

# Cryosphere and related hazards in High Mountain Asia in a changing climate

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## Analysis of temporal trends, changes in spatial distribution and meteorological thresholds of GLOF and debris flows in Central Asia: Tools for practitioners

# Background

**Funding:** UK Research and Innovation, 2021 – 2022, project “Bridging over troubled waters: Improving preparedness and reducing vulnerability to debris flow in Central Asia”

**Aim:** To improve decision making and enhance policies on reduction of risks and vulnerability to glacier lake outburst floods (GLOF) and debris flow (DF) in Central Asia (CA).

Risk management strategies are based on risk avoidance and availability of short-term meteorological and hydrological forecasts. Both require detailed information about location of DF sources (existing and potential), settlements and infrastructure, topography, characteristics of landcover and its evolution, sediment availability, timing of observed DF, and meteorological thresholds resulting in their formation.

## **Objectives:**

- Develop online database of debris flow
- Analyse meteorological factors of debris flow formation
- Develop and make available software for analysis of meteorological data

# Current state of DF research in

## + Kazakhstan

The nature of mudflow phenomena, mechanism of formation and movement of mudflows, physical and mechanical properties of mudflow material have been studied

The mudflow hazard potential in the mountains and foothills has been assessed, the overview map of mudflow-susceptible areas has been created;

Methods of the regional forecast of mudflows are developed, criteria of formation of mudflows, methods of determination of characteristics of mudflows are established;

The methodological documents on the mudflow problem have been prepared;

New devices to automatically measure the characteristics of mudflows during their movement, as well as devices for automatic warning of a moving mudflow are being created ;

New designs of mudflow protective structures have been developed

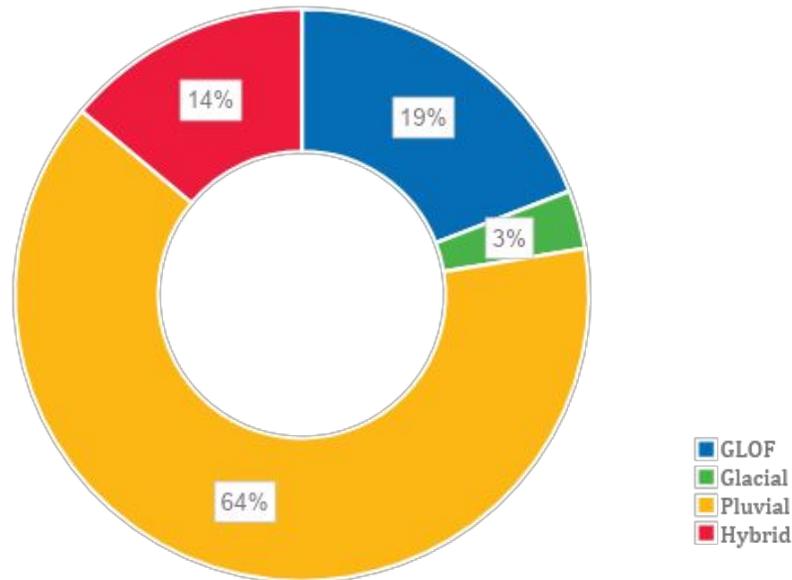
— The greatest success has been achieved in solving issues related to the nature of mudflow phenomena and determining their qualitative characteristics. The results of determining the quantitative characteristics of mudflows are much more modest;

There are no uniform regulatory documents on the design of mudflow protective measurements;

There are no scientifically-based standards for mudflow protective projects, clear instructions regulating the construction of mudflow protective structures and the conduct of various mudflow protective measurements.

# DF in Kazakhstan (central Ile Alatau)

Types of DF in the Central part of Ile Alatau



Types of DF	Triggering mechanism	DF count	Percentage (%)
GLOF	High air temperatures, moraine dam failure	<b>86</b>	19.1
Glacial	High air temperature, high runoff from glacier surfaces leading to oversaturation of substrate but not to GLOF	<b>15</b>	3.3
Pluvial	Intensive and / or prolonged rainfall	<b>288</b>	63.7
Hybrid	Combination of strong rainfall and high air temperature facilitating snow melt in the non-glacierized areas	<b>63</b>	13.9
<b>Total</b>	-	<b>452</b>	

# Mudflow risk management

## tools

Timely notification of the population, continuous analysis and warning of mudflows requires the preparation of a regularly updated database indicating the exact location of the hazardous object (mudflow center and / or moraine lake, intra moraine canals) and information about past hazards with calculated characteristics, causes of formation and damage. In decisions made of preventing mudflow phenomena, the spatial aspect of information is important where it is necessary to assess the general condition of the hazardous facility, its location, and the size of the impending threat. For such purposes in the world are used various geographic information database systems. GIS applications provide a detailed analysis of all social, economic and topographical features that affect the economy of a particular area.



Characteristics of mudflow centers



Analysis of the influence of meteorological elements on the mudflow formation

Evaluated characteristics of mudflows (retrospective analysis)

Photos from different years, it should be replenished

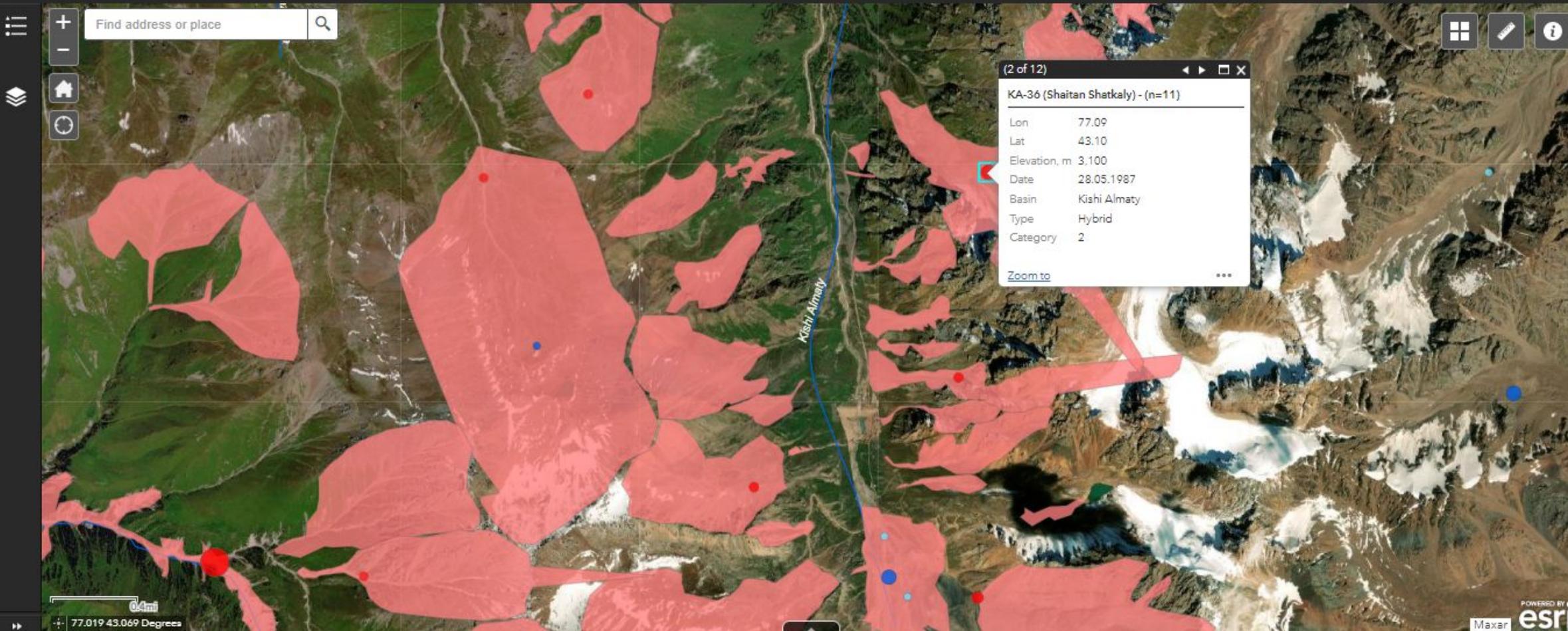


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https://uordg.maps.arcgis.com/apps/webappviewer/index.html?id=7c1ae91917294b029bf838d5368dc4f8

### Information Platform: GLOF and Debris Flow





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https://uordg.maps.arcgis.com/apps/webappviewer/index.html?id=7c1ae91917294b029bf838d5368dc4f8

## Information Platform: GLOF and Debris Flow

Find address or place

KA-26 (Mayakovskogo)

Name	KA-26 (Mayakovskogo)
Catchment	Kishi Almaty
Type	5
Area_km2	1.06
Length_m	1,801.00
Width_m	967.00

Attachments:  
[20210924\\_151335.jpg](#)

[Zoom to](#)

0.2mi  
77.072 43.062 Degrees

Maxar esri

# DF-Met :

- App enabling statistical analysis of meteorological data (versions in C# and Python)
- Users do not require programming skills
- Input data:
  - Daily temperature and / or precipitation
  - Station altitude
  - A record of DF
- Output data:
  - **Degree Day Temperature** (sum of  $t > 0^{\circ}\text{C}$ ) and **cumulative precipitation**(CP) for any day of the year for number of days specified by user
  - Frequency distributions of DDT and CP any day of the year showing rankings of a day specified by the user and days on which DF events were observed in the past.
  - **Water Supply Intensity** (WSI) statistics for **Intensity-Duration threshold** calculation

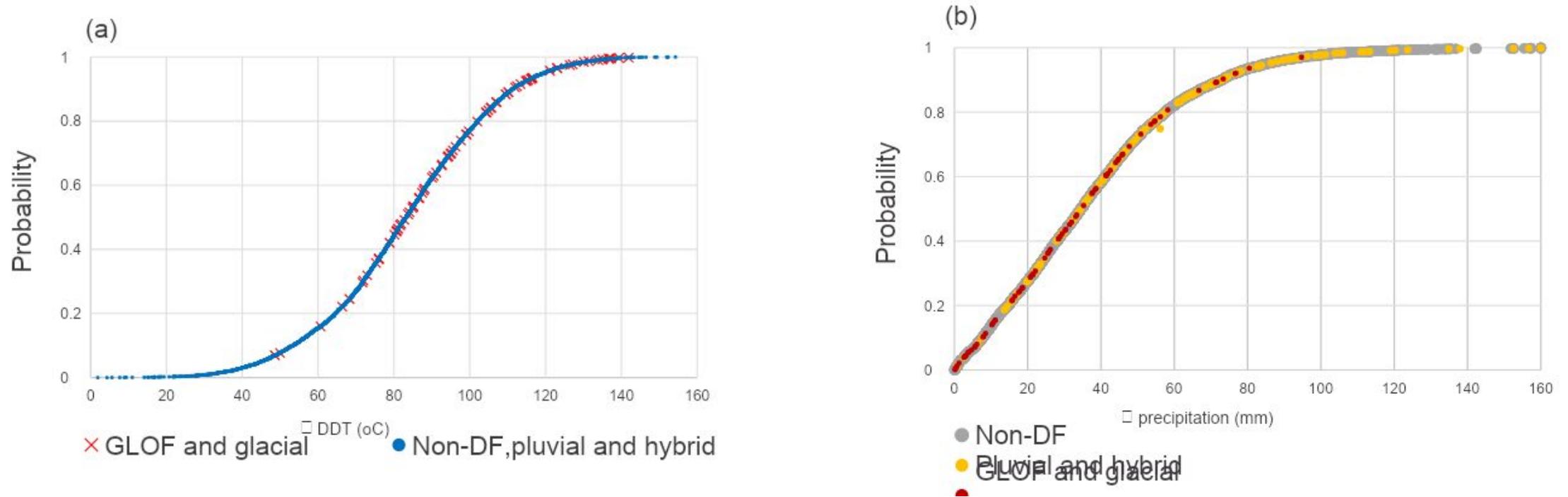
The screenshot displays the DF-MET application interface. At the top, there is a menu bar with 'Menu' and 'Other Functionality'. The main area contains several input fields and checkboxes:

- Choose a file for data:** A file selection button.
- Choose the number of the sheet which contains your data:** A dropdown menu with the value '2' selected.
- Choose a file for debris flow:** A file selection button.
- Choose the number of the sheet which contains your pluvial/hybrid debris flow dates:** A dropdown menu with the value '1' selected.
- Choose the number of the sheet which contains your glacial debris flow dates:** A dropdown menu with the value '2' selected.
- Include Day?
- Maximum?
- Single Day? 30 October 2022
- Start Day:** 01 January 1936
- End Day:** 30 October 2022
- Write the number of cumulative days:** 10

At the bottom, there is a dropdown menu for 'Precipitation' and a 'Run' button.

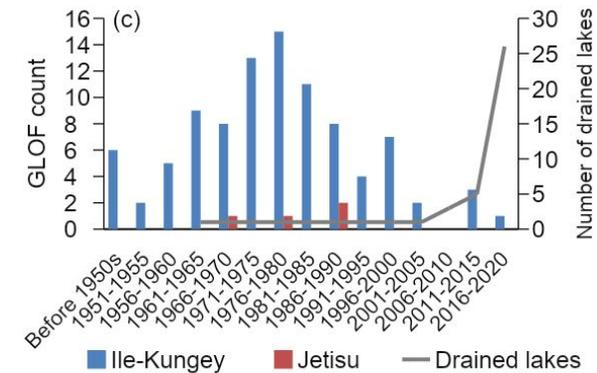
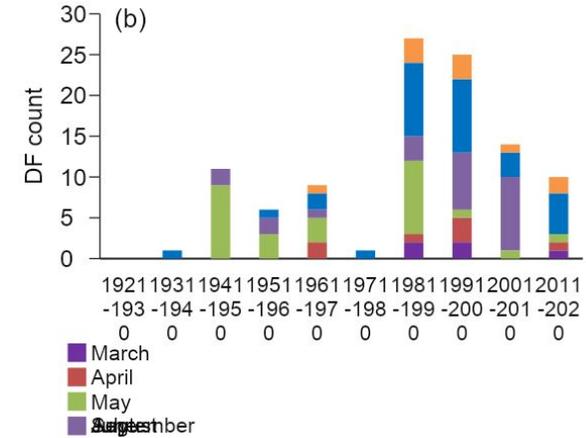
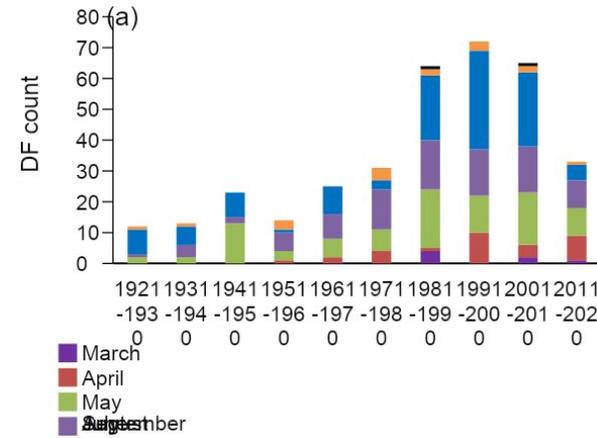
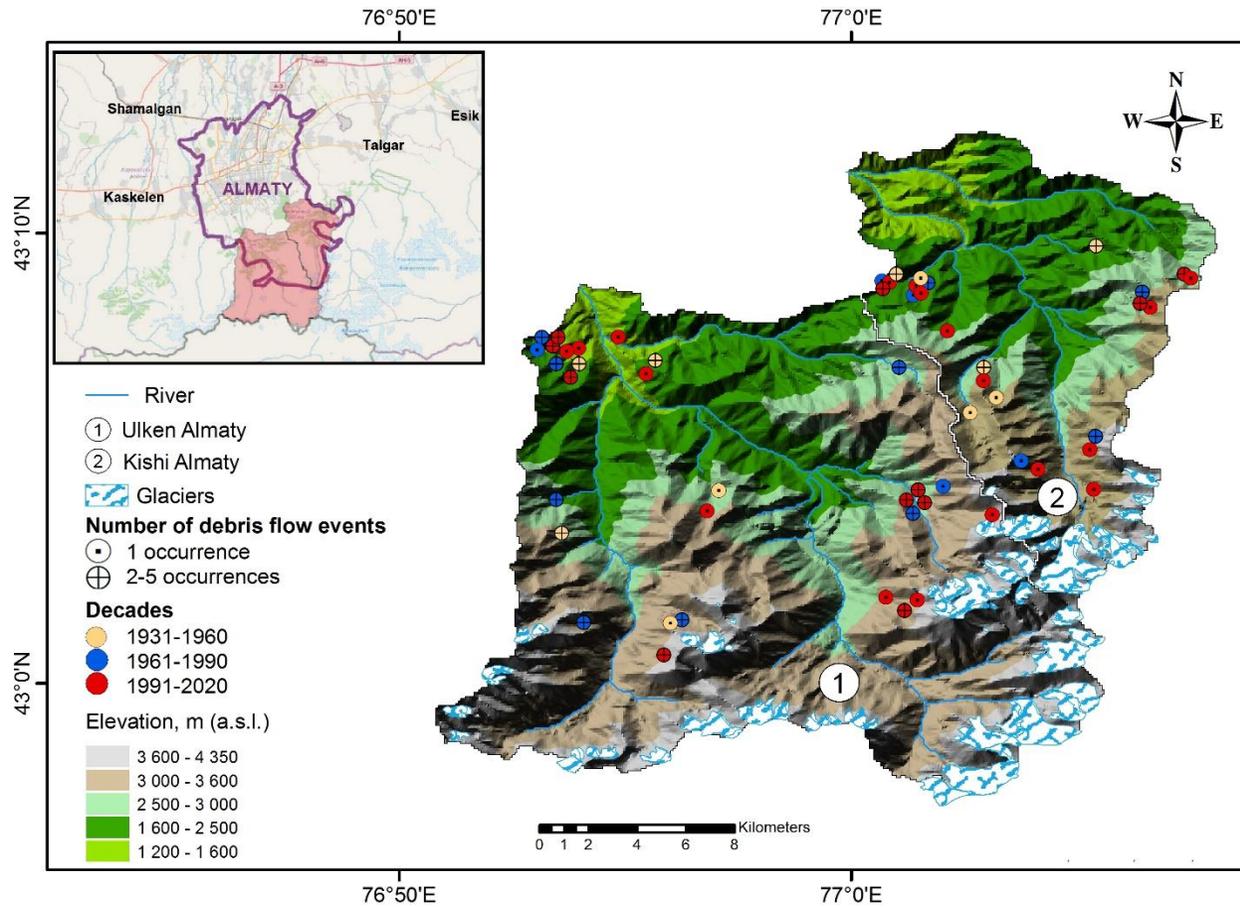
The logo banner on the right side of the interface includes the University of Reading logo, the GGM (Centre of Glacial Geology) logo, and the CARGC logo. Below the logos, the text reads: 'DF-MET Meteorological Indices for Analysis and Forecast of Debris Flow Formation'.

# 10-day sums of DDT and non-zero 10-day sums of precipitation in JJA derived from a sample containing days with and without DF



Index	Temperature					Precipitation				
	Pluvial	Hybrid	GLOF	Glacial	No DF	Pluvial	Hybrid	GLOF	Glacial	No DF
N days	119	35	64	18	7463	121	35	68	18	7687
Mean	81.8	83.3	<b>95.7</b>	<b>110.6</b>	82.1	<b>63.1</b>	45.6	32.0	14.3	37.1

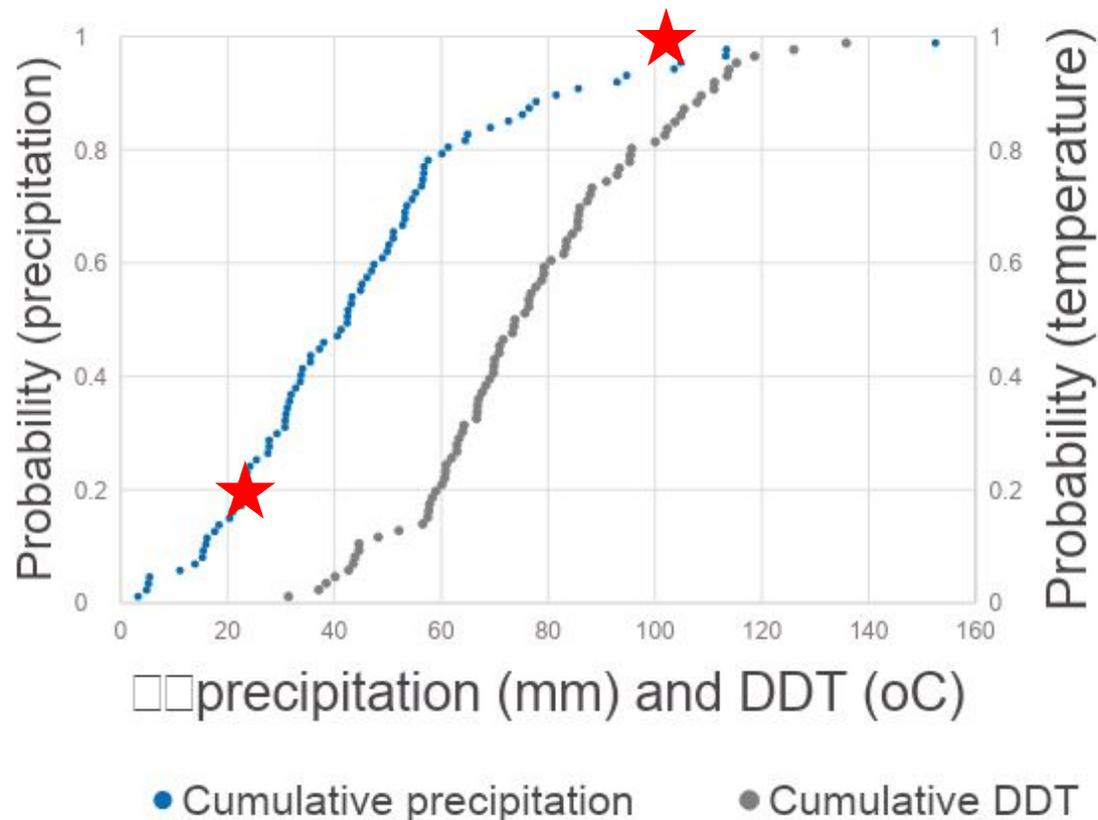
# Results: Spatio-temporal distribution of DF



Changes in the occurrence of (a) pluvial, (b) hybrid and (c) GLOF DF

Spatial distribution of DF:  
Increase in elevation 1991-2021

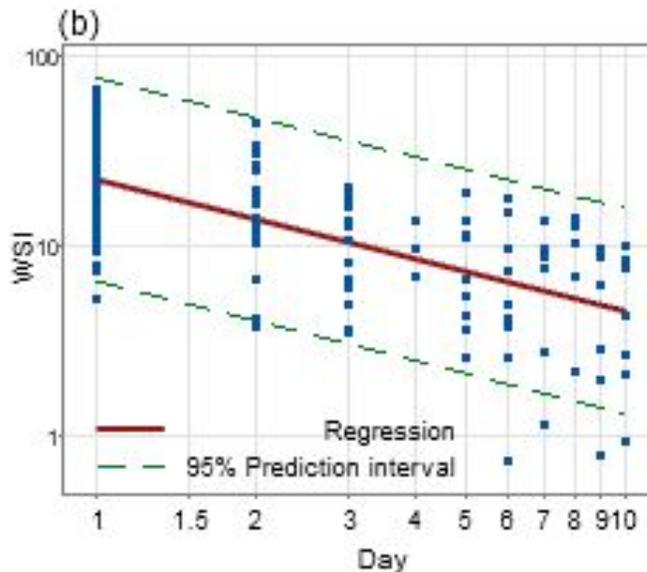
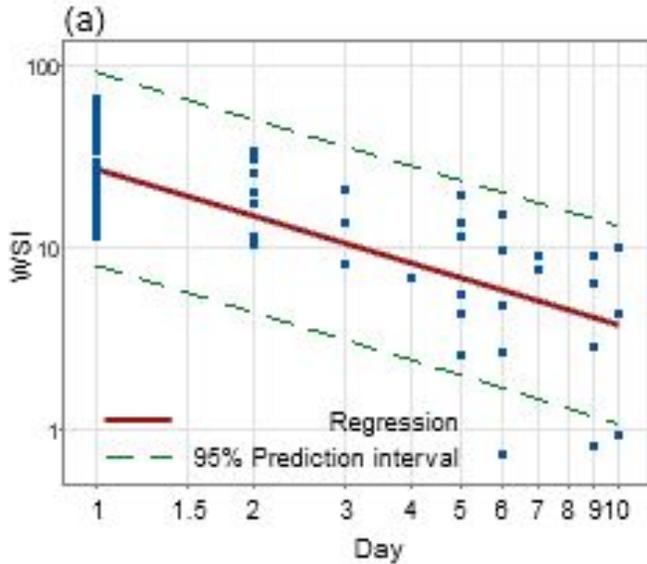
# Cumulative distribution functions (CDF) of 10-day DDT and CP for a selected day



- How close are DDT and CP on a given day to those observed on days with DF?
- CDF can be calculated for any day of the year using all available observations for a given day
- Example: 6 June 1936-2021 using meteorological data from BAL and Mynzhylki stations
- Symbols: GLOF of different types observed on 6 June between 1936 and 2021

★ 6 June 2021: DDT ( $101^{\circ}\text{C}$ ) at 99% derived from all 6 June days in 1936-2021 indicating high risk of GLOF. CP (22.8 mm) is at 18% probability indicating low risk pluvial DF.

# Intensity – duration thresholds for pluvial DF initiation in (a) Ulken and Kishi Almaty and (b) Aksai



Catchment	Number of events	Regression equation	R <sup>2</sup>	P value
KA, UA	87	$WSI = 27.209 * D^{-0.865}$	0.56	< 0.001
Aksay	213	$WS = 22.473 * D^{-0.691}$	0.45	<0.001

WS – water supply intensity (mm per day); Duration (days)

50% probability of 10-day WSI capable of triggering DF in Ulken and Kishi Almaty catchments

Day 1 - 28 mm day<sup>-1</sup> (full range 11-65 mm day<sup>-1</sup>)

Day 5 - 11 mm day<sup>-1</sup>

Day 10 - 7 mm day<sup>-1</sup>

# Conclusions

- **All known GLOF events in the northern Tien Shan and Jetysu Alatau**
- **DF events registered in the central Ile Alatau**
- **Online platform developed using ArcGIS Online (URL) including coordinates, elevation, date of occurrence, and antecedent 10-day DDT and precipitation**
- **The platform is designed to provide quick access to the data without any specialized software**
- **The platform will be updated and expanded regularly and will eventually include data from other regions of the Tien Shan**

# Thank you

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