

Importance of Characterizing Uncertainties in Multiphase Flow Predictions

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Flow Assurance Technical Section Luncheon Series
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Premise

- Inadequate or non-existent consideration of uncertainties for use in decision making.
 - Disasters
 - Everyday decisions, e.g., equipment sizing & operations
 - Data and models
- We need to do more.

Objectives

- Present arguments on why to consider uncertainties
- Provide a few examples.
- Make a few recommendations
- Promote discussion

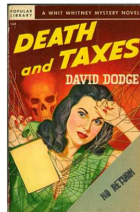
Personal Background

- Retired from Chevron Energy Technology Company
- Multiphase Production Systems -> FA
 - Multiphase Transport & Metering
- Advanced Production Systems
 - Separation Systems

Uncertainty is Good

- *"Nothing is certain except death and taxes"*: Benjamin Franklin
- *"Be confident, not certain"*: Madeleine Albright

- Certainty
 - Discourages discourse
 - Sensitive to unknowns & small flaws
 - Promotes risk bias
- Confidence Under Uncertainty
 - Encourages discourse
 - Allows for unknowns
 - Is robust
 - Provides "defensible" argument
 - Can be inspiring



"Confidence that is valued depends on uncertainty": Gene Kouba

Reasons to Embrace Uncertainty

- Establish & maintain credibility
- Expand scope of capabilities
 - Help formulate better questions & provide better answers
- Take advantage of risk/reward
- Influence better decision making

"Real knowledge is to know the extent of one's ignorance": Confucius

Decision Analysis

Expected Value = $\sum (x \cdot P(x))$

Expected Value for binary outcomes

- $EV = P_{\text{success}} \cdot V_{\text{success}} + P_{\text{failure}} \cdot (-C_{\text{failure}})$
- $P_{\text{success}} + P_{\text{failure}} = 1$
- $P_{\text{success}} = (EV + C) / (V + C)$

Recommendation

- Learn how your clients are making decisions

Issues

- Biases
- Lack of models
- Lack of data

Bias

- Expert bias
 - Thinking Fast & Slow, Daniel Kahnemann
 - The Wisdom of Crowds: James Surowiecki
 - Patrick Hester: "Epistemic Uncertainty Analysis: An Approach Using Expert Judgment and Evidential Credibility", Int J of Quality, Statistics, and Reliability, 2012
 - [https://en.wikipedia.org/wiki/W. Edwards Deming](https://en.wikipedia.org/wiki/W._Edwards_Deming)

Recommendation

- Review potential biases
 - Ambiguity effect
 - Anchoring
 - Automation bias
 - Availability heuristic
 - Belief bias
 - Ben Franklin effect
 - Curse of knowledge
 - Regressive bias



- https://en.wikipedia.org/wiki/List_of_cognitive_biases

- Ambiguity - tendency to avoid options for which missing information makes the probability seem "unknown".
- Anchoring - tendency to rely too heavily, or "anchor", on one (usually the first) trait or piece of information.
- Availability - tendency to overestimate the likelihood of events with greater "availability" in memory.
- Regressive - A certain state of mind wherein high values and high likelihoods are overestimated while low values and low likelihoods are underestimated

Value of Uncertainty Analysis

- Global
- Industrial
- Individual

Value of Uncertainty Analysis Industry Examples

- Articles from *Independent Project Analysis (IPA)*

"E&P Industry's Lost Decade": Neeraj Nandurdikar

"Bad Engineering - Biggest Project Bane": Eoin O'Cinneide

"Wanted: A New Type of Business Leader to Fix E&P Asset Developments": Neeraj Nandurdikar

- Cyclic nature of O & G industry
- Questionable decision making

"Reliability of Expert Judgments and Uncertainty Assessments":
SPE Distinguished Lecture, 2010-2011, Steve Begg

The fundamental problem: *"Industry performance does not live up to expectations, or possibilities"*

- People tend to grossly under-estimate (or ignore) uncertainty
- Better decision-making requires accurate (unbiased & appropriate range) uncertainty assessment
- Naive understanding of economics

"Whether you, your group or company explicitly recognize it or not – technical work is fundamentally about uncertainty assessment for the purpose of making decisions": Steve Begg

Recommendation

- Quantify uncertainty
- Define qualitative terminology
 - IPCC defines "Very high confidence" - $\geq 90\%$

Uncertainty Analysis Techniques

- Graphical techniques
- Evaluation of classical statistical confidence bounds
- Monte Carlo simulation
- Response surface
- Differential sensitivity techniques
 - Taylor series expansion
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Recommendation

- Explore, practice, and evaluate uncertainty analysis techniques

Occam's razor

Non sunt multiplicanda entia sine necessitate
 "Entities are not to be multiplied without necessity"

"other things being equal, simpler explanations are generally better than more complex ones"

"All models are wrong, but some are useful"

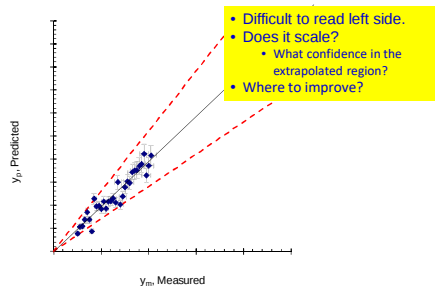
George Box

Models are like guide books. They can be ...

- Incorrect
- Out of date
- Too simple
- Too complicated

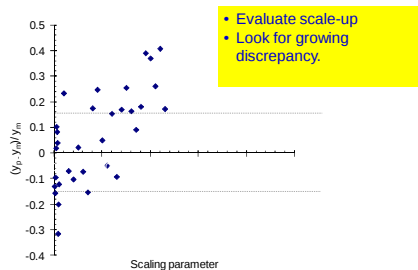
Parity Plot

Characterizing uncertainty

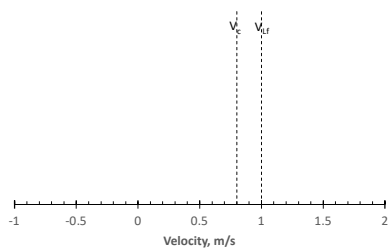


Discrepancy Plot

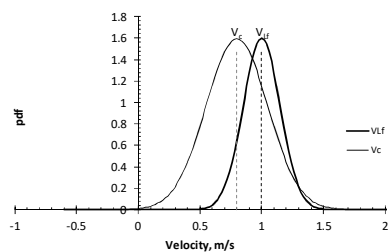
Characterizing uncertainty



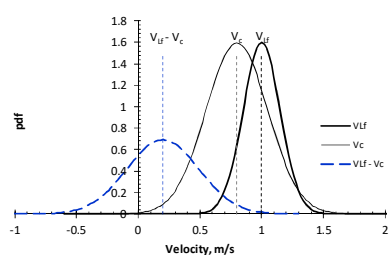
Sand Transport



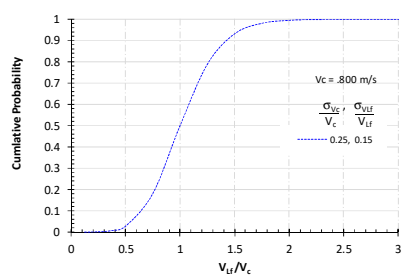
Velocity Distributions



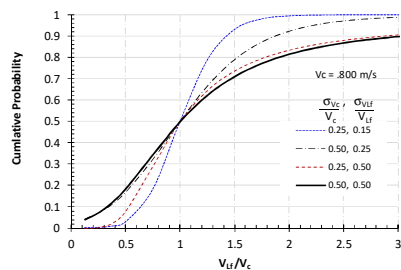
Velocity Distributions



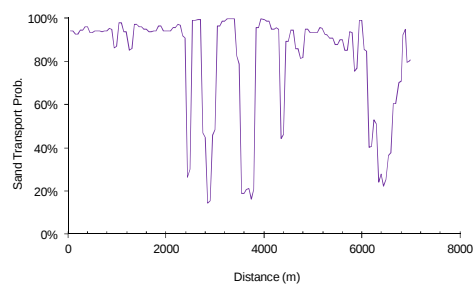
Cumulative probability distribution



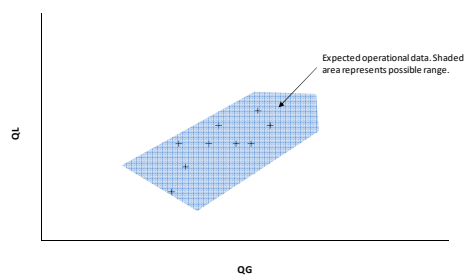
Cumulative probability distribution



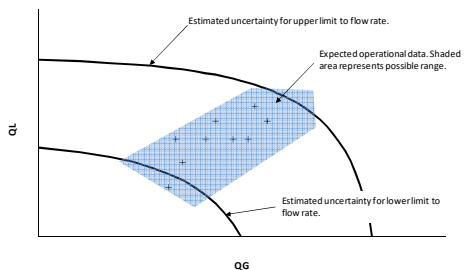
Probability of sand transport



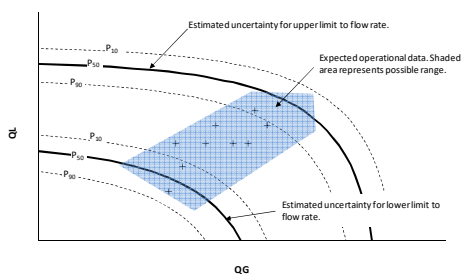
Uncertainties in pipeline operating points and envelope



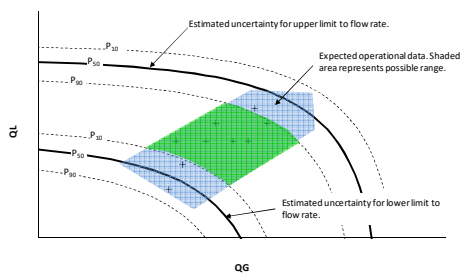
Uncertainties in pipeline operating points and envelope



Uncertainties in pipeline operating points and envelope

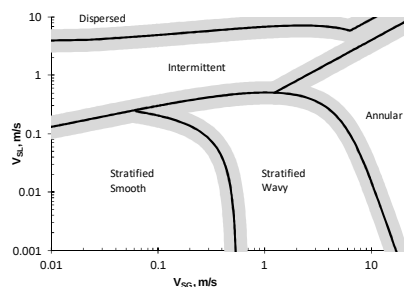


Uncertainties in pipeline operating points and envelope

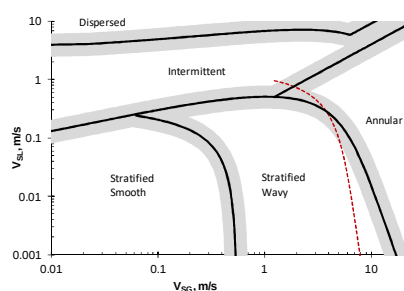


Uncertainty in flow patterns

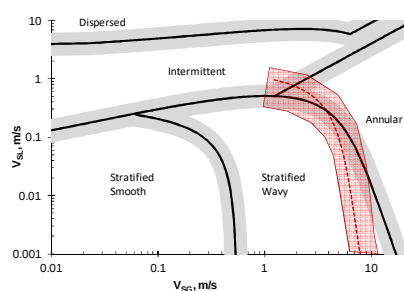
"A Methodology and Database to Quantify the Confidence Level of Methods for Gas-Liquid Two-Phase Flow Pattern Prediction", Pereyra, et al., ChERD, 2011



Uncertainty in flow patterns



Uncertainty in flow patterns



Gaps

- Lack of accurate measurements
- Disregard for measurement errors
- Failure to report uncertainties in simulations & closure relationships
- Flow pattern uncertainty near transitions
 - Dispersions & pseudo-slugs modeling
- Ability to propagate uncertainties from input data, intermediate data, and closure relationships
- Scale up data needed for confidence in extrapolation

Conclusions

Improved decisions in FA require...

- Better estimates of uncertainties
 - requires improved understanding
 - methodologies
 - types & effects of bias
- More appropriate data
 - Focus on characterizing uncertainties
 - Evaluate scale-up
 - Uncertainty analysis can help identify critical data needs

Summary

Value of uncertainty

- Manage risk by establishing level of confidence in predictions & recommendations
 - Decision Support Package
 - Optimize solutions and avoid under design or grossly over designed systems
- Better design of experiments and modeling
 - Extrapolate to new, unfamiliar conditions
- Notion of “defensible” argument.
- Optimize R&D funds
 - Breakthrough in phenomenological models vs implementation of uncertainty analysis.

Recommendations - Immediate

- Understand decision making techniques
- Learn how your clients are making decisions
- Review potential biases
- Explore uncertainty analysis techniques

Recommendations

- Encourage vendors
 - to provide best estimates of uncertainties in ...
 - closure relationships, assumptions, numerical procedures
 - to incorporate propagation of uncertainties from input data & internal models.
- Identify & rank uncertainties
- Develop reasonable expectations
- Encourage & support cooperative research to characterize uncertainties.

Recommendations

Intermediate term

- Develop & publish on use of new & existing methodologies for characterizing & combining multiphase flow uncertainties.
- Identify types of scale-up data
 - Estimate value of data.

Longer Term

- Acquire sufficient data to improve extrapolation.

Thank You

TABLE D.1 Language Adopted by the IPCC to Describe Confidence About Facts or the Likelihood of an Outcome

Terminology for Describing Confidence About Facts	
<i>Very high confidence</i>	At least 9 out of 10 chance of being correct
<i>High confidence</i>	About 8 out of 10 chance
<i>Medium confidence</i>	About 5 out of 10 chance
<i>Low confidence</i>	About 2 out of 10 chance
<i>Very low confidence</i>	Less than 1 out of 10 chance
Terminology for Describing Likelihood of an Outcome	
<i>Virtually certain</i>	More than 99 chances out of 100
<i>Extremely likely</i>	More than 95 chances out of 100
<i>Very likely</i>	More than 90 chances out of 100
<i>Likely</i>	More than 65 chances out of 100
<i>More likely than not</i>	More than 50 chances out of 100
<i>About as likely as not</i>	Between 33 and 66 chances out of 100
<i>Unlikely</i>	Less than 33 chances out of 100
<i>Very unlikely</i>	Less than 10 chances out of 100
<i>Extremely unlikely</i>	Less than 5 chances out of 100
<i>Exceptionally unlikely</i>	Less than 1 chance out of 100
SOURCE: IPCC (2007a).	