

Stakeholder-identified Gaps

In February of 2022, NASA Science Mission Directorate hosted a two-day wildfire stakeholder engagement workshop with an objective of understanding barriers to wildfire management currently faced by federal, state, local, tribal, and territorial land management agencies in the United States. The NASA Wildland Fires Program and FireSense have been using this information to inform how NASA science and technology can be more effectively applied to support timely decision making and operations in pre-, active and post-fire management environments. The workshop was comprised of a series of subject matter expert panel discussion and breakout groups that addressed different aspects of pre-, active, and post-fire management. The primary findings are shared below, organized by theme:

Pre-fire Environment

- Given the level of complexity in the data products and information needed to inform decision-making activities, the integration of fire weather, climate, and fuels data into useful, accessible information and tools is essential. There is a need for improved research to operations integration, a centralized and consolidated hub of vetted information, enhanced data resolution with lower latency, and improved communications. Mechanisms and capabilities to validate cutting-edge research and emerging tools to support Research-to-operations (R2O) processes and procedures is “embarrassingly slow”.
- A need exists to validate short- and long-term fire-related forecasts (all areas fire - weather, fuel, fire potential, etc.) with truth. Otherwise, enhancements are near impossible and lead to a lack of confidence in data and information by fire and land management. Notable gaps in timely and integrated weather-to-fuels information includes: understory and canopy data; green-up; snow cover; accurate land cover types (agriculture/cropland -- distinguish orchard vs. brush); and soil moisture data, especially in connection to organic soils and deep duff.
- Decision support tools require comprehensive fire components (e.g., air quality, fuel, weather) and a consolidated approach to provide useful information to the field.
- R2O requires mutual agreement on how to verify and validate fire and land products.
- There is a need to integrate forecast and climatology at a reasonable resolution. Fine resolution data (fire-scale; less than 0.25 or 0.5 degree) are needed to resolve microclimates (e.g., under canopy deviates from seasonal) in all aspects of fire including but not limited to weather, fuel, soil moisture, and fire danger, that influence fire conditions near and below the surface.
- Global partnerships to deliver fuels status (e.g., SMAP, Optical data, NRT Fuel moisture) would be beneficial. In another example, the LANDFIRE fuel model has a latency of 2 years, but fire managers require an update at least every 6 months.
- Precise, accurate, and consistent wind forecasts at the necessary resolution were also noted as a data need.
- Prescribed fire represents a substantial portion of fire weather forecasting, and it is essential to support increased prescribed fires. To safely identify ‘windows of burn opportunities’, requires allocated personnel, enhanced computing resources and integrated fuels-meteorology-smoke transport models at the required micro-landscape scale.
- At a larger scale, enhanced forecasts for seasonal/monthly planning that integrate climate-weather and fuels are necessary, while balancing Air Quality (AQ).

- Comprehensive risk assessments that convey to fire management and communities fall into two categories: static (current community risk); and dynamic (changing fuel/fire over next days). Probabilistic forecasts were suggested as valuable to accurately assess future risks. An integrated solution is one that requires: accurate and useful risk assessments; enhanced computing resources and science for model development at both local and regional scales; and social science to enhance community understanding of prescribed fire smoke impacts and to provide a basis to inform local building codes.
- The composition, structure, and moisture status of fire fuels, along with topography and weather, interact to drive fire behavior, while the proximity of hazardous fuels conditions to valuable assets (homes and infrastructure) is a key component of fire risk. Having an accurate characterization of the pre-fire environment can help managers mitigate fire risk (e.g., fuels treatment) and also aid in the management of active fire.
- Importantly, building fire-resilient landscapes and settlements is more than a challenge to ecosystem management, but equally involves human settlements, community and indigenous values and social tolerance for differing risks.
- Fuels management, which is typically achieved via removal of fuel via mechanical techniques or prescribed fire, is an important aspect of building fire-adapted communities. Despite the evidence supporting the use of prescribed fire as a fuels management strategy, it is still largely underutilized in fire-prone regions because of negative community perceptions of fire and smoke. A monumental shift in these negative perceptions is required before treatment can be realized at scales large enough to make significant impacts, and this ultimately requires communication strategies that build trust among communities and between communities, scientists, and land managers.
- There is not yet a standard set of risk and resilience metrics. Information on risk and resilience involves consideration of risk on multiple time scales. At the longest time scale, risk is affected by ecosystem structure and human settlement patterns. On seasonal and shorter time scales, fine fuels and fuel moisture affect potential fire behavior. On very short time scales, ignition sources, lightning, wind affecting powerlines and human presence all affect ignition risk.
- Tools and models for assessing fire risk, and how much mitigation action might reduce that risk need to be more robust, and data to inform such tools, as they are developed, are not widely available, are often out of date and may or may not actually characterize the key ecological, moisture and infrastructural parameters affecting risk and resilience. Considerable work needs to be done with stakeholders to determine the most informative observations, integrate them into robust models, and partner with user communities to ensure acceptance.
- Participants expressed needs for improved data delivery and usability. For data to be useful it needs to characterize current conditions, and have been collected contemporaneously, meaning that data should be routinely and frequently collected, especially data that characterize phenomena that change frequently. Once collected, data must also be transferred to users in a timely manner so that the information informs current conditions.
- Analysis and quality control must not create long delays between acquisition and distribution. Once distributed, data must be “fit for purpose” or application-ready to minimize the burden on users, especially when decisions are time-critical. That means data should not require extensive additional analysis and processing once delivered, be in easily used formats and units, and have

sufficient contextual information (uncertainty) that users know the degree to which they can rely on a given data source.

- As new data become available with advancing technology, from satellite, UAS, citizen and sensor network platforms, models and analysis tools must be available, tested and accepted for use to enable these new data to enter decision processes.
- As models advance, they may become more demanding of data, equally as data become more informative, resolved in time and space and widely available, models need to advance to make use of the increasing information content. Neither data nor models/analysis tools should be advanced for their own sake, rather user needs and analyzed cases where inadequate information prevented effective decision making should guide priorities for new approaches.
- Co-development of observing systems and analysis tools/models needs to be done within communities of practice, teaming resource professionals, community leaders, scientists, and the broad fire-affected communities.

Active Fire

- Satellite-based Earth Observation (EO) instruments provide routine coverage to help identify and track active fires, and current capabilities provide either moderate spatial resolution and infrequent coverage (e.g., VIIRS, MODIS) or coarse spatial resolution and frequent coverage (e.g., GOES). Gaps in moderate resolution coverage currently limit advances in fire science and applications needed to support the management of extreme fire events and their unprecedented impacts on communities, ecosystems, and air quality.
- Fire data are produced in a range of data formats, based on inconsistent definitions and product standards. A community-wide effort to adopt a common format for analysis-ready data (consistent with CEOS and/or OGC Standards) could streamline the process to ingest and analyze fire data from different platforms. Consistent definitions and quality assurance would assist the end user in data selection and analysis.
- Further reductions in data latency would benefit a range of stakeholders who depend on real-time fire data, regardless of whether those are delivered from satellite platforms, airborne assets, or ground networks.
- Incident fire teams are often active in remote locations, without access to updated information, and fire management teams, making decisions in the field, are hampered by an overabundance of data, often without perspective, rather than useful information. The information and forecasts from predictive services are not targeted at the appropriate scale, which when compounded with the lack of available communication systems leads to a disconnect between available and actionable information.
- Fire management occurs at a local level, involving hundreds of stakeholders. This can and does lead to information being siloed and not available to all who would need it. Communicating life-saving information to the front lines will require improvements in communications to remote crews with limited connectivity. Specific needs include regular updates on the fire location and behavior, forecasts, and other management activities.
- In addition to communication during a fire event, closing the communication gaps between data producers and data users will require further training and support for new data products and a two-way sharing of data between research and analysis teams and fire suppression efforts. For

example, fire spread forecasts could be more accurate if they account for planned fire suppression efforts.

- Advances in fire detection and tracking can benefit from a range of new and emerging data sources and analytic techniques. Source data systems and applications need to continue to improve the ease of access/use of data and help users better understand limitations/caveats of data products.
- Ground-based camera networks provide rapid detection information for the WUI and other high-value infrastructure but require improved analytics techniques for rapid data reduction and then incorporation into operational decision-making processes with other observation / information sources.
- Machine learning (ML) and artificial intelligence (AI) show great promise for rapid analysis of data across a range of platforms and may accelerate the delivery of downscaled products for specific end users, including climate data needed to forecast fire spread in complex terrain.
- Regular observations of the fire front and smoldering fuels behind the fire front are necessary to support fire suppression efforts and improve estimates of fire emissions and air quality impacts from large fire events.
- Real-time, accurate geolocation of fire detections is especially critical in the Wildland-Urban Interface (WUI), where tens to hundreds of meters matter.
- Synthesizing fire data as events, not pixels, is an important step towards a common denominator for fire science and fire management.
- Fire behavior information is also critical to understand the conditions under which PyroCBs form and collapse, as both conditions represent critical events for fire management and public safety.
- Finally, key gaps remain in fire detection and tracking in the WUI, where current models do not fully account for fuels in the built environment.
- The path from research to operations could include a testbed environment to benchmark and quantify the advances from specific data or model improvements in support of stakeholder needs. There is a need to strengthen and sustain training efforts on how to use new tools and technology, and the strengths, limitations, and complementary nature of new information.
- During an active fire, satellite data provide the information needed to estimate smoke emissions and to understand and predict fire weather in near real time, helping scientists and environmental managers better serve communities downwind of the fire. Despite many advances, this is a very challenging area that can involve combining satellite data with information from in situ sensors and merging observational data with multiple types of models to make predictions, with stringent requirements on turning out high quality information, quickly.
- Insufficient resolution of data products remains a barrier for many potential users. Air quality managers would benefit from updates throughout the day to help local communities plan for smoke events and at spatial scales capable of representing gradients within urban areas and fire perimeters. Long latencies typical of many satellite data products are a major barrier limiting their integration into fire weather forecast models.
- Though multiple observations provide information on total column aerosol and trace gases, the lack of vertical information identifying the height of a plume makes it difficult to accurately incorporate this information into forecast models and can greatly reduce predictive skill.

- Insufficient information about boundary layer height and its diurnal evolution limits the ability of air quality managers and fire weather forecasters to provide reliable information about near surface impacts of smoke plumes, particularly at night.
- In densely populated areas where WUI fires are becoming more common, lack of information on the composition of smoke plumes, particularly those that may include toxic compounds not traditionally associated with wildland fires, is a pressing issue not well addressed by current observations.
- There has been substantial progress in many aspects of modeling and observing fire weather, including development of coupled fire-atmosphere models, new approaches to simulating plume rise, and the use of mobile radar observations during active fires. However, such research approaches often face major challenges that limit their adoption in operational systems. It can be difficult to distribute new types of information to government agencies and to integrate experimental data into forecasting tools and established data streams. Support for technical approaches including co-development of shared code and data repositories and workflow tools is critical.
- Air quality and fire weather managers face many technical barriers when they attempt to incorporate Earth observations into decision-making. Standardized formats and centralized locations for data are needed to serve all communities, particularly those serving on the front lines who are forced with making time sensitive decisions.
- More robust coordination of data services would also support integration of observations into forecast models and help users combine multiple existing datasets in the near term.
- Providing uniform warnings and services for fires across the country, which face geographic differences, complex regulatory environments that span federal, state, local, tribal, and territorial agencies, and varying levels of fire expertise in field office staff, is a major challenge.
- Improving communication of existing tools and services is critical in making sure that advances truly serve the communities they are intended to support.

Post-Fire

- It can be difficult to access the data necessary to do a post-fire analysis. There are many reasons for this. In some cases not enough observations are collected and made available post-fire, and if data are available there are firewalls related to when data can be shared and what data are shared between agencies. Agencies may limit data access until they are thoroughly assessed due to fears of potential misinterpretation and collateral impacts. The process to apply for access to these data could be more transparent.
- Harmonizing different types of data represents a significant gap in the wildfire community. These different types of data could be integrated as layers with a data mapping platform. The data types mentioned by the group that would be useful in post-fire analysis were: vegetation data, geologic map information, burn severity maps, high resolution imagery, soil type and moisture information, above ground structure locations, as well as spectral, photogrammetry, and topographic data. The group mentioned it would like to see satellite (Landsat and Sentinel), SmallSat (high resolution NIR and TIR) and airborne data included in the database. These data were associated with science gaps including difficulty capturing small-scale cultural features in existing imagery, and reliability of remote warning capabilities for soil moisture, precipitation, and flow monitoring.

- The group made a strong case for the need for a centralized database of wildfire related data. They would like this database to mention the types of data available and how they could be used on the front page to increase the “discoverability” of data types they may not be familiar with. To increase accessibility of the data, the group suggested the database be formatted similar to existing well-known mapping portals such as: [GWIS-Current Situation](#).
- Remotely acquired wildfire data are typically stored locally and need to be directly shared with those requesting access. However, many wildfire agencies suffer from a lack of resources and dedicated remote sensing personnel that can process, classify, and share these data. This results in delays to scientific and public data access and can limit capacity to fully utilize actionable information to identify post-fire risk within the period where data are needed.
- Improved lines of communication are needed to connect groundcrews and those researching and monitoring post-fire cascading hazards with the existing databases and networks of data.
- Once the scientific community has worked with the data and determined the risk associated with post-fire cascading hazards this information must be communicated the public through different websites, maps, and venues.
- There is a need for established methods for sharing these data with the public. This could be resolved if there were a common understanding of when data can be shared, and where it should be shared. The location of this information would then need to be advertised to the public with special attention given to those that may be in high-risk areas.
- Addressing fires in wildland urban interface (WUI) areas requires immediate attention within minutes to hours to save lives and infrastructure; thus, essential demographics and infrastructure information are necessary in advance. Developing new Decision Support Systems (DSS) integrating ground-based and remote sensing data with advanced artificial intelligence (AI) algorithms and models could help fire detection, tracking, evacuation, assessment of post-fire impacts, and restoration measures.
- Knowledge of pre-fire vegetation composition along with the capability to characterize the composition of vegetation regrowth and regrowth trajectories at various spatial scales is central to determining both future fire risk and post-fire management decisions.
- New vegetation can govern water infiltration capacities, affecting downstream water supply, but we lack details on the timing and scale of these impacts. Therefore, we need information pre-wildfire and then rapidly post-wildfire on site characteristics, vegetation, and ecological condition to focus restoration efforts. Specific to restoration, priority should be on the most impacted watersheds.
- A spatially explicit long-term dataset on building footprints, defensible space, and demographics is needed to address WUI fires during preparatory, recovery, and post-recovery phases. Very high-resolution remote sensing data could be helpful here.
- Approaches that promote defensible space, coupled with home hardening, are essential to improve any home's chance of surviving a wildfire. Specifically, owners of tribal lands and cultural heritage do not have proper early warning systems (EWS) before the fire hits them; thus, developing EWS should be a priority.
- Data from very high-resolution remote sensing, hyperspectral, fine-resolution LIDAR, and unmanned aerial systems (UAS)—all combined through data fusion algorithms—would provide valuable information on pre- and post-fire vegetation, site characteristics and infrastructure

impacts. More detailed, better resolution and faster data are essential for effective fire management.

- Data should be linked to freely accessible DSS useful to land managers and the public. The DSS should integrate robust artificial intelligence algorithms and models useful for evaluating fire risk to people, vegetation, infrastructure, and fire impacts.
- The services from the national Monitoring Trends in Burn Severity (MTBS) system and Burned Area Emergency Response (BAER) teams are beneficial for post-fire management and restoration efforts; however, more such programs with better data latency are needed to address wildfire problems.
- Specific to capacity building, a unified approach across bureaus and agencies on remote sensing, geospatial tools, Unmanned Aerial Systems (UAS), and information technology (IT) is needed.