The Fire and Smoke Model Evaluation Experiment

NASEM Briefing
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(and the many contributors to FASMEE)

Factors influencing smoke production

-Considerable uncertainty remains

-Uncertainty presents a major challenge to prescribed burning

From NWCG Rx410, Smoke Management Techniques

Combustion and Consumption is Affected by Fuel

- Loading
- Size
- Arrangement
- Continuity
- Fuel Moisture

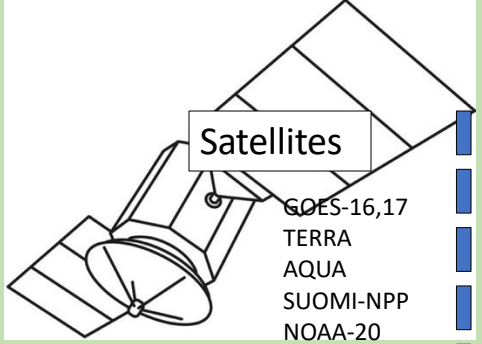
From NWCG Rx410, Smoke Management Techniques

Context: controls & uncertainty

Selected modeling systems that describe fire & smoke

Model	Description	Applications	FASMEE Datasets	References
MesoNH/ ForeFire	Mesoscale non-hydrostatic model coupled with a surface atmospheric interaction model (SURFEX).	Desktop (unix)	Meteorology and plume dynamics	[5]
Vesta	Large-scale, cell-based wildland fire simulator developed within the Fire Paradox project.	Desktop	Gridded fire behavior and fire radiative energy observations.	[11]
WFDS	Wildland-Urban-Interface Fire Dynamics Simulator: computational fluid dynamics model that resolves buoyant flow, heat transfer, combustion, and thermal fuel degradation.	Desktop (unix) STANDFIRE (under development)	Fuel consumption, gridded fire behavior and radiative energy, meteorology and plume dynamics.	[10]
WRF-SFIRE (Spread FIRE model)	Weather Research and Forecasting—Spread Fire: combined atmosphere and fire spread model.	High performance computing cluster	Gridded fire behavior, meteorology and plume dynamics.	[3,4]

BlueSky Pipeline: Smoke Modeling Components



Atmosphere

HYSPLIT
CMAQ
WRF-Chem

Temporal Allocation of Emissions

Vertical Allocation of Emissions

GOES
WRAP
CMAQ
FEPS

Briggs
Frietas
Sofiev

Emission Factors

FEPS
SERA
Literature (Urbanski, Yokelson etc)

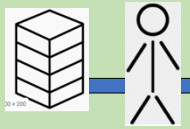
Fuel Consumption

CONSUME
FOFEM
FEPS

Fuel Characteristics

FCCS
FCCS-LF
NFDRS

Fire Activity and Burned Area



GOES, VIIRS, MODIS
Fire Info System (FIS)
IRWIN
Rx Systems
Manual

SMOKE EMISSIONS REFERENCE APPLICATION (SERA)

Emission Factors by Pollutant | Smoke Emissions References | Change Log

Filter summaries by: Include outliers

Combustion Phase	Burn Type	Platform*	Region	Vegetation Type	EPA Pollutant Category	Slash
Flaming	Broadcast Rx (Field)	Aerostat	North	Conifer forest	Air Toxin (TOX)	Exclude (default)
Residual smoldering	Other (Lab)	Airborne	Southeast	Grassland	Criteria Air Pollutant (CAP)	Include
Smoldering	Pile burn (Field)	Ground	West	Hardwood forest	Greenhouse Gas (GHG)	Slash-only
Unspecified	Pile burn (Lab)	Tower		Mixedwood forest	Hazardous Air Pollutant (HAP)	
Unspecified	Wildfire (Field)			Organic soil	Ozone Depleting Substance (OZD)	
				Other	Ozone Precursor (OZP)	
				Shrubland	Persistent Bioaccumulative Toxic (PBT)	

Use checkboxes in the table below to further limit output to selected pollutants.

Apply filter Reset

*Platform applies only to field burns (i.e., broadcast Rx, pile burn, or wildfire). Lab burn + platform will yield 0 records.

Download this summary table | Download source EFs for this summary table

Emission Factor Summaries: Showing all 490 pollutants, across all categories (excluding outliers and slash)

Pollutant	Formula	Pollutant Category	Count	EF (g/kg) Mean	EF (g/kg) SD	EF (g/kg) Min	EF (g/kg) Max	MCE (0-1) Mean	MCE (0-1) SD
Primary Gases/Aerosols									
ammonia	NH_3	inorganic gases	262	1.407	1.340	-0.100	6.600	0.910	0.053
carbon dioxide	CO_2	inorganic gases	721	1,590.061	162.833	828.500	2,234.420	0.908	0.046
carbon monoxide	CO	inorganic gases	768	97.005	49.683	1.500	302.000	0.904	0.054
methane	CH_4		589	4.656	3.322	0.000	24.100	0.906	0.046
nitric oxide	NO	nitrogen oxides	293	2.043	1.878	0.003	9.600	0.922	0.036
nitrogen dioxide	NO_2	nitrogen oxides	246	1.236	0.958	0.048	5.287	0.925	0.031
nitrogen oxides	NOx	nitrogen oxides	145	3.654	2.679	0.027	11.290	0.888	0.075
particulate matter 2.5μm	PM2.5	particulate matter	510	17.943	13.980	1.100	78.000	0.907	0.048
sulfur dioxide	SO_2	inorganic gases	142	1.039	0.718	0.000	3.415	0.927	0.032
Other Gases/Aerosols									
1,1,1,2-tetrachloroethane	$C_2H_2Cl_4$		1	0.001	0.000	0.001	0.001	0.963	0.000
1,1,1-trichloroethane	$C_2H_3Cl_3$		11	0.000	0.000	0.000	0.000	0.898	0.016
1,1,2,2-tetrachloroethane	$C_2H_2Cl_{14}$	haloalkanes	2	0.005	0.001	0.004	0.005	0.908	0.022
1,1,2-trichloro-1,2,2-trifluoroethane	$C_2Cl_3F_3$		2	0.000	0.000	0.000	0.000	0.956	0.007
1,1-dichloro-1-fluoroethane	CH_3CCIF_2	haloalkanes	2	0.001	0.000	0.001	0.001	0.900	0.023
1,1-dichloroethane	$C_2H_4Cl_2$		1	0.000	0.000	0.000	0.000	0.963	0.000
1,1-dichloroethene	$C_2H_2Cl_2$		1	0.001	0.000	0.001	0.001	0.940	0.000
1,1-difluoroethane	$C_2H_4F_2$	haloalkanes	2	0.001	0.000	0.000	0.001	0.900	0.023
1,2,3,4-tetrahydrochrysene	$C_{18}H_{16}$		1	0.006	0.000	0.006	0.006	0.000	0.000
1,2,3-trimethylbenzene	C_9H_{12}	aromatics	30	0.044	0.060	0.002	0.305	0.911	0.025
1,2,4-trichlorobenzene	$C_6H_3Cl_3$		1	0.003	0.000	0.003	0.003	0.963	0.000
1,2,4-trimethylbenzene	C_9H_{12}	aromatics	87	0.020	0.022	0.001	0.109	0.915	0.030
1,2-butadiene	C_4H_6		7	0.005	0.003	0.002	0.012	0.922	0.016
1,2-dichloroethane	$C_2H_4Cl_2$	haloalkanes	13	0.001	0.001	0.000	0.002	0.899	0.019
1,2-dichlorotetrafluoroethane	$C_2Cl_2F_4$		3	0.000	0.000	0.000	0.000	0.936	0.007
1,2-diethylbenzene	$C_{10}H_{14}$		10	0.004	0.002	0.002	0.008	0.934	0.019
1,2-propadienyl-benzene	C_9H_8		4	0.016	0.008	0.005	0.026	0.000	0.000
1,3,5-trimethylbenzene	C_9H_{12}	aromatics	56	0.003	0.002	0.000	0.010	0.913	0.031
1,3-butadiene	C_4H_6	alkynes and alkenes	107	0.161	0.149	0.000	0.719	0.918	0.038

Focus: key modeling system

Improvements are needed to fire & smoke models

-Efforts like the Smoke & Emissions Model Intercomparison Project (Larkin et al 2012) highlighted needs for improvements

-Data sets are needed for development, evaluation, and improvement

-Attempts occurred to collect data sets at common-fire events (e.g., RxCADRE)

Consensus findings from post-RxCADRE workshops (2012-13)

-Integrated, large research campaigns are critical for making advances in wildland fire behavior, fire effects, and smoke science.

-An investment in coordinated sampling of fire–atmosphere interactions will benefit the science community and fire and fuels managers, who rely on operational fire and smoke models to guide wildland fire management (including prescribed burning).

-Measurements should be driven by model/tool needs, but also governed by oversight from a start-to-finish perspective

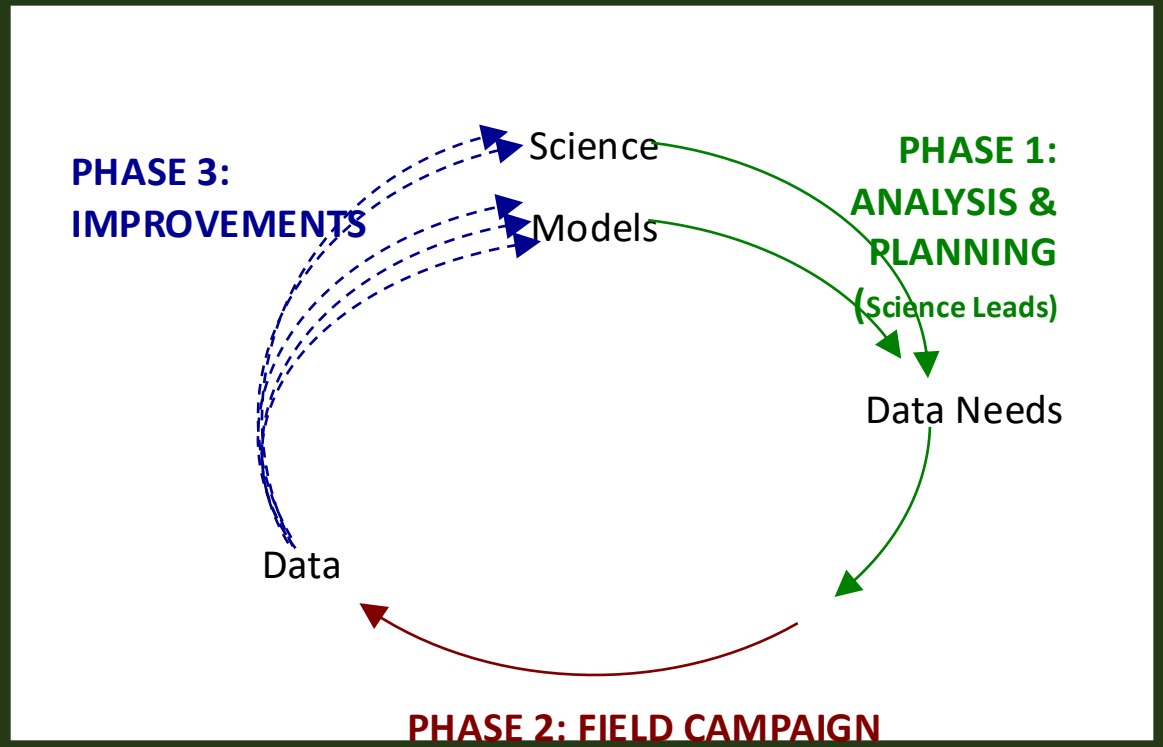
Fire And Smoke Model Evaluation Experiment

-FASMEE is an observational campaign to support:

-evaluation of current operational fire and smoke modeling systems,

-and advancement of new models and tools into operational use.

-FASMEE's uniqueness lies in its design to collect a coordinated library of fire and smoke data for use as training and evaluation inputs.



FASMEE objectives

FASMEE Planning: Phase I (2014-2017)

Interviews with modelers and scientists re: data inputs needed for model development:

> "What data sets would help to evaluate [model] and advance beyond the current generation?"
>
> "What would be needed to collect and create a coordinated set of model-input data sets for fire and smoke model evaluation and evolution?"

Detailed Study Plan resulted:

-measurement specifications,

-estimated budget,

-individual Discipline teams for measurement, and

-liaison/logistics group to facilitate access to burns

FASMEE Phase I

Models served by FASMEE datasets (partial list) – Output from Phase I Study Plan

Next Slide: Measurement Specifications (Also Phase I)

Model	Description	Applications	FASMEE Datasets	References
CAWFE	Coupled Atmosphere-Wildland Fire-Environment (CAWFE): a coupled weather—wildland fire computational model.	NCAR Simulation model (Janice Coen)	Fire behavior, meteorology and plume dynamics.	[7]
FIRETEC	HIGRAD/FIRETEC: physics-based, 3-D model that represents the coupled interaction between fire, fuels, atmosphere, and topography.	Simulation Model, Los Alamos National Laboratory, included in STANDFIRE	Fuel consumption, gridded fire behavior and radiative energy, meteorology and plume dynamics.	[9]
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Disciplinary Measurement Teams

Smoke Emissions, Chemistry, & Transport
-Emissions factors (flaming, smoldering, biological)
-Smoke evolution & aging
Airborne, tower, & surface measurements

Fuels and Consumption
-Multi-scale characterization
-Links to moisture dynamics
Airborne & surface LiDAR;
ground sampling

Modeling
-Physics-based (2-D & 3-D)
-AI-ML (new addition)
-integration of observations across multiple disciplines and platforms serve as inputs

Plume and Meteorology
-Mixing and entrainment
-Interactions of multiple cores & ignitions
Airborne, & tower measurements; LiDAR

Fire Dynamics
-Spatial/temporal heat flux
-Relationship to fire effects
Airborne, ground, & satellite

Fire Effects
-Mortality mechanisms
-Rich datasets will reveal new processes
Airborne & surface measurements

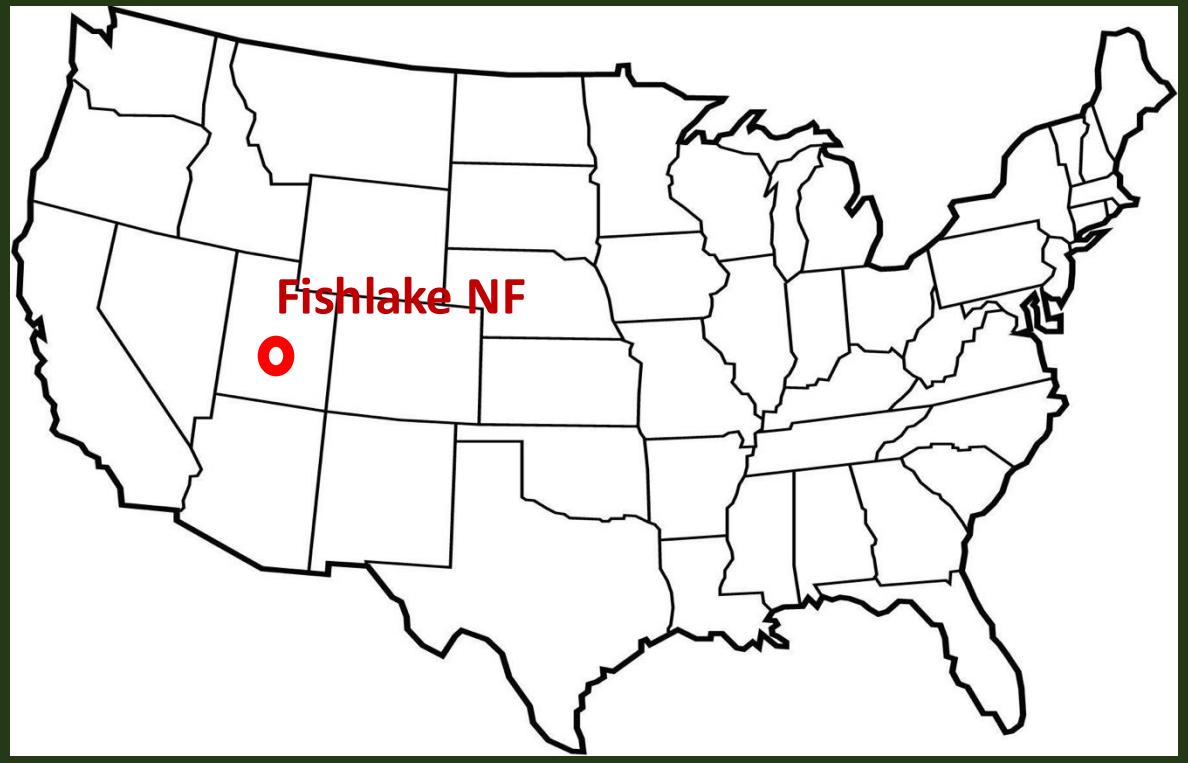
Discipline organization

Historic focus on high-severity fire…

…but, some modeling requires simpler terrain;

…renewed emphasis on “typical” prescribed fire;

…need for reduced uncertainty related to smoldering in organic soils (duff, peat, muck) and PM2.5 production



High-intensity “wildfire-surrogate” burns sought; found at Fishlake NF

Initial focus: high intensity

Fire Behavior Packages in Fishlake Rx unit, 2019 (B. Butler, RMRS)

2016-2020: “bridge-funding” by PNWRS

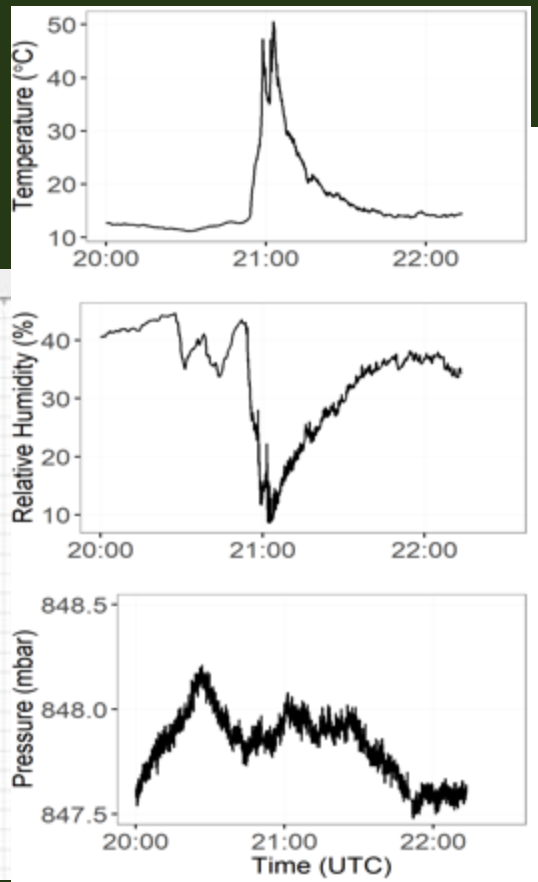
Coordination with WE-CAN/BB-Flux and FIREX-AQ--smoke and chemistry measurements

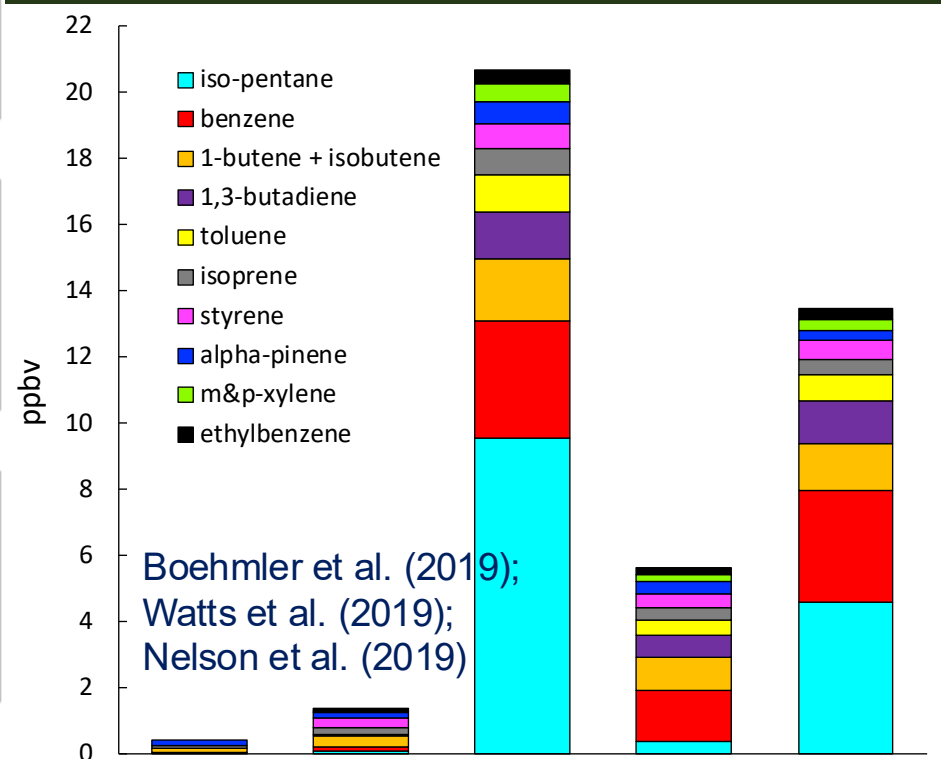
- Campaigns Supported
  - WE-CAN & BBFLUX NSF: summer 2018
  - FIREX-AQ NOAA/NASA: summer 2019
- Assisted in selecting wildfires for airborne measurements
- 30+ publications (and continuing)
- 11 archived datasets (with more coming soon)

Proof-of-concept: UAS smoke measurements based on Phase I specifications

Atmospheric sensing and sampling:

- -Air quality (PM, CO, CO_2, O_3…)
- -Air sampling (VOCs, trace gases)
- -Meteorology (soundings, modeling)
- -IR: Combustion efficiency and MCE
- -Imagery: Plume development & movement





Proof of concept
Firefighter smoke exposure-avoidance by directing holding & mop-up by air

UAS supported fire crews locating spots following prescribed burns

2016-2020 achievements

FY22: Priority R&D Project Designation

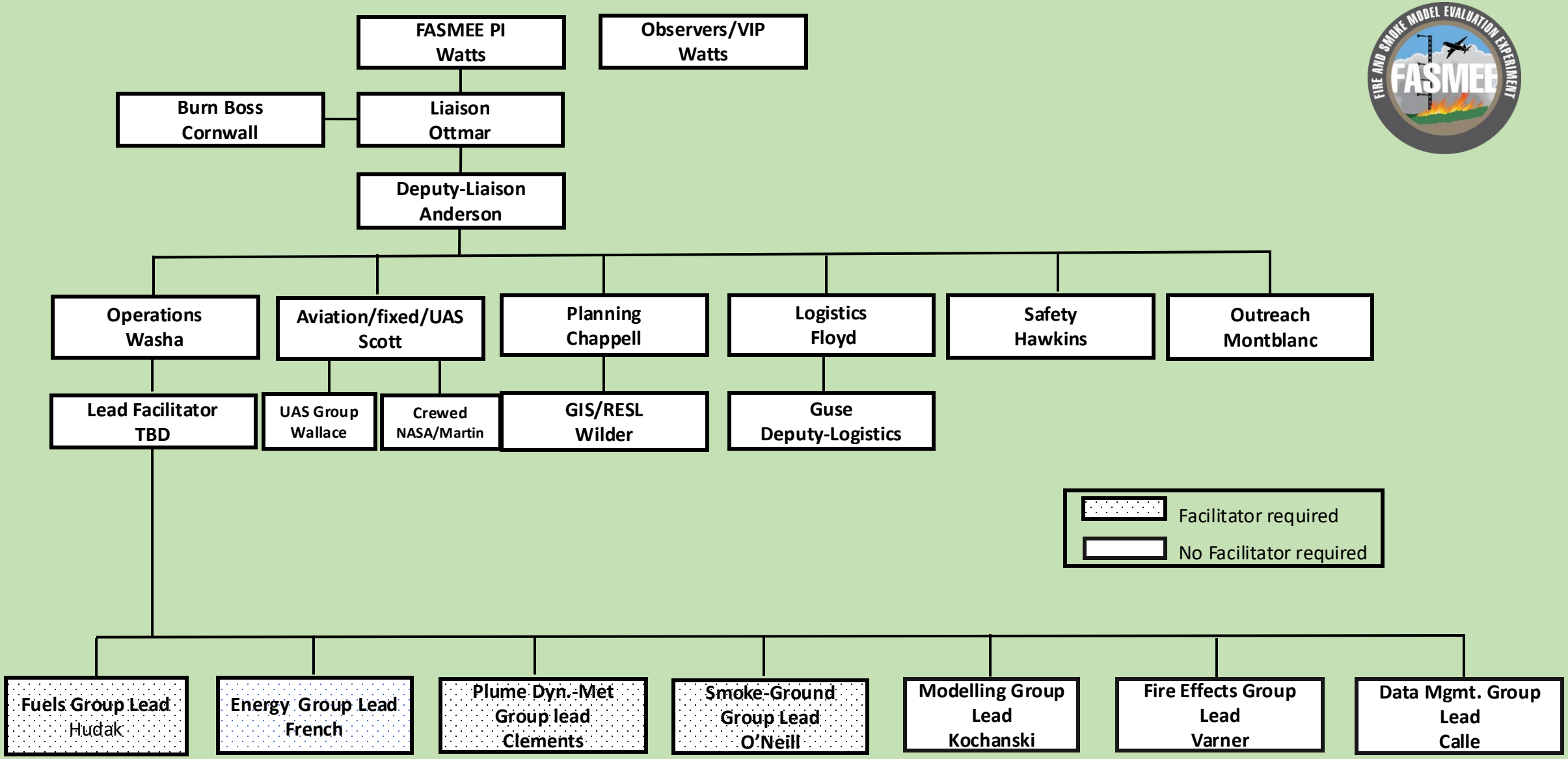
-Re-organization of disciplines; recruitment of new partners

-Resumption of field campaigns post-pandemic

-New emphasis areas:
- -Data Integration/Management
- -Partnerships and outreach to under-represented/DEI
- -Carbon & Climate

-Current status: over 100 participants among 6+ agencies & 12+ university/NGO cooperators in at least 20 States

Operational Development:
FASMEE Integrated Research Management Team (IRMT)



2016-2020 achievements

October 2023 campaign

-Over 50 research participants

-Simultaneous flight: 3 UAS, two crewed aircraft (USFS, UI, Trident, NASA)

-Data site established (NASA LaRC)

-USFS/NASA Field Day: informed host community of research activities; broad agency outreach goals

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Airborne Science Data for Atmospheric Composition

2023

Data Archive: FireSense / FASMEE 2023

File Sharing [private]: Telecons, Meetings, Reports, etc.

Relevant Data / Links

MODIS/ASTER Airborne Simulator (MASTER) FireSense Campaign Page

Field Data Archive Introduction

Data Upload Tools

Steps for submitting data to the Archive

Data Submittal / Scanning

» Help FScan

Register PI dataIDs

ICARTT Data Format Document

Useful Tools

- Download HDFView -- visual tool for browsing & editing HDF files
- Download FileScanning S/W for Windows (Requires IE)

» What's New

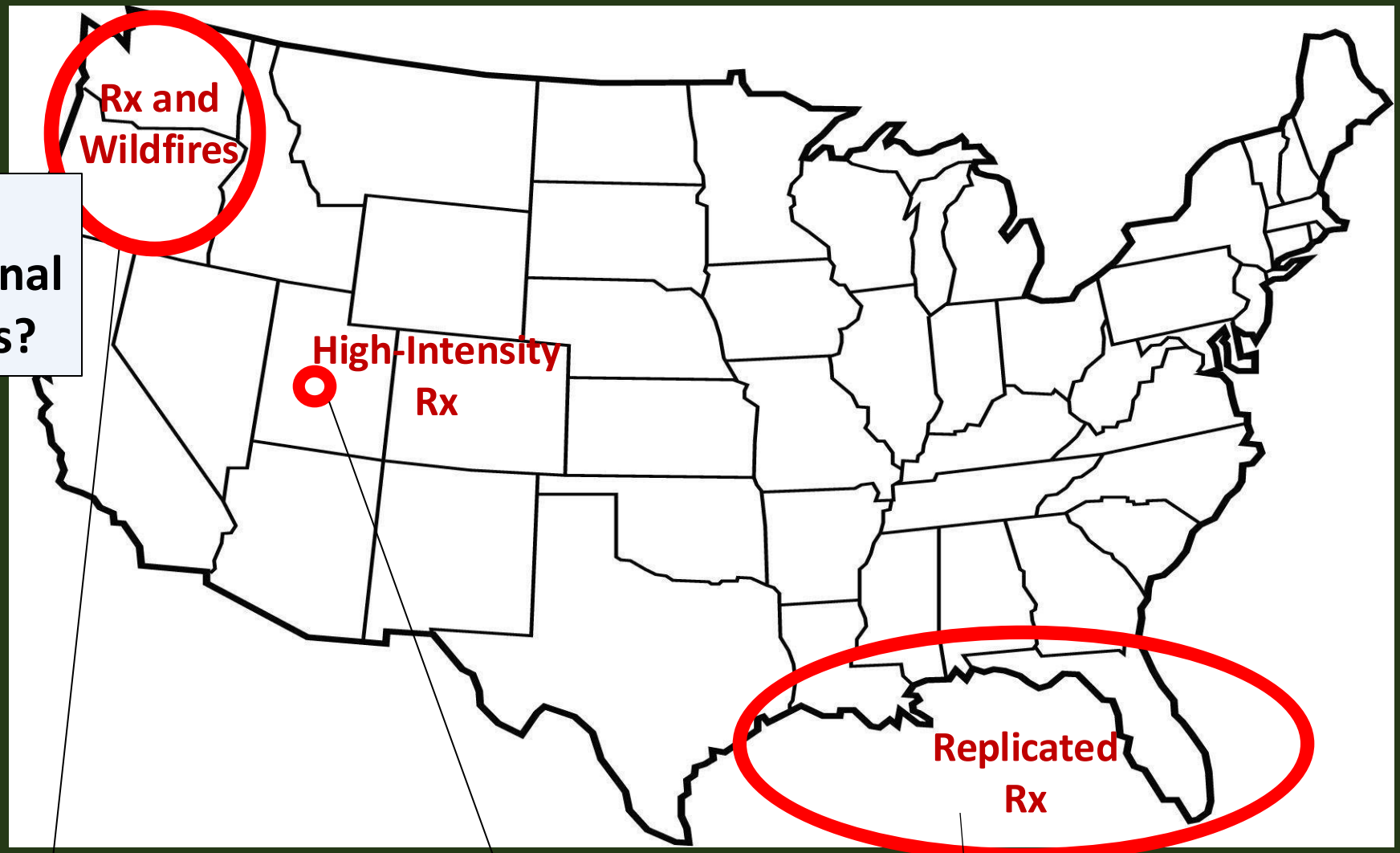
- Download Flight Planning S/W for Windows (Requires Google Earth)

FireSense | FASMEE

The **Fire and Smoke Model Evaluation Experiment (FASMEE)** is a multi-agency, interdisciplinary collaborative effort to identify and collect critical measurements of fuels, fire behavior, fire energy, meteorology, smoke, and fire effects that will be used to evaluate and advance operational-used fire and smoke models. These data will promote science advancement that will give us a better understanding of wildland fire including how a fire behaves, the production and spread of smoke, and fire effects. This knowledge will promotes better prediction of the spread of smoke and the effects on people's health, firefighter health and safety and aids in the allocation of firefighting resources. Data collection has been initiated on large wildfires and prescribed fires within the Western Wildfire and Southwest field campaigns, and the 5-year study plan extends these data collection efforts over large prescribed burn units until 2028.

2016-2020 achievements

Possible additional field sites



Alaska; International Locations?

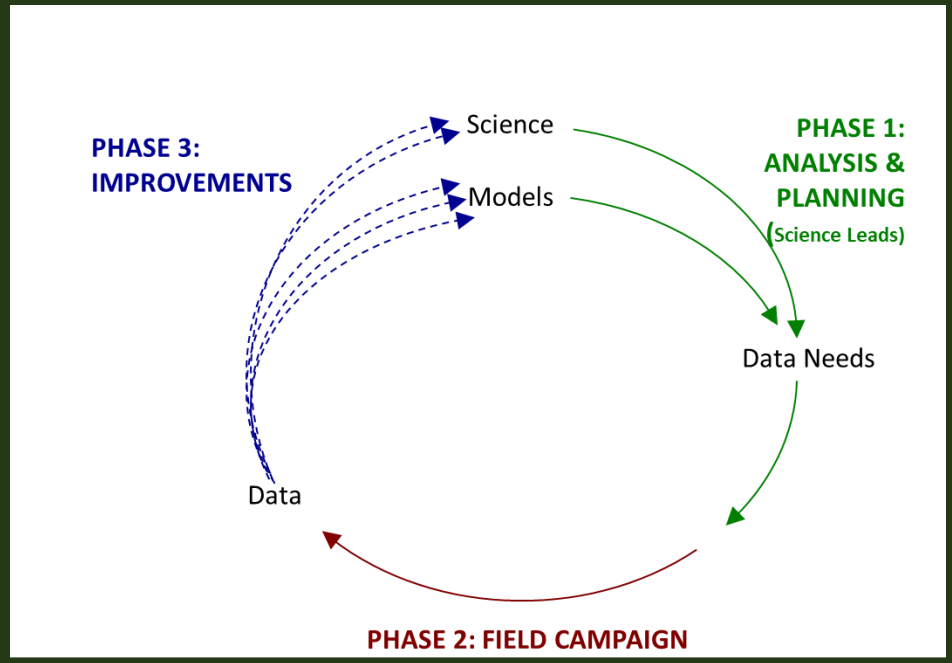
USFS Priority Landscape(s)

Fishlake NF

Southeast US

Addressing Gaps & Next-Steps Planning

-Workshops in 2024 for identifying “hard” gaps and updating study plan
    -NSF co-sponsored
    -May 2024: Study Plan & work plans update (new science & needs)
        -Planning for Fall ‘24 field campaign included
    -Jan 2025: Data & modeling workshop
        -Applying the “data library” to model evaluation & improvement
        -A chance to continue for another cycle



Further reading: www.fs.usda.gov/research/pnw/centers/fasmee
www.fasmee.net

Video: UAS over small-unit burns, Fishlake NF (Utah)