

Technical documentation for the CWFIS Seasonal Forecast: Version 2

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Executive Overview

The Canadian Wildland Fire Information System (CWFIS) provides year-round monitoring of observed fire activity and forecasted potential fire danger and behaviour over Canada. One of the core CWFIS forecast products is the monthly seasonal forecast, which was first developed in 2008. In 2026, the product was updated to version 2 to fully utilize the outputs of the latest version of the Canadian Seasonal to Interannual Prediction System (CanSIPSv3), which became operational in June 2024. Version 2 of the CWFIS seasonal forecast (SFV2) features a number of improvements over the previous version. This document provides a technical overview of how SFV2 is produced, along with a description of its outputs and interpretation.

Introduction

Seasonal forecasting of fire danger is an essential application of climate models in wildfire decision support systems, providing fire agencies with valuable information to deploy resources early and informing public safety and health. Typically, these systems forecast fire weather indices that indicate conditions conducive to fire occurrence and spread, but do not directly predict fire occurrence or behaviour (which depends on vegetation types and topography).

Although seasonal forecasts of fire danger are most skillful for lead-times of 1-2 months (Di Giuseppe et al. 2020, Borries-Strigle et al. 2025), seasonal forecasting is a rapidly evolving science, and both physics-based and data-driven (i.e., machine learning) models are continually improving. Moreover, medium- to long-range weather forecasting depends on the use of ensembles to capture the inherent uncertainty in these models (both in initial conditions and in the parameterization of physical processes). At longer lead times, ensemble means of forecasted fire weather indices can provide greater skill than deterministic high-resolution models (Chen et al. 2025), highlighting the so-called “blessings of high dimensionality” of ensembles (Christiansen 2019).

The Canadian Wildland Fire Information System (CWFIS) includes a seasonal forecast of fire weather severity. The first version of the seasonal forecast (SFV1) was developed in 2008 and was based on forecast monthly values of temperature and precipitation from the Dynamical Seasonal Forecast System developed by Environment and Climate Change Canada (ECCC). Using additional approximations,

these monthly values were used as inputs to the Canadian Fire Weather Index (FWI) System to estimate monthly fire weather severity (Anderson et al. 2007). Inputs to the SFV1 were updated in 2011 and 2019, coinciding with ECCC’s operational releases of the Canadian Seasonal to Interannual Prediction System (CanSIPS) versions 1 and 2. In June 2024, version 3 of CanSIPS became operational, allowing for a major overhaul of the CWFIS seasonal forecast to version 2 (SFV2). In this technical document, we describe the data sources, methodology, and outputs of the SFV2. We also provide guidance on interpreting the forecast outputs and illustrate relevant case studies.

Methods and Data

The CWFIS seasonal forecast is based on applying the Canadian Fire Weather Index (FWI) System to outputs of the Canadian Seasonal to Interannual Prediction System (CanSIPS), which provides predictions of numerous atmospheric variables at 6-hourly temporal resolution, and at lead times out to 7 months.

The FWI System

The FWI System can be used to estimate several components of fuel moisture, fire behaviour and overall fire danger based on daily weather inputs. A full description of the FWI system can be found [here](#). Inputs to the FWI system consist of four weather variables: temperature, relative humidity, wind speed, and rainfall. Temperature, relative humidity and wind speed are the values at noon (local standard time), and rainfall is the 24-hour accumulated value ending at noon (local standard time) each day.

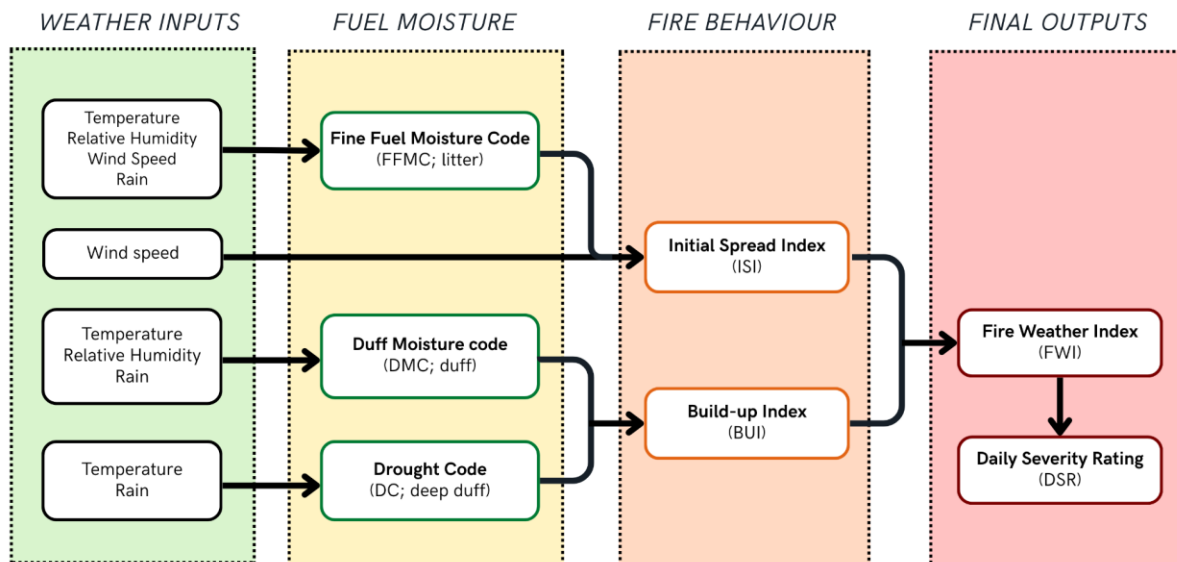


Figure 1: The FWI System (adapted from Van Wagner 1987).

As shown in the figure above, the FWI System consists of six components that account for the effects of fuel moisture and wind on fire behaviour (Van Wagner 1987). The first three components are the fuel moisture codes: the Fine Fuel Moisture Code (FFMC), the Duff Moisture Code (DMC), and the Drought Code (DC). These are, respectively, numeric ratings of the average moisture content of the litter and other fine fuels, of the loosely compacted organic layers of moderate depth, and of the deep, compact organic layers. High values indicate dry fuels. Only the DC is capable of carrying over fall moisture conditions into the spring.

The remaining three components – the Initial Spread Index (ISI), the Buildup Index (BUI), and the Fire Weather Index (FWI) – are fire behaviour indices that represent, respectively, the rate of fire spread, the fuel available for combustion, and the frontal fire intensity; their values rise as the fire danger increases.

The Daily Severity Rating (DSR) and its time-averaged value, the Seasonal Severity Rating (SSR), are extensions of the FWI System. The DSR is a transformation of the daily FWI value, calculated as follows:

$$DSR = 0.0272 FWI^{1.77}$$

Higher FWI values are emphasized through the power relation. The DSR can be accumulated over time as the cumulative DSR, or it may be averaged over time as the SSR:

$$SSR = \frac{1}{n} \sum_{i=1}^n DSR_i$$

where DSR_i is the DSR value for day i , and n is the total number of days. The DSR can be averaged over a month as the Monthly Severity Rating (MSR), which, when further averaged over the multi-model ensemble used in SFV2, is called the Forecast Severity Rating (FSR).

Data sources

The current version of the CWFIS seasonal forecast relies on two data products, as described here.

The Canadian Seasonal to Interannual Prediction System (CanSIPsv3)

A seasonal prediction system that produces probabilistic forecasts of climate conditions during the upcoming 7 months. CanSIPsv3 consists of two coupled atmosphere-ocean-land climate models: CanESM5 and GEM5.2-NEMO (Diro et al. 2024). Forecasts are generated using a 40-member ensemble, consisting of 20 simulations from each of the two underlying models. The 20 simulations use randomly perturbed initial conditions to represent uncertainty, whereas using two models allows for some uncertainty in the physics parameterizations. Outputs of the system include numerous atmospheric variables at a spatial resolution of $1^\circ \times 1^\circ$ (with global coverage) and a 6-hourly temporal resolution. The conversion of these model outputs to the inputs required for the FWI system is shown in Table 1. It is important to note that CanSIPsv3 forecasts are issued by Environment and Climate Change Canada (ECCC) on the 1st of each month.

Table 1: Conversion of CanSIPsv3 outputs to daily FWI inputs

Weather variable	CanSIPS variable name(s)	Calculation	Interpolation
2m temperature	tas (6 hourly)	$T = \text{tas} - 273.15$ (Kelvin to °C)	Linear interpolation to local noon
2m relative humidity	tas, tdps (6 hourly)	RH calculated using approximation from Alduchov and Eskridge, 1996; values clipped to range (0, 100)	Linear interpolation to local noon
10m wind speed	uas, vas (6 hourly)	$WS = 3.6 \sqrt{uas^2 + vas^2}$ (m/s to km/h)	Linear interpolation to local noon
24-hour accumulated precipitation	lwepr (daily)	$P = 1000 \text{ lwepr}$ (m to mm)	Linear weighting to approximate 24-h precipitation, ending local noon

ERA5 Reanalysis

The ERA5 reanalysis is the fifth-generation atmospheric reanalysis produced by the European Centre for Medium-Range Weather Forecasts (ECMWF; Hersbach et al. 2020). ERA5 is a historical gridded dataset that provides hourly estimates of a large number of atmospheric, ocean-wave, and land-surface variables at 0.25° spatial resolution (approximately 31km at the equator). ERA5 has been previously used to generate fire weather datasets for research, showing good agreement with station observations (McElhinny et al. 2020). The ERA5 variables used to calculate FWI System outputs are shown in Table 2.

Table 2: ERA5 variables used for FWI calculation

Weather variable	ERA5 variables used	Calculation	Extraction
2m temperature	2m_temperature (T2m)	$T = \text{T2m} - 273.15$ (Kelvin to °C)	Extract daily local noon value
2m relative humidity	2m_temperature (T2m), 2m_dewpoint_temperature (D2m)	RH calculated using approximation from Alduchov and Eskridge, 1996; values clipped to range (0, 100)	Extract daily local noon value
10m wind speed	10m_u_component_of_wind (u10) 10m_v_component_of_wind (v10)	$WS = 3.6 \sqrt{u10^2 + v10^2}$ (m/s to km/h)	Extract daily local noon value
24-hour accumulated precipitation	total_precipitation (TP)	$P = 1000 \text{ TP}$ (m to mm)	Sum hourly values between 1 pm previous day and noon of current day (24 values)

Main calculation steps

The CWFIS seasonal forecast is based on the daily outputs of the FWI System, which include the Fire Weather Index (FWI) and the Daily Severity Index (DSR). The main steps are:

STAGE 1. PROCESSING WEATHER INPUTS

Convert weather inputs to daily noon values: The CanSIPS forecast outputs (see Table 1) required for the FWI calculation are linearly interpolated from 6-hourly values to daily noon (local-standard-time), accounting for time zones. This is done for each of the two models and for all 20 ensemble members of each model. At this time these daily inputs are not further bias-corrected.

Calculate snow proxy: the maximum daily 2m temperature is estimated, taking the maximum of the 6-hourly CanSIPS forecast of 2m values for each calendar day (adjusted for time zone); this is used as a proxy for snow-free conditions to turn on the FWI calculation, as described below.

Startup moisture codes: The ERA5 reanalysis is used to compute all outputs of the FWI System, including the fuel moisture codes (FFMC, DMC and DC) required for start-up of the main forecast. Because ERA5 is available with a latency of 5 days¹, the start-up fuel moisture codes can only be calculated up to 6 days before the forecast initialization date.

STAGE 2. SYSTEM STARTUP

Determine fire season mask: The maximum daily 2m temperature (Tmax) is used to calculate a fire season mask. The FWI calculation is turned on (or off) according to a snow-proxy condition that corresponds to 3 days with maximum daily temperature $\geq 12^{\circ}\text{C}$ (or 3 days $\leq 5^{\circ}\text{C}$), following Wotton and Flannigan (1993). To ensure fire season status can be determined on the forecast initialization date, three days of the corresponding ERA5 Tmax data (regridded using bilinear interpolation) are concatenated at the beginning of the CanSIPS forecast.

Overwintering the DC: The FWI calculation uses an overwintering procedure (as per McElhinny et al. 2020) to account for drought conditions that carry over from fall to spring. This involves adjusting the start-up DC values at the start of the fire season based on the fall value and the overwinter precipitation amount (see Lawson and Armitage 2008).

STAGE 3. FWI CALCULATION

Calculate FWI indices: At forecast initialization, the startup fuel moisture codes and daily weather inputs are used to calculate the FWI system outputs for the two models and each

¹ See <https://cds.climate.copernicus.eu/datasets/reanalysis-era5-single-levels?tab=overview>

ensemble member, using the standard FWI calculation (Van Wagner 1987, Lawson and Armitage 2008).

Early-season startup: If the calculation is initialized during the winter, the DC will continue to be overwintered until the fire season starts (as determined by the fire season mask). The fall DC value (from ERA5) is then used along with the accumulated overwinter precipitation from ERA5 (before the forecast initialization date) and the overwinter precipitation from CanSIPS following forecast initialization, to adjust the DC for the first day of the fire season. The other moisture codes are set to their default values (FFMC=85, DMC=6).

Mid-season activation: When the forecast is initialized after the fire season is already turned on, the previous day's moisture codes from ERA5 are directly used to start up the calculation. For example, the June 1st forecast uses May 31st ERA5-derived values of FFMC, DMC and DC. However, due to ERA5 latency, the calculation can only be run on June 6th in this example.

STAGE 4. SUMMARIZING OUTPUTS

Aggregate ensemble values: The outputs of the forecast (daily FWI values for 20 ensemble members for two models) are then post-processed to produce monthly summaries suitable for visualization. There are different ways this aggregation can occur, for example:

1. Taking the mean or median value with respect to days of the month and ensemble members.
2. Finding the probability of an event by dividing the number of members where the event occurs by the total size of the ensemble.

Climatology calculation: To determine forecast anomalies or categories of output variables (e.g., monthly FWI and DSR), it is necessary to calculate climatologies for each variable of interest. To do this, we use CanSIPS hindcasts from 1991 to 2020 and calculate the relevant climatology separately for each forecast initialization month. For example, to calculate anomalies for monthly FWI values from the June 1st-initialized forecast, we use all June-initialized hindcasts from 1991 to 2020 and calculate the climatology by taking the mean over the 30 monthly FWI hindcasts for each lead time (7 months).

Masking of final outputs: For daily forecast outputs, the fire season can be either on or off, depending on location and day of the year (as well as individual ensemble member and model). Therefore, to indicate whether the fire season has started or ended in the monthly forecast outputs, we further mask each monthly output if more than half of the values (across days of the month and ensemble members) are turned off.

Visualization: Monthly maps (see Forecast outputs section) are produced for lead times of 1-4 months.

Forecast outputs

The four monthly outputs displayed on the CWFIS are as follows:

Forecast Severity Rating

The Forecast Severity Rating (FSR) map displays at each location the forecasted average monthly value of the daily severity rating; each value represents the mean across all days of the given month and across all ensemble simulations.

Forecast Severity Anomaly

The Forecast Severity Anomaly map displays at each location the category of the forecast severity rating determined by the percentiles of historical forecasts from 1991 to 2020. The five distinct categories are: well below average (below 10th percentile), below average (10th to 33rd percentile), average (33rd to 66th percentile), above average (66th to 90th percentile), and well above average (above 90th percentile).

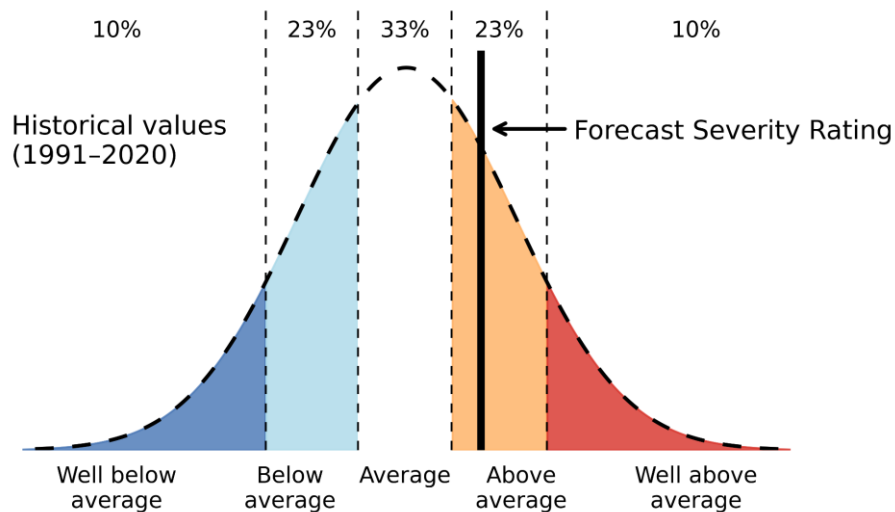


Figure 2: The Forecast Severity Anomaly is given by the category of the Forecast Severity Rating (the monthly mean of the ensemble mean of the DSR). The categories are defined by the percentiles of the distribution of FSR values from hindcasts over the climatological period 1991-2020, for the same forecast initialization month.

Probabilistic forecast

The probabilistic forecast map displays at each location the probability of the most likely tercile category of the forecast severity rating. The tercile categories are determined by historical forecasts from 1991 to 2020 as follows: below average (lowest 33% of values), normal (middle 33% of values), and above average (highest 33% of values). The probability of each category is determined from the number of individual ensemble members in each category. If the probability of the most likely tercile is less than 40%, we instead show conditions as normal to reflect the greater uncertainty in the forecast.

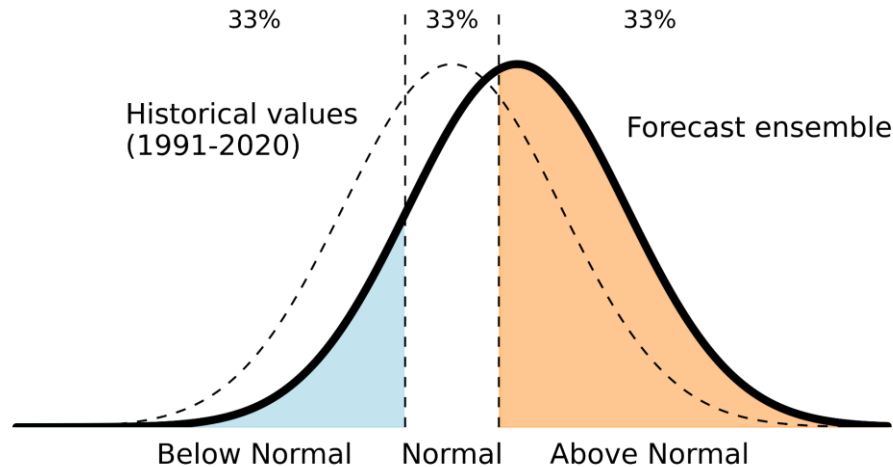


Figure 3: The tercile probability map shows the probability of the most likely tercile category. The tercile categories are given by the bottom, middle and top third of FSR values for the hindcasts (initialized for the same forecast month) over the climatological period 1991-2020. The probability is determined by the number of mean monthly DSR values in the 40-member ensemble that fall into each category.

95th Percentile Fire Weather Days

This map displays at each location the median number of days per month when the FWI exceeds the 95th percentile of historical fire-season FWI values from 1991 to 2020. This definition is linked to the concept of potential spread days and is associated with weather conditions that can cause wildfires to spread rapidly, making fire suppression significantly more difficult (Podur and Wotton 2011, Wang et al. 2014).

The first official CWFIS seasonal forecast is issued on the first business day after the 6th of April each year.

Case studies

Each of the map types outlined in the previous section is shown in Fig. 4 for the example of the August-Initialized forecast for August 2025 (i.e., one-month lead time). The extreme fire weather conditions observed in Atlantic Canada in August 2025 are also apparent in the seasonal forecast as shown by comparing forecasted to historical values (i.e., Forecast Severity Anomaly, 95th Percentile Fire Weather Days). The Forecast Probability map provides confidence that the extreme conditions forecast for Atlantic Canada also have a high probability (i.e., above-average conditions are forecast with a probability of 70-100% for much of Atlantic Canada).

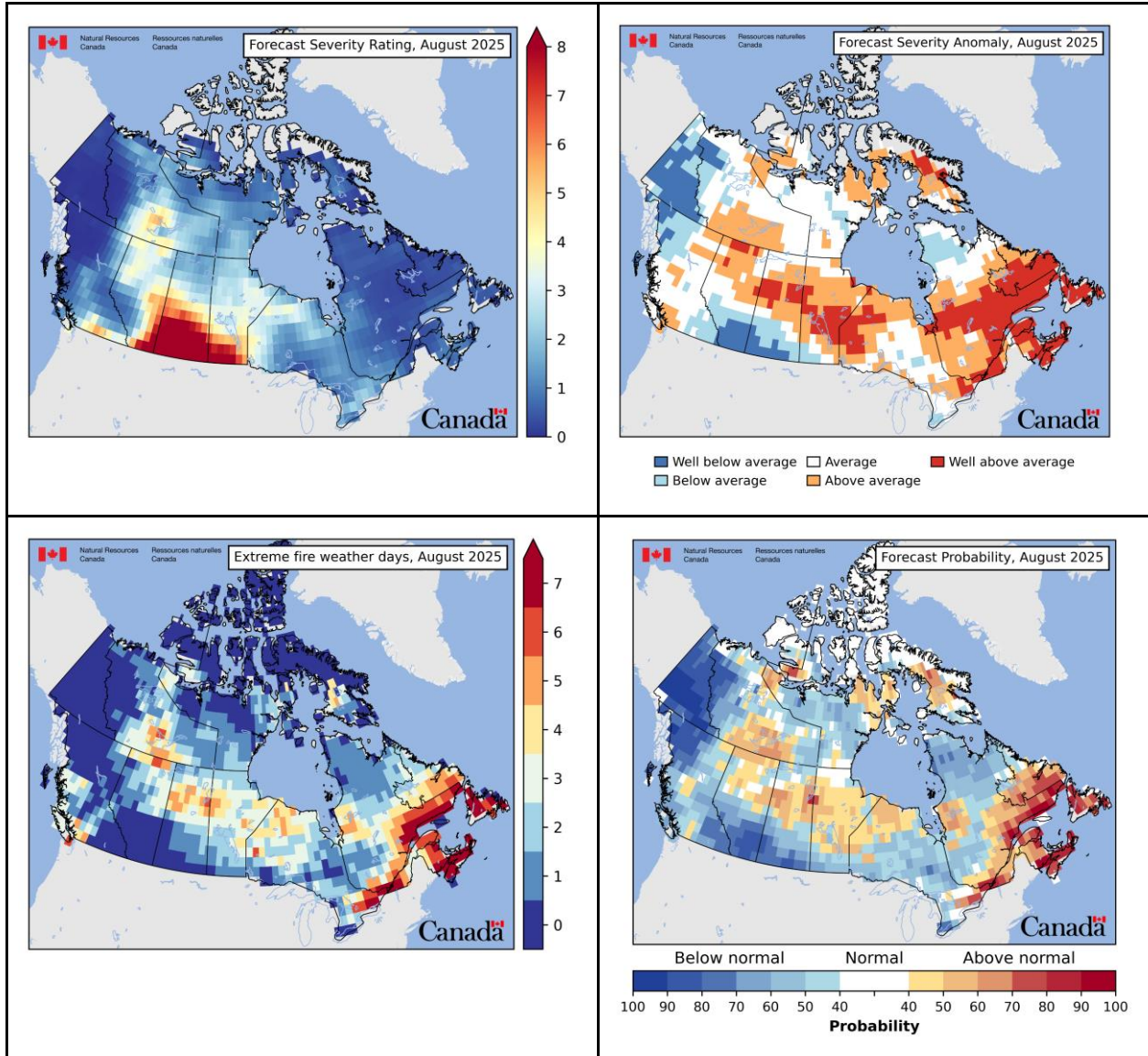


Figure 4: Forecast for August 2025: examples of four output maps.

The 2023 fire season in Canada was exceptional, with extreme fire weather conditions occurring over a large proportion of the country, particularly in the spring and early summer (Jain et al. 2024). Figure XX shows the March- and April-initialized forecast for June (lead times of 4 and 3 months, respectively). The April-initialized forecast appears more skillful at predicting extreme fire weather conditions in June, likely due to both the shorter lead-time and the challenges of predicting beyond the spring predictability barrier (Zheng and Zhu 2010).

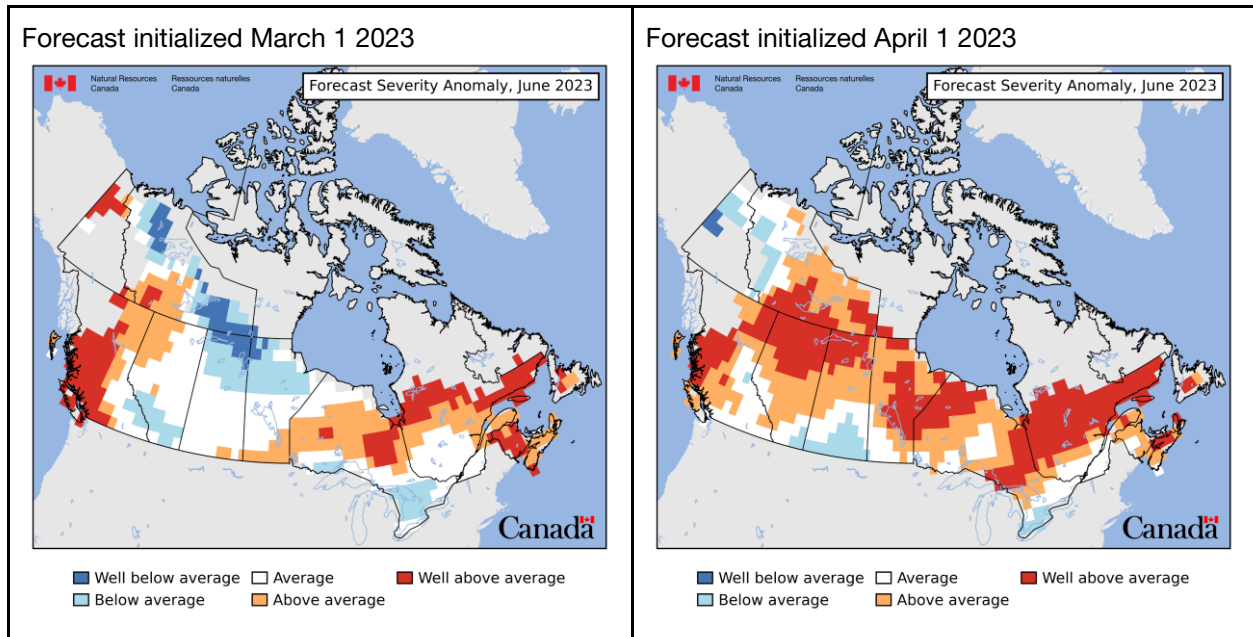


Figure 5: Forecast for June 2023: lead times of 4 months (March forecast) or 3 months (April forecast)

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