**Data:**

In this study, we utilized the latest global, long-term Freeze/Thaw Earth System Data Record (FT-ESDR, 1979–2021) available at the National Snow and Ice Data Center (NSIDC) (https://nsidc.org/data/nsidc-0477/versions/5). This dataset classifies frozen and thawed states (F/T) by comparing microwave brightness temperatures to a grid-specific threshold. This threshold is derived from an empirical linear regression that correlates brightness temperature with surface air temperature within each grid, employing the Modified Seasonal Threshold Algorithm (MSTA). MSTA enhances the consistency of F/T records from different microwave sensors—including the Scanning Multichannel Microwave Radiometer (SMMR), the Special Sensor Microwave/Imager (SSM/I), and the Special Sensor Microwave Imager/Sounder (SSMIS)—across four decades.

To ensure data precision, pixels exhibiting an open water fraction greater than 20% (impacting 17.17% of grids in Canada), an elevation gradient exceeding 300 meters (affecting 4.55% of grids), or both conditions (0.46% of grids) were excluded. Our analysis leveraged a combined dataset that merges data from both AM and PM satellite overpasses. A grid is classified as 'frozen' if either the AM or PM overpass indicates a frozen state, as 'thawed' if both overpasses are thawed, and as 'transitional' if the AM overpass is frozen while the PM overpass is thawed, or vice versa. Notably, both 'transitional' and 'inverse transitional' states were aggregated under the 'transitional' category for the purposes of this study.

**Method:**

After computing the annual and monthly counts of frozen, thawed, and transitional states per grid, we employed the Mann-Kendall (M-K) trend test to detect any potential monotonic trends, increasing, decreasing or no trend, across the dataset. Only pixels that passed the M-K significance test with a p-value of ≤0.05 were further analyzed. For these statistically significant pixels, we calculated linear regression slopes to quantify the trends. This methodology enabled us to create a detailed spatial map depicting the trends in number of freeze/thaw (F/T) per grid across Canada for the period from 1979 to 2021.

1. **Annual Analysis**

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| A map of canada with different colored areas  Description automatically generated |
| Annual Trends in the Number of Days with **Thawed** Soil Conditions, 1979–2021: This map visualizes the yearly variation in the number of transition days, measured in days per year. Grids highlighted in green indicate an increasing trend, while red grids signify a decreasing trend, and yellow denotes no significant trend detected. Only pixels that have passed the Mann-Kendall test with a p-value of ≤ 0.05 are displayed, ensuring the statistical significance of observed trends.. |
| A map of canada with orange and green areas  Description automatically generated |
| Annual Trends in the Number of Days with **Frozen** Soil Conditions, 1979–2021: This map visualizes the yearly variation in the number of transition days, measured in days per year. Grids highlighted in green indicate an increasing trend, while red grids signify a decreasing trend, and yellow denotes no significant trend detected. Only pixels that have passed the Mann-Kendall test with a p-value of ≤ 0.05 are displayed, ensuring the statistical significance of observed trends. |

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| A map of canada with green and red areas  Description automatically generated |
| Annual Trends in **Transition** Days Between Frozen and Thawed or Between Thawed and Frozen Soil States (1979–2021): This map visualizes the yearly variation in the number of transition days, measured in days per year. Grids highlighted in green indicate an increasing trend, while red grids signify a decreasing trend, and yellow denotes no significant trend detected. Only pixels that have passed the Mann-Kendall test with a p-value of ≤ 0.05 are displayed, ensuring the statistical significance of observed trends. |

**Monthly Analysis:**

January

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| **A map of canada with different colored areas  Description automatically generated** | **A map of the north america  Description automatically generated** |
| A map of canada with green and black dots  Description automatically generated | |
| Trends in Frozen, Thawed, and Transitional Soil States (1979–2021) for January: This map visualizes the yearly variation in the number of transition days, measured in days per year. Grids highlighted in green indicate an increasing trend, while red grids signify a decreasing trend, and yellow denotes no significant trend detected. Only pixels that have passed the Mann-Kendall test with a p-value of ≤ 0.05 are displayed, ensuring the statistical significance of observed trends. | |

February

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| Trends in Frozen, Thawed, and Transitional Soil States (1979–2021) for Feburary: This map visualizes the yearly variation in the number of transition days, measured in days per year. Grids highlighted in green indicate an increasing trend, while red grids signify a decreasing trend, and yellow denotes no significant trend detected. Only pixels that have passed the Mann-Kendall test with a p-value of ≤ 0.05 are displayed, ensuring the statistical significance of observed trends. | |

March

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| Trends in Frozen, Thawed, and Transitional Soil States (1979–2021) for March: This map visualizes the yearly variation in the number of transition days, measured in days per year. Grids highlighted in green indicate an increasing trend, while red grids signify a decreasing trend, and yellow denotes no significant trend detected. Only pixels that have passed the Mann-Kendall test with a p-value of ≤ 0.05 are displayed, ensuring the statistical significance of observed trends. | |

April

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| Trends in Frozen, Thawed, and Transitional Soil States (1979–2021) for April: This map visualizes the yearly variation in the number of transition days, measured in days per year. Grids highlighted in green indicate an increasing trend, while red grids signify a decreasing trend, and yellow denotes no significant trend detected. Only pixels that have passed the Mann-Kendall test with a p-value of ≤ 0.05 are displayed, ensuring the statistical significance of observed trends. | |

May

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| Trends in Frozen, Thawed, and Transitional Soil States (1979–2021) for May: This map visualizes the yearly variation in the number of transition days, measured in days per year. Grids highlighted in green indicate an increasing trend, while red grids signify a decreasing trend, and yellow denotes no significant trend detected. Only pixels that have passed the Mann-Kendall test with a p-value of ≤ 0.05 are displayed, ensuring the statistical significance of observed trends. | |

June:

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| Trends in Frozen, Thawed, and Transitional Soil States (1979–2021) for June: This map visualizes the yearly variation in the number of transition days, measured in days per year. Grids highlighted in green indicate an increasing trend, while red grids signify a decreasing trend, and yellow denotes no significant trend detected. Only pixels that have passed the Mann-Kendall test with a p-value of ≤ 0.05 are displayed, ensuring the statistical significance of observed trends. | |

July

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| Trends in Frozen, Thawed, and Transitional Soil States (1979–2021) for July: This map visualizes the yearly variation in the number of transition days, measured in days per year. Grids highlighted in green indicate an increasing trend, while red grids signify a decreasing trend, and yellow denotes no significant trend detected. Only pixels that have passed the Mann-Kendall test with a p-value of ≤ 0.05 are displayed, ensuring the statistical significance of observed trends. | |

August:

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| Trends in Frozen, Thawed, and Transitional Soil States (1979–2021) for Auguest: This map visualizes the yearly variation in the number of transition days, measured in days per year. Grids highlighted in green indicate an increasing trend, while red grids signify a decreasing trend, and yellow denotes no significant trend detected. Only pixels that have passed the Mann-Kendall test with a p-value of ≤ 0.05 are displayed, ensuring the statistical significance of observed trends. | |

September

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| Trends in Frozen, Thawed, and Transitional Soil States (1979–2021) for September: This map visualizes the yearly variation in the number of transition days, measured in days per year. Grids highlighted in green indicate an increasing trend, while red grids signify a decreasing trend, and yellow denotes no significant trend detected. Only pixels that have passed the Mann-Kendall test with a p-value of ≤ 0.05 are displayed, ensuring the statistical significance of observed trends. | |

October

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| Trends in Frozen, Thawed, and Transitional Soil States (1979–2021) for October: This map visualizes the yearly variation in the number of transition days, measured in days per year. Grids highlighted in green indicate an increasing trend, while red grids signify a decreasing trend, and yellow denotes no significant trend detected. Only pixels that have passed the Mann-Kendall test with a p-value of ≤ 0.05 are displayed, ensuring the statistical significance of observed trends. | |

November

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| Trends in Frozen, Thawed, and Transitional Soil States (1979–2021) for November: This map visualizes the yearly variation in the number of transition days, measured in days per year. Grids highlighted in green indicate an increasing trend, while red grids signify a decreasing trend, and yellow denotes no significant trend detected. Only pixels that have passed the Mann-Kendall test with a p-value of ≤ 0.05 are displayed, ensuring the statistical significance of observed trends. | |

December

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| Trends in Frozen, Thawed, and Transitional Soil States (1979–2021) for December: This map visualizes the yearly variation in the number of transition days, measured in days per year. Grids highlighted in green indicate an increasing trend, while red grids signify a decreasing trend, and yellow denotes no significant trend detected. Only pixels that have passed the Mann-Kendall test with a p-value of ≤ 0.05 are displayed, ensuring the statistical significance of observed trends. | |