Navigating Allocation Uncertainty: Understanding Correlation and Its Impact

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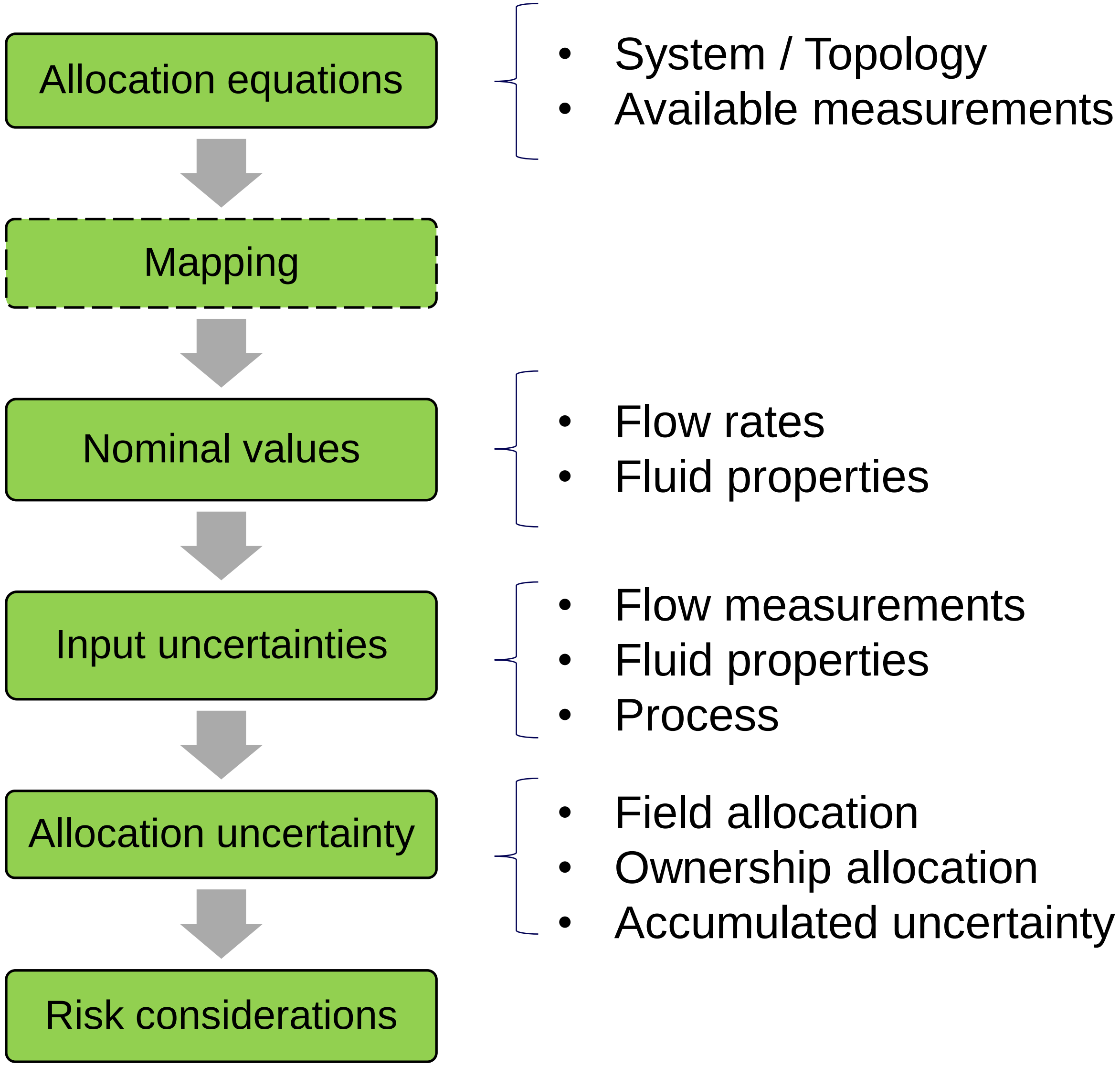
Agenda

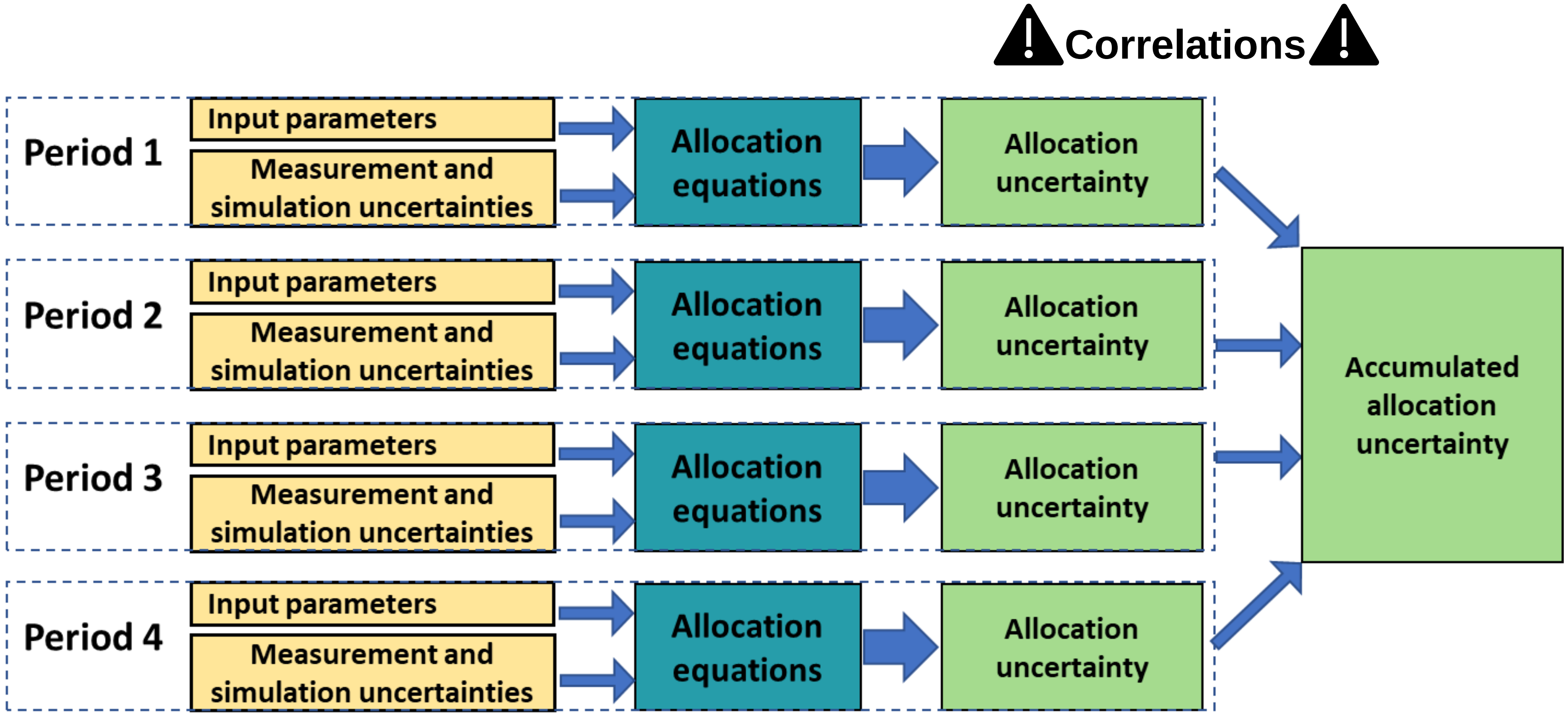
- **Introduction**
  - Continuation of previous work.
- **What & Why**
  - What is correlation and why it is important.
- **How**
  - How to include the correlation and how does it effect the results
- **Conclusions**

Previous work



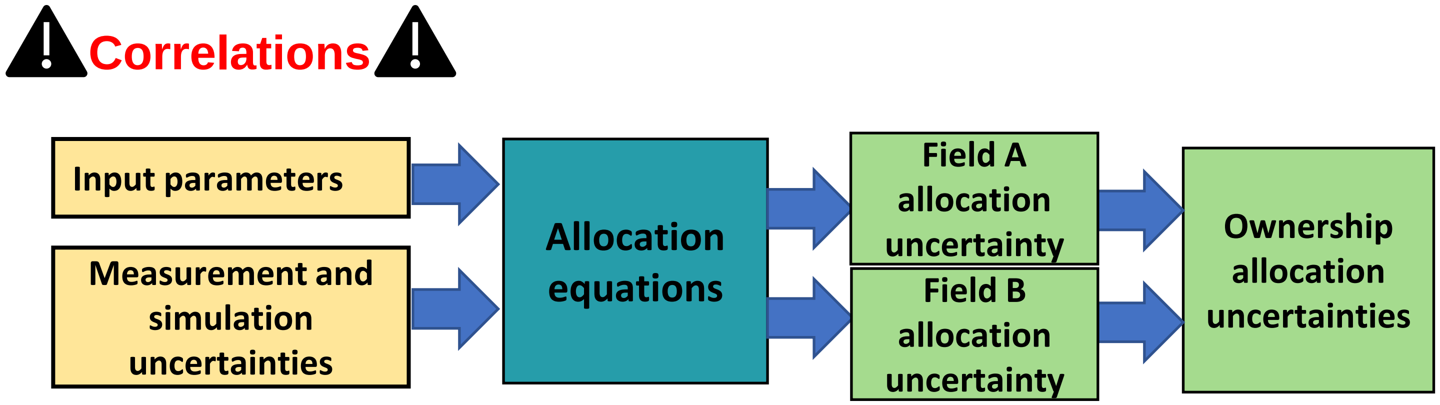
Previous work

Accumulated **correlated** allocation uncertainty over time



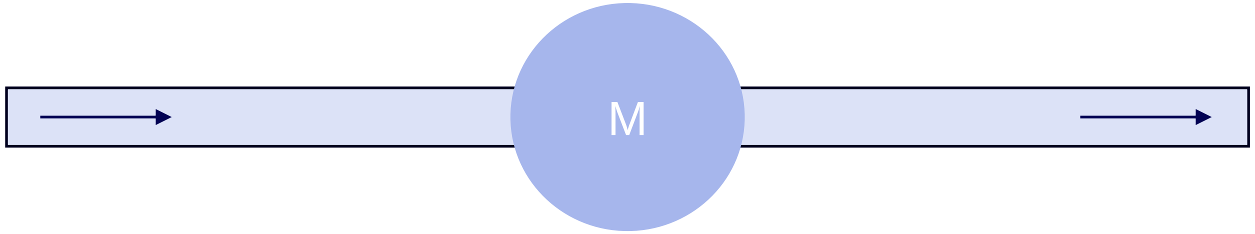
Understanding Correlation and Its Impact

Correlated inputs



What is *correlation*?

Single meter correlation

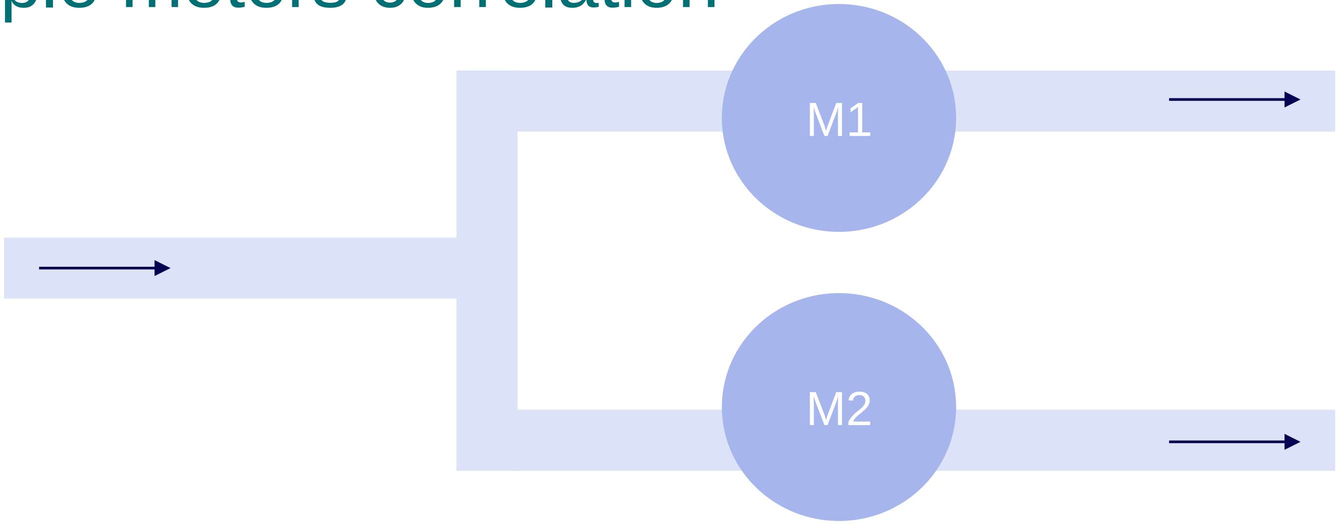


- With one meter, correlation often refers to a constant bias – the measurement is systematically too high or too low across all readings.

- This correlated error is a systematic bias that persists in measurements over time.

What is *correlation*?

Multiple meters correlation



M = M1 + M2

- **Correlation**: Errors in the two meters' measurements are linked, not independent.
  - **Positive Correlation:** Both meters tend to over- or underestimate together, larger error when summed.
  - **Negative Correlation**: (Less common) Errors move in opposite directions; one high, the other low.
  - **No Correlation**: Errors are independent; one meter’s error doesn't predict the other's.

How to deal with correlation in practice?

- **Covariance method (ISO GUM):** Directly estimates how input measurements vary together statistically.

- **Decomposition method** (ISO 5168, Handbook gas USM, in agreement with ISO GUM): Analyses uncertainty sources to identify and quantify common factors causing correlation.

- **Redefinition of measurement function**: Modifies the mathematical model to explicitly account for known dependencies between inputs.

Covariance Method: The Role of 'r'

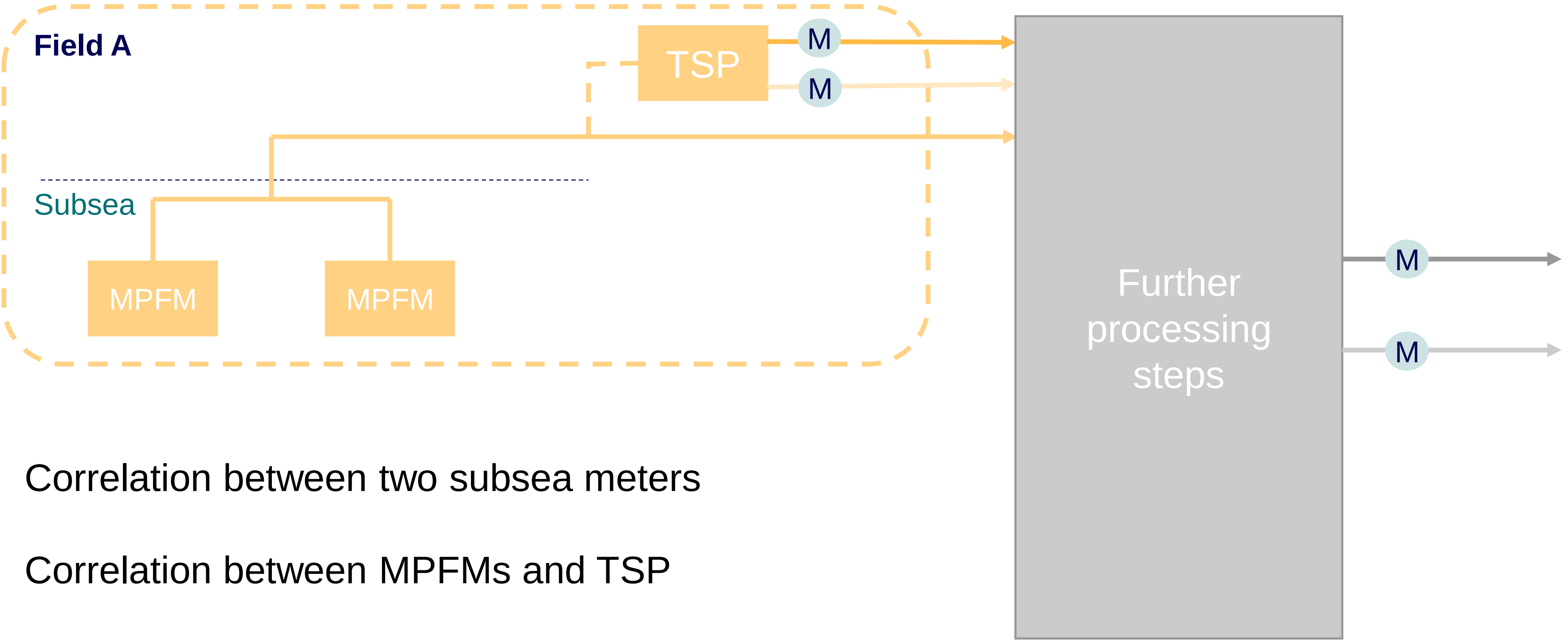
$$u_c^2(f(x_1, \ldots, x_n)) = \sum\left(\frac{\partial f}{\partial x_i}u(x_i)\right)^2 + 2\sum\sum\frac{\partial f}{\partial x_i}\frac{\partial f}{\partial x_j}\boldsymbol{r_{i,j}}u(x_i)u(x_j)$$

The covariance method requires estimating the correlation coefficient ('r') between input measurements.

- **r = -1: Indicates full negative correlation** – errors move in opposite directions proportionally.
- **r = 0: Indicates no correlation** – errors are statistically independent.
- **r = 1: Indicates full positive correlation** – errors move in the same direction proportionally.

Estimating 'r' is crucial for quantifying the combined uncertainty of the allocation system.

Correlated allocation system



- Correlation between two subsea meters
- Correlation between MPFMs and TSP

Correlations

Correlation between meters

MPFMs

- Same manufacturer
- Measuring conditions (T&P, production profiles)
- Common sampling / PVT
- Field effects

MPFMs & TSP

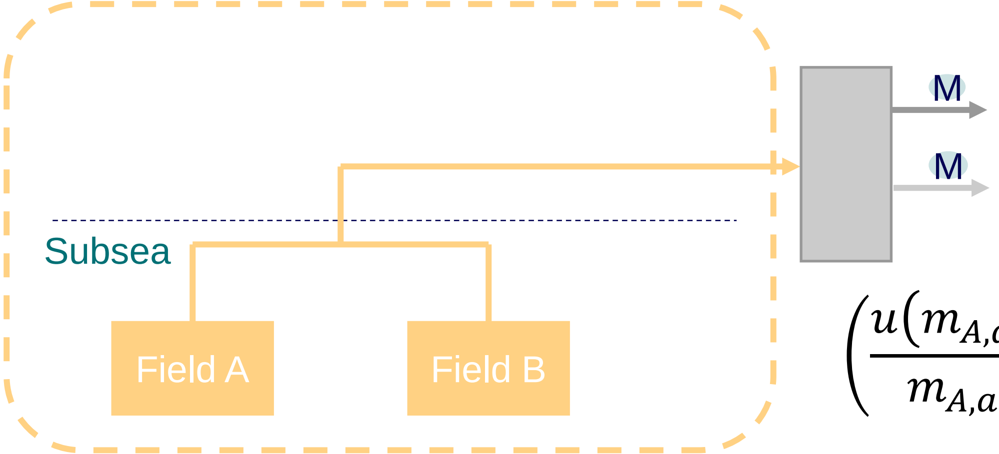
- K-factor calibration
- Stability of flow conditions
- Laboratory analysis
- Density measurements

Correlation over time

- Systematic field effects
- Calibration units
- Sampling over large time intervals
- ORFs simulation

Allocation pro rata

Without correlation



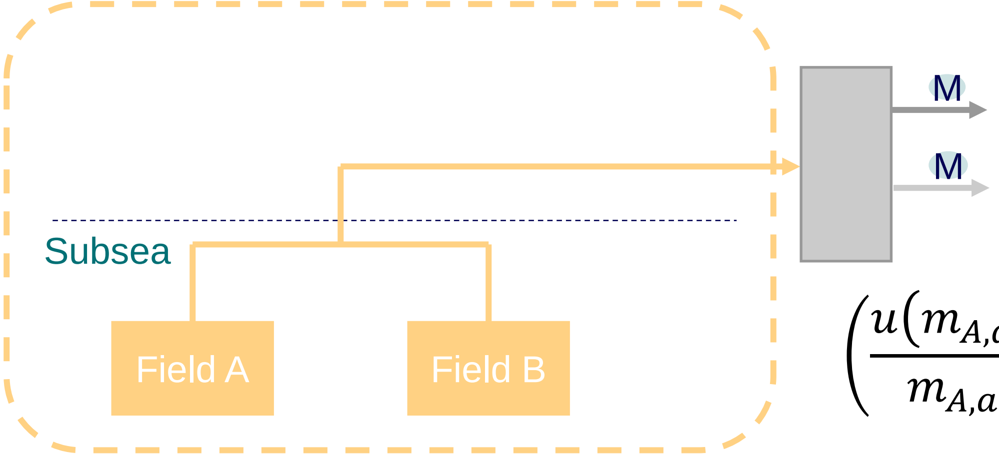
$$m_{A,all} = m_{exp,calc} \cdot \frac{m_{A,calc}}{m_{A,calc} + m_{B,calc}}$$

$$\left(\frac{u(m_{A,all})}{m_{A,all}}\right)^2$$

$$= \left(\frac{u(m_{exp,calc})}{m_{exp,calc}}\right)^2 + \left(\frac{m_{B,calc}}{m_{A,calc} + m_{B,calc}}\right)^2 \left(\left(\frac{u(m_{A,calc})}{m_{A,calc}}\right)^2 + \left(\frac{u(m_{B,calc})}{m_{B,calc}}\right)^2\right)$$

Allocation pro rata

With correlation



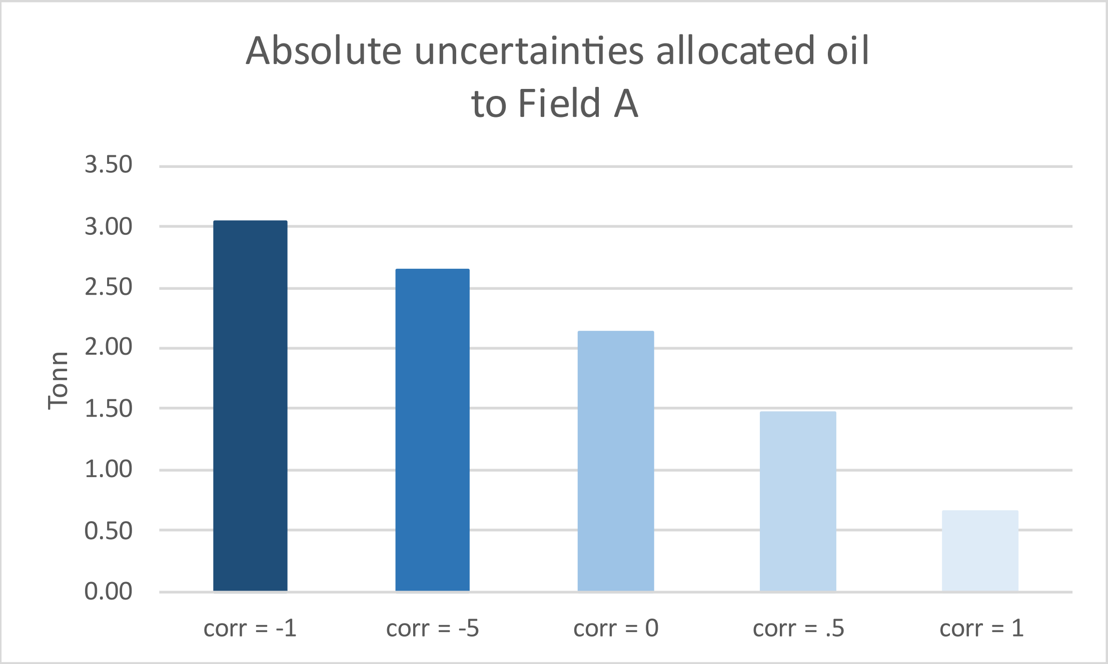
$$m_{A,all} = m_{exp,calc} \cdot \frac{m_{A,calc}}{m_{A,calc} + m_{B,calc}}$$

$$\left(\frac{u(m_{A,all})}{m_{A,all}}\right)^2$$

$$= \left(\frac{u(m_{exp,calc})}{m_{exp,calc}}\right)^2 + \left(\frac{m_{B,calc}}{m_{A,calc} + m_{B,calc}}\right)^2 \left(\left(\frac{u(m_{A,calc})}{m_{A,calc}}\right)^2 + \left(\frac{u(m_{B,calc})}{m_{B,calc}}\right)^2\right)$$

$$-2\, r \left(\frac{m_{B,calc}}{m_{A,calc} + m_{B,calc}}\right)^2 \frac{u(m_{A,calc})}{m_{A,calc}} \frac{u(m_{B,calc})}{m_{B,calc}}$$

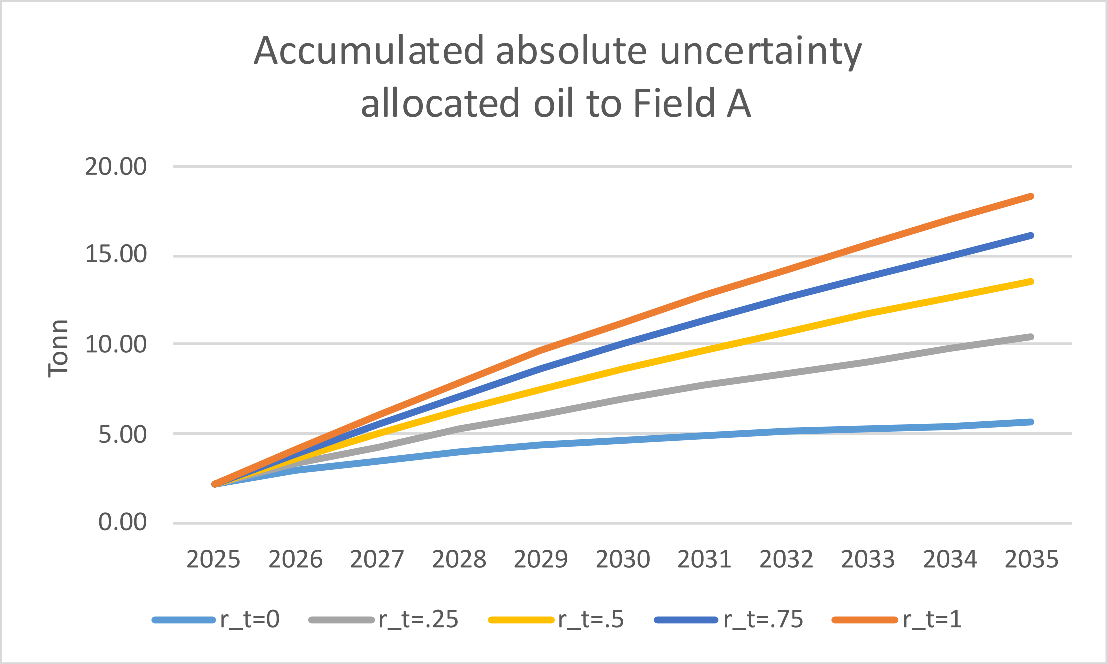
Impact of Fields Correlation on Allocated Uncertainty



Fields Correlation significantly affects Uncertainty:

- **Positive Correlation Minimizes Uncertainty**:
  - Errors move in the same direction, stabilizing the pro-rata allocation ratio.
  - Lower uncertainties for allocated oil/gas.
- **Negative Correlation Maximizes Uncertainty**:
  - Errors move in opposite directions, amplifying variability in the pro-rata allocation ratio.
  - Higher uncertainties for allocated oil/gas.

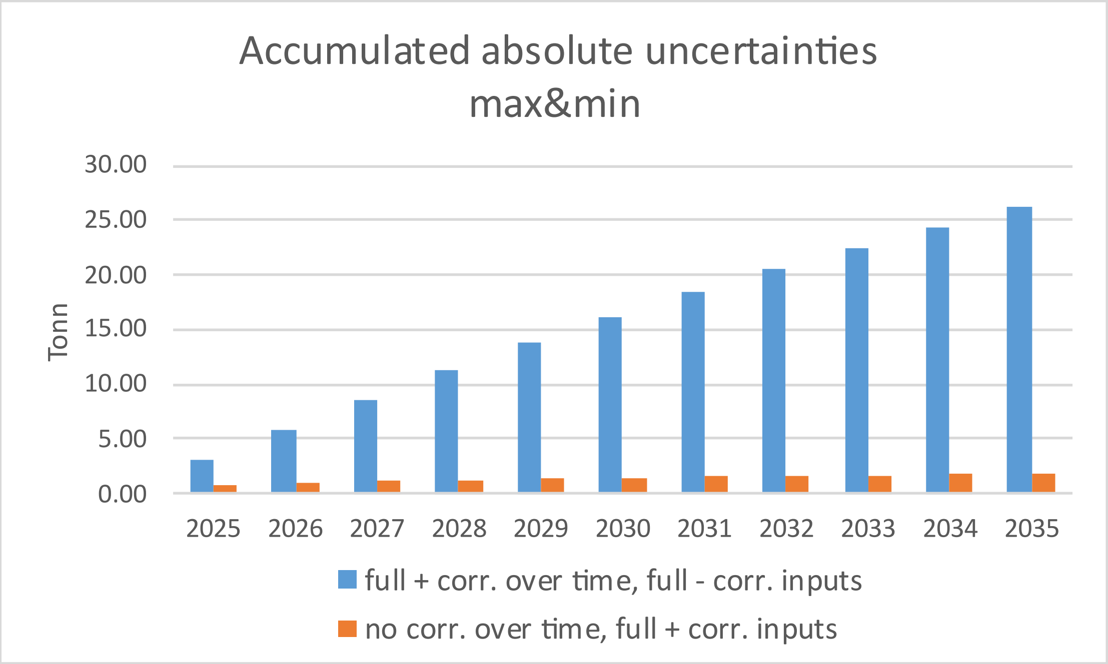
Impact of Time-Series Correlation on Accumulated Uncertainty



- **Correlation Beyond Meters:** How measurement errors behave year-on-year significantly impacts the total long-term uncertainty.
- **Error Persistence Drives Accumulation**:
  - **Positive Time Correlation** $(r_t > 0)$: If systematic errors persist in the same direction, they accumulate ⟹ higher uncertainty.
  - **Zero Time Correlation** $(r_t = 0)$: When errors are random and independent, they tend to average out ⟹ lower uncertainty.

Crucial for Long-Term Risk: Understanding and quantifying time-series correlation is essential for estimating the long-term uncertainty of allocated quantities.

Total Uncertainty Range: Defining the Extremes

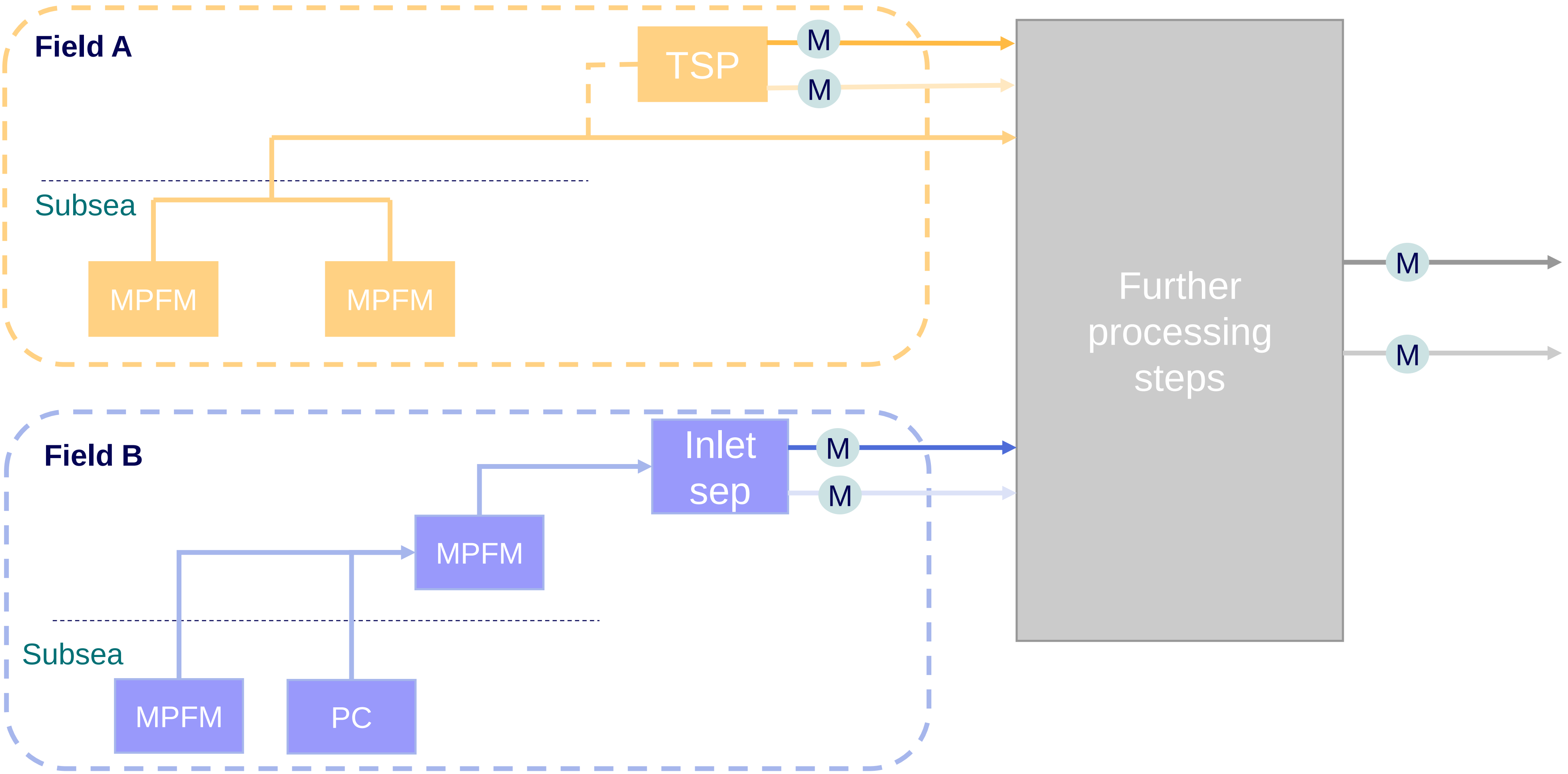


Total accumulated uncertainty determined by **correlation between fields and over time.**

- **Minimum Possible Outcome:**
  - Meters errors are positively correlated ($r_{AB} = 1$, low annual unc.), **AND** errors are random year-to-year ($r_t = 0$, averaging over time).
- **Maximum Possible Outcome:**
  - Meters errors are negatively correlated ($r_{AB} = -1$, high annual unc.), **AND** errors accumulate over time ($r_t = 1$).

Strategic Implication: Understanding these extremes defines the full range of potential long-term allocation uncertainty, guiding risk assessment and mitigation efforts.

Correlated allocation system



Correlation's Impact on Uncertainty: Insights & Actionable Strategies

- **Dual Impact of Correlation:**
  - **Inter-meter correlation** (r_{AB}) directly influences uncertainty (for pro-rata positive correlation reduces uncertainty).
  - **Time-series correlation** (r_t) dictates long-term error accumulation (positive correlation increases total uncertainty).
- **Defining the Uncertainty Envelope**: Analysing limit cases helps us establish the full range of potential long-term uncertainty.

Implications & Next Steps:

- **Risk Management:** Uncertainty ranges to better assess financial risks.
- **Optimization Opportunities:** Explore strategies to optimize meter calibration to minimize allocation uncertainty where possible.

Tools and best practice for allocation uncertainty

Joint Industry Project - Call for partners

NORCE is calling for partners to start a new joint industry project (JIP) aimed at the following:

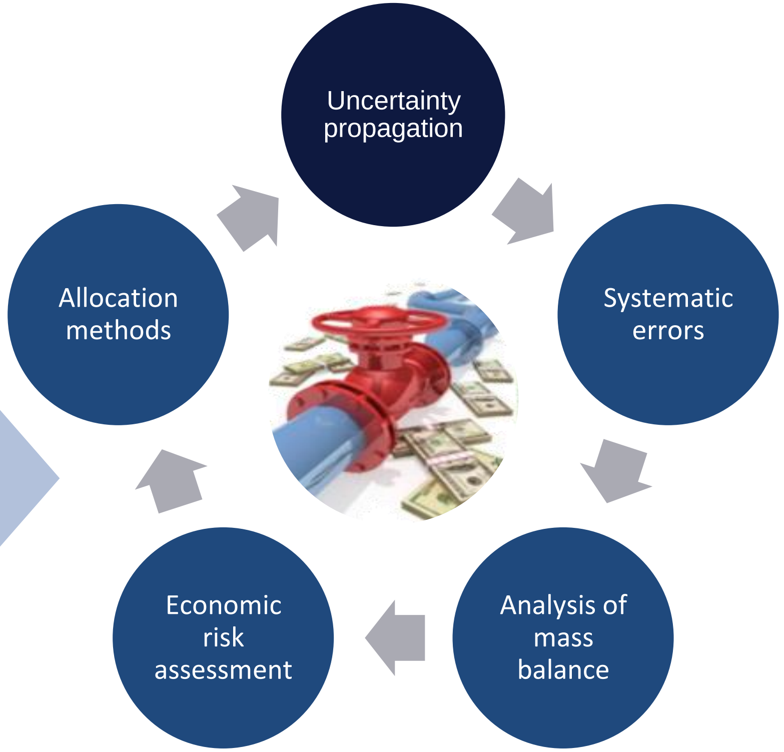
- Develop **Best Practice Guidelines** for Allocation Uncertainty Analysis
- Develop **tools** for use
  - in the design/project phase to estimate allocation uncertainty and economic risk for different allocation concepts (online)
  - in the operational phase to calculate allocation uncertainty, economic risk, and identify (systematic) errors in an automated process, considering current rates, compositions, mass balances, and historical data

Design of allocation systems:
Estimate uncertainties and economical risk for different concepts

Operational phase:
Calculate allocation uncertainty, economic risk and identify errors in an automated process

Guidelines and recommendations

Tools for analysis of allocation systems



Timeline:

Project start-up (tentative): January 2026
Project duration (expected): 3 years

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Thank you. Takk.

Merci. Gracias. Obrigado.

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