INCORPORATION OF RADAR PRECIPITATION ESTIMATES IN A DROUGHT INDEX APPLICABLE TO WILDLAND FIRE

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Abstract. The Keetch-Byram Drought Index is a measure of drought designed for application to forest fires. The Florida Division of Forestry has improved the spatial resolution of the KBDI by utilizing radar-based precipitation estimates in the calculation. The resulting product has become an integral component of the Division's decision making process with regard to allocation of fire fighting resources.

INTRODUCTION

Drought is a very complex phenomenon as is evident by the wide range of definitions that can be found for this term. Palmer (1965) gives seven different definitions and states that this list is by no means exhaustive. Keetch and Byram (1968) developed an index that assessed moisture conditions as they relate to wildland fire. This drought index, hereafter referred to as the KBDI, is defined as a numerical representation of the net impact of evapotranspiration and precipitation on the cumulative moisture deficit in the duff and upper soil layers. The KBDI is calculated on a daily basis, allowing for very rapid response to precipitation events. This fast response is critical to wildland fires as their threat quickly decreases due to significant rainfall.

The KBDI was designed to relate to the flammability of organic material in the ground. When dry, this material is additional fuel for a fire and thus leads to increased fire intensity and potential control problems. The KBDI provides land managers with a continuous scale of reference (running from 0-no moisture deficit to 800-moisture deficit of eight inches) for estimating the potential impacts of drought on prescribed burning and fire suppression. The KBDI is widely accepted in the wildland fire community and is an integral component of the 1988 revision to the National Fire Danger Rating System (Burgan, 1988). A pair of papers by Melton (1989 and 1994) summarized expected fire behavior on wildfires and prescribed fires based on various ranges of the KBDI.

After Florida's extremely severe fire season in 1998, the Florida Division of Forestry determined that they had a need to track the KBDI at a higher spatial resolution than was provided using data from the National Weather Service (NWS) Automated Surface Observing System (ASOS) network. The primary input variable to the KBDI that needed improved resolution was precipitation. Florida began using daily radar-based precipitation estimates from the NWS network of Next Generation Radars (NEXRAD or WSR-88D) in their calculation of the KBDI, which provided precipitation data at spatial resolution of 4 km across the state. Radar data has been incorporated in the Florida Division of Forestry's calculation of the KBDI since April of 1999 and has become a critical component of their decision-making process for allocating resources for wildfire suppression and managing one of the nation's largest prescribed burning programs.

This paper describes the process used by Florida for calculating the KBDI that incorporates both traditional weather observations (temperature and rainfall) and radar precipitation estimates. Merging the rainfall observations with the radar estimates provides a means to maintain the accuracy of the observations while gaining the spatial pattern seen by the radar. Examples of the products produced by this system will be shown along with a discussion of its pros and cons.

METHODOLOGY

The KBDI is a cumulative index based on a simple budget as it seeks to balance precipitation against evapotranspiration. The KBDI has inputs of maximum daily temperature, daily and annual precipitation and is based on the following assumptions (Keetch and Byram, 1968):

- The rate of moisture loss in a forested area depends on the vegetation density. Vegetation density is assumed to be a function of annual precipitation.
- The vegetation-rainfall relationship is approximated by an exponential curve.
- The rate of moisture loss from soil is determined by evapotranspiration relations.
- The depletion of soil moisture with time follows an exponential curve.
- The depth of the soil layer considered has a field capacity of eight inches of available water.

The KBDI is calculated on a daily basis by first subtracting the daily rainfall total (*r*) in inches multiplied by 100 from the previous days KBDI value (K_0). The change in the KBDI due to the evapotranspiration part of the budget is calculated as a function of the previous days KBDI (K_0), daily high temperature (*T*, in degrees Fahrenheit), and the sites annual mean precipitation (*R*). The complete KBDI calculation is given by:

$$K = K_0 - 100r + \frac{(800 - K_0)(0.968\exp(0.0486T) - 8.30)}{1000\left[1 + 10.88\exp(-0.441R)\right]}$$

The daily rainfall total (*r*) used in the above calculation results from using ASOS observations to correct the estimated precipitation from the WSR-88D hourly digital precipitation array data. The goal of the correction scheme is to maintain the actual observed values where present, but have the radar provide a means of interpolating between these known values. The process to accomplish this is similar to that employed by Stellman et al. (2001). The first step in this process involved determining a mean bias for all rain gauge/radar data pairs and subtracting this bias from all radar estimates. The second step involved determining the local correction between observed rainfall and the bias corrected radar estimate, and then using a distance-weighted average to interpolate these local corrections throughout the radar grid. The reader is referred to the work of Rinehart (1997) for an excellent introduction to rainfall estimation with radars.

CONCLUSIONS

The KBDI maps produced by the Florida Division of Forestry's Forest Protection bureau have become one of the most visited parts of the Division's web site (http://flame.fl-dof.com/fire_weather/kbdi). These maps include statewide views of county average KBDI values as well as the high-resolution 4 km data (Figure 1). The county average maps are derived from the 4 km data. In addition to maps a text report is generated that contains the mean, min and max KBDI values found in each county. This information has been used to allocate fire suppression resources and to ban both prescribed burning and the sale/use of fireworks during times of severe drought.

While the radar-based KBDI products have become an integral part of the Florida Division of Forestry's daily business, the system is not without its faults. Contamination of the radar precipitation estimates by non-precipitation data is the primary fault. The correction scheme does help to minimize this problem in most cases; smoke plumes from large fires are a frequent source of contamination. During May and June, the peak of Florida's wildfire season, these plumes often occur on days when afternoon thunderstorms are also occurring, limiting the ability of the correction scheme to remove the erroneous signal from the plume. Thus, these plumes will pass through the system as valid rainfall unless there is a collocated rain gauge showing no rainfall. This fault leads to very localized errors in the product and is not considered a fatal flaw as the gains in spatial resolution far outweigh these localized errors.

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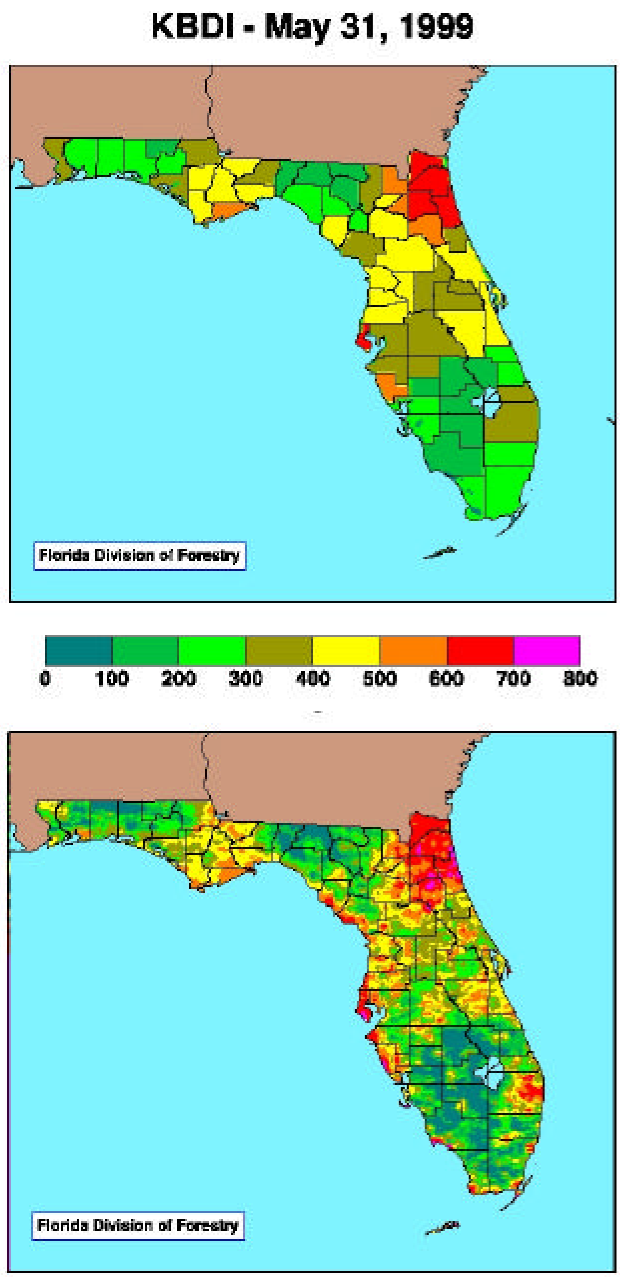

Figure 1. Maps of county average KBDI (top) and full 4 km resolution KBDI data (bottom).