ESA Climate Detectives

Tianran Wang, Chawanvit Tangwongsiri, Haolin LIU, BOGOLYUBOV Grigoriy
LAZARD Serena, OZYEGIN Yaz, and VON SCHWEICKHARDT Antoinette

Project title

The Combined Effects of Seasonal Temperature Variation and Tourism on Avalanche Activity in Davos, Switzerland

Research question

How do monthly temperature variations and levels of winter tourism influence the frequency and type of avalanches in Davos, Switzerland?

Introduction

Avalanches definition

Avalanche impact

Why it matters for Davos

Research question

Dry avalanche

- Common in winter when temperatures are below freezing.
- Usually starts from a weak layer of snow beneath a slab.
- Triggered by: new snowfall, wind-loading, or human activity (e.g., skiers).
- Travel very fast (up to 300 km/h) and can be extremely destructive.
- Produce a powder cloud that can suffocate people even without direct impact.
- Less dense than wet avalanches.

Wet avalanche

- Happen during warmer weather, especially in spring or during rain.
- Caused by meltwater or rainwater weakening the snowpack.
- Slower-moving (usually 15–60 km/h) but carry more mass and debris.
- Often natural triggers, less human-triggered than dry avalanches.
- Very destructive due to weight and volume.
- Leave behind a dense, cement-like debris field.

Comparison

- Dry = Fast + Powdery + Cold Weather
- Wet = Slow + Heavy + Warm Weather

Factors that influence avalanches

WEATHER (TEMPERATURE, PRECIPITATION, ETC.)

VEGETATION

HUMAN ACTIVITY (TOURISM)

Survey distribution

Survey distribution in school

Quick Quiz on Avalanche Safety

WT

WANG Tianran <Tianran... Thursday, March 6, 2025 at 7:40 AM

To: **Liste des eleves 5-T; Liste des professeurs**

Dear All,

I hope you had a great skiing season, especially with yesterday being the final day on the slopes. I invite you to take a quick anonymous quiz as part of the ESA Climate Detectives project to gather research on avalanche safety.

Your participation contributes valuable data and enhances our understanding of avalanche safety. Please click the link below to start: Quiz link

This quiz takes less than a minute. After submitting, you'll see which questions you missed, allowing you to learn more about avalanche safety. An infographic will also be provided post-quiz to summarize the results and share important safety tips.

Thank you for your support in this initiative. If you have questions, feel free to reach out.

Best regards,
Tim Wang

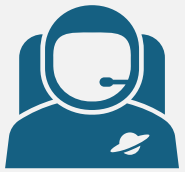
Tourism vs Avalanche Frequency

Data from 2013–2019

Tourism data: overnight stays and arrivals from the Swiss Federal Statistical Office

Avalanche data: human-triggered avalanches from EnviDat

Temperature vs Avalanche Type and frequency



DATA FROM NASA MODIS (DAYTIME AND NIGHTTIME LAND SURFACE TEMPS)

USED PYTHON, NUMPY, PANDAS, XARRAY

Temperature Analysis Coding (1)

[1]:
```
# Libraries for working with NetCDF format
import pandas as pd
import xarray as xr
```

[2]:
```
# Open NetCDF dataset and convert the time to use Pandas' Datetime class
dataset = xr.open_dataset('data/observations.nc')
dates = pd.to_datetime(dataset['time'].dt.strftime('%Y-%m-%d'))
dataset = dataset.assign_coords(time=('time', dates))
```

[3]:
```
# Create a dataframe to hold all new data
df = pd.DataFrame({
    'date_release': dataset['time'],
    # Mean of all temperature values of different latitude and longitude
    'lst_day': dataset['LST_Day_1km'].mean(dim=['lat', 'lon'], skipna=True),
    'lst_night': dataset['LST_Night_1km'].mean(dim=['lat', 'lon'], skipna=True)
})

# Calculate the temperature difference
df['temp_diff'] = df['lst_day'] - df['lst_night']

# Sort it by date
df = df.sort_values(by='date_release').reset_index(drop=True)
df.head()
```

[3]:

	date_release	lst_day	lst_night	temp_diff
0	2000-02-24	NaN	263.551304	NaN
1	2000-02-25	264.647892	263.304679	1.343213
2	2000-02-26	268.407157	262.688196	5.718961
3	2000-02-27	270.189265	263.259348	6.929917
4	2000-02-28	271.989118	264.847696	7.141422

[4]:
```
# Open the CSV avalanche dataset
avalanche = pd.read_csv('data/avalanche.csv')

# Converting the date release type to use Pandas' Datetime class
avalanche['date_release'] = pd.to_datetime(avalanche['date_release'],␣
 ↪dayfirst=True)
avalanche.head()
```

[4]:

	date_release	snow_type	trigger_type	max_elevation_m	min_elevation_m	\
0	1998-11-06	dry	NATURAL	2476.0	2439.0	
1	1998-12-07	dry	NATURAL	2562.0	2484.0	
2	1998-12-07	dry	NATURAL	2494.0	2356.0	
3	1998-12-07	dry	HUMAN	2115.0	2017.0	
4	1998-12-07	dry	NATURAL	2085.0	1986.0	

	aspect_degrees	length_m	width_m	perimeter_length_m	area_m2	\
0	4.0	63.0	33.0	168.0	1413.0	
1	42.0	101.0	123.0	355.0	8762.0	
2	21.0	127.0	351.0	834.0	30522.0	
3	200.0	166.0	85.0	454.0	7837.0	
4	42.0	128.0	18.0	265.0	1522.0	

	aval_size_class	weight_AAI	max.danger.corr
0	2	0.1	NaN
1	2	0.1	3.0
2	3	1.0	3.0
3	2	0.1	3.0
4	2	0.1	3.0

[5]:
```
# Merge the avalanche dataset with the dataframe holding new data
data = avalanche.merge(df, on='date_release', how='left')

# Save it as `build/daily.csv`
data.to_csv('build/daily.csv')
```

[6]:
```
# Redo the merging for monthy data
data = avalanche.merge(df, on='date_release', how='left')

# Filter the following values out the dataset:
# trigger_type: UNKNOWN, DESTRUCTIVE
# snow_type: mixed, unknown
data = data.loc[~data['trigger_type'].isin(['UNKNOWN', 'DESTRUCTIVE'])]
data = data.loc[~data['snow_type'].isin(['mixed', 'unknown'])]

# Convert the date in dataset to only contain year and month
data['date_release'] = data['date_release'].dt.to_period('M')

# Filter out two dataset containing only the dry/wet data
dry_data = data[data['snow_type'] == 'dry']
wet_data = data[data['snow_type'] == 'wet']

# Calculate the monthly count of dry/wet data
dry_count = dry_data.groupby('date_release').size().
↪reindex(data['date_release'].unique(), fill_value=0)
```


Temperature Analysis Coding (2)

```
wet_count = wet_data.groupby('date_release').size().
  ↪reindex(data['date_release'].unique(), fill_value=0)

dry_count.head()
```

[6]:
```
date_release
1998-11     1
1998-12    37
1999-01    14
1999-02    27
1999-03     5
Freq: M, dtype: int64
```

[7]:
```
# Set new subsets dry_count/wet_count
data['dry_count'] = data['date_release'].map(dry_count)
data['wet_count'] = data['date_release'].map(wet_count)

# Mean all numeric values in each subsets between a month to remove duplicate␣
  ↪month
data = data.groupby('date_release').mean(numeric_only=True)

# Reindex to start from 0 and save to `build/monthly.csv`
data.reset_index().to_csv('build/monthly.csv')
data.head()
```

[7]:

date_release	max_elevation_m	min_elevation_m	aspect_degrees	length_m
1998-11	2476.000000	2439.000000	4.000000	63.000000
1998-12	2362.886364	2261.431818	185.454545	150.250000
1999-01	2373.642857	2275.214286	169.214286	153.428571
1999-02	2473.928571	2372.178571	159.178571	158.642857
1999-03	2238.444444	2106.611111	146.555556	221.222222

date_release	width_m	perimeter_length_m	area_m2	aval_size_class
1998-11	33.000000	168.000000	1413.000000	2.000000
1998-12	71.136364	408.977273	7111.590909	2.068182
1999-01	38.642857	346.357143	4244.000000	2.142857
1999-02	63.571429	406.821429	7224.642857	2.071429
1999-03	76.555556	539.722222	12057.055556	2.000000

date_release	weight_AAI	max.danger.corr	lst_day	lst_night	temp_diff
1998-11	0.100000	NaN	NaN	NaN	NaN
1998-12	0.198182	2.909091	NaN	NaN	NaN
1999-01	0.228571	2.785714	NaN	NaN	NaN
1999-02	0.164286	3.607143	NaN	NaN	NaN

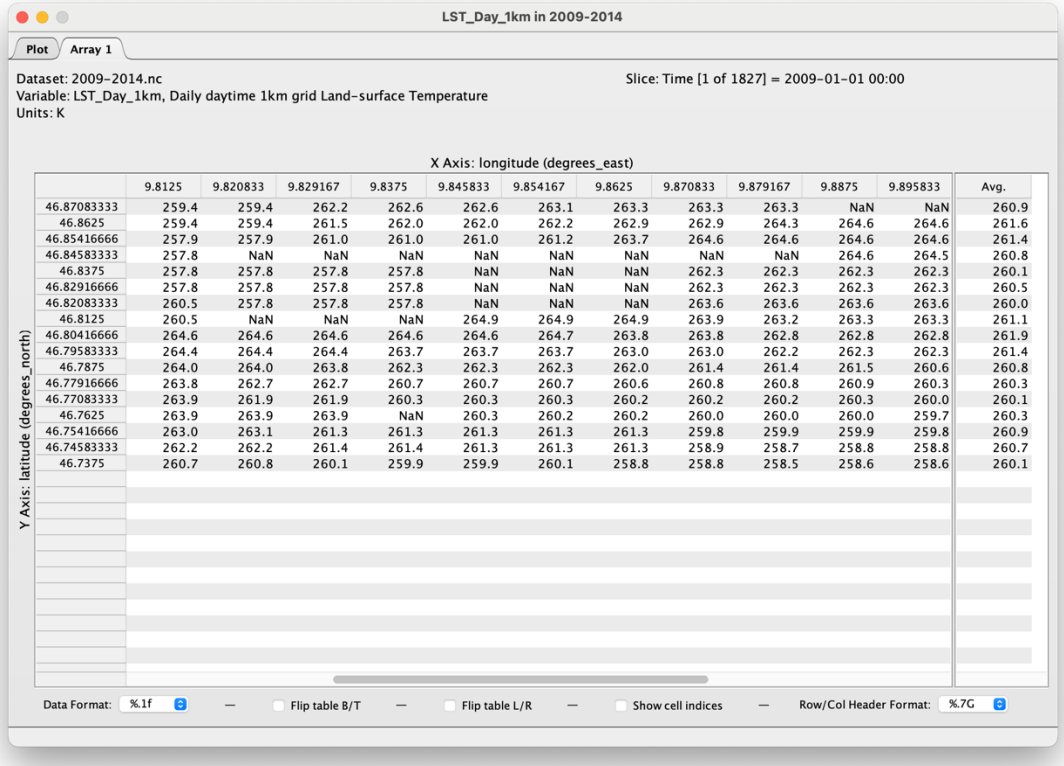
Temperature Analysis Coding (3)

Temperature Analysis Coding (5)

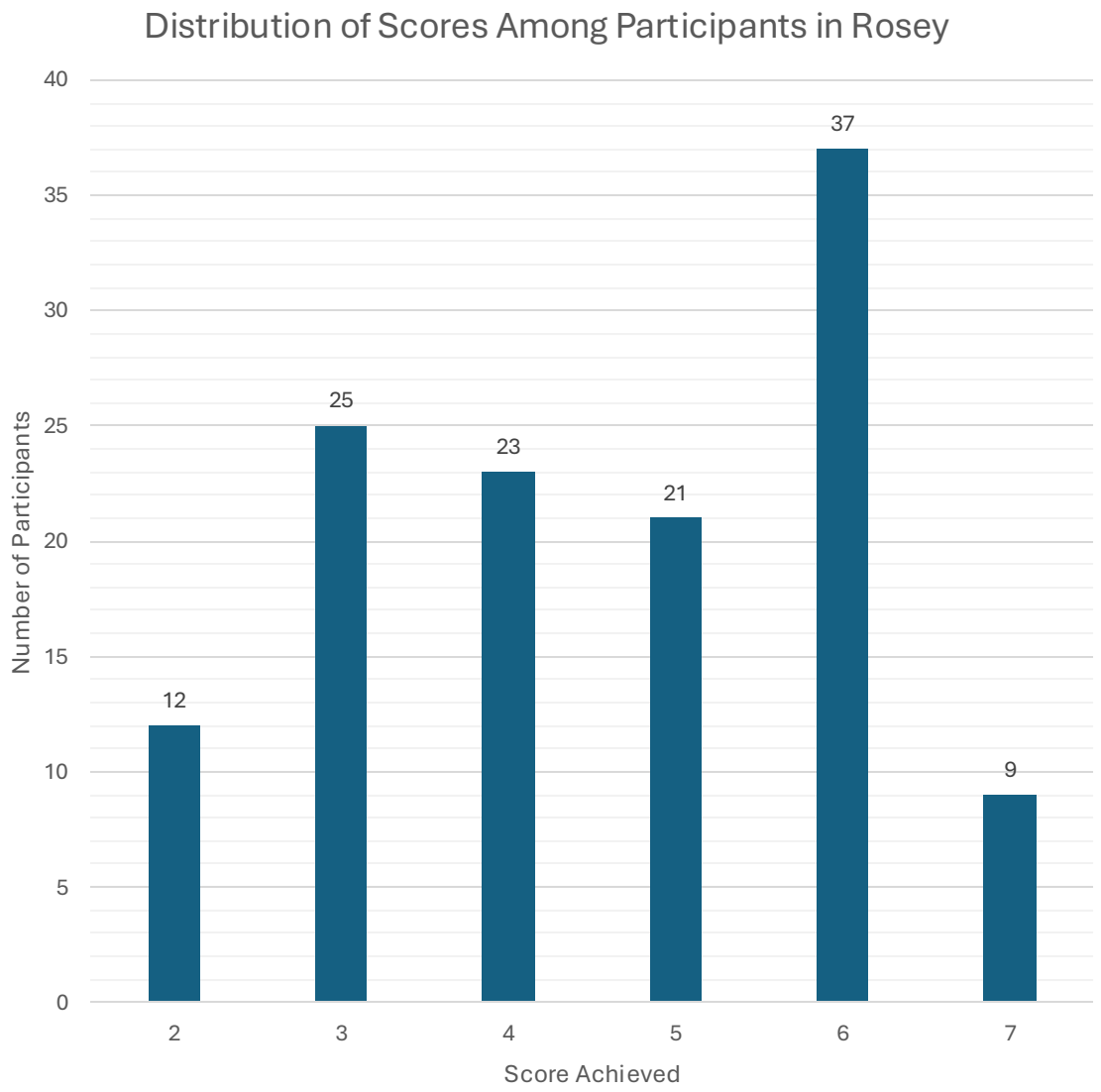
```
1999-03         0.235000         2.722222       NaN         NaN         NaN

              dry_count  wet_count
date_release
1998-11             1.0        0.0
1998-12            37.0        7.0
1999-01            14.0        0.0
1999-02            27.0        1.0
1999-03             5.0       13.0
```

Visual method (Panoply)

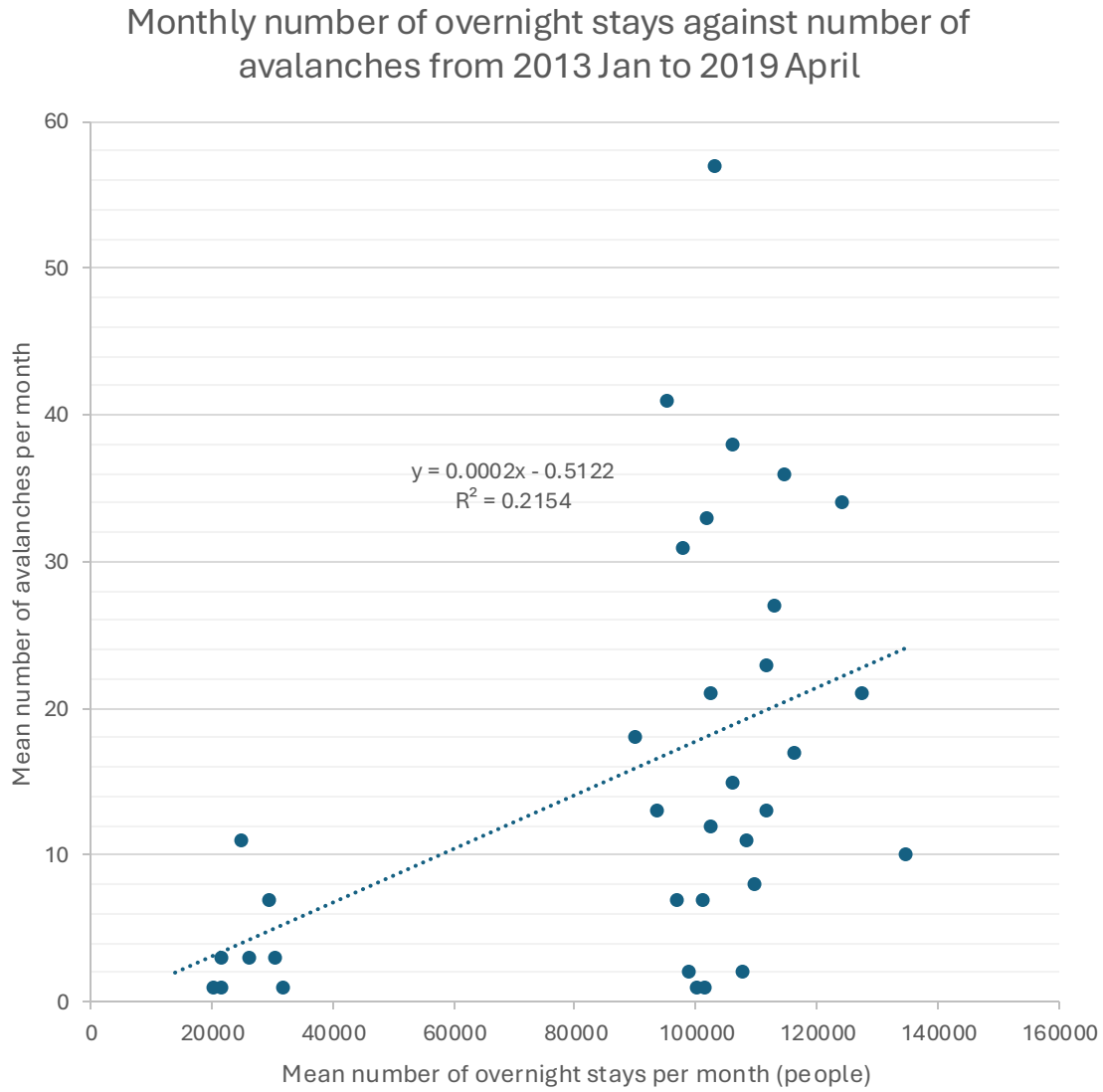


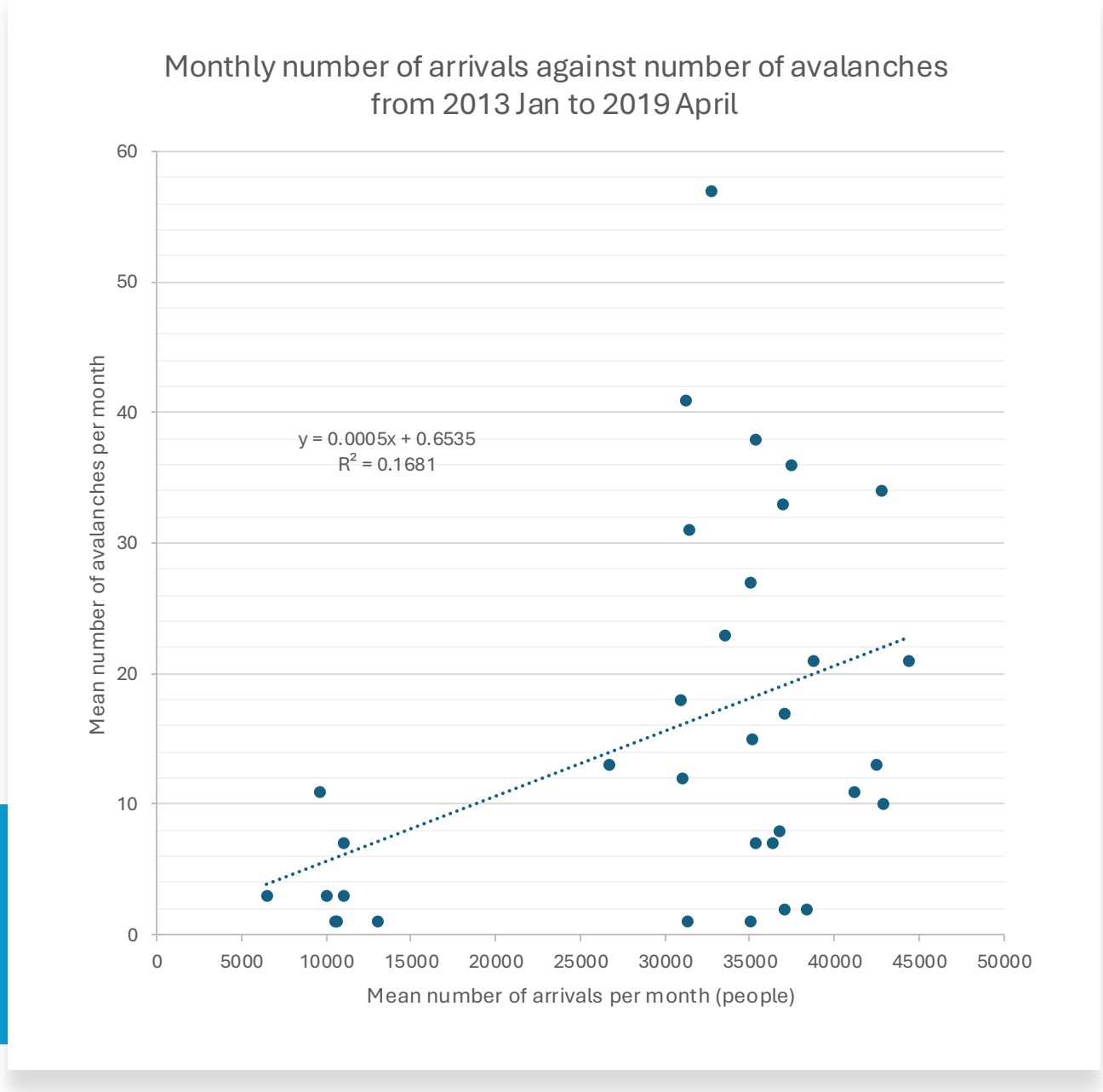
	9.8125	9.820833	9.829167	9.8375	9.845833	9.854167	9.8625	9.870833	9.879167	9.8875	9.895833	Avg.
46.87083333	259.4	259.4	262.2	262.6	262.6	263.1	263.3	263.3	263.3	NaN	NaN	260.9
46.8625	259.4	259.4	261.5	262.0	262.0	262.2	262.9	262.9	264.3	264.6	264.6	261.6
46.85416666	257.9	257.9	261.0	261.0	261.0	261.2	263.7	264.6	264.6	264.6	264.6	261.4
46.84583333	257.8	NaN	NaN	NaN	NaN	NaN	NaN	NaN	NaN	264.6	264.5	260.8
46.8375	257.8	257.8	257.8	257.8	NaN	NaN	NaN	262.3	262.3	262.3	262.3	260.1
46.82916666	257.8	257.8	257.8	257.8	NaN	NaN	NaN	262.3	262.3	262.3	262.3	260.5
46.82083333	260.5	257.8	257.8	257.8	NaN	NaN	NaN	263.6	263.6	263.6	263.6	260.0
46.8125	260.5	NaN	NaN	NaN	264.9	264.9	264.9	263.9	263.2	263.3	263.3	261.1
46.80416666	264.6	264.6	264.6	264.6	264.6	264.7	263.8	263.8	262.8	262.8	262.8	261.9
46.79583333	264.4	264.4	264.4	263.7	263.7	263.7	263.0	263.0	262.2	262.3	262.3	261.4
46.7875	264.0	264.0	263.8	262.3	262.3	262.3	262.0	261.4	261.4	261.5	260.6	260.8
46.77916666	263.8	262.7	262.7	260.7	260.7	260.7	260.6	260.8	260.8	260.9	260.3	260.3
46.77083333	263.9	261.9	261.9	260.3	260.3	260.3	260.2	260.2	260.2	260.3	260.0	260.1
46.7625	263.9	263.9	263.9	NaN	260.3	260.2	260.2	260.0	260.0	260.0	259.7	260.3
46.75416666	263.0	263.1	261.3	261.3	261.3	261.3	261.3	259.8	259.9	259.9	259.8	260.9
46.74583333	262.2	262.2	261.4	261.4	261.3	261.3	261.3	258.9	258.7	258.8	258.8	260.7
46.7375	260.7	260.8	260.1	259.9	259.9	260.1	258.8	258.8	258.5	258.6	258.6	260.1



Survey results

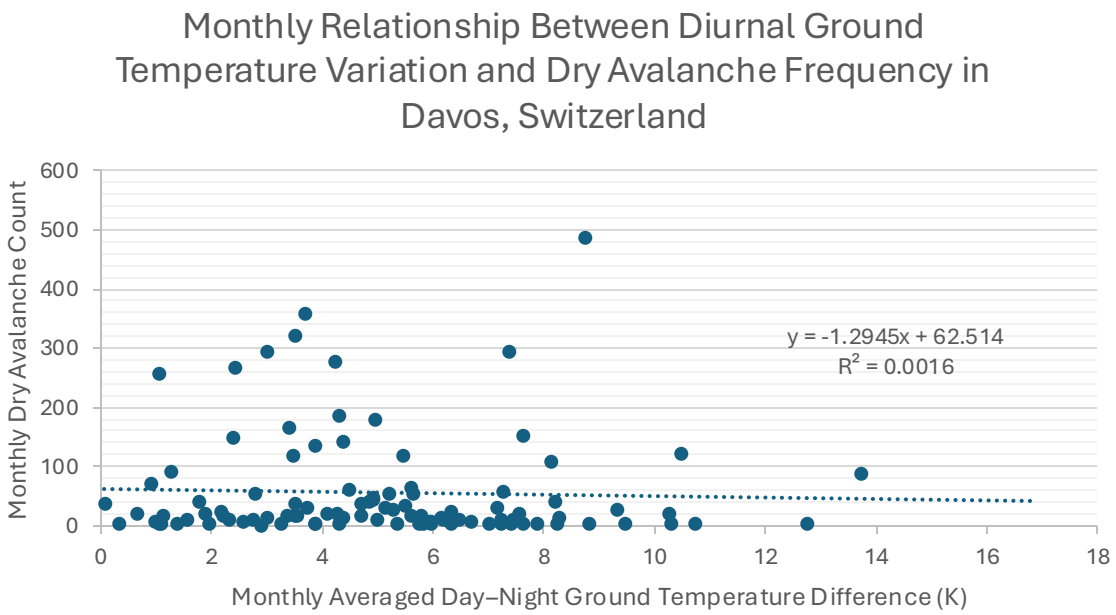
Tourism results (overnight stays)

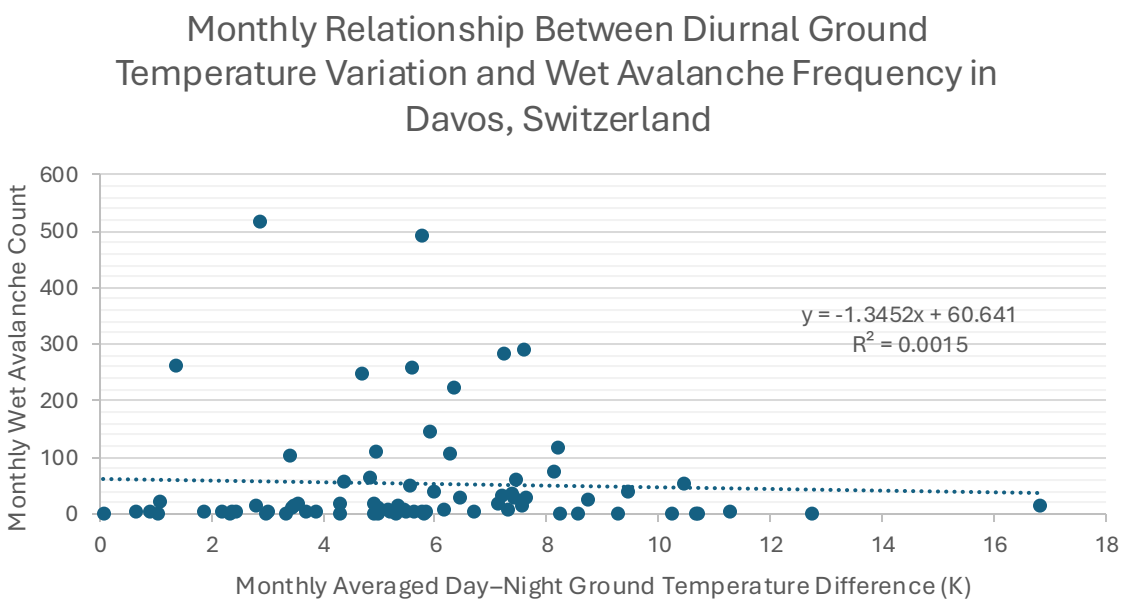




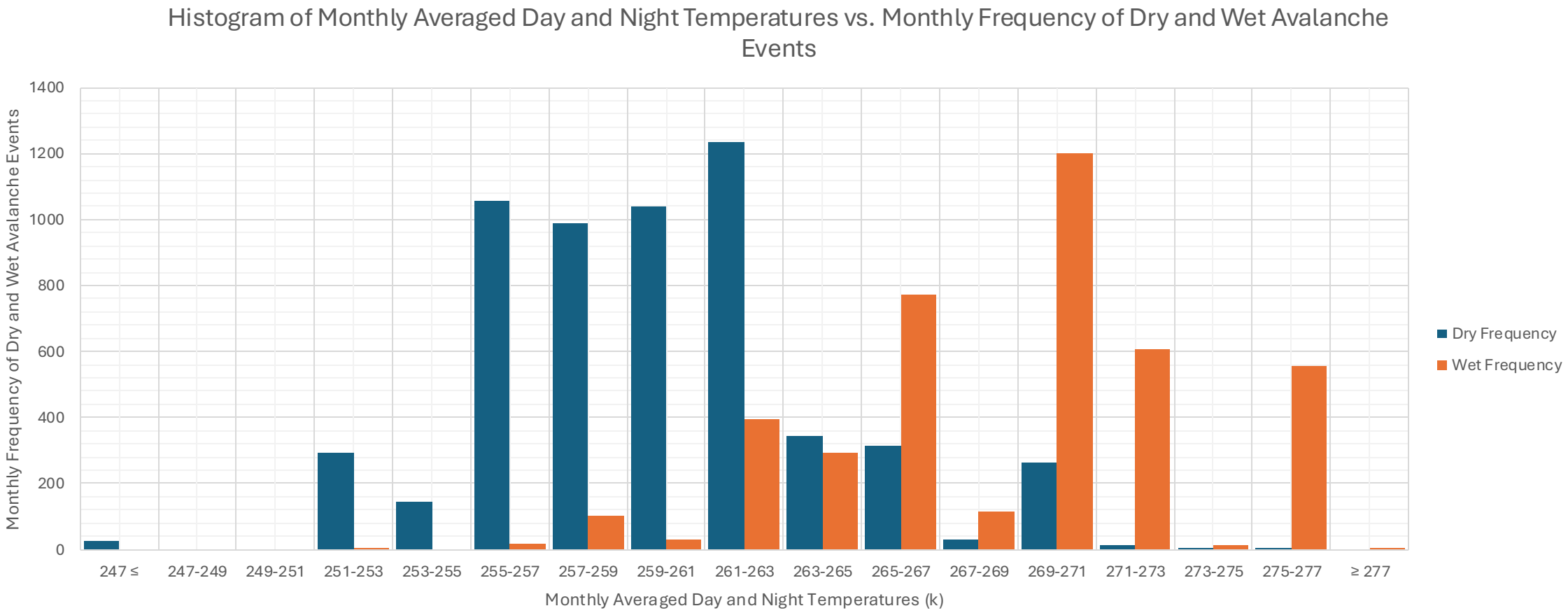
Tourism results(arrivals)

Temperature variation results





Average temperature results



Reliability of Swiss Tourism Data (FSO)

- Covers hotel arrivals & overnight stays by commune, month, and visitors' country.
- Adheres to strict quality standards under the Charter of Swiss Official Statistics.
- Rigorous validation and adherence to standards ensure high reliability despite missing explicit uncertainty measures.

Avalanche Data Reliability

Includes 13,918 avalanche records over 21 winter seasons.

Utilizes standardized observational methods and aligns with the European avalanche warning system.

Peer-reviewed research supports its reliability even without explicit uncertainty measures.

MODIS LST Uncertainty Propagation Calculations

Daily Uncertainty:

- Day: 0.1865 K (from 161 average valid pixels)
- Night: 0.0688 K (from 207 average valid pixels)

Diurnal Temperature Difference:

- Daily uncertainty: ~0.1988 K
- Propagated monthly uncertainty: ~0.0363 K

Histogram Data:

- Daily average uncertainty: ~0.0994 K; Monthly: ~0.0181 K
- *Caption note:* “Each bin is based on monthly averaged MODIS LST data with a propagated uncertainty of ±0.0181 K.”

Survey Data Conclusion

Many residents and tourists in high-risk avalanche areas lack knowledge about avalanche protection and survival.

Lack of awareness on necessary safety equipment; cost is a barrier, but training and subsidies could help.

Slope angle identification is an issue; recommend equipment or better slope signage for skiers.

People struggle to recognize avalanche sounds; videos/audio at resorts could improve awareness.

Few understand survival time limits when buried; safety training and proper gear are critical.

Tourism and Avalanche Frequency conclusion

- Weak positive correlations between tourism (overnight stays/arrivals) and avalanche frequency suggest human presence isn’t a major trigger.
- Natural factors (snowfall, temperature, slope stability) are primary drivers of avalanches.
- More tourists may lead to higher reporting, not necessarily more avalanches.
- Emphasizes need for public safety measures during peak tourist seasons.
- Future studies should include environmental controls (e.g., snowfall, terrain) for better predictions.

Temperature Analysis conclusion

- Diurnal ground temperature variation has negligible effect on avalanche frequency.
- Avalanche type shifts with overall temperature: dry avalanches at colder temps, wet avalanches more frequent above 267 K.
- Climate change may increase wet avalanches, which are more destructive.
- Long-term warming trends may affect snowpack and avalanche behavior.
- Future research should include other meteorological factors to enhance forecasting and risk mitigation.

Actions to be taken to make a difference

Increase tourist education on avalanche safety

Develop cheaper safety gear and tech (e.g. slope angle detectors)

Add video/audio safety briefings in ski resorts

Promote skiing in groups, using proper equipment

Further research

- Study additional factors like precipitation and wind.
- Include regions beyond Davos for broader insight.
- Use findings to improve avalanche forecasting and risk management.

Q&A