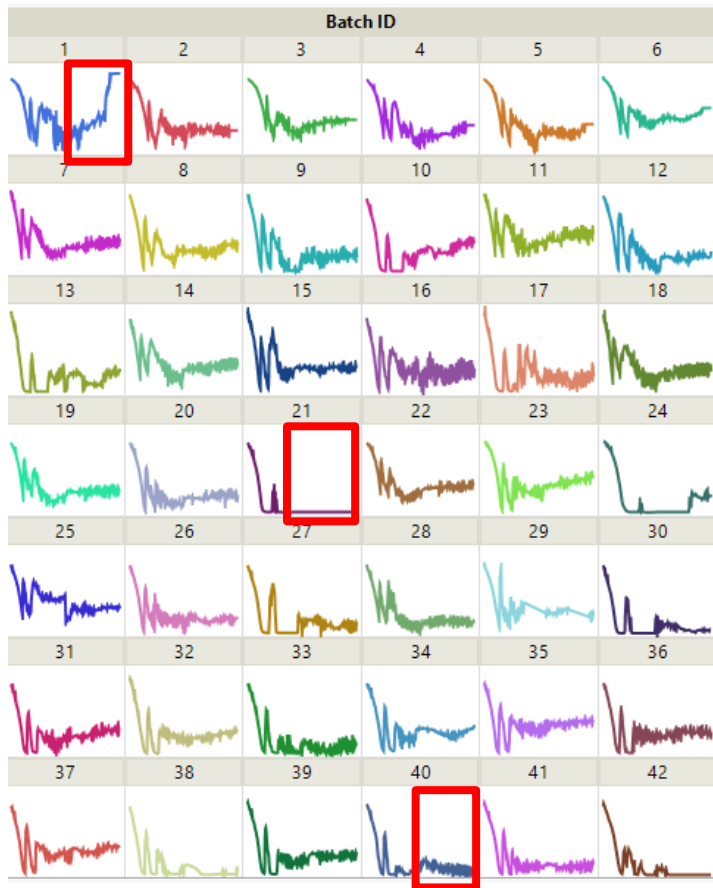


Offline response

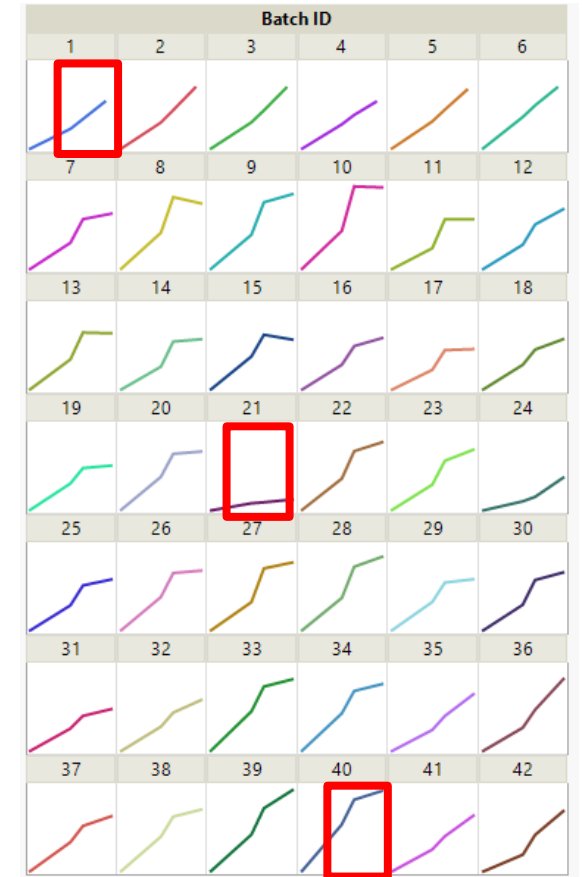


Online data analysis with functional data explorer platform

pO2



Harvest yield



Which sensor profiles lead to a good yield?

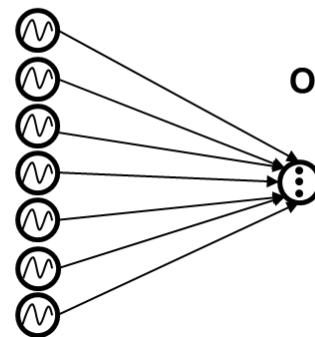


Online data

- pO2
- Temperature
- O2
- Feed
- Air
- Tank Level
- pH

Offline response

Harvest yield

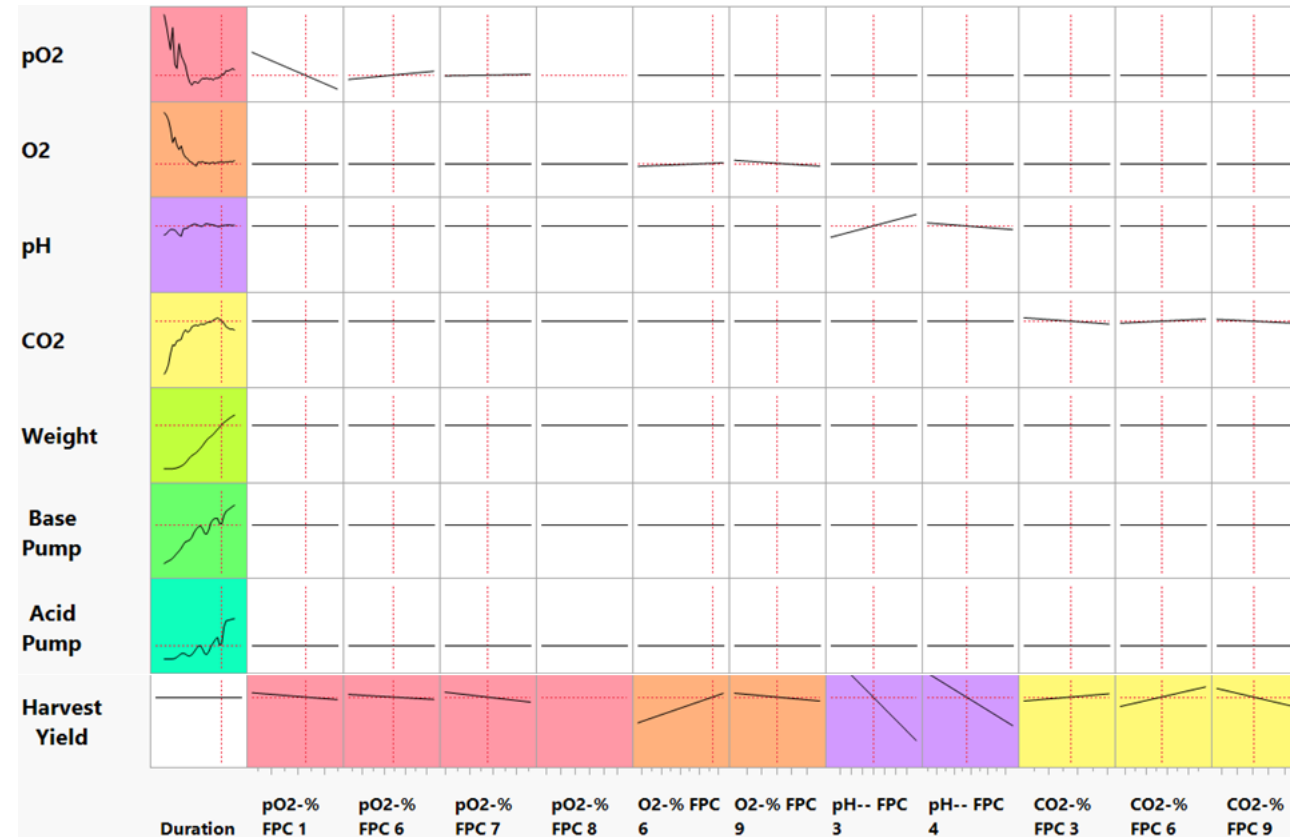
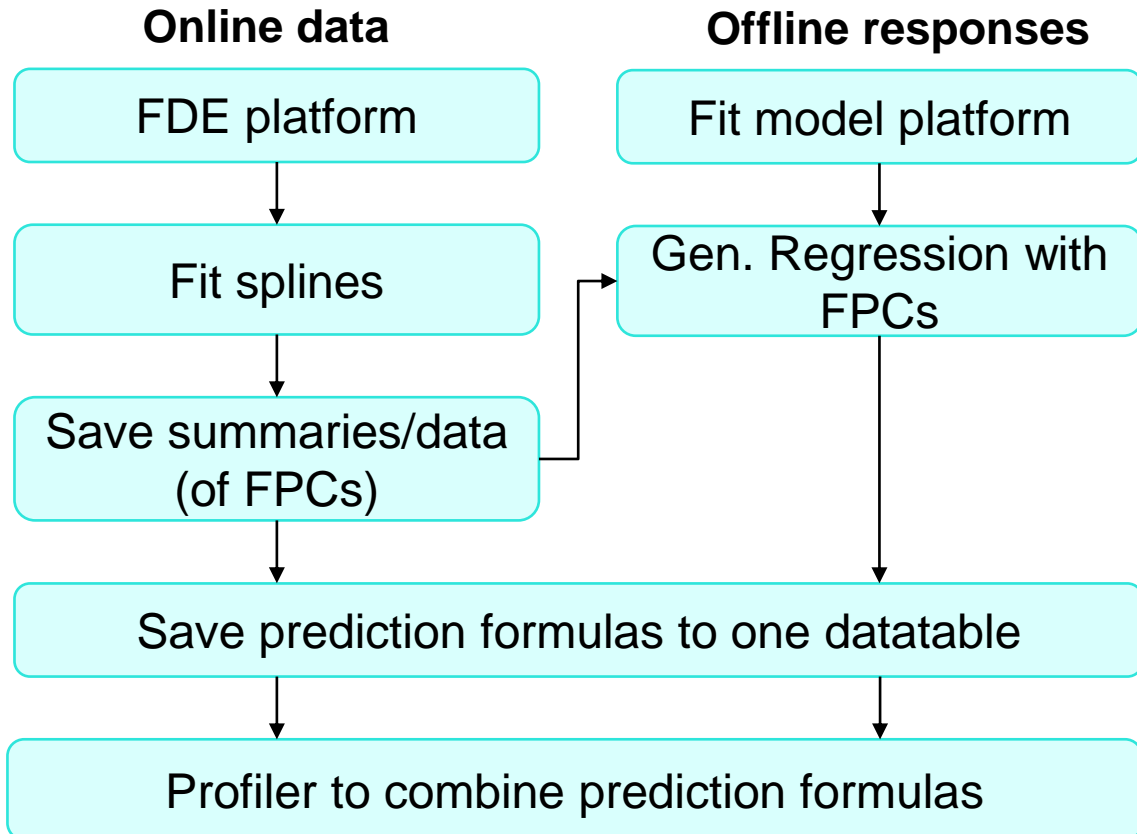




Online data analysis with functional data explorer platform

Goal: Which sensor profiles lead to a good yield?

Analysis: → JMP Live Demo



Summary



Statistical analysis with JMP gives the power to:

- Explore and visualize complex processes easier
- Deeper process understanding which parameters are important and interact
- Speak one language to all levels from technician to manager

