

Modelling, Uncertainty, and Data for Engineers

Use your phone to scan the QR  
and answer this survey!

OR

Type the URL into your browser:



# MUDE (CEGM1000 25) Introductory Questionnaire



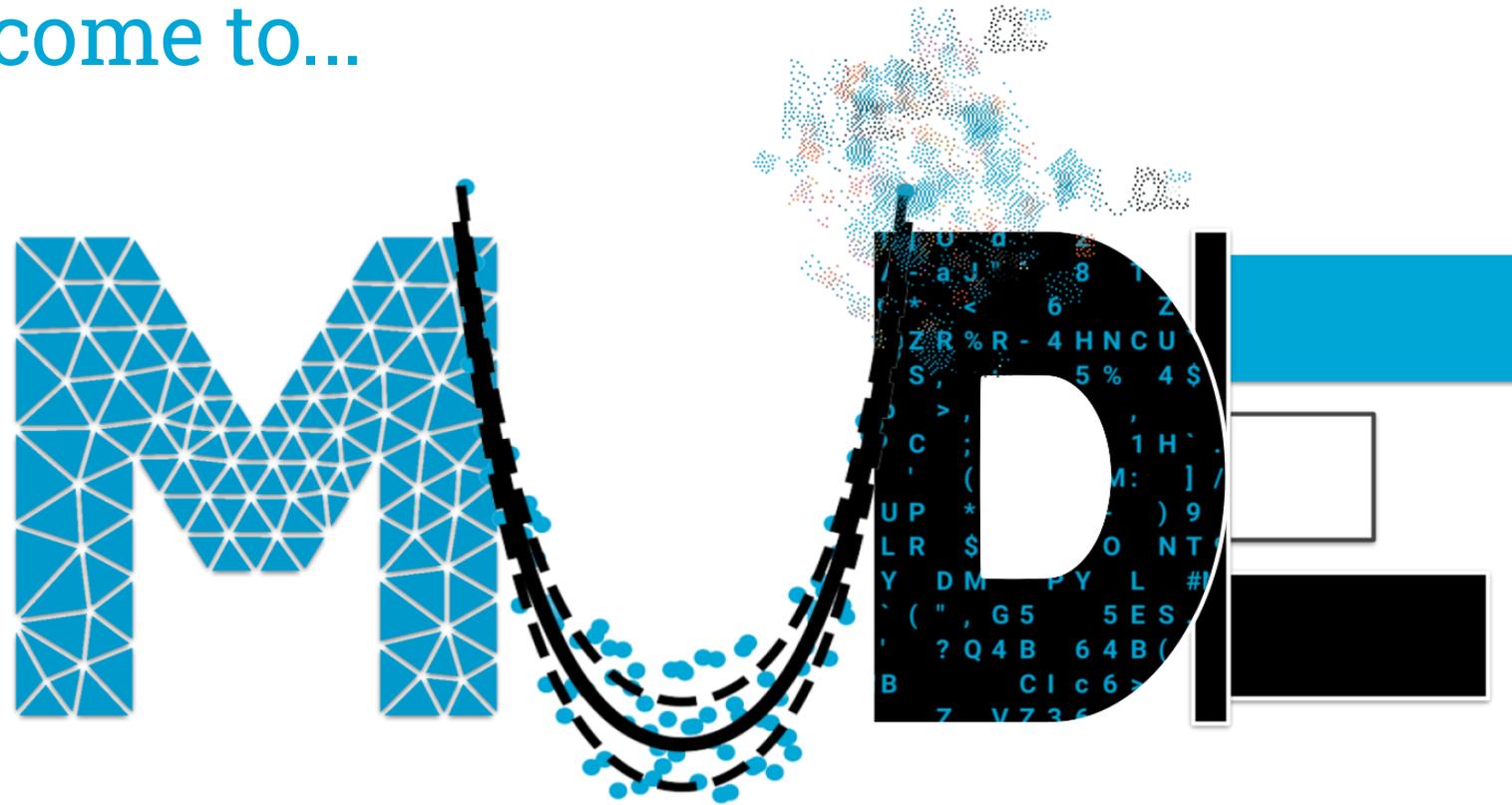
<https://forms.office.com/e/itvaQC3jaR>

Welcome to...

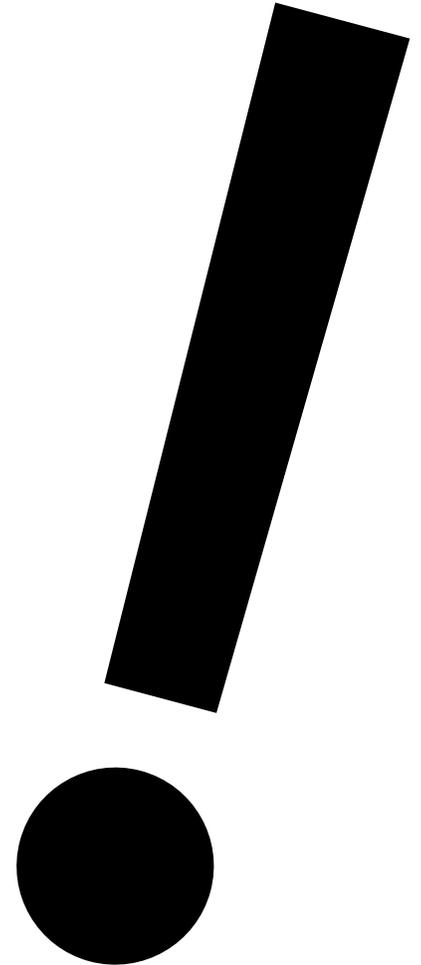


Modelling, Uncertainty, and Data for Engineers

Welcome to...



Modelling, Uncertainty, and Data for Engineers

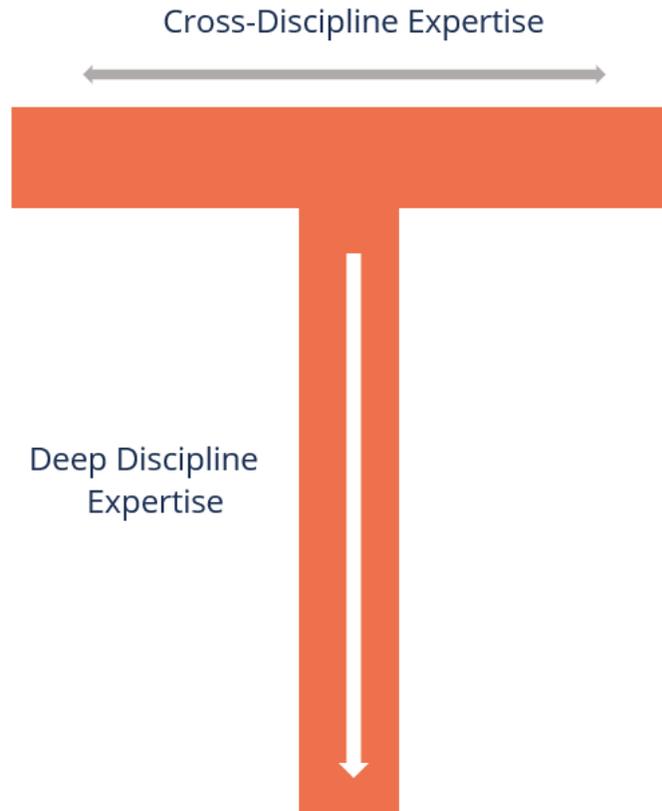


# Nice to meet you!

Go to: [vevox.app](https://vevox.app)

Session ID: 147-912-491

# Modelling, Uncertainty and Data for Engineers (MUDE)



T-Shaped Skills

- Landing zone
- Engineering fundamentals related to **M**, **U**, **D**
- Improve coding literacy
- 12 EC, Q1 + Q2, all programmes  
[ >300 students! ]

# Welcome MSc students 2025-2026

Prof.dr.ir. Stefan Aarninkhof  
Dean of Faculty of Civil Engineering  
and Geosciences (CEG)

Sept. 2, 2025



# Early inspiration (1985)



*Eastern Scheldt storm surge barrier (NL)*

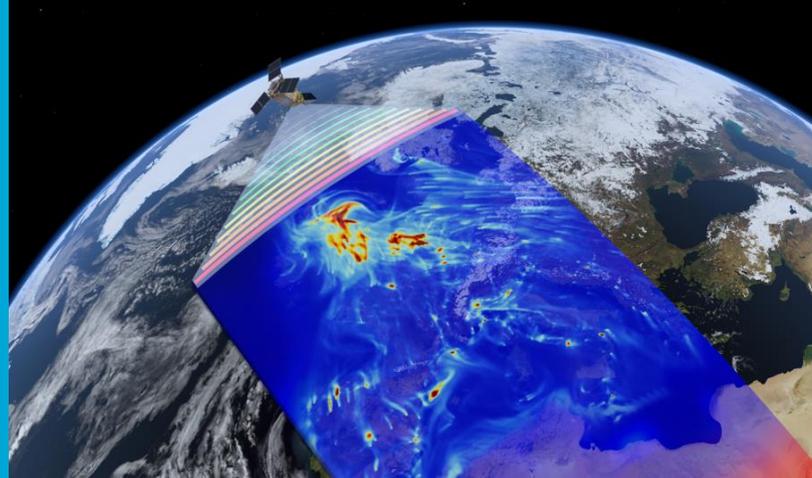
## Professional timeline



Year	Affiliation
1990-1996	Civil Engineering, TU Delft
1995	Ecole des Ponts et Chaussées, Paris
1996-2003	PhD @ TU Delft
1996-2006	Delft Hydraulics (nowadays Deltares)
2006-2016	Boskalis
2016-present	Professor of Coastal Engineering, TU Delft
2020-2024	Chair of Hydraulic Engineering Department
2022-2024	Director of EcoShape   Building with Nature
2024-present	Dean, Faculty of Civil Engineering and Geosciences

# Drivers for CEG

- Climate change
- Energy Transition
- Urbanisation & Mobility
- Clean water
- Resource availability
- Biodiversity
- Infrastructure replacement & restoration



# Our scope

Water Management

Geoscience and Engineering

Transport and Planning

Engineering Structures

Geoscience and Remote Sensing

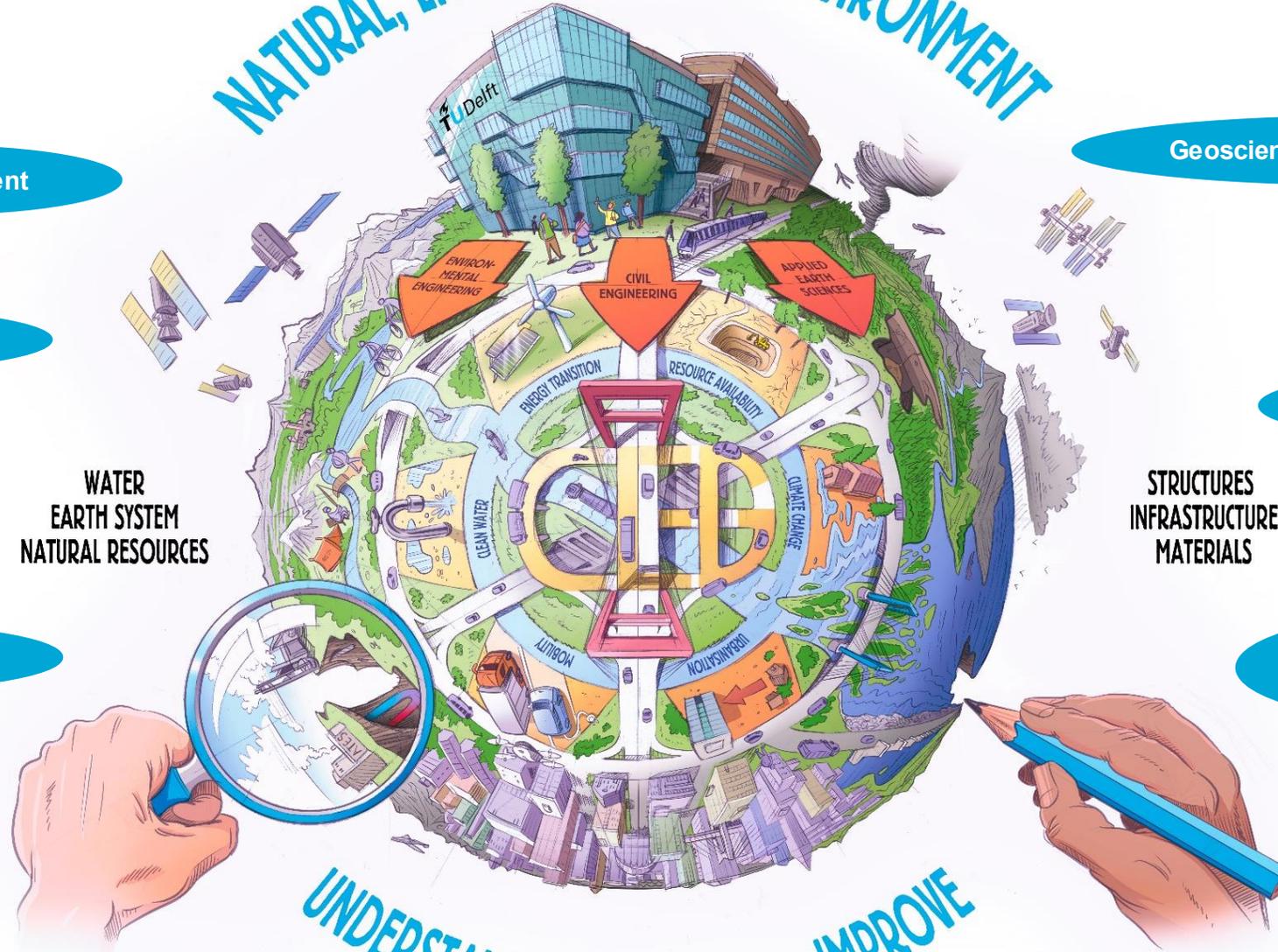
Hydraulic Engineering

STRUCTURES  
INFRASTRUCTURE  
MATERIALS

Materials, Mechanics,  
Management & Design

WATER  
EARTH SYSTEM  
NATURAL RESOURCES

# NATURAL, LIVING AND BUILT ENVIRONMENT



# UNDERSTAND • INTERVENE • IMPROVE

# Importance of fundamental knowledge

*Complex, density-driven currents cause difficulties with placement  
Maasdeltatunnel (Rotterdam)*



GEBROKEN KABEL

## Herstel mislukte afzinkoperatie Maasdeltatunnel 'gaat maanden duren'

Gepubliceerd op 13-06-2023 om 17:05

De voorbereiding van het afzinken van het eerste tunneldeel in maart. © ANP / Hollandse Hoogte / MediaTV

Het beschadigde deel van de Maasdeltatunnel gaat eind juni naar een reparatiedok in de Botlek in Rotterdam. Dat maakt Rijkswaterstaat in een online update bekend. De beheerder verwacht dat het tunneldeel na aankomst "ongeveer drie maanden" op het dok ligt.

Het tunneldeel botste in april tegen een kade tijdens een [mislukte afzinkoperatie](#) op het Scheur tussen Rozenburg en Maassluis. Daar moet de tunnel uiteindelijk onder water komen te liggen.

Maasdeltatunnel, Nieuwe Waterweg (2023)

# CEG in a changing world

- Focus on UN Sustainable Development Goals (SDGs)
- Increased stakeholder engagement
- New technologies
- Moral dilemma: balancing different interests
- Engineering vs societal reality
- Inherent uncertainties
- Leave room for the unknown



# Importance of MUDE

- Generic basis in modelling, uncertainty and data analysis
  - Relevant for all three programs: CE, AES and EE
  - Specialization at later moment
- Educate for entire career, not for first job



# Take home message

- Be prepared to enter a challenging field
  - High-profile projects, major impact to society
  - Strong knowledge basis, work in multi-disciplinary teams
- Benefit from interaction
- Take time to explore what is driving you



# What is MUDE?

- What do current professionals need?
  - Programming literacy
  - Modelling concepts
  - Data structures and analysis
  - Uncertainty/risk comprehension
- Multidisciplinary group work helps to facilitate this

# What is MUDE?

- NOT about applications from your specialization
  - Get grounded in fundamentals applicable across the fields
- NOT a math course as you know them from your BSc
  - Taught by CEG staff, connected to CEG applications
- NOT crash course in Python
  - Some prior experience is expected, means to catch up are there
- NOT going to make you a "pro" coder
  - Get comfortable with coding, see a host of cool implementations

# MUDE: in a nutshell

## Theory & Applications (~60%)

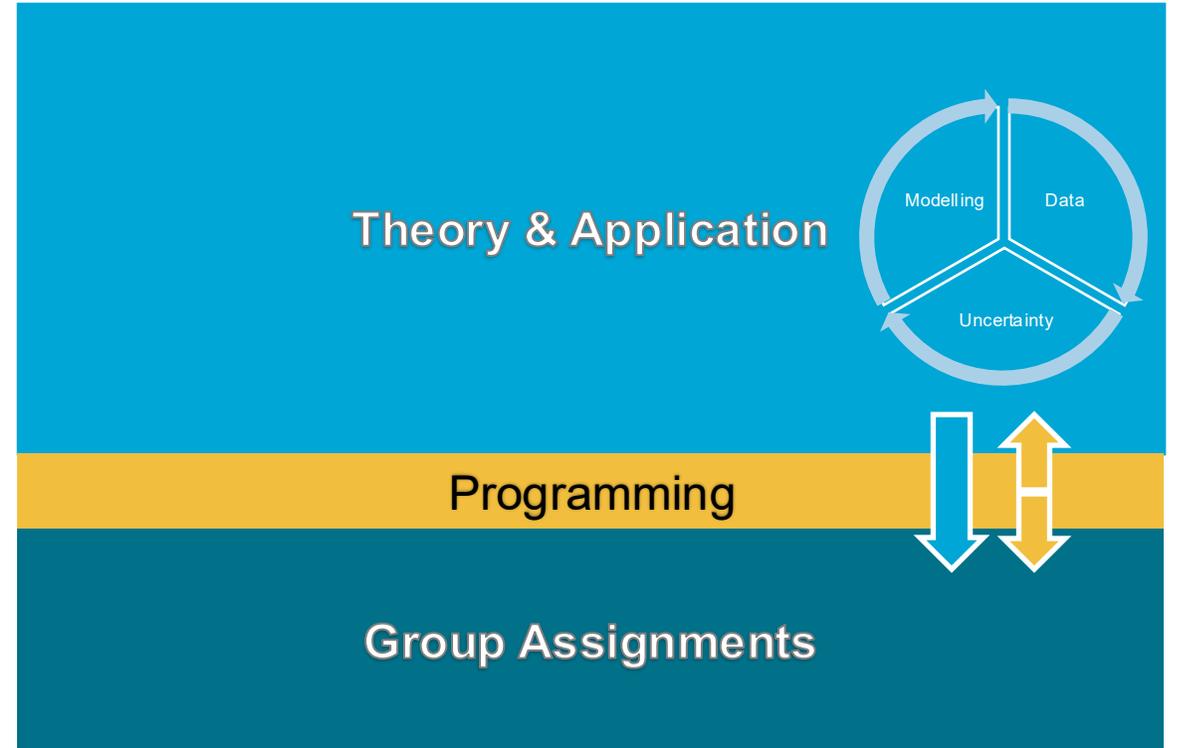
- Website and online book
- Applications drawn from all programmes

## Group Assignments (~30%)

- Apply theory and programming to real problems
- Submit a weekly Report
- Collaborative and multidisciplinary

## Programming (~10%)

- Coding and software engineering skills
- Effective documentation and communication
- Weekly Programming Assignments



# Who are your MUDE teachers?

- Over 50 people involved!
  - Many familiar faces → you will meet them in class
- Your MUDE Guides

- J-ee-ah (Jug, See, Art)
- Lei (Lay an egg)

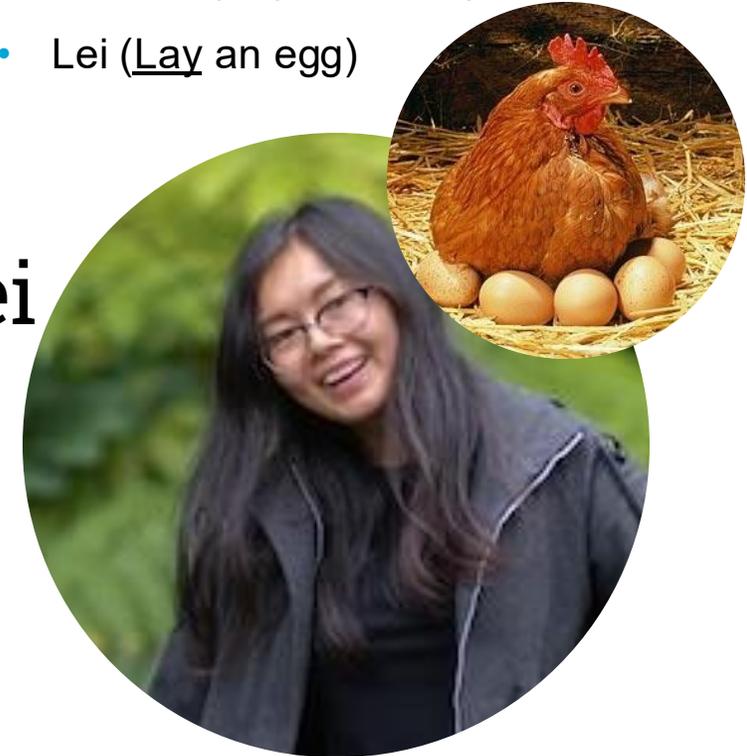
Frans



Tom



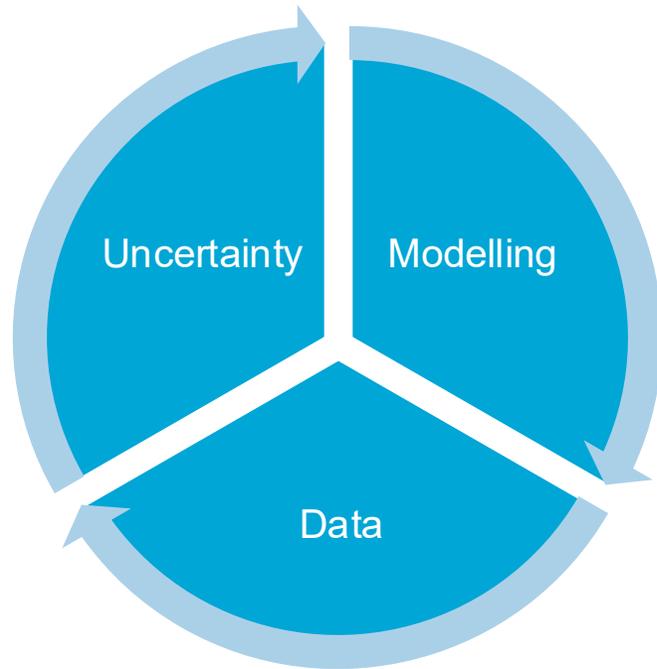
Jialei



→ The best people to ask about logistics, personal issues, etc (MUDE-CEG@tudelft.nl)

→ At least one of us will always be present in every class session

# Theory & Application Weekly Content



1.1	Landing zone – Introduction to Modelling
1.2	Numerical modelling
1.3	
1.4	Univariate distributions
1.5	Multivariate distributions
1.6	Uncertainty propagation
1.7	Observation Theory
1.8	
2.1	Partial Differential Equations, Finite Difference Modelling and Finite Volume Modelling
2.2	Finite Element Modelling
2.3	Signal Processing
2.4	Time-Series Analysis
2.5	Optimization
2.6	Machine Learning
2.7	Extreme Value Analysis
2.8	Risk & Reliability

	Monday	Tuesday	Wednesday	Thursday	Friday
8:45					<p>Group Assignment* 08:45-12:30</p> <p>Multiple rooms</p>
10:45	<p>Lecture 10:45-12:30</p>		<p>Workshop 10:45-12:30</p> <p>Multiple rooms</p>		
12:45					
					*compulsory

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8:45					<div style="background-color: #c00000; color: white; padding: 10px; border: 2px solid black; border-radius: 10px;"> <p style="text-align: center;">Group Assignment* 08:45-12:30</p> <p style="text-align: center;">Multiple rooms</p> </div> <div style="background-color: #c00000; color: white; padding: 5px; border: 2px solid black; border-radius: 10px; margin-top: 5px;"> <p style="text-align: center;">Report due at end</p> </div>
10:45	<div style="background-color: #006666; color: white; padding: 10px; border: 2px solid black; border-radius: 15px; text-align: center;"> <p>Lecture 10:45-12:30</p> </div>	<div style="background-color: #fff9c4; padding: 10px; border: 2px solid black; border-radius: 15px; text-align: center;"> <p>Question Hour/Tutorial (programming) 10:45-11:45 (theory) 11:45-12:30</p> </div>	<div style="background-color: #006666; color: white; padding: 10px; border: 2px solid black; border-radius: 15px; text-align: center;"> <p>Workshop 10:45-12:30</p> <p>Multiple rooms</p> </div>		
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12:45				<div style="background-color: #fff9c4; padding: 10px; border-radius: 10px; text-align: center;">           Question Hour 12:45-13:45         </div>	<div style="background-color: #e67e22; color: white; padding: 10px; border-radius: 10px; text-align: center;">           Programming assignment out           <span style="color: #e67e22; font-size: 2em;">➔</span> </div>
	<div style="border-top: 1px dashed #e67e22; margin-top: 10px;"></div> *compulsory				<div style="background-color: #e67e22; color: white; padding: 10px; border-radius: 10px; text-align: center;">           Programming assignment due           <span style="color: #e67e22; font-size: 2em;">➔</span> </div>

# Buddycheck

- You are in the same group for a quarter
- Weekly survey on how groupwork is going
- Buddycheck will not be seen by your groupmates
- Important to inform us as early as possible so we can help if there are any concerns or issues
- Opens on Friday, due on Monday
- **PART OF YOUR PORTFOLIO**

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	*compulsory				

# Programming Learning Line

- Provides essential programming skills, based in Python
- Content based on inputs from industry (e.g., Deltares, HKV, RHDHV, RWS, ...)
- Some examples of what you will learn:
  - Coding standards and good practices
  - Effective documentation, communication, visualization
  - Debugging, Version control
  - And more!



# Programming Learning Line

Weekly programming assignments:

- New programming topics
- Preparations for workshop and group assignment
- Fundamental programming concepts

Struggling with fundamental programming concepts → self-study required! Join programming tutorials on Tuesday in Q1 week 2 – 5

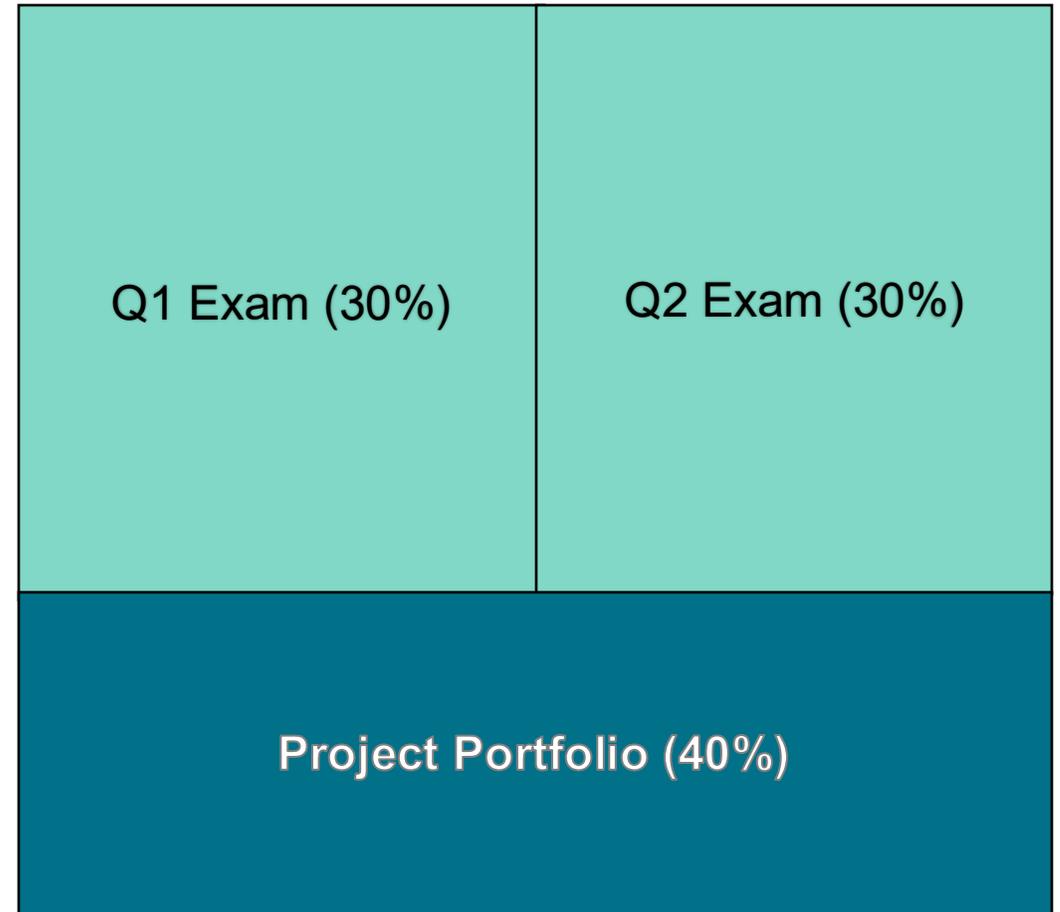
```
mirror_mod = modifier_ob.  
Set mirror object to mirror  
mirror_mod.mirror_object  
operation == "MIRROR_X":  
mirror_mod.use_x = True  
mirror_mod.use_y = False  
mirror_mod.use_z = False  
operation == "MIRROR_Y":  
mirror_mod.use_x = False  
mirror_mod.use_y = True  
mirror_mod.use_z = False  
operation == "MIRROR_Z":  
mirror_mod.use_x = False  
mirror_mod.use_y = False  
mirror_mod.use_z = True  
selection at the end -add  
mirror_ob.select= 1  
modifier_ob.select=1  
context.scene.objects.active  
("Selected" + str(modifier_ob.name))  
mirror_ob.select = 0  
= bpy.context.selected_object  
data.objects[one.name].select  
print("please select exactly  
OPERATOR CLASSES -----  
types.Operator):  
X mirror to the selected  
object.mirror_mirror_x"  
mirror_x"  
context):  
context.active_object is not None
```

# Practicalities: Personal Computer

- You should have one! (Mac, Windows, Linux are all OK)
- Bring it with you
- Keep it closed during Monday lectures
- Wednesday workshops may include Jupyter exercises
- Friday will **definitely** require a computer
- **Is this an issue? Contact [MUDE-CEG@tudelft.nl](mailto:MUDE-CEG@tudelft.nl) immediately.**

# Practicalities: Assessment

- 60%: 2 written exams (Q1 + Q2)
- 40%: Project Portfolio
  - 70%: Group Work (weekly)
  - 15%: Programming Assignments (weekly)
  - 15%: Buddycheck (weekly)
- See MyTimetable for up-to-date exam info

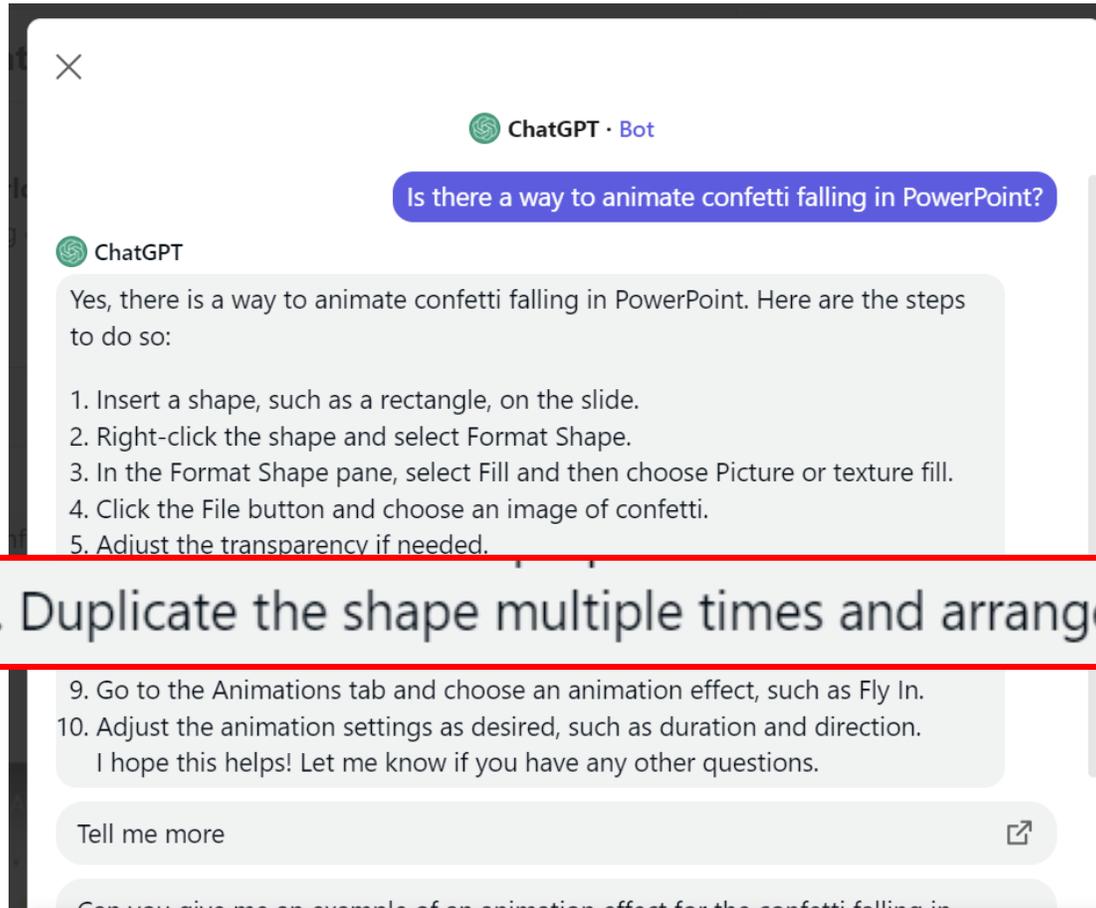


# Special Requests

- Does anyone want to work in a group in a separate room?
- i.e., Quiet place
- Email [MUDE-CEG@tudelft.nl](mailto:MUDE-CEG@tudelft.nl)
- We will prioritise students with special sensory or learning needs!

September, 2023

# Using ChatGPT in MUDE?



- Is it feasible?
  - Yeah
- Is it practical?
  - No way!

# Is it getting better?

September, 2024



- More detailed?
  - Yeah
- Is it feasible still?
  - Yeah
- Is it practical now?
  - Definitely not!!!

is there a way to animate falling confetti in powerpoint?

September, 2025

Yes, you can animate falling confetti in PowerPoint using built-in animation tools. While PowerPoint doesn't have a default "confetti" animation, you can create the effect manually or use pre-made elements. Here are a few ways to do it:

### Option 1: Use Pre-Made Confetti GIF or Video

#### Easiest method

1. **Find a confetti animation** (GIF or video with transparent background):
  - Search for "confetti transparent GIF" or "confetti green screen video."
  - Ensure it's a looping animation if needed.
2. **Insert into PowerPoint:**
  - Go to **Insert > Pictures** (for GIFs) or **Insert > Video**.
  - Resize and position it at the top of the slide.
3. **Set to autoplay:**
  - Select the video/GIF.
  - Go to **Animations > Animation Pane > Start With Previous**.
4. (Optional) **Remove green background** using the **Remove Background** tool or video editing beforehand.

- This year, it finally tells us to get an external image!

**September, 2025**

## Option 2: Create Confetti Effect with Shapes and Animation

More customizable but time-consuming

### 1. Draw confetti pieces:

- Insert small shapes (circles, stars, rectangles) in different colors.
- Use **Insert > Shapes**.

### 2. Animate them:

- Select each shape.
- Go to **Animations > Add Animation > Motion Paths > Down**.
- Adjust the **duration** to make the fall slower (e.g., 2–5 seconds).
- Use **Timing > Start: With Previous** or **After Previous**.
- Add **Spin** or **Grow/Shrink** animations for more realism.

### 3. Duplicate and randomize:

- Copy multiple shapes.
- Vary the motion path direction, duration, and start time slightly to make it look natural.

## Option 3: Use PowerPoint Add-ins or Templates

There are some animated PowerPoint templates or add-ins (like **PresenterMedia** or **Envato Elements**) that offer pre-animated confetti effects.

- But it's still suggesting the old way in option 2!
- You can use ChatGPT, but
  - **Be careful with the results**
  - **Get assisted, not replaced**
  - **Let us know when you use it**

# Practicalities

All material is accessible through the website:

[mude.citg.tudelft.nl](https://mude.citg.tudelft.nl)

**Brightspace:** Course information, announcements and updates. Join CEGM1000-25!

**Online textbook:** [mude.citg.tudelft.nl/book](https://mude.citg.tudelft.nl/book)

**Questions and answers:** [answers.citg.tudelft.nl](https://answers.citg.tudelft.nl)

**MUDE email:** [MUDE-CEG@tudelft.nl](mailto:MUDE-CEG@tudelft.nl) (personal issues only)

## 10 min break...

If you haven't already,  
use your phone to scan the QR  
and answer this survey!

OR

Type the URL into your browser.

MUDE (CEGM1000 25)

Introductory Questionnaire



<https://forms.office.com/e/itvaQC3jaR>

# Introduction to modelling

- **What's a model?**
- In short: a model is a purpose-built abstraction of physical reality
- **Let's see it in more detail.**



# What is a model?

**A model is a purpose-built abstraction of physical reality**

- We interact with complex systems in reality
- How will the river respond to the discharge?
  - Temperature? → Heat transfer
  - Erosion in the margin? → Hydrodynamics and sediment transport
  - Contaminants? → Water quality
- Then we make an abstraction to analyze the aspects we are interested in

9/2/2025



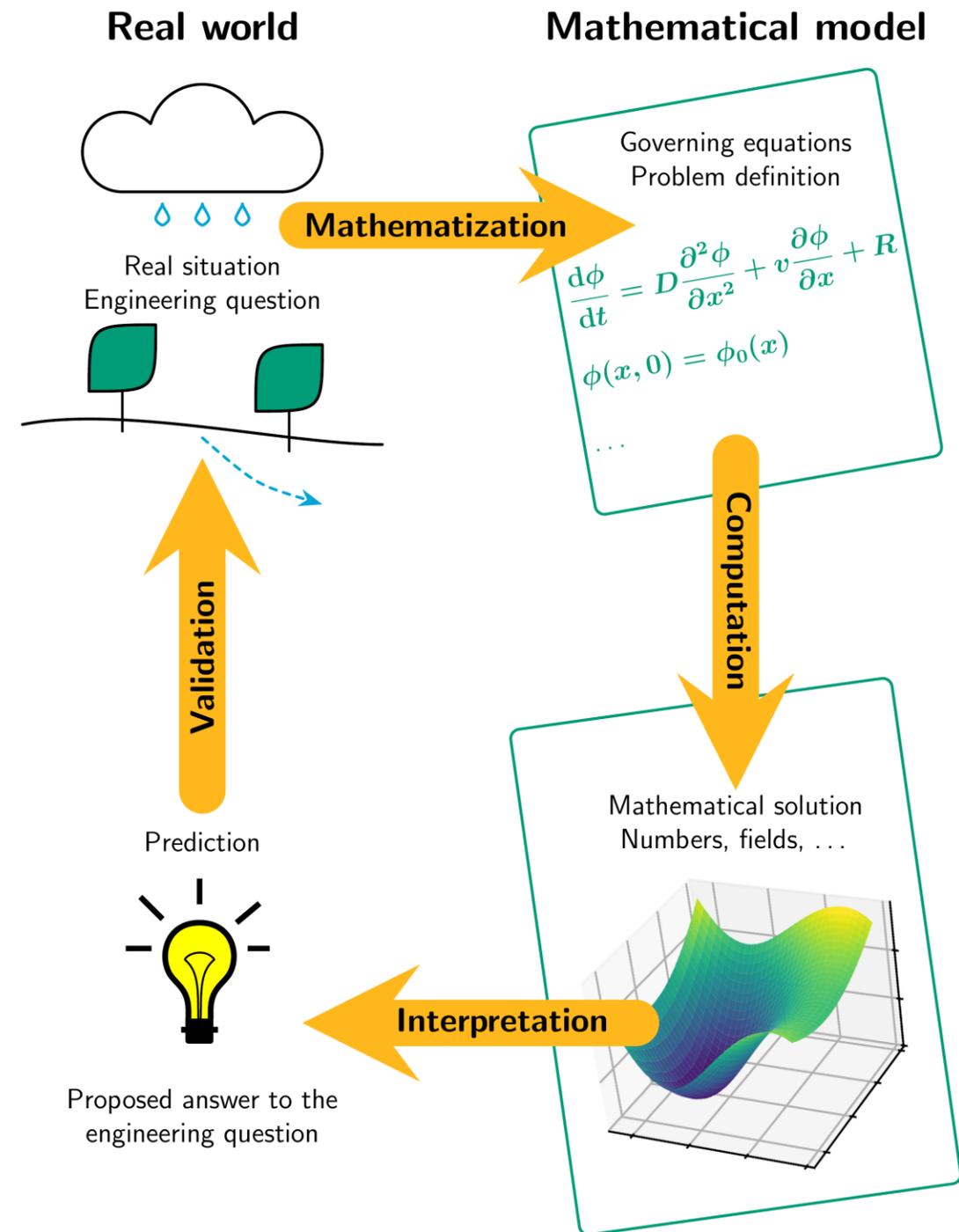
"Anglo American's Drayton mine - mine water discharge" by lockthegate is licensed under CC BY 2.0.

# The modeling workflow

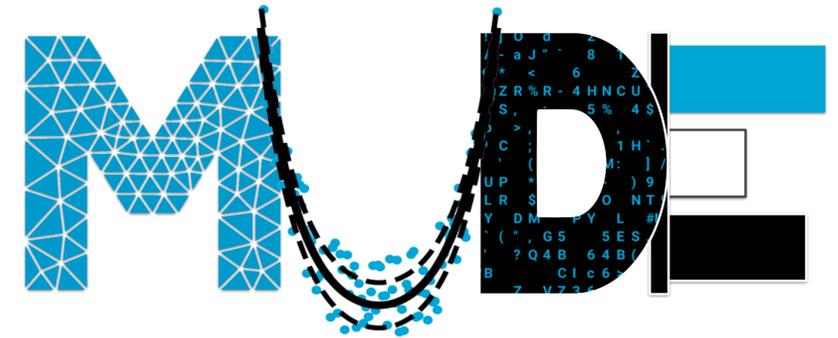
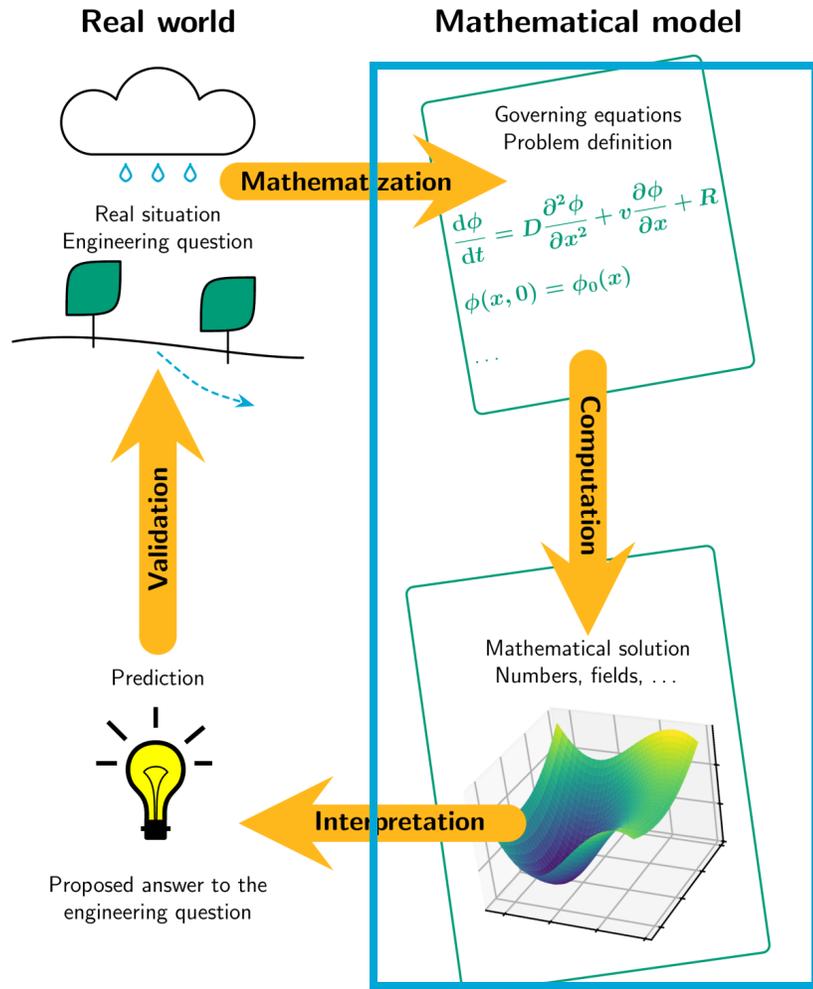
- Mathematization: from real world to equations
- Computation: finding the solution to the equations
- Interpretation: connecting back to real world
- Validation: comparing model results to real observations

Additional (iterative) steps:

- Verification: check computation results
- Calibration: tweak model parameters



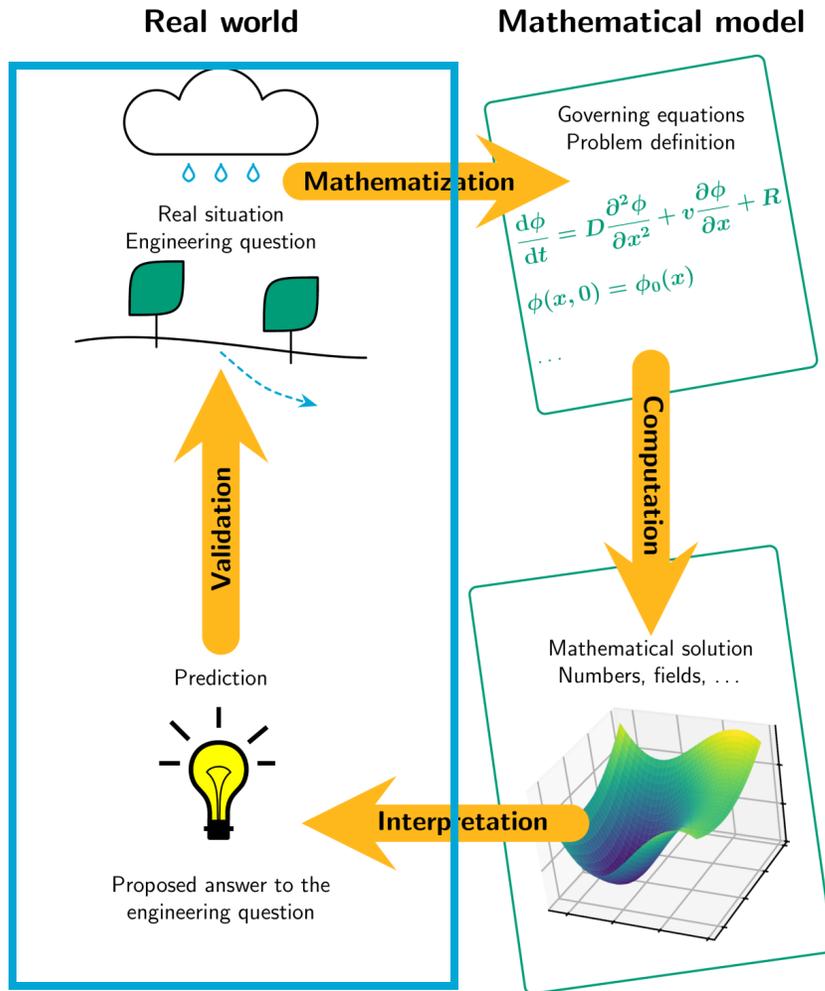
# Modelling in MUDE



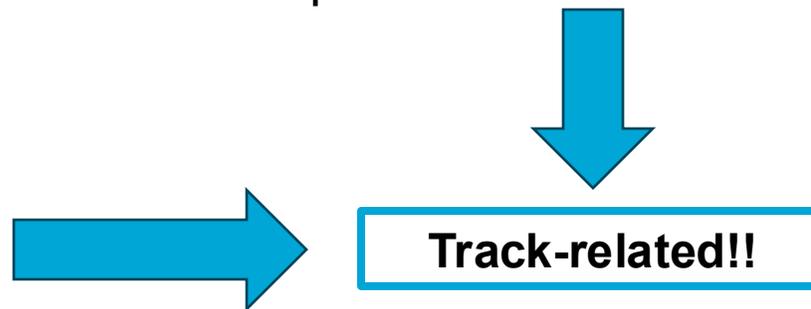
Modelling, Uncertainty, and Data for Engineers

# What is a model?

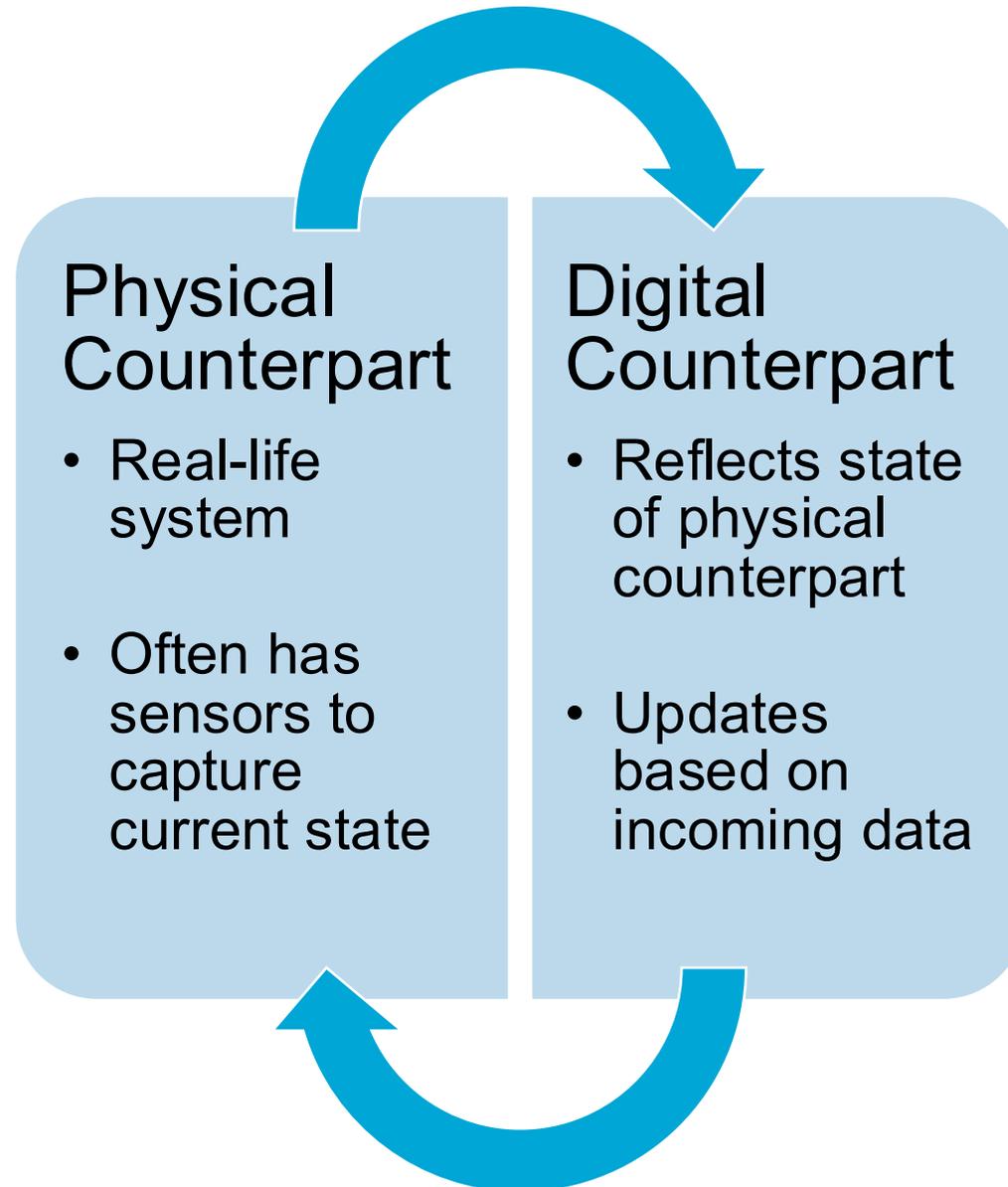
A model is a purpose-built abstraction of physical reality



- Once we have the model:
- Computations: use it!
- Interpret the results to get the answer to your question



# A note on Digital Twins



# Classifying Models

- Conceptual models
- Mechanistic models
- Phenomenological models
- Data-driven models



# Classifying Models

- **Conceptual models**
- Mechanistic models
- Phenomenological models
- Data-driven models

## Concept:

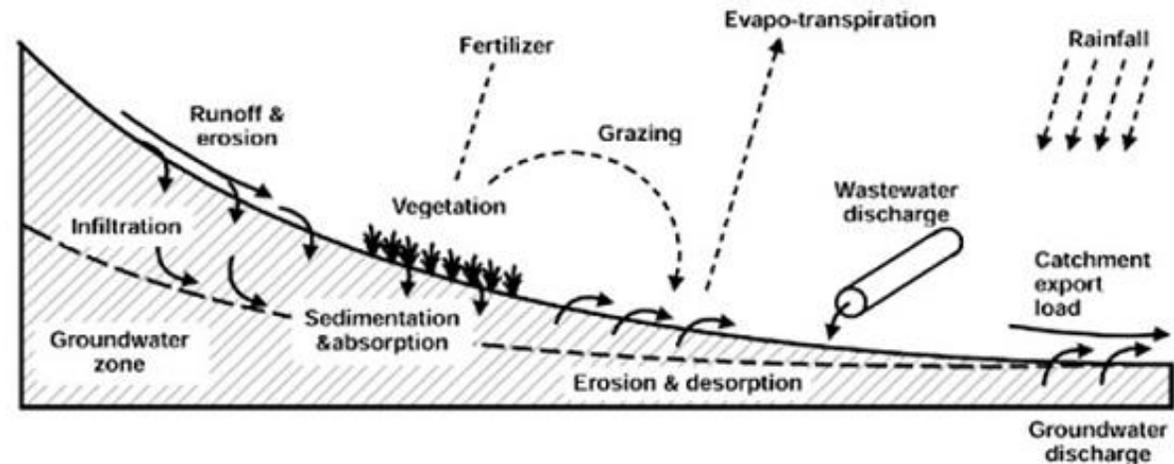
Simplified representation of a system or phenomenon

Uses simplified concepts and relationships to understand a process

## Examples:

Water cycle

Nodes and links to represent road networks



# Classifying Models

- Conceptual models
- **Mechanistic models**
- Phenomenological models
- Data-driven models

## Concept:

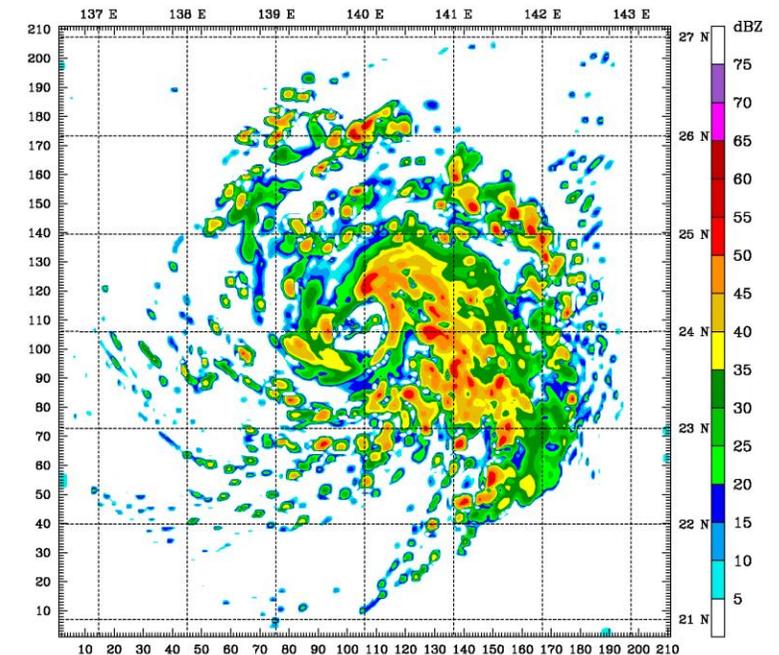
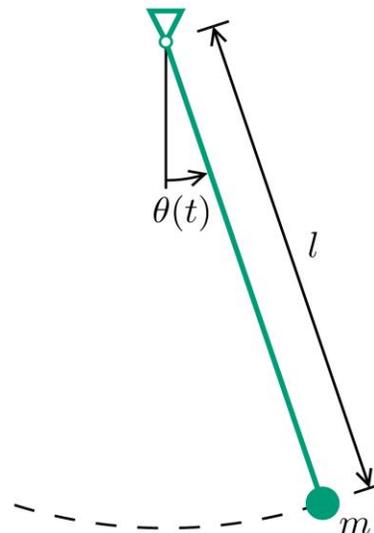
Physical, chemical, or biological laws to describe the behavior of constituting parts of the modeled system

Embodies the idea that a complex system is the summation of many basic phenomena

## Examples:

Newton's laws for describing dynamic motion

Weather models



Atmoz, CC BY-SA 3.0, via Wikimedia Commons

# Classifying Models

- Conceptual models
- Mechanistic models
- **Phenomenological models**
- Data-driven models

## Concept:

Mathematical consistency between quantities, relationship between quantities is hypothesized

Model is constructed by setting up appropriate experiments, measuring observations, fitting hypothetical structure with data.

## Examples:

Behavioral modelling (e.g. route choice in transport)

Friction modelling



# Classifying Models

- Conceptual models
- Mechanistic models
- Phenomenological models
- **Data-driven models**

## Concept:

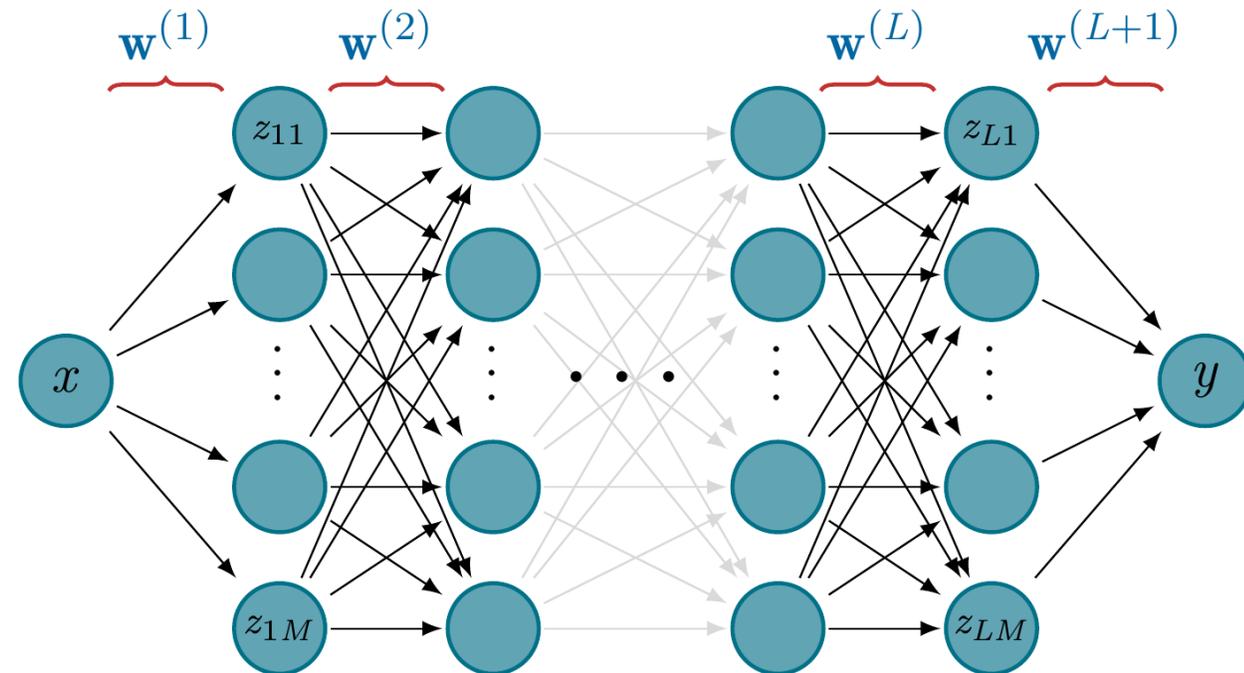
Use of data to create empirical and probabilistic relations between the desired output and input

## Examples:

Large language models

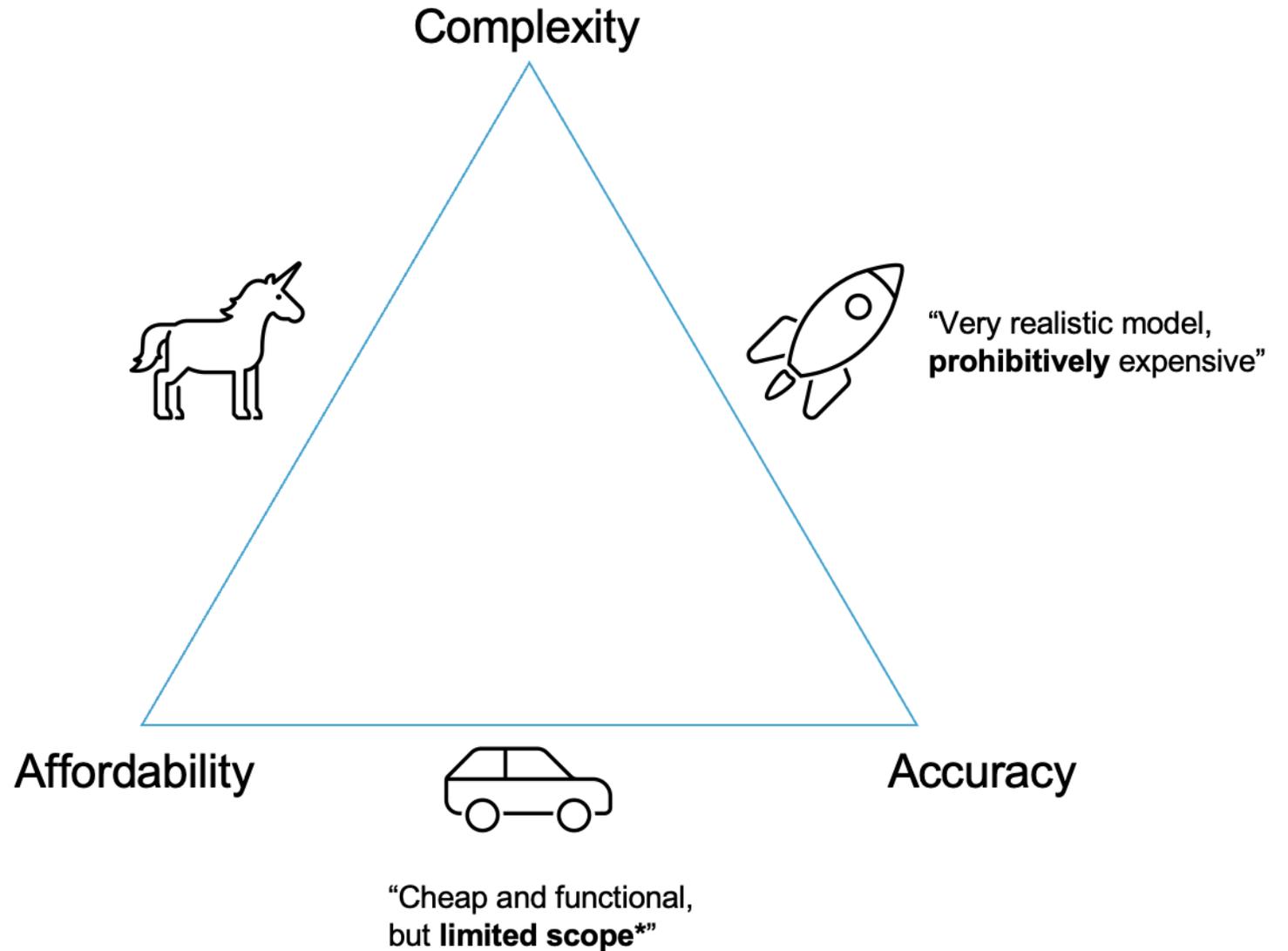
Weather models (increasingly)

Models can also be a combination of different types of model!



# Trade-offs

- How detailed does the model need to be?
- How well does it need to reflect reality?
- What is our budget?



# Let's assess some models

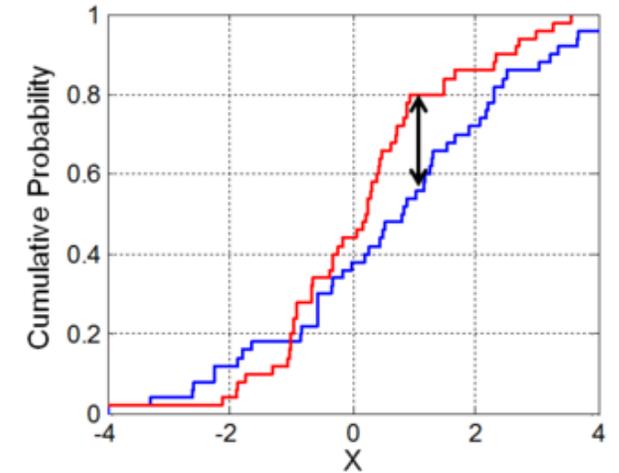
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Session ID: 147-912-491

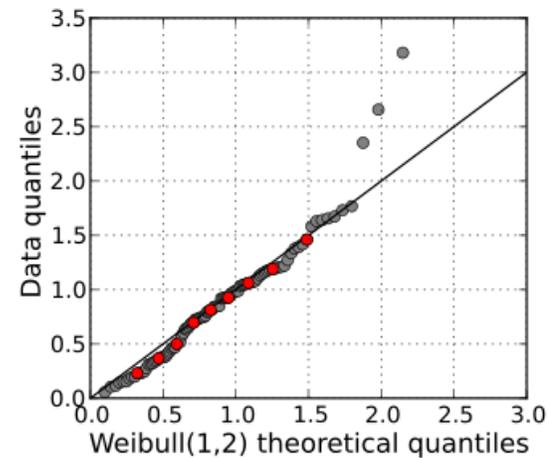
# Goodness of Fit

- Methods that gives insight into the performance of models
- For example:
  - Square differences
  - Pearsons chi-square test
  - Bias
  - And many more!
- More on this throughout MUDE!

KS test



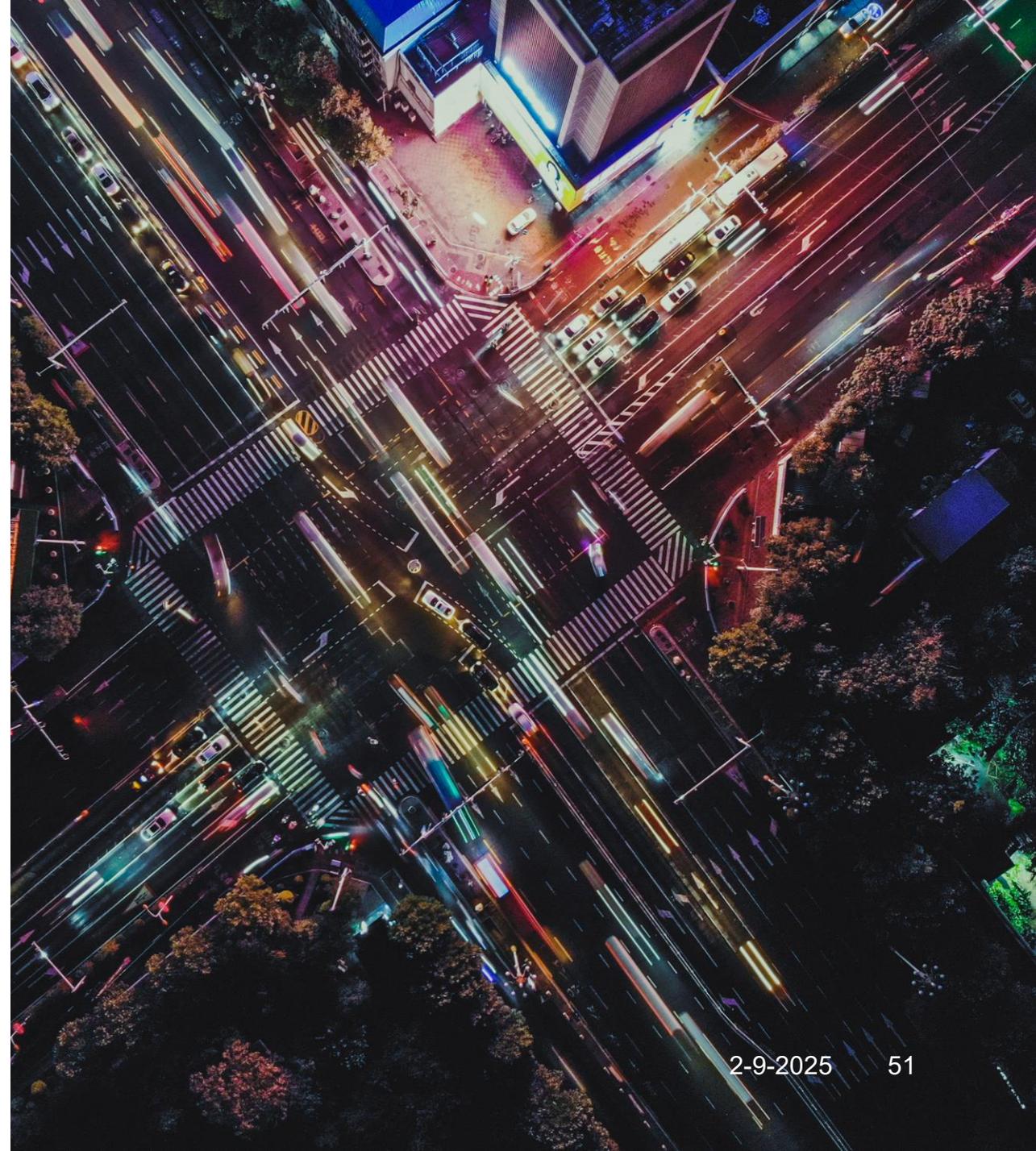
QQ plot



$$RMSE = \sqrt{\frac{\sum_{i=1}^N (y_i - \hat{y}_i)^2}{N}} = \sqrt{MSE}$$

# Uncertainty Classification

- Aleatoric – 'coin flip'
  - Inherent uncertainty in a system
- Epistemic – lack of knowledge
  - Limits to what we know and can measure
- Error – deficiency in modelling and simulation
  - Limitation of modelling or data collection methods



# What type of uncertainty is present?

Go to: [vevox.app](https://vevox.app)

Session ID: 147-912-491

# Main takeaways

- Models are an abstraction of reality
- There are many possible choices for a model
- No 'right' model, all about purpose
- Need to consider assumptions, uncertainty sources etc.

When dealing with Modelling, Uncertainty and Data, Engineering context matters!

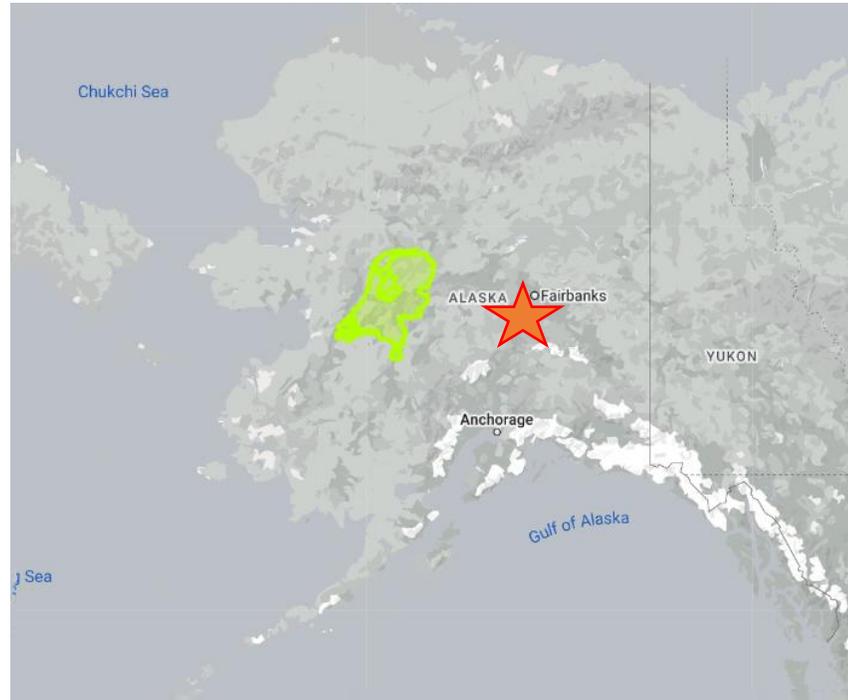
For reliable Engineering, understanding tools for Modelling, Uncertainty and Data matters!





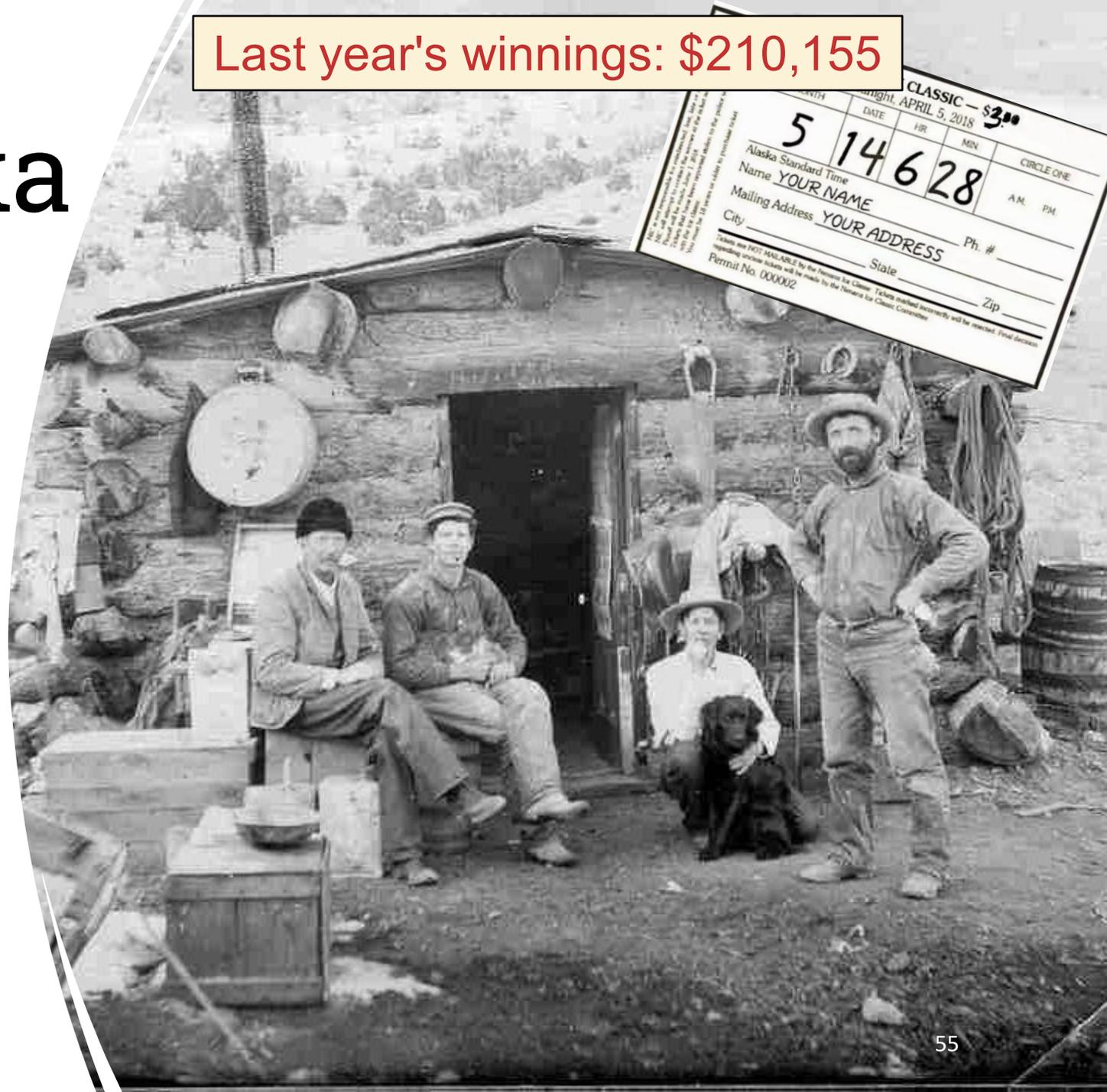
# Common interest?

# Nenana Alaska Ice Classic



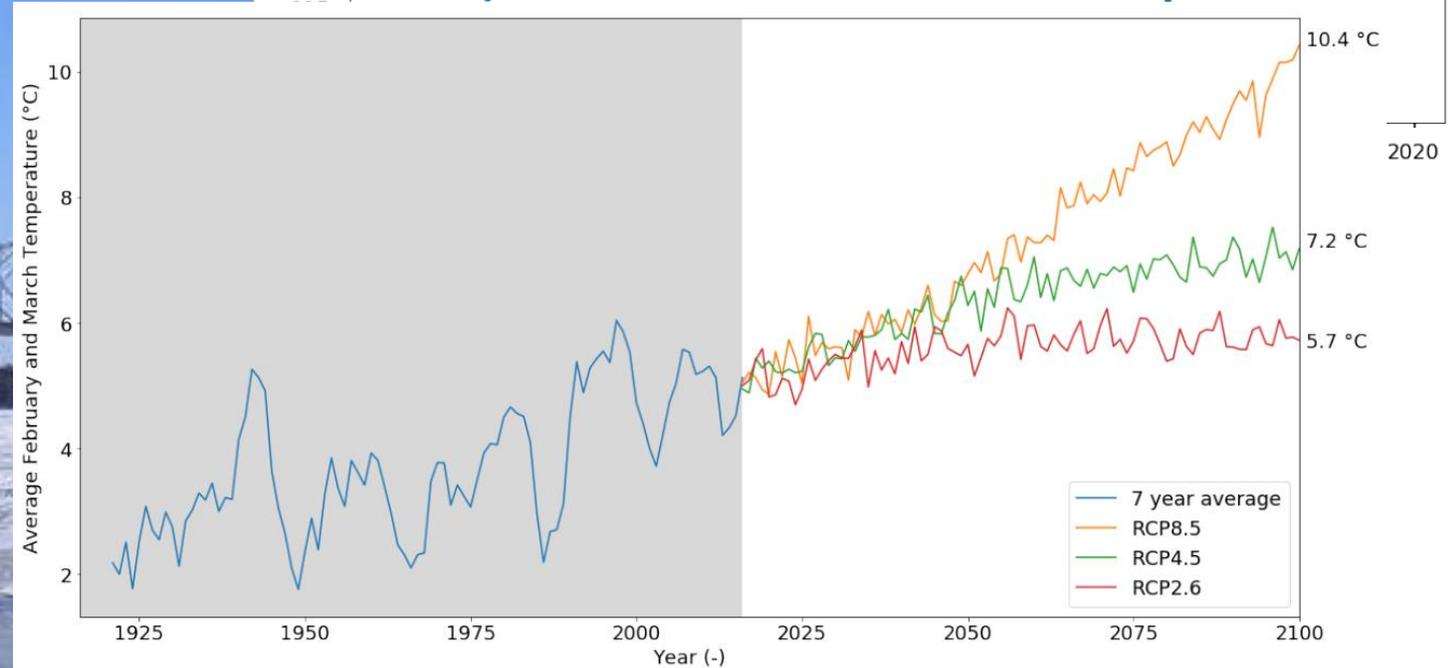
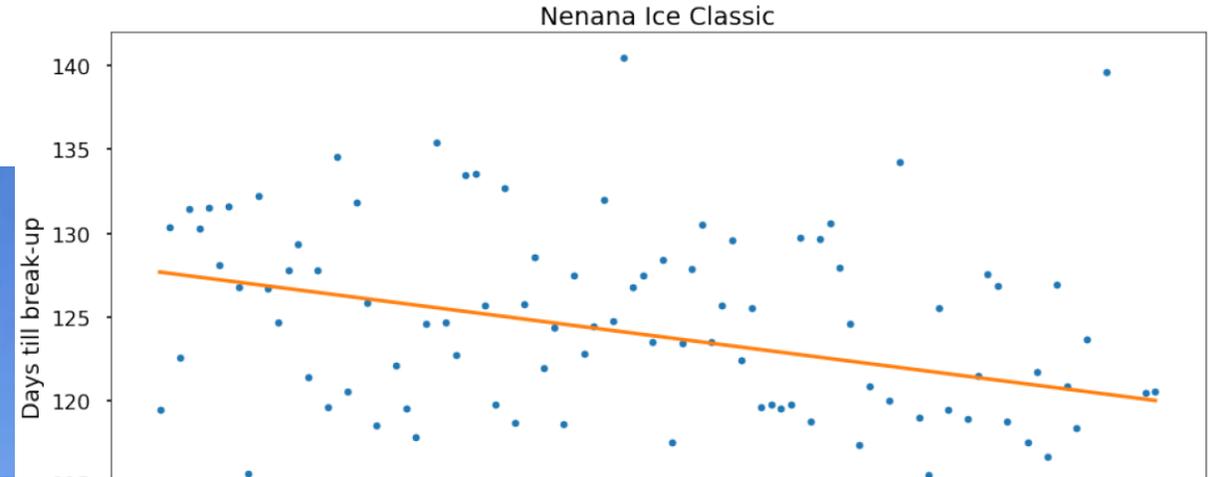
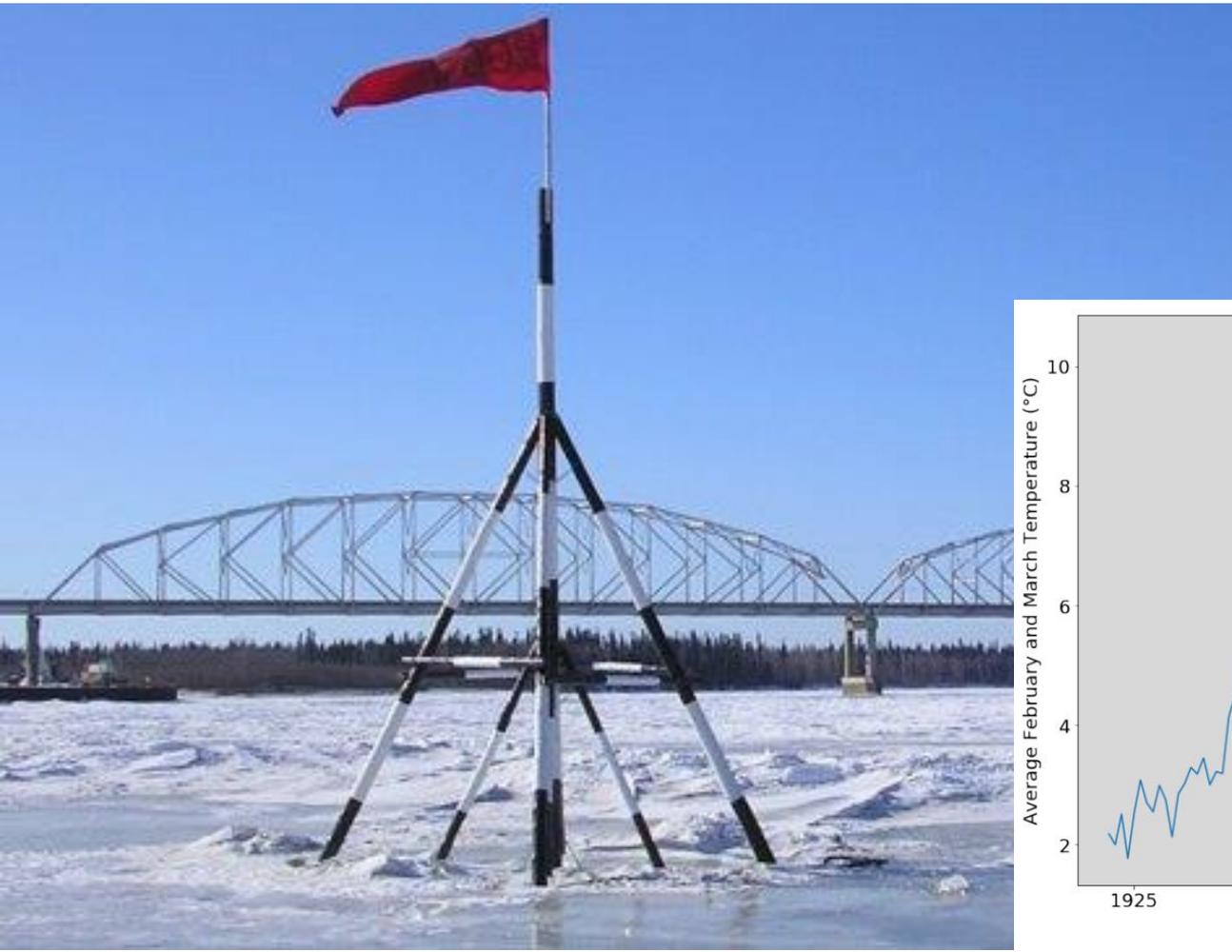
9/2/2025

Last year's winnings: \$210,155



# What does the Nenana Ice Classic have to do with MUDE?

- Predict the day and time of "break up"



# What does the Nenana Ice Classic have to do with MUDE?

- Analyze the data (time series, signal processing)
- Formulate physics-based and data-driven models to predict break-up date and time
- Maximize probability of success
- Optimize the betting strategy

These are all MUDE topics!

# What now?

- Fill out the Questionnaire
- Visit the MUDE Website and read it
- Read the Book!
- Get your computer ready with PA1.1
  
- See you in class tomorrow at 10:45!
  - Keep an eye on Brightspace

## MUDE (CEGM1000 25) Introductory Questionnaire

