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GCInsights: Consistency in Pyrocartography Starts With Color

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Abstract. Fire progression maps provide operational and public information regarding wildland fire spread, size, and proximity to critical assets through time. Cartographic guidance regarding the use of color to denote the sequential nature of fire progression is limited, leading to inconsistency in fire progression maps produced for operational, research, and public applications. Because this inconsistency potentially limits the map's accessibility and ability to effectively communicate information, I provide colormap recommendations to facilitate consistent, intuitive, and accessible fire progression mapping.

1 Introduction

Wildland fire's movement across the landscape results from factors including weather, fuels, topography, fire history, and fire suppression activities. The most extreme cases of fire spread occur when strong winds and the orientation of topography align with accumulations of continuous fuels available to burn at high intensity and produce downstream ignitions–spot fires–meters to kilometers ahead of the flaming front. Fire progression maps (FPMs) provide a first-order visualization of a wildfire's current perimeter and spread since ignition (Figure 1). Typically, FPMs are produced daily using aircraft-based infrared data, though near-real estimates are increasingly available using satellite data (Chen et al., 2022; Berman et al., 2023).

Operationally, FPMs assist fire managers in formulating strategies and implementing tactics for achieving desired management outcomes and to understand prior management efforts. Forecast FPMs produced by fire behavior models using existing fire perimeters or ignition locations support fire management by simulating fire spread possibilities and potential smoke production (Kochanski et al., 2023). Public information officers and agency websites (e.g., https://inciweb.wildfire.gov/), share FPMs with the public, media, and agency partners to provide updates on fire activity and suppression efforts. Researchers and Burned Area Emergency Response teams may use FPMs to evaluate when a particular area burned, since the time of burning in a particular location often does not coincide with the ignition or containment date. Simulated FPMs extend to pre-fire planning efforts to help prioritize fuel management strategies and locations by mapping potential growth given varying treatments and ignition locations. Taken together, the creation and dissemination of FPMs for applications throughout the fire cycle motivates the need for maps that communicate effectively.

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2 Current Guidelines, Current Challenges

To provide a basis for consistency in geospatial products during wildfire incidents, the U.S.-based National Wildfire Coordinating Group (NWCG) maintains a set of cartographic standards called the NWCG Standards for Geospatial Operations "GeoOps" (Publication Management System 936) (National Wildfire Coordinating Group, 2024). GeoOps provides guidance on map product standards for wildland fire mapping with two specific recommendations for FPMs. First, it recommends using "standardised" color ramps (or colormaps) to show trends instead of discrete values when showing more than five time steps. Second, it recommends the standard element of the fire perimeter data for each time period, transitioning from cool (older) to warm colors (more recent).

Despite this guidance, at the time of writing, the GeoOps examples demonstrate known challenges in visual communication: the use of inconsistent (i.e., "standardised" is not defined explicitly), and potentially non-colorsafe colormaps to portray fire progressions (Figure A1). This highlights a missing, but easily remedied, aspect in GeoOps: the recommendation for sets of color-safe colormaps that improve accessibility (Crameri et al., 2020; Stoelzle and Stein, 2021) and address 508 Compliance, a U.S. Federal Standard (United States Congress, 1973). Further, the lack of consistency in FPMs (Figure A1, Chen et al. (2022); Kochanski et al. (2023)) represents another potential limiting factor in user cognition for maps already displaying complex information (Bunch and Lloyd, 2006) if the maps change from day-to-day, incident-to-incident, or across applications.

3 Colormap Recommendations

Near-daily fire perimeters using airborne infrared data from California's 2013 Rim Fire (17 August–24 October 2013; 104,131 ha) and 2021 Dixie Fire (13 July–27 September; 389,824 ha (fully contained on 25 October 2021)) serve to demonstrate alternative colormaps that address aforementioned limitations (Figure 1). Perimeter data was acquired from the National Interagency Fire Center (http://www.ftp.wildfire.gov). For clarity, we omit other standard cartographic elements of FPMs (key geographic features including topography, hydrography, and roads).

Fire progression across space over time is an ordinal process, implying sequential maps (Figure 1c-f) are more logical than diverging maps (Figure 1a-b). Further, mapping temporal data enhances the complexity of the display, implying the use of diverging colormaps to show sequential processes may cause users to misinterpret or miss important changes Buckley (2017). As the GeoOps notes, fire progressions include a thermal component as recently burned areas demonstrate intuitively higher temperatures. This motivates the cool-to-warm sequence, and whether such colormaps should preserve intuitive associations (i.e., hot red-to-cool blue) instead of physically-consistent associations (i.e., black-body emission temperatures) remains open to discussion. Here, we select the colormaps “Batlow” and "Managua" from Crameri (2021), the Colorbrewer Brewer et al. (2003) sequential “YlOrBr” (yellow-orange-brown; reversed to mimic the blackbody radiation color curve), and the perceptually-uniform, hue- and luminance-varying "Turbo" as suggested alternatives.

Beyond intuitiveness, colormaps should consider perceptual uniformity and other components of color accessibility (Crameri et al., 2020; Heggli et al., 2023; Ware et al., 2023). Labeling reference contours (isochrons) could incorporate accessibility if other elements of cartographic representation are desired or once continuous colormaps become difficult to interpret (Figure

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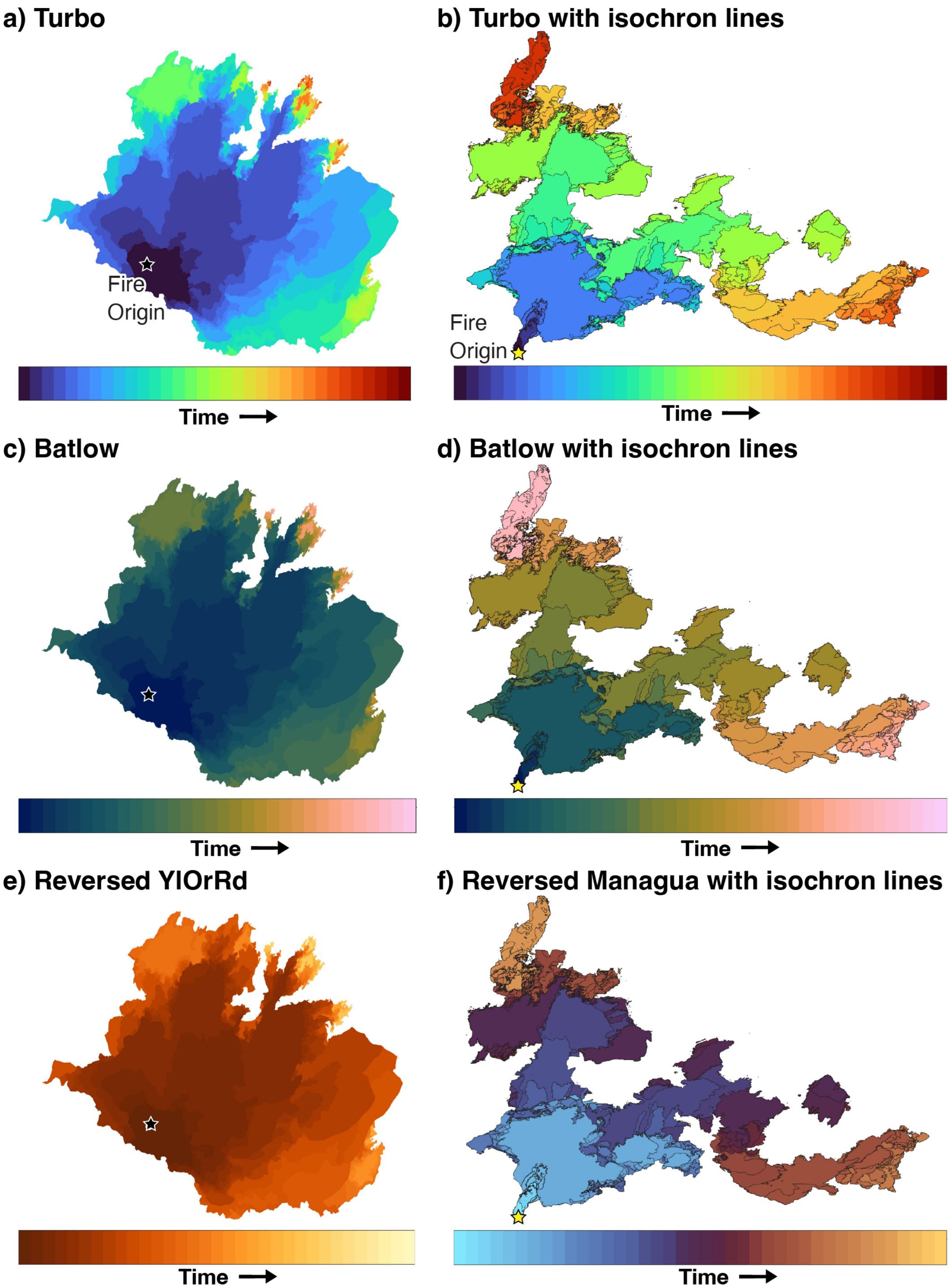

Figure 1. Fire progression maps of the 2013 Rim Fire (left column) and the 2021 Dixie Fire (right column) using colormaps and simple techniques to increase accessibility.

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1b,d,f). This latter issue relates to “just noticeable differences” (Ware et al., 2023)–the smallest difference between two colors–as color differences converge towards imperceptibility on long duration (weeks-to-months) wildfires. Multiple days of minimal fire activity interspersed with occasional rapid growth days or lack of infrared data may warrant situation-specific adjustments to colormaps.

Rainbow colormaps occur in FPM research (e.g., Chen et al. (2022)) and remain frequently used in scientific literature (Westaway, 2022). While Ware et al. (2023) argue that rainbow colormaps are rightly critiqued by the visualization community, when used appropriately their accessibility limitations can be addressed through better design (e.g., "Turbo"; Figure 1a-b).

4 Towards Consistency in Pyrocartography

Globally increasing fire activity (Sayedi et al., 2024) implies FPMs will become more important visual communication aids supporting wildland fire operations, research, and public information. However, accessibility and consistency in visual-product-based science communication is important if improving user cognition and decision making is a goal (Williams and Eosco, 2021; Heggli et al., 2023). Establishing a baseline set of standardised colormaps targeting accessibility and consistency in FPMs, especially if incorporated into cartographic standards (e.g., as updates to GeoOps; T. Beauchaine, personal communication, November 25, 2024), may benefit users of FPMs before, during, and after wildland fire. Because many options satisfying these basic criteria exist, I conclude by encouraging the pyrocartographic community to work towards developing a set of standardised colormaps. The four suggested colormaps (Figure 1), one of which is an example in GeoOps (Figure A1d), intend to provide a starting point.

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Appendix A: NWCG Examples and Colorblindness Simulation

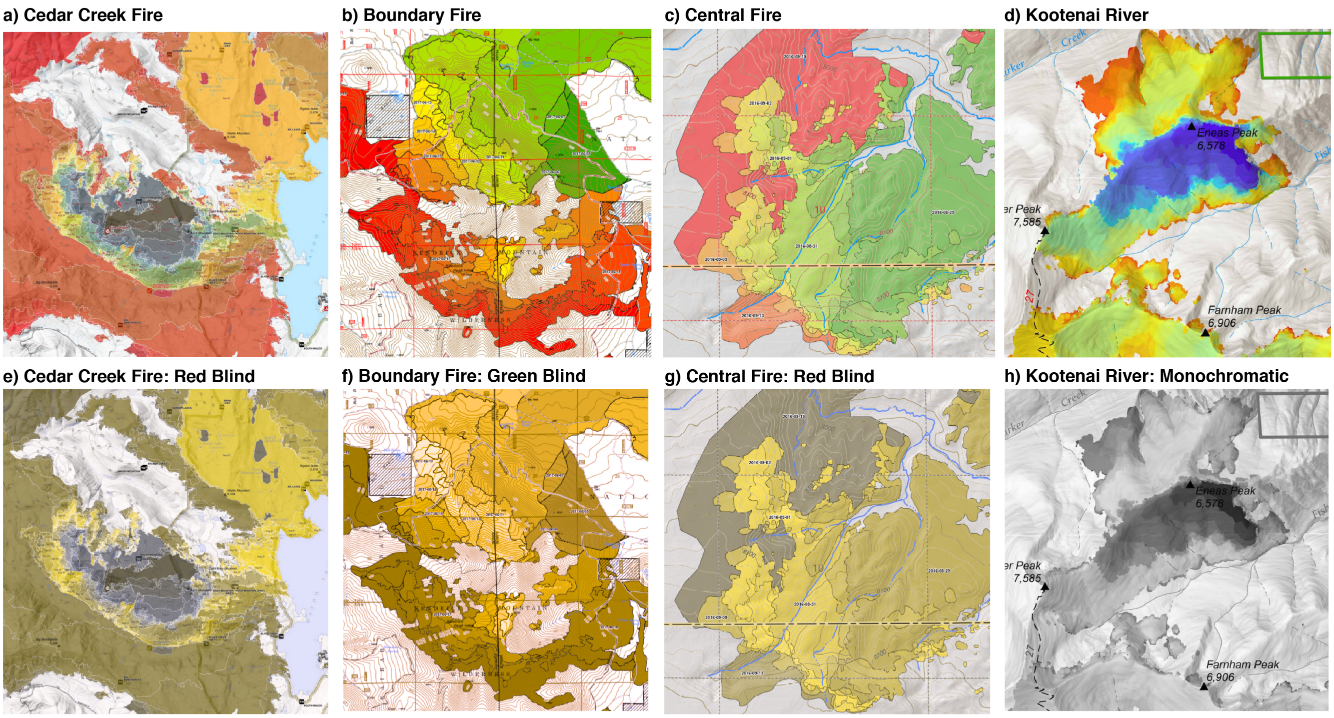

Figure A1. (a-d) The four fire progression examples provided in the NWCG Standards for Geospatial Operations ("GeoOps") Publication Management System 936 document (National Wildfire Coordinating Group, 2024) and accessed on 25 November 2024, reproduced under CC0 (public domain). Legends are omitted for clarity but colors progress forwards in time from cold (brown (a), green (b-c), or blue (d); older) to hot (red (a-d); recent). (e-h) The Coblis color blindness simulator (https://www.color-blindness.com/coblis-color-blindness-simulator/) demonstrates how these examples create varied colorblindness challenges (e-g) or black and white printing challenges (h).

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