Handout for: Group Assignment 1.1, Friday, Sep 6, 2024

Modelling, Uncertainty, and Data for Engineers

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Introduction

Our overall goal is to build a model to predict when the ice breaks apart and win >$200,000!!!

To help achieve this goal, the following slides contain:

Part I: Overview of the Nenana Ice Classic (how the betting competition works)

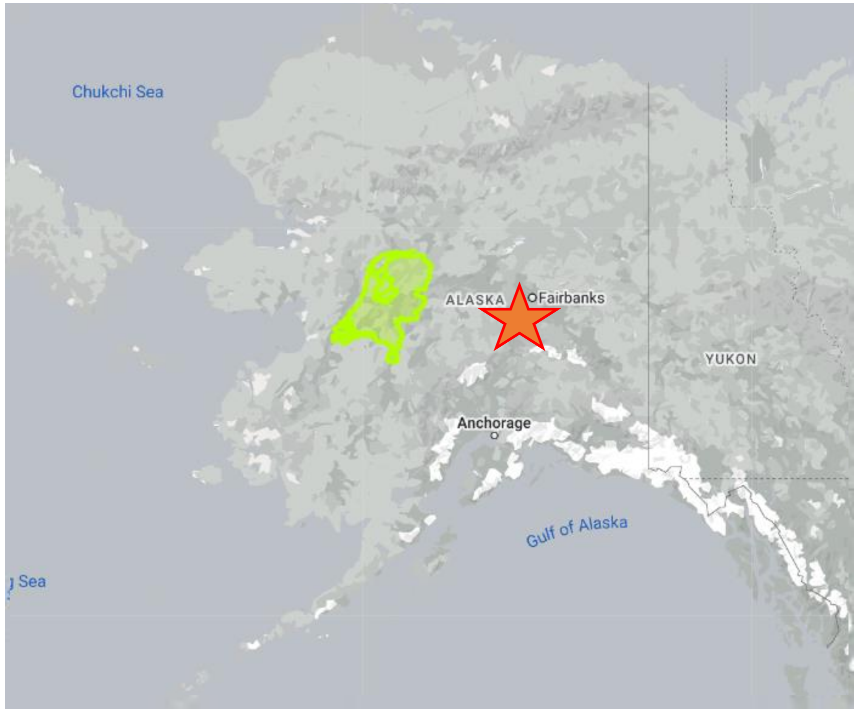
Part II: Illustration of available data and physical processes

Part III: Description of Tasks to Complete MUDE Group Assignment 1.1

Spend a few minutes scanning through Part I and Part II to see what is there, but otherwise they are meant to be a reference while you work through the Tasks in Part III.

Part I: Overview of the Nenana Ice Classic

Nenana Alaska Ice Classic



Last year's winnings: $210,155

Nenana Ice Classic

- Each year you can bet on the day and time the river ice in the Tanana River, Alaska will break apart along the waterfront of the town Nenana (the town is called Nenana because it is located just upstream from the confluence of this tributary with the Tanana River)
- A tripod is constructed on the ice during the first weekend in March. Break-up time is determined as follows: "*The Tripod is setup with a unique pulley and clock system that stops the clock once the tripod has moved downstream by 100 ft.*" (see next page)
- You can buy a ticket for $3 and place a bet between Feb 1 and April 5. Our goal is to create a model to predict the ice break-up and WIN!!!
- Visit the website for more information, or to view a live webcam of the river nenanaakiceclassic.com

What do the tripod, tower and mechanism look like?

RIVAHMAN,THURSDAY, APRIL 22, 2010. Retrieved Sep 7, 2023.
https://rivahman.blogspot.com/2010/04/nenana-ice-classic.html

The elegant antique timing contraption of the Nenana Ice Classic awaits the moment of breakup on the Tanana River. One rope trips the siren. One rope trips the cleaver, which cuts the main rope, setting the tripod free as the fourth rope pulls the pin on the clock. (Dermot Cole / Alaska Dispatch News) 2017. Retrieved Sep 7, 2023.

https://www.adn.com/opinions/2017/05/01/this-antique-engineering-marvel-records-spring-breakup-in-alaska-like-clockwork/

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Part II: Illustration of available data and physical processes (organized by scale)

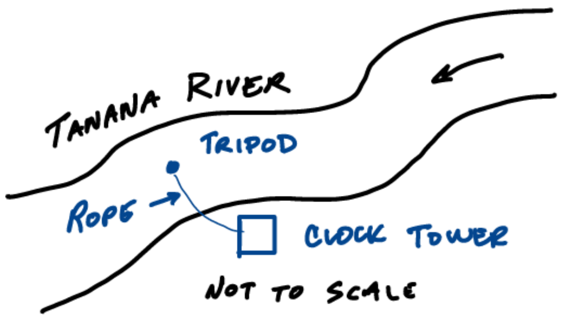
Scale	Physical Process	Variable	Symbol	Units
Local	River discharge	Monthly average discharge	Q_{month}	m3/s
		Water level at freeze-up	H_F	m
		Water level at break-up	H_B	m
	Ice thickness	Ice thickness	t	m
	Ice deformation / melting	River temperature	T_r	°C
Watershed	River discharge	Average spring precipitation	P_{AM}	mm
		Glacial reduce	V_G	m^3
	Ice thickness	Average winter temperature	T_{DJM}	°C
	Snow cover / solar radiation	Average winter precipitation	P_{DJFM}	mm
	Ice deformation / melting	Monthly average temperature	T_{month}	°C
Regional	Ice thickness	Accumulated degree-days frost	ADDF	°C
	Snow cover / solar radiation	Cloud coverage	CC_{month}	%
		Sun hours	t_{sun}	h
	Ice deformation / melting	Heat wave days per month	HWd_{month}	d
		Accumulated degree-days thaw	ADDT	°C
Large (Global)	Pacific Ocean surface temperature	ENSO effect in February-May	$ENSO_{FMAM}$	°C
		PDO effect in February-May	$ENSO_{FMAM}$	°C

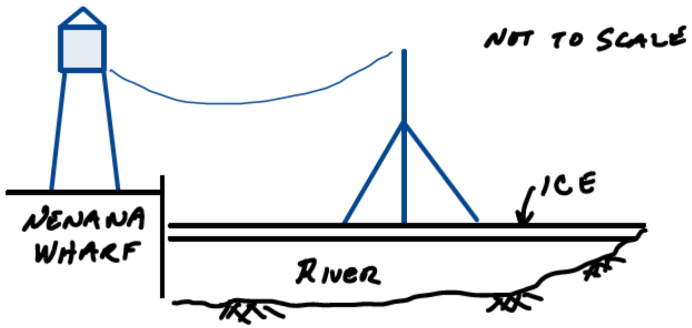
Local Elements: Key System Components

The setup of the tripod and clock is interesting and should be included in your model. This setup directly determines the definition of ice break-up: a rope is attached from the tripod to a clock on the riverbank. When the rope is pulled tight it stops the clock; this time is used to determine the winning guess of the breakup day and time (down to the minute).

As such, these components could be interesting to include in a model:

- River
- Ice
- Tripod
- Rope





Diagrams illustrate their positions and orientations relative to each other

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Local Scale: Nenana Waterfront

Physical Process	Variable	Symbol	Units
River discharge	Monthly average discharge	Q_{month}	m3/s
	Water level at freeze-up	H_F	m
	Water level at break-up	H_B	m
Ice thickness	Ice thickness	t	m
Ice deformation / melting	River temperature	T_r	°C

Image source: https://www.google.com/url?sa=i&url=https%3A%2F%2Fen.wikipedia.org%2Fwiki%2FNenana_Ice_Classic&psig=AOvVaw3tnHXKo9OPR3-LQdijw42w&ust=1694170505343000&source=images&cd=vfe&opi=89978449&ved=0CBAQjRxqFwoTCICe9omrmIEDFQAAAAAdAAAAABAE

Watershed Scale

Physical Process	Variable	Symbol	Units
River discharge	Average spring precipitation	P_{AM}	mm
	Glacial reduce	V_G	m3
Ice thickness	Average winter temperature	T_{DJM}	°C
Snow cover / solar radiation	Average winter precipitation	P_{DJFM}	mm
Ice deformation / melting	Monthly average temperature	T_{month}	°C

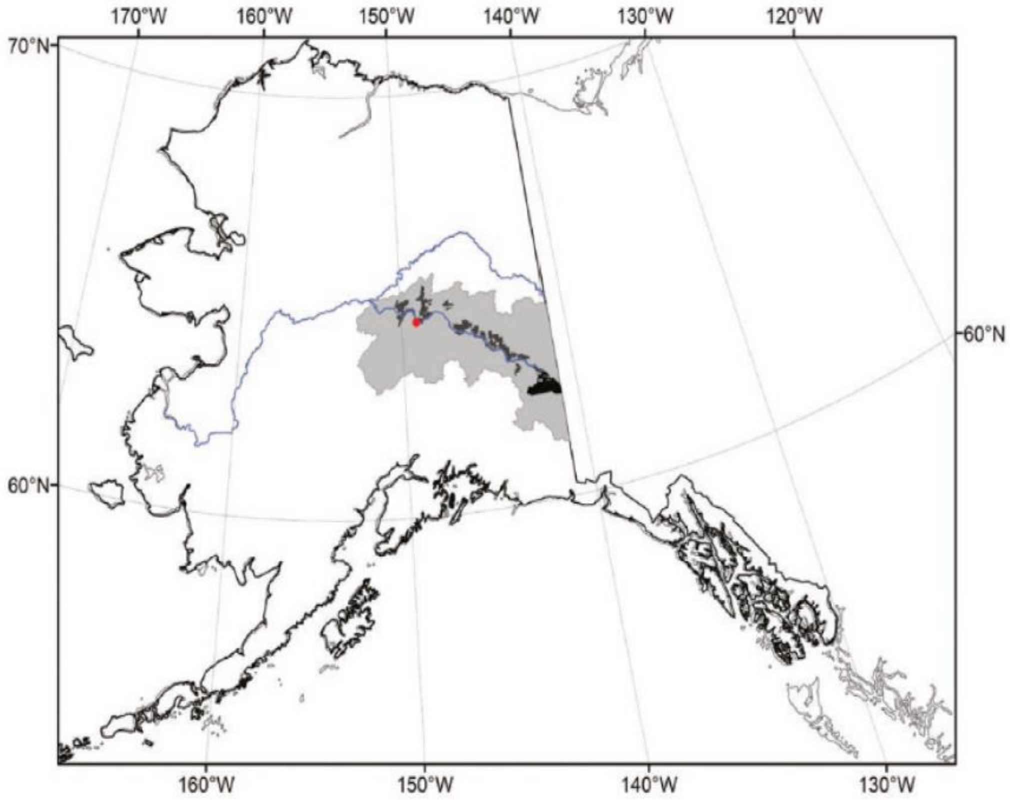

Figure 1.2: Location of Tanana river basin (grey), Yukon and Tanana river (blue) and Nenana (red dot) (edit by Terwogt, 2021, from original figure by Pattison et al., 2018).

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Regional Scale

Physical Process	Variable	Symbol	Units
Ice thickness	Accumulated degree -days frost	ADDF	°C
Snow cover / solar radiation	Cloud coverage	CC_{month}	%
	Sun hours	tsun	h
Ice deformation / melting	Heat wave days per month	HWd_{month}	d
	Accumulated degree -days thaw	ADDT	°C

Image source: https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.britannica.com%2Fplace%2FAlaska&psig=AOvVaw1AvtDd25Wq1B4mNgEmI9H5&ust=1694170043967000&source=images&cd=vfe&opi=89978449&ved=0CBAQjRxqFwoTCKC-762pmIEDFQAAAAAdAAAAABAE

Large Scale (Global)

Physical Process	Variable	Symbol	Units
Pacific Ocean surface temperature	ENSO effect in February-May	$ENSO_{FMAM}$	°C
	PDO effect in February-May	$ENSO_{FMAM}$	°C

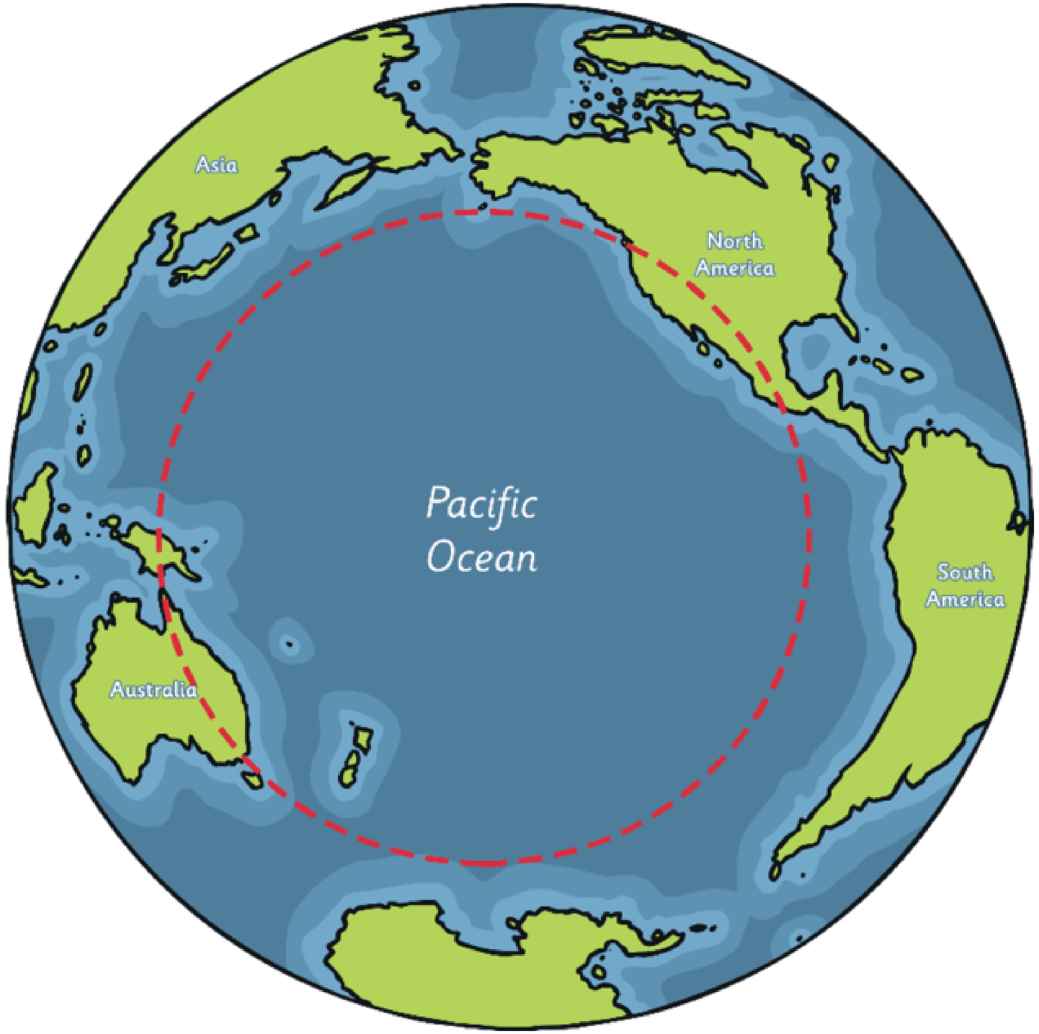


Image source: https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.twinkl.com.mx%2Fteaching-wiki%2Fpacific-ocean&psig=AOvVaw3XdTtRt9HFJBiucLYfpQ18&ust=1694169645723000&source=images&cd=vfe&opi=89978449&ved=0CBAQjRxqFwoTCMDzhPCnmIEDFQAAAAAdAAAAABAE

Task 1: Model classification and decisions (warm-up)

Consider the 4 descriptions of models on the next page, then complete the following tasks:

- Classify the models using the 4 categories from the textbook
- Rank each according to the corners of the triangle diagram (place dot on triangle): complexity, accuracy, affordability (for affordability, consider money and/or computation time)
- Decisions: which simplifications have been made? (4 types)
- Which GoF measures could you use, and on which variables? (refer to those in the textbook, but don't worry if you can't think of much for this one – it's harder to do when you can't see the results)
- Which model do you think would be the most useful for helping us win the Ice Classic bet? Why?

Try splitting into pairs within your group and each choose a model to consider, then after a few minutes regroup and explain your results to each other. It is OK if you don't get through all 4 models.

Task 1: Four Example Models

These models have been arranged in order of large to small scale and can be considered as one of many tools that could be used to inform your prediction for break-up day and time in the Nenana Ice Classic. Each model may have more than one "sub-model" that you can consider.

1) From a global climate model considering ENSO (sea-surface temperatures in the South Pacific Ocean) and Alaska temperatures (a) determine the heat exchange of the system which leads to (b) precipitation (c) river discharge and (d) ice melting rate.
2) Consider the heat of the sun, cloud coverage and the snow/ice cover at a regional scale (whole Alaska for instance) to (a) determine the heat absorption of the ground and/or snow/ice. Then (b) determine the rate of ice melting in the river from the river temperature and discharge due to snowmelt and rainfall.
3) Consider river water discharge and river water temperature (a) to determine ice melting rate in the river within 1 km upstream of Nenana, which is used to (b) predict deformation and movement of ice downstream and (c) the tension in the rope until it reaches a point that the clock is stopped.
4) Given a velocity of ice moving downstream (slowly) as it melts and deforms (as a plastic continuum), (b) calculate the rope tension as in model 3 above. The velocity is derived from (a) past measurements that are represented with a probability distribution.

Task 2: Modelling Ice Breakup

- Consider the following set of slides that introduce two important aspects of river ice:
  1. Ice thickness, and
  2. River ice break-up mechanisms

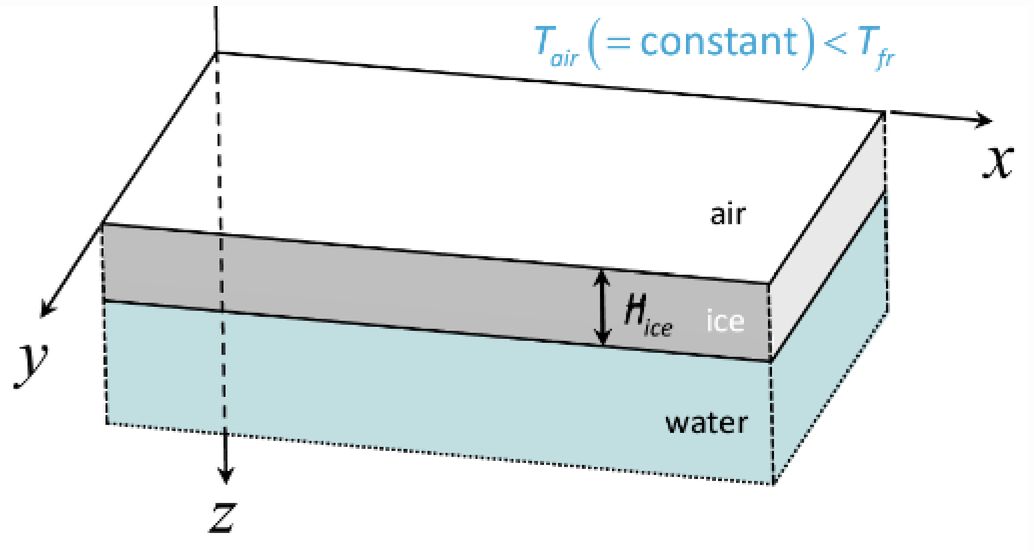
- Next, look at the data analysis that follows, which captures our previous attempts to evaluate these processes for the Nenana Ice Classic:
  A. Overview of temperature, discharge and ice thickness data
  B. Exploration of ice thickness data and break-up day
  C. Exploration of discharge data and break-up day

Finally, imagine it is April 1, 2025: make a prediction using the information provided on the last slides of this Task.

>>> <u>There are some "ice experts" in each classroom to help you interpret the data and reason through the prediction</u>

Task 2: Modelling Ice Breakup

To model the ice growth, you could use the Ashton model, which aims to determine how an ice layer grows as a function of time, given the constraint that the temperature of air is constant, smaller than the freezing temperature and everywhere the same.



$$\frac{dh}{dt} = \left(\frac{1}{\rho_{ice} L}\right)\left(\frac{T_{water} - T}{\frac{h}{k_{ice}} + \frac{1}{H_{ia}}}\right)$$

- h = ice thickness
- t = time
- ρ_{ice} = ice density
- L_{ice} = ice fusion heat
- T_{water} = temperature at the ice-water interface
- T = air temperature
- k_{ice} = ice thermal conductivity
- H_{ia} = bulk heat transfer coefficient (air-ice)

Task 2: Modelling Ice Breakup

Beltaos (1984) Threshold between mechanical and thermal breakup of river ice cove

Excerpt from Abstract

Extreme ice-jam flood events in rivers occur during a type of breakup that is partly governed by the mechanical properties of the ice cover, and known as "mechanical". By contrast, thermal breakups are preceded by advanced thermal decay of the ice and can only produce insignificant, if any, jamming…It is shown that there is a site-specific rise in water level above the freeze-up elevation, which delineates mechanical from thermal events. The threshold value is approximately proportional to the thickness of the ice cover, and also depends on local river morphology and hydraulics

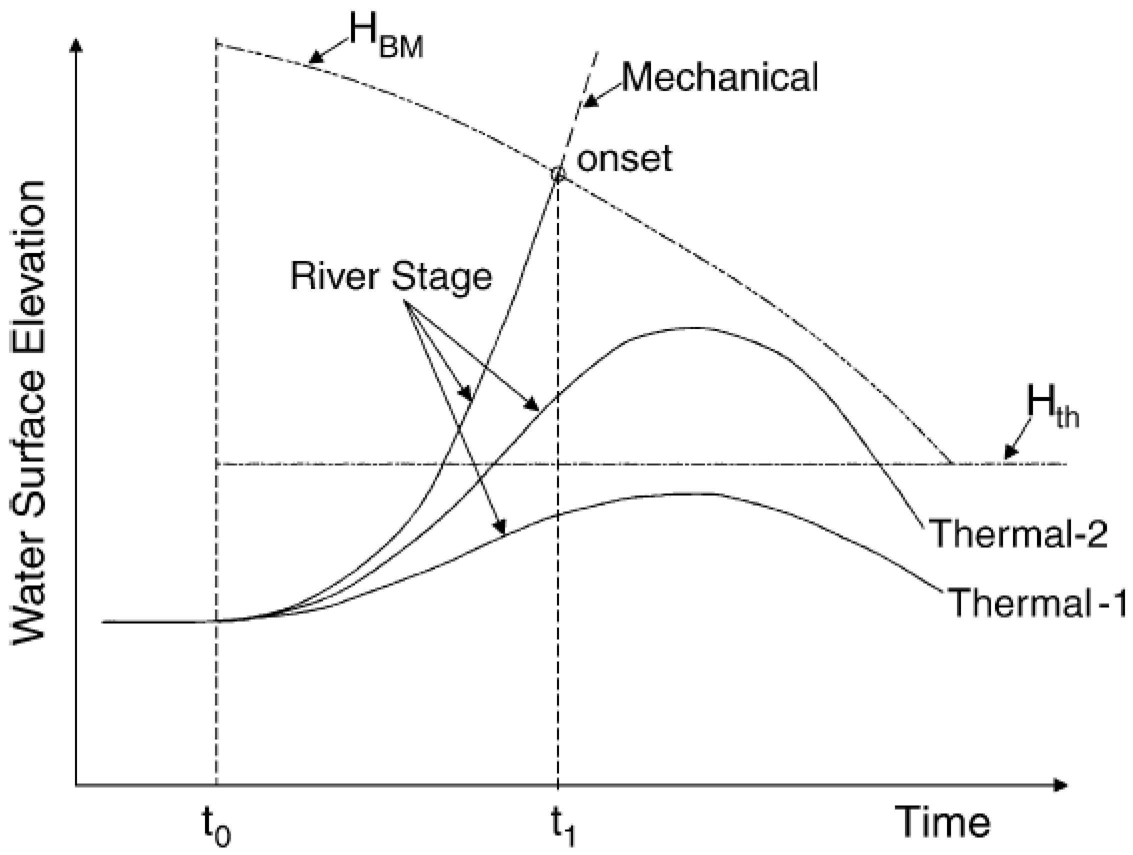


Fig. 8. Illustration of different types of breakup events that may result from different river stage hydrographs.

- If the river rises rapidly, a *mechanical breakup* occurs
- If the river rises slowly, or does not exceed some threshold, a *thermal breakup* occurs

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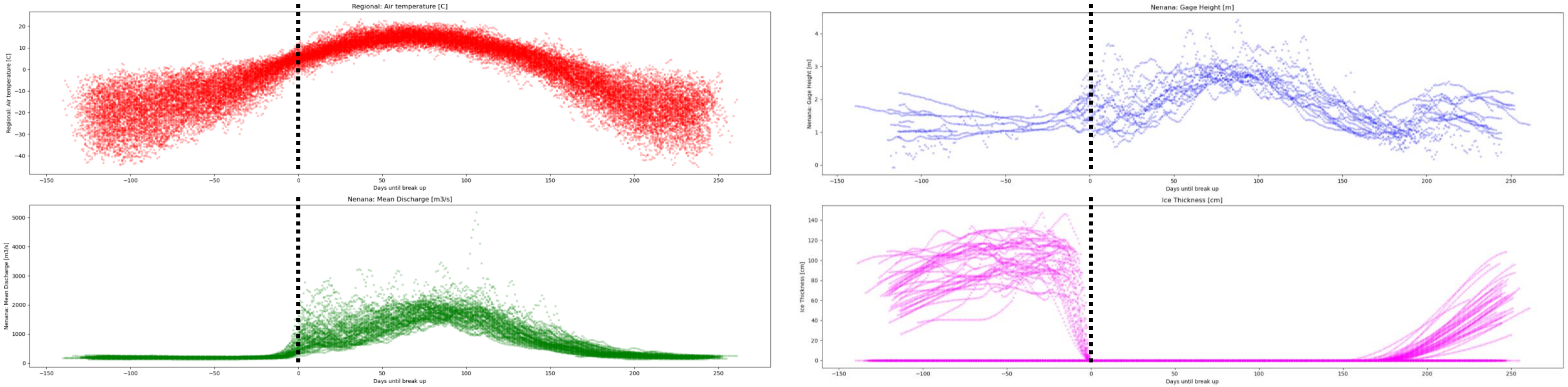
Task 2: Modelling Ice Breakup

- Historical data, normalized such that actual breakup day is at 0

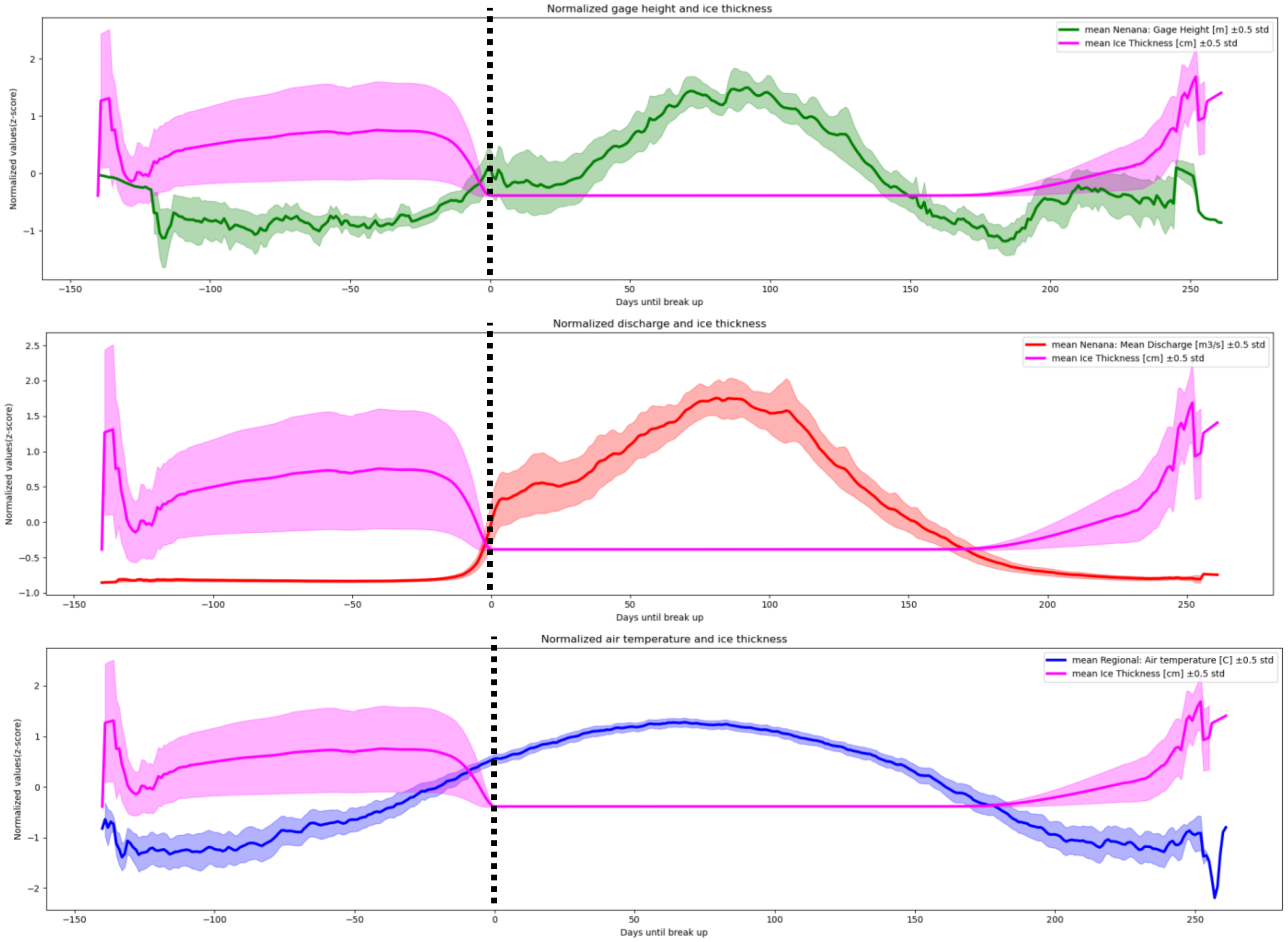


Note that "Gage Height" is measured directly (next to the Ice Classic tower) and is a point measurement, whereas discharge is inferred from this value and representative of the eriver along that reach.

Data: Ice Thickness, Temperature, Discharge

Task 2: Modelling Ice Breakup

- Key variables plotted with ice thickness
- Colored bands indicate one standard deviation of historic data
- Ice thickness is a combination of physical observations, combined with the Ashton model to and an interpolation method to fill in the days with no data



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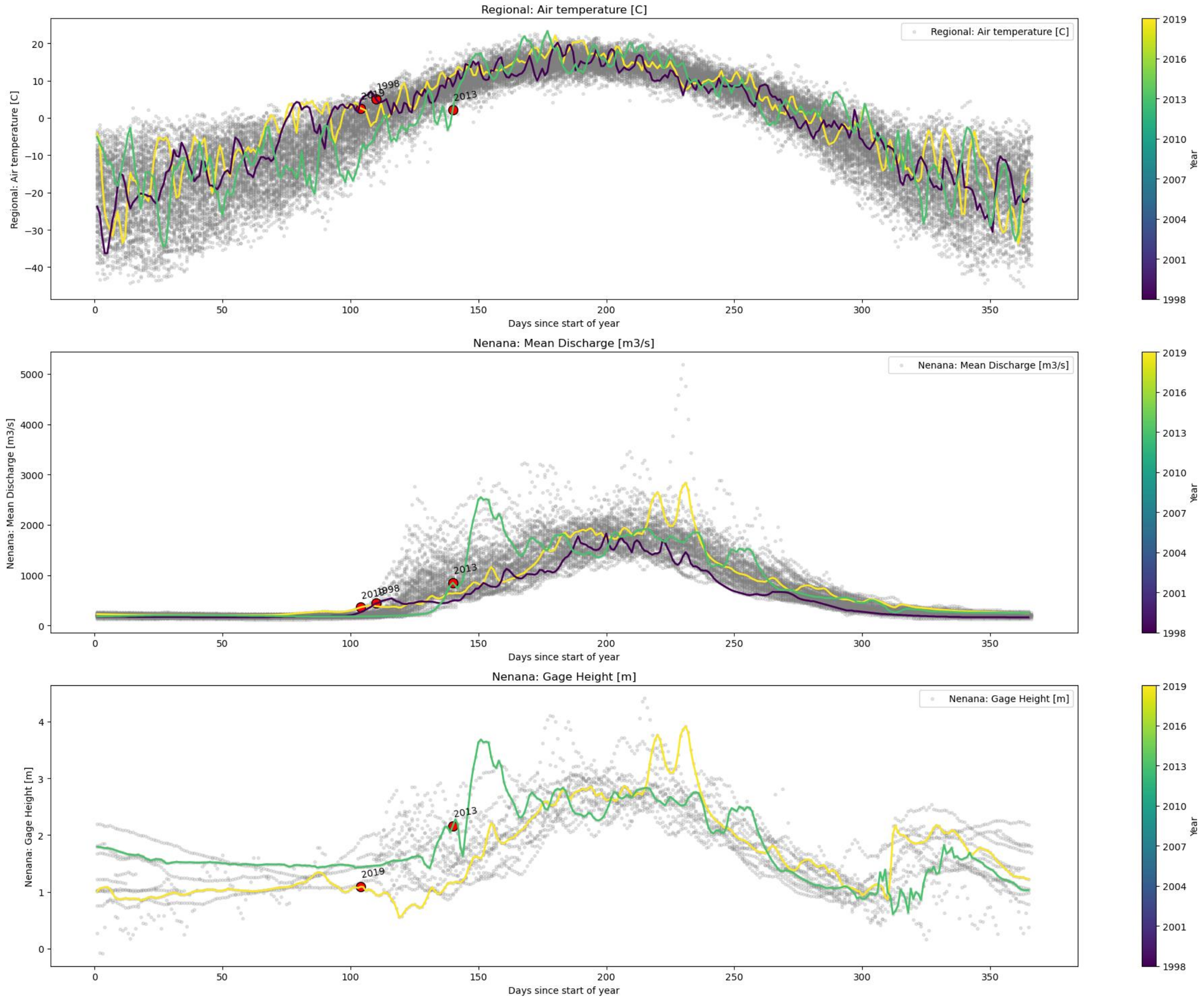
Task 2: Modelling Ice Breakup

- Historic data with several years highlighted: 1998, 2013, 2019
- Horizontal axis is absolute days since start of year



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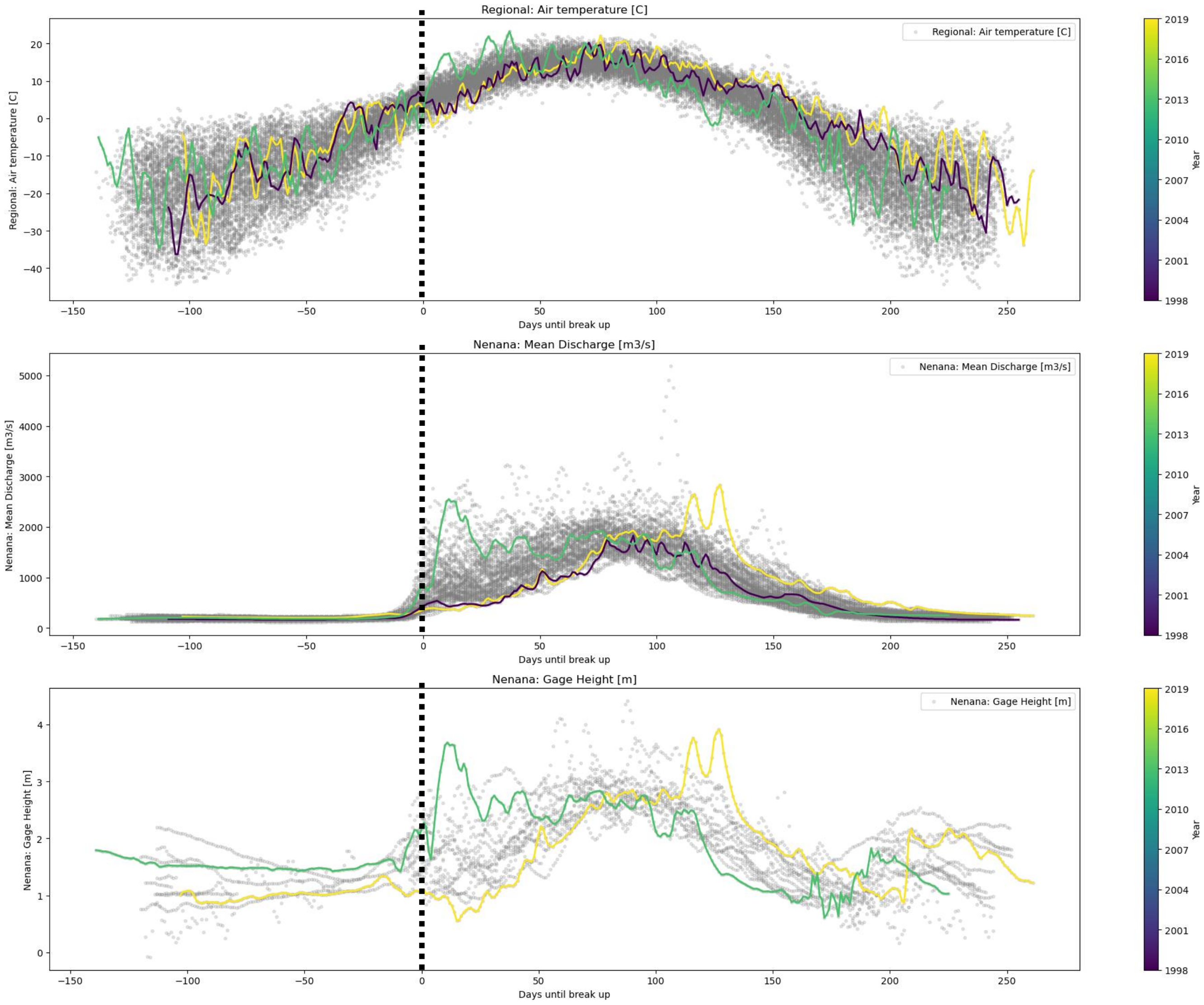
Data: Ice Thickness, Temperature, Discharge

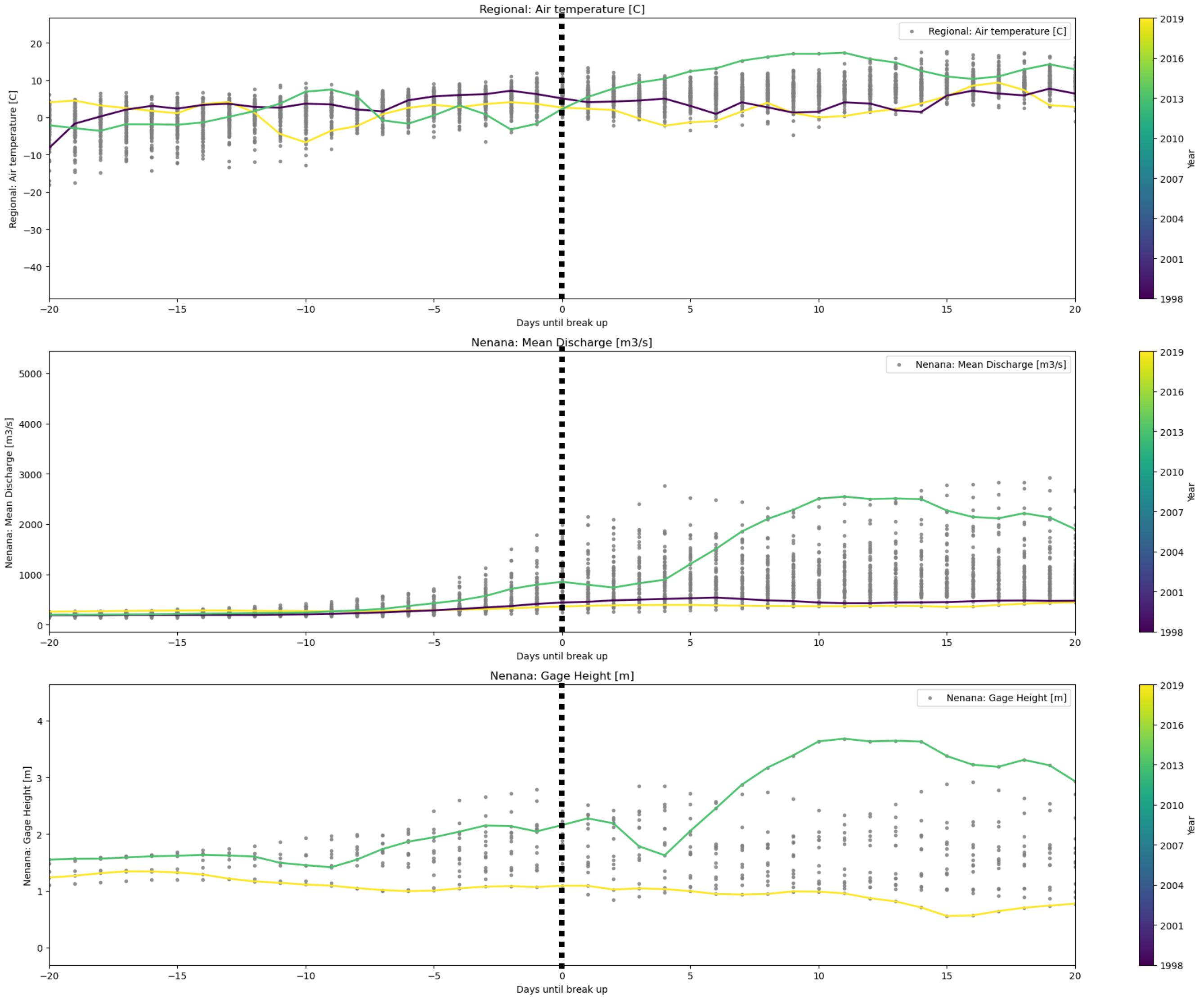
Task 2: Modelling Ice Breakup

- Historic data with several years highlighted: 1998, 2013, 2019
- Horizontal axis is normalized such that actual breakup day is at 0



Task 2: Modelling Ice Breakup

- Same as previous slide, but these are zoomed-in around the break-up date (+/-20 days)



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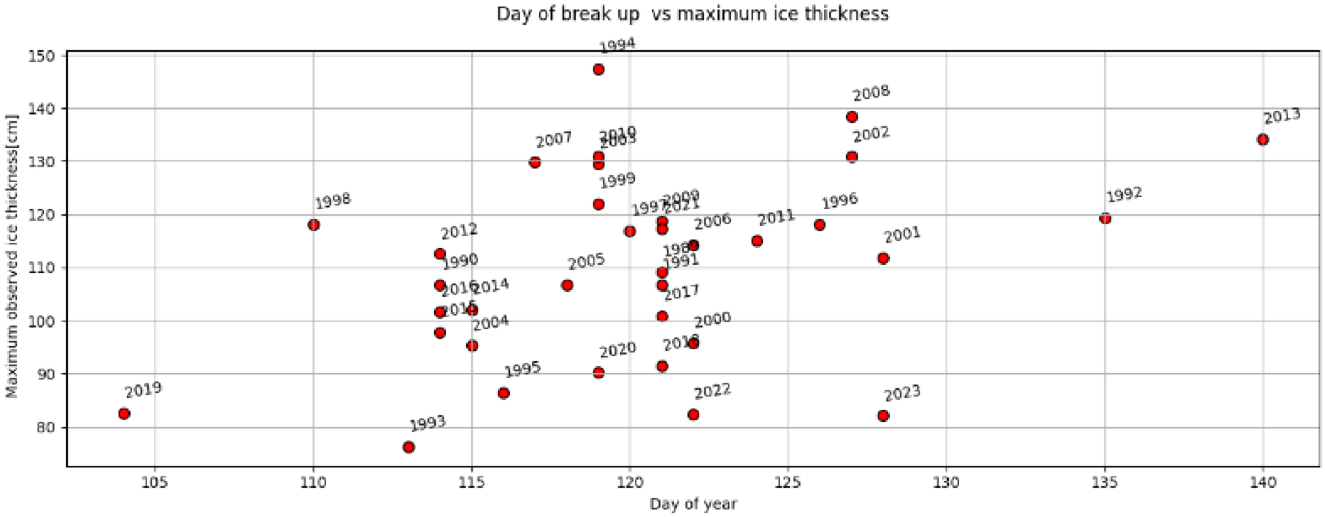
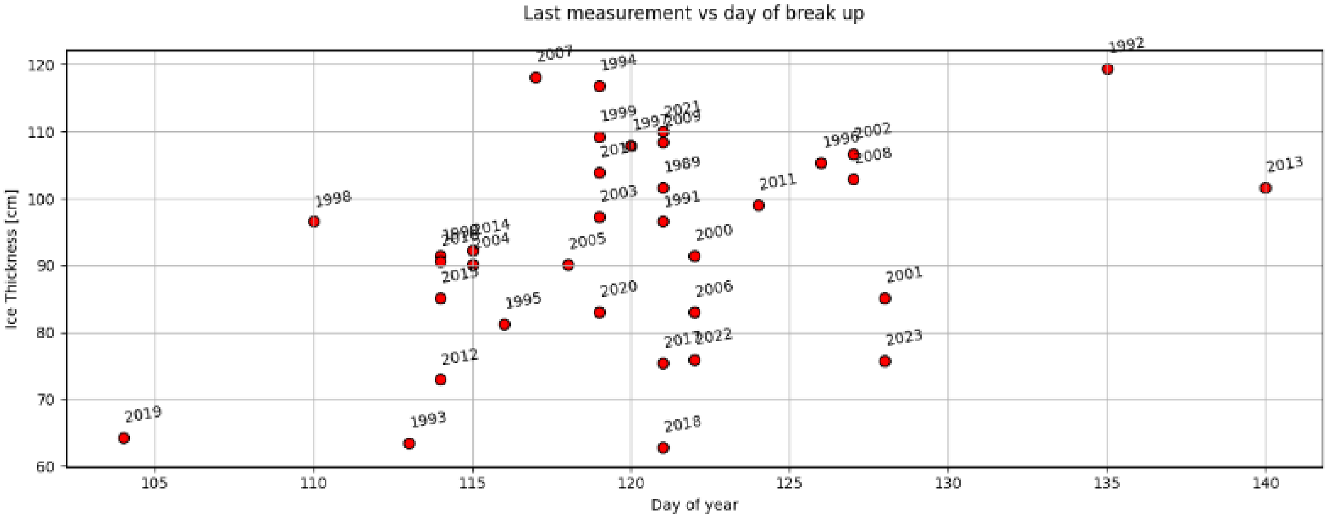
Data: Ice Thickness, Temperature, Discharge

Task 2: Modelling Ice Breakup

- Maximum ice thickness and Last Measured ice thickness (y-axes) plotted againt actual breakup day of that year

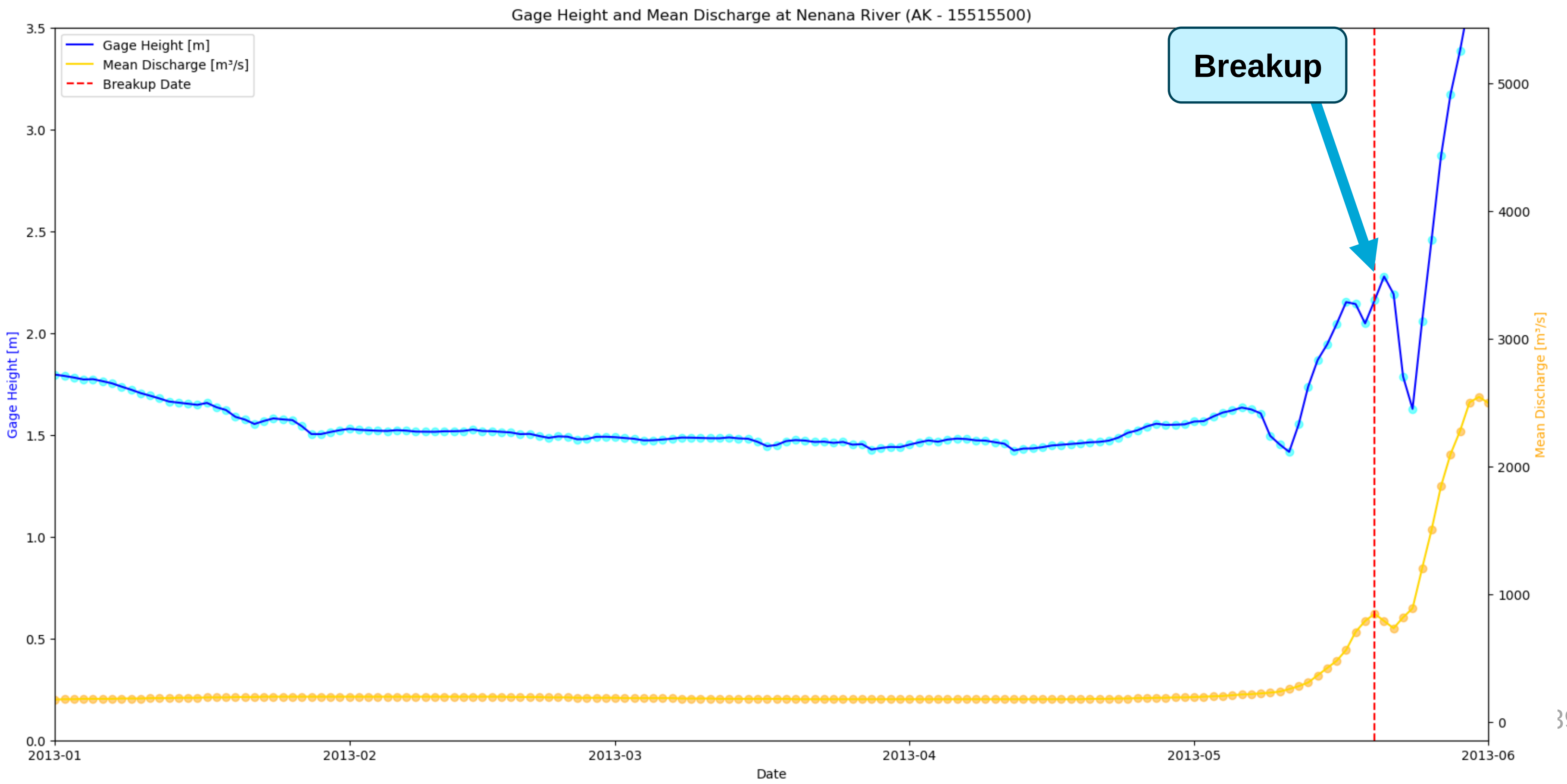




Data: Ice Thickness, Temperature, Discharge

Task 2: Modelling Ice Breakup

- Discharge and Gage Height (height of river surface elevation) prior to breakup in 2013
- River is clearly rising when breakup occurs → indicates Mechanical Breakup Mechanism



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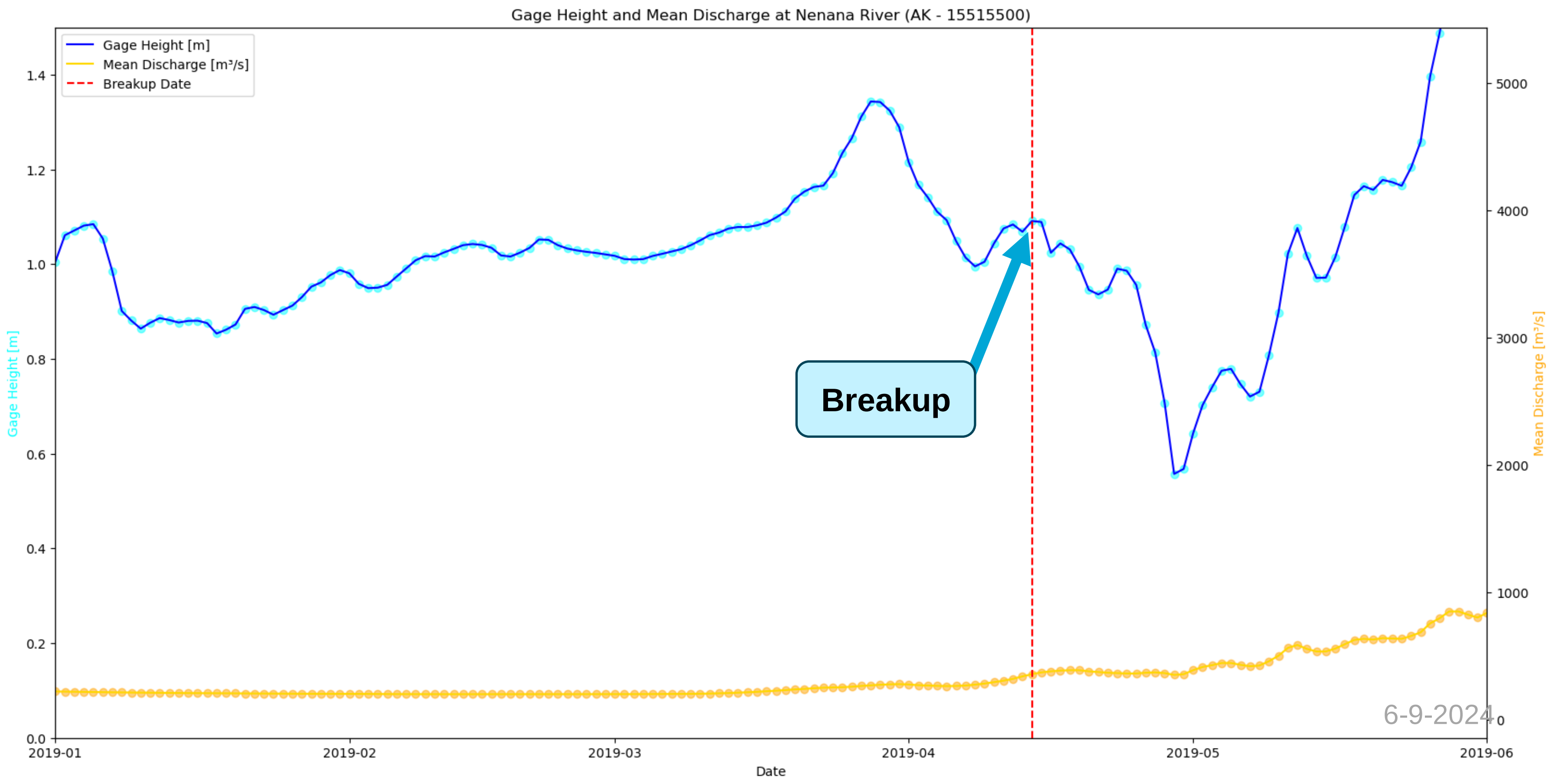
Data: Ice Thickness, Temperature, Discharge

Task 2: Modelling Ice Breakup

- Discharge and Gage Height (height of river surface elevation) prior to breakup in 2019
- Compared to previous slide, river level is low; no significant increase → indicates Thermal Breakup Mechanism



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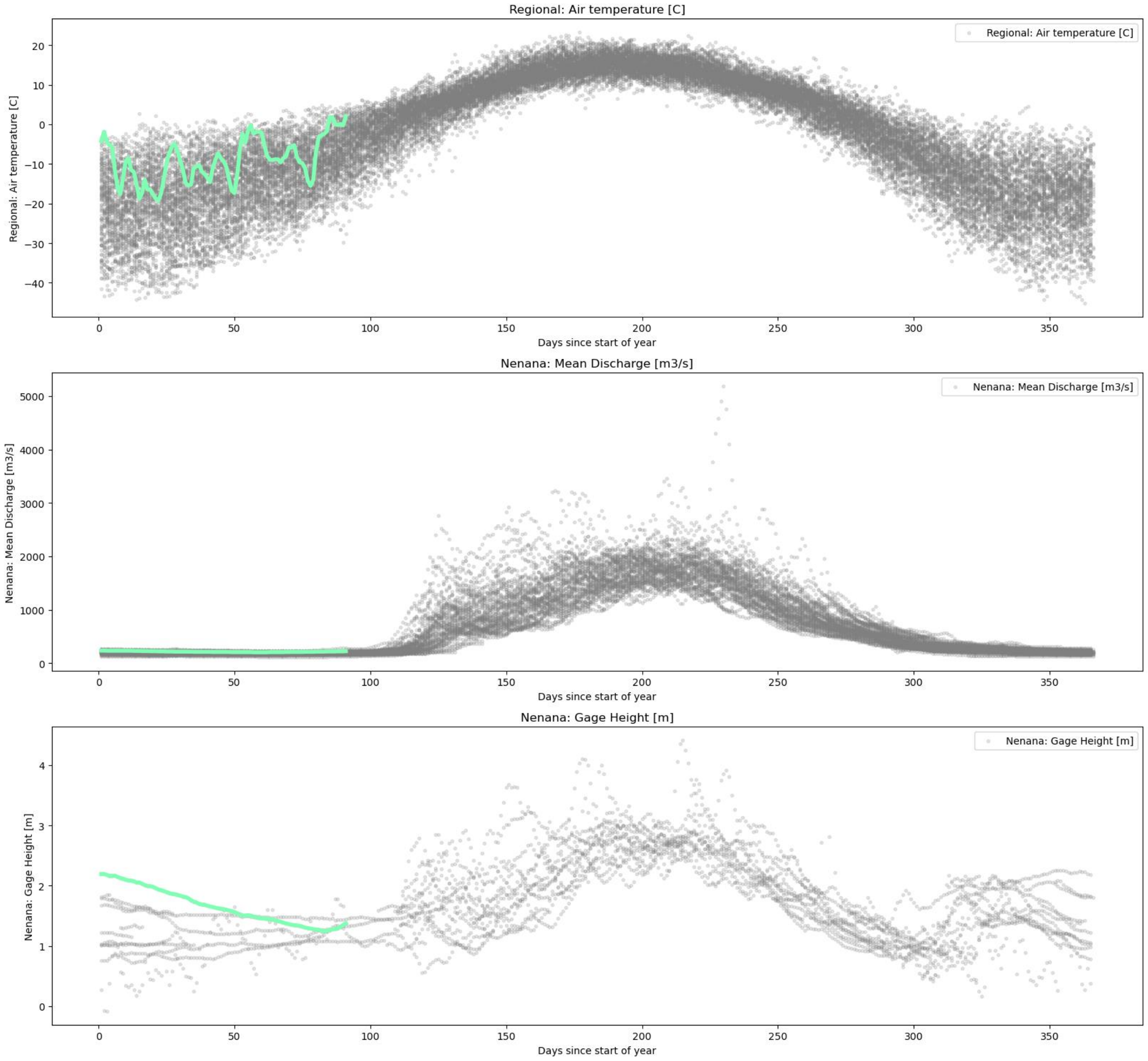
Hypothetical Information for 2025

Task 2: Modelling Ice Breakup

- Hypothetical situation, April1st 2025,



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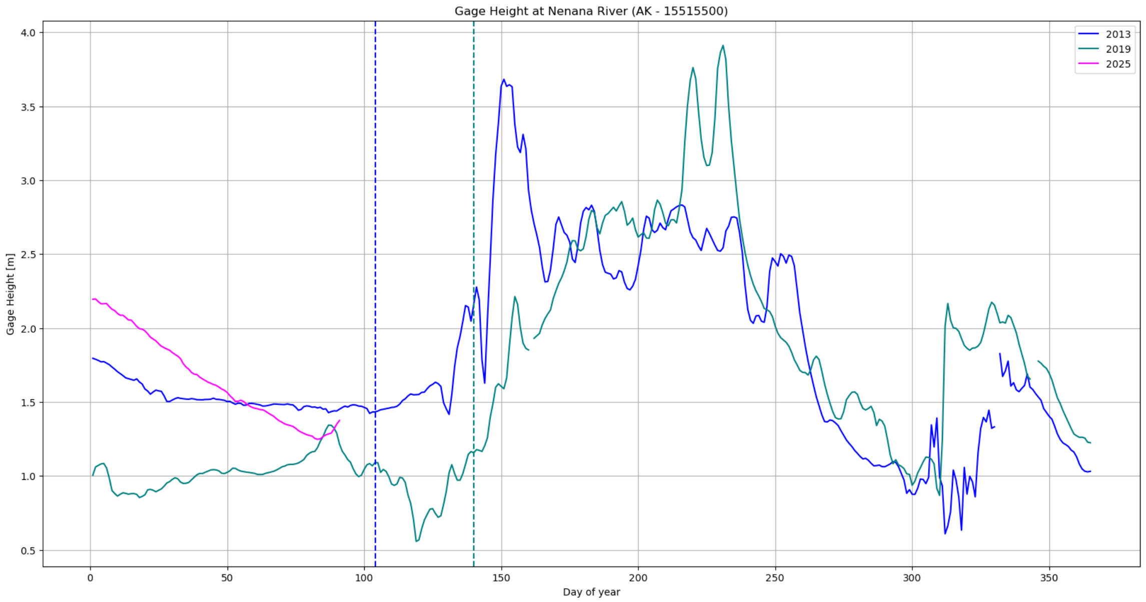
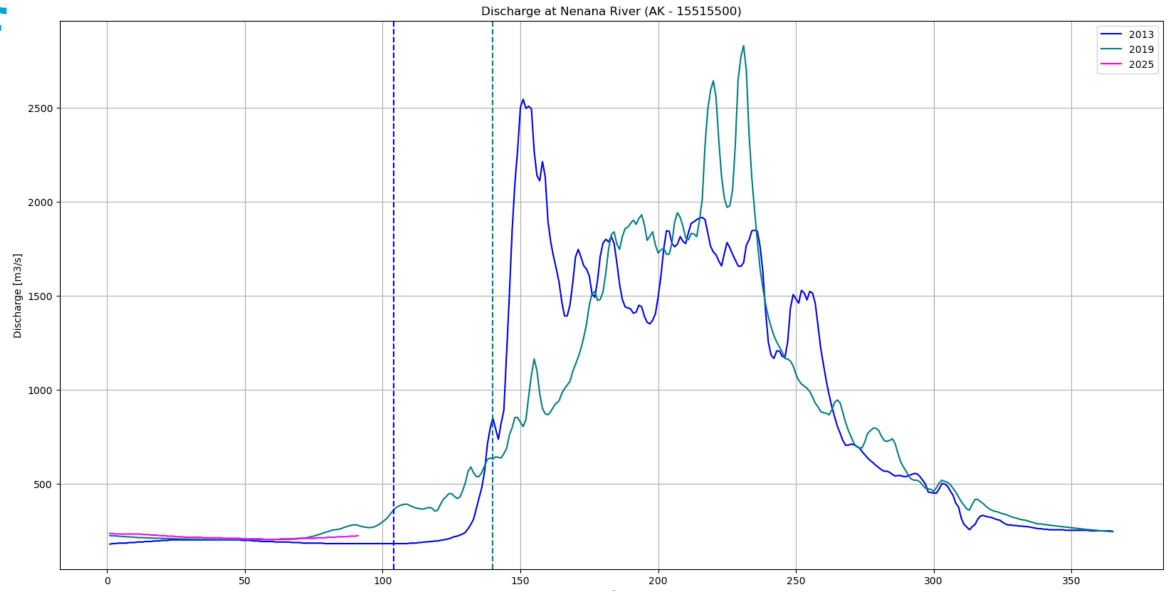
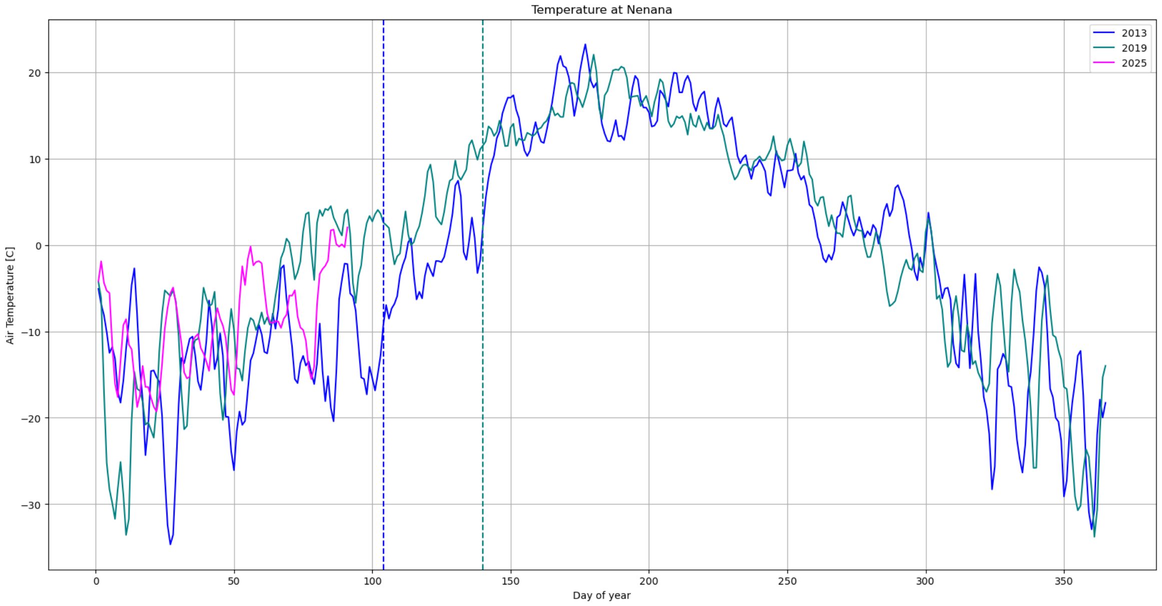
Hypothetical Information for 2025

Task 2: Modelling Ice Breakup

- Hypothetical situation, April 2025 (red line)
- Compared with 2013, 2019
  (breakup indicated in dashed lines during those years)







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Hypothetical Information for 2025

Task 2: Modelling Ice Breakup

Using the information on the previous slides…

Imagine its April 1, 2025 and you need to submit your prediction/ticket for the Nenana Ice Classic:

- In addition to the hypothetical information on the slides immediately before this one, you observe that:
  - There was more snow than average
  - The 10-day forecast indicates there will be an average temperature of -2 C, but there are 2 days which could rise above 0 C during the daylight hours
  - The most recent ice measurement is 1.1 m, but the maximum measurement (a couple weeks ago) was 1.4 m

Task 3: Make a Prediction for the 2025 competition!

>>> There are some “ice experts” in each classroom to help you interpret the data and reason through the prediction

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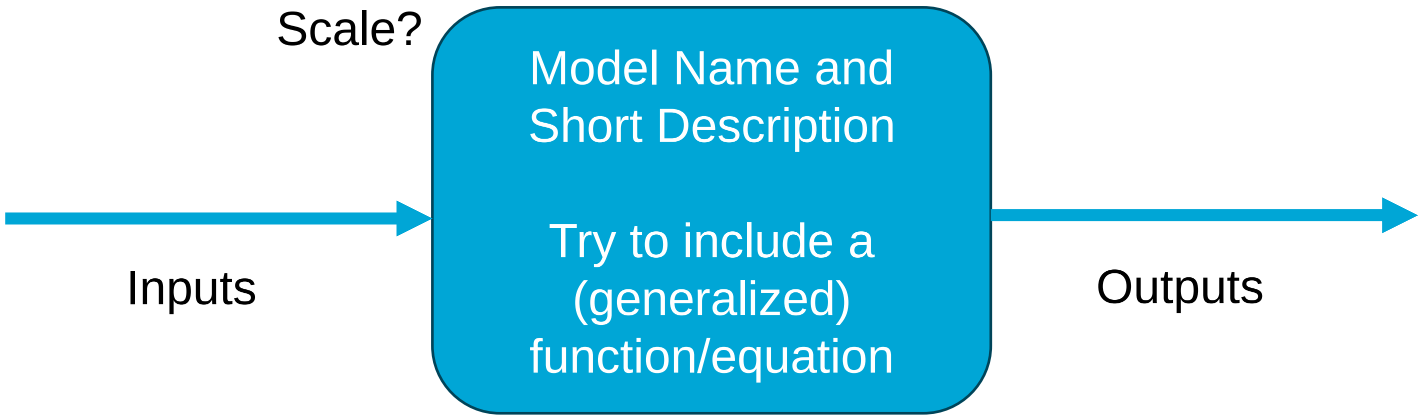
Task 3: Improving the Model

- Now that you are familiar with the data that is available and have already been given a hint of some key relationships, we want you to give a recommendation on how we can better predict when breakup occurs.
- For this task: *describe a model of a specific physical process or variable of interest that can be used to better predict the **day** of ice breakup. Imagine that there are no restrictions on complexity or cost.*
- *Include:*
  - Short description of the model, as well as a generalized equation (if possible)
  - A diagram of the model (see template on next page). If your model is complex, you can break it down into sub-models (using several instances of the diagram)
  - A description of the model Classification, Decisions, Inputs/outputs
- Finally, reflect for a few minutes and answer this:

Identify the least feasible part of your model in terms of cost/complexity/accuracy. What are the primary limitations?

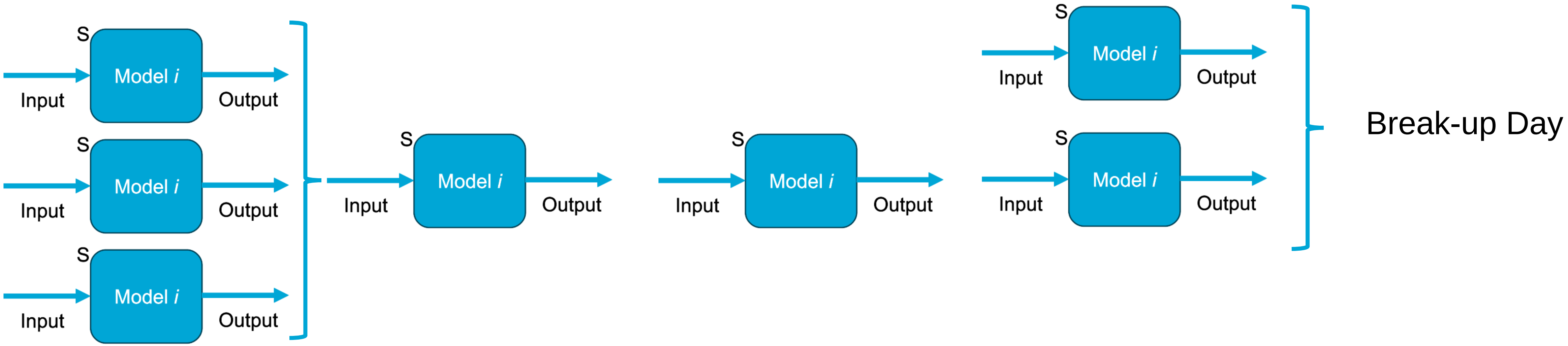
Task 3: Improving the Model

- You can use this template to represent your model, or sub-components of your model
- Specify classification and decisions
- Try to illustrate the entire system from Global to Local by putting together multiple models (connecting inputs/outputs) … see next page



Task 3: Improving the Model

- Here is a suggestion for how you might be able to Illustrate the subcomponents of your model



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