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IN THE CITY OF NEW YORK

PyrE, an interactive fire module within the NASA-GISS Earth System Model

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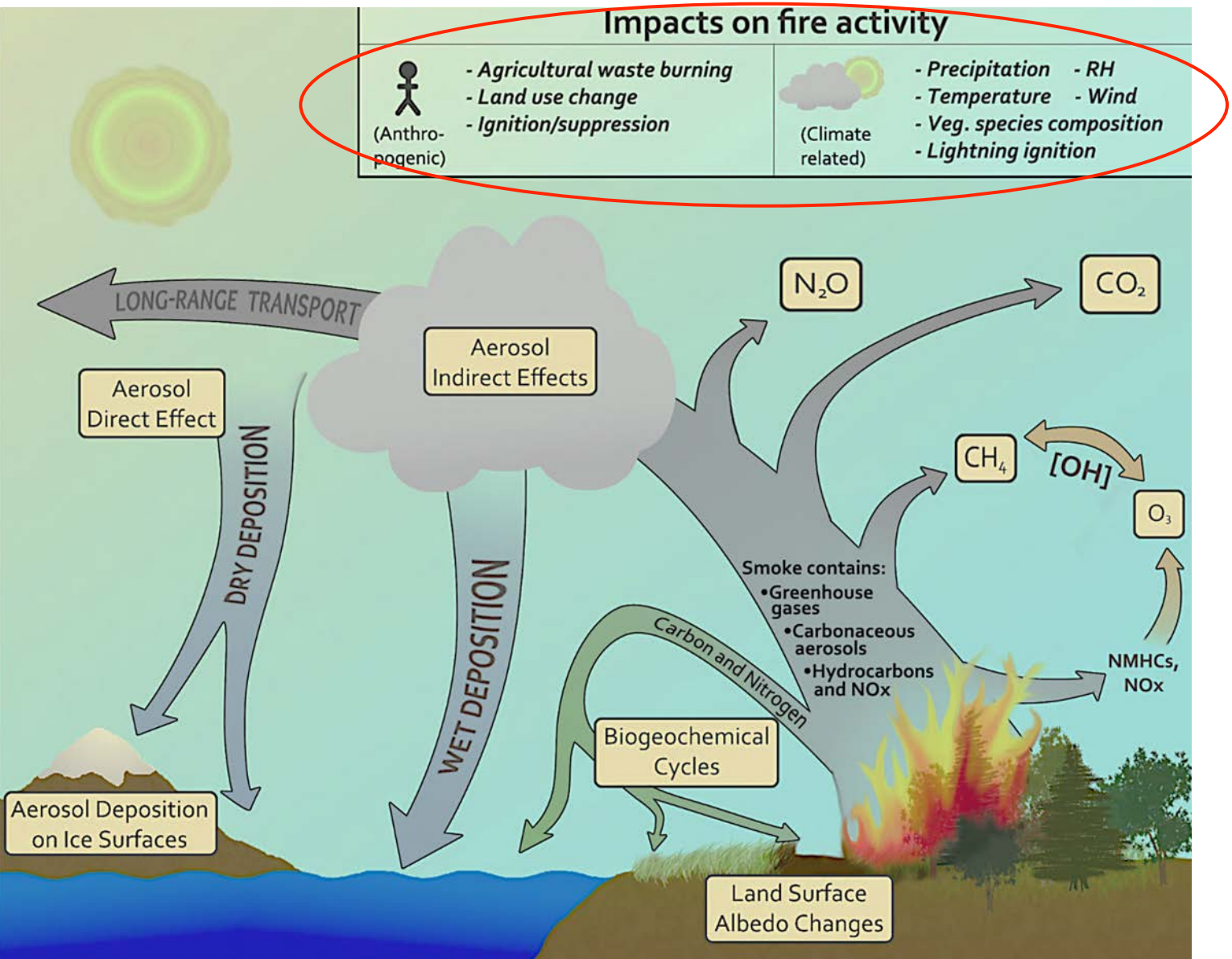
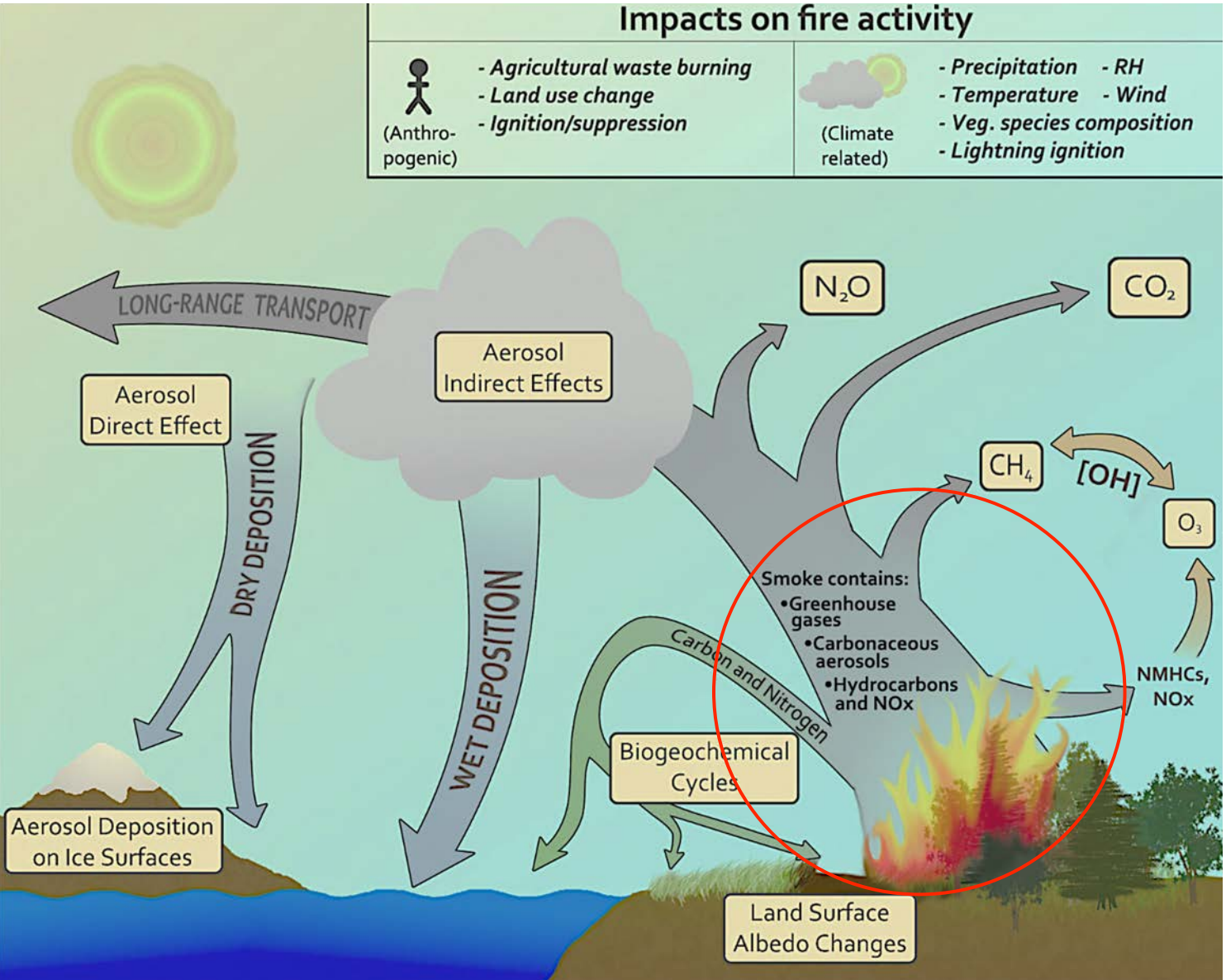
DEC 5th 2017 – MODIS (Terra)

Fire activity is driven by environmental parameters and human behavior



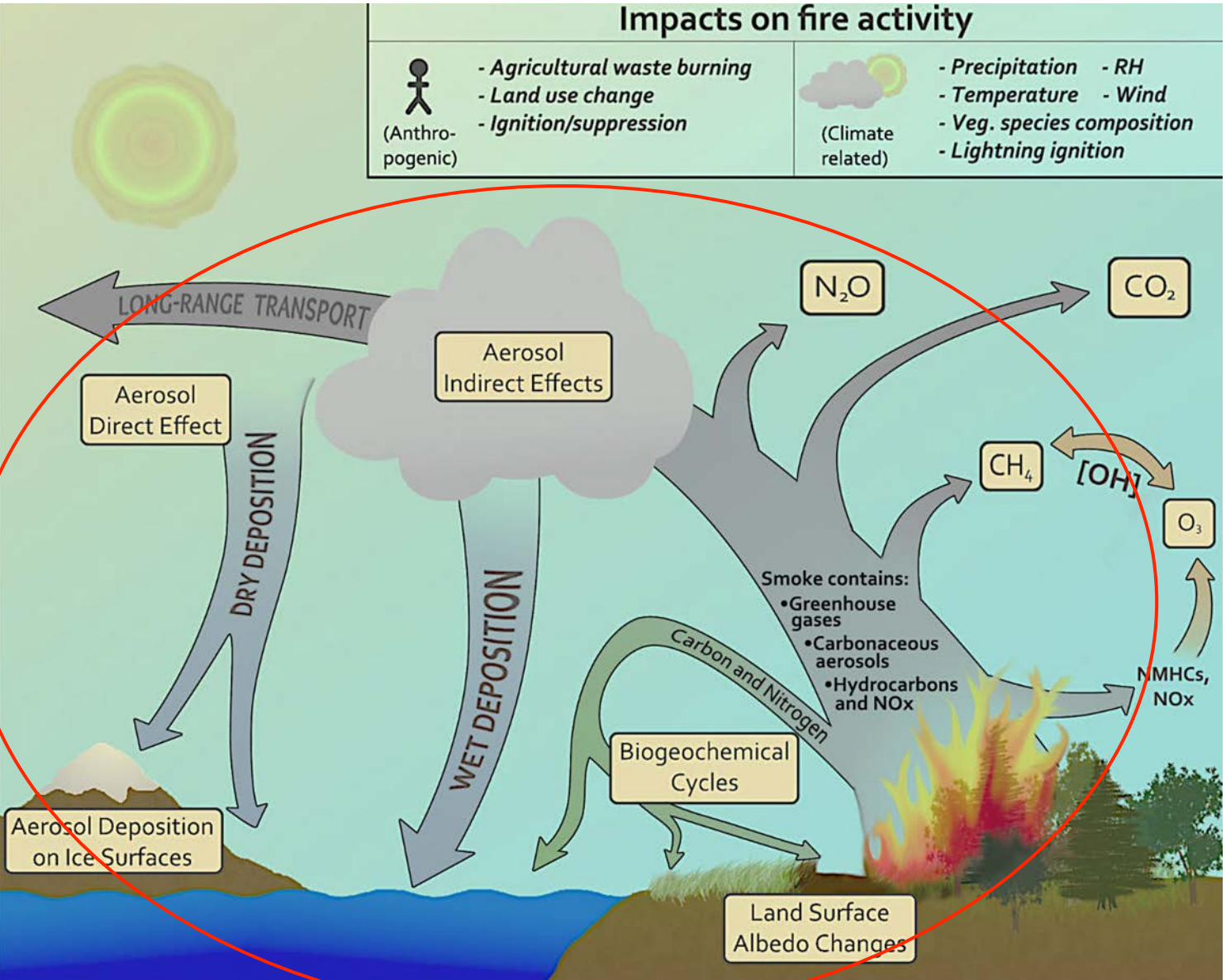
Ward et al., 2012

Fires are a source of air pollution



Ward et al., 2012

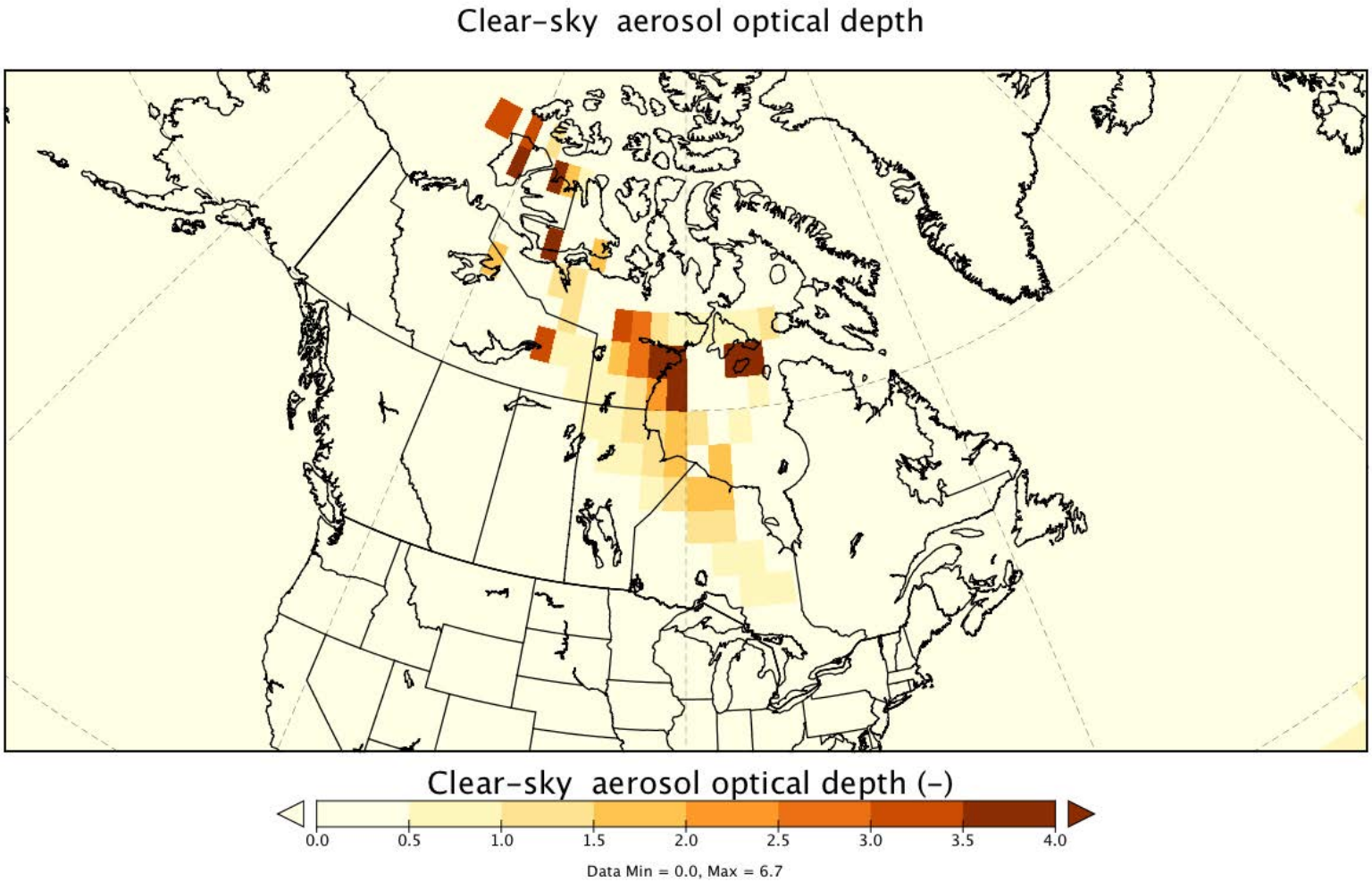
Fires have a range of climate impacts



Ward et al., 2012

Can fires affect weather

Clear-sky AOD on August 15 18:00 UTC



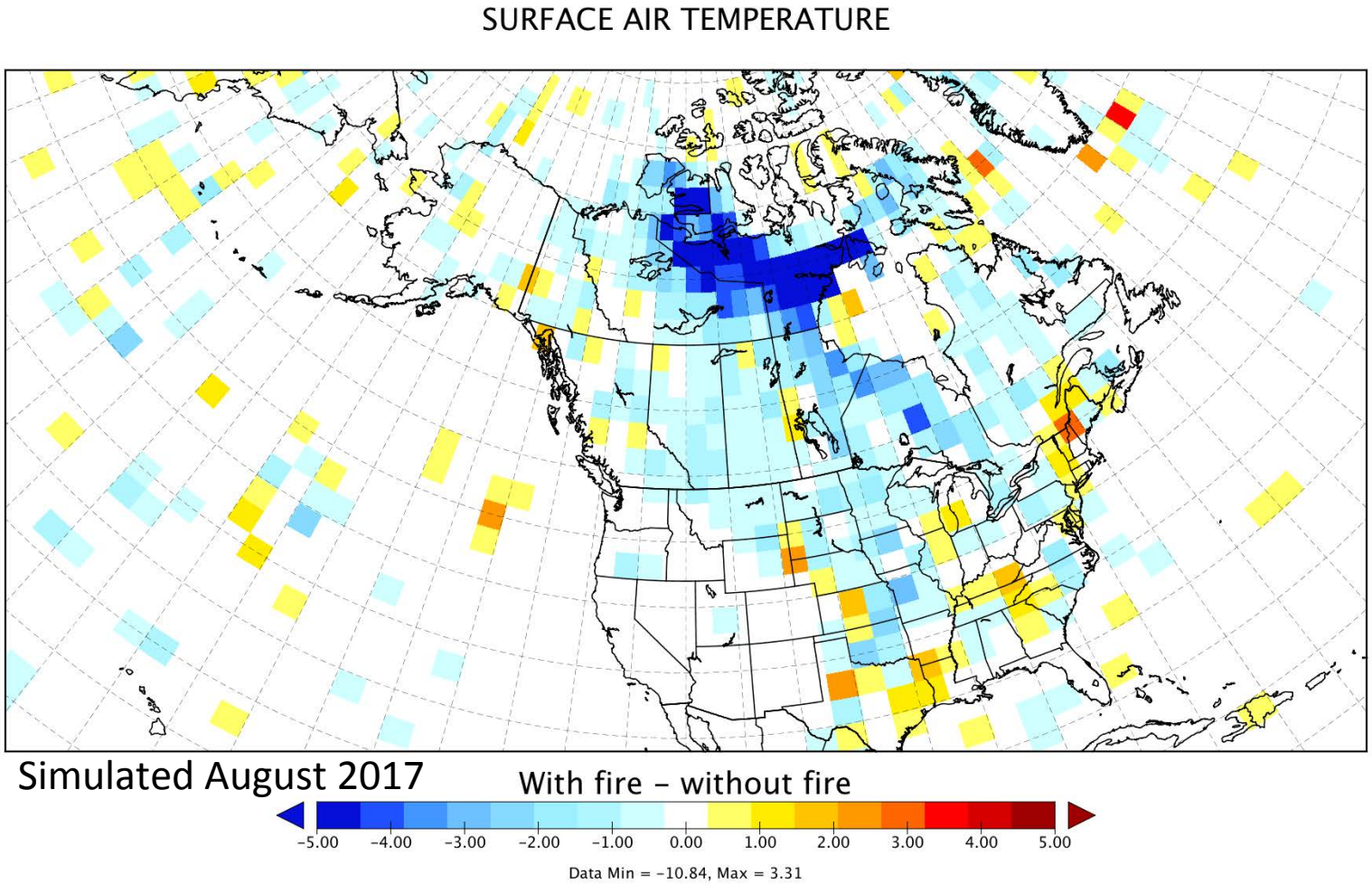
Did all this smoke cool the surface?

Courtesy of Robert Field

Can fires affect weather

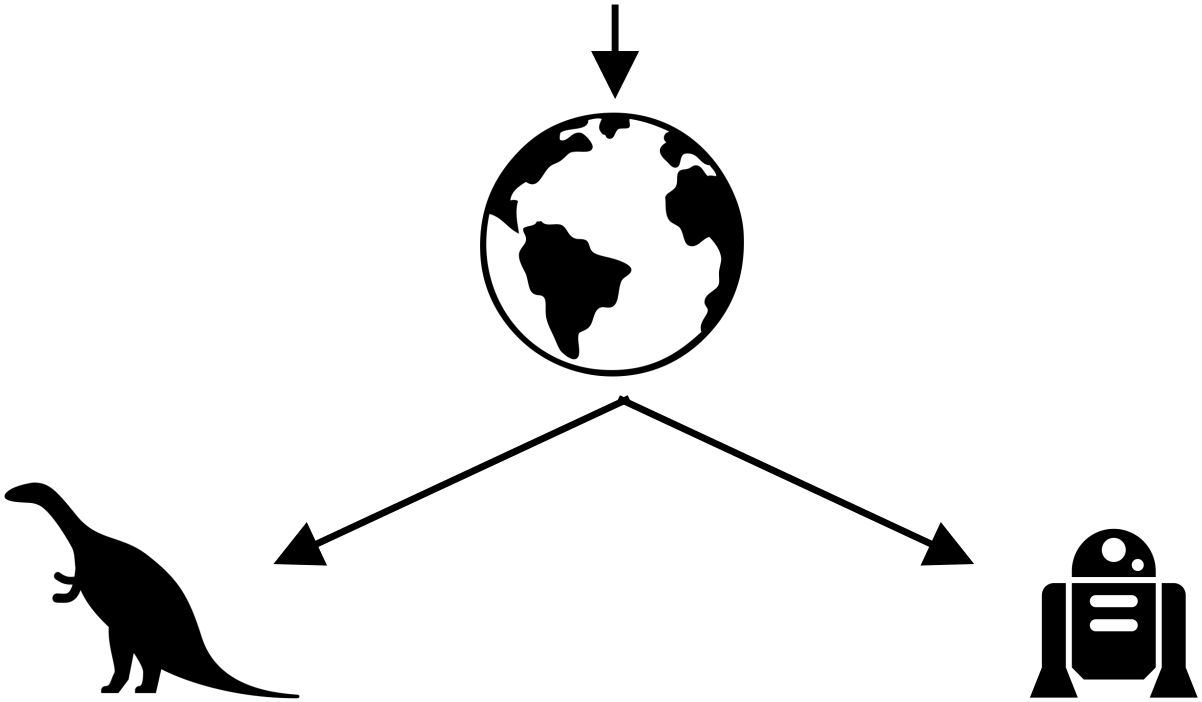
Modeled surface temperature difference (fire - no fire)

> 5 °C cooling under plume



Courtesy of Robert Field

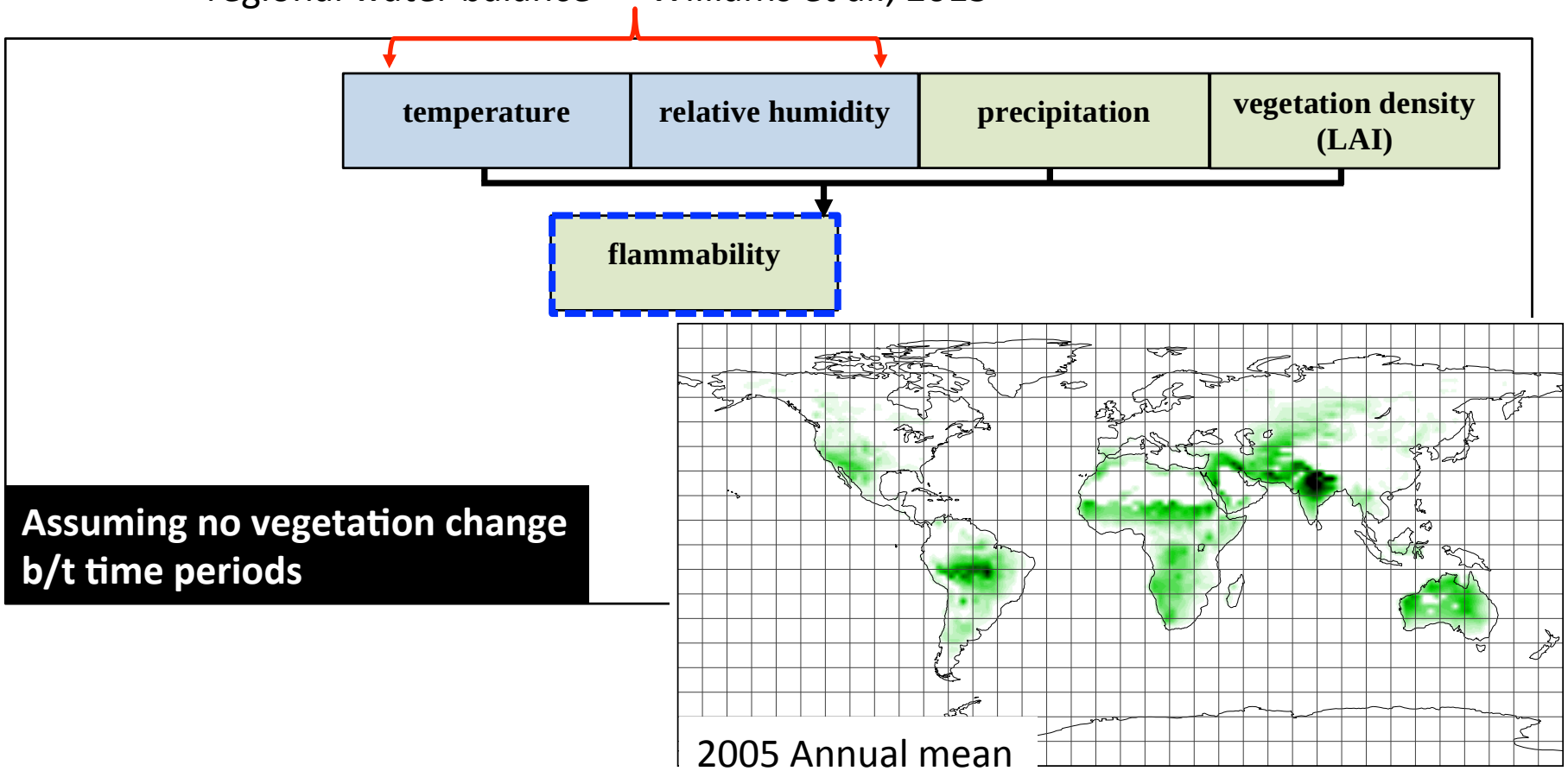
Simulating fires interactively is a tool to study biosphere forcing and feedbacks



In past, present and future…

NASA-GISS PyrE
Initial fire conditions set by flammability

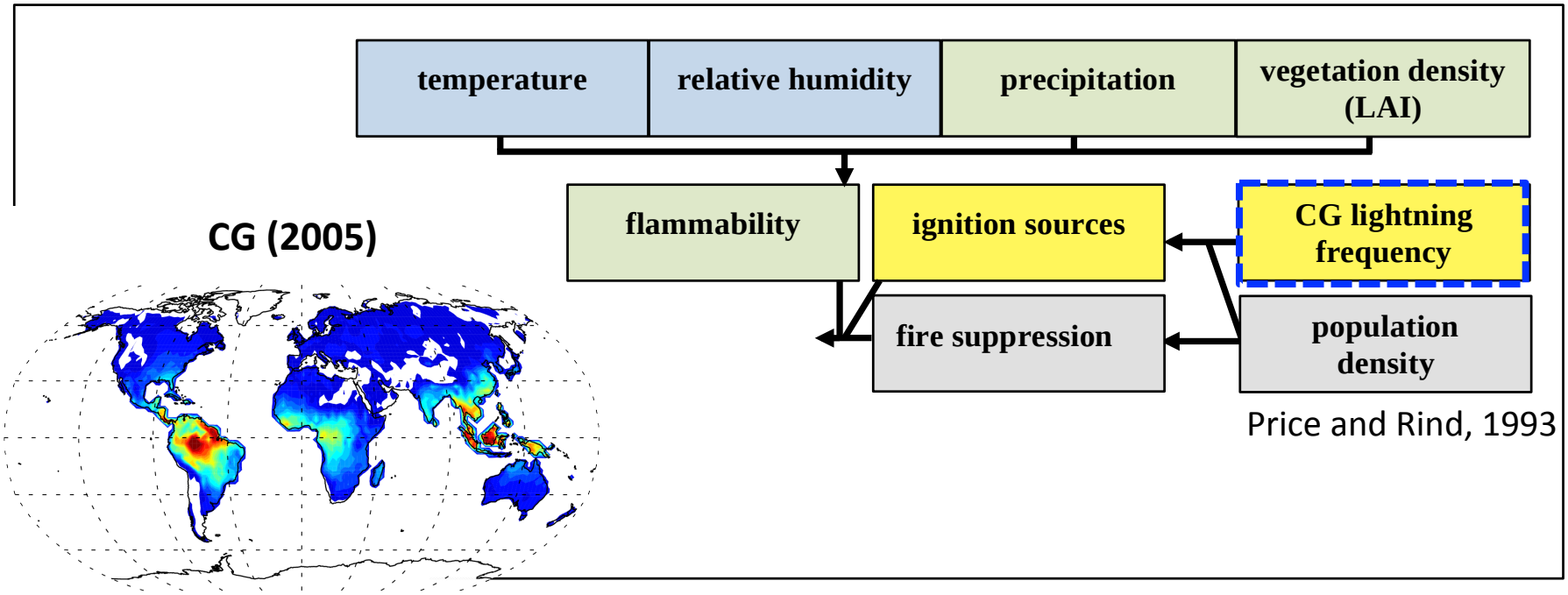
"VPD appears to be a simple and holistic indicator of regional water balance" – Williams et al., 2015



Assuming no vegetation change b/t time periods

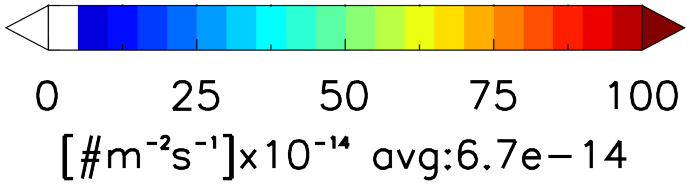
Pechony and Shindell (2009, 2010)

Explicitly calculating ignition and suppression



Price and Rind, 1993

CG (2005)



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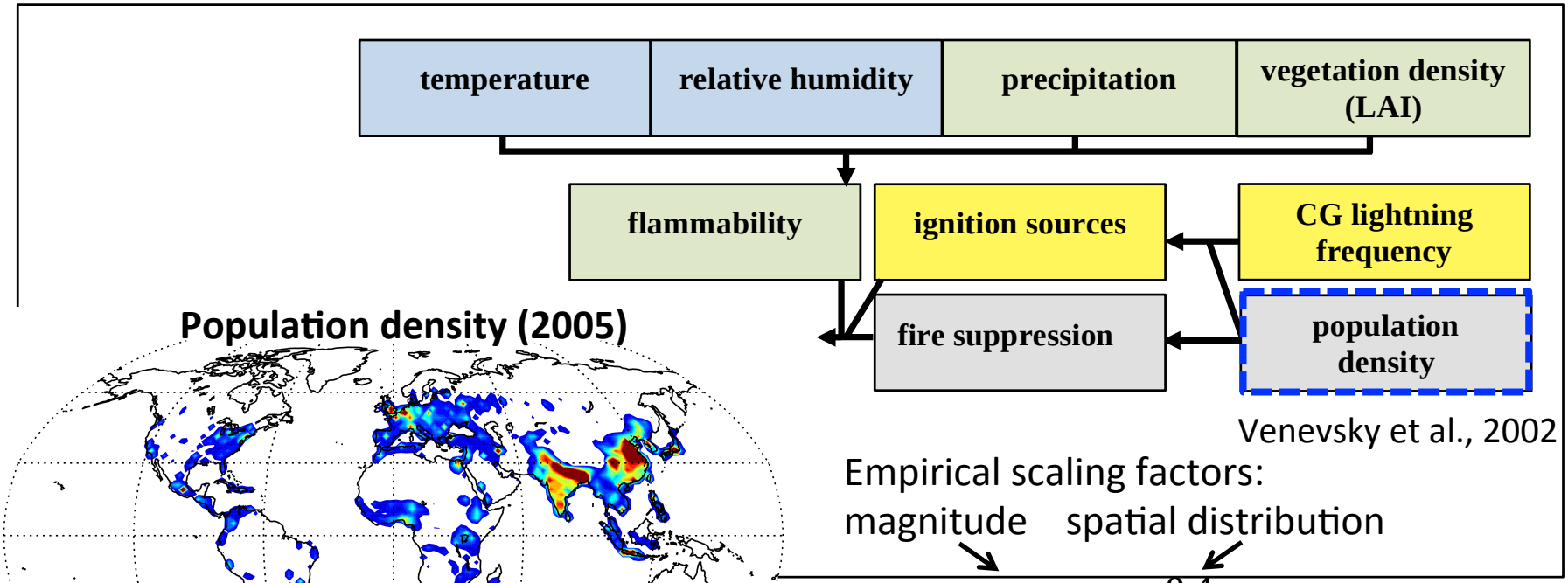


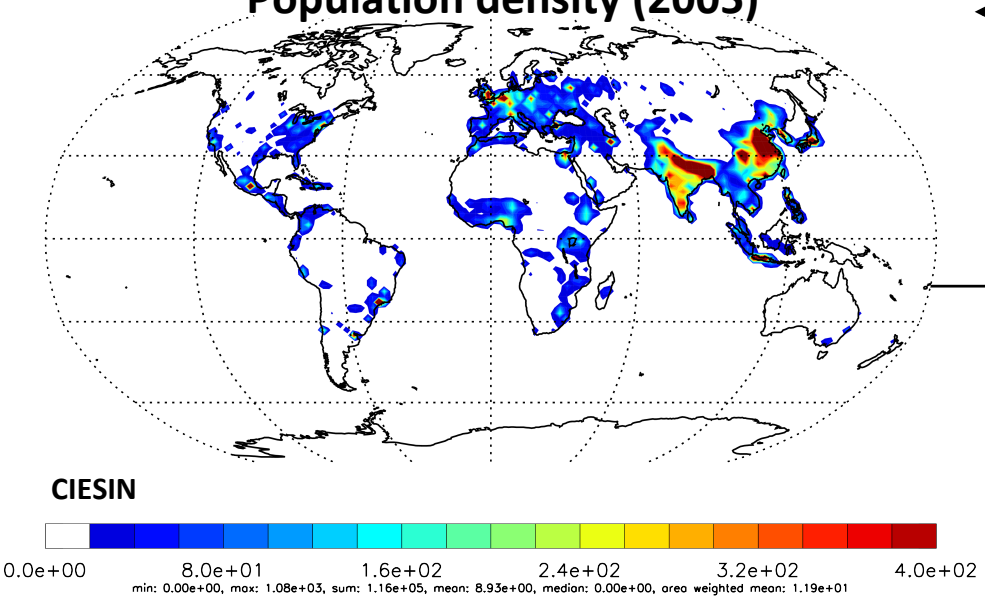
Venevsky et al., 2002

Empirical scaling factors:

magnitude spatial distribution

$$I_A = 0.2 \cdot PD^{0.4}$$

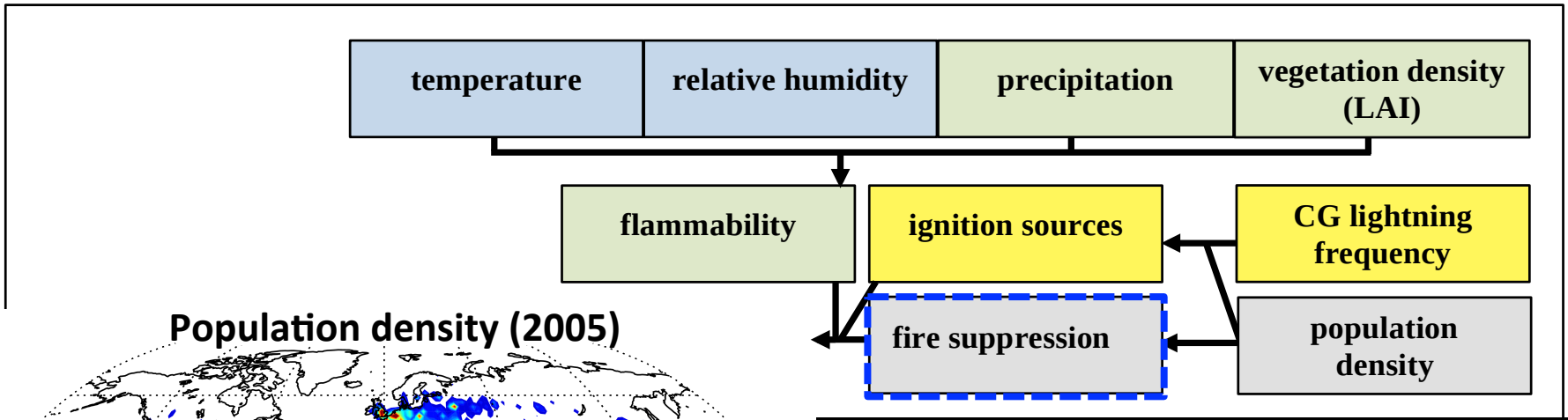
Population density (2005)

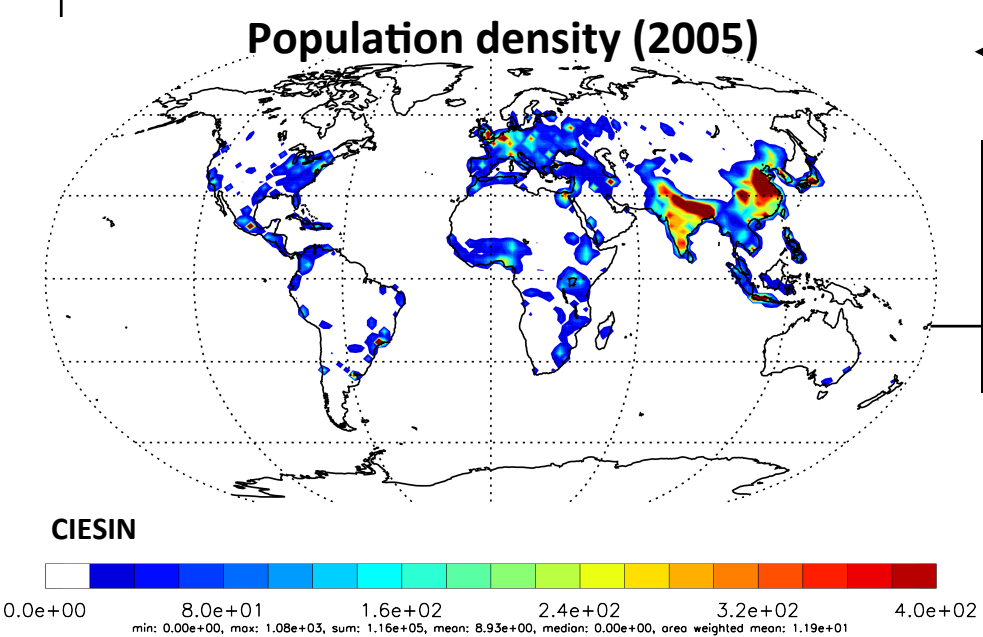


Population density increases with time

Pechony and Shindell (2009, 2010)

Explicitly calculating ignition and suppression



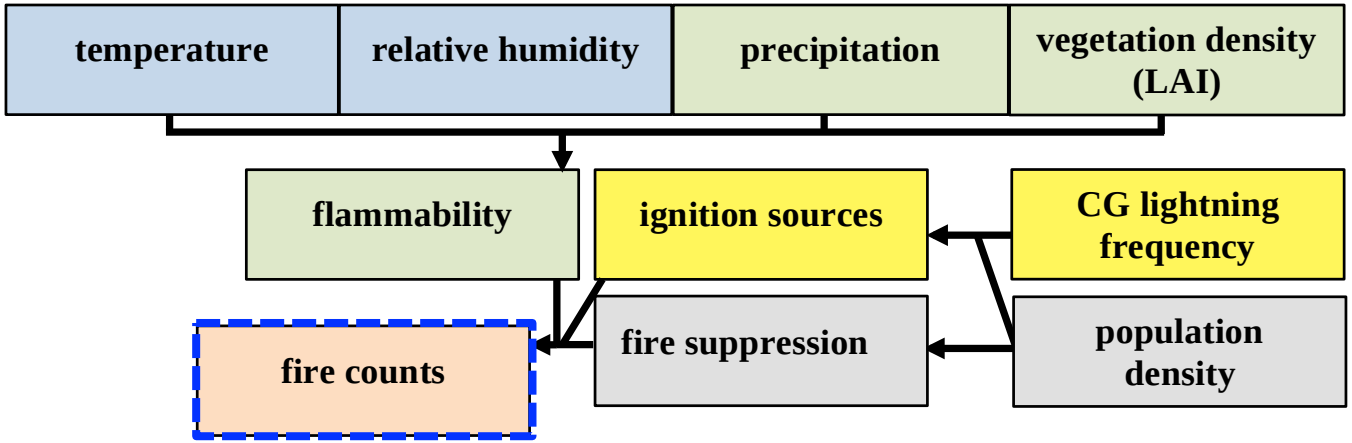


Fire suppressions ranges (exponentially):
5% in unpopulated areas
95% in densely populated areas
(more than 100 people/km^2)

Population density increases with time

Pechony and Shindell (2009, 2010)

Fire counts are a function of flammability, ignition, and suppression

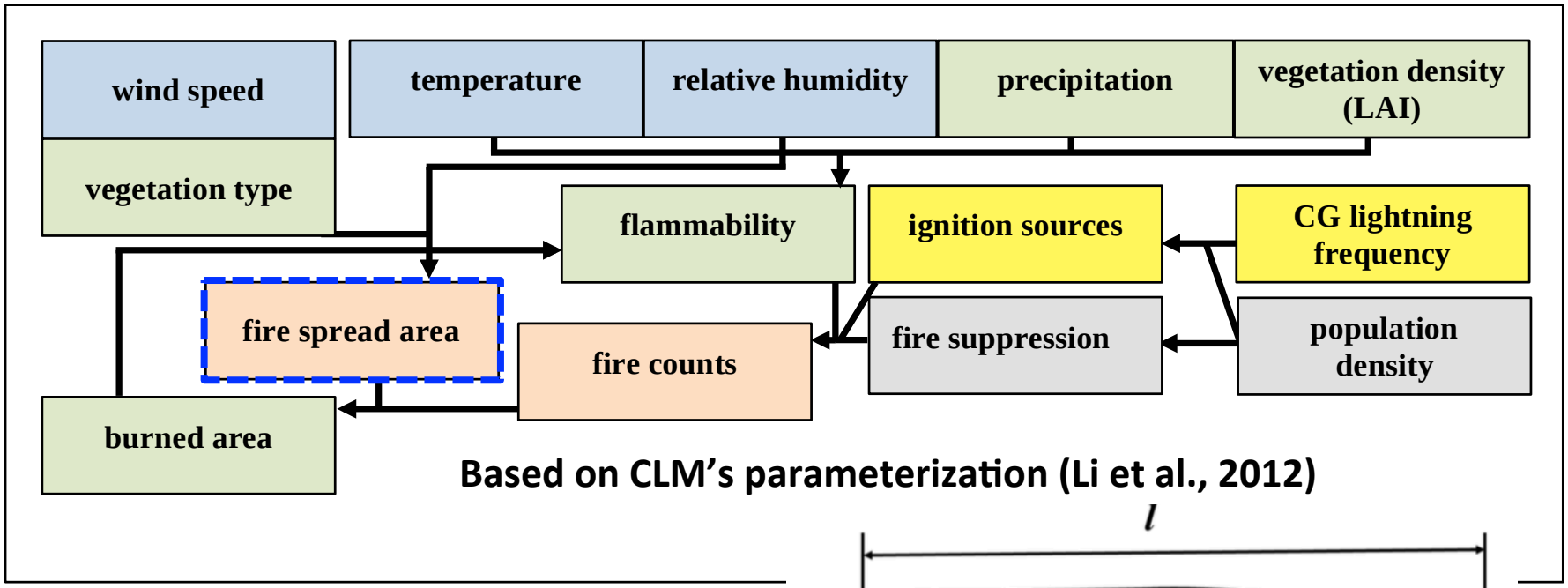


$$\mathrm{MODEL_{FC}} = F \cdot TF_{MODIS} \cdot (I_N + I_A) \cdot f_{NS}$$

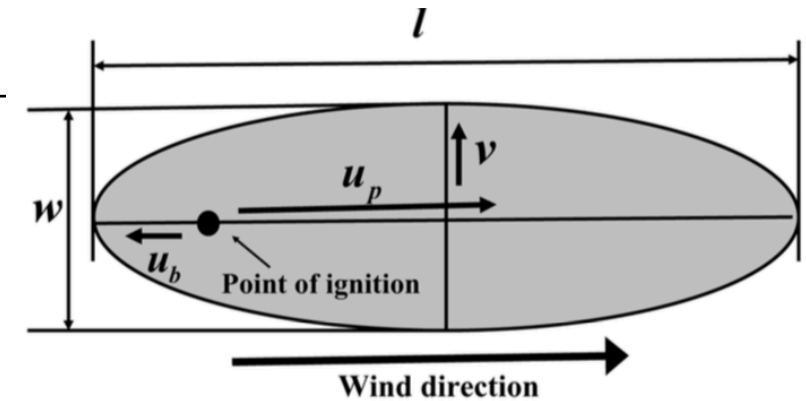
Scaling factor based on MODIS fire counts

Pechony and Shindell (2009, 2010)

Adding a physical parameterization for fire spread and burned area (BA)

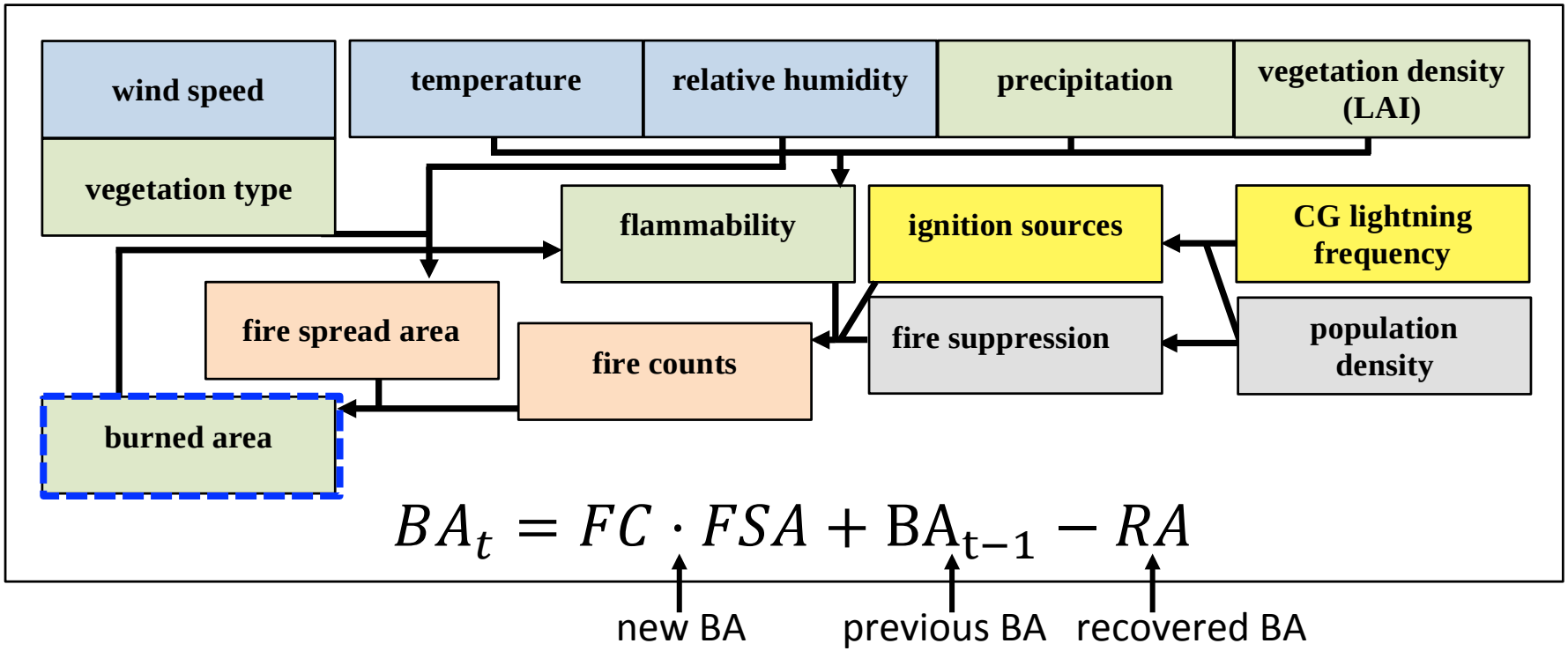


Based on CLM's parameterization (Li et al., 2012)



Mezuman et al., in preparation (A)

Adding a physical parameterization for fire spread and burned area (BA)



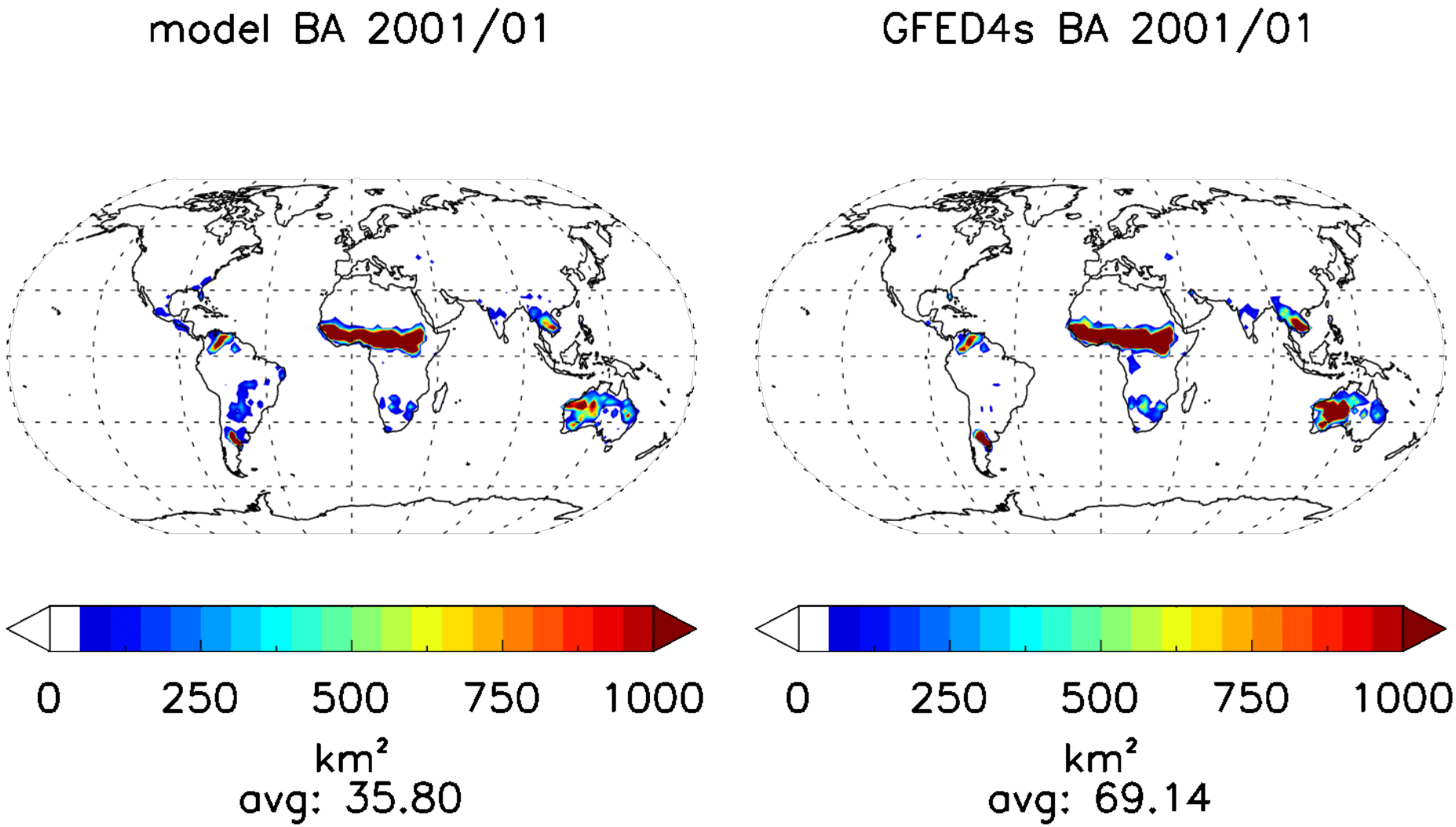
Mezuman et al., in preparation (A)

Offline burned area (BA):

MODIS FC

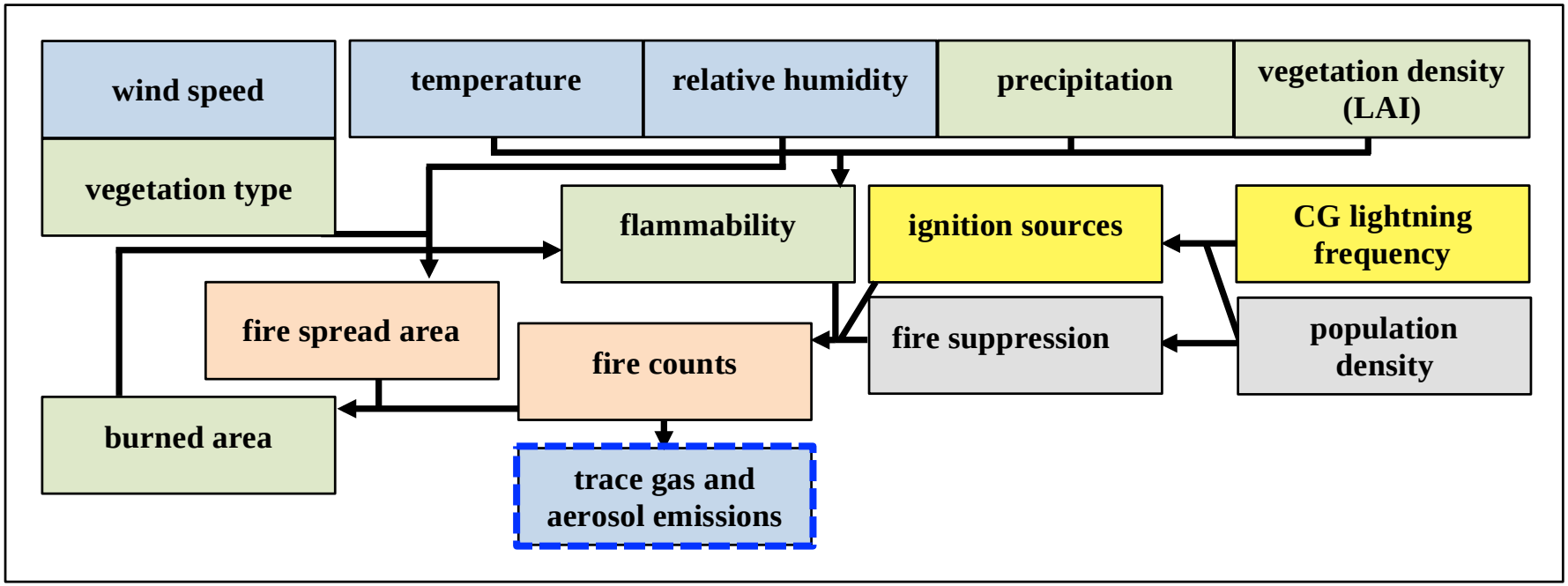
Surface RH, wind speed from a 2001 nudged simulation

ENT DVGM's recovery time



Mezuman et al., in preparation (A)

Fires affect atmospheric composition through interactive emissions



Mezuman et al., in preparation (A)

Emission Per Fire Count (EPFC)

For each grid box (i, j) a set of n linear equations is constructed:

$$E_{inventory}(i,j) = \mathrm{MODIS_{FC}}(\mathrm{i,j}) \cdot \sum_{veg\ type=1}^{n} \left(EPFC_{veg\ type} \cdot frac_{veg\ type}(\mathrm{i,j})\right)$$

n - number of vegetation types (i.e. grassland, rainforest etc.)

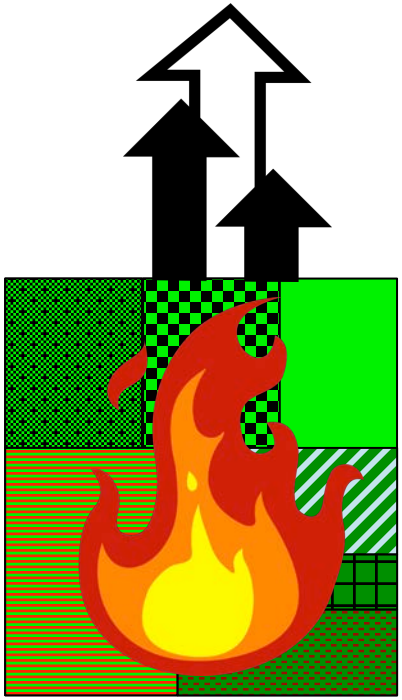
$E_{inventory}$ - fire emissions in the grid box (AR5, GFED2,3, etc.)

$MODIS_{FC}$ - MODIS fire count in the grid box

$frac_{vegtype}$ - fraction of each vegetation type in the grid box

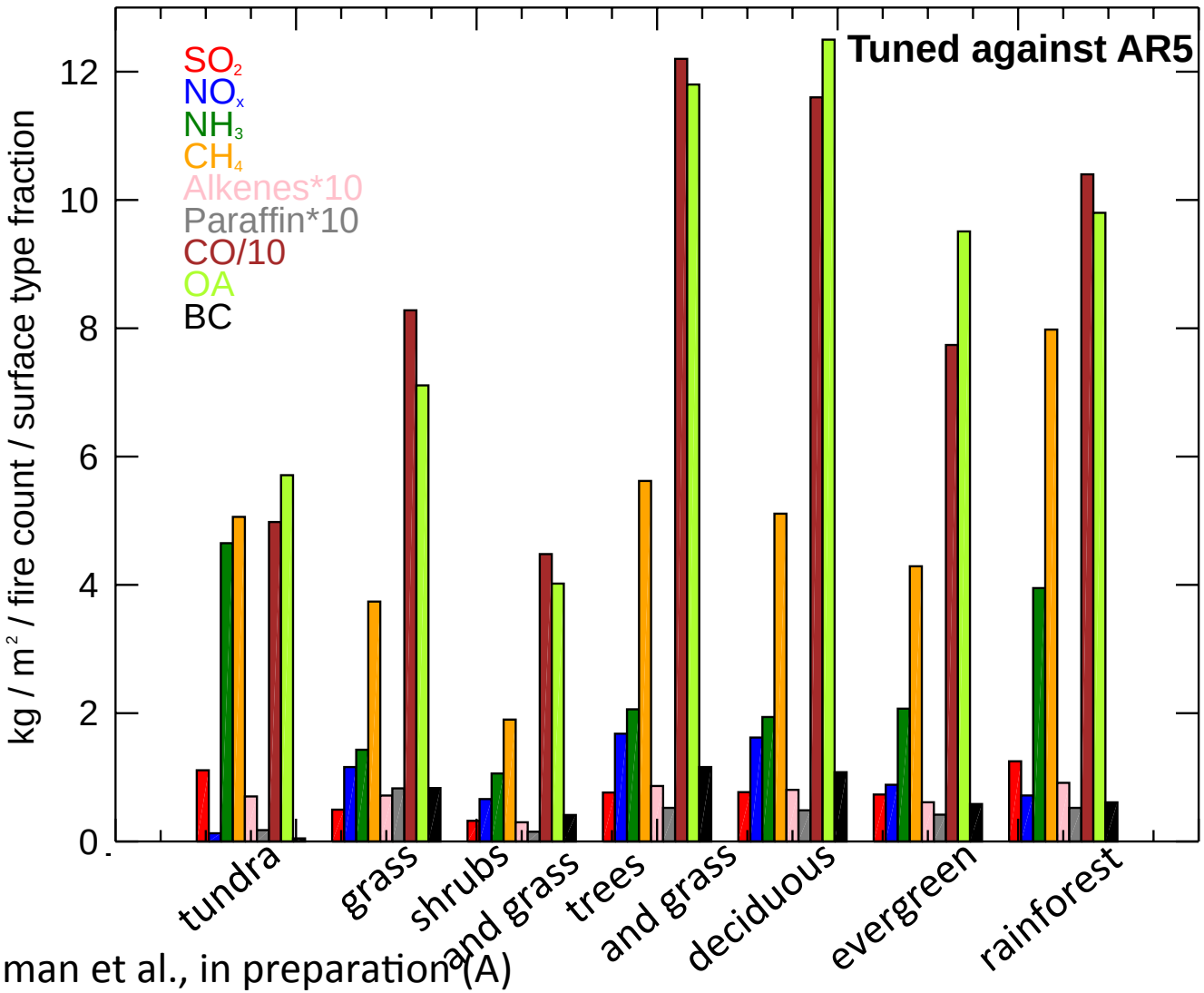
$\boldsymbol{EPFC_{veg\ type}}$ **- EPFC factor for each vegetation type (the unknown)**

Solution of linear equations using least-squares minimization method

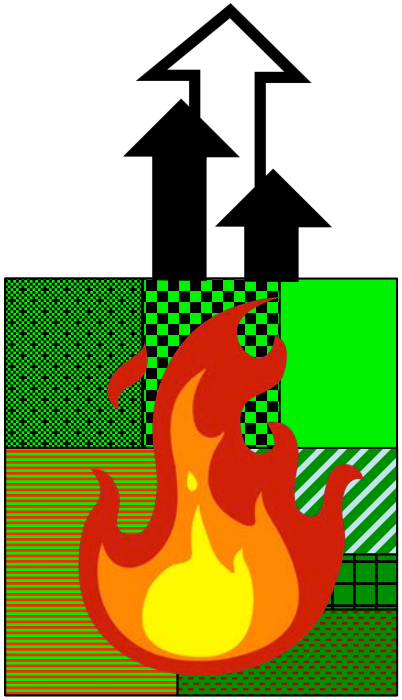


Mezuman et al., in preparation (A)

EPFC is a function of flammable surface type and species



Most emissions are of CO and OA



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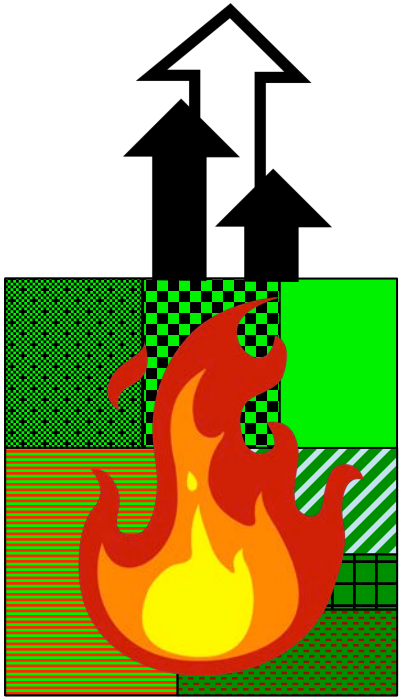
Solution of linear equations using least-squares minimization method

$$E_{\boldsymbol{model}}(i,j) = \mathrm{MODEL_{FC}}(\mathrm{i,j}) \cdot \sum_{veg\ type=1}^{n} \left(EPFC_{veg\ type} \cdot frac_{veg\ type}(\mathrm{i,j})\right)$$



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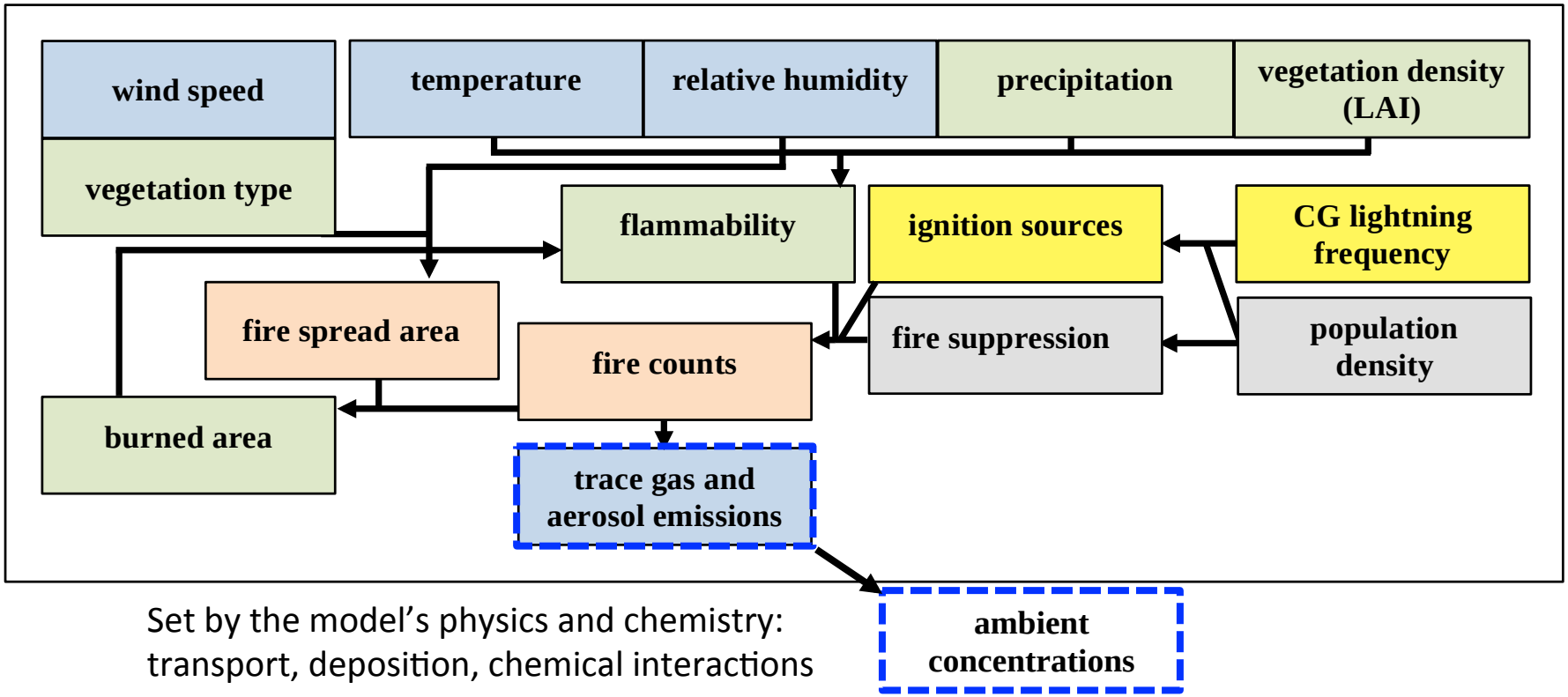


Set by the model's physics and chemistry: transport, deposition, chemical interactions

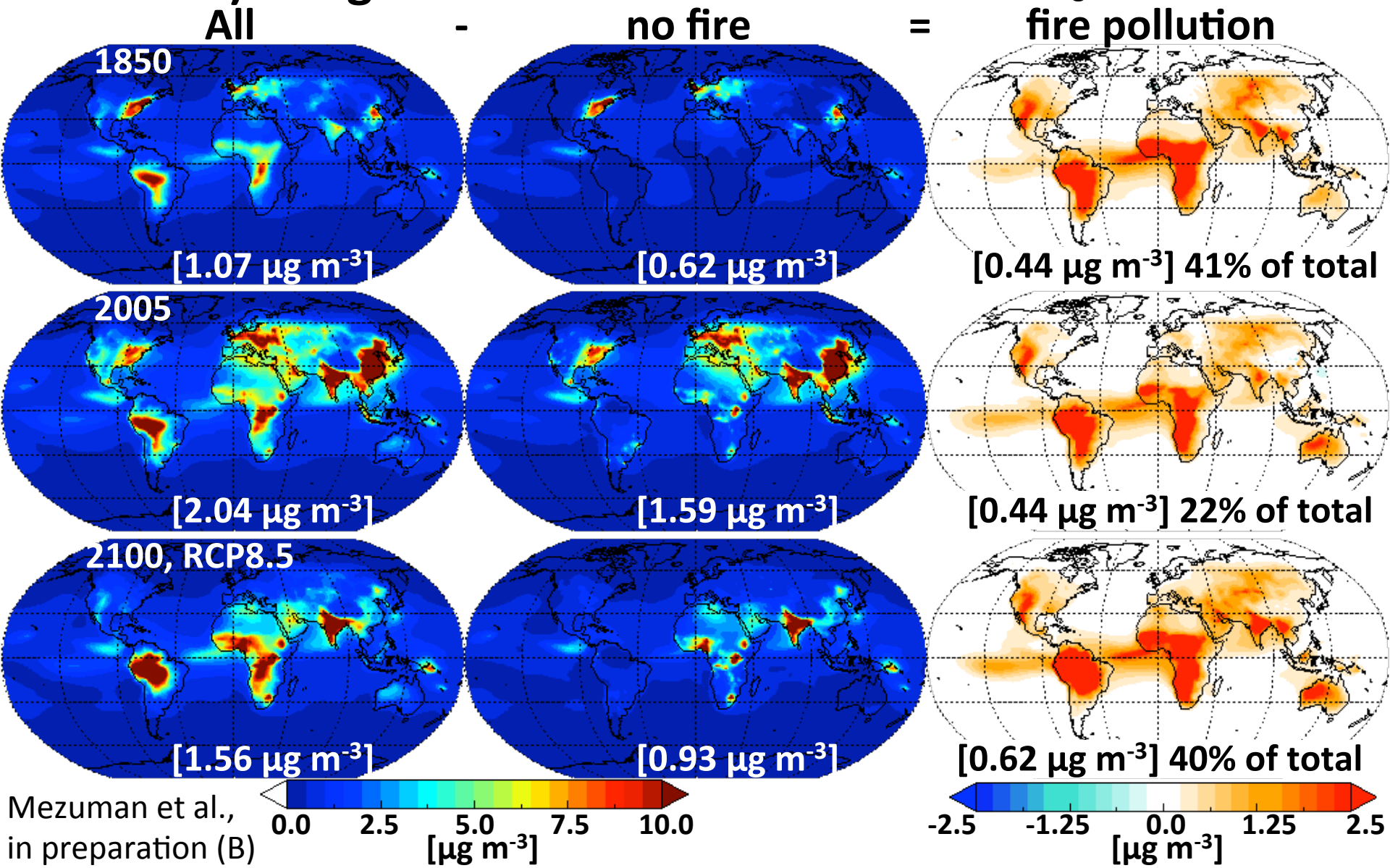
Mezuman et al., in preparation (A)

Applications

Study <u>fire pollution</u> and <u>health impacts</u>

Regardless of time period fire pollution (surface PM2.5) is high

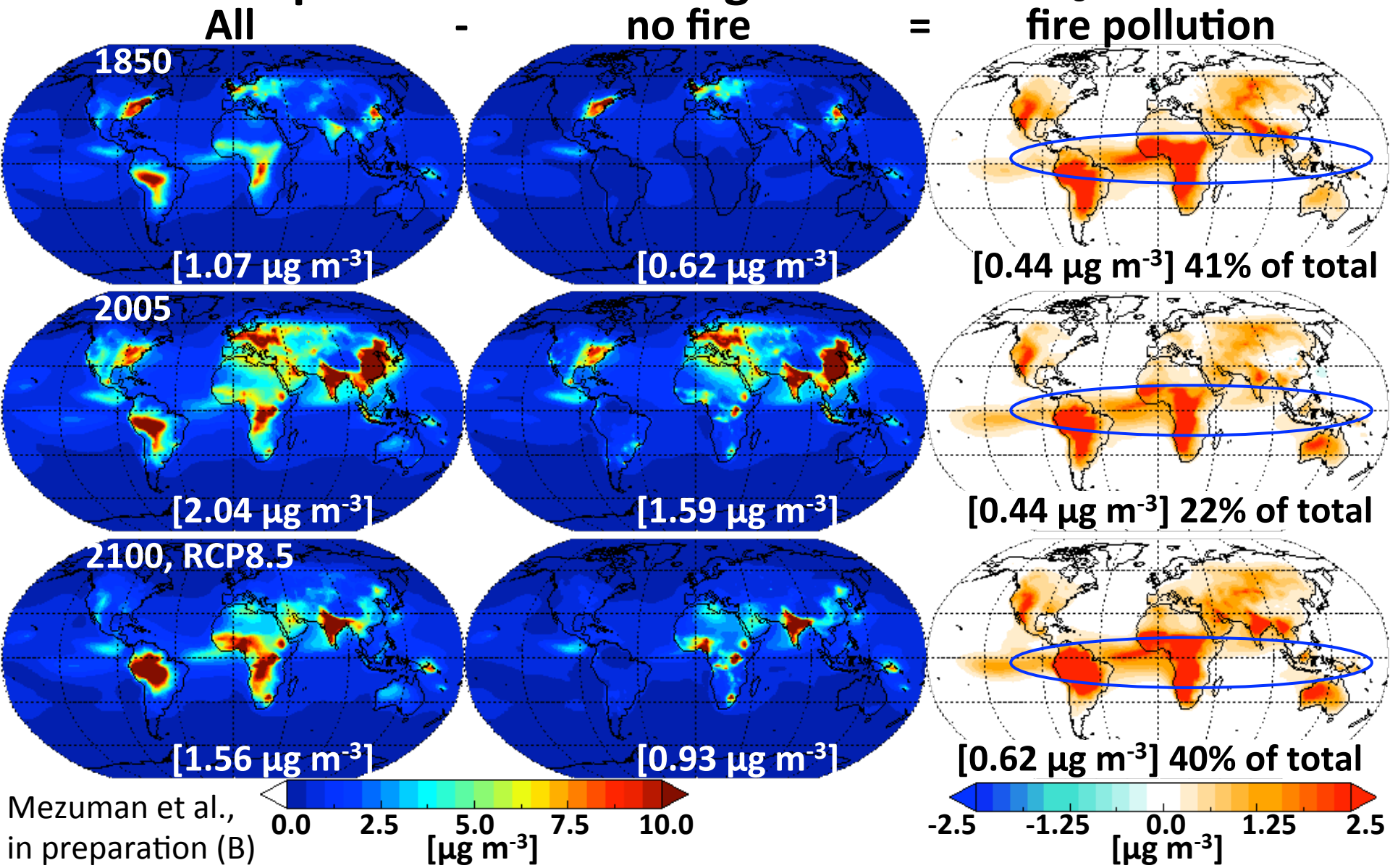
*excluding dust and sea salt



Mezuman et al., in preparation (B)

Annually, fire pollution (surface PM2.5) is dominating in the tropical continental regions

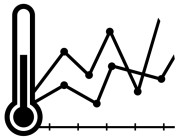
*excluding dust and sea salt

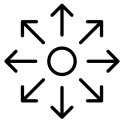


Mezuman et al., in preparation (B)

Applications

Study <u>fire pollution</u> and <u>health impacts</u>



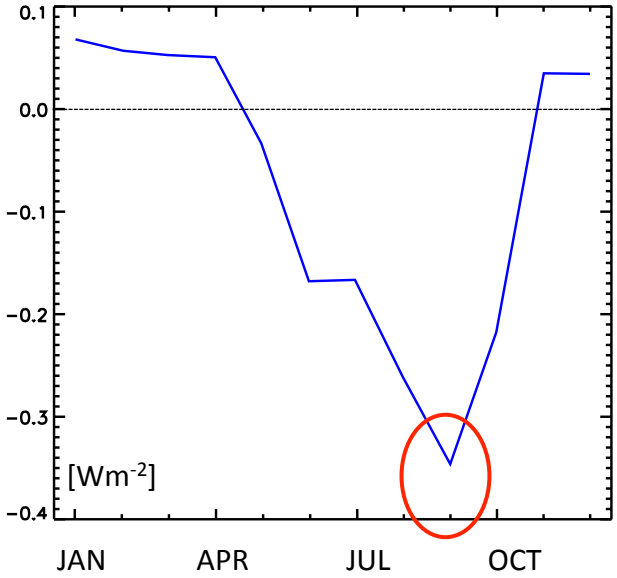


Evaluate <u>climate impact</u> and <u>radiative forcing</u>

Overall fire aerosols have a cooling effect on the climate system

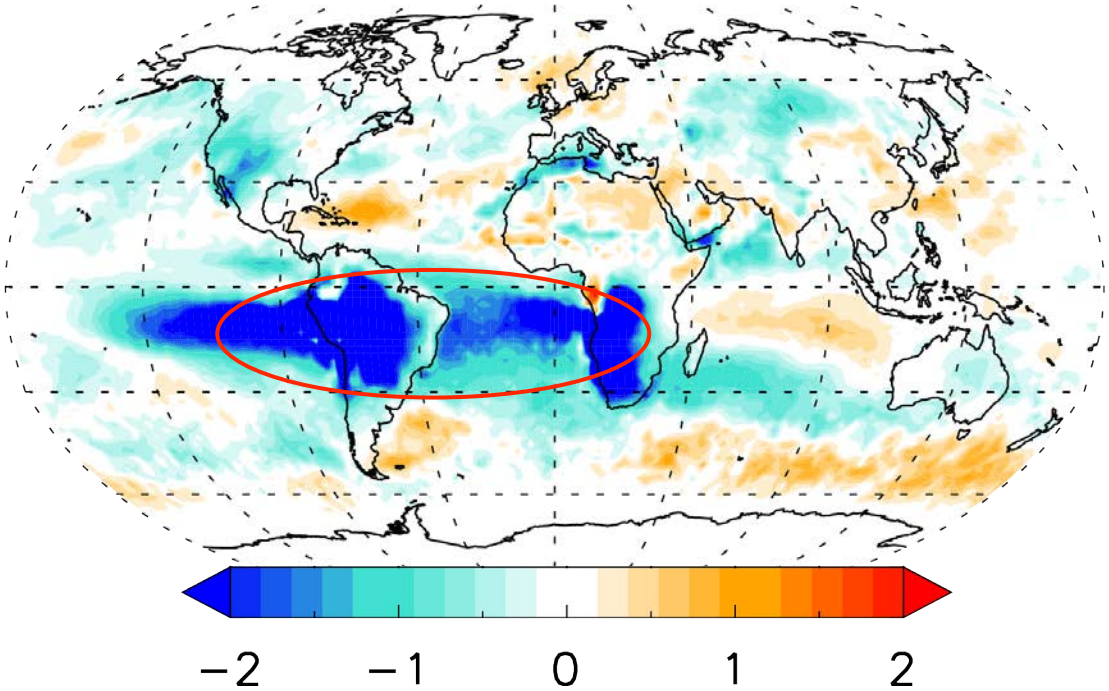
fire aerosol SWF ≡ (all – no fire) aerosol SWF

2005 10-year climatological mean



SEP 2005

10-year climatological mean



[Wm^{-2}] avg: -3.46e-1

Mezuman et al., in preparation (A)

Overall fire aerosols have a cooling effect on the climate system

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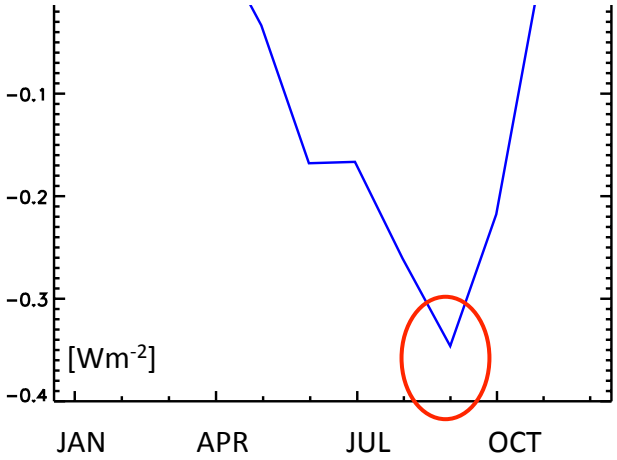
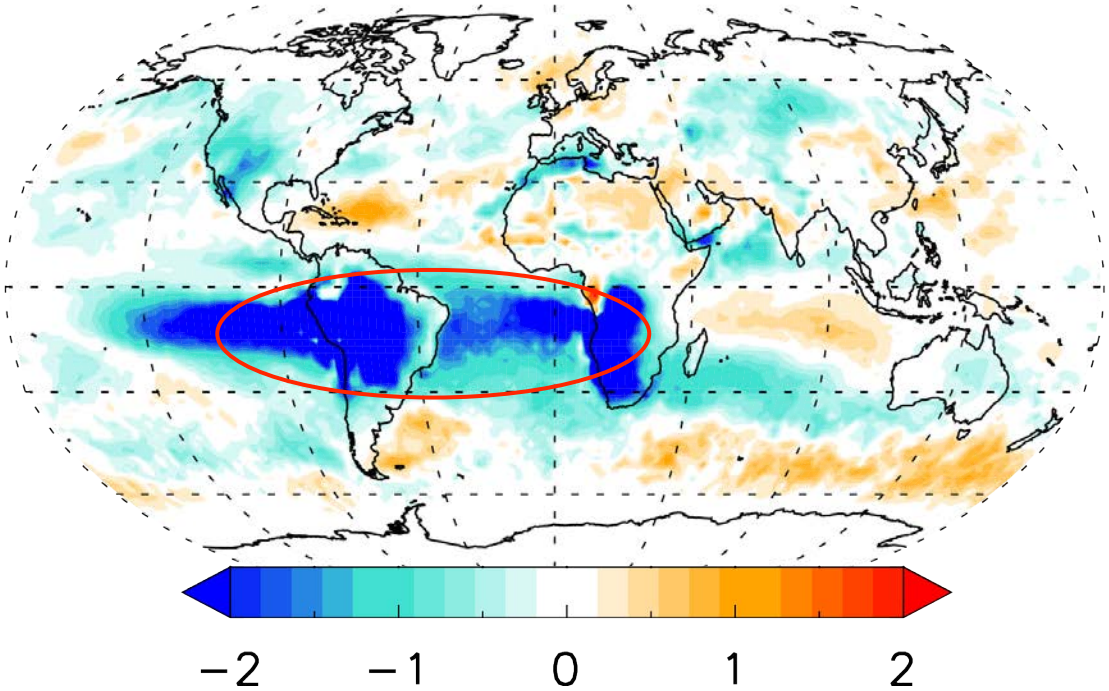
2005 10-year climatological mean

To a first degree follows seasonality of BB emissions



SEP 2005

10-year climatological mean



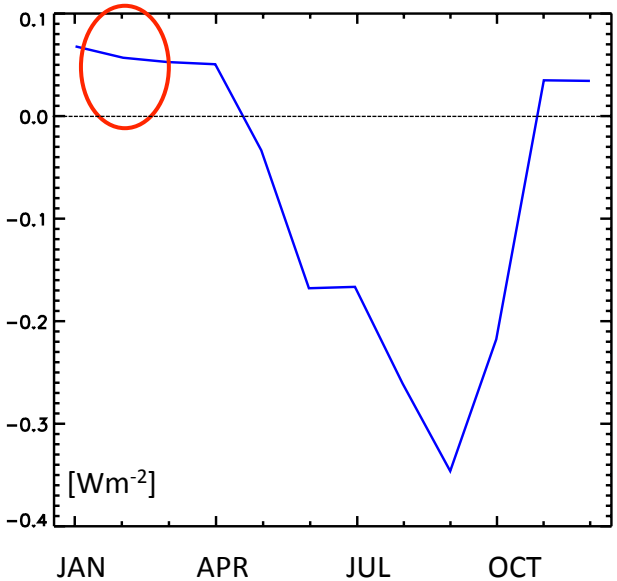
[Wm^{-2}] avg: -3.46e-1

Mezuman et al., in preparation (A)

A warming signal along with a decrease in dust emissions (and load) due to decreases wind

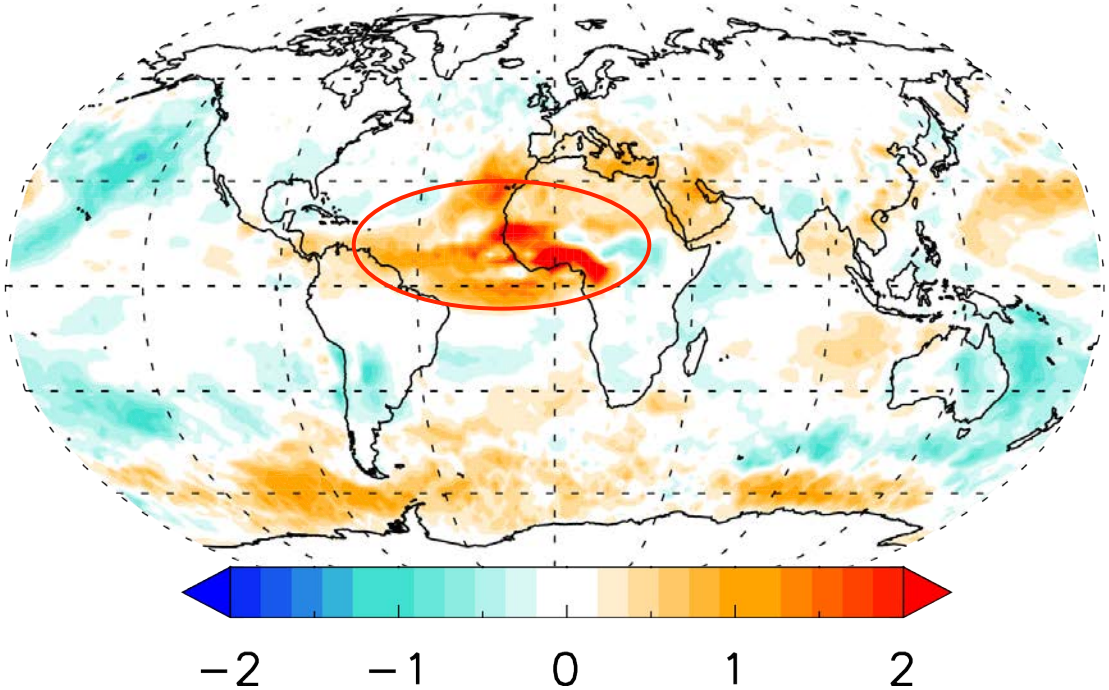
fire aerosol SWF ≡ (all – no fire) aerosol SWF

2005 10-year climatological mean



FEB 2005

10-year climatological mean



[Wm^{-2}] avg: 5.69e-2

Mezuman et al., in preparation (A)

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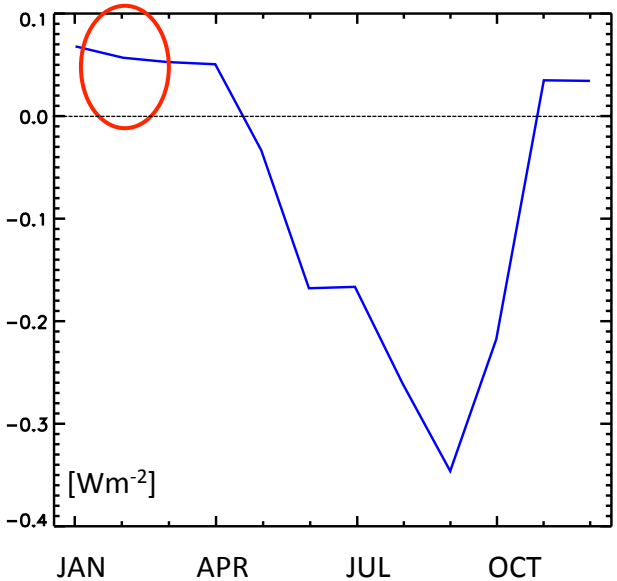
2005 10-year climatological mean



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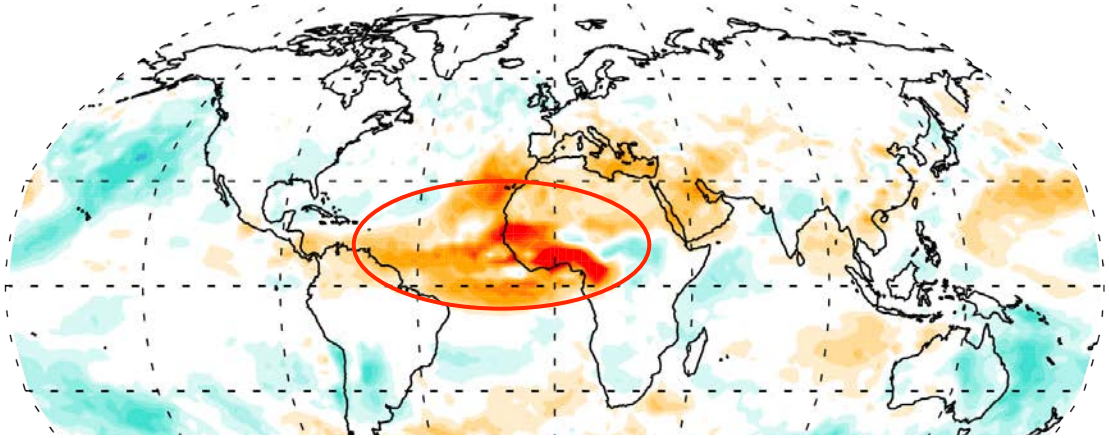
10-year climatological mean



Two things could be at play:

- fire-climate feedbacks
- natural variability

➢ Requires further investigation

[Wm^{-2}] avg: 5.69e-2

Mezuman et al., in preparation (A)

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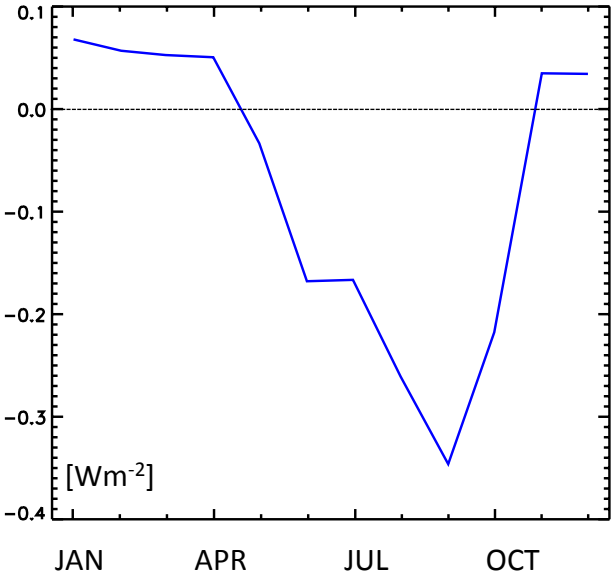
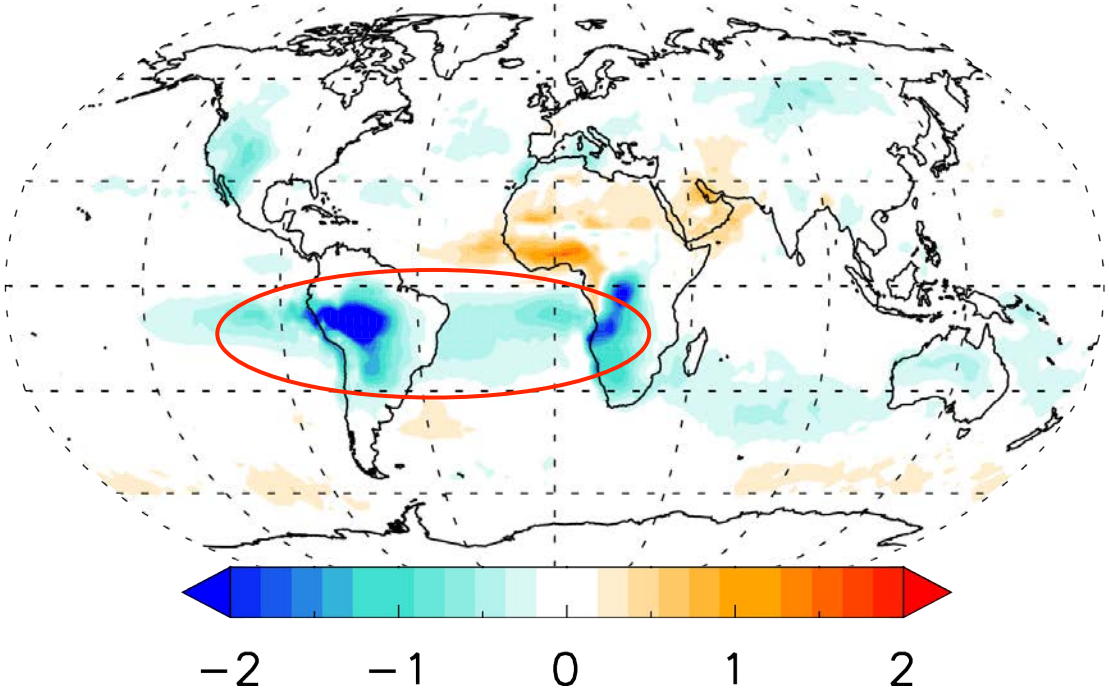


2005
10-year climatological mean



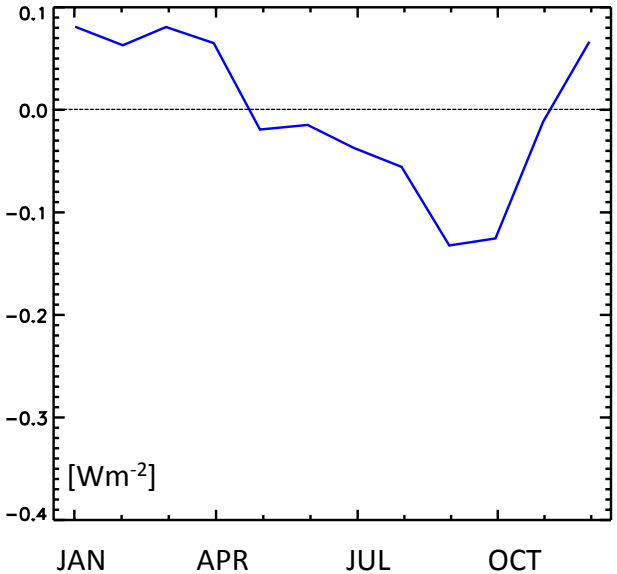
[Wm^{-2}] avg: -7.52e-2

Mezuman et al., in preparation (A)

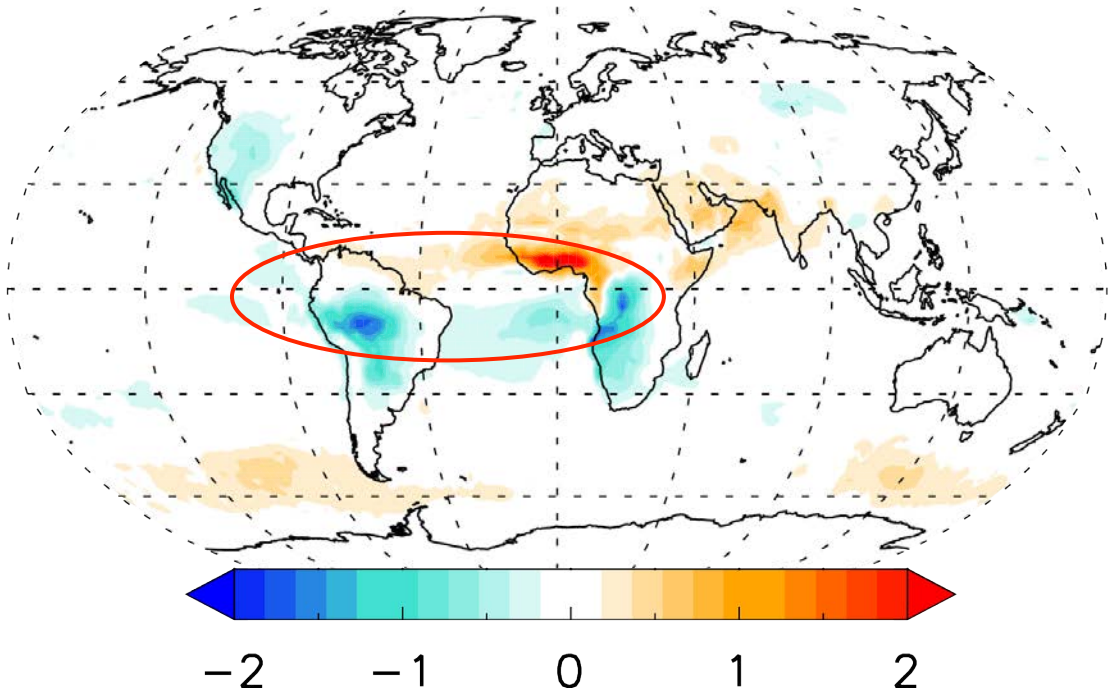
A weaker forcing is observed for the preindustrial along with less fire emissions

fire aerosol SWF ≡ (all – no fire) aerosol SWF

1850 10-year climatological mean



1850
10-year climatological mean



[Wm^{-2}] avg: -3.63e-3

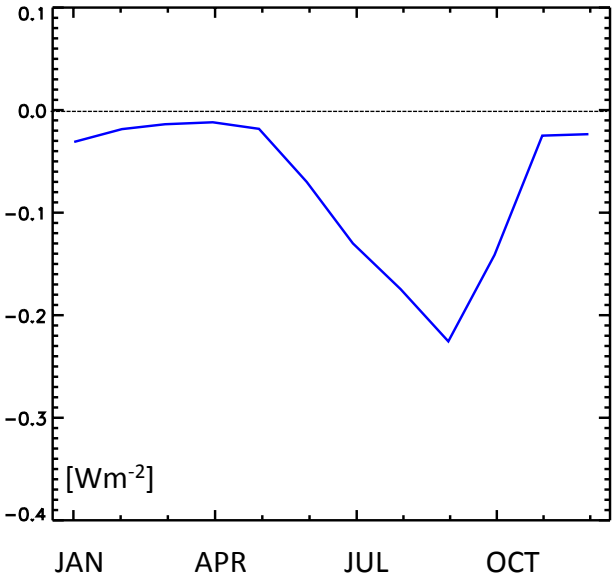
Mezuman et al., in preparation (A)

By excluding the effects of coarse* aerosols a clearer fire signal is observed

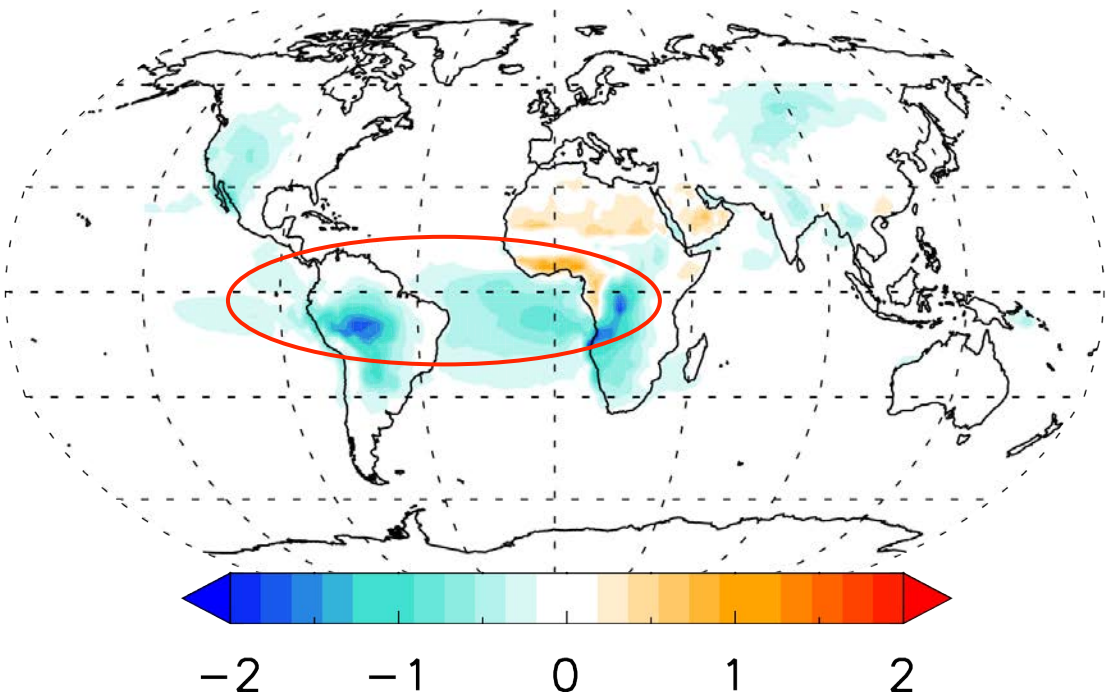
fire aerosol SWF ≡ (all – no fire) aerosol SWF

*excluding mineral dust and sea salt

1850 10-year climatological mean



1850
10-year climatological mean



[Wm^{-2}] avg: -7.39e-2

Mezuman et al., in preparation (A)

Conclusions

- Fire pollution is substantial in PI, PD and future
  - strongest in the tropics
- Overall fire aerosols cool the climate (PD mean SWF -0.075 Wm^{-2})
- To a first degree this is controlled by BB emissions
  - Seasonality
  - Magnitude (smaller emissions and SWF in PI)
- Complex effects at play need further study:
  - fire-climate feedbacks
  - natural variability