## Abstract

The Canadian Fire Weather Index (FWI) System is the mostly widely used fire danger rating system in the world. We have developed a global database of daily, gridded FWI System calculations from 1980–2012. Input weather data were obtained from the NASA Modern Era Retrospective-Analysis for Research, and two different estimates of daily precipitation from rain gauges over land. FWI System Drought Code (DC) calculations from the gridded datasets were compared to calculations from individual weather station data for a representative set of stations in North, Central and South America, Europe, Russia, Southeast Asia and Australia. Agreement between gridded calculations and the station-based calculations tended to be most different over the tropics for strictly MERRA-based calculations. This dataset can be used for analyzing historical relationships between fire weather and fire activity at continental and global scales, in identifying large-scale atmosphere–ocean controls on fire weather, and calibration of FWI-based fire prediction models.


## 1 Introduction

Fire danger rating systems are used to identify conditions under which vegetation fires can start and spread. This is done by modeling the moisture content of different classes of fuels in response to changing weather conditions, and potential fire behaviour if a fire were to start. The Canadian Forest Fire Weather Index (FWI) System (Van Wagner, 1987) is the most widely used fire danger rating system in the world. It has operated in its current form in Canada since 1970, and certain components have been adapted for operational use in New Zealand, Fiji, parts of the United States, Mexico, Argentina, Spain, Portugal, Indonesia, Malaysia, and Finland (Taylor and Alexander, 2006) and regionally across Europe (Camia and Amatulli, 2009). It has been used for estimating future activity in boreal regions (de Groot et al., 2013) and globally (Flannigan et al., 2013) under different climate change scenarios. Because of its use in such a broad





NHESSD
2, 6555–6597, 2014

# Summary of Comments on Development of a global fire weather database for 1980--2012

## Page: 3

Number: 1 Author: Subject: Highlight Date: 17/04/2015 12:32:59

Make more quantitative in terms of what is put here. So instead of 'gridded' it becomes 'gridded at * resolution', instead of 'individual weather station data' it becomes data from ### individual weather stations. For the results, be more quantitative in the results, what is said is very vague. Be more specific. Since you use acronym MERRA, put (MERRA) first time used. As you do not use DC, then do not put the acronym.

range of fire environments, it is central to the ongoing development of real-time global fire danger rating systems (de Groot et al., 2006).

Use of the FWI System either operationally or for research purposes begins with experimental fires and laboratory experiments when possible, expert consultation, and historical analyses of FWI variability and relationships to past fire activity. Historical analyses are possible only after hourly measurements of surface temperature, humidity, wind speed and precipitation are compiled for as many years as available. Typically, these data are from surface weather station networks, and require significant effort in constructing a gap-free record. FWI System maps are usually calculated from geostatistically-interpolated weather fields from the individual stations.

Recent work has been done to calculate FWI System values from meteorological reanalyses over Portugal and Spain (Bedia et al., 2012), the whole of Europe (Camia and Amatulli, 2010) the Great Lakes region of the US (Horel et al., 2014), Siberia (Chu et al., 2014) and globally for use as a baseline against which fire danger in a changing climate can be assessed (Flannigan et al., 2013). Reanalysis products have their own biases, but remain a critical research tool because of their overall utility (Rienecker et al., 2011). For the purposes of historical FWI System calculations, they have the advantages over raw weather station data of providing spatially and temporally continuous records based on estimates of weather input fields using the internal, physical consistency of a numerical weather prediction model and modern data assimilation techniques. They provide the only practical means possible of calculating FWI values consistently at continental scales.

This paper describes our development of a global FWI dataset for the period 1980–2012 based on the National Aeronautics and Space Administration (NASA) Modern Era Retrospective-Analysis for Research (MERRA) (Rienecker et al., 2011). Because precipitation in reanalyses tends to be less well-constrained by observations, we also use two global, gridded precipitation datasets. Our goals were to:

1. Provide easily accessible historical FWI System data for new regions of interest.





NHESSD
2, 6555–6597, 2014

# Page: 4

Number: 1 Author: Subject: Highlight Date: 17/04/2015 12:37:24

State scale it is gridded.

Number: 2 Author: Subject: Highlight Date: 17/04/2015 12:39:28

I suggest that these are (i), (ii), ..., as you use 1., 2., ... for major headers.

2. Provide a consistent and homogenized product for continental and global-scale FWI analyses.

3. Provide a product that can be easily updated and expanded over time[1]

## 2 Description of the FWI System

[2]he FWI System is composed of three moisture codes and three fire behaviour indices (Van Wagner, 1987). The Fine Fuel Moisture Code (FFMC) is designed to capture changes in the moisture content of fine fuels and leaf litter on the forest floor where fires can most easily start. The Duff Moisture Code (DMC) captures the moisture content of loosely compacted forest floor organic matter and relates to the likelihood of lightning ignition. The Drought Code (DC) captures the moisture content of deep, compacted organic soils and heavy surface fuels. The three moisture codes are calculated on a daily basis using the previous day's moisture codes and the current day's weather. The Initial Spread Index (ISI) is driven by wind speed and FFMC and represents the ability of a fire to spread immediately after ignition. The Buildup Index (BUI) is driven by the DMC and DC and represents the total fuel available to a fire. The Fire Weather Index (FWI) combines the ISI and BUI to provide an overall rating of fireline intensity in a reference fuel type and level terrain. Additionally, the Daily Severity Rating (DSR) is scaled from the FWI to provide categorical difficulty of control measures. Dowdy et al. (2009) provide an accessible description of the underlying equations. Taylor and Alexander (2006) summarize the history behind the FWI System and how different fire management agencies have adopted different components for specific fire management needs.

[3]WI System calculations require measurements of 12:00[4] temperature at 2 m, relative humidity at 2 m and wind speed at 10 m, and precipitation[6]taled over the previous 24 h. Measurements are taken in a clearing but the FWI System was designed such that the indices are representative of the conditions within a forest stand. Because each





NHESSD
2, 6555–6597, 2014
Development of a global fire weather database for 1980–2012
R. D. Field et al.

# Page: 5

Number: 1 Author: Subject: Highlight Date: 17/04/2015 12:41:50

This is in general a strong introduction, but it feels just a tad light on references towards the beginning, and towards the end, I suggest that you tell the reader how the paper is organized. In other words "This paper is organized as follows. We first described the Canadian FWI System in more detail (Section 2). We then...."

Number: 2 Author: Subject: Highlight Date: 17/04/2015 12:44:29

If you are going to state there are three and three, then break them out. So "The three moisture codes are:
(i) ******
(ii) ******
(iii) *****"
and then do the same for the other three. This will make it easier for the reader.

Please ensure that references are included anywhere needed so reader can come back to these if needed.

You have so many acronyms building up, that I suggest you either in the introduction, or in this section, you introduce a table of acronyms for the entire paper.

Number: 3 Author: Subject: Highlight Date: 17/04/2015 12:50:52

I would suggest this needs a reference, unless you are saying what you are doing. But, you are not defining how FWI is calculated, but rather following established literature.

Why is 'System' in caps?

Number: 4 Author: Subject: Highlight Date: 17/04/2015 12:48:25

This is why it is important to do a table of acronyms. You have put in 'LT' without every defining it, so first time introduced here, it needs to be defined "local time" in brackets.

Number: 5 Author: Subject: Highlight Date: 17/04/2015 12:53:22

Although it is clear that precip is totaled over 24 h, it is not clear whether temperature is an hourly measurement (averaged over hour or instantaneous on the hour) and more importantly the wind, as this values changes a lot if one is considering 1 minute vs. one hour averaged measurements. I would suggest rereading the rest of your paper, considering whether what you are saying requires the reader to go back to other literature to figure out what you did 'exactly', as in the example I have given.

Number: 6 Author: Subject: Highlight Date: 17/04/2015 12:51:00

day's calculation requires the previous day's moisture codes, weather records must be continuous and any missing data must be estimated. Too much missing weather data, particularly precipitation, can lead to errors that accumulate over time.

In cold regions, the calculations begin with the arrival of spring and are stopped with the onset of winter. Ideally, the spring startup moisture code values reflect whether or not winter was dry, however this is defined. We based our start-up approach on that of the Canadian Wildland Fire Information System (CWFIS), described at: http://cwfis.cfs.nrcan.gc.ca/background/dsm/fwi. First, snow conditions are examined for the possibility of startup after a winter with substantial snow cover, defined as having a mean snow depth of 10 cm or greater and snow present for a minimum of 75 % of days during the two months prior to startup. This requirement was modified from the CWFIS approach of considering snow days in January and February to allow for seasonality in regions other than Canada. In this case, start-up occurs when the station has been snow free for three consecutive days, and moisture code values representing wet, saturated conditions (DMC = 6, DC = 15) are used. For locations without significant snow cover, startup occurs when the mean daily temperature is 6 °C or greater for three consecutive days. The DMC is set to 2 times the number of days since precipitation and the DC is set to 5 times the number of days since precipitation. The FFMC is set to 85 regardless of whether significant winter snow cover was present because of its short memory, with a timelag of 3 days required to lose 2/3 of the free moisture content in light, fine fuels. The timelag for DMC fuels is 12 days, and 51 days for DC, reflecting longer equilibration times. The calculations are stopped with either the arrival of snow or a mean temperature below 6 °C for three consecutive days.

This approach was chosen to capture the effect of winters with below-normal precipitation, but to avoid fuel and site-specific parameters described in the approach of Lawson and Armitage (2008), which required too much local expert knowledge for our global scope. We also masked out fire-free regions for which the FWI System calculations are not meaningful. Cold regions were excluded based on the requirement that





NHESSD
2, 6555–6597, 2014

# Page: 6

Number: 1 Author: Subject: Highlight Date: 17/04/2015 12:54:20
Any references you might give?

Number: 2 Author: Subject: Highlight Date: 17/04/2015 12:56:53
Based on the introduction and what was written previously, I don't have a feeling for what these values represent, what a typical range is. Perhaps you can give a better feeling for all of your codes, when they are introduced, and typical ranges?

Number: 3 Author: Subject: Highlight Date: 17/04/2015 12:57:32
Same as previous comment, I don't have a feel for what this number means.

Number: 4 Author: Subject: Highlight Date: 17/04/2015 12:59:21
Based on this paragraph, which is key, do you feel that an intelligent outsider not familiar with the index, would be able to repeat what you have done? I think they would find it difficult. I suggest that you go through this paragraph, and really consider if someone can go step by step and recreate your approach. I think most steps are there, it is just written in a manner that is not conducive to 'the approach considers the following steps'.

Number: 5 Author: Subject: Highlight Date: 17/04/2015 13:02:21
Either tell us (in the next two sentences, or following them) that the number and areas of the masked out areas will be given in Section *, or tell us here how many areas and grid cells this is for each case.

One item that is not clear here, is does this mean that if ten years it has a 'masked' criteria and one year it does not, you do consider it for that one year? So average temperature is less than -10 deg C, except for one year it is -9 deg C?

mean annual temperature be greater than −10 °C. Desert regions were excluded based on the requirement that mean annual precipitation be greater than 0.25 mm day$^{-1}$.

## 3 Weather data

### 3.1 Gridded fields

The starting point for our calculations was the NASA Modern Era Retrospective-Analysis for Research (Rienecker et al., 2011). MERRA is NASA's state-of-the-art re-analysis product which uses the GEOS-5 atmospheric general circulation model run at 1/2° latitude × 2/3° longitude horizontal resolution and with 72 vertical levels. Sea surface temperature and sea ice boundary conditions are prescribed from Reynolds et al. (2002). Observational constraints from a wide variety of in-situ and remotely sensed sources are used. Pressure, temperature, humidity and wind observations are obtained from surface weather stations, upper air stations, aircraft reports and drop-sondes, ship and buoy observations, as well as weather satellites and research instruments such as MODIS and QuikSCAT. Raw radiance data are assimilated directly from microwave and infrared sounders with different observational periods, using embedded forward radiative transfer models to estimate instrument-equivalent fields. Precipitation is constrained most directly from Special Sensor Microwave Imager (SSM/I) radiances and Tropical Rainfall Measuring Mission (TRMM) rain rate estimates when available, but not by surface gauges. Further details are provided by Rienecker et al. (2011) and references therein.

Among FWI input variables, the MERRA precipitation estimates are most strongly influenced by the model physics, which, for convective precipitation especially, must be approximated using subgrid-scale parameterizations. This introduces considerable uncertainty into the MERRA precipitation. We therefore considered FWI System calculations using two other daily, global precipitation datasets that are based on rain-gauge data. Sheffield et al. (2006) have produced global 1° × 1° fields of meteorological





NHESSD
2, 6555–6597, 2014
Development of a global fire weather database for 1980–2012
R. D. Field et al.

# Page: 7

Number: 1 Author: Subject: Highlight Date: 17/04/2015 13:02:59

provide a couple sentences below this header, stating "In this section we *******, ***** and *****" so reader knows what is coming.

Number: 2 Author: Subject: Highlight Date: 17/04/2015 13:03:26

Add "(MERRA)

fields useful for land hydrology models. Their precipitation estimates start with monthly precipitation estimates from the University of East Anglia (UEA) Climatic Research Unit (CRU) monthly global gridded product (Mitchell and Jones, 2005) which are distributed at a daily frequency using National Centers for Environmental Prediction (NCEP)/National Center for Atmospheric Research (NCAR) reanalysis (Kalnay et al., 1996).

The National Oceanic and Atmospheric Administration (NOAA) Climate Prediction Center (CPC) produces estimates of global, daily precipitation fields over land from rain gauge data (Chen et al., 2008). Their optimal interpolation method makes use of the covariance structure of the precipitation field, which, compared to more simple distance-only based interpolation methods, should improve estimates where orography is important. The accuracy of gauge-based estimates ultimately depends on the rain gauge density, which for our purpose was most sparse in northern Canada and Alaska, northern Russia, sub-Saharan Africa and equatorial Southeast Asia. The Sheffield and CPC precipitation fields will ultimately share much of the same raw data and should not be considered truly independent. The important differences in this context are in their approaches to interpolation over sparse regions and estimates at a daily time scale. In total, we produced three global FWI System datasets: MERRA only, MERRA with Sheffield (SHEFF) precipitation, and MERRA with CPC precipitation. Throughout the paper we refer to each FWI version by the name of the precipitation input.

### 3.2 Station data

We compared the calculations from gridded data to those based on individual station data for a representative set of stations obtained from a variety of sources. Whenever possible, data was used that had previously been used by individual agencies for FWI System calculations. As such, the length of record varied by agency. We sought pairs of stations in the same region to guard against localized effects and possible errors in single weather station records. Similar to the use of the two precipitation datasets, this is not a strict validation of the gridded FWI calculations per se, since some of the





NHESSD
2, 6555–6597, 2014

Development of a global fire weather database for 1980–2012

R. D. Field et al.

# Page: 8

Number: 1 Author: Subject: Highlight Date: 17/04/2015 13:10:12

Somewhat vague here. Either refer to later section where you will be more precise, or state "discussed in more detail below" or be more precise here.

Number: 2 Author: Subject: Highlight Date: 17/04/2015 13:07:52

Again, a bit vague. Either state the section (e.g., further details given in Section *) or give the specifics here.

Number: 3 Author: Subject: Highlight Date: 17/04/2015 13:08:24

Same comment. Be more precise here, or tell us it is coming.

weather station data will have been assimilated into the MERRA analyses or the gridded precipitation fields. The comparison to station-based calculations instead provides a sense for users of the smoothing that occurs for grid-cell scale calculations. Individual station calculations were compared to the average over the area defined by the station coordinates buffered by a $1/2^{\circ}$ latitude and longitude band. Snow depth was generally not available for the station data and was instead sampled from the MERRA estimates. This also simplified our comparison by eliminating DMC and DC startup values as a potential difference between datasets.

Table 1 lists the stations used and the period covered. The majority of stations were from World Meteorological Organization (WMO)-level synoptic stations and will therefore adhere somewhat to a common set of data quality standards. For consistency, comparison with the gridded FWI calculation was over the period of available data only for each individual station. Additional quality control and gap filling was applied following local procedures.

Data for Canadian stations came from Environment Canada for the years 1979–1998, 1999 or 2006 for the fire season, which was determined using a temperature threshold as outlined in Wotton and Flannigan (1993). Data for stations in Thailand had no more than 3 % missing data for any of the input parameters. Missing data was interpolated temporally or spatially, and subject to established homogeneity tests for temperature and precipitation (Alexandersson, 1986; Manomaiphiboon et al., 2013). Wind siting was rated at least "fair" for all stations, indicating the absence of large barriers to unobstructed wind measurements. For Australia, four pairs of stations were selected with each of these stations having no more than 0.7 % of days with missing data for any of the input parameters. Missing data for wind speed, relative humidity and temperature were replaced by the average of the previous and subsequent days of available data, and missing data for precipitation were replaced by data from the nearby station (using the station pairs listed in Table 1). The rainfall data are for the 24 h period prior to 09:00 LT on the listed day. The four pairs of Australian stations have operated continuously throughout the study period (i.e., without being moved to





NHESSD
2, 6555–6597, 2014

# Page: 9

Number: 1 Author: Subject: Highlight Date: 17/04/2015 13:09:27
periods

Number: 2 Author: Subject: Highlight Date: 17/04/2015 13:09:16

Number: 3 Author: Subject: Highlight Date: 17/04/2015 13:12:52
"following local procedures which we now describe."

Number: 4 Author: Subject: Highlight Date: 17/04/2015 13:12:03
Grammar?

Number: 5 Author: Subject: Highlight Date: 17/04/2015 13:11:22
in-text citation needed?

Number: 6 Author: Subject: Highlight Date: 17/04/2015 13:14:11
Break this out into specifics, with
(i)Thailand.
(ii) Australia
(iii) All countries.
this will make it easier for the reader.

a different location). Data for Mexico and Guatemala were obtained from the Mexico Forest Fire Information System operated by the Canadian Forest Service at the Northern Forestry Centre. Weather data is collected in near real time from stations operated by the meteorological offices of the respective countries and supplying observations through the WMO's Global Observing Program and Global Telecommunications Service. The closest pairs of stations with the best observation records were chosen for this study, which were Mexicali and Tijuana in northwestern Mexico and Huehuetenango and Guatemala City Aurora in Guatemala.

For regions when no direct agency FWI System input data were available, we obtained raw hourly weather data directly from the 1 NOAA National Climatic Data Center (NCDC) Integrated Surface Database (ISD) (Smith et al., 2011) In many cases for the ISD stations, there 2 were large periods of missing data. Missing values were filled with those from MERRA for the sake of being able to continue the calculations. Periods with too much missing station data over an antecedent period, 3 however, were excluded from our monthly climatological means and comparison. We required that 80 % of the previous 120 days had precipitation reporting for at least 18 h per day. This allowed us to make use of the precipitation reported as both daily and hourly totals, but with an effort to avoid introducing a systematic bias due to missing precipitation reports. The start and end years in Table 1 indicate the full period over which some data were available, but in most case the actual periods included when comparing the DC to the gridded datasets were shorter, often only a few years. 4 Stations in southern Europe tended to have higher quality from the mid 2000s onward, for example, whereas data from Indonesia was typically only of sufficient quality in the mid 1990s. The comparisons with the gridded calculations take this into account, but we make therefore make comparisons between stations with a fair degree of caution. Information on data quality for the NCDC stations is provided as part of the dataset.



NHESSD
2, 6555–6597, 2014

Development of a global fire weather database for 1980–2012

R. D. Field et al.

# Page: 10

Number: 1 Author: Subject: Highlight Date: 17/04/2015 13:17:06

All of these need in-text citations for the actual data bases. Try to avoid putting web addresses (if that is what you use) in the text, and instead put them in the reference list.

So (NCDC, 2015) in the text.
Then in the reference list.
NCDC (NOAA National Climatic Data Center) (2015) Home page. [Online] Available from: http//www.***.**** [Accessed 1 April 2015].

I suggest you do this for all of the 'data' places you refer to.

Number: 2 Author: Subject: Highlight Date: 17/04/2015 13:23:03

It wasn't clear to me how big these periods of missing data were, or how many. In other words, consective numbers and totals. This needs much better explanation.

I get to Table 1 and go through this paragraph and the last, and I still don't really have a concrete feeling for how much gaps impacted the data or elsewhere. . This is an important item to explain.

The way this is being written, almost requires the reader to consult with the authors to figure out exactly what was done--the reader would not do the same analysis given the same sets of data, as they would be unsure how gaps were dealt with.

Number: 3 Author: Subject: Highlight Date: 17/04/2015 13:23:46

How often did this occur? Which locations?

Number: 4 Author: Subject: Highlight Date: 17/04/2015 13:25:09

This is good, but still not enough to know exactly which years and for how many hours/days/consective periods, data were missing. You could always include supplementary material with this information?

# Results

We used the Drought Code for our comparison between station and gridded calculations because it will most directly capture the sensitivity to different precipitation input datasets.

## 4.1 North America

Figure 1 shows the monthly mean DC for three regions in Canada, for each of the three gridded datasets and two weather stations, and for northwestern Mexico. The Southern British Columbia (BC) interior DC captures the southern, drier part of Canada's Montane Cordillera ecozone (Stocks et al., 2002). Fires in this region are numerous but tend to be smaller (Jiang et al., 2010), more often caused by humans and subject to intense fire management due to relatively high population density compared to other forested regions of the country. The DC values between the two stations are consistent for the station-based calculations, peaking in September with values approaching 450. The DC seasonality is captured well by the MERRA and CPC-based calculations, but has a low bias for the SHEFF precipitation, the DC for which peaks closer to 350. Presumably this is because of the lower spatial resolution CRU/NCEP reanalysis-based estimates used in SHEFF and the influence of weather stations on the much wetter west coast.

Large fires occur most frequently in Canada in the Boreal Shield West ecozone (Stocks et al., 2002). Using our startup definition, the DC fire season starts in April, one month later than in British Columbia. Both stations are located in Manitoba, in the western portion of the ecozone. The DC peaks in August–September between 250 and 300, reflecting the net drying that occurs in deeper fuels over the summer. The MERRA only-based DC (blue line) has a slightly higher bias than the SHEFF or CPC based DC relative to the station-based calculations, but all gridded DC calculations peak within the 300–425 danger class for that region during August and September, consistent with long-term CWFIS estimates. For reference, Amiro et al. (2004) determined that





NHESSD
2, 6555–6597, 2014

Development of a global fire weather database for 1980–2012

R. D. Field et al.

# Page: 11

Number: 1 Author: Subject: Highlight Date: 17/04/2015 13:26:04

Again, help the reader out, tell them what is coming. "Here we present results for each continent" or something like that.

Number: 2 Author: Subject: Highlight Date: 17/04/2015 13:27:55

Here and below, avoid having numbers on their own. So here, it would be approaching DC = 450. This of course will 'repeat' it, but much easier to read.

Number: 3 Author: Subject: Highlight Date: 17/04/2015 13:31:25

Here and elsewhere, if you use words like small, large, frequent, few, then add some quantitative descriptions, so "large fires (e.g., on average five fires > *** ha every year)" the maximum DC in this region calculated over days with large fires only was over 400 during September. The lower DC values in the Boreal Shield East ecozone compared to the Boreal Shield West values are consistent with a lower burned area (Stocks et al., 2002). This is presumably due to the influence of large-scale, cyclonic precipitation originating in the southern US which rarely arrives to in the Boreal Shield West, and appears to have a slightly stronger influence on the Val-D'or station which is to the east of Earlton. The spread between the MERRA, SHEFF and CPC-based DC calculations is comparable to the differences between the two stations.

The stations in Mexico capture the DC condition toward the southern extent of North America. Tijuana is a coastal city with a Mediterranean climate, separated by a low mountain range from Mexicali, which is on the western edge of the Sonoran desert. This arid environment has fuels similar to those found in the San Diego area in southern California (Minnich and Chou, 1997), consisting of areas of chaparral and grassland in the mountains, and some broadleaf trees in the intermittent riparian zones. Fires are generally smaller on the Mexican side of the border compared to the California side, possibly in part due to differences in suppression programs (Minnich and Chou, 1997). Mexicali (15 mm annually) is a much drier location than Tijuana (230 mm annually), with the maritime influence in Tijuana providing heavier winter precipitation. Summer convective monsoon thundershowers provide Mexicali with light but regular rainfall from later summer through the early part of the winter. Due to the aridity of this environment, DC values routinely exceed 1000, and often reach 1500 in the hottest and driest summer periods. During the wetter seasons, the DC values are usually reduced to the 700–800 range in Mexicali and 300–500 in the coastal Tijuana area. The absence of winter snow or a strong wet season means that, on average, deep fuel moisture does not fully recharge and the DC does not "zero-out". The MERRA data generally has the highest DC values, although all model variations closely follow the DC trends in the hot and dry late summer and early autumn period. The CPC and SHEFF DC are lower than either station during the spring.





NHESSD
2, 6555–6597, 2014

# Page: 12

Number: 1 Author: Subject: Highlight Date: 17/04/2015 13:33:38

"(on average, 75 mm yr^-1 from YYYY to YYYY, reference)" speed indicated by the DC is about 52 days (i.e. the time to lose about two thirds of its free moisture above equilibrium), as compared to about 12 days for the DMC and 2/3 of a day for the FFMC, with the FFMC and DMC also being important indicators of severe fire weather conditions in Australia in addition to the DC (Dowdy et al., 2010).

## 8 Global FWI variability

Figure 8 shows the mean May snow depth and fraction of days over which the FWI System is active, based on our startup and shutdown procedures. The maps essentially show the dependence and variability of FWI System startup on snow cover, in this case estimated from MERRA.

Figure 9 shows the mean, global Fire Weather Index (FWI) during January and July for all three datasets. The mean FWI is calculated from 1980 onwards, excluding 1979 as a moisture code equilibration year. We describe FWI seasonality according to selected fire regions defined by van der Werf et al. (2010), starting with the MERRA-based calculations. In January, FWI calculations are not active over the Boreal North America and Boreal Asia regions. Over Temperate North America and Europe, mean FWI values reflect only a small number of anomalous warm and snow-free days during which the calculations were active. At low latitudes, the highest values based on MERRA are over Northern Hemisphere Africa, which contributes significantly to global emissions, when the ITCZ is displaced to the south. FWI is also high ($> 40$) in areas of Southern Hemisphere South America, the southern half of Australia, excepting its eastern coast, and northwest India. There are moderate (20–40) FWI values in Mexico and parts of continental Southeast Asia. Elsewhere, the FWI is generally low, including over the Amazon basin, Northern Hemisphere South America, the Congo basin, and Equatorial Southeast Asia.

In June, the FWI System is active over the northern Boreal regions, and does generally not exceed 30. Although an FWI of 30 is well below the seasonal peak at low latitudes, this can reflect severe fire danger conditions over the boreal regions. In the northern temperate regions, high values are seen over the fire prone regions of the





NHESSD
2, 6555–6597, 2014
Development of a global fire weather database for 1980–2012
R. D. Field et al.

# Page: 21

Number: 1 Author: Subject: Highlight Date: 17/04/2015 13:49:01

Figure 8 feels like it belonged 'before' the results section, coming after the methodology. But, this is your decision to make where you want it to appear.

Number: 2 Author: Subject: Highlight Date: 17/04/2015 13:47:01

Unclear. refer reader to section where discussed, or be specific.

Number: 3 Author: Subject: Highlight Date: 17/04/2015 13:49:37

I think you need to put the end date (at least for the Figure 9) not 'onwards' or not the gauge-based calculations are better will ultimately depend on the underlying rain gauge density. This information was available for the CPC precipitation dataset, shown in Fig. 10 during the 1979–2012 period. Values less than 1 indicate stations not operating during the full analysis period. Users are encouraged to consider rain gauge density for any region over which analyses are performed.

Globally, gauge density is highest over the US, eastern Brazil and the populated coastal regions of Australia. Density is reasonably high over central South America, which suggests that the low bias in the MERRA precipitation is genuine and that the MERRA FWI values there are unreliable. This is likely the case for MERRA's high precipitation and low FWI biases over continental Southeast Asia also, or for Thailand at least, where the CPC station density is high. In the northern Boreal region, coverage is sparse but fairly even across fire prone areas. In Southeast Asia, rain gauge density is low over the severe burning regions of Borneo and Sumatra. This limits spatially-detailed FWI analysis over the region, although previous analyses have shown that precipitation covariance over the region is strong enough (Aldrian and Susanto, 2003) that the FWI System values should provide useful information at a provincial or state-level. Identifying a more appropriate FWI version over tropical Africa is difficult due to the sparse and uneven gauge distribution, as cautioned by Chen et al. (2008) for precipitation-based analyses in general.

## 5 Summary

We have developed a global database of the Canadian FWI System components using MERRA reanalysis and two different gauge-based precipitation datasets. This dataset can be used for historical relationships between fire weather and fire activity at continental and global scales, in identifying large-scale atmosphere–ocean controls on fire weather, calibration of FWI-based fire prediction models, and as a baseline for projections of fire weather under future climate scenarios as the reanalysis products improve.





NHESSD
2, 6555–6597, 2014
Development of a global fire weather database for 1980–2012
R. D. Field et al.

# Page: 23

Number: 1 Author: Subject: Highlight Date: 17/04/2015 13:56:24

I get to the end of the results, after looking at all the figures, and I don't feel like I really have a good feeling (same was true for the data) that I understood, other than a fairly qualitative description, the range of the data spatially, temporally, in terms of DC. I would suggest thinking about some other ways of presenting summary statistics for the data, so is not just 'all' page after page of descriptive results.

There are two main items being used for FC--spatially gridded data and time, and these do not come through well in the final results their variability.

Finally, coming to the end of the results, and discussion, I do not have a good feeling for uncertainties and limitations. This is particularly important for a paper like this, as to what uncertainties there might be for the resulting data produced in time.

Number: 2 Author: Subject: Highlight Date: 17/04/2015 13:52:52

Throughout, you need to better signal (without it being core to the argument in the text) the supplementary material.

**Table 1.** Weather stations used for comparison to gridded calculations. Abbreviations are as follows: Environment Canada (EnvCan), GTS (Global Telecommunications System), Canadian Forest Service Northern Forestry Centre (NoFC), National Oceanic and Atmospheric Administration National Climatic Data Center (NCDC), Canadian Forest Service Great Lakes Forestry Centre (GLFC), Australian Bureau of Meteorology (BoM), Thailand Meteorology Department (TMD), Malaysian Meteorological Department (MMD).

| ID | Name | Country | Lat. | Lon. | Source | Start year | End year |
|---|---|---|---|---|---|---|---|
| 1123970 | Kelowna | Canada | 49.88 | −119.48 | EnvCan | 1980 | 2006 |
| 1126150 | Penticton | Canada | 49.48 | −119.58 | EnvCan | 1980 | 1998 |
| 5050960 | Flin Flon | Canada | 54.77 | −101.85 | EnvCan | 1980 | 1999 |
| 5052880 | The Pas | Canada | 53.82 | −101.25 | EnvCan | 1980 | 1999 |
| 6072225 | Earlton | Canada | 47.71 | −79.83 | EnvCan | 1980 | 1999 |
| 7098600 | Val-dOr | Canada | 48.10 | −77.78 | EnvCan | 1980 | 1995 |
| 760016 | Mexicali | Mexico | 32.63 | −117.00 | GTS–NoFC | 1999 | 2012 |
| 760023 | Tijuana | Mexico | 32.55 | −116.97 | GTS–NoFC | 1999 | 2012 |
| 78627 | Huehuetenango | Guatemala | 15.32 | −91.47 | GTS–NoFC | 1999 | 2012 |
| 78641 | Guatemala City | Guatemala | 14.58 | −90.52 | GTS–NoFC | 1999 | 2012 |
| 836120 | Campo Grande | Brazil | −20.45 | −54.72 | NCDC | 1980 | 2012 |
| 833620 | Cuiaba | Brazil | −15.65 | −56.10 | NCDC | 1980 | 2012 |
| 2460 | Stockholm Arlanda | Sweden | 59.65 | 17.95 | GTS–NoFC | 2001 | 2012 |
| 2464 | Stockholm Bromma | Sweden | 59.35 | 17.95 | GTS–NoFC | 2001 | 2012 |
| 2974 | Helsinki Vantaa | Finland | 61.32 | 24.97 | GTS–NoFC | 2004 | 2012 |
| 2975 | Helsinki Malmi | Finland | 61.25 | 25.05 | GTS–NoFC | 2001 | 2012 |
| 10616 | Hahn | Germany | 49.95 | 7.27 | GTS–NoFC | 2001 | 2012 |
| 10708 | Saarbruecken | Germany | 49.22 | 7.12 | GTS–NoFC | 2001 | 2012 |
| 286960 | Kalachinsk | Russia | 55.03 | 74.58 | NCDC-GLFC | 1980 | 2010 |
| 296360 | Toguchin | Russia | 55.23 | 84.40 | NCDC-GLFC | 1980 | 2010 |
| 80010 | La Coruna | Spain | 43.37 | −8.42 | NCDC | 1980 | 2012 |
| 80420 | Santiago | Spain | 42.89 | −8.41 | NCDC | 1980 | 2012 |
| 83910 | Seville | Spain | 37.42 | −5.88 | NCDC | 1980 | 2012 |
| 84100 | Cordoba | Spain | 37.84 | −4.85 | NCDC | 1980 | 2012 |





NHESSD
2, 6555–6597, 2014

Development of a global fire weather database for 1980–2012

R. D. Field et al.

# Page: 32

Number: 1 Author: Subject: Highlight Date: 17/04/2015 13:19:06

Tell us who's ID this is.

Tell us whether these are 'full years' used.

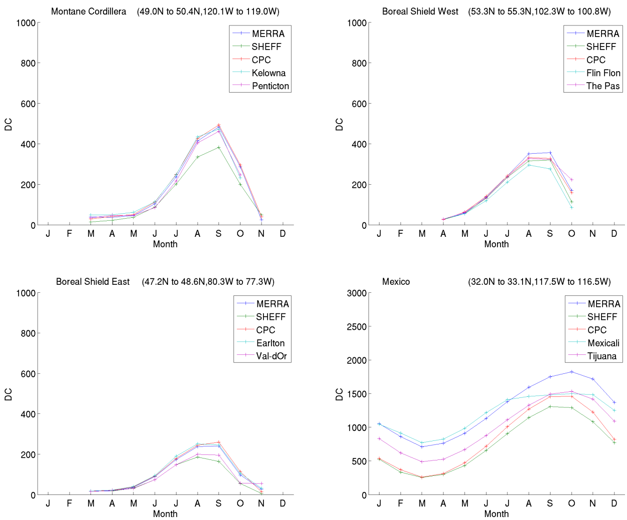


Figure 1. Monthly mean Drought Code (DC) for three regions in Canada and northwestern Mexico. Note the different DC scale for Mexico.





NHESSD
2, 6555–6597, 2014

Development of a global fire weather database for 1980–2012

R. D. Field et al.

Title Page
Abstract Introduction
Conclusions References
Tables Figures
◂ ▸
Back Close
Full Screen / Esc
Printer-friendly Version
Interactive Discussion

# Page: 34

Number: 1 Author: Subject: Highlight Date: 17/04/2015 13:40:50

Figure caption feels a bit incomplete and definitely not stand alone.

Tell us what the monthly mean DC is based on (years used, data input--or refer reader to section in the text). For subsequent figures you can state "See Figure 1 caption for further details"

In terms of the figures themselves, label them A, B, C, D.

Add 'degrees' (symbol) for anywhere you have lat and long measurements.

You have done monthly mean DC measurements for a given number of years. But what this does not give us an idea of is the spread of DC values over the years. I suggest you need to discuss this (in the text--is it normally distributed, thus justifying the use of a mean?) and here, consider using +- 2 s.d., or perhaps 25%-75% (and mode). This will put much of the results into much better context.

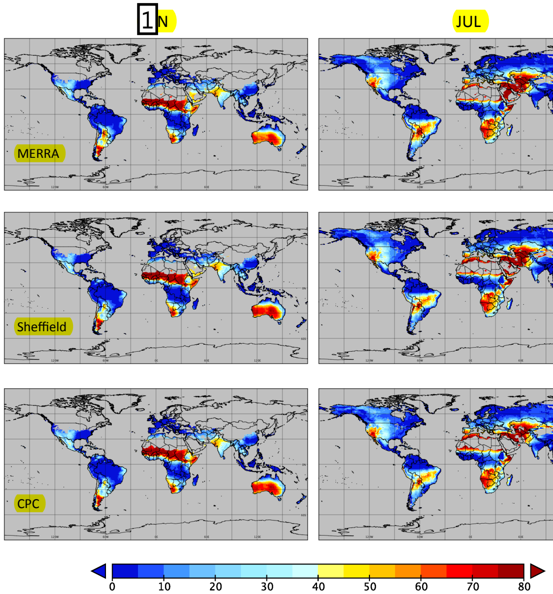


**Figure 9.** Global mean FWI for January and July based on MERRA precipitation (1980–2012), Sheffield precipitation (1980–2008), and CPC precipitation (1980–2012).





NHESSD
2, 6555–6597, 2014

# Page: 42

Number: 1 Author: Subject: Highlight Date: 17/04/2015 13:57:35

Do you really mean global mean FWI, or rather global gridded (size of grid cell) mean FWI?

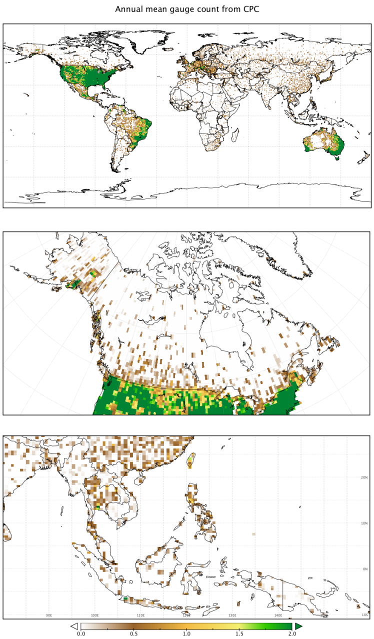


**Figure 10.** Average 1979–2012 CPC rain gauge coverage (gauges/grid cell) for the globe (top), Canada (middle), Southeast Asia (bottom).





NHESSD
2, 6555–6597, 2014

# Page: 43

Number: 1 Author: Subject: Highlight Date: 17/04/2015 13:43:27

Be consistent. use the word 'average' or 'mean' throughout, but do not go back and forth.

As before, make it clear to the reader whether underlying probability of the values in each cell over the years is normally distributed or not, make figure caption more complete (what is grid resolution, refer reader to where procedure discussed, etc.).