

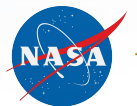
A31E-06:

Wildfire Emission Factor Uncertainty and Modeled Atmospheric CO and O₃

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Fire emissions impact air quality, weather and climate

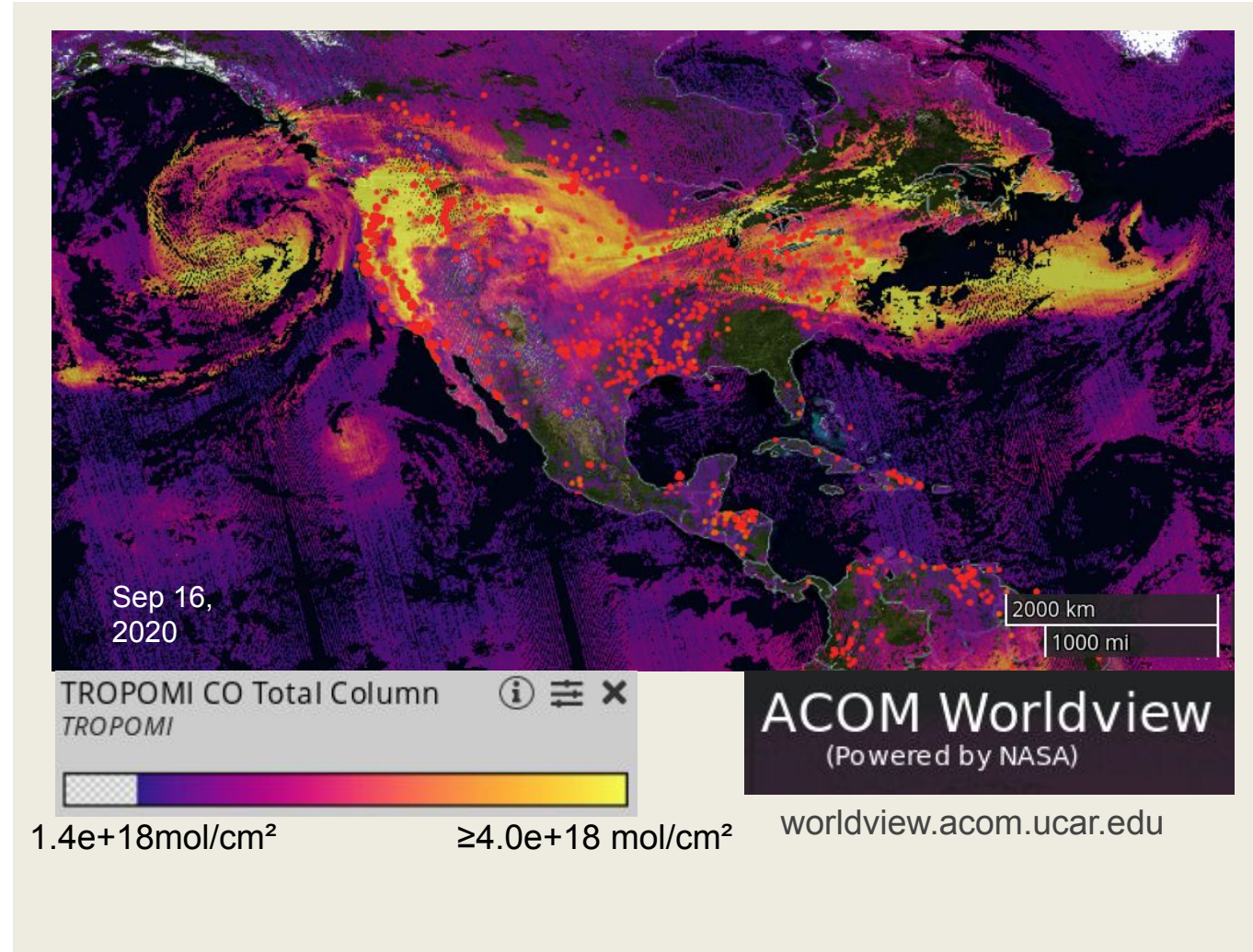
Trace gases and aerosols emitted from fires degrade air quality:
tropospheric ozone (O_3), $PM_{2.5}$

Fire aerosols change weather properties:
clouds, precipitation

Two-way climate feedback

Large differences have been found
between global inventories of emissions

- **Quantify the role of uncertainty
in fire emission factors**



Creating global fire emissions

Method 1



Burned area

x

Biomass loading and fraction burned

CMIP6 a.k.a GFED **FINN** (active fire)



Fuel consumption
(kg C burned)

x

Biome-specific
Emission Factors
kg/kgC

Determined from field and laboratory studies
(e.g. [1] Akagi et al. 2011)

Emissions
(2014)

Method 2



Fire radiative power (FRP)

x

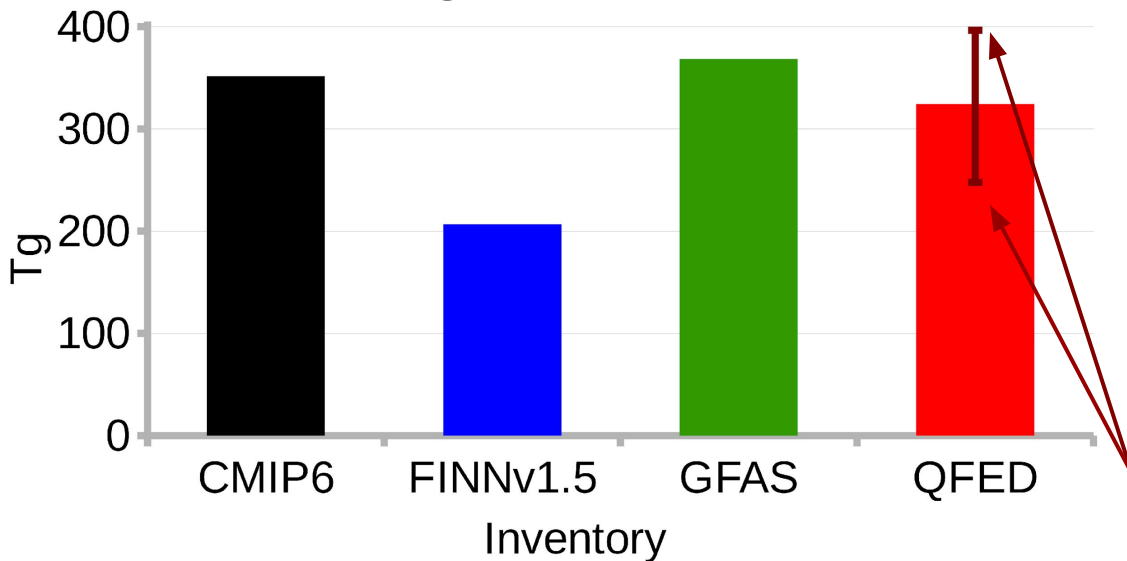
Biome-specific conversion factors

GFAS **QFED**



Comparing carbon monoxide (CO) emissions globally, 2014

Global Tg CO emissions in 2014



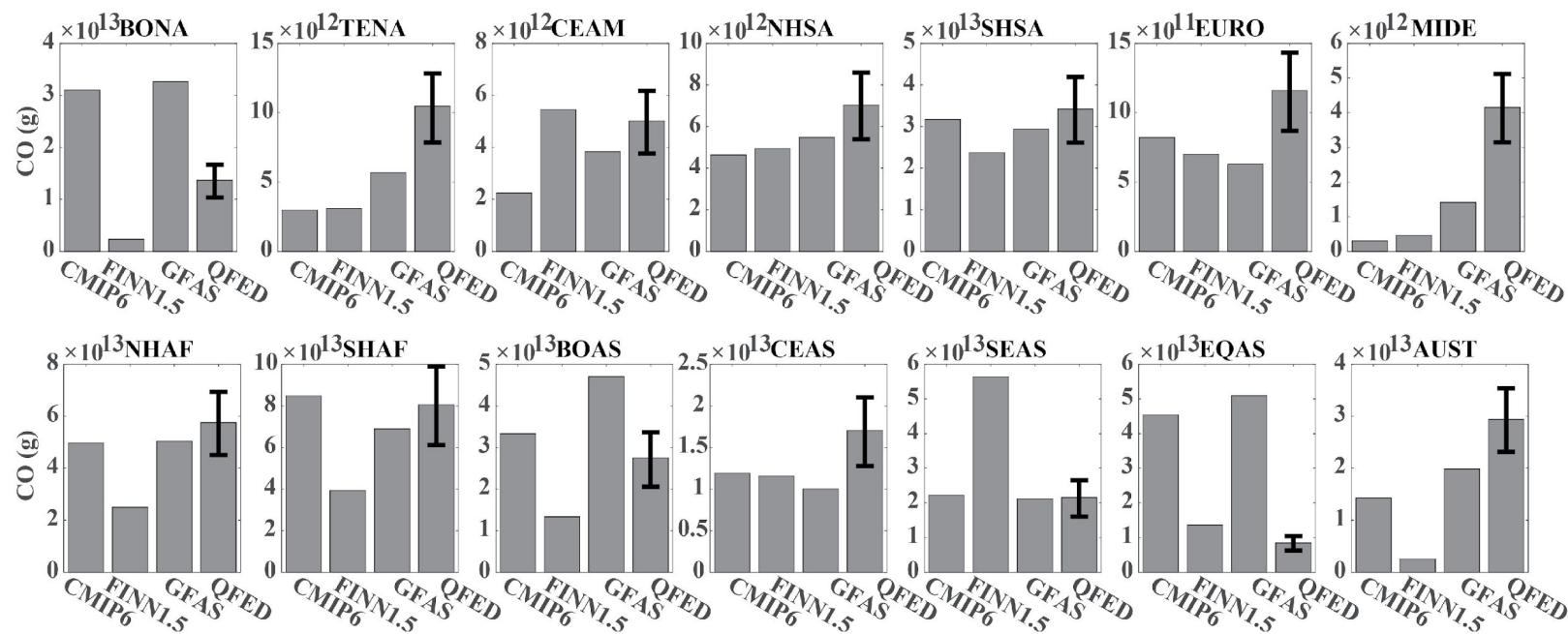
CO from four inventories:

- **CMIP6 v1.2** - Coupled Model Intercomparison Project (based on GFED4s)[2]
- **FINN v1.5** - Fire INventory from NCAR [3]
- **GFAS v1.2** - Global Fire Assimilation System (ECMWF-CAMS) [4,5]
- **QFED v2.5** - Quick Fire Emissions Dataset (NASA/NCAR hybrid)[6]

CO emission factor uncertainties are used to create minimum and maximum emissions for the QFED inventory

- 6 simulations of CO-only changes

CO emissions in different regions



2014 emissions in the 14 GFED regions

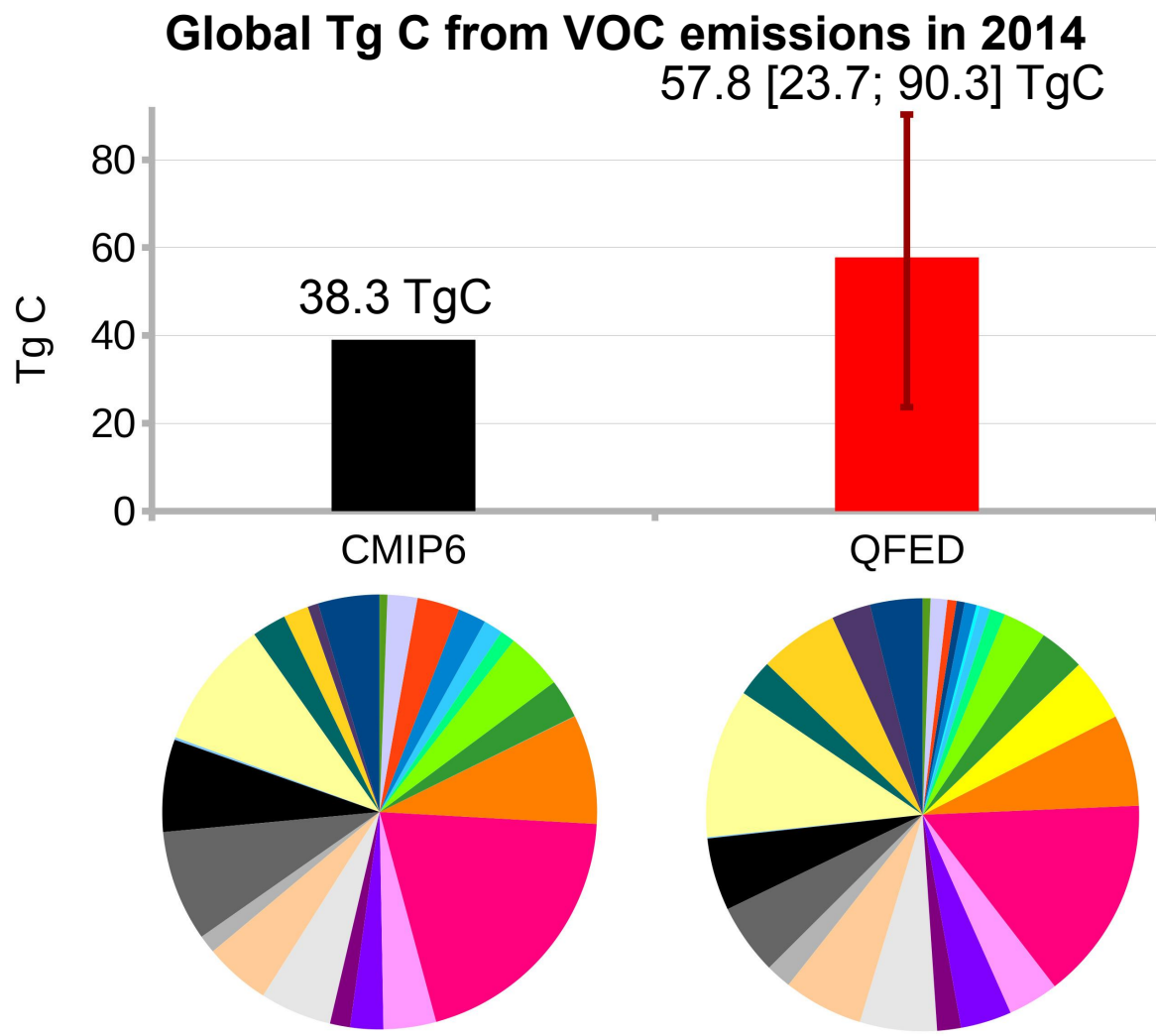
([7] Giglio et al., 2006)

Different regions → different inventories have the highest fire CO emissions

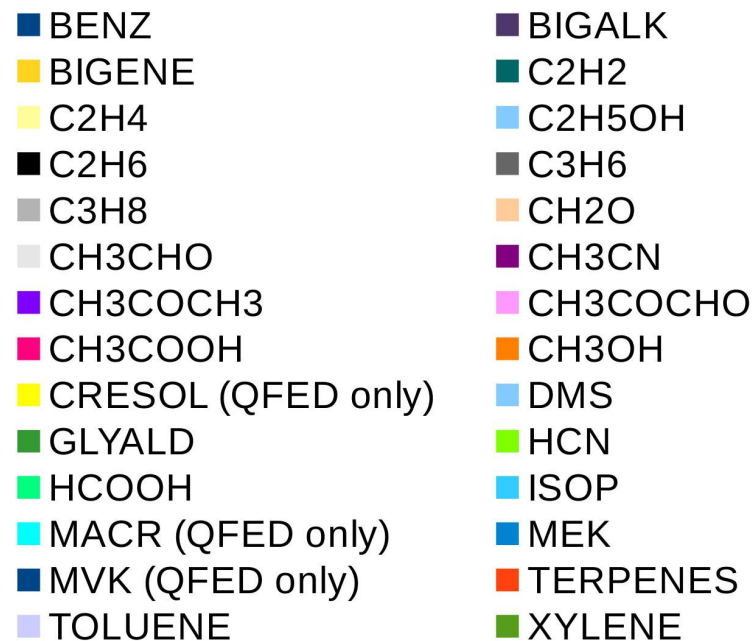


[W. Tang]

Volatile organic compounds (VOC) global emissions, 2014



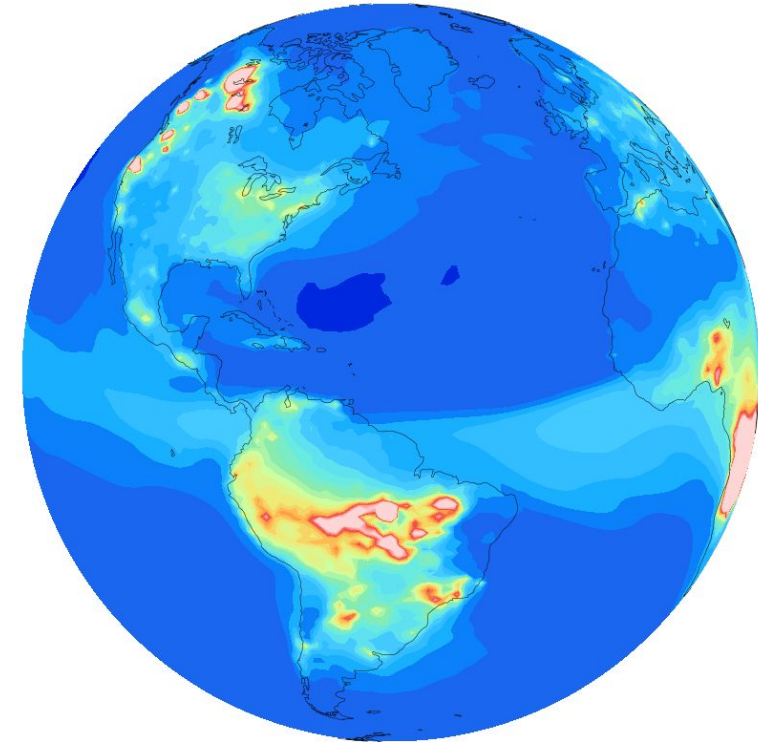
- Species co-emitted with CO will impact the atmospheric oxidation capacity
- All QFED emissions, plus their respective emission factor uncertainties (all + or all -)
- 3 extra simulations



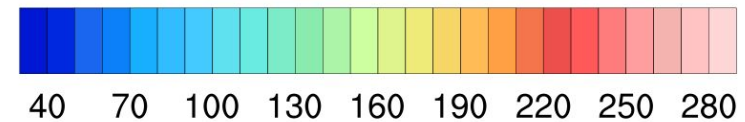
Exploring chemistry using a global model

CAM-chem surface CO, August 2014

- CESM2.0 full chemistry
- $0.92^\circ \times 1.25^\circ$ horizontal resolution
- 32 level vertical resolution
- T1 Chemistry ([8] Emmons et al., 2020)
- Specified dynamics: MERRA2 nudged at 1%
- Emissions:
 - Biogenic - MEGAN coupled to CLM
 - Anthropogenic - CMIP6
 - Fire - sensitivity studies, mainly look at QFED



CO (ppb)

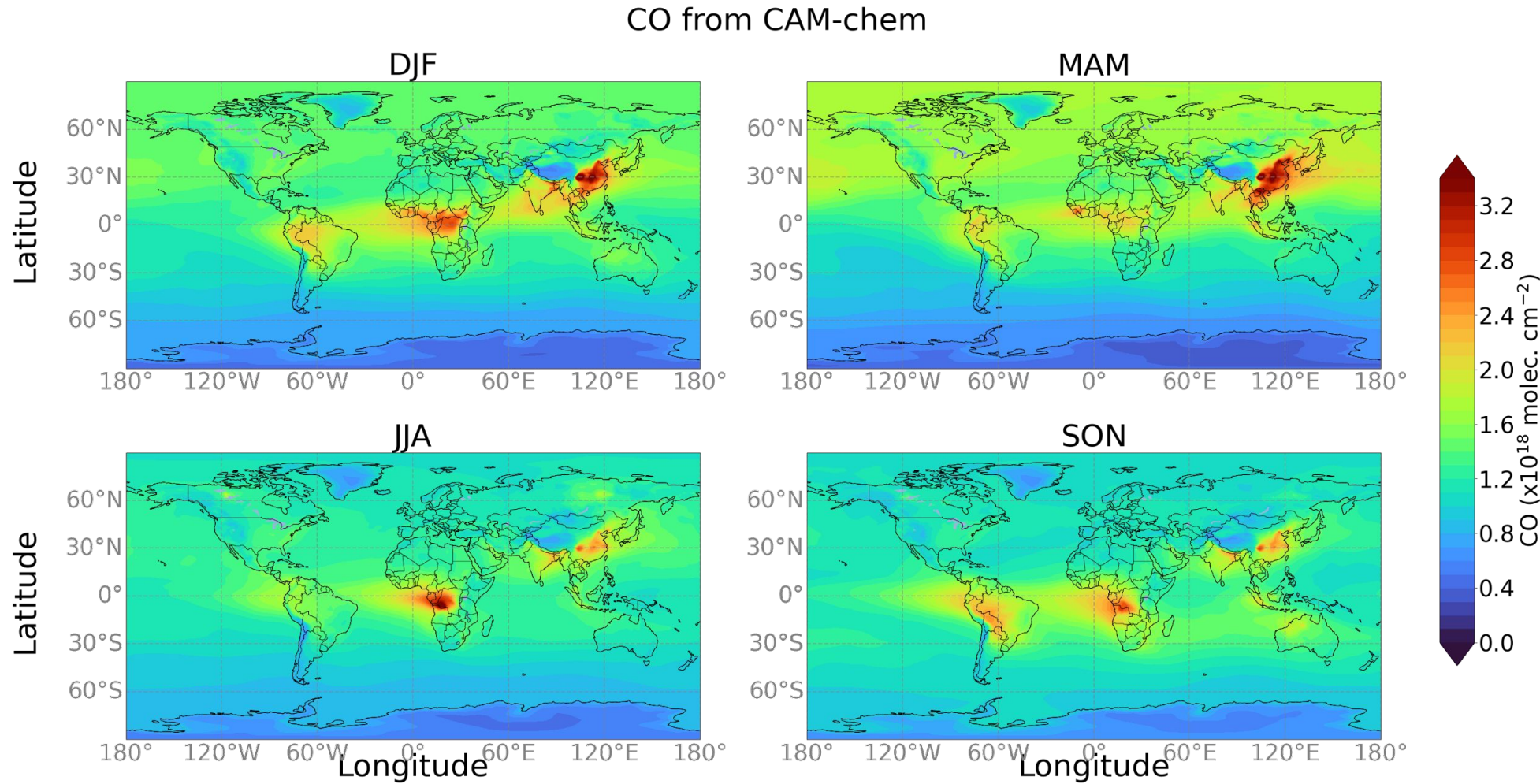


High-performance computing support from Cheyenne ([doi:10.5065/D6RX99HX](https://doi.org/10.5065/D6RX99HX)) provided by NCAR's Computational and Information Systems Laboratory, sponsored by the National Science Foundation.

Simulated column CO seasonal averages: using QFED emissions

CO is produced by incomplete combustion

Large amounts of column CO over regions dominated by fire emissions or large sources of anthropogenic emissions

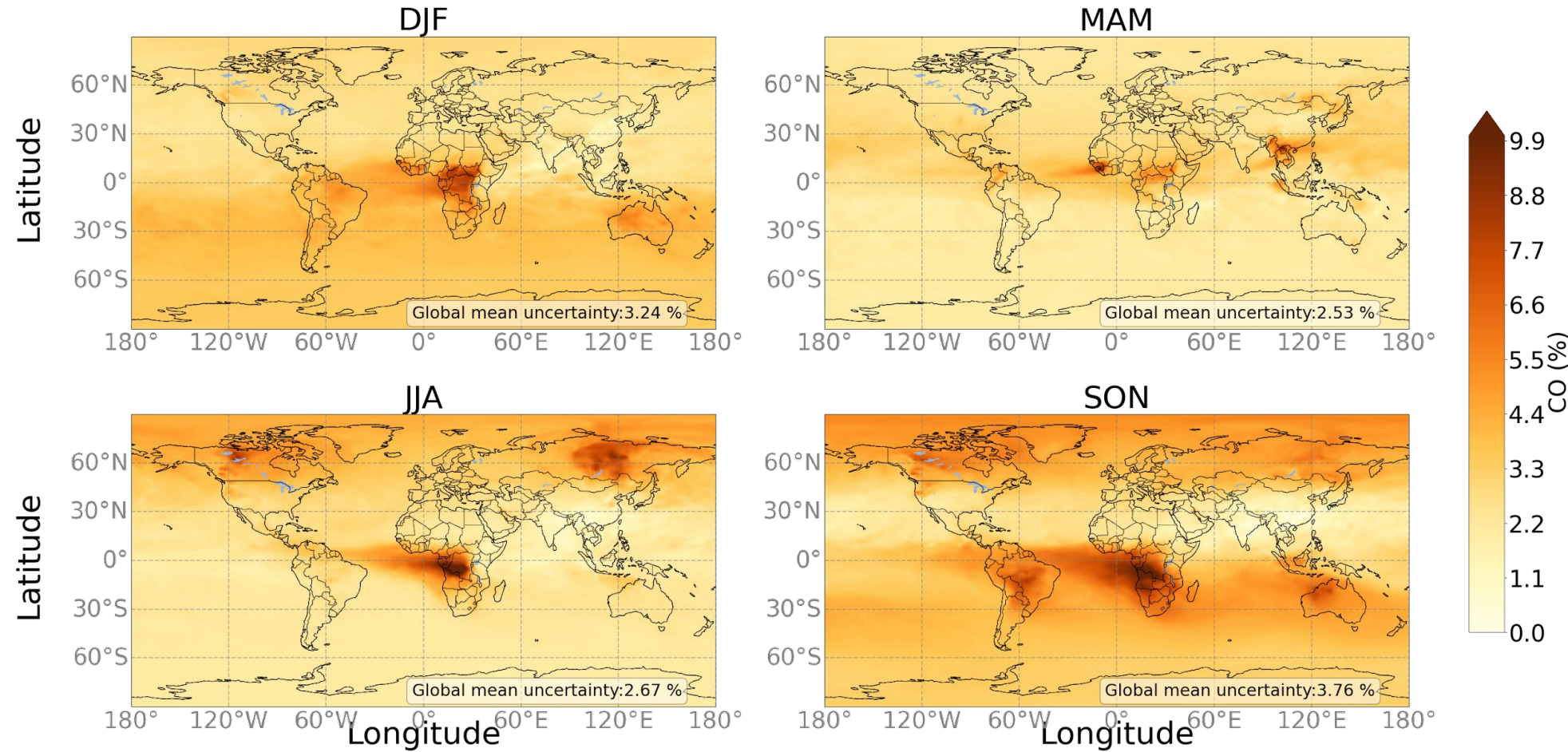


Seasonal uncertainty in column CO

Only including
uncertainty in CO
fire emission
factors

Global:
CO E.F. uncert: 3.1%

CO from CAM-chem

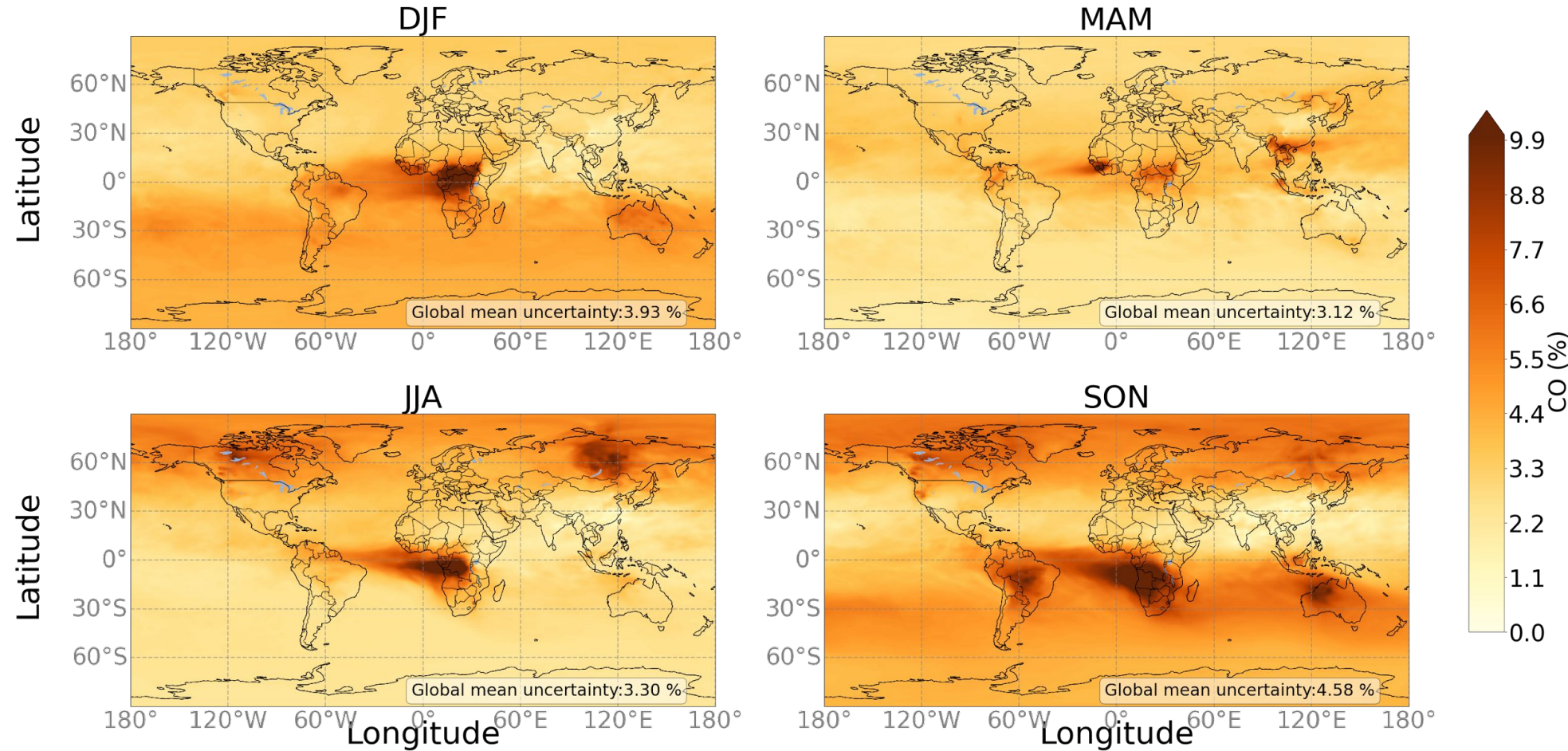


Seasonal uncertainty in column CO

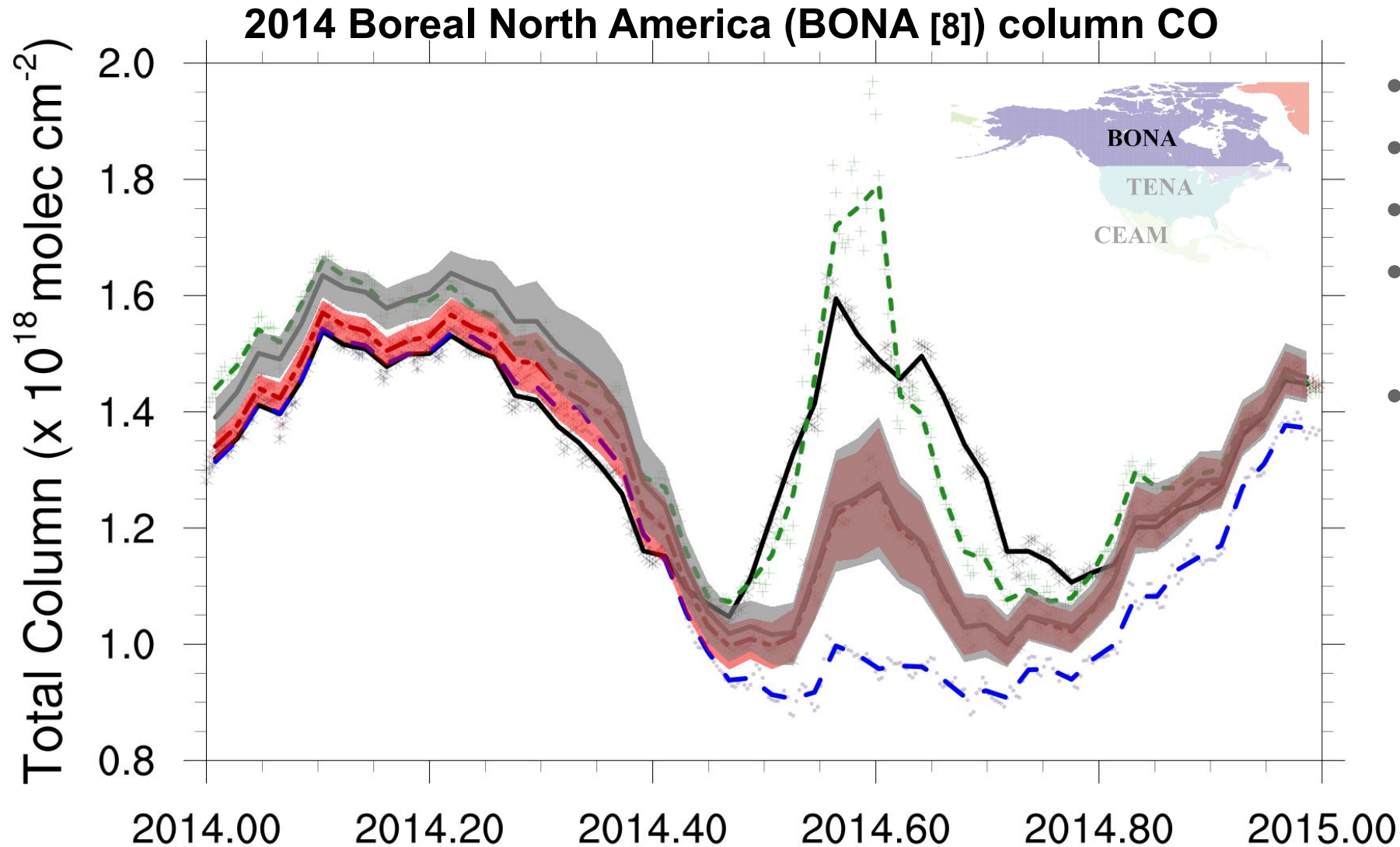
Including
uncertainty in all
fire emission
factors

Global:
CO E.F. uncert: 3.1%
All E.F. uncert: 3.7%

CO from CAM-chem



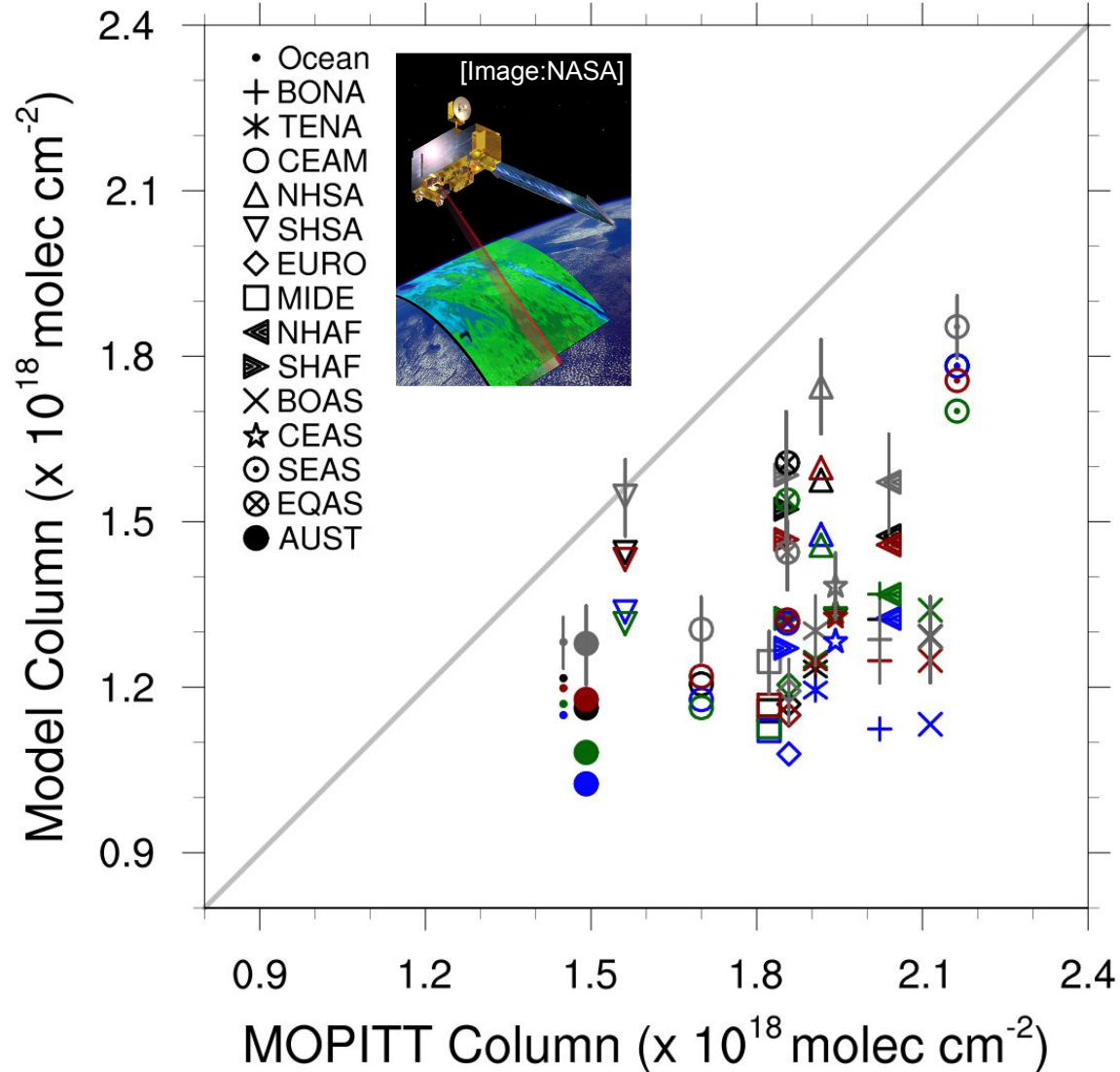
Temporal evolution of uncertainty



- **CMIP6 v1.2**
- **FINN v1.5**
- **GFAS v1.2**
- **QFED v2.5**
+/- CO uncert
- **QFED v2.5**
+/- all uncert

Outside the fire season, emission factor uncertainty bounds inventory differences.

Regional annual CO comparisons with Terra/MOPITT



Model
underestimates
measurements

Regional
differences

- **CMIP6 v1.2**
- **FINN v1.5**
- **GFAS v1.2**
- **QFED v2.5**
- **+/- CO uncert**
- **QFED v2.5**
- **+/- all uncert**

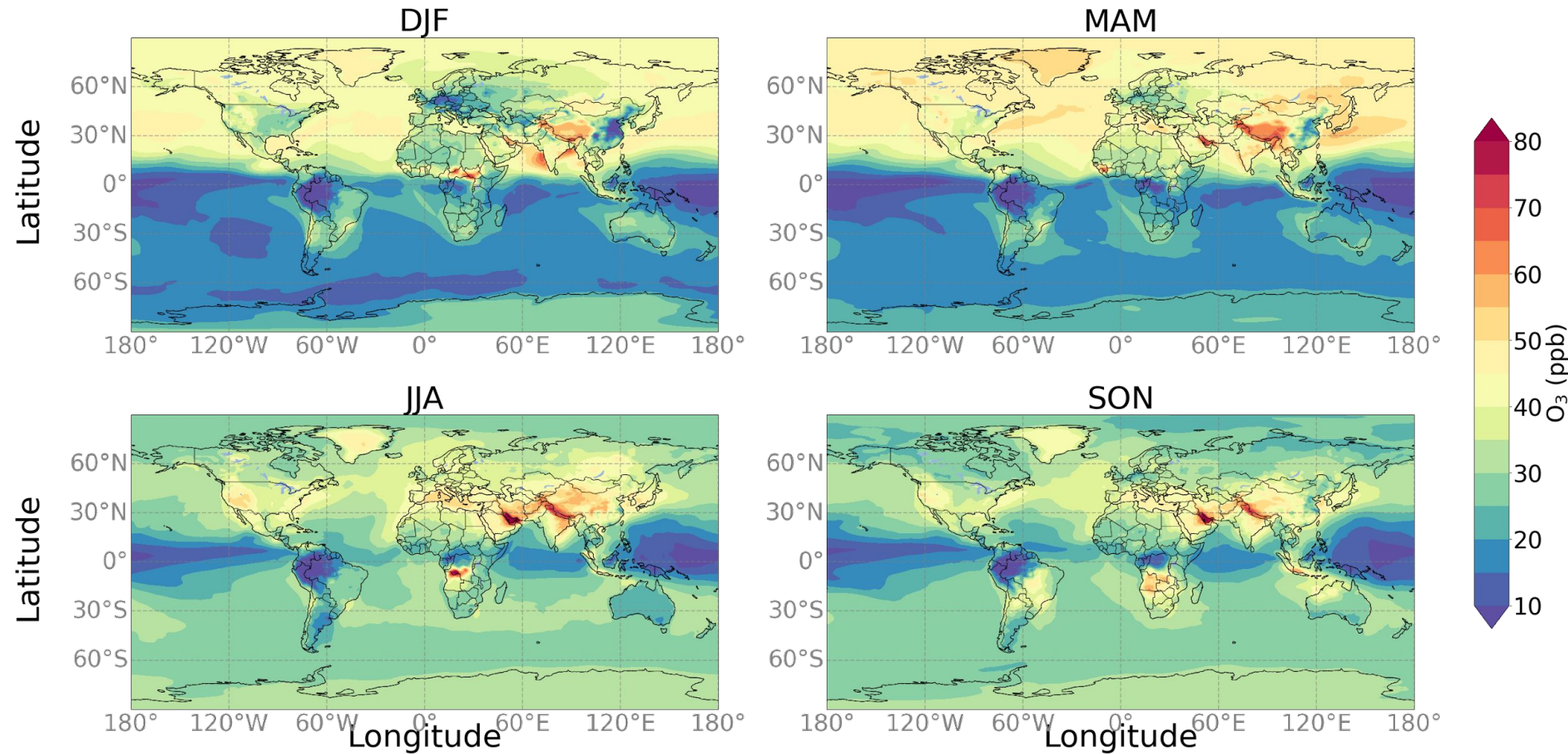


Surface layer ozone (O_3) from simulations with QFED

O_3 is created photochemically

Relationship to emissions is complex

Surface O_3 from CAM-chem

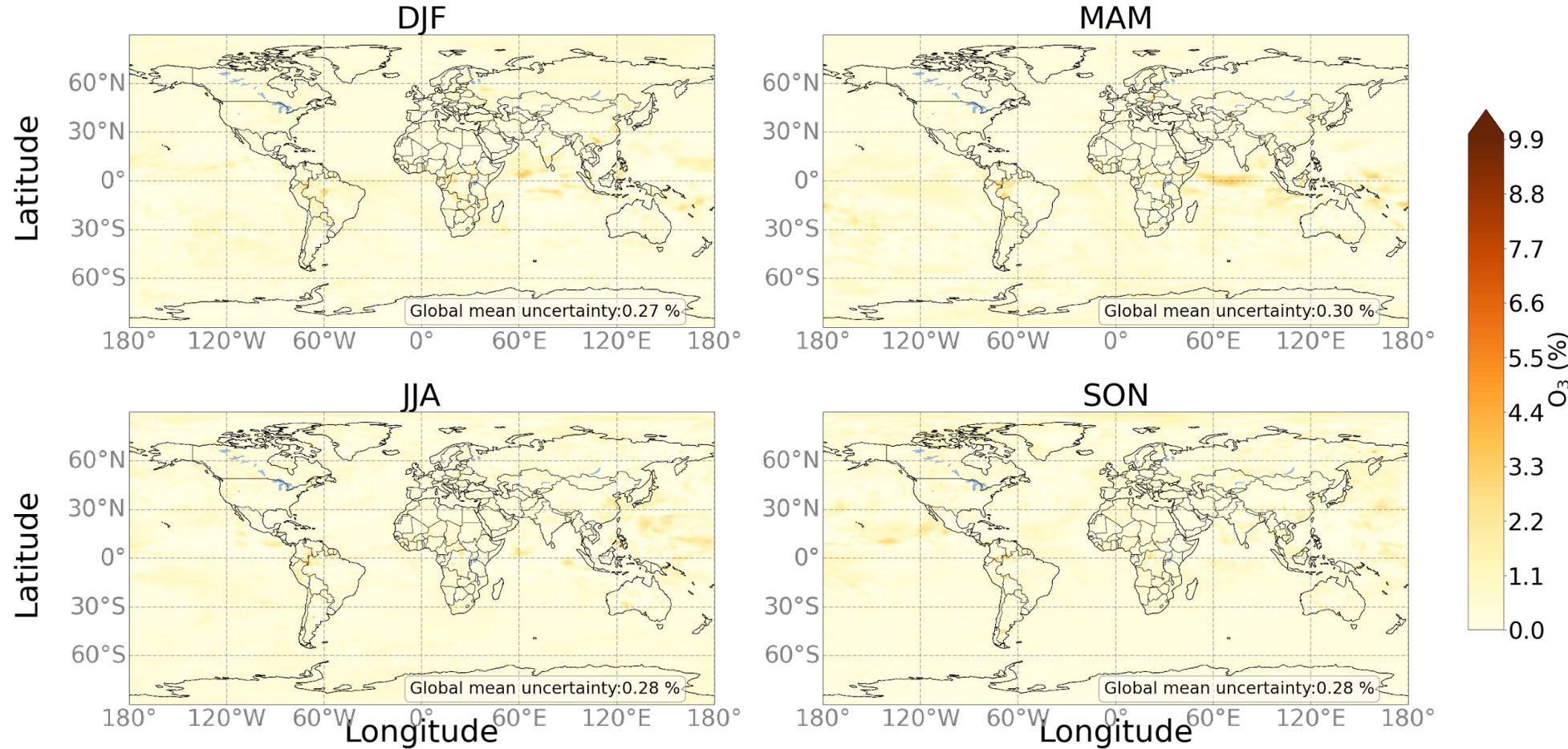


Seasonal uncertainty in surface O_3

Only including
uncertainty in CO
fire emission
factors

Global:
CO E.F. uncert: 0.3%

Surface O_3 from CAM-chem

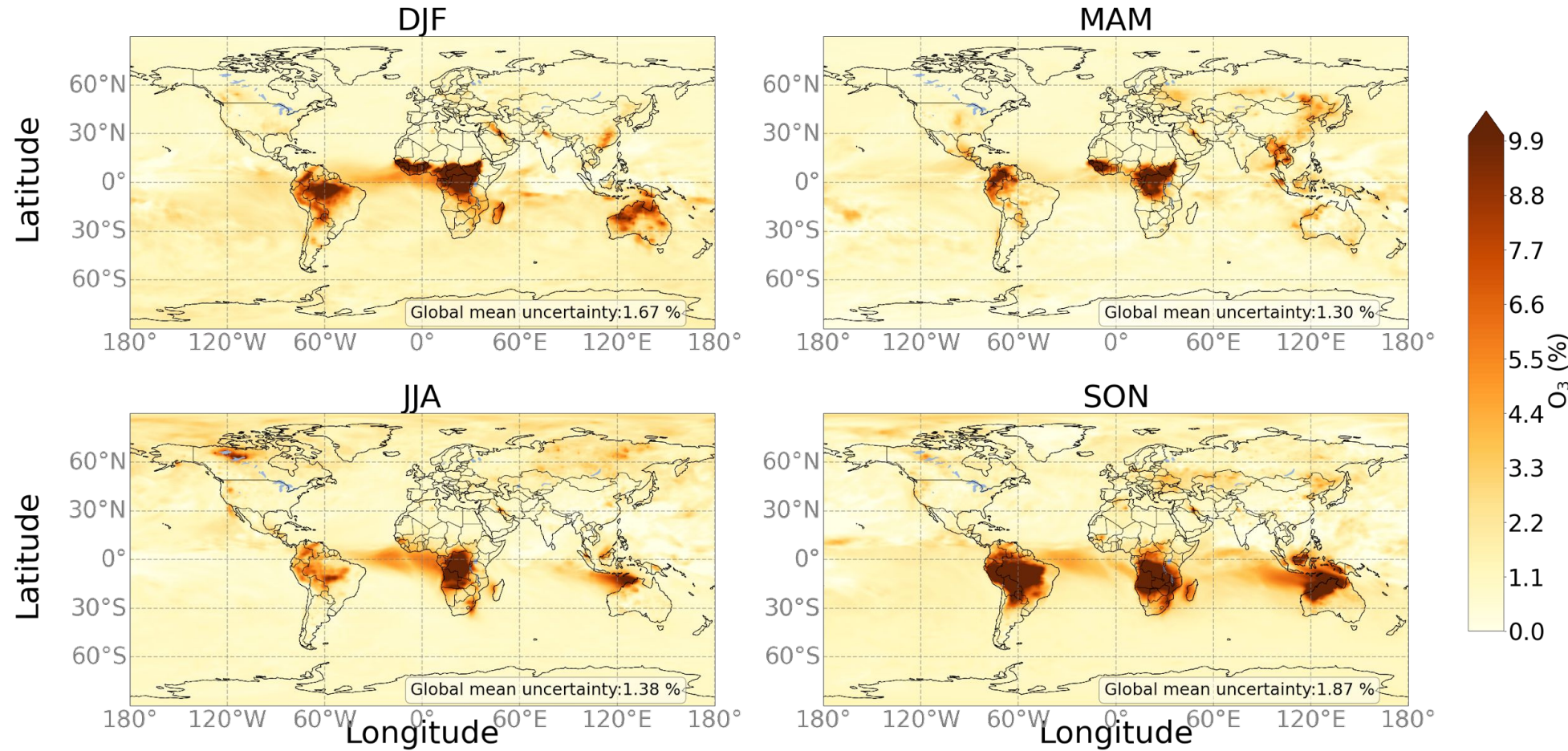


Seasonal uncertainty in surface O_3

Including
uncertainty in all
fire emission
factors

Global:
CO E.F. uncert: 0.3%
All E.F. uncert: 1.6%

Surface O_3 from CAM-chem



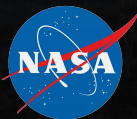
Summary

Fire emission factor uncertainty can explain some differences between global inventories. Remaining differences are likely due to algorithm differences such as land cover used, fire detection and cloud handling.

CO emission factor uncertainty results in global average $\sim 3.1\%$ uncertainty in modeled column CO. All emission factor uncertainties adds an extra $\sim 0.6\%$.

Most uncertainty in surface O_3 originates from all fire emission factor uncertainties, which contributes $\sim 1.6\%$ uncertainty globally.

Regional evaluation of modeling with global inventories is essential.



References

Emission Factors: **[1]** Akagi, S. K., et al. (2011), Atmos. Chem. Phys. 11, 4039-4027

CMIP6: **[2]** van Marle, M. J. E., et al., (2017), Geosci. Model Dev., 10, 3329-3357,
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GFAS: **[4]** Kaiser, J. W., et al. (2012), 9, 527–554, Biogeosciences <https://doi.org/10.5194/bg-9-527-2012>.

[5] Di Giuseppe, F., et al., (2018), Atmos. Chem. Phys., 18, 5359–5370, <https://doi.org/10.5194/acp-18-5359-2018>.

QFED: **[6]** Darmenov, A. & da Silva, A. (2015), NASA GMAO Technical Report, Vol. 38, 183 pp., available at:
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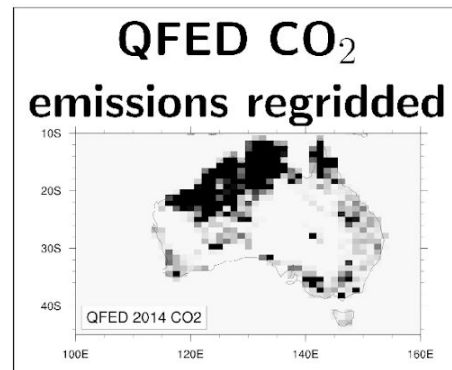
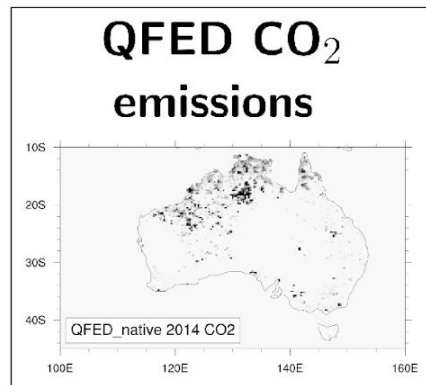
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CAM-chem T1 Chemistry: **[8]** Emmons, L. K., et al., (2020). JAMES, 12, e2019MS001882,
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Artwork on slide 3 by Caparelli ArtNScience

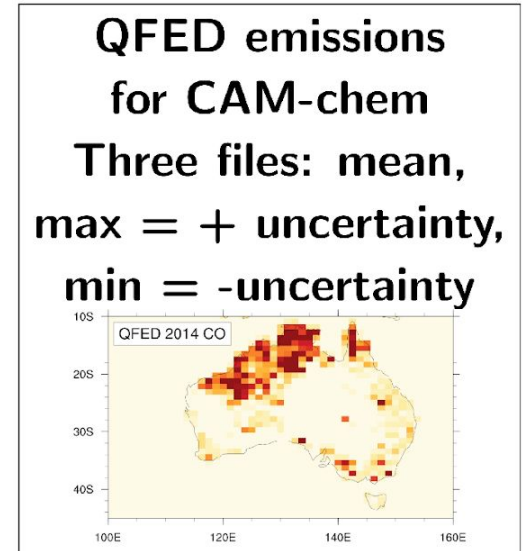
Extra: Creating emission bounds

How emission bounds are created using emission factor uncertainties



$$\text{Emission Ratios: } \frac{\text{Species E.F.} \pm \sigma_s}{\text{CO}_2 \text{ E.F.} \pm \sigma_{\text{CO}_2}}$$

E.F. = emission factor
 $\sigma = \text{uncertainty}$



Created using emission factors
compiled for FINN.

Applied separately over four biomes.