« Analyse par télédétection et modélisation des fumées des feux de forêt dans l'ouest des États-Unis en été 2020 et de leur transport à travers l'Atlantique »

Xavier Ceamanos[1], Quentin Coopman[2], Maya George[3], Jérôme Riedi[4,5], Mark Parrington[6], and Cathy Clerbaux[3,7]

[1]*CNRM, Météo-France/CNRS/Univ. de Toulouse*
[2]*Dept. of Atmospheric & Oceanic Sciences, McGill Univ.*
[3]*LATMOS/IPSL, Sorbonne Univ./UVSQ/CNRS*
[4]*ICARE Data and Services Center, Univ. de Lille/CNRS/CNES*
[5]*LOA, Univ. de Lille/CNRS*
[6]*ECMWF*
[7]*Univ. Libre de Bruxelles*

xavier.ceamanos@meteo.fr

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Wildfires

An essential part of ecosystems, yet a hazard to humans

- Increasingly devastating and longer wildfire seasons across the planet due to changing climate (recurring droughts, alteration of landscape, stronger winds and thunderstorms) [*WMO, 2021*]
- Smoke emitted by wildfires (a cocktail of gases and particulate matter) is harmful for humans [*Chen et al., 2021*]

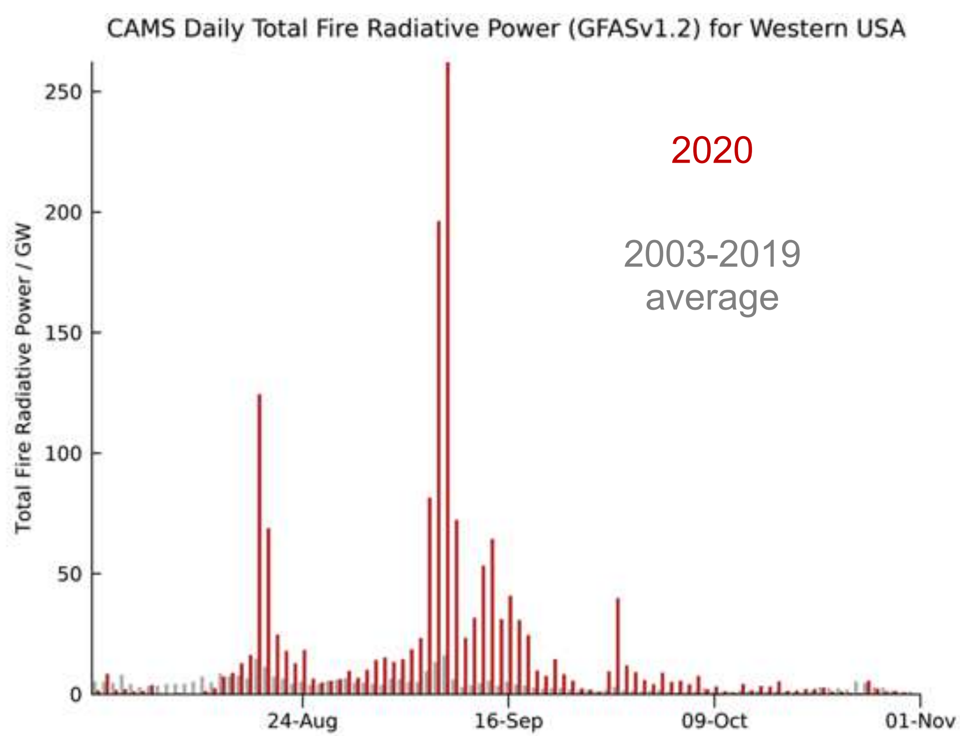
Wildfire and smoke [Credits: National Park Service]

- Wildfire smoke is often transported across thousands of kilometers altering downwind air quality!

Western US: a region at risk

The 2020 wildfire season

- Record-breaking fires in California, Oregon, and Washington



Daily estimates of total fire radiative power (FRP, a measure of radiative heat output) from the Copernicus Atmosphere Monitoring Service (CAMS) Global Fire Assimilation System (GFAS) for Western US.

- Largest wildfire season recorded in California's modern history, with 9917 fires, 10000 structures destroyed, and 4% of the state burned
- Large amounts of smoke were injected into the upper troposphere and transported across the Atlantic to Europe [*Baars et al., 2021*]

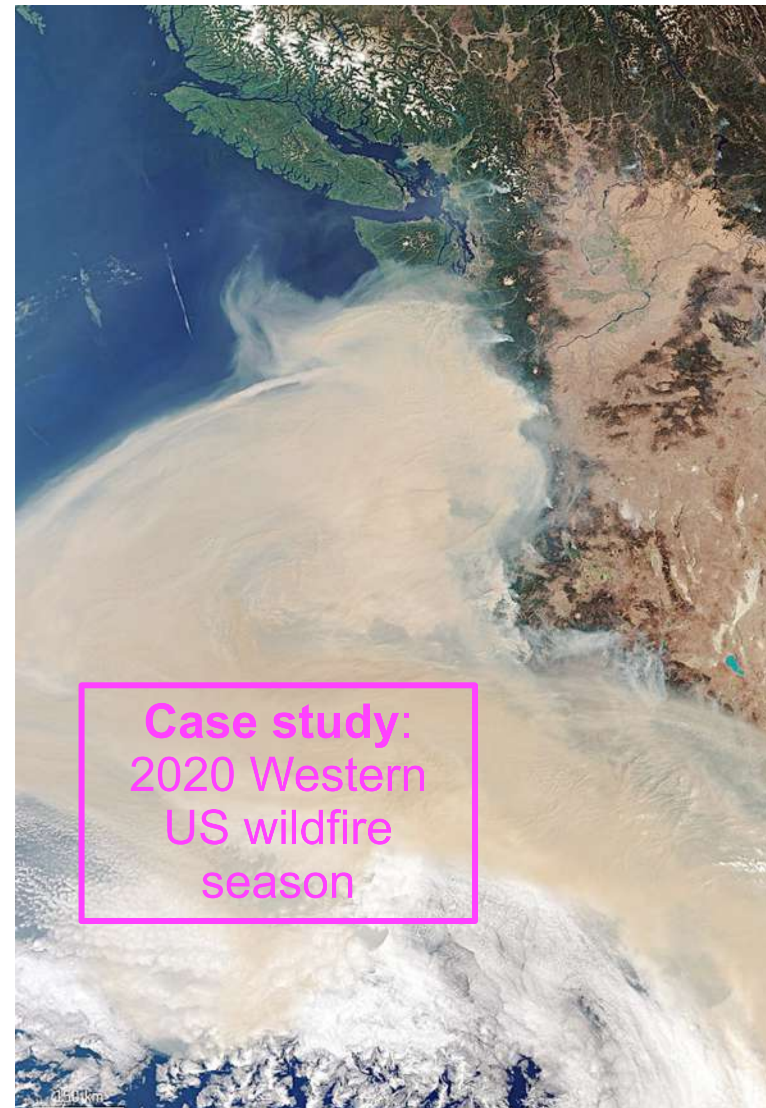
Satellite remote sensing

And its potential for monitoring fire smoke

- Operational forecasting systems are used to predict the impact of wildfires on local and remote air quality
- Models accuracy is impacted by limited knowledge on emission estimates and numerical diffusion [*Zhuang et al., 2018*]
- Satellite observations can contribute to reducing some of these uncertainties (e.g., by initializing operational forecasts)

What can satellite observations bring further to our understanding (and therefore to modeling) of emission, transport, and evolution of biomass burning emissions?

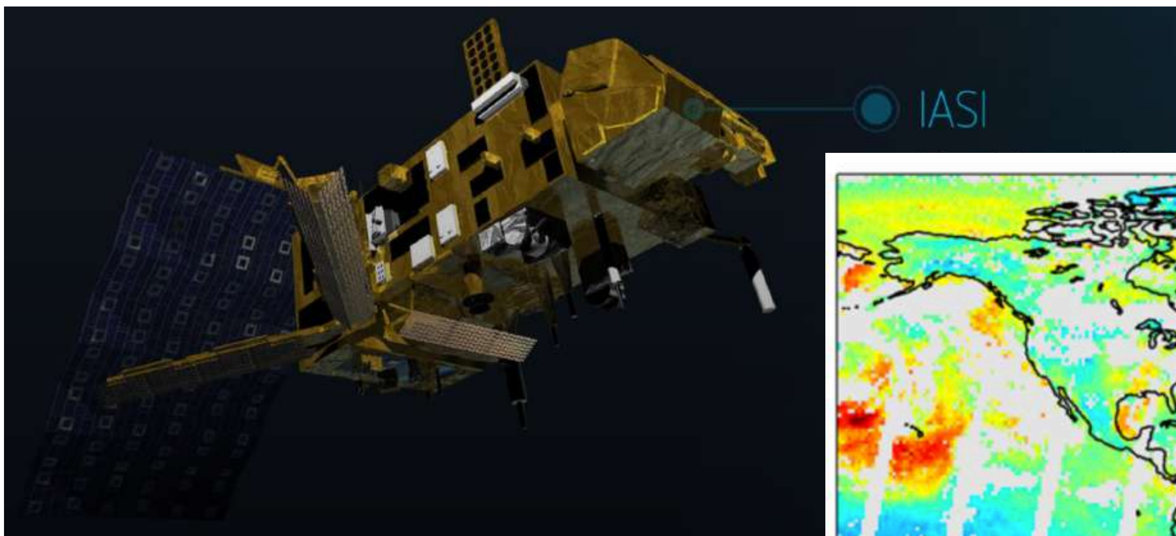
Sentinel-3 image on 10 September 2020 (ESA)



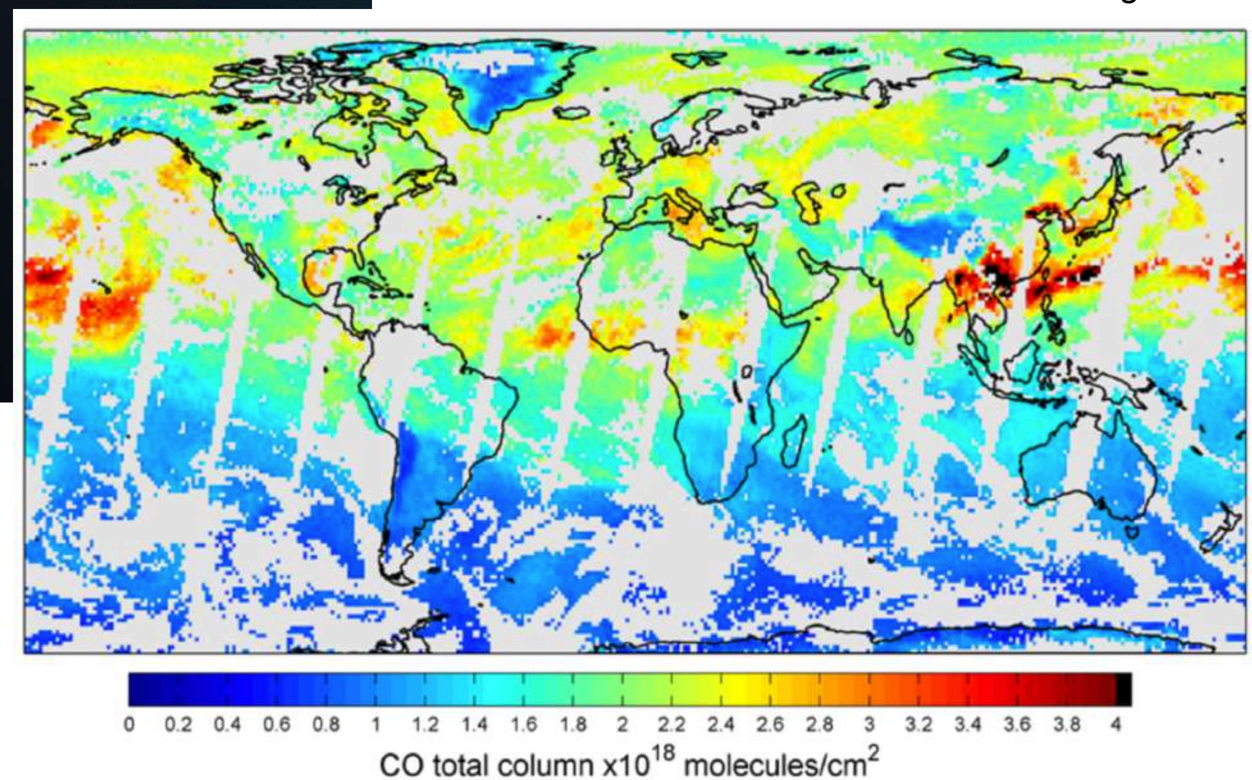
Satellite data

Carbon monoxide (CO) concentration

- CO observations are obtained from the Infrared Atmospheric Sounding Interferometer (IASI) on the Metop satellite [*George et al., 2015*]



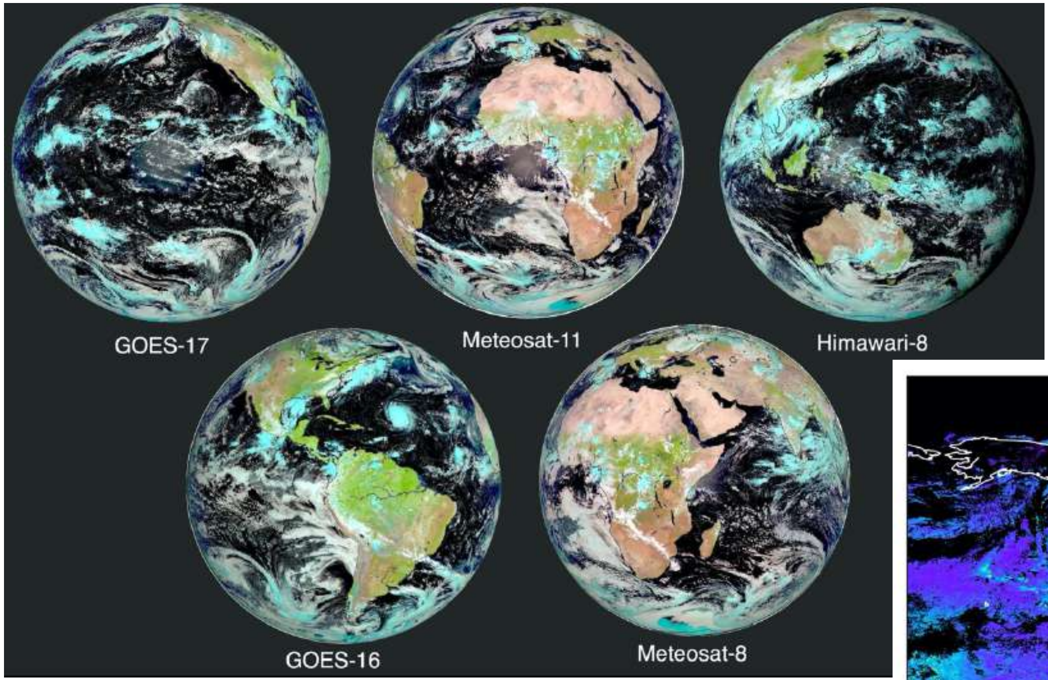
CO total column global distributions for 15 April 2013 (morning overpass) derived from IASI with the FORLI algorithm



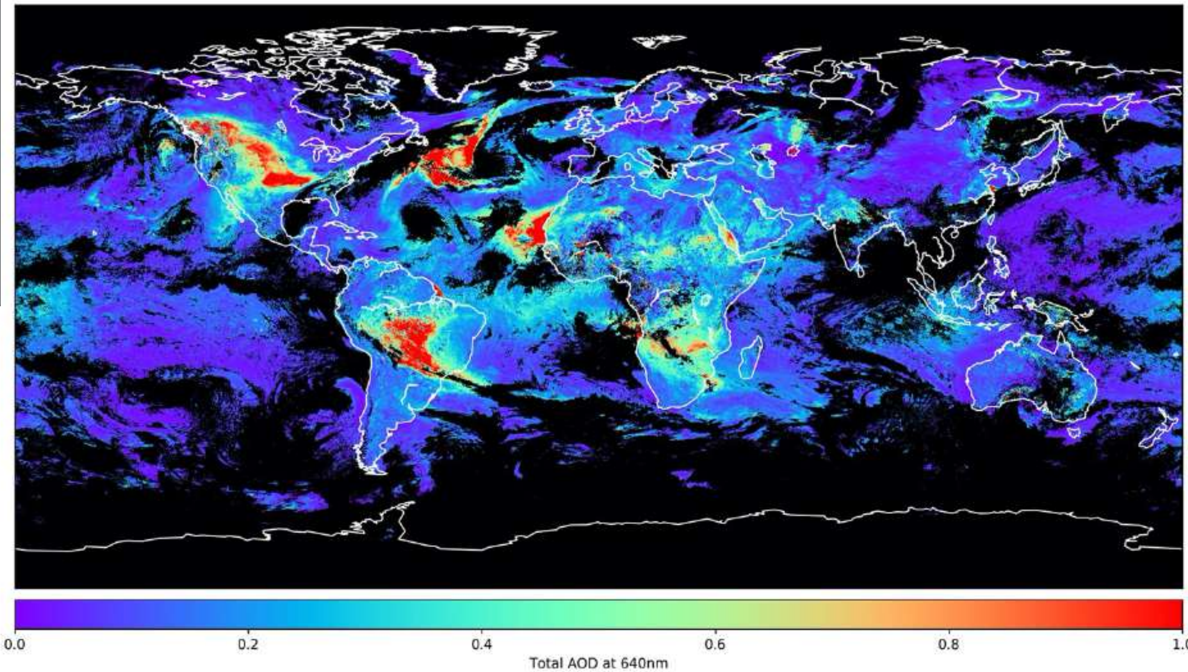
Satellite data

Aerosol optical depth (AOD)

- AOD observations are obtained from the GEO-ring, a constellation of five meteorological geostationary satellites [*Ceamanos et al., 2021*]



Color composites of spectral radiance measured by the GEO-ring at noon on 18 September 2020

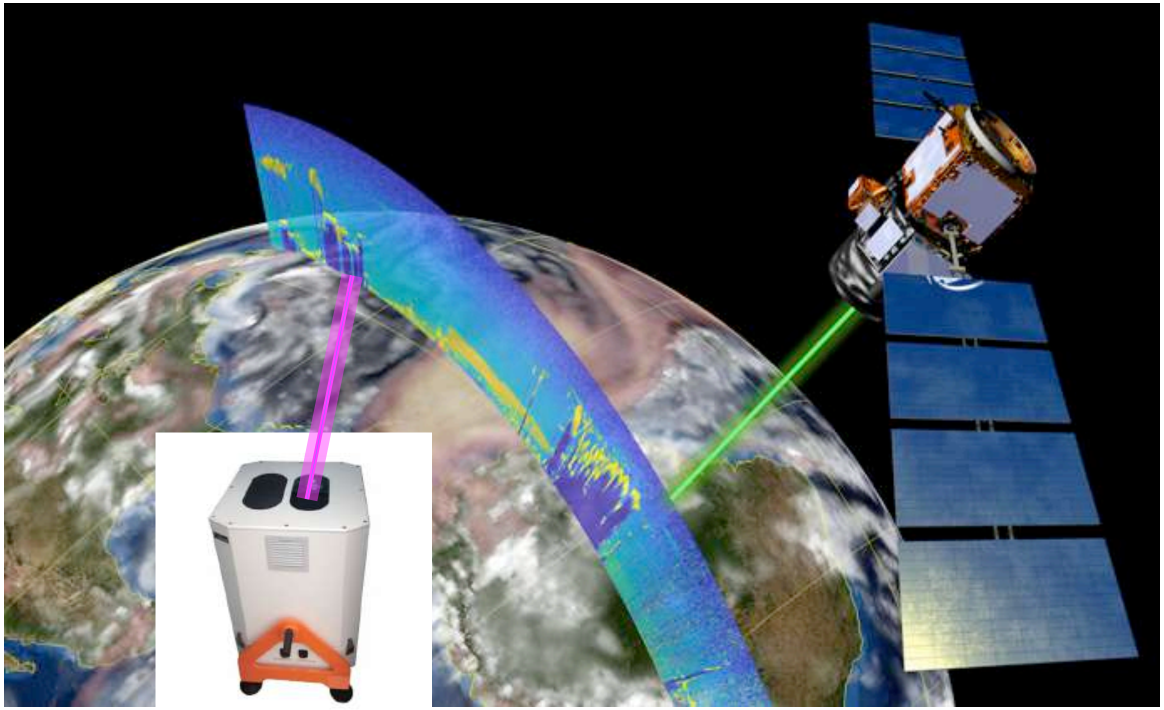


Quasi-global map of daily AOD at 0.64µm on 18 September 2020 obtained from the GEO-ring with the AERUS-GEO algorithm

Satellite data

Lidar vertical profiles

- Lidar observations are provided from the CALIOP/CALIPSO satellite mission [*Winker et al., 2009*] and ground-based systems



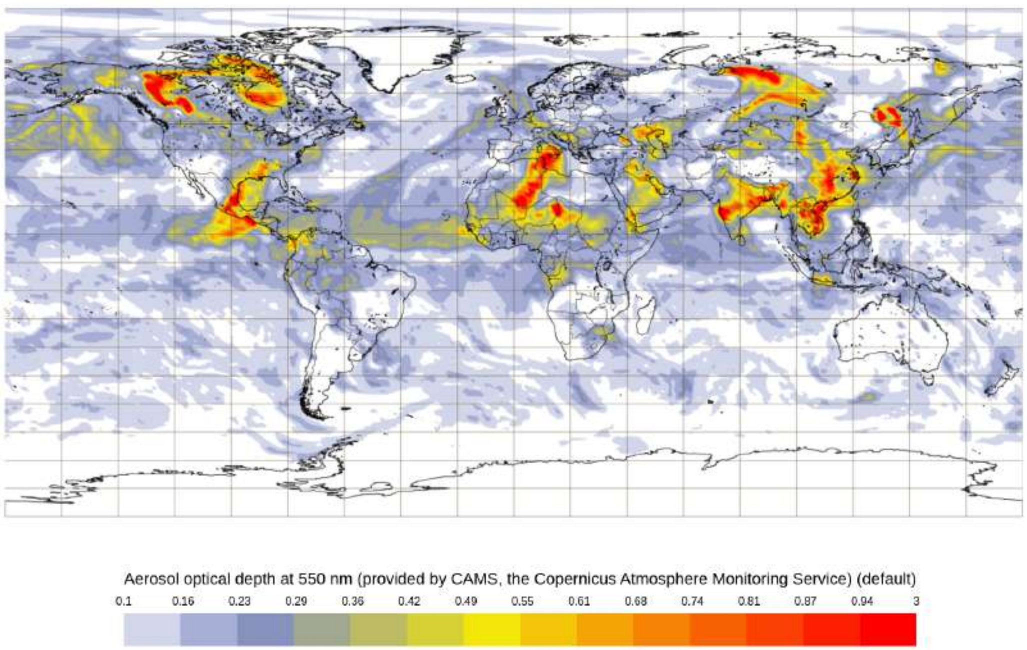
CALIOP observations of lidar backscatter (Credits: ECMWF/NASA)

Observations from micro LiDAR CE376 (Credits: CIMEL)

Model data

CO concentration and AOD

- Analyses of aerosols and carbon monoxide are provided by the CAMS operational system, which assimilates satellite observations of atmospheric composition



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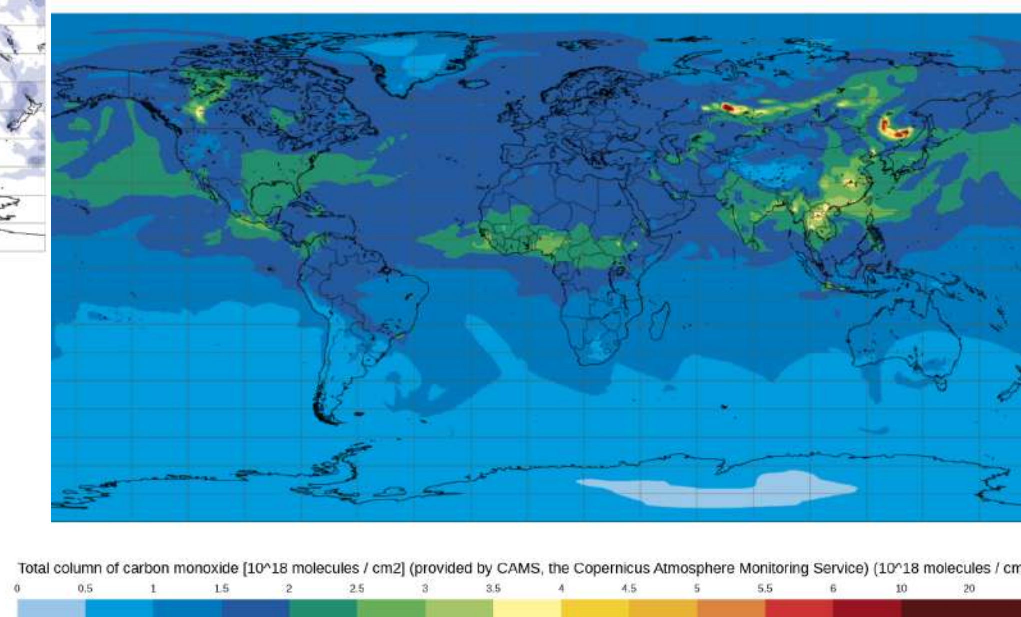
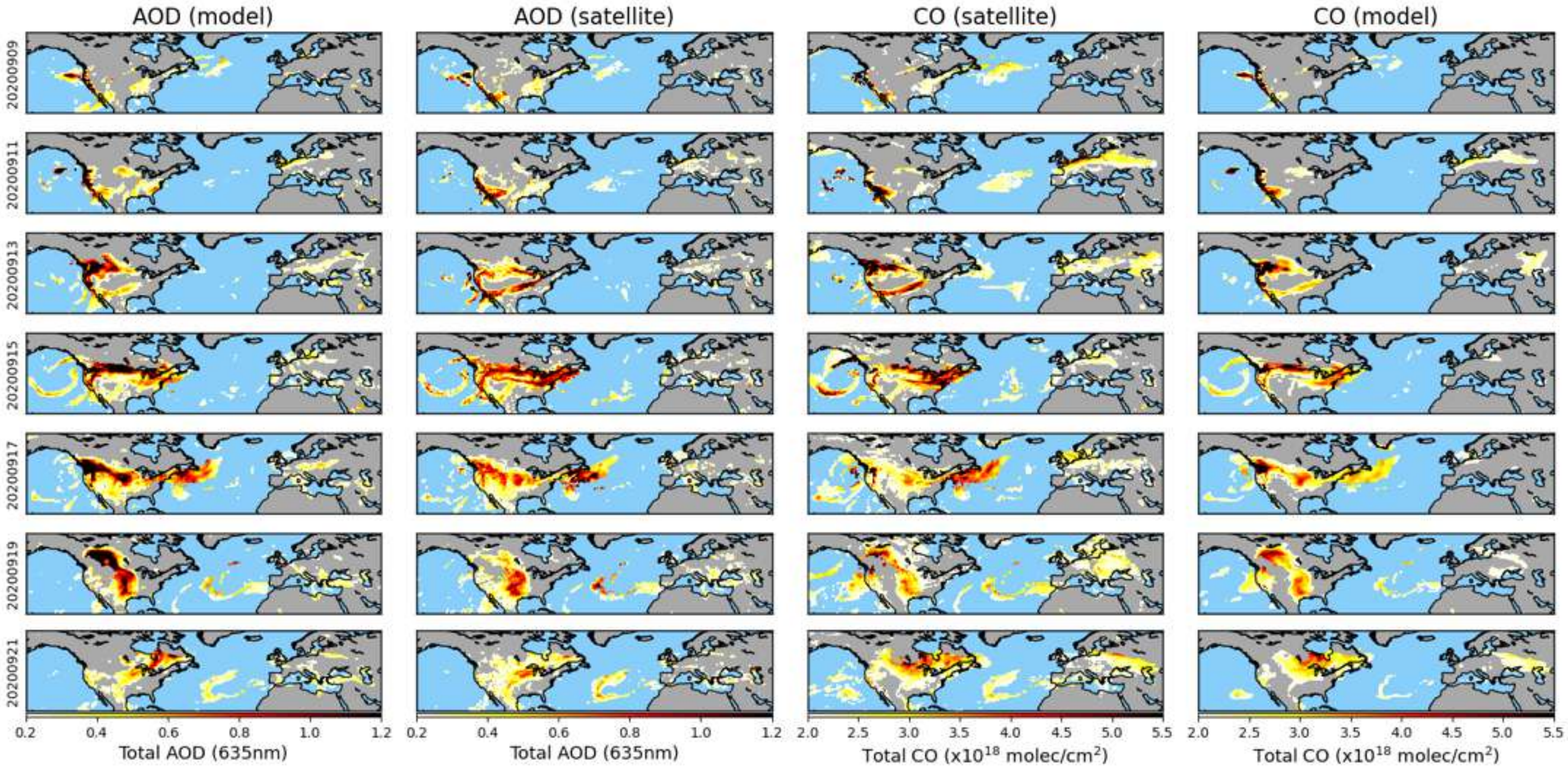


Monitoring smoke plumes

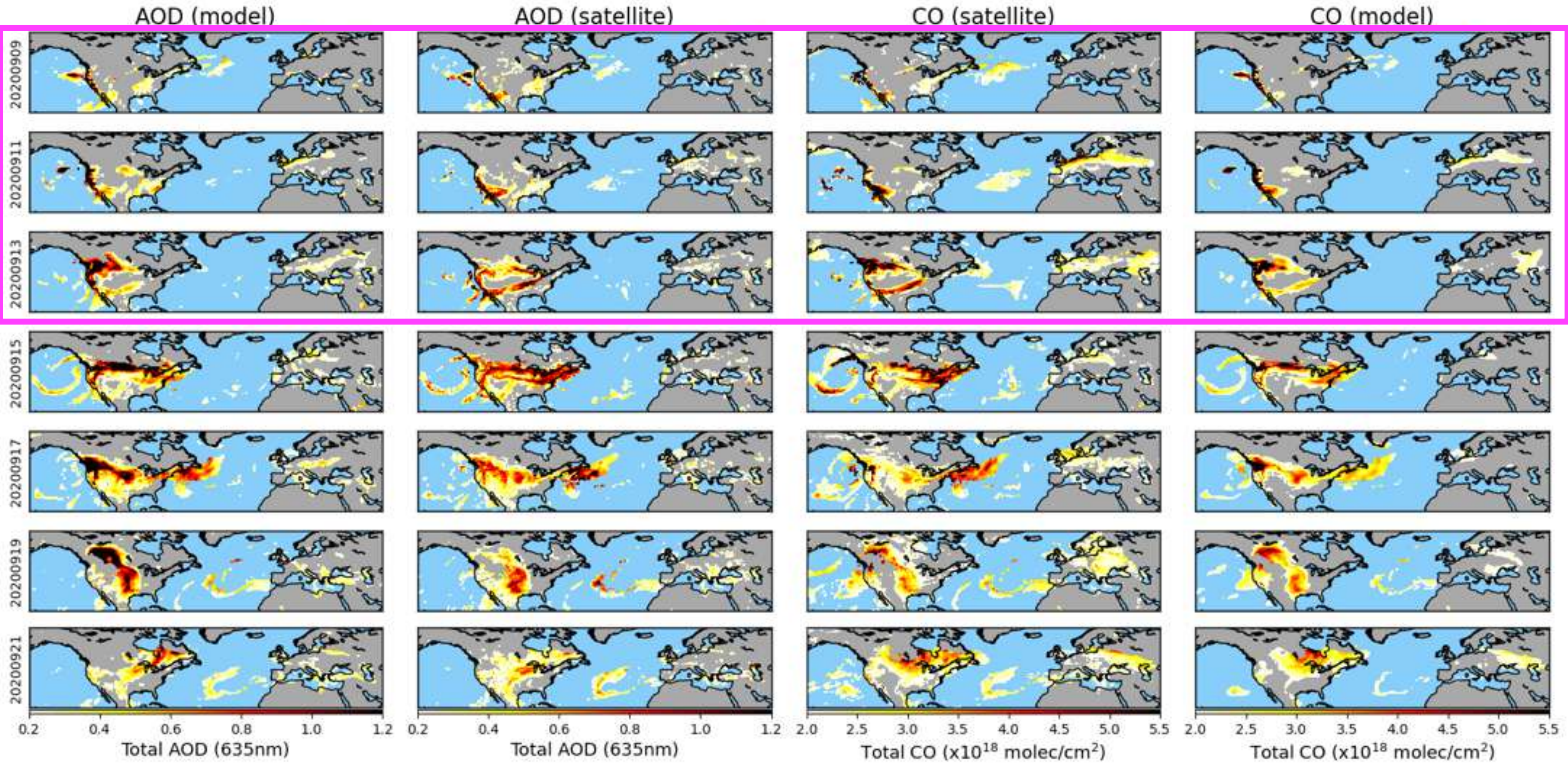
**AOD and CO are shown for values larger than 0.2 and 2 ×1018 molec/cm2, respectively, to highlight thick aerosol plumes only. Regions corresponding to heavy cloud cover and coarse aerosol particles were masked in the data preprocessing.*

Using satellite and model data



Monitoring smoke plumes

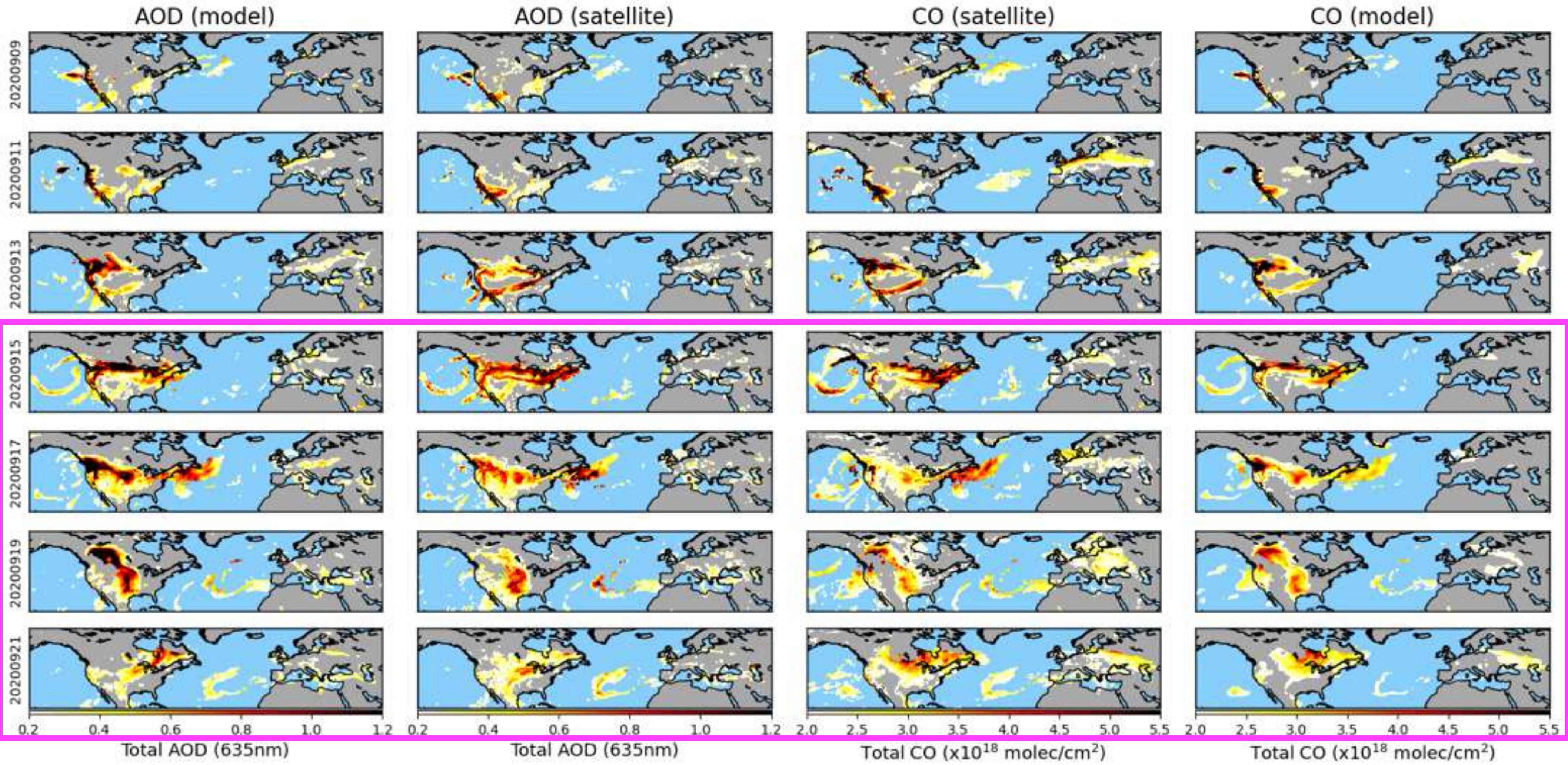
Using satellite and model data



Maximum smoke emission in Western US

Monitoring smoke plumes

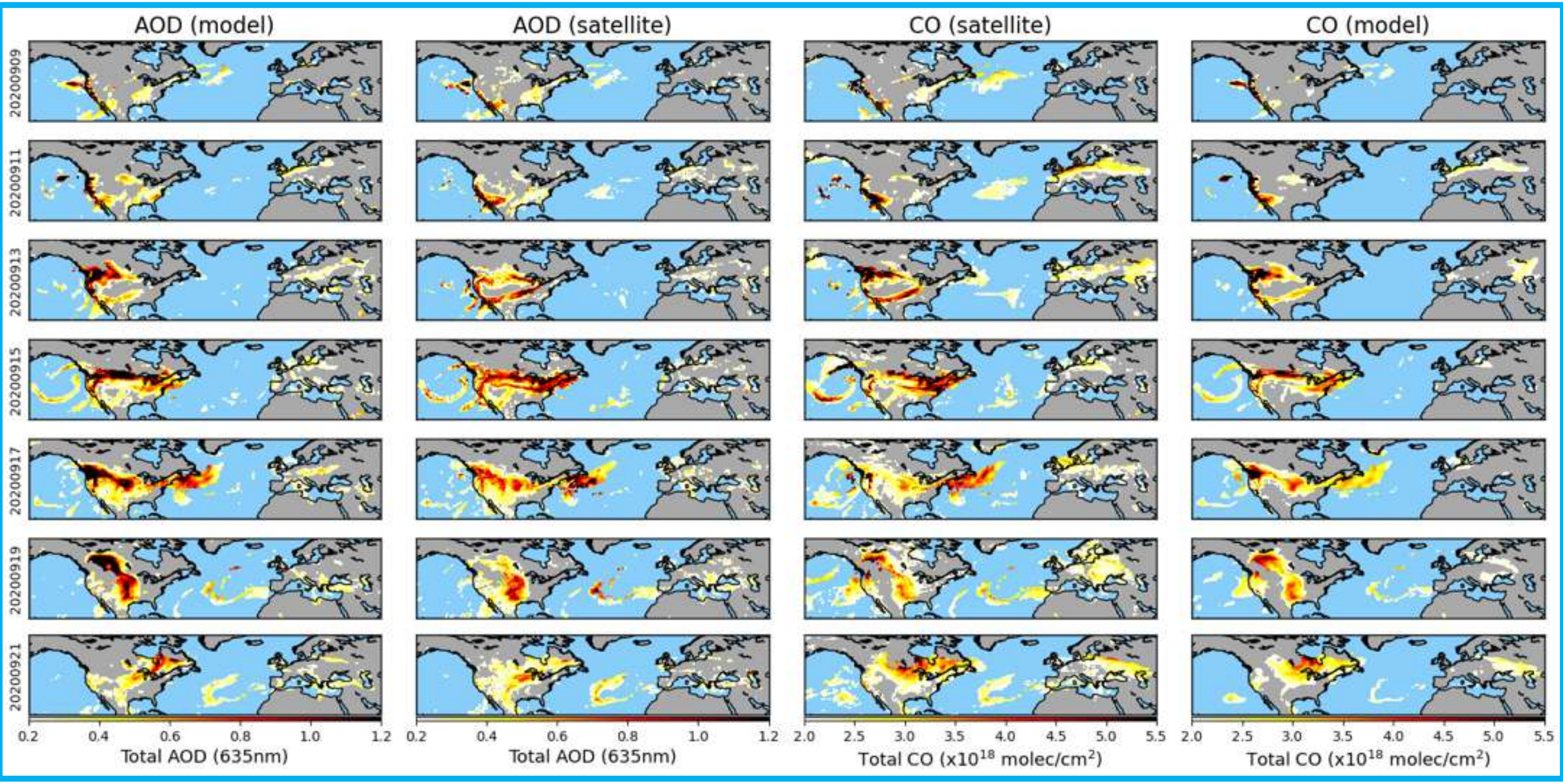
Using satellite and model data



Intense long-range transport of plumes across the Atlantic

Monitoring smoke plumes

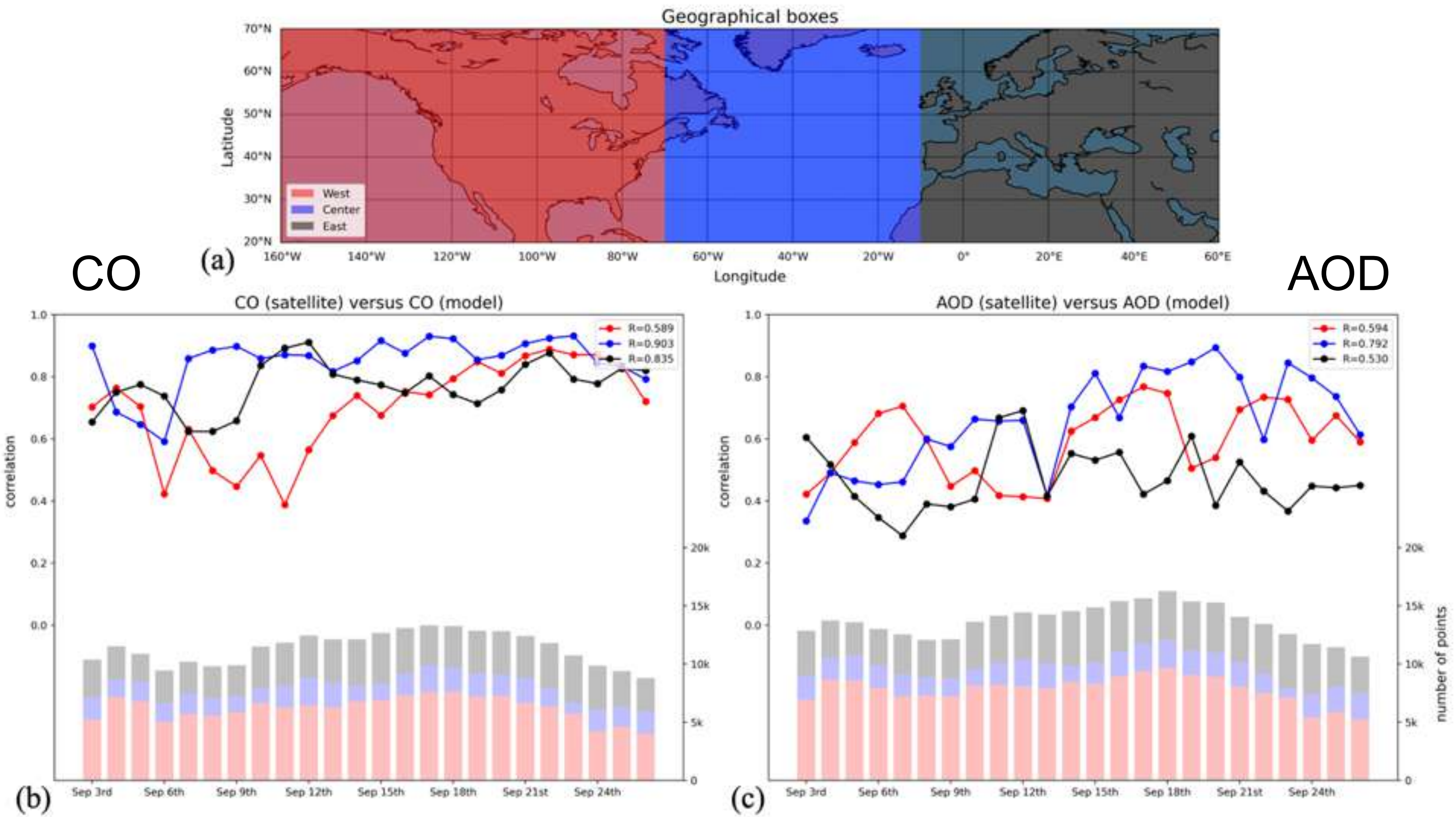
Using satellite and model data



Good agreement overall, despite some localized differences

Data assessment

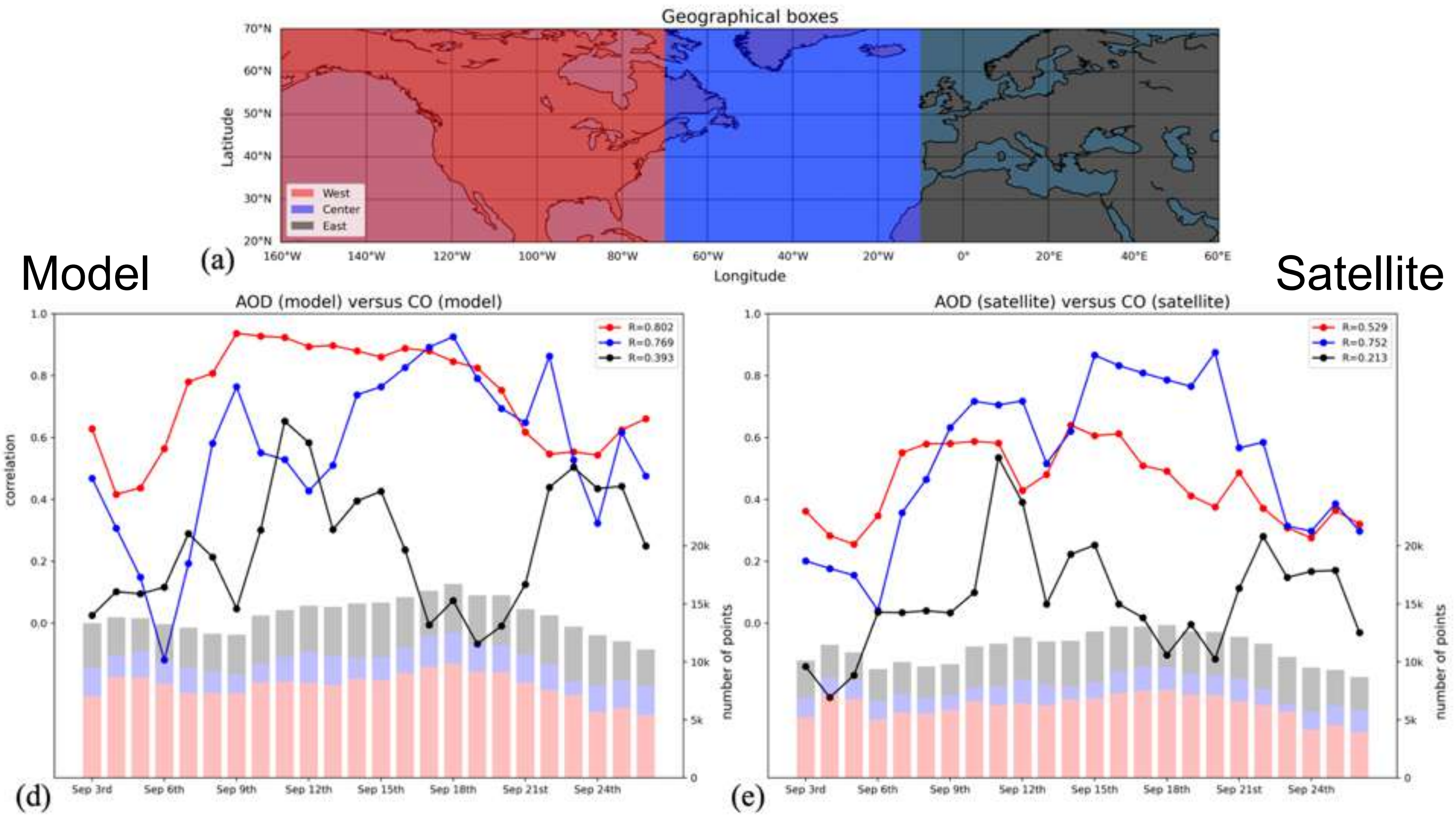
Satellite versus model



Good agreement in general, especially for CO, with lower correlation during intense emission

Data assessment

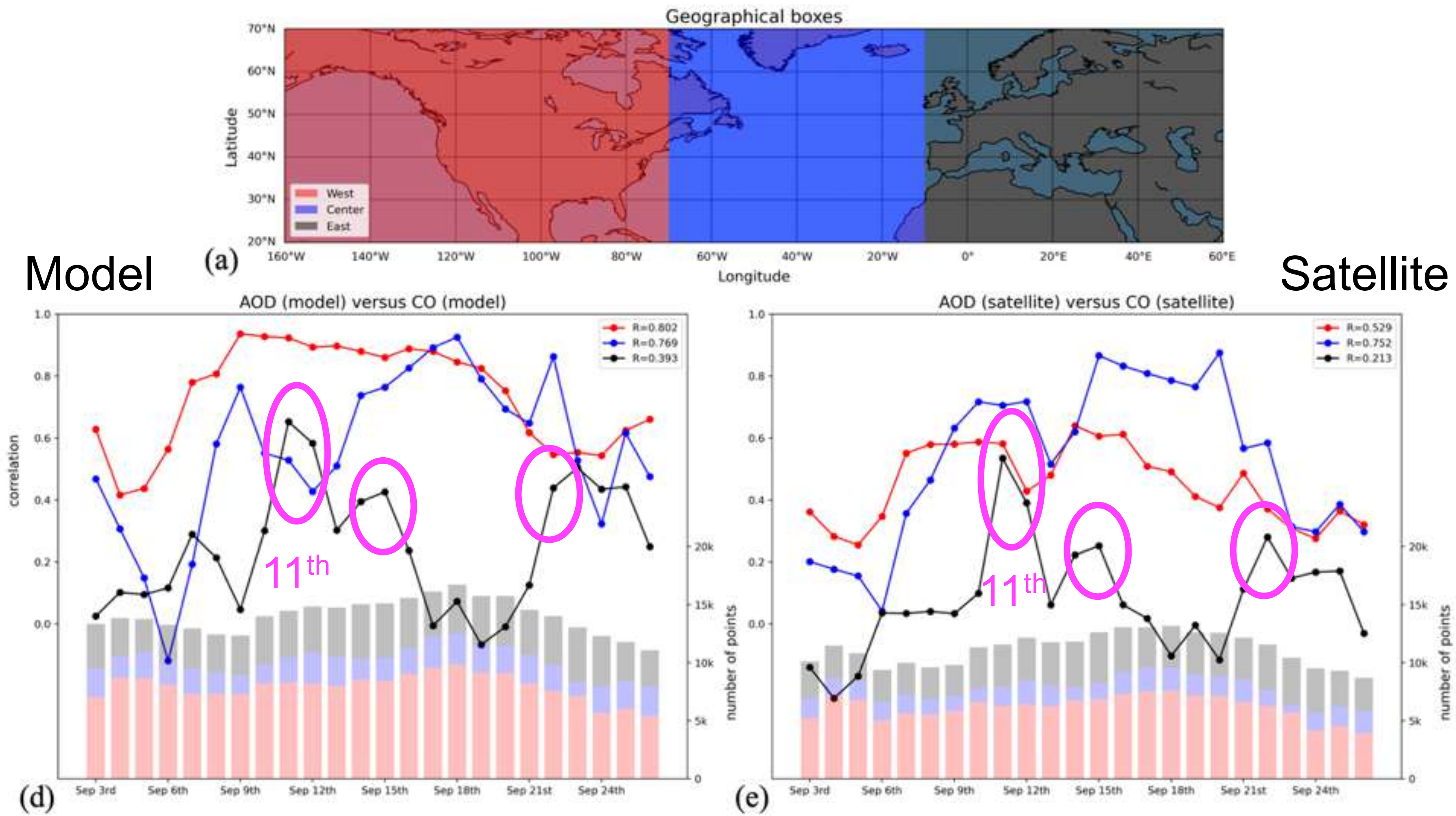
AOD versus CO



Generally decreasing AOD/CO correlation along the transport of smoke

Data assessment

AOD versus CO

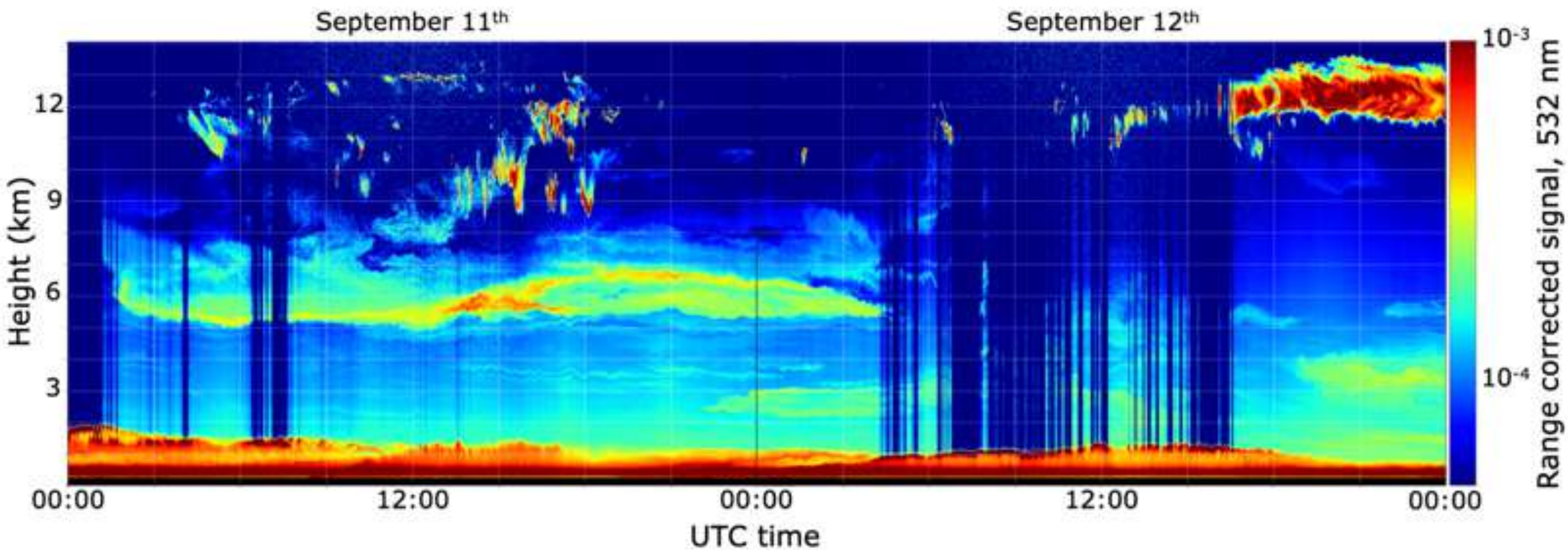


Arrival of biomass burning plumes to Europe?

Local detection of smoke plumes in Europe

Using ground-based lidar stations

Vertical profile of range-corrected lidar signal on 11 and 12 September 2020 from the ground-based METIS lidar over Villeneuve d'Ascq.

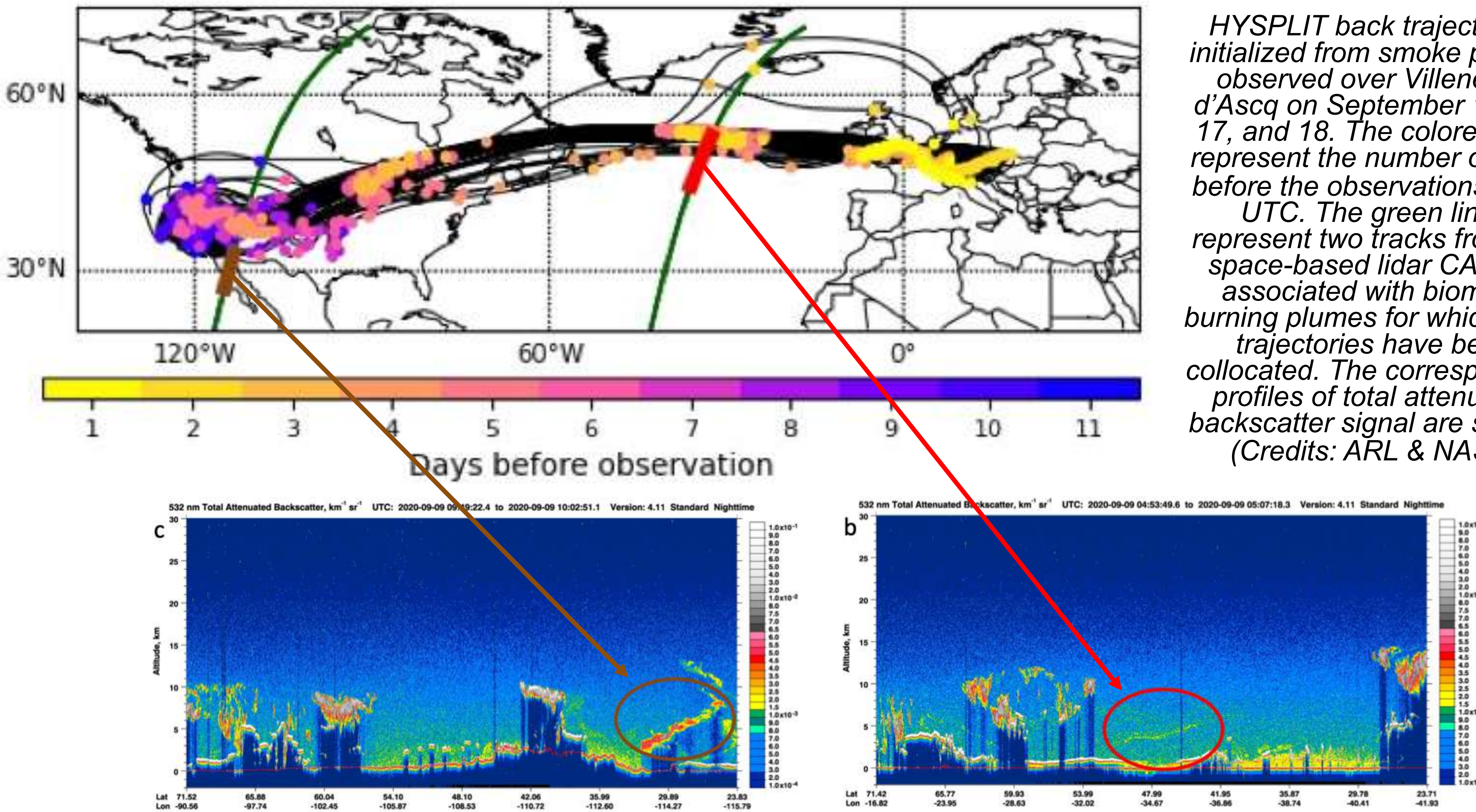


An aerosol layer extending between 5 and 7 km was measured on 11 September and remained visible on the 12.

Similar smoke plumes were detected on 14, 17, and 18 September

Local detection of smoke plumes in Europe

Analyzing air parcel back trajectories

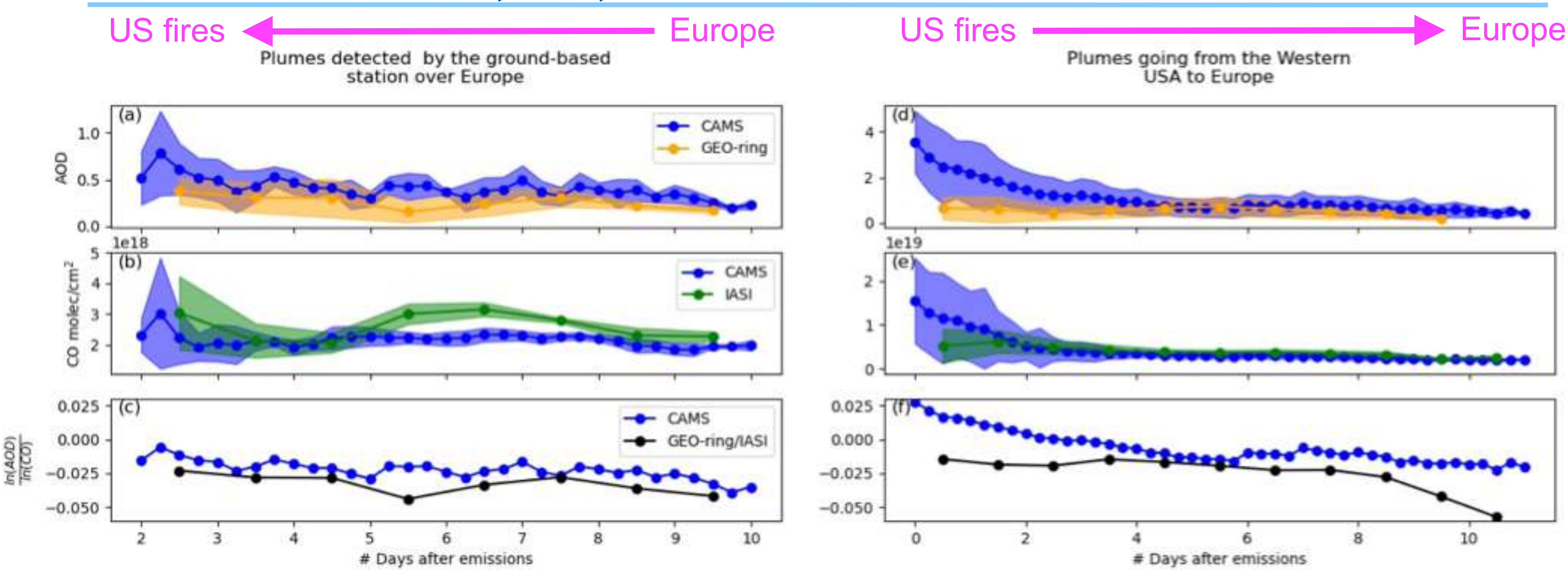


HYSPLIT back trajectories initialized from smoke plumes observed over Villeneuve d'Ascq on September 11, 14, 17, and 18. The colored dots represent the number of days before the observations at 12 UTC. The green lines represent two tracks from the space-based lidar CALIOP associated with biomass burning plumes for which back trajectories have been collocated. The corresponding profiles of total attenuated backscatter signal are shown. (Credits: ARL & NASA)

Confirmation that the plumes measured over Europe were originated in Western US

Analysis along back & forward trajectories

Evolution of AOD, CO, and AOD/CO



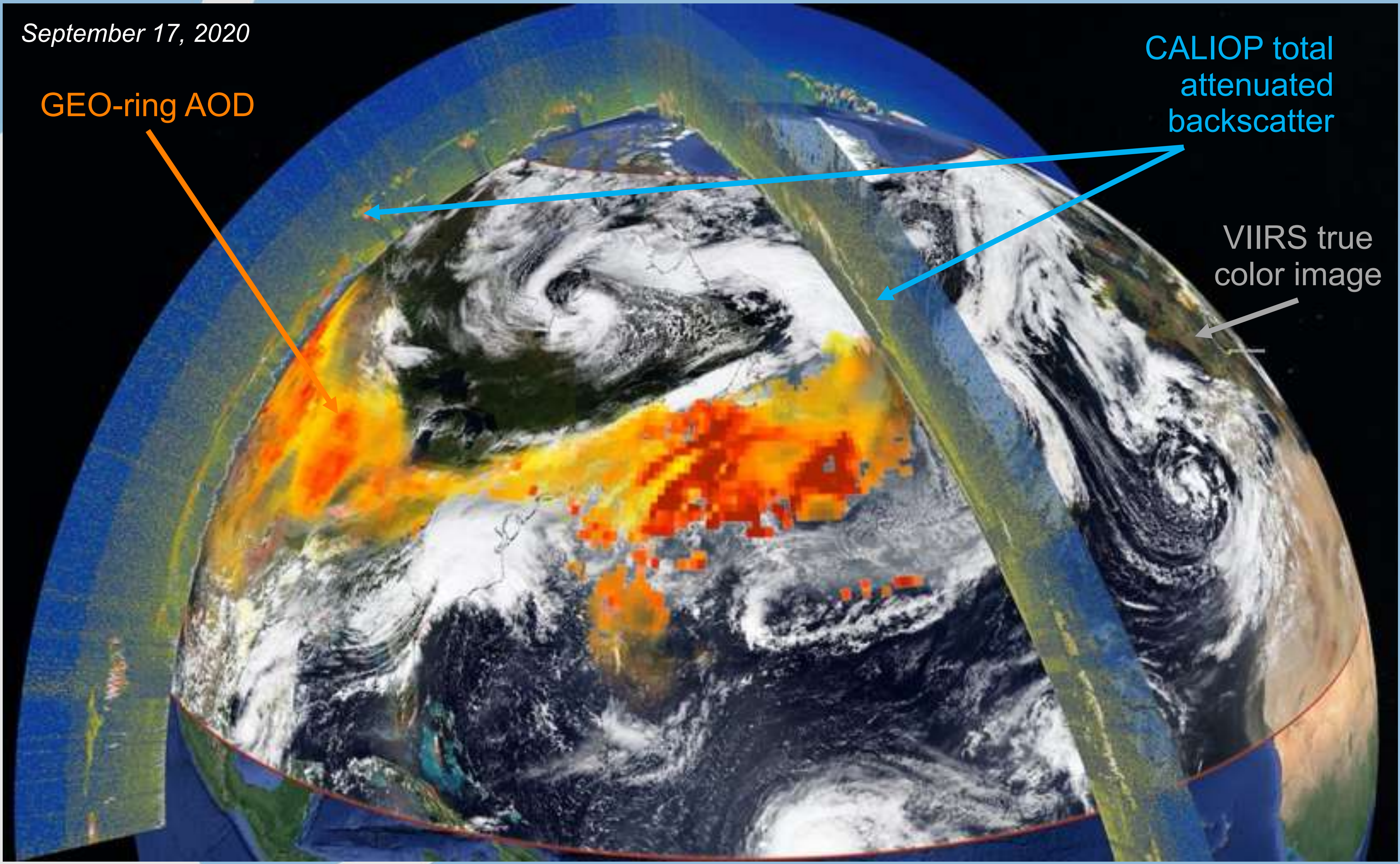
A consistent decrease in AOD and CO is observed, but also some differences mainly at the emission sources (especially for forward trajectories)

The variation of AOD/CO during the transport of smoke is smaller for plumes that are detected over Europe than for plumes that are potentially not, which may point to an aerosol removal process along transport (precipitation?)

Conclusions

Biomass burning aerosols are predicted to become the predominant source of fine particulate matter in many regions of the world

- Satellite & model data on AOD and CO are proved to be useful to monitor the transport of smoke plumes
- Good agreement between CAMS analyses and satellite observations, despite some differences at the emission sources mainly
- Assimilation of fire smoke satellite observations (e.g., from upcoming GEO missions) are expected to lead to improvements in forecasting
- Systematic analysis of AOD/CO observed by satellites and models could be used to infer information on precipitation and other aerosol removal processes along smoke transport



Thanks for your attention

xavier.ceamanos@meteo.fr