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Applications of geostationary satellite measurements to fire and smoke science and management

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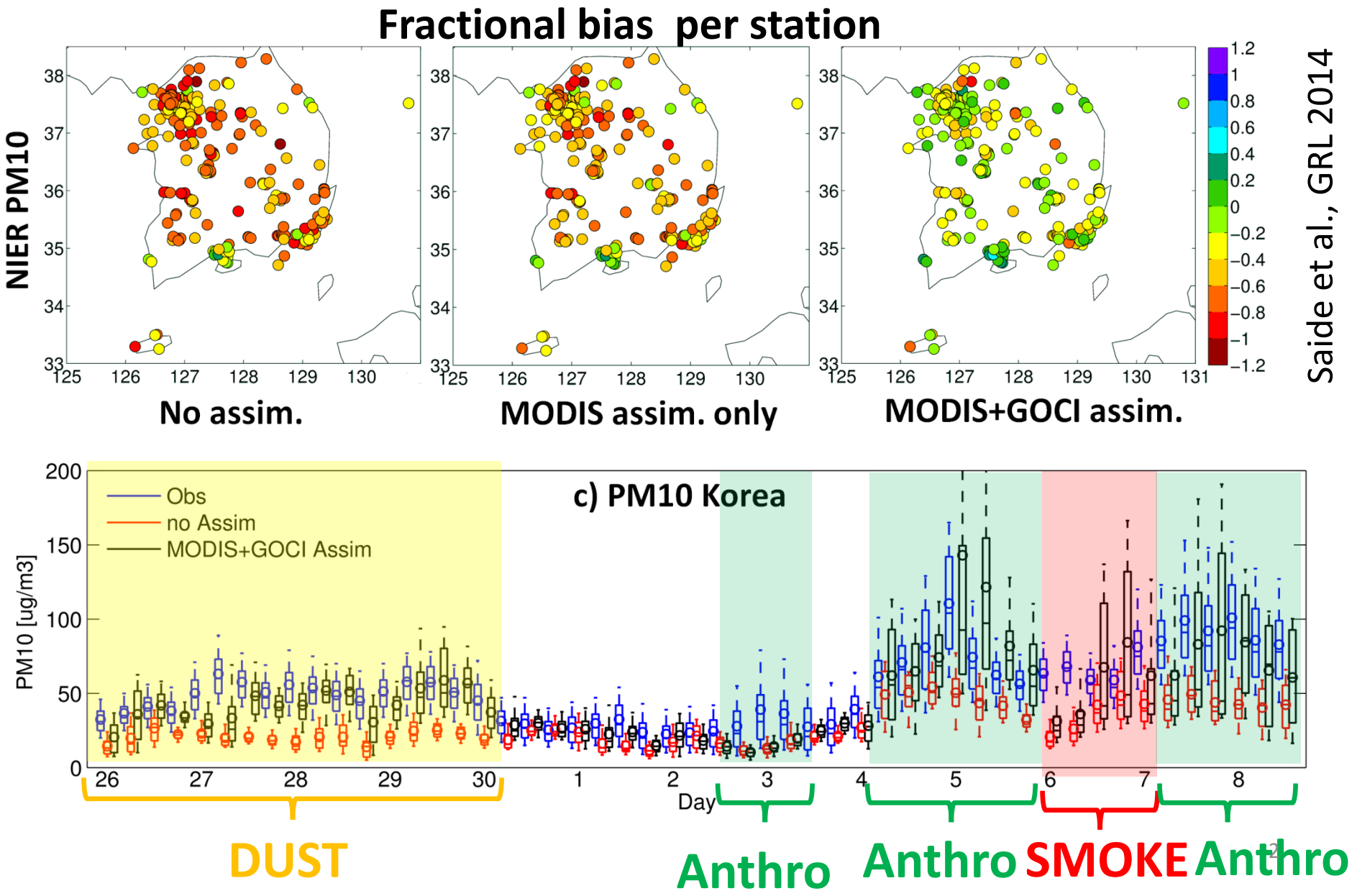
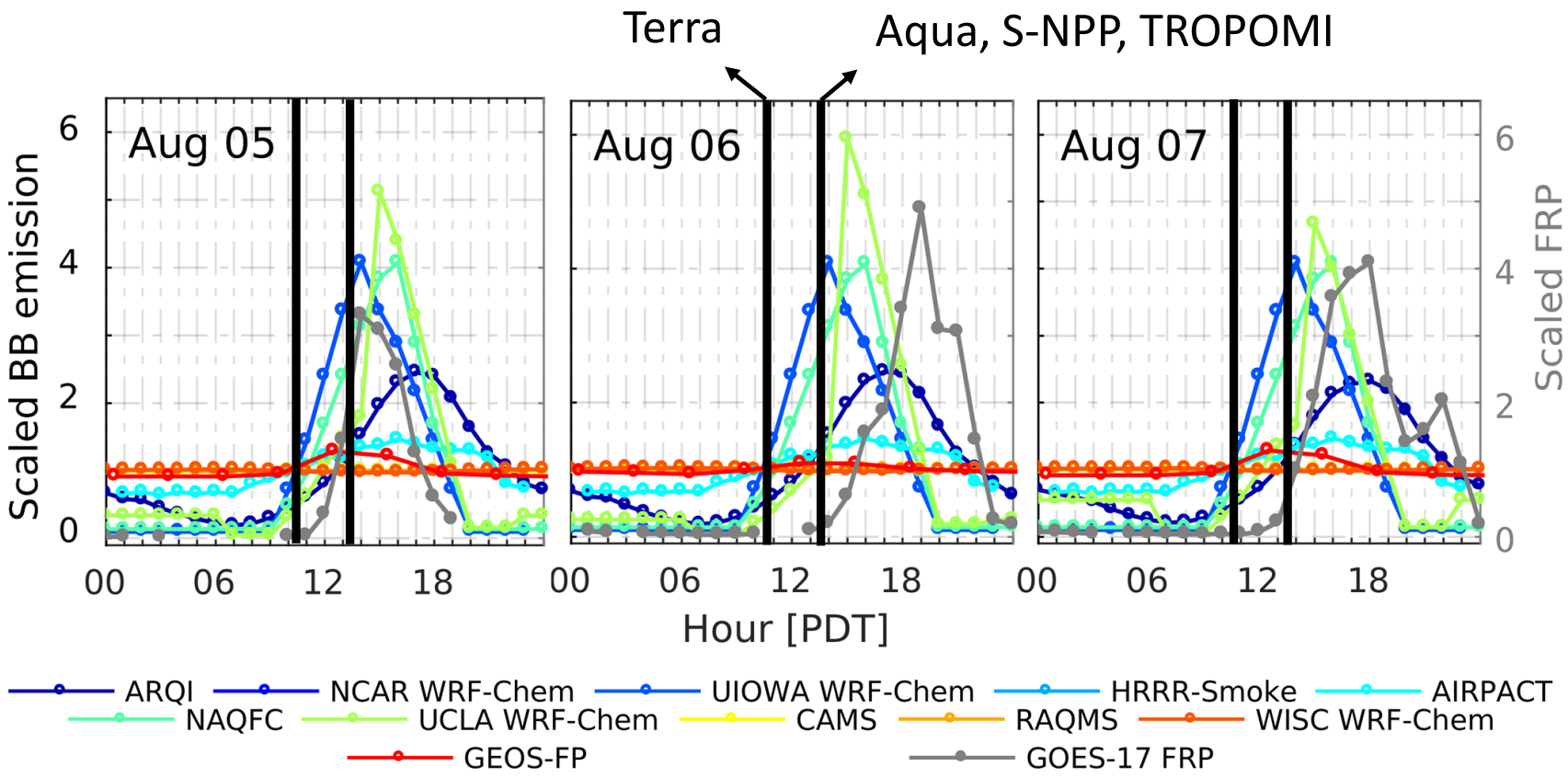
With contributions from many including Laura Thapa, Xinxin Ye, Oscar Neyra, Charles Ichoku, Shobha Kondragunta, Rose Dominguez, Amber Soja, Emily Gargulinski, Ravan Ahmadov, Eric James, Bradley Pierce, Aditya Kumar, Paul Makar, Jack Chen, Didier Davignon, Greg Carmichael, Gonzalo Ferrada, Jeff McQueen, Jianping Huang, Rajesh Kumar, Louisa Emmons, Farren L. Herron-Thorpe, Mark Parrington, Richard Engelen, Vincent-Henri Peuch, Arlindo da Silva, James Limbacher, Mariel Friberg, Alexei Lyapustin, Kevin Bowman, Kazu Miyazaki, Demetrios Pagonis, Pedro Campuzano-Jost, Hongyu Guo, Jose-Luis Jimenez, Richard Moore, Elizabeth Wiggins, Chris Holmes, and the FIREX-AQ team

More is better? For air quality data assimilation yes!

- Much larger forecast improvements are obtained when additionally assimilating Geostationary data
- Improvements are found for multiple types of pollution evens, including smoke



Geostationary observations are especially important for fires and smoke!



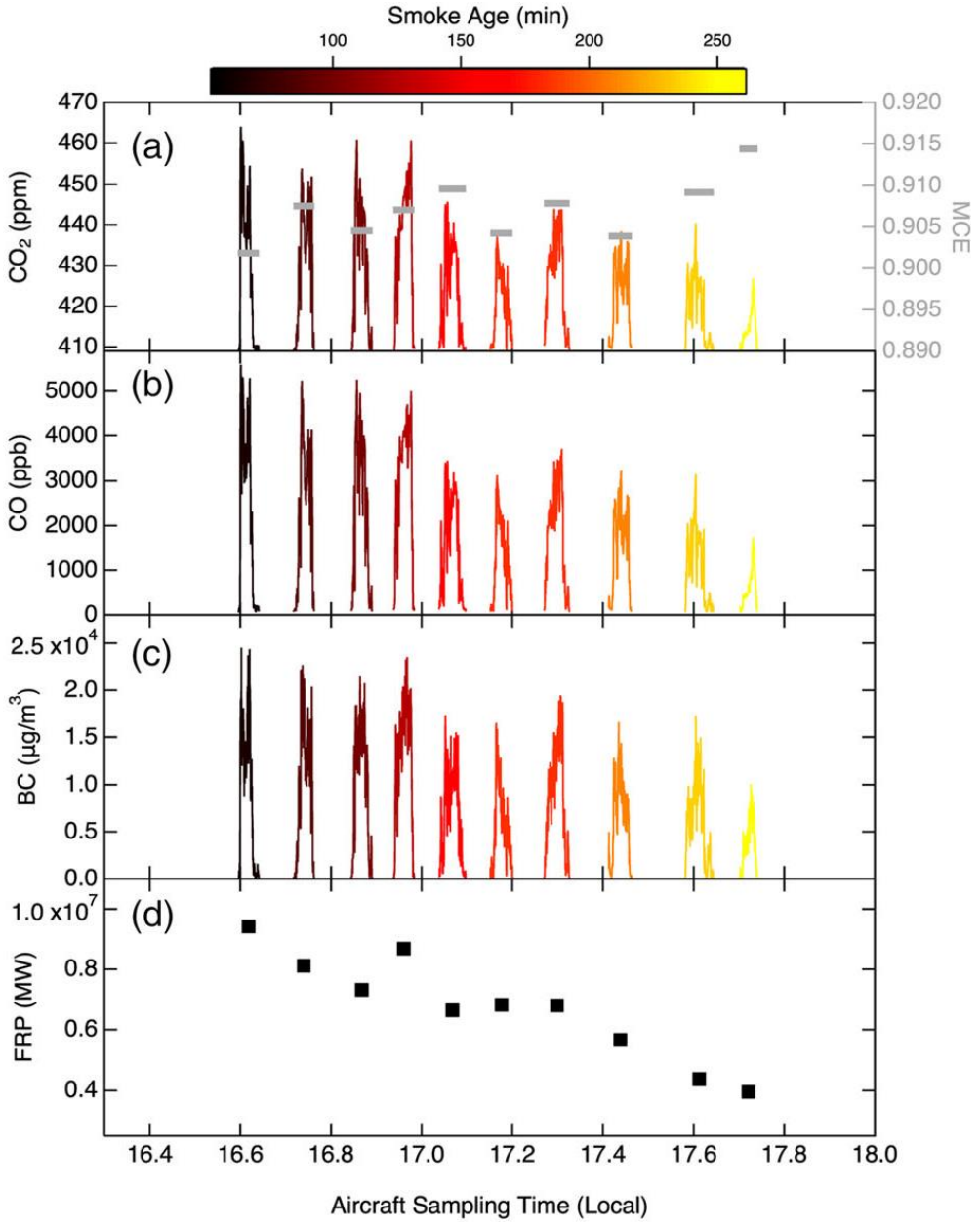
Williams Flats Fire (2019)

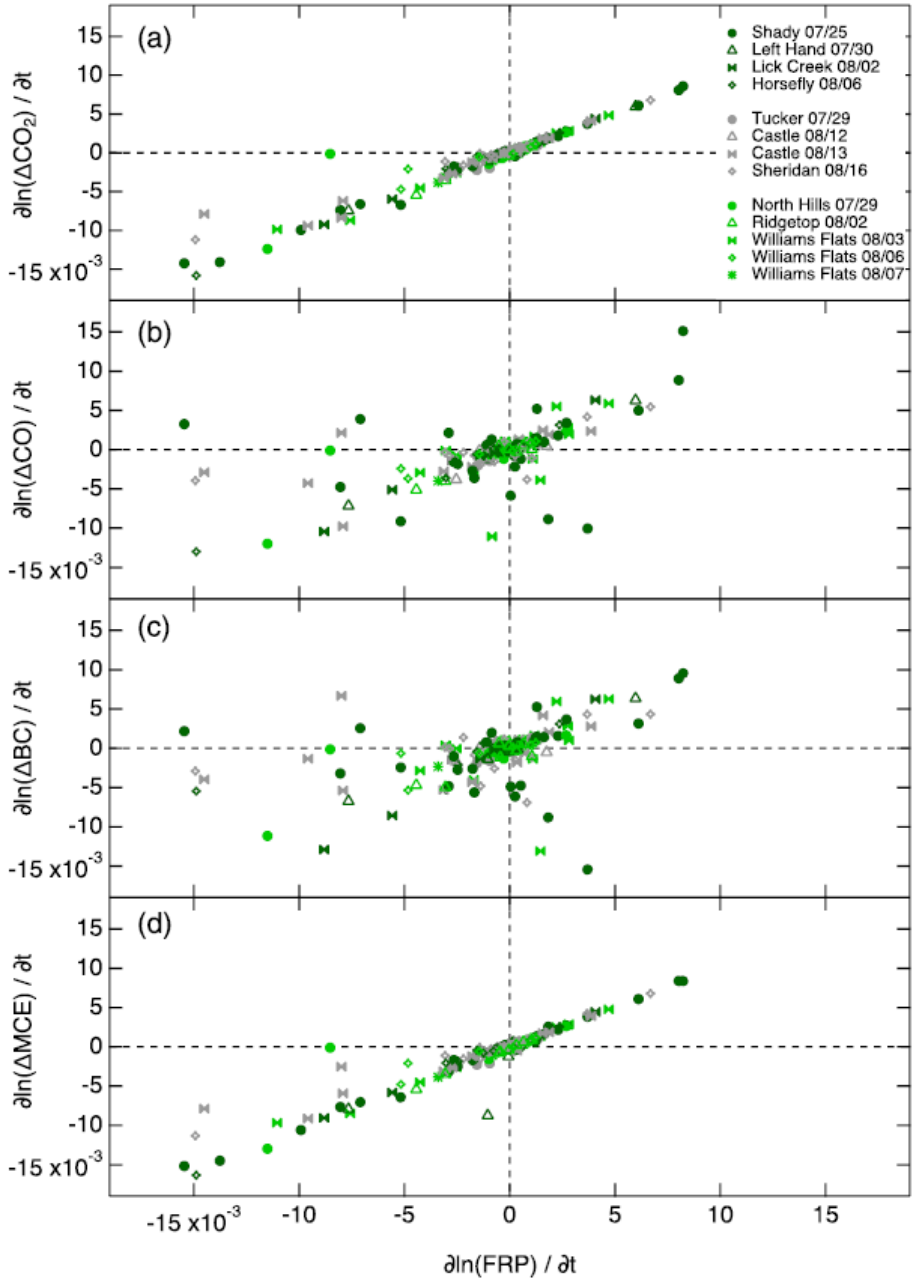
Ye et al., ACPD 2021

GOES17 imagery compiled by Chris Holmes (FSU)

But most smoke emission inventories rely on LEO data. Does Geo data adds value? Yes!

Williams Flats Fire (2019)

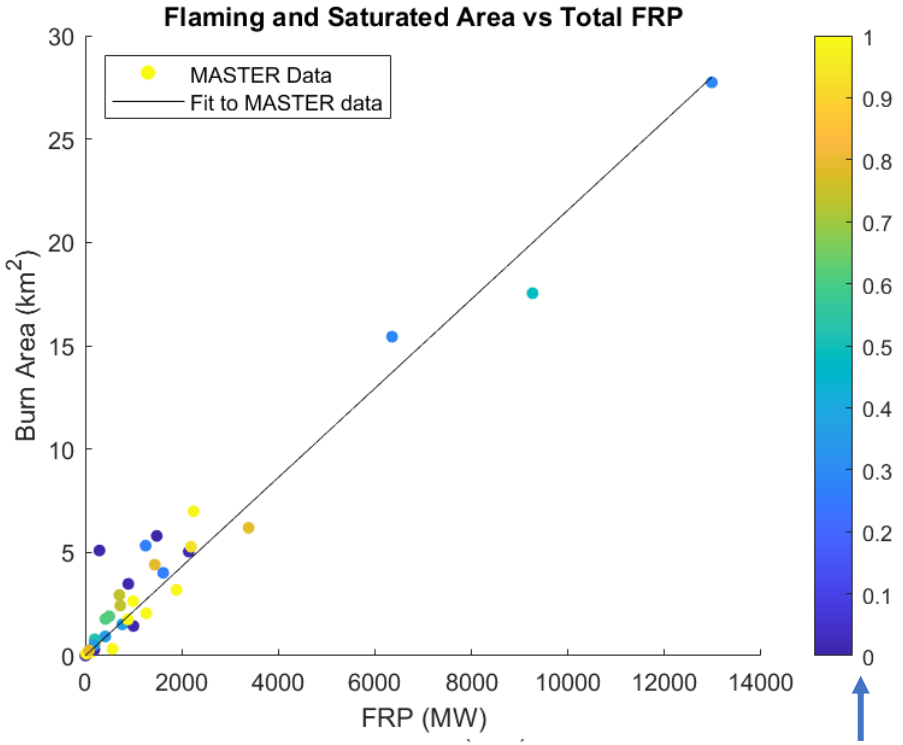


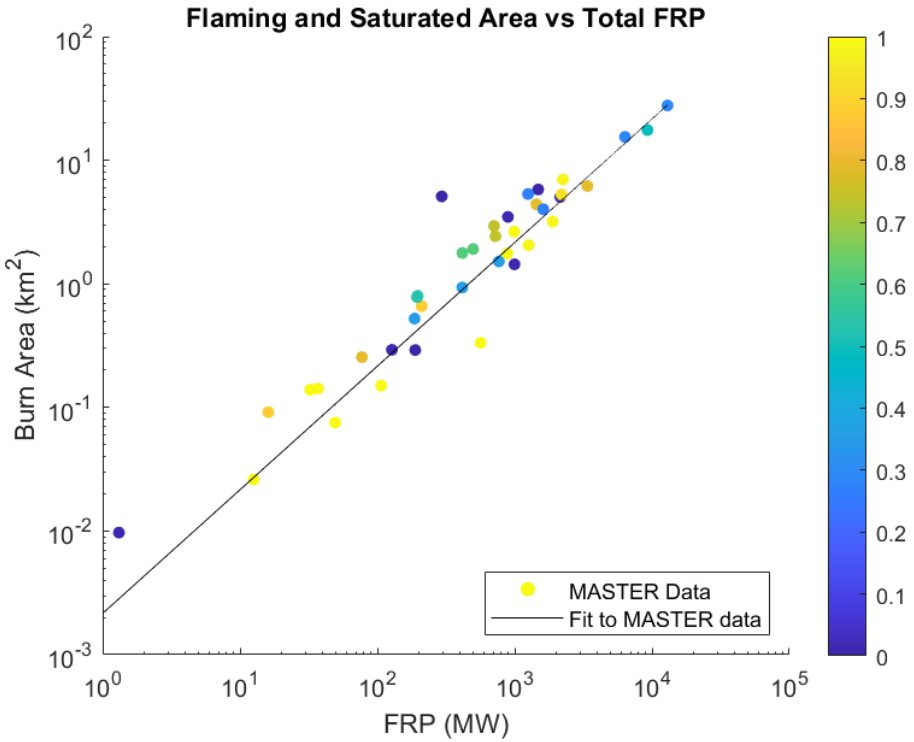


Geostationary FRP Reveal Link Between Fire Behavior and Aerosol and Gas Emissions (Wiggins et al., GRL 2020)

Geostationary FRP can also be used to estimate instantaneous fire area used in plume injection parameterizations

MASTER (airborne multispectral imager) can be used to derive relationships that can use geostationary FRP as input





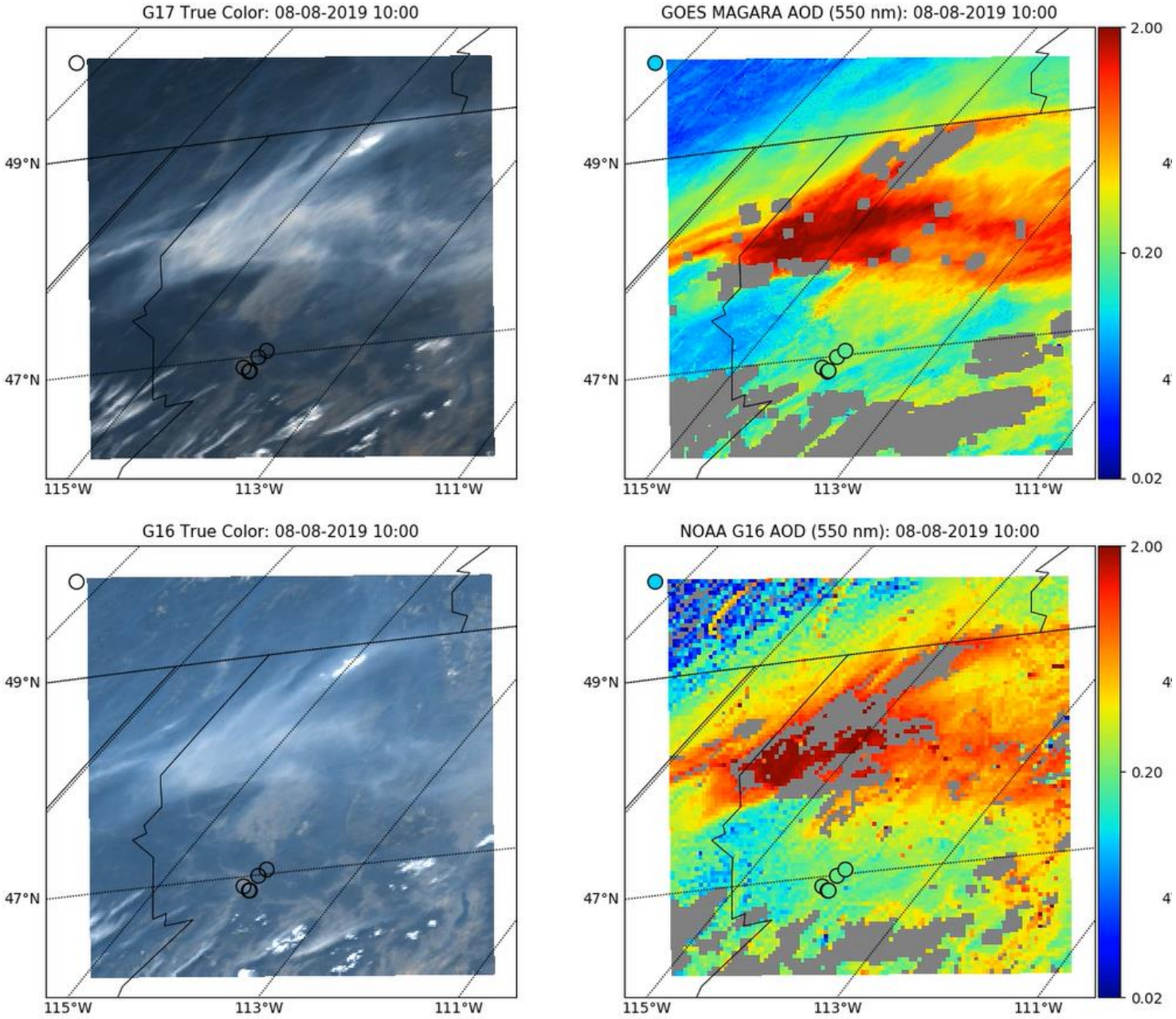
Grassland fraction

FRP derived using algorithm developed by Charles Ichoku (Howard Univ) and FRP validation against satellite data by Shobha Kondragunta (NOAA)

Thapa et al., in preparation

But we already have geostationary information on fires (e.g., AOD, FRP), is that sufficient?

- Missing retrievals for dense smoke
- Land cover sometimes difficult retrievals
- New retrievals are showing promise! (e.g., GEO-GEO Stereo Aerosols , MAIAC)

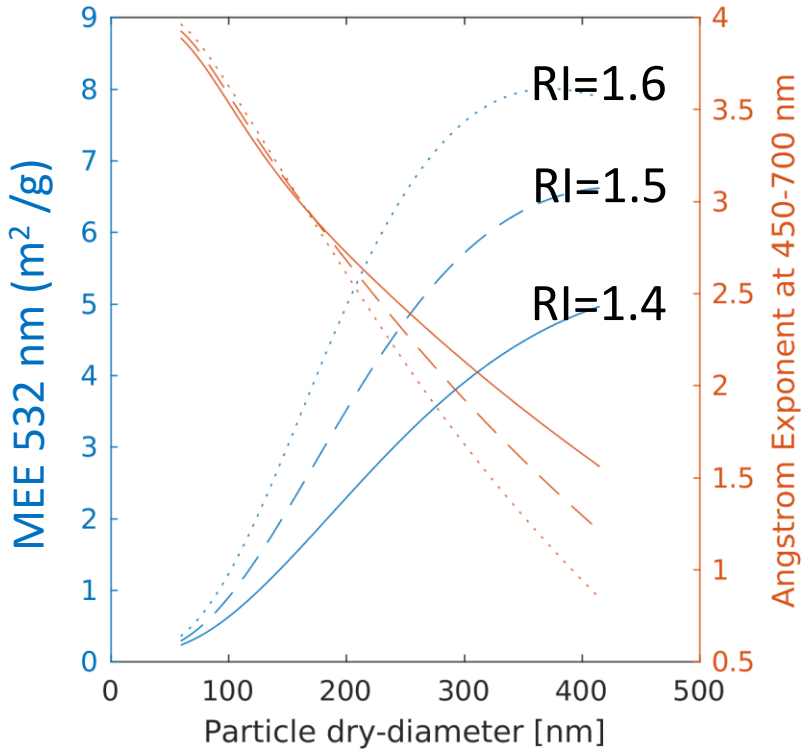


GEO-GEO Stereo Aerosols retrievals (MAGARA) for Williams Flats fire aged smoke based on Limbacher and Kahn (AGU 2019) Retrievals. Credit: James Limbacher and Mariel Friberg

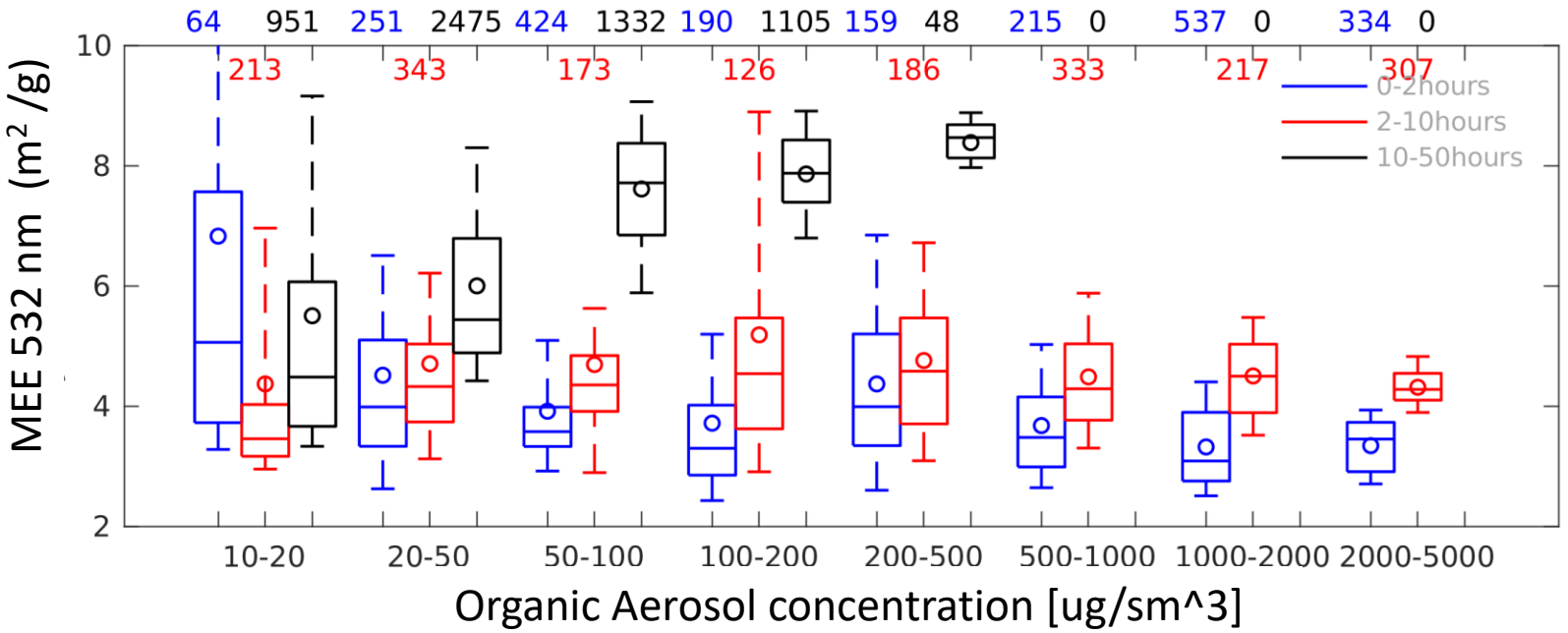
Also, need to make assumptions to convert from AOD to smoke mass (e.g., PM2.5)

EXTINCTION = MEE x MASS

MEE: Mass Extinction Efficiency

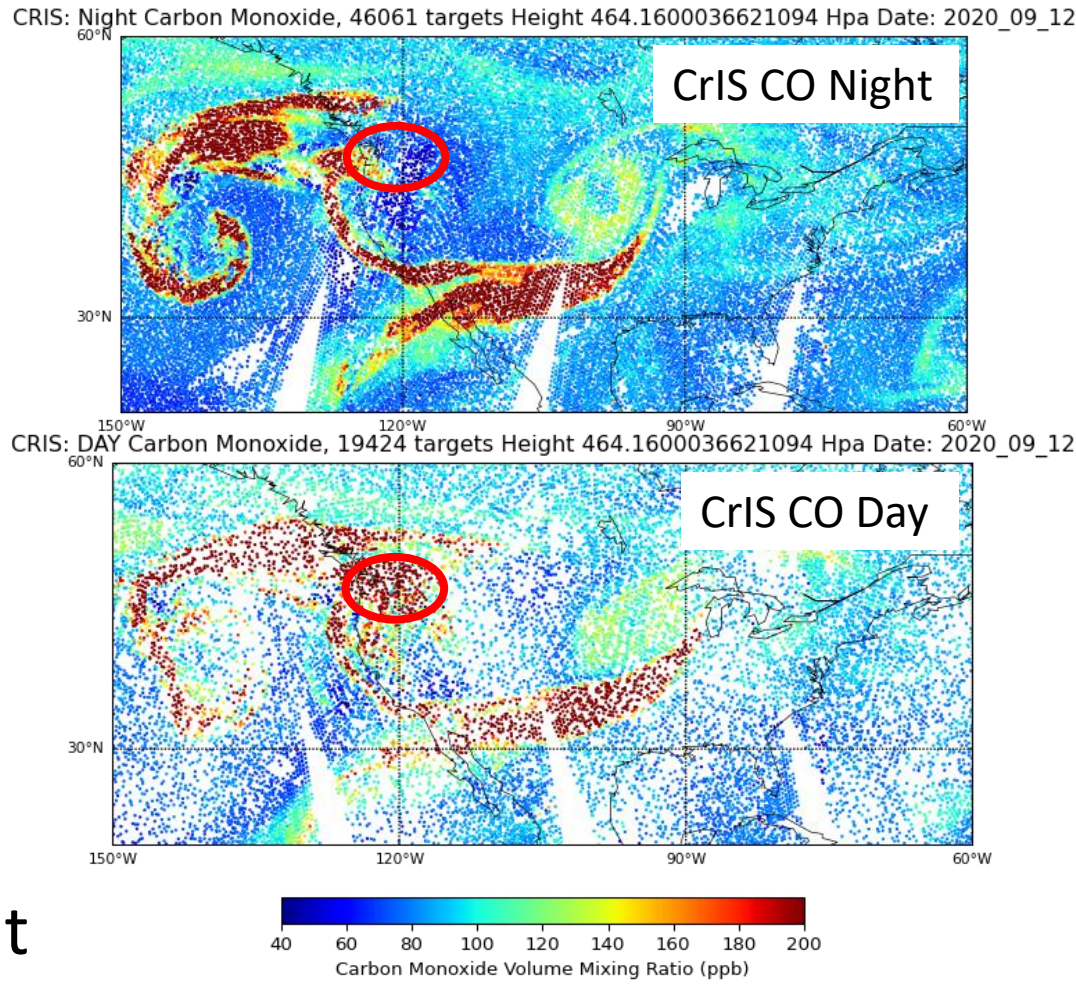


- MEE using FIREX-AQ data shows large variability for a single fire, going to small values for fresh dense smoke (~3 m^2/g) to large values for 1-day old smoke (up to 9 m^2/g)
- Current models do not capture these trends



How can GEO-XO add to the current constellation?

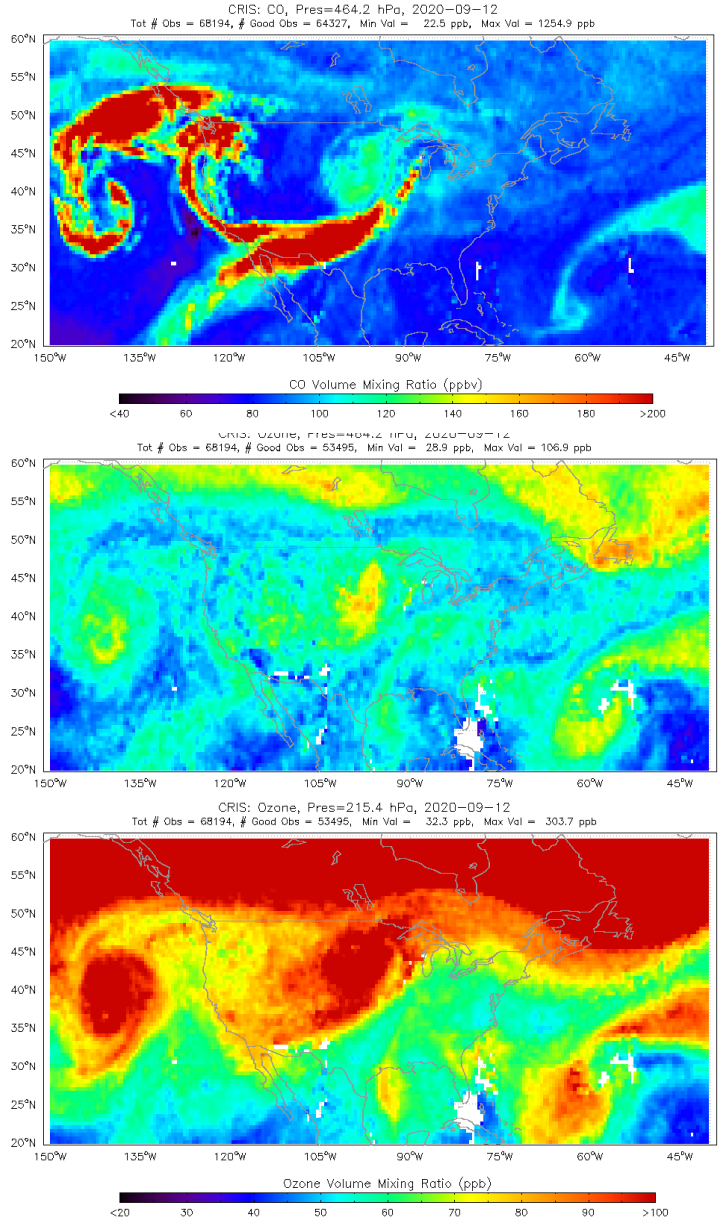
- CO is a good smoke tracer
- There is no conversion from optical properties to mass when using CO columns
- If CO emissions from fires are estimated, ratios of emission factors can be used to go from CO to aerosols
- CO retrievals do not saturate as for AOD and are less dependent on land cover
- Infrared sounders (e.g., CrIS) can provide vertically resolved CO and both day and night coverage



CO CrIS retrievals from NASA JPL (TROPESS) at ~7 km altitude during the 2020 mega fires (credit to Oscar Neyra, Kevin Bowman and Kazu Miyazaki)

How can GEO-XO add to the current constellation?

- Total-column and free-tropospheric CO could be used to derive boundary layer CO (on going work using TROPOMI and CrIS)
- Better constrain chemical transformations happening in plume due to multi-specie retrievals
- Better constraining sources of ozone (e.g., smoke vs stratospheric)
- Provide detailed information on MCE evolution through CO and NO_2 column ratios (see van der Velde et al., ACP 2021)
- and more…



CO and Ozone CrIS retrievals from NASA JPL (TROPESS) during the 2020 mega fires (credit to Kazu Miyazaki)

Take away points

- Current geostationary retrievals of fires and smoke are highly relevant for smoke science and management
- However, they have limitations (e.g., total column, saturate at high smoke loads, conversion from optical properties to aerosol mass can be challenging)
- Future geostationary satellites measuring atmospheric composition will help fill many of the gaps of the current constellation and provide unprecedented data for the study and management of smoke

Questions or Comments?

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