Everything you wanted to know about Drought Code in Alaska . . . but were afraid to ask

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Recent studies by experts in Alaska and Canada have given us much new insight into the Drought Code (DC) component of the Fire Weather Index System used in both places. While other components of the FWI are simple in concept and easily validated by field observations, there have long been questions about the DC: what does it represent? How it should be interpreted and validated? How and if we should "overwinter" DC? How to convert DC to a moisture content (gravimetric or volumetric) or *vice versa*? Canadian fire scientist Chelene Krezek-Hanes recently finished her PhD thesis, which reported on her extensive field work and remote sensing experiments and has yielded four published papers so far. Meanwhile, Alaska fire ecologist Eric Miller teamed up with University hydrology experts to validate the DC's assumptions against field data in Alaska. What follows is a short digest of these recent efforts.

Nearly all fire weather indices reflect moisture content in some part of the fuel bed, but the DC was originally an index of water balance that tracks seasonal accumulations of rainfall and losses of evaporation (Miller 2020). A relationship to soil moisture was not added to the DC until its incorporation into the FWI System in the early 1970s. Eric Miller *et al.* (2023) recently investigated the **water balance assumptions underlying the DC** in interior Alaska boreal forest and found they greatly overestimate drought in conifer forests on permafrost. Miller's team used 3 atmospheric eddy covariance flux towers around Fairbanks to accurately measure precipitation inputs and evaporative losses. The DC model poorly represented water balance, overpredicting drought on any given day by a factor of about six. Black spruce forests on permafrost evaporate only 1/3 to 1/2 as much as hardwood stands and wetlands, and transpiration loss is limited by soils that often remain frozen until after summer solstice. Feathermosses both insulate the permafrost and retard the evaporation of soil moisture as it thaws. Eric's findings explain Alaska managers' assertions that the DC does not accurately represent drought, especially at the beginning and end of the fire season. Overpredicting evaporation and plant water transport, as well as an under-accounting of precipitation inputs seem to be responsible for the errors. For example, the threshold rainfall requirement of the DC water balance model means that 43% of seasonal precipitation is not counted in interior Alaska, where summer rainfall events are typically light, and the total cumulative summer precipitation averages just 245 mm. In fact, Eric suggests doing away with the threshold requirement might be an easy preliminary fix to improve performance. Meanwhile, Eric suggests the DC may be adding more error than value to the BUI calculation and should be viewed with healthy skepticism as an index for ecosystems on permafrost.

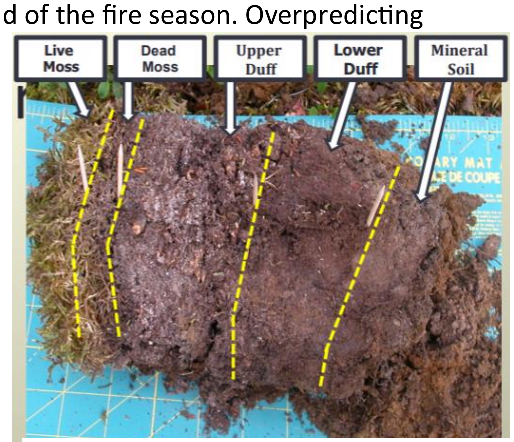

Figure: J.Barnes & E.Miller presentation- Duff fuel moisture and FWI codes (2014).

Deep drying of moss duff greatly increases consumption, and therefore emissions.

Chelene describes field work to **validate the DC** with observed volumetric moisture content (measured by dielectric probes). Her Alberta and Ontario field sites span a variety of forest types from warmer aspen and mixed forest ecotypes to jack pine and black spruce. A minority of the sites had permafrost. Agreement between VMC calculated from DC and from the moisture probes at 10-18 cm was reasonably good over the 3 years of the study. Note that the probes were inserted at an angle, at her sites where duff layers were only 5-13 cm deep, so that the length of the probe integrated its measurement over that 10-18 cm depth regardless of material type: litter, humus, or contact with mineral soil. This contact with mineral soil, as well as the generally thin organic layers included in her study areas in Ontario and Alberta may help explain the more positive outcomes of her validation efforts explained by Eric's findings above. She also notes that the DC algorithm does not account for moisture added from thawing permafrost. Unfortunately, when she tried to incorporate satellite moisture detection from SMAP and other landform factors (using the more complex CaLDAS (Canadian Land Data Assimilation System model) the fit was poor, indicating CaLDAS may not yet be a good option to re-calibrate DC during the season. In Alberta, DC (converted to volumetric water content--VMC) agreed better with observed MC when not overwintered—it overpredicted drought when carried over.

Key Point: *DC does a reasonable job of representing observed moisture changes in organic layers over a wide range of forest types in Canada but less so in the deep organic layers and permafrost-affected forests of interior Alaska. The largest sources of error in DC seem to be associated with overwintering procedures in Canada but a poor fit to biophysical water balance in Alaska.*

Tip-- How to convert DC to a moisture content using its prescribed bulk density (*139 kg/m³*):

$$MC = 400e^{\frac{-DC}{400}}$$

Note: this equation (Wotton 2009) differs slightly from Van Wagner's (1987) equation because the gravimetric MC of the DC at saturation (DC = 0) is 400%.

The question on **overwintering the DC** was a major thrust of Chelene's thesis. In short, less than half her study areas demonstrated a significant relationship between previous fall DC and number of spring fires—the primary driver of spring fires remains dryness of surface fuels indicated by the FFMC. Although it looks like there may be times when fall drought persists into the following spring, the methods for calculating this carry over are relatively subjective and weather observations may not extend long enough in the fall to capture it accurately. In Chelene's study areas, overwintering the DC did not improve correlation with field MC except in select cases. Curiously, overwinter precipitation (one of the inputs to the overwinter calculation) was positively (but not significantly) associated with number of spring fires and negatively associated with spring MC! This is not unlike the weak positive association some investigators have found between snowpack and acres burned in Alaska (Butteri 2005). Accurately setting the spring DC is important because errors in DC season start can carry through the season and affect FWI calculations throughout the fire season (McElhinny, et al. 2020). Chelene concludes that the current overwinter adjustment and DC spring starting methods in Canada introduce errors into fire danger calculations, mainly because of various ways agencies apply them rather than the procedure itself.

Recent instances of over-wintering fires in Alaska and Siberia as well as large and destructive spring fires in Canada raise questions about **drought in the winter**. Does drought persist and how do we detect it? Does using an overwintering model on the DC give real information on spring drought? DC is normally started just below "saturation" at 15 to account for the 3 days after snowmelt. Depending on the year, snow free conditions and the ground thaw may occur on the same day, or weeks apart. Although surface drying can start immediately, deeper layers cannot start drying until the ground thaws. Chelene's data suggests we should modify our practice of starting DC/DMC calculations so soon and base start on ground thaw when data is available. In practice, DC did not indicate the drought conditions before recent critical fire events, including the notorious May 2016 Horse River fire. Local managers found that consumption rates from the fire were better related to moisture conditions measured *in situ* rather than overwintered DC values (Elmes, et al. 2018). Chelene concludes that the adjustment of the DC with electronic moisture probes may provide more accurate season ending and starting moisture contents when the overwinter adjustment is needed.

Tip: *If you're curious, DC of 15 theoretically represents a volumetric moisture content of 54% at 15-18 cm deep (assuming default value of 139 kg/m^3 bulk density) (Hanes 2022, Fig. 4-5).*

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