



# US EPA and the Fire Sciences: *Current and Future Emissions Characterization, Brown Carbon and the **SPECIATE** Database*

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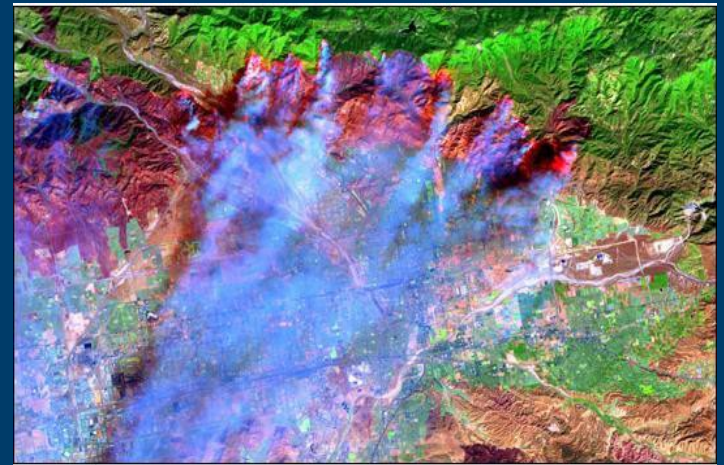


*August, 2010: Smoke from wildfires blankets Ryazan, Russia.*



*Bastrop County Complex Wildfire, Texas.  
September 9, 2011.*

NASA ASTER image of San Bernardino  
during the Fire/Grand Prix fires on  
October 26, 2003.  
Red denotes fire extent.



## *Outline – Two Parts*

### Fire Science in EPA's Office of Research and Development

- Fire science under the ORD Air, Climate and Energy Program
- Focus: Brown carbon in fire emissions
- Focus: The SPECIATE Database

### Research Needed: Climate Change, Fire Emissions and Human Health

- How might smoke emissions change under warming climate conditions?
- What would a fire emissions inventory suitable for projecting smoke exposure under warming climate look like?

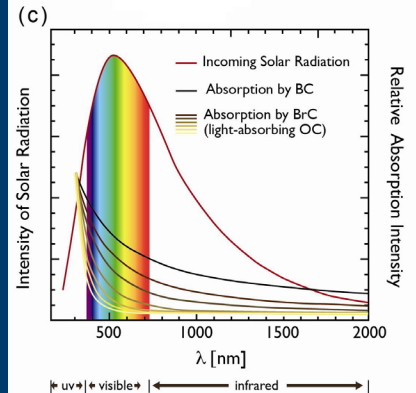


## Part 1:

# Fire Science in EPA's Office of Research and Development



**Smoke Emissions and AQ Impacts Modeling**  
*George Pouliot, NERL*



**Biomass Emissions Factors**  
*Mike Hays et al.,  
 Brian Gullett et al.,  
 NRMRL*

**Brown Carbon**  
*Brooke Hemming, NCEA  
 Amara Holder &  
 Mike Hays, NRMRL  
 Andy Ghio, NHEERL*



**In Vivo Test**

WILDFIRE PM (100 µg)

OROPHARYNGEL ASPIRATION

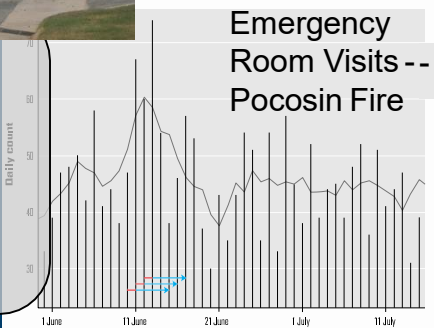
MOUSE 3

BALF Analysis

- Lung injury
- Lung inflammation
- **Cardiac function**

**Smoke Toxicology**  
*Ian Gilmour et al.,  
 David DeMarini et al.,  
 Andy Ghio et al.,  
 NHEERL*

**Smoke Epidemiology**  
*Wayne Cascio and  
 Ana Rappold et al.,  
 NHEERL*



## What is Brown Carbon (BrC)?

- A complex, as-yet-undefined organic material. Also called “humic-like substances (HULIS)”
- Generally lumped into the “OC” fraction of PM in emissions factors
- Appears to be similar to the Fulvic and Humic Acids found in soils
- Appears to very efficiently bind metal ions, just like the soil acids
- Appears to be primarily generated during the smoldering phase of biomass combustion. (Another form – “secondary” BrC – forms through photochemistry in cloud droplets.)

Smoldering tree (Cachier)



Smoldering biomass (Watson)



Head fire (Cachier)



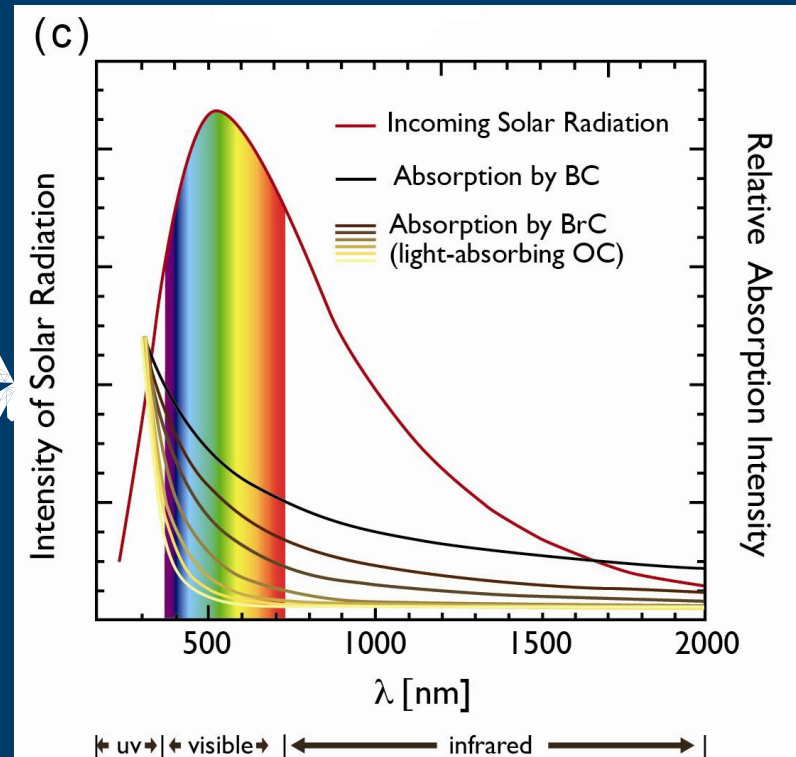
Smoldering elephant dung (Cachier)



Head fire (Cachier)



Smoldering biomass (Watson)



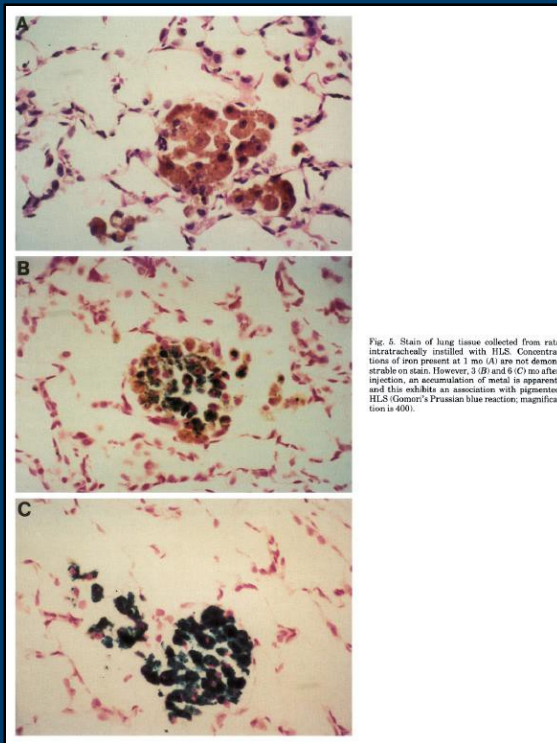
**Color/optical properties of BrC vary with fuel and fire stage**

Yellow

Smaller particle phase organics absorbing in the near UV range

“Browner” larger, more complex molecules with aromatic “zones” that absorb several discrete wavelengths across the visible spectrum

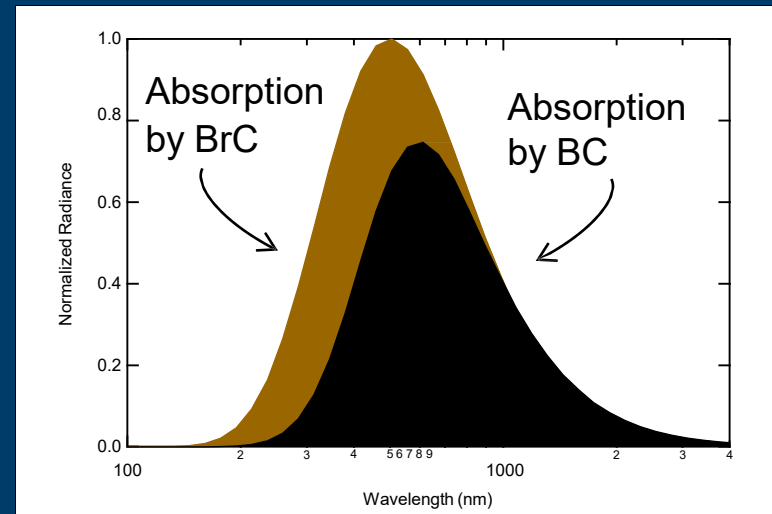
## Human Health Effect



Rat lung tissue after exposure to HULIS (BrC).

(Ghio et al., Am. J. Physiol. 1994 Apr; 266 (4 Pt1): L382-8.)

## Climate Effect



Chris Cappa, UC Davis, 2013.

Accounting for fire emissions mass, BrC could absorb more solar energy than wildfire BC. Implies a possible BrC-induced regional warming effect during active fire seasons. Impacts to consider: regional hydrological cycles, ecosystems stress

# “State of the Art” Fire Emissions Factors -- No BrC, No Specific PM Organics\* at all

<i>Compound</i>	<i>Tropical Forest (g/kg<sup>-1</sup>)</i>	<i>Savanna (g/kg<sup>-1</sup>)</i>	<i>Crop Residue (g/kg<sup>-1</sup>)</i>	<i>Boreal Forest (g/kg<sup>-1</sup>)</i>	<i>Pasture Maintenance (g/kg<sup>-1</sup>)</i>	<i>Temperate Forest (g/kg<sup>-1</sup>)</i>	<i>Extratropical Forest (g/kg<sup>-1</sup>)</i>
102 Gases	...to varying degrees of completeness and certainty						
Not Gases							
TSP	13	--	--	--	--	--	--
Total Particulate Carbon	5.24 (2.91)	3.00 (1.43)	--	--	10.6 (4.8)	--	--
Condensation Nuclei (0.003 – 3 um diameter)	5.9 x 10 <sup>16</sup>	--	--	--	--	--	--
PM <sub>2.5</sub>	9.1 (3.5)	7.17 (3.42)	6.26 (2.36)	15.3 (6.7)	14.8 (6.7)	12.7 (7.5)	15.0 (7.5)
PM <sub>10</sub>	18.5 (4.1)	--	--	--	28.9 (13)	--	--
Black Carbon (BC) – Really “EC”	0.52 (0.28)	0.37 (0.20)	0.75	--	0.91 (0.41)	--	0.56 (0.19)
Organic Carbon	4.71 (2.73)	2.62 (1.24)	2.30	--	9.64 (4.34)	--	8.6-9.7
Assorted Ions	✓	✓	--	--	✓	--	--
Ca, Mg, Na, K	✓	✓	--	--	✓	--	--

For complete details, see Table 1, Akagi, S. K., R. J. Yokelson, et al. (2011). Emission factors for open and domestic biomass burning for use in atmospheric models. *Atmospheric Chemistry and Physics* **11(9)**: 4039-4072.

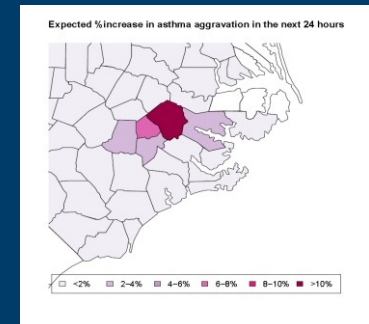
\* In part, because models aren't equipped to do aerosol phase organic chemistry

**The role of composition and particle size on the toxicity of wildfire emissions** (PIs and co-PIs: Gilmour, Higuchi, Hays, Dye, Hazari, DeMarini (EPA))

- **Quantify relative cardiopulmonary toxicity and mutagenicity** of coarse/fine/ultrafine PM from both smoldering and active flame phases for 4 important biomass fuels (pine, oak, peat, and a SE pine/deciduous mix).
- **Rank the pulmonary, cardiac and mutagenic effect of PM from these fuels**, accounting for fire phase against ambient urban and rural PM.
- **Determine the role of composition** (e.g., LPS and organics) on the relative potency of each sample.

**Estimating fire smoke related health burden and novel tools to manage impacts on urban populations** (PIs and co-PIs: Rappold & Fann (EPA), Reich (NCSU), Broome, Cope, Johnson, Morgan (Australia))

- **Fire smoke and health risk estimates, and health and economic impact assessment** (eg BenMAP) based on smoke emissions from the last decade
- **Real time health impacts tools**, based on methodology developed in first phase.



Asthma aggravation from BENMAP CE for June 12, 2008, Evans Road Fire, NC



## Focus: ORD's *SPECIATE* Database

- **SPECIATE** is the EPA's repository of volatile organic gas and particulate matter (PM) speciation profiles of air pollution sources.
- In use (with on-going development by EPA/ORD) for over 20 years.
- Regarded as the international standard for speciation profiles (a critical input into the calculation of emissions factors).
- Latest release is described in:  
[EPA \(2014\). "SPECIATE Version 4.4 Database Development Documentation."](#) Final Report. EPA/600/R-13/307.
- Needs substantial improvement regarding fire emissions, BC and BrC.

- Room for improvement: **Fire emissions**
  - Urbanski et al. compilations --funded by the JFSP -- are being added and will be part of SPECIATE4.5
  - *Question*: Will these be sufficient to adequately represent fire emissions under changing climate? (**Science-limited**)
- Room for improvement: **Brown Carbon**
  - Need to include BrC, but the science isn't there, yet. (**Science-limited**)
- Room for improvement: **Black Carbon**
  - Currently only list EC, as measured by thermo-optical methods
    - Inadequate for modeling source-dependent climate and visibility impacts
  - Newer methods characterize BC by optical properties
    - SPECIATE is not currently configured to include these data (**Resources-limited**)
    - New common data reporting format and quality standards needed (**Resources-limited**)

## Including BC<sub>optical</sub> in SPECIATE : Tasks

- Assessing current measurements by method
  - Quantities measured
  - Can these be reconciled to achieve a common set of metrics?
    - May need a set of “best practice” recommendations to assist in establishing method application consistency
    - Need to engage the BC measurements community to define these
- Data quality standards
  - Optical\*-equivalent to SPECIATE’s current data quality criteria
- Build the database infrastructure to support this new data-type
  - With particular emphasis on the inclusion of measurement-related metadata

## Including BC<sub>optical</sub> in SPECIATE : Project Status

- The BC subteam of the SPECIATE Workgroup is seeking the resources necessary for the community outreach and database infrastructure expansion. We are reaching out to:
  - Internal (EPA) stakeholders
  - Interested international agencies (CEC to start)
  - Your suggestions are welcome!
- Establishing common BC optical metrics, measurement best practice recommendations and data quality standards will take some effort
  - But, these tasks are long overdue.
    - » *We're all weary of the "Carbon Wars"*

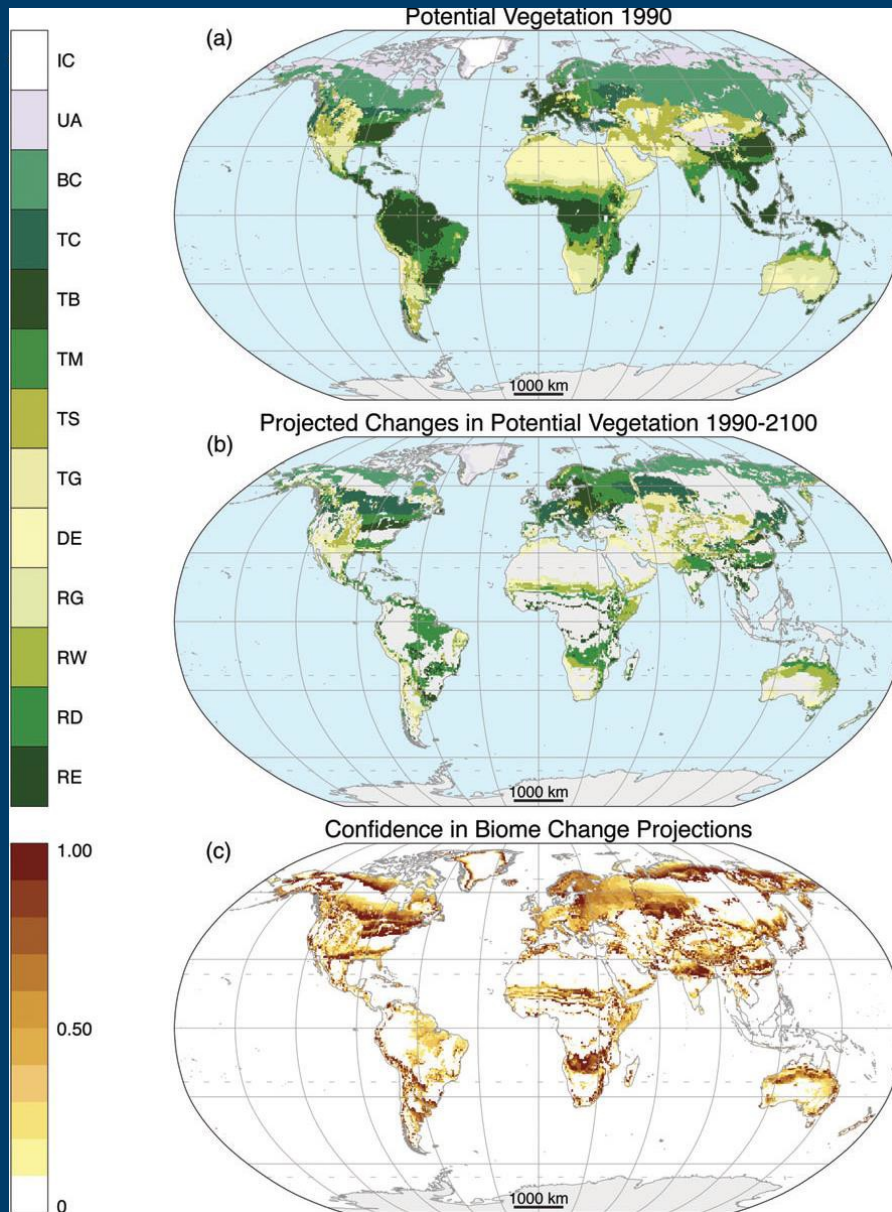
## Part 2: Research Needed -- Climate Change, Fire Emissions and Human Health/Ecosystems Impacts

### *Key Points*

Primary fire emissions vary with...

- Fire stage
- Fuels, Fuel conditions, Fire conditions

➤ *All are subject to change with warming climate*



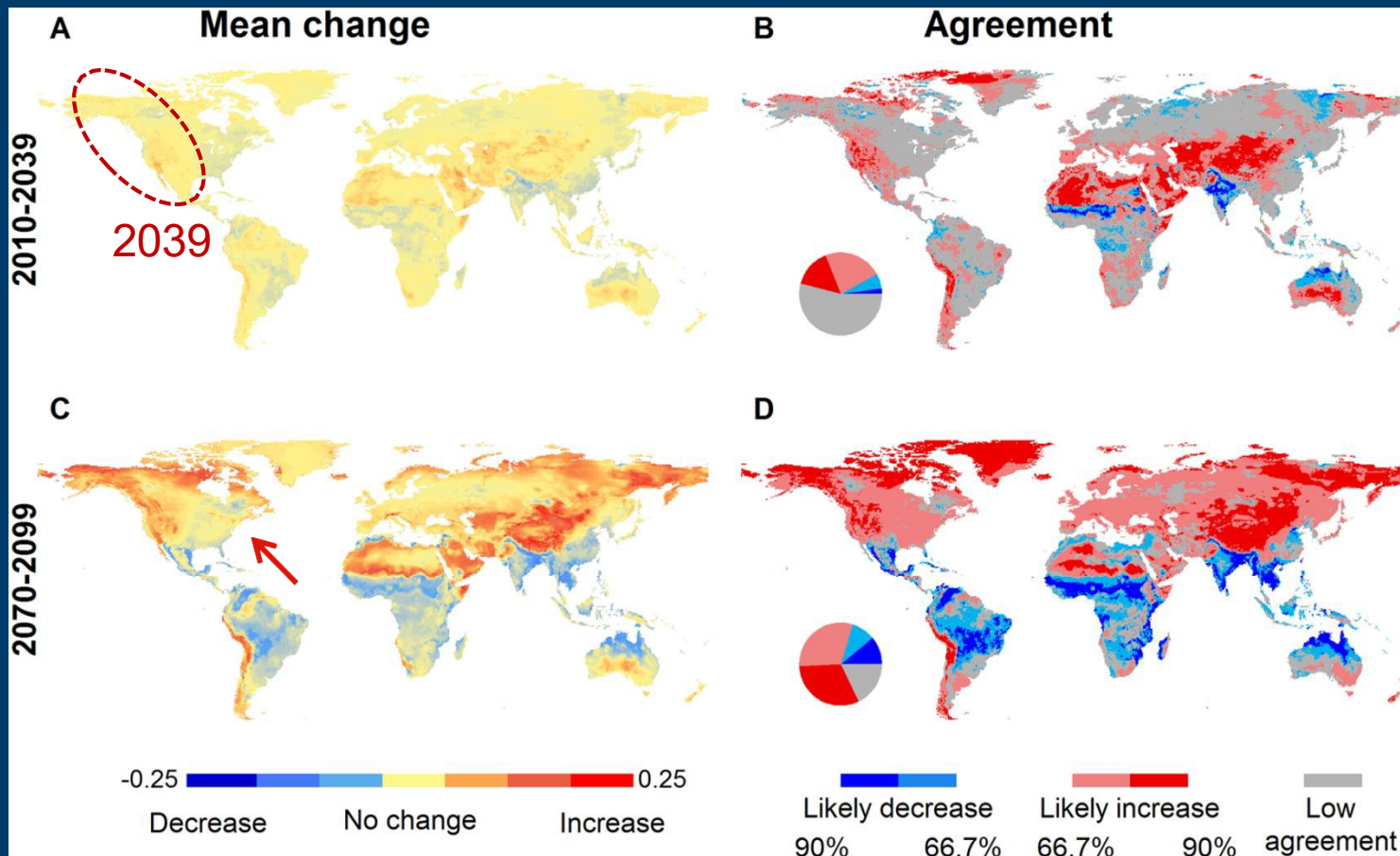
9 GCMs used to calculate “Vegetation Potential”

- 1990
- 1990 → 2100

*Marked changes projected over the century with changing climate*

Gonzalez et al. (2010) *Global Ecol. Biogeogr.*, DOI: 10.1111/j.1466-8238.2010.00558.x

# Results of another ensemble climate modeling study suggests increasing fire frequency with warming climate through 2099



Ensemble mean change (A, C) and degree of model agreement (B, D) in predicted fire probability among the 16 GCMs for 2010 2039 and 2070 2099 time periods (change assessed from baseline probabilities 1971 2000).

## How many emissions factors would one need for a climate-change relevant fire emissions inventory?

### Variables affecting fire emissions composition and optical properties

#### Fuel composition

Biomass species\*\*\*

Form (Wood, foliar material, duff, peat)\*\*\*

Soils\*\*\*

#### Combustion conditions

Meteorology\*\*\*

Fuel moisture\*\*\*

#### Fire stage

Preheating

Pyrolysis and smoldering

Flaming combustion

\*\*\* = subject to change with warming climate, land-use change

- Impacts on human health and ecosystems are sensitive to the chemical composition of fire-derived PM and gas-phase emissions
- Single “composite” emissions factors will not capture the effects of significant climate change-derived meteorological changes and changing biomes on fire emissions composition.
- Detailed evaluation of the obvious smoke composition-determining variables is needed for climate change-related wildfire adaptation planning.



Your comments are invited.

Contact me

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Assessment