Good Fire Weather

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ABSTRACT: Extreme fire weather receives substantial attention, yet conditions allowing readily manageable fire, or ”good fire weather” remain less studied with no formal definition. We propose a qualitative definition of good fire weather as ”the set of atmospheric conditions before, during, and following ignition allowing wildland fire to achieve beneficial outcomes while minimizing hazards from fire and smoke.” We explain beneficial fire outcomes and share examples of the multiscalar challenges in observing and forecasting good fire weather to inform decision making using schematics and a case study. Suggestions for ways the weather enterprise can support good fire weather forecasting are provided.

Keywords: Beneficial Fire, Fire Weather, Prescribed Fire, Wildland Fire

1. First, What Is "Fire Weather"?

Weather comprises a foundational component of the total fire environment, or "the surrounding conditions, influences, and modifying forces of topography, fuel, and weather that determine fire behavior" (National Wildfire Coordinating Group 2025b). Fire weather directly influences "fire ignition, behavior, and suppression" (National Wildfire Coordinating Group 2025b) and is initially evaluated using near-surface air temperature and relative humidity as well as low-level stability and winds.

2. When Is Fire Weather "Good"?

Good fire weather creates an environment allowing readily manageable fire behavior. This facilitates safely achieving wildland fire management objectives by minimizing extreme fire behavior (Werth et al. 2011). During wildfires, protecting life and property is a key objective. Management objectives vary depending on the location, the season, and community needs but include reducing fuels to lower wildfire hazard and spurring desired ecological outcomes by reducing vegetation competition, mitigating invasive species, stimulating regeneration of fire-adapted species, improving soil health, and enhancing habitat (Figure 1a-b; Huffman et al. 2020; Hankins 2024). Wildfires often burn during good fire weather producing beneficial effects. An equally valuable objective is increasing well-being through ecocultural stewardship (Hankins 2024). Beneficial fires lit by humans, including traditional, prescribed, and cultural fire, are planned to coincide with good fire weather to achieve these benefits. A range of temperatures, relative humidities, and winds both on and before the burn day can achieve fuel moistures to produce desired outcomes.

The parameters defining good fire weather (the 'prescription') can vary markedly. The weather must be sufficiently hot and dry to allow ignitions and fire spread but not so hot, dry and windy that a fire cannot be controlled with available holding resources. Thus, good fire weather is a "Goldilocks" situation (Lutz 2024). Wind often differentiates between conditions conducive to dangerous fire behavior and ideal conditions for beneficial fire; some circumstances dictate wind is required to meet objectives. Cloud cover, increased relative humidity, and precipitation helps control fires, indicating good fire weather includes a temporal trend component.

Minimizing smoke impacts from beneficial fire to human health, visibility, and agricultural production will ensure community support for burning (Figure 1c-d). A complete definition of good fire weather includes atmospheric conditions that favorably transport and disperse pollutants. During burning, an unstable vertical profile of temperature and presence of winds aloft allows smoke to rise and become available for transport.

3. What Does Good Fire Weather Look Like?

Because good fire weather occupies a middle-ground (“Goldilocks”) between weather extremes, conditions can quickly become unfavorable, especially in mountains or coastal regions. Too cold and moist means not meeting objectives. Conditions may abruptly turn hot, dry, and windy. Microclimates can provide good fire weather refugia (Figure 1c). Observations from Santa Rosa, California highlight this variability during a spring 2025 period (Figure 2). Comparisons to hourly mean values calculated daily between 1991–2025 provide climatological context.

Near-to-slightly-below-average daytime temperatures and light winds on 30 April–3 May produced brief windows of good fire weather for prescribed burning. Elevated nighttime relative humidities provided recovery. Drier conditions on 3 May increased fine fuel availability to burn, though afternoon winds likely exceeded prescriptions. Above-average temperatures and below-average relative humidity on 4 May looked good but with a catch: warming continued with notable overnight drying and increased vapor pressure deficits into 5 May with the onset of gusty, offshore, downslope “Diablo” winds. Good fire weather returned on 6 May with in-prescription conditions before becoming colder, moister, and cloudier on 7 May. The lagged drying effect of the warm Diablo winds on 10 hr fuels and the subsequent recovery implies 6 May offered an optimal beneficial fire window.

4. How Can the Weather Enterprise Improve Good Fire Weather Forecasts?

We define good fire weather as the set of atmospheric conditions before, during, and following ignition allowing wildland fire to achieve beneficial outcomes while minimizing hazards from fire and smoke. Although undesired extreme fire behavior or effects may still occur, “good fire weather” represents a parameter space for beneficial fire.

Intentional beneficial fires range from meter scales (pile burns) to 2,000+ ha prescribed burns (Hankins 2024). Active burning typically lasts 0.5–8 hours. Considering contemporary operational numerical weather and smoke transport models use horizontal resolutions of 1.33–4 km (133–1,600 ha) with hourly updates (Dowell et al. 2022), a scale mismatch is apparent (Figure 1). While synoptic to mesoscale conditions broadly indicate good fire weather, finer spatial (0.5–1 km^2) and temporal resolutions (output every 5–30 min) with hourly initializations approach necessary and sufficient resolutions to meet operational needs (Hatchett et al. 2024).

Advances in computing, model initialization and physics, and post-processing will improve forecast skill and resolution.Expanding official and community-provided observations enables initialization and verification of weather and smoke transport forecasts while also supporting smoke early warning systems (Prince et al. 2024). Training practitioners to use increasingly-available probabilistic forecast information (Skinner et al. 2023) improves decision making (Ripberger et al. 2022) and trust (Burgeno and Joslyn 2023). Communicating information is especially salient when good fire weather leads to widespread community burning, but forecasted rapid changes in the fire environment necessitate securement (Lindley et al. 2025). Collaboration between users and producers of fire weather information can iteratively improve products and services (Wells et al. 2025), aiding continued strategic expansion of beneficial fire and stewardship (North et al. 2024). This will better prepare communities to experience wildland fire in a fire-dependent and increasingly fire-prone world.

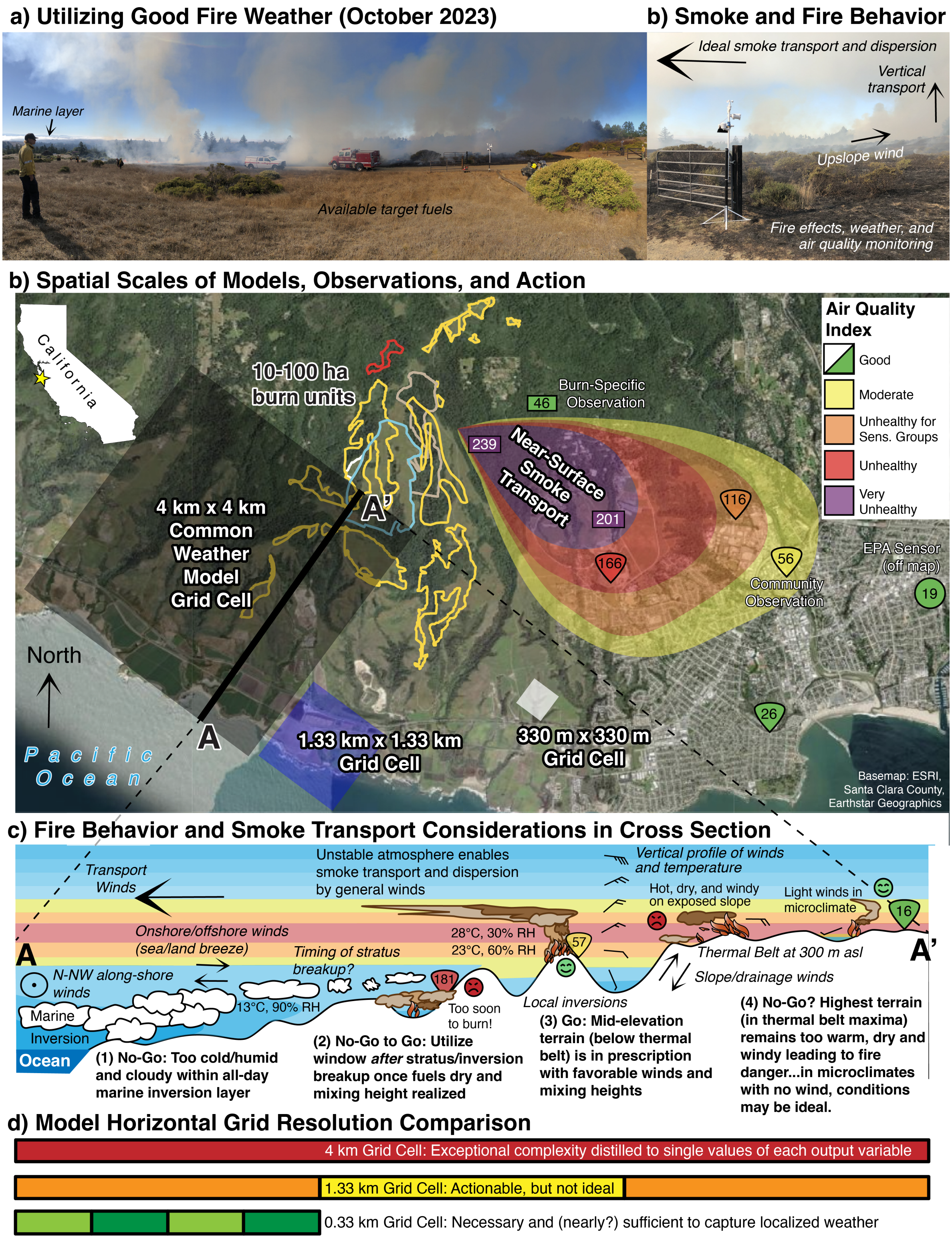

FIG. 1. Good fire weather requires understanding numerous multiscalar processes, highlighting the value of high-resolution observations and models.

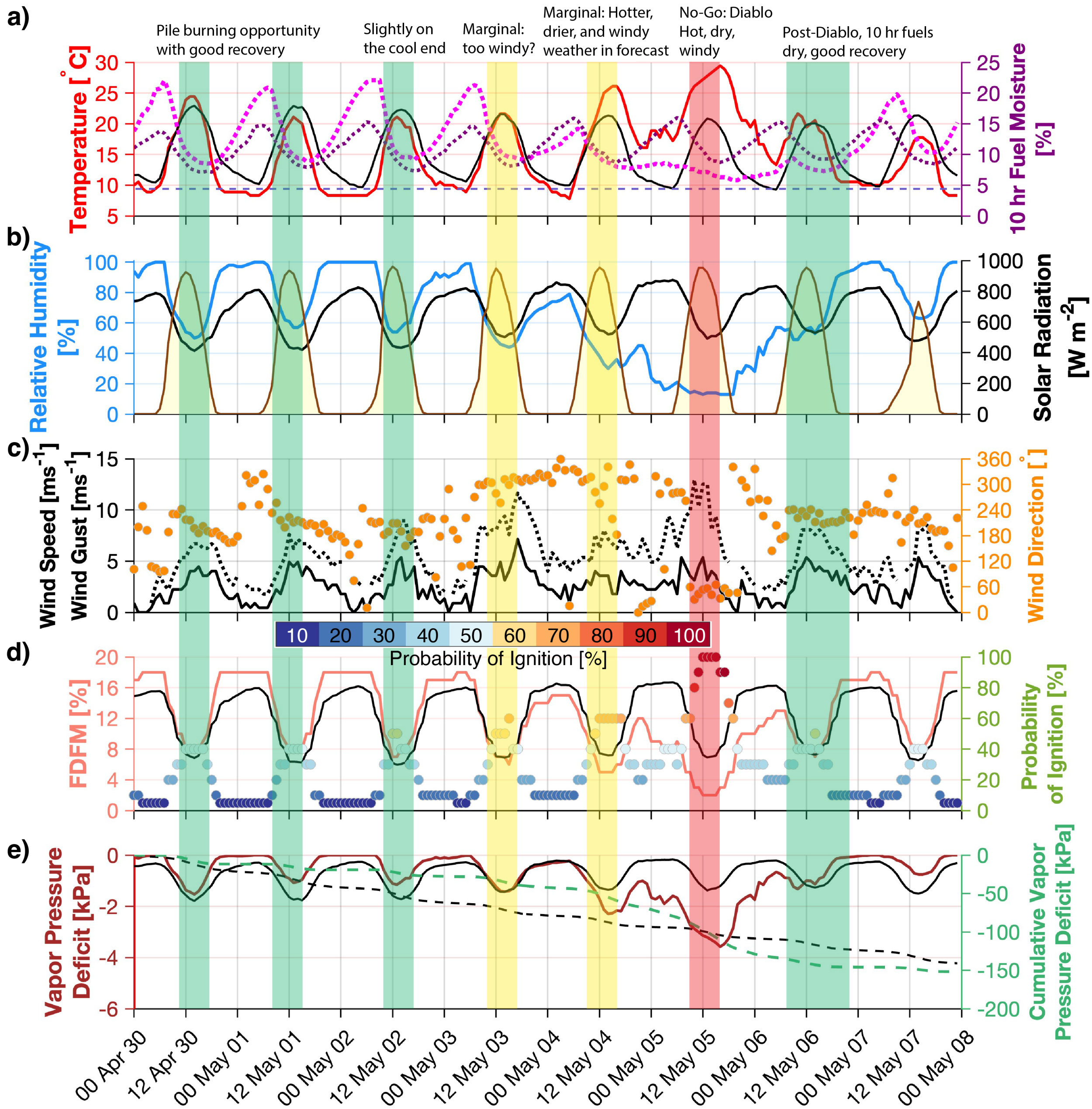

FIG. 2. Hourly observed and calculated fire weather information spanning 30 April-08 May 2025 from the Santa Rosa, California Remote Automated Weather Station. Fine and dead fuel moisture (FDFM) and probability of ignition (d) are calculated at a low-angle, south aspect level with the fire using lookup tables (National Wildfire Coordinating Group 2025a). Black lines in a-b, d-e (dashed purple in a and black in e) show hourly climatologies. In (b), wind speed (gust) is solid (dashed).

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References

Burgeno, J. N., and S. L. Joslyn, 2023: The impact of forecast inconsistency and probabilistic forecasts on users' trust and decision-making. *Weather, Climate, and Society*, **15 (3)**, 693–709, https://doi.org/10.1175/WCAS-D-22-0064.1.

Dowell, D. C., and Coauthors, 2022: "The High-Resolution Rapid Refresh (HRRR): An Hourly Updating Convection-Allowing Forecast Model. Part I: Motivation and System Description". *Weather and Forecasting*, **37 (8)**, 1371–1395, https://doi.org/10.1175/WAF-D-21-0151.1.

Hankins, D. L., 2024: Climate resilience through ecocultural stewardship. *Proceedings of the National Academy of Sciences*, **121 (32)**, e2310072 121, https://doi.org/10.1073/pnas.2310072121, https://www.pnas.org/doi/pdf/10.1073/pnas.2310072121.

Hatchett, B. J., J. L. Vickery, Z. T. Tolby, T. A. Jones, P. S. Skinner, E. M. Wells, and K. J. Thiem, 2024: Fire Weather Testbed Evaluation #001: The Warn-on-Forecast System for Smoke. NOAA Technical Memorandum OAR GSL-68, https://doi.org/https://doi.org/10.25923/nd0m-4j95.

Huffman, D. W., J. P. Roccaforte, J. D. Springer, and J. E. Crouse, 2020: Restoration applications of resource objective wildfires in western us forests: a status of knowledge review. *Fire Ecology*, **16 (1)**, 18, https://doi.org/10.1186/s42408-020-00077-x.

Lindley, T. T., and Coauthors, 2025: Dry return flow: a critical fire weather pattern on the southern Great Plains. *Journal of Operational Meteorology*, **13**, 69–82, https://doi.org/https://doi.org/10.15191/nwajom.2025.1306.

Lutz, E., 2024: The Goldilocks Rx: Seasonal sweet spots and other factors that shape timing of prescribed burns. URL https://www.egret.org/the-goldilocks-prescription-for-prescribed-fire/, Last Accessed: 2025-06-14.

National Wildfire Coordinating Group, 2025a: Fire Behavior Field Reference Guide, PMS 437. URL https://www.nwcg.gov/publications/pms437, Last Accessed: 2025-07-04.

National Wildfire Coordinating Group, 2025b: NWCG Glossary of Wildland Fire, PMS 205. URL https://www.nwcg.gov/publications/pms205/nwcg-glossary-of-wildland-fire-pms-205, Last Accessed: 2025-07-24.

North, M. P., and Coauthors, 2024: Strategic fire zones are essential to wildfire risk reduction in the Western United States. *Fire Ecology*, **20 (1)**, 50, https://doi.org/10.1186/s42408-024-00282-y.

Prince, S. E., S. E. Muskin, S. J. Kramer, S. Huang, T. Blakey, and A. G. Rappold, 2024: Smoke on the horizon: leveling up citizen and social science to motivate health protective responses during wildfires. *Humanities and Social Sciences Communications*, **11 (1)**, 253, https://doi.org/10.1057/s41599-024-02641-1.

Ripberger, J., A. Bell, A. Fox, A. Forney, W. Livingston, C. Gaddie, C. Silva, and H. Jenkins-Smith, 2022: Communicating Probability Information in Weather Forecasts: Findings and Recommendations from a Living Systematic Review of the Research Literature. *Weather, Climate, and Society*, **14 (2)**, 481–498, https://doi.org/10.1175/WCAS-D-21-0034.1.

Skinner, P. S., and Coauthors, 2023: Interpreting Warn-on-Forecast System Guidance, Part I: Review of Probabilistic Guidance Concepts, Product Design, and Best Practices. URL /view/noaa/56441, journal Article.

Wells, E. M., B. J. Hatchett, K. Thiem, Z. Tolby, S. Hoekstra, J. Vickery, and D. Nietfeld, 2025: Noaa fire weather testbed launches first in-person evaluation. *Bulletin of the American Meteorological Society*, **106 (6)**, 359–363, https://doi.org/10.1175/BAMS-D-24-0204.1.

Werth, P. A., and Coauthors, 2011: *Synthesis of knowledge of extreme fire behavior: Volume I for fire managers*. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, https://doi.org/10.2737/pnw-gtr-854, URL http://dx.doi.org/10.2737/PNW-GTR-854.