L-Band SAR Fuel Products for the Wildfire Cycle in Conjunction with FASMEE Prescribed Burn Campaigns

Karen An[1], Yunling Lou[1], and Cathleen Jones[1]

[1]Affiliation not available

April 25, 2024

L-Band SAR Fuel Products for the Wildfire Cycle in Conjunction with FASMEE Prescribed Burn Campaigns

Jet Propulsion Laboratory
California Institute of Technology

ABSTRACT

Wildland fuel load and soil moisture measurements contribute to understanding the rate of fuel consumption and fire radiative power. Lower-than-usual fuel moisture during drought conditions results in higher fuel availability, fire intensity, rate of spread, and more difficult suppression. A joint collaboration has been made between the Fire and Smoke Model Evaluation Experiment (FASMEE) project and the NASA UAVSAR (Uninhabited Aerial Vehicle Synthetic Aperture Radar) team. This project aims to implement and validate fuel products based on new L-band UAVSAR acquisitions made in conjunction with FASMEE prescribed burn campaigns, developing gap-filling products that integrate seamlessly with existing operational response platforms. Airborne SAR data from UAVSAR has a high signal-(to-noise ratio, high spatial resolution (7 x 7 m), and is sensitive to vegetation biomass and moisture changes. FASMEE has identified fuel biomass and moisture as key measurements to determine the rate of fuel consumption during their burn campaigns and serve as inputs for decision support tools. SAR data has the potential to update outdated and limited field measurements currently used in fire models to characterize wildfire fuels, but also requires these coincident measurements for initial validation. UAVSAR serves as the airborne prototype for the future space sensor NISAR, which will allow for continuous measurements of biomass and moisture changes across the globe. Current partnerships with fire managers will allow for the development of practical and useful data products to be used for wildland fuel estimation, and make way for future extended coverage with NISAR.

AUTHORS

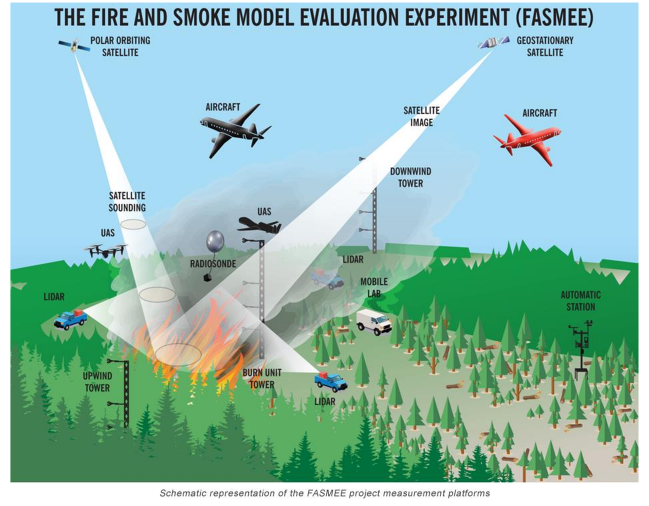
Karen An[1], Yunling Lou[1], Cathleen Jones[1]
Email: karen.an@jpl.nasa.gov

AFFILIATION

[1] Jet Propulsion Laboratory, California Institute of Technology

INTRODUCTION

The Fire and Smoke Model Evaluation Experiment (FASMEE) is a multi-agency effort to collect critical measurements of fuels, fire behavior, fire energy, meteorology, smoke, and fire effects that will be used to evaluate and advance operationally-used fire and smoke models.



Gridded fuel load and fuel moisture products will help improve FASMEE's ability to manage future prescribed burns and integrate ground and remote-based measurements (Prichard et al., 2019). Fuel moisture products would modernize current field measurements which feed into FASMEE decision support tools. Biomass change products would improve upon current structure from motion and LiDAR datasets, which complement field measurements to further characterize heterogeneous fuel distributions. The ability of SAR to differentiate vegetation species offers insight into the efficacy of the campaigns and fuel consumption by type (e.g. shrubs, grasses, forests). With detailed fuel consumption rates, smoke models are better able to predict heat- release rates and emissions. These models are of critical importance to the wildland fire user community and require validated inputs to be implemented.

DATA

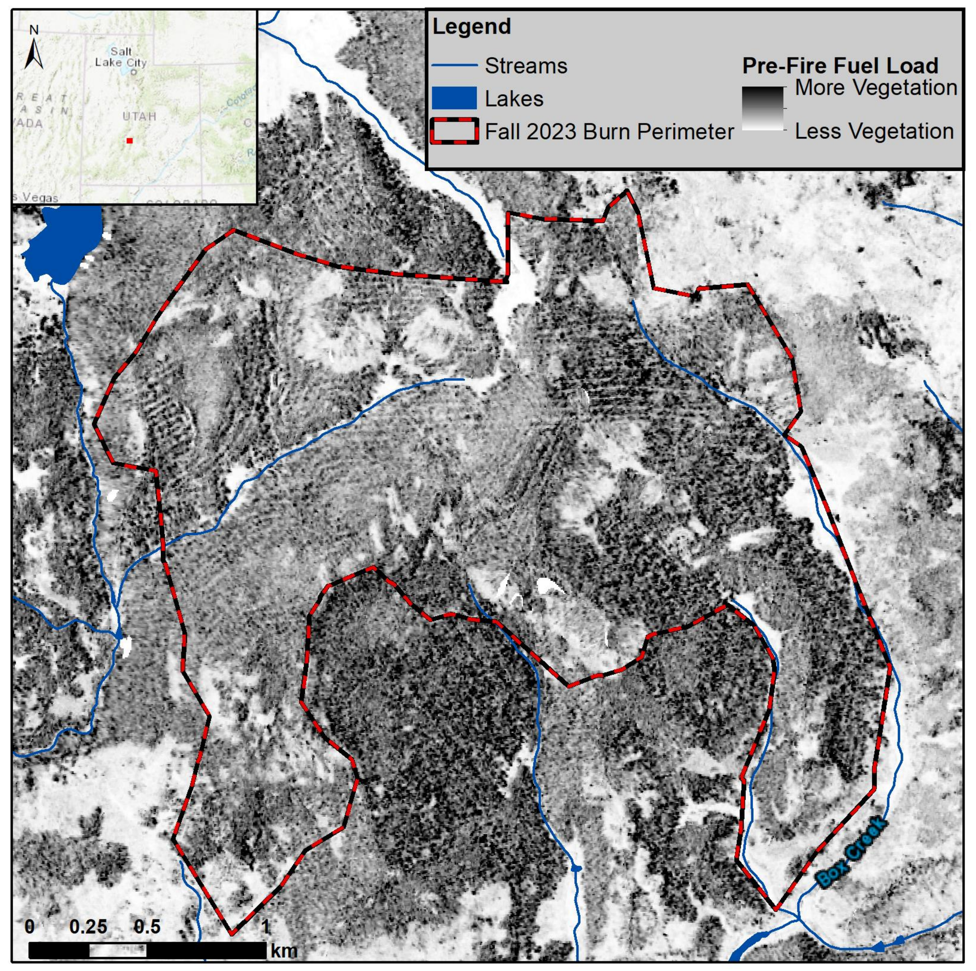
NASA's Uninhabited Aerial Vehicle Synthetic Aperture Radar (UAVSAR) is an airborne radar which collects high resolution, quad-polarimetric products. The instrument is located in a pod attached to a Gulfstream-III, which flies at ~12.5 km altitude, and is an L-band (23.8 cm wavelength) instrument with high signal-to-noise ratio and repeat flight track accuracy. The image swath is 22 km wide, and the left-side-looking incidence angles range from 22°–67°.

UAVSAR data (fishla_01601, fishla_09601) was collected over Fishlake National Forest, Utah during the Fall 2023 FASMEE campaign (10/09-10/10):

UAVSAR	Pre-Fire	Active Fire	Post-Fire
Acquisition Date	07/27/2023	10/10/2023	10/17/2023
Data Products	1 PolSAR image (for each flight heading)	• 5 PolSAR images (each heading) • 3 InSAR Pairs	• 1 PolSAR image (each heading) • 1 InSAR Pair (07/27-10/10)

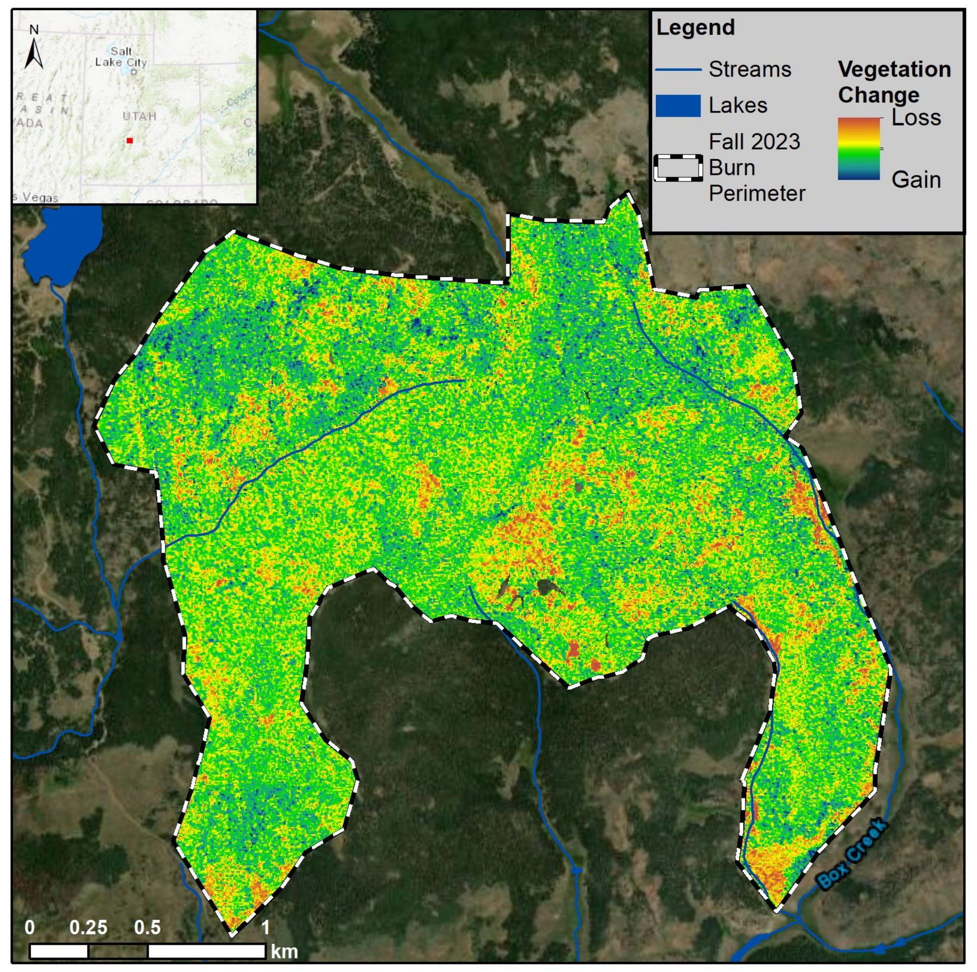
RESULTS

Pre-Fire Fuel Load



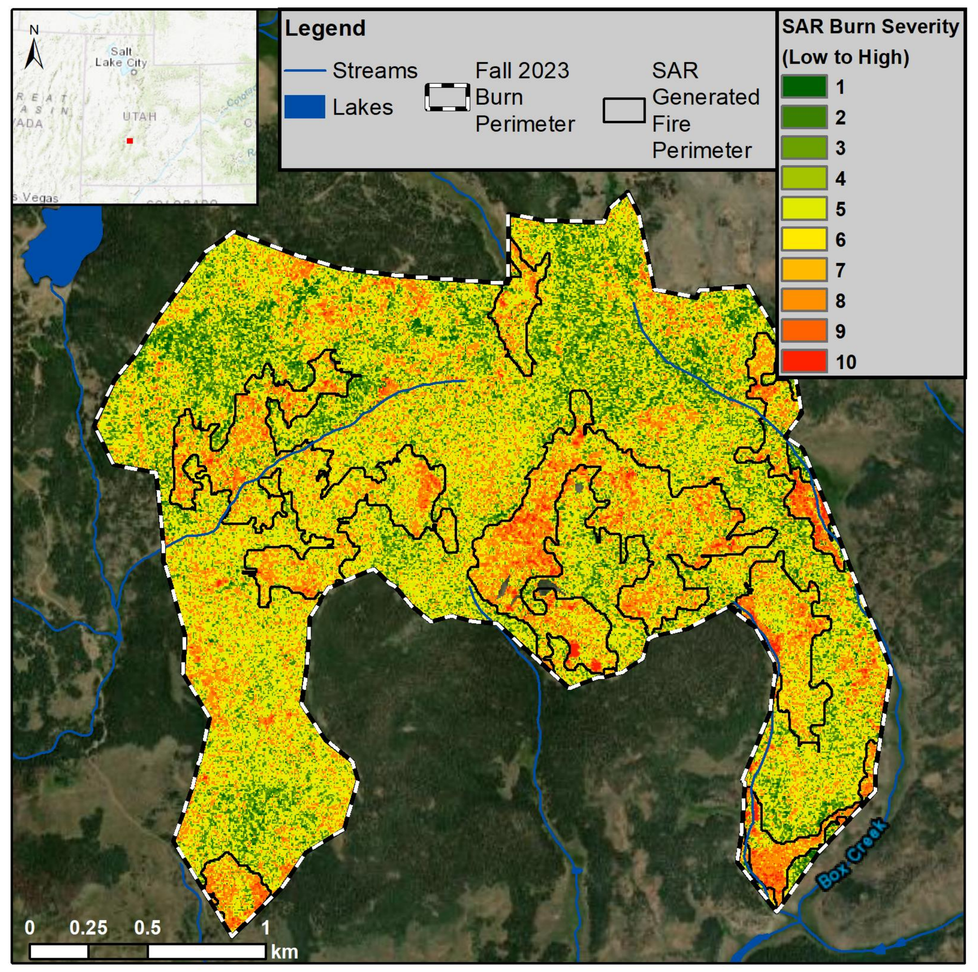
Single HV image (07/27/2023) showing pre-fire fuel availability. Two flight lines (fishla_01601, fishla_19601) are merged using a weighed incidence angle method. Striped features within the burn perimeter show "slash lines" where timbers are placed to aid fire managers with ignition.

Post-Fire Vegetation Change

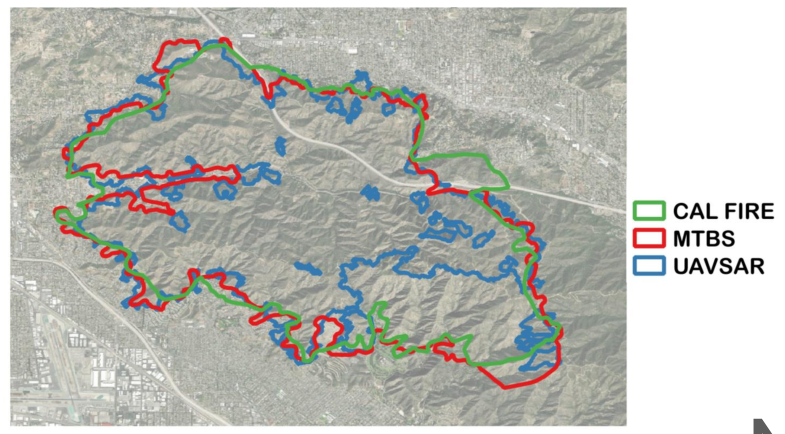


HV log ratio pre- (07/27/2023) and post- (10/17/2023) burn within the burn perimeter. High values (orange/red) indicate a loss of HV and volume scattering. Low values (green/blue) show a gain of HV between the images.

SAR-Generated Burn Severity & Fire Perimeter



SAR-based burn severity map with 10 classes is generated from the HV log ratio image after applying k-means clustering. The small fire perimeters are also based on the HV log ratio image, after applying superpixel segmentation. The same fire perimeter method is applied to the 2017 La Tuna Fire (Los Angeles, CA) to compare with published perimeters from CALFIRE and MTBS (Monitoring Trends in Burn Severity) based on optical imagery.



METHODS

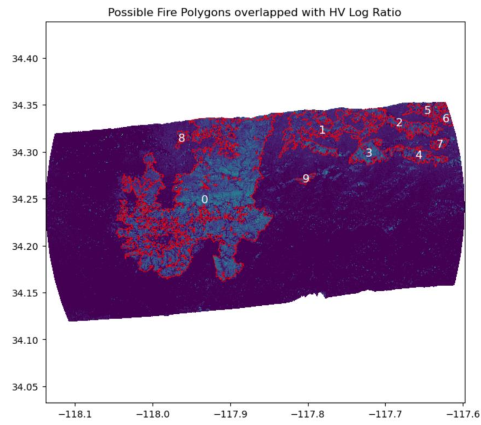
1) Radiometric Terrain Correction: RTC is performed (Simard et al., 2016) on all UAVSAR data to improve backscatter estimates by removing geometric distortions and terrain areas under radar shadow. Chambolle's total variation (TV) algorithm is also applied to the image to reduce speckle while persevering edges and fine details.

2) HV Log Ratio: The HV polarization is an indication of healthy biomass, due to its relationship to volume scattering. To study the loss of vegetation, the log ratio of pre- and active/post-fire data is found to reduce noise (compared with a simple HV difference) while highlighting areas of HV change:

$$\log \frac{Pre\ Fire\ HV}{Active\ or\ Post\ Fire\ HV}$$

3) Superpixel Segmentation: Felzenszwalb's algorithm is used to group pixels that share similar characteristics into larger segments. The mean and standard deviation of the HV log ratio are used to assign the burn severity classes.

3) K-Means Clustering: Lloyd's algorithm is used to distinguish burned/unburned areas, based on the mean and standard deviation of the segmented features.



NEXT STEPS

- Repeat analysis for all active fire acquisitions
- Compare InSAR pairs (e.g. coherence) to PolSAR HV log ratio
- Compare with in situ data and other sensors (SLAP, SMAP)
  - Coincident fuel load and fuel moisture field measurements were conducted during the campaign, but data was not available at the time of writing.
- Apply burn severity clustering method to create gridded fuel moisture product
- Repeat analysis with NISAR-simulated data (upcoming NASA-ISRO SAR mission)

REFERENCES

- Prichard, S., Larkin, N. S., Ottmar, R., French, N. H., Baker, K., Brown, T., ... & Watts, A. (2019). The fire and smoke model evaluation experiment—a plan for integrated, large fire–atmosphere field campaigns. Atmosphere, 10(2), 66.
- Simard, Marc, et al. "Radiometric correction of airborne radar images over forested terrain with topography." IEEE Transactions on Geoscience and Remote Sensing 54.8 (2016): 4488-4500.

Acknowledgements: Wen Tao Lin (Case Western Reserve University), Charles Z Marshak (Jet Propulsion Laboratory, California Institute of Technology)

Service Layer Credits: Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community