Historical aerosol emissions

Brian I. Magi and Vaishali Naik

8th AeroCom Workshop, NOAA GFDL

5 October 2009

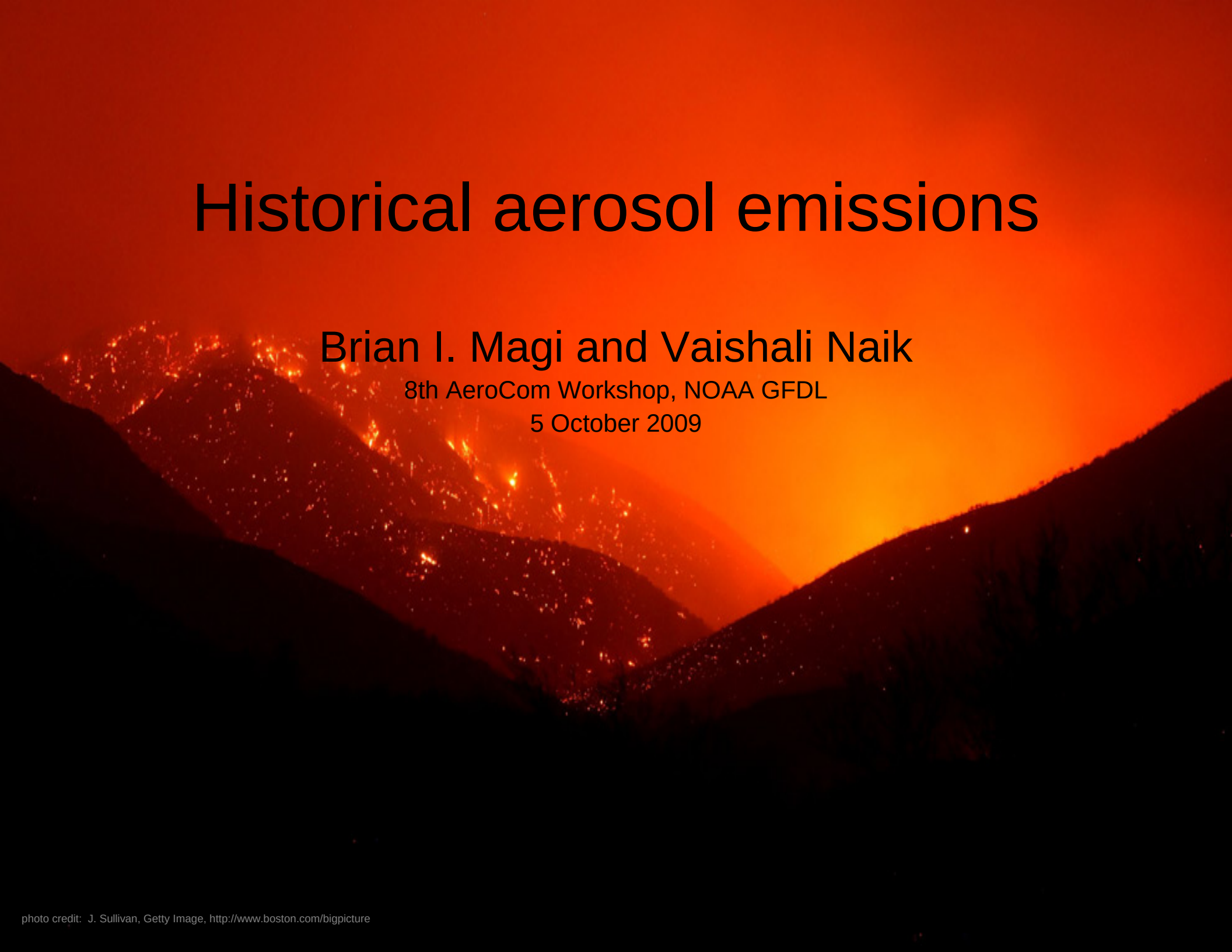

photo credit: J. Sullivan, Getty Image, http://www.boston.com/bigpicture

IPCC AR5 Emissions Inventories

included*	not included
biomass burning**	volcanos***
anthropogenic	SOA
ship	natural
aircraft	sea salt
	dust

** 0.5x0.5 spatial resolution, monthly temporal resolution for every decade from 1850-2000*
*** decades from 1850-1900 are equivalent*
**** more about volcanos in next talk*

Overall Historical Emissions Development (in alphabetical order):

Tami Bond, Janusz Cofala, Veronika Eyring, Claire Granier, Angelika Heil, Mikiko Kainuma, Zbigniew Klimont, Jean-Francois Lamarque, David Lee, Catherine Liousse, Aude Mieville, Keywan Riahi, Martin Schultz, Steven J Smith, David Stevenson, and John Van Aardenne

Grassland and forest fire emissions:

For the "year 2000" climatology please refer to the following publication:
Van der Werf, G., J. T. Randerson, L. Giglio, G. J. Collatz, P. S. Kasibhatla, and A. F. Arellano Jr. (2006), Interannual variability in global biomass burning emissions from 1997 to 2004, Atmos. Chem. Phys., 6, 3423-3441.

For the 1960-2000 RETRO inventory use:
Schultz, M.G., A. Heil, J.J. Hoelzemann, A. Spessa, K. Thonicke, J. Goldammer, A.C. Held, J.M. Pereira, M. van het Bolscher (2008), Global Wildland Fire Emissions from 1960 to 2000, Global Biogeochem. Cyc., doi:10.1029/2007GB003031.

The reference for the 1850-1960 period is the following:
Mieville, A., C. Granier, C. Liousse, B. Guillaume, F. Mouillot, J.F. Lamarque, J.M. Grégoire, G. Pétron (2009), Emissions of gases and particles from biomass burning during the 20th century using satellite data and an historical reconstruction, Atmospheric Environment, submitted.

International shipping emissions:

Buhaug, Ø., J. J. Corbett, Ø. Endresen, V. Eyring, J. Faber, S. Hanayama, D. S. Lee, D. Lee, H. Lindstad, A.Z. Markowska, A. Mjelde, D. Nelissen, J. Nilsen, C. Pålsson, J. J. Winebrake, W.¬Q. Wu, and K. Yoshida, Second IMO GHG study 2009; International Maritime Organization (IMO) London, UK, March, 2009.

Eyring, V., I. S. A. Isaksen, T. Berntsen, W. J. Collins, J. J. Corbett, O. Endresen, R. G. Grainger, J. Moldanova, H. Schlager, and D. S. Stevenson, Transport impacts on atmosphere and climate: Shipping, Atm. Env., doi:10.1016/j.atmosenv.2009.04.059, 2009.

Aviation emissions:

Lee et al. (2009) in preparation (QUANTIFY Scenarios), Developed from the approach of Lee, D.S., et al., Aviation and global climate change in the 21st century, Atmospheric Environment (2009), doi:10.1016/j.atmosenv.2009.04.024

For historical and year 2000 sulfur emissions of other anthropogenic emissions sectors:

Smith et al. (2009) in preparation; updated from Smith, Steven J., Pitcher, H., and Wigley, T.M.L. (2001) Global and Regional Anthropogenic Sulfur Dioxide Emissions. Global and Planetary Change 29/1-2, pp 99-119 Smith, Steven J, Robert Andres, Elvira Conception and Josh Lurz (2004) Sulfur Dioxide Emissions: 1850-2000 (JGCRI Report. PNNL-14537).

For historical and year 2000 black and organic carbon emissions of other anthropogenic emissions sectors:

Updated from: Bond, T.C., E. Bhardwaj, R. Dong, R. Jogani, S. Jung, C. Roden, D.G. Streets, S. Fernandes, and N. Trautmann (2007), Historical emissions of black and organic carbon aerosol from energy-related combustion, 1850-2000, Glob. Biogeochem. Cyc., 21, GB2018, doi:10.1029/2006GB002840, with new emissions factors developed in collaboration with C. Liousse

Outline

1. Biomass burning emissions
2. Anthropogenic emissions
3. Comparisons
4. Future emissions

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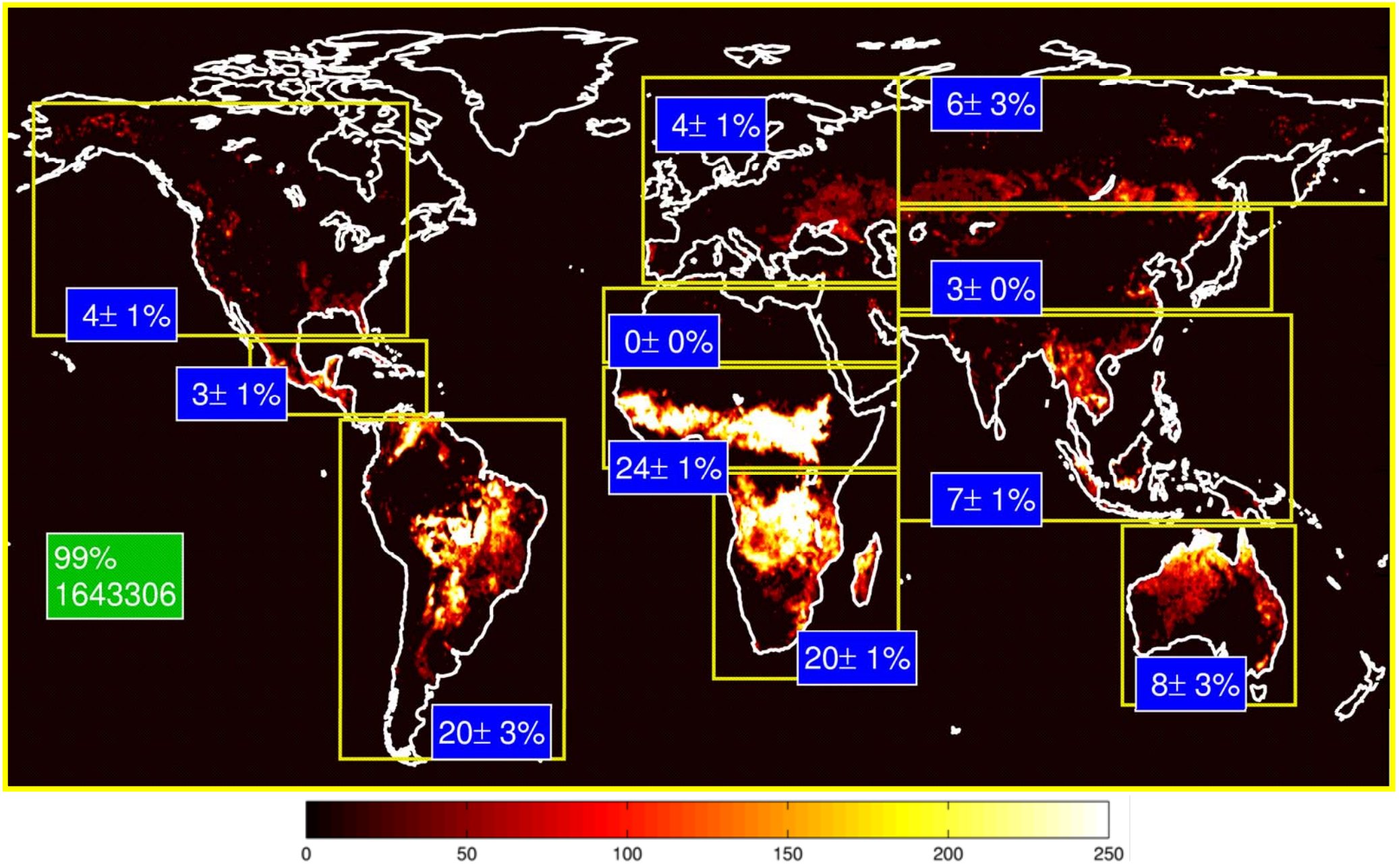
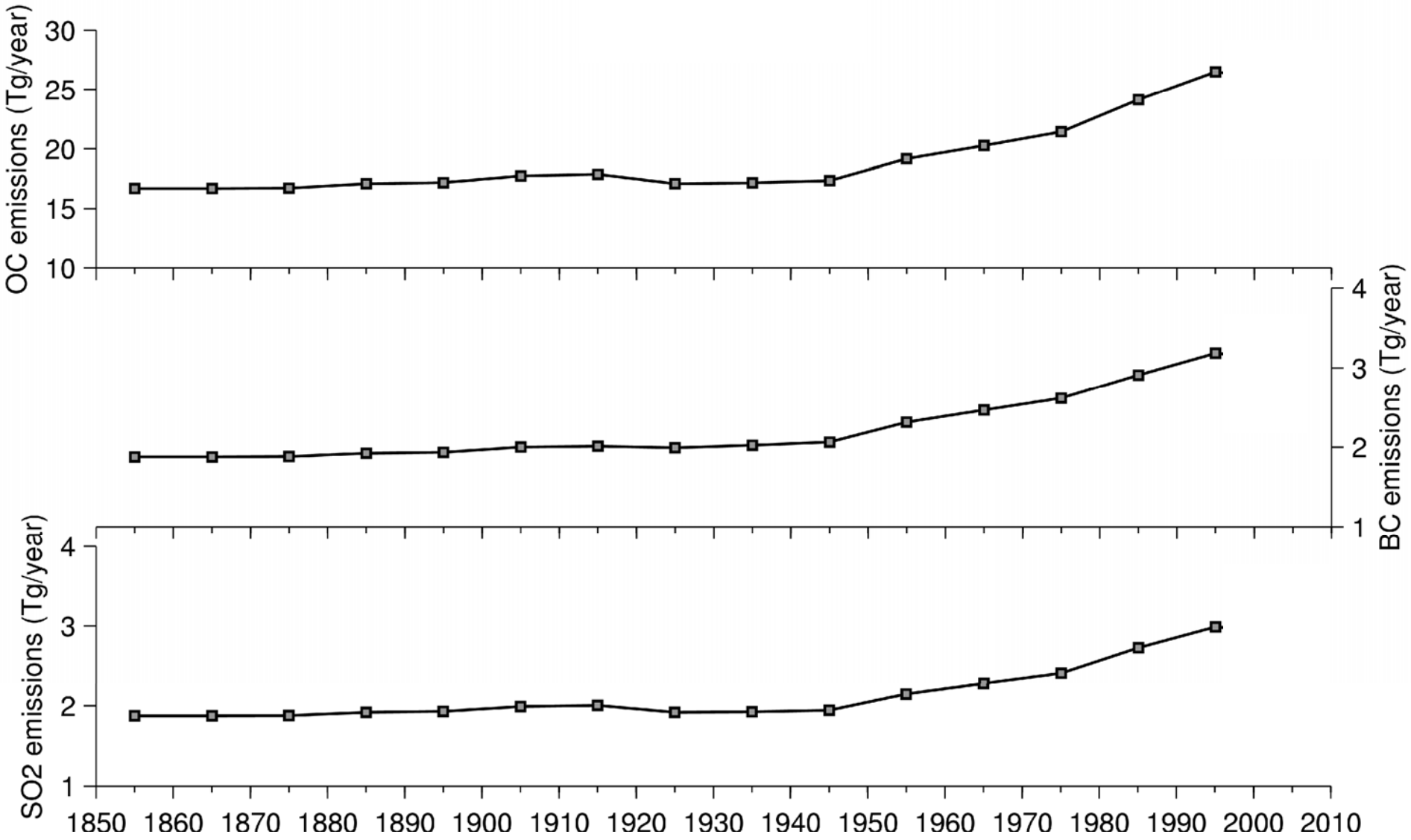
Fire Counts



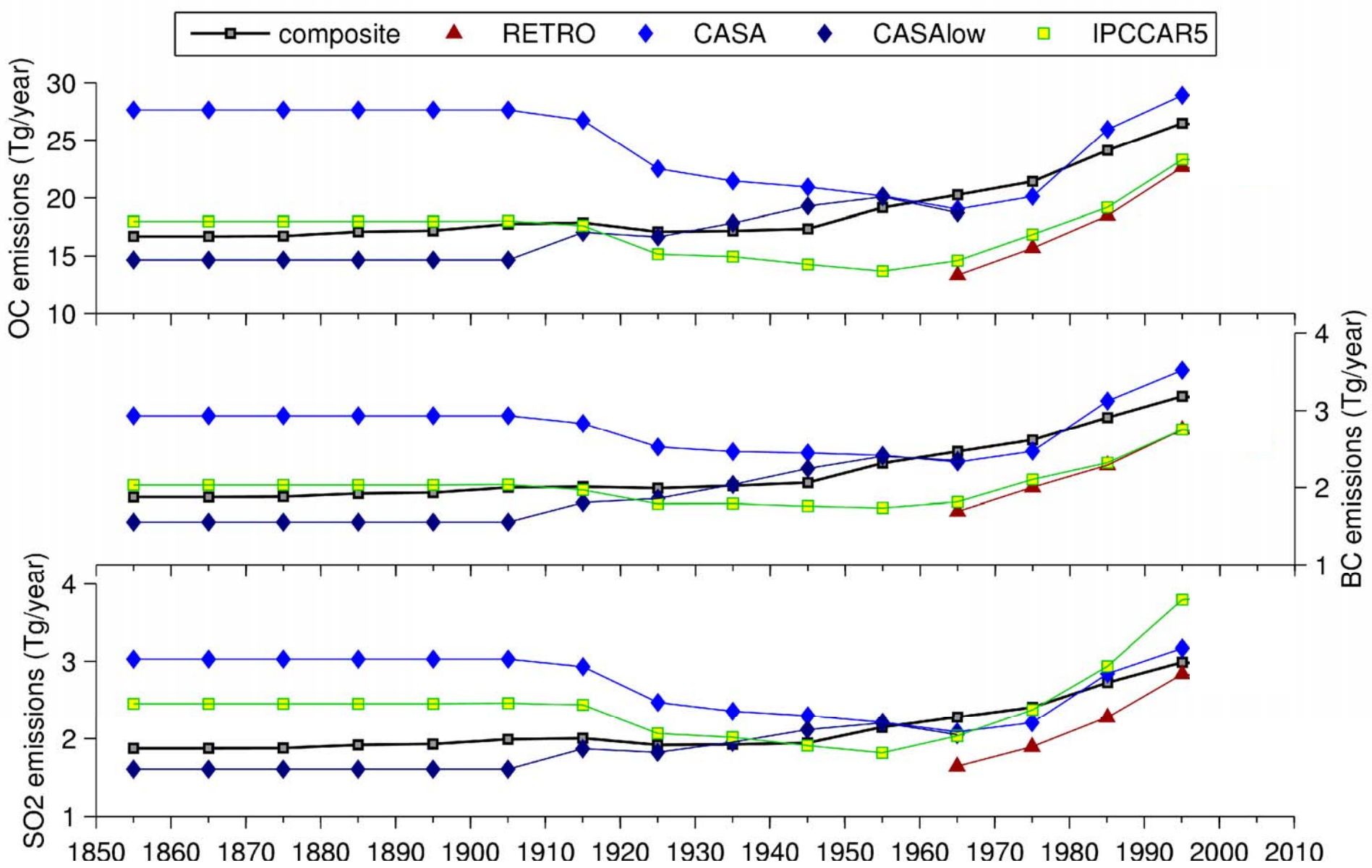
Data source: MODIS Collection 5 Fire Product (Giglio et al., *J. Geophys. Res*., 2006)

IPCC AR5 Biomass Burning Emissions Methodology



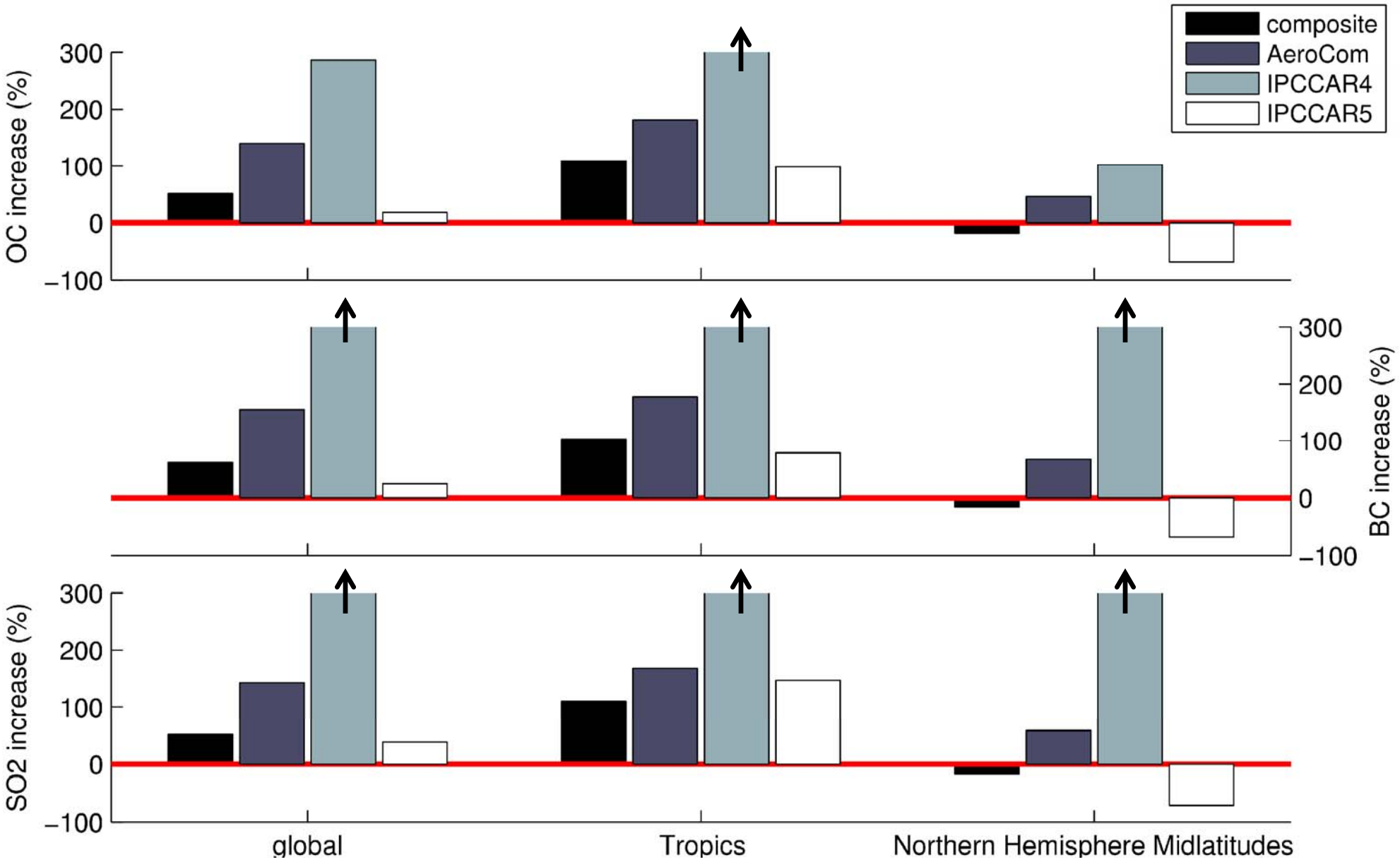
References: **GFEDv2**, van der Werf et al. (2006); **RETRO**, Schultz et al. (2008); **CASA**, Mouillot et al. (2006); **ito**, Ito and Penner (2005)

IPCC AR5 Biomass Burning Emissions Methodology



References: RETRO, Schultz et al. (2008); CASA, Mouillot et al. (2006)

Increase in Biomass Burning Emissions since Preindustrial



1. Biomass burning emissions
2. Anthropogenic emissions
3. Comparisons
4. Future emissions

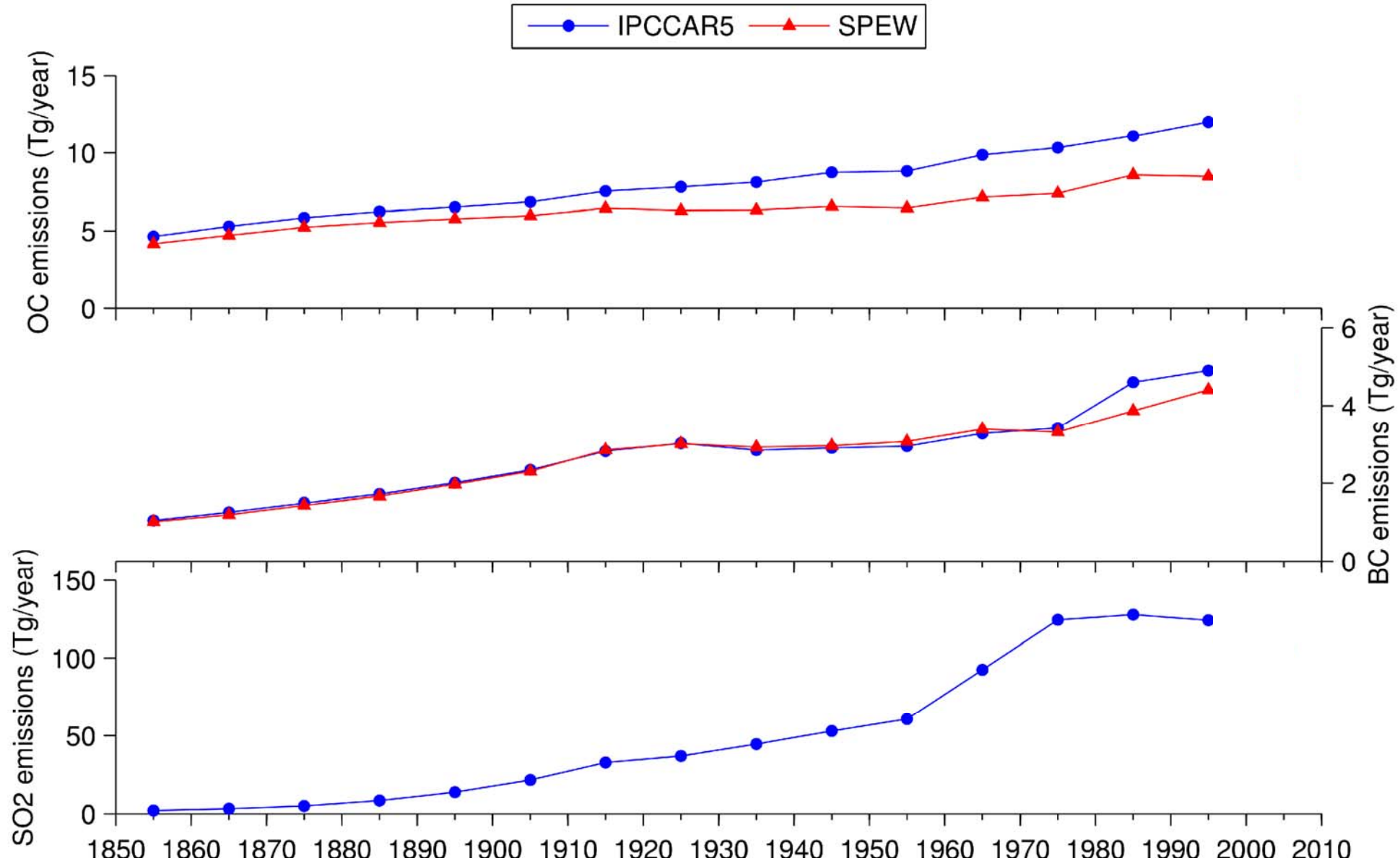
photo credit: Guang Nu, Getty Image, http://www.boston.com/bigpicture

Anthropogenic Emissions Sectors

1. **agricultural waste sector** – open burning of agricultural residue and animal waste
2. **domestic sector** – biofuels transitioning to fossil fuels (fuel and energy as sub-categories)
3. **energy sector** – biofuels for heating, mostly fossil fuels from power generation
4. **industrial sector** – steel and iron production using coal-boilers, coking ovens with changing efficiencies
5. **transportation sector** – car and train emissions; ships and aircraft in other categories
6. **waste treatment sector** – open burning of domestic waste (in landfills, for example)

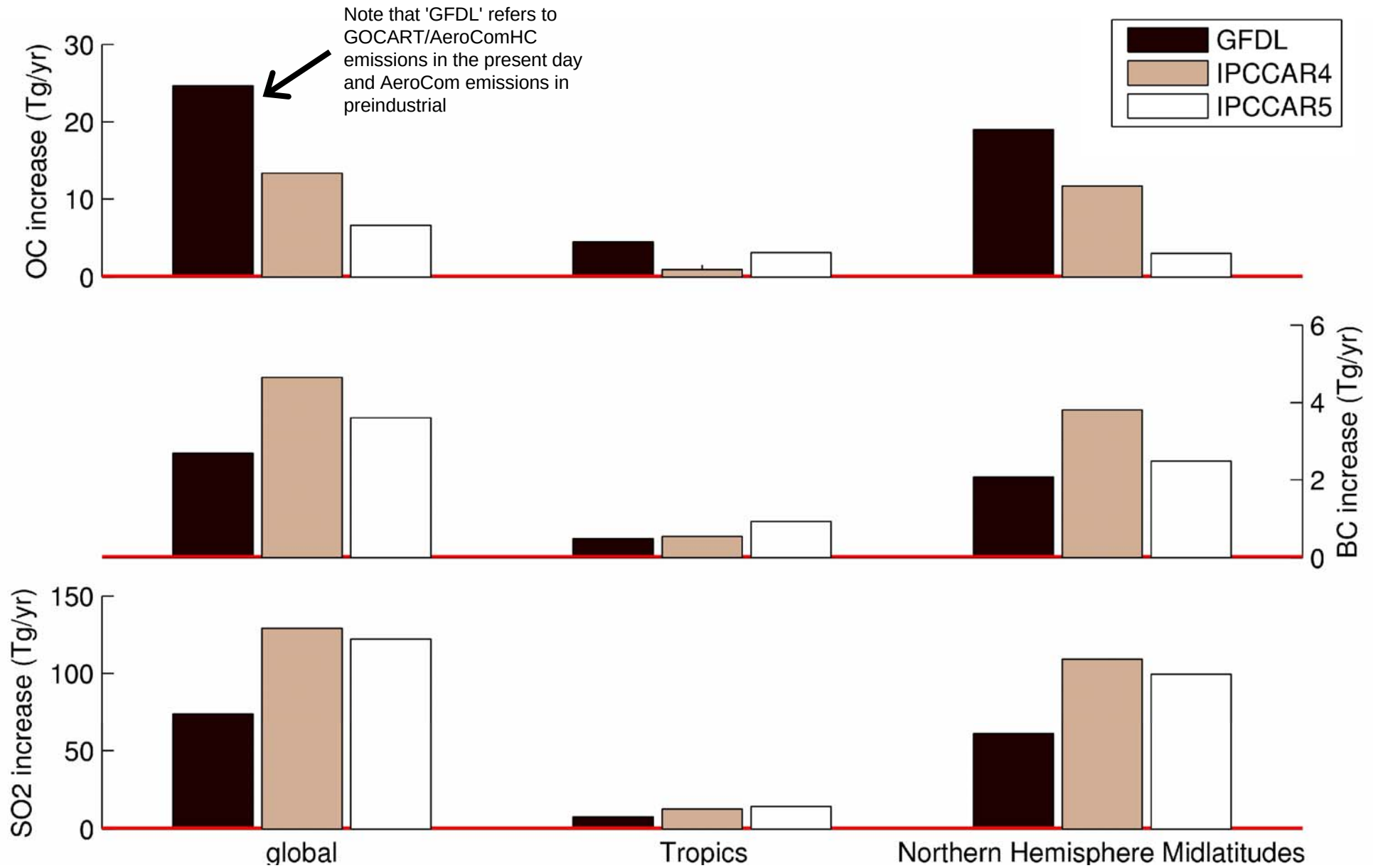
References: Bond et al. (2004); Bond et al. (2007); Fernandes et al. (2007)

IPCC AR5 Anthropogenic Emissions Methodology



References: Bond et al. (2007); Fernandes et al. (2007); SPEW Emissions Inventory available at http://www.hiwater.org/

Increase in Anthropogenic Emissions since Preindustrial



1. Biomass burning emissions
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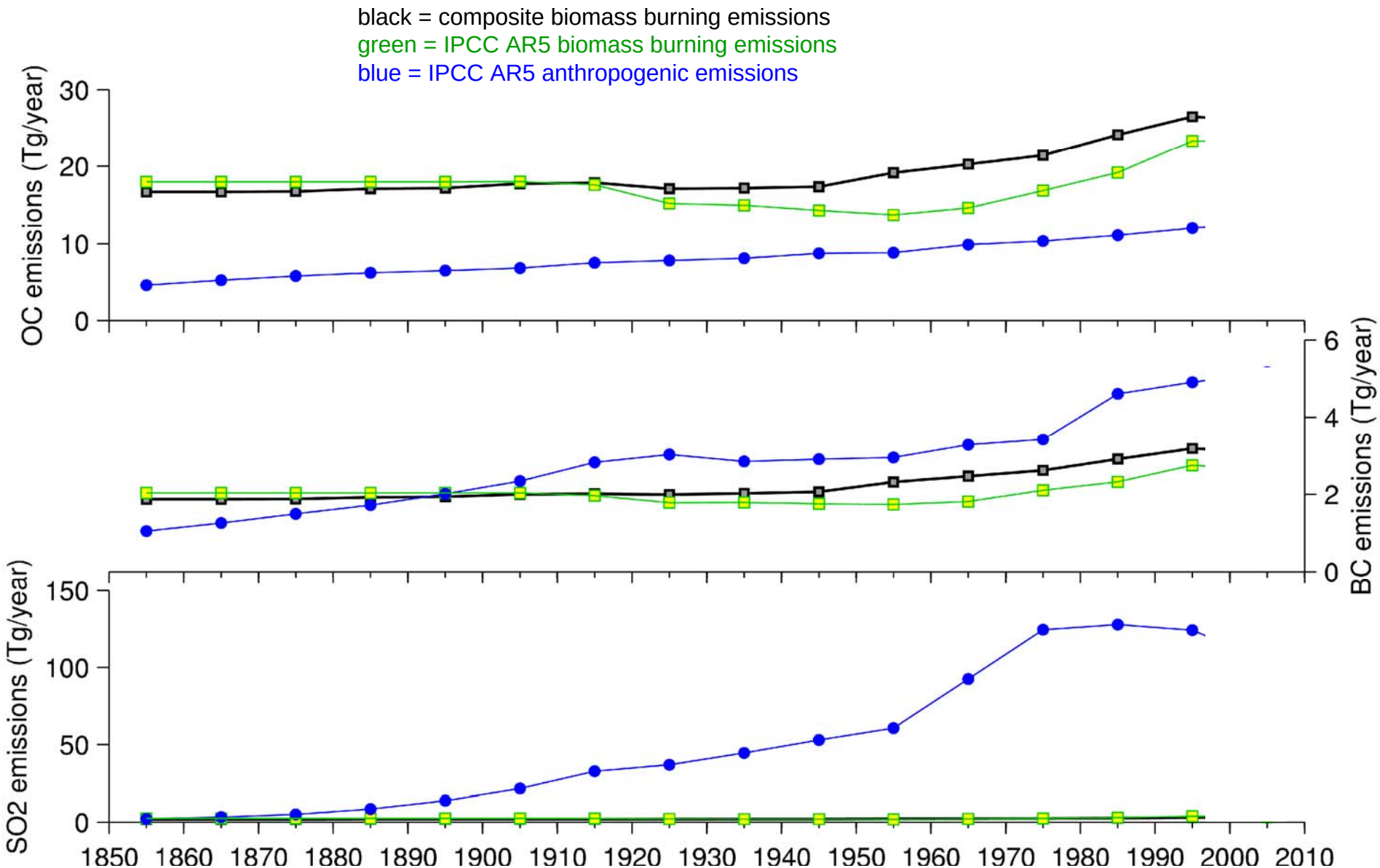
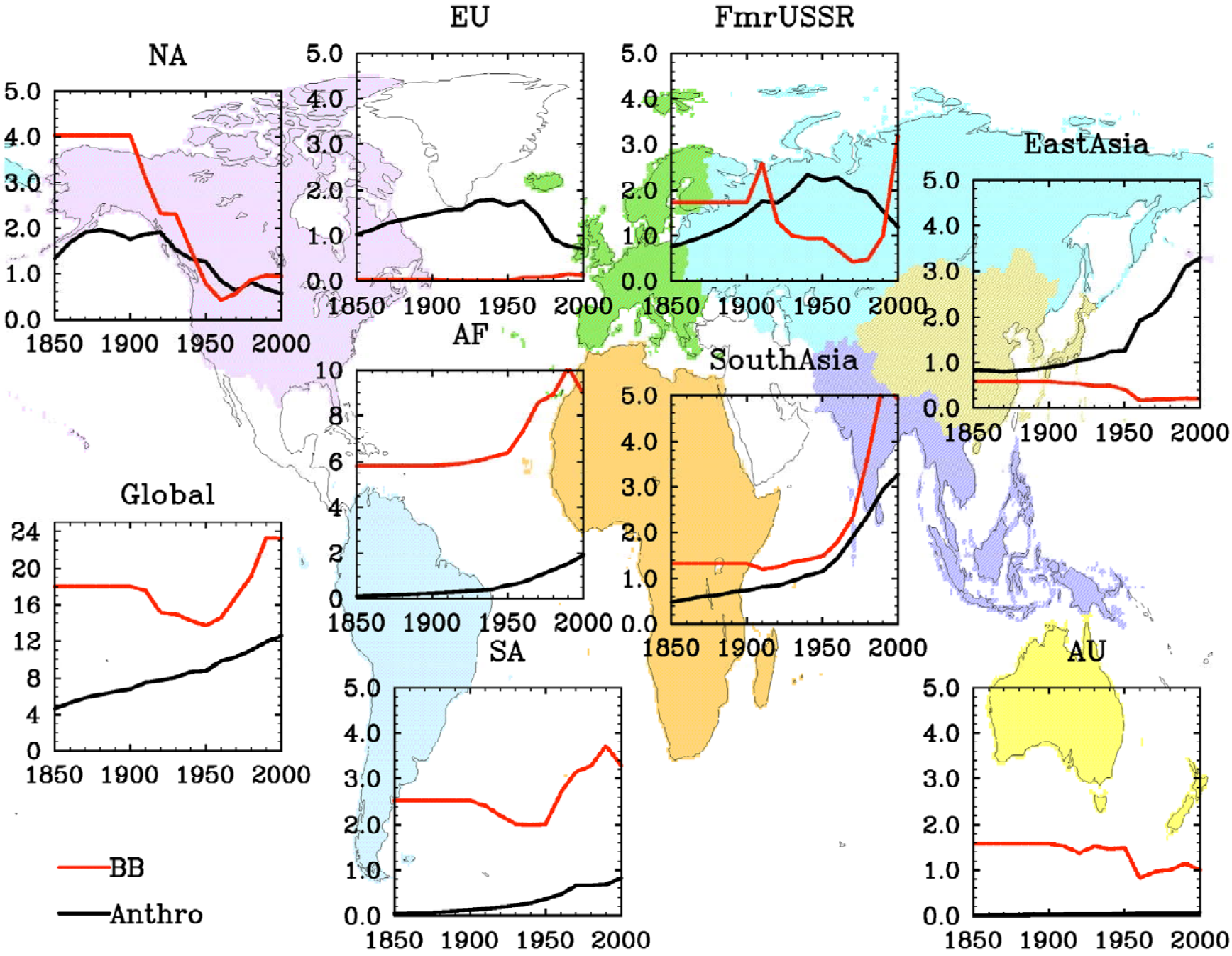
photo credit: Bullit Marquez, AP Photos, http://www.boston.com/bigpicture

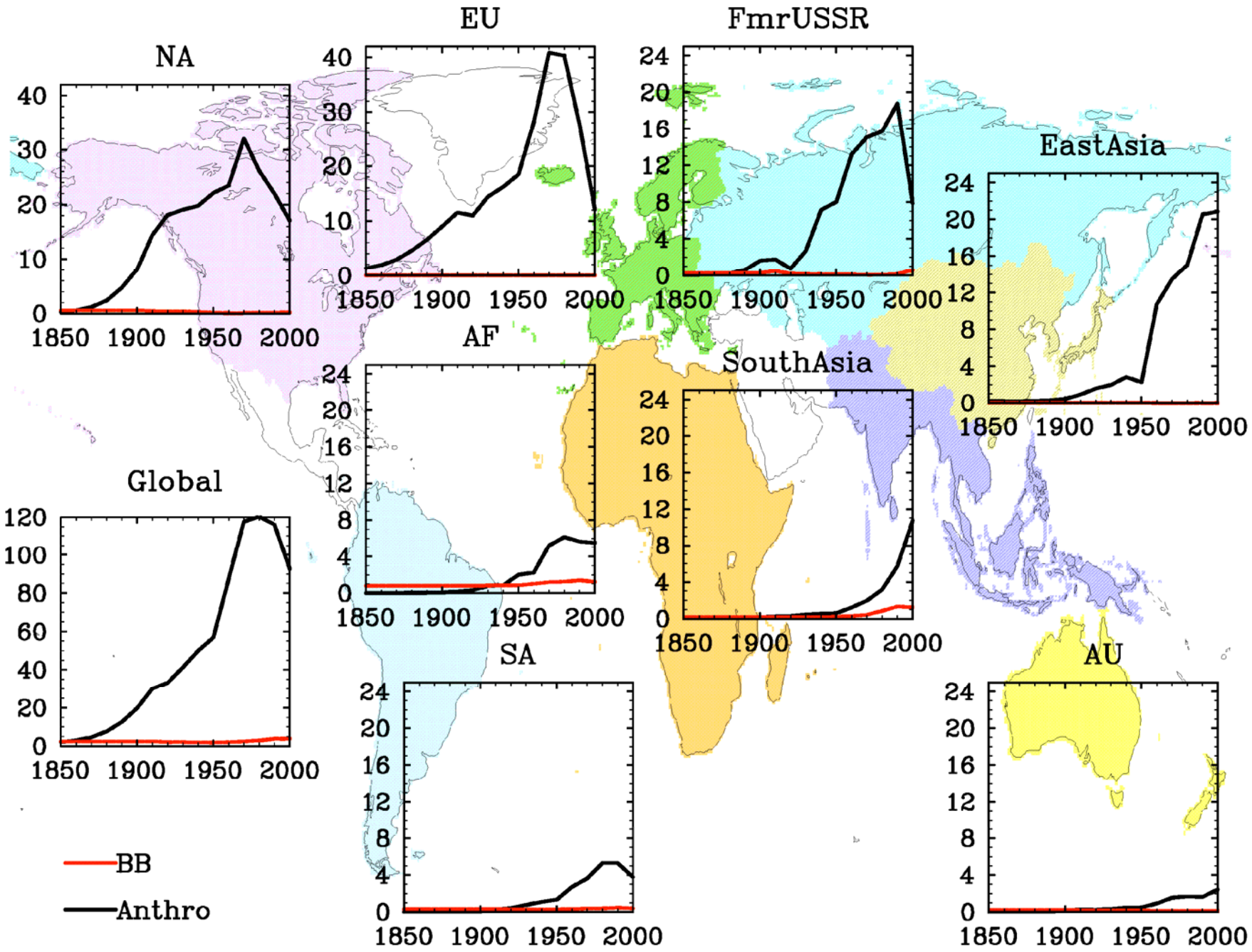
Emissions Summary



Historical trend – IPCC AR5 **OC** Emissions (Tg/yr)



Historical trend – IPCC AR5 SO_2 Emissions (Tg/yr)

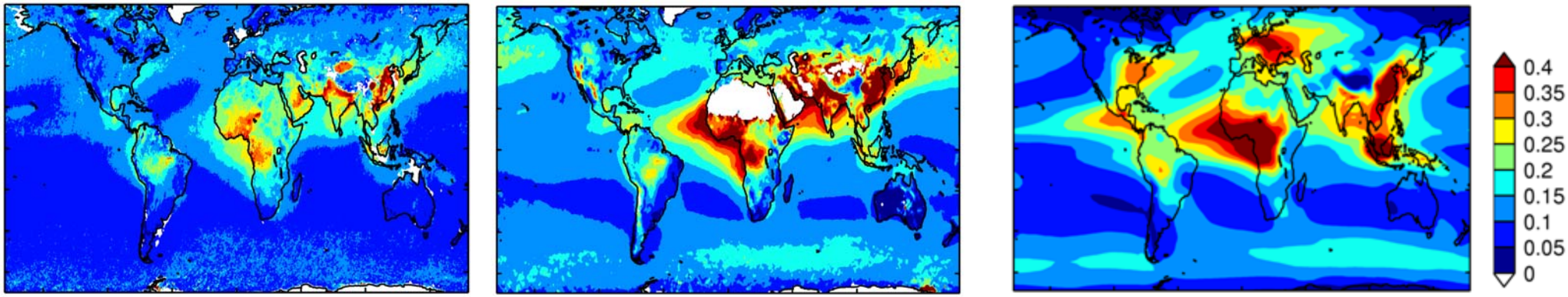


Aerosol Optical Properties

MISR 2000–2009 mean annual AOD550 = 0.12

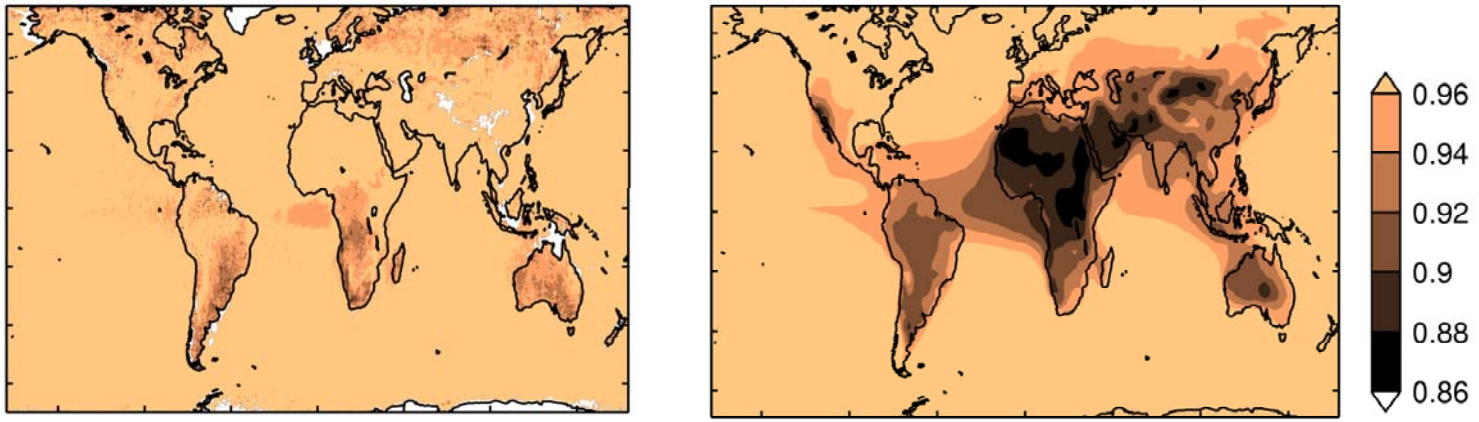
MODIS 2000–2009 mean annual AOD550 = 0.16

GFDL AM3s 1981–2000 mean annual AOD550 = 0.15

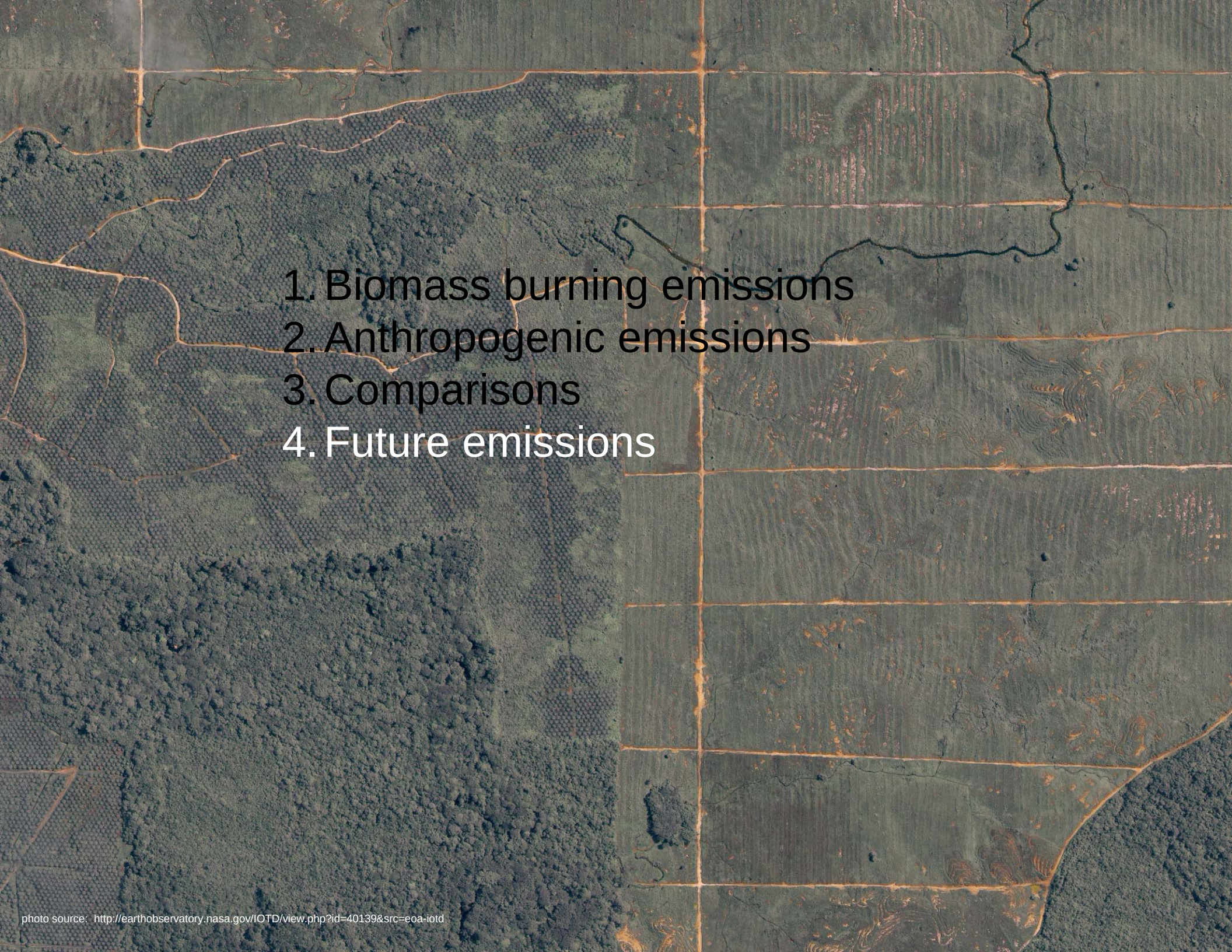


MISR 2000–2009 mean annual SSA550 = 0.97

GFDL AM3s 1981–2000 mean annual SSA550 = 0.97



Data source: MISR Level 3 CGAS F08_0031 product at http://www-misr.jpl.nasa.gov/; MODIS Collection 5 monthly MOD08_M3 product at http://modis.gsfc.nasa.gov/



1. Biomass burning emissions
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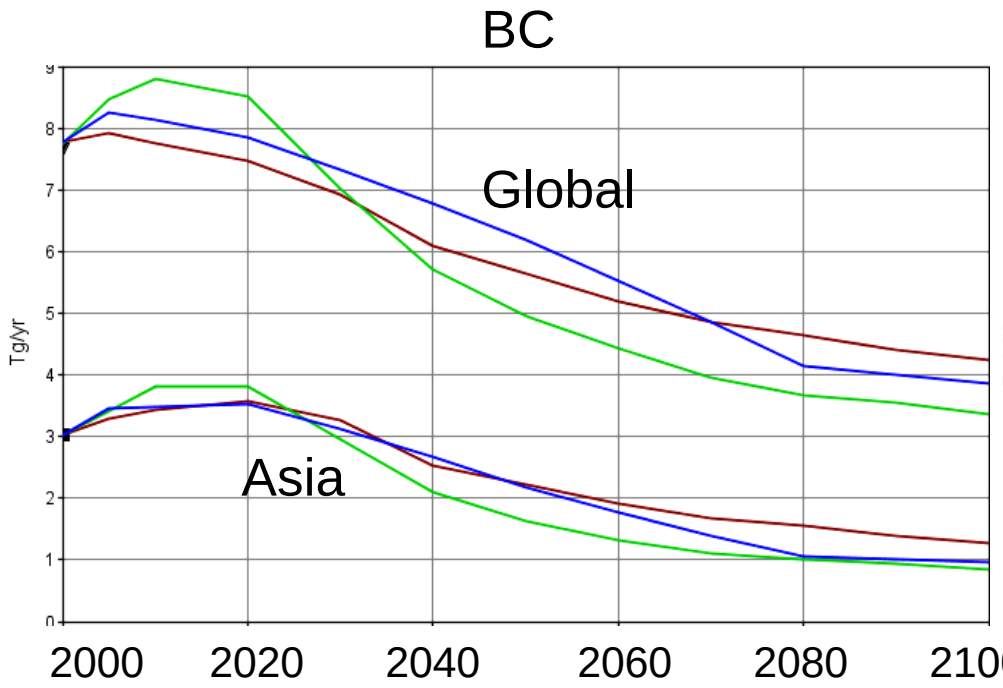
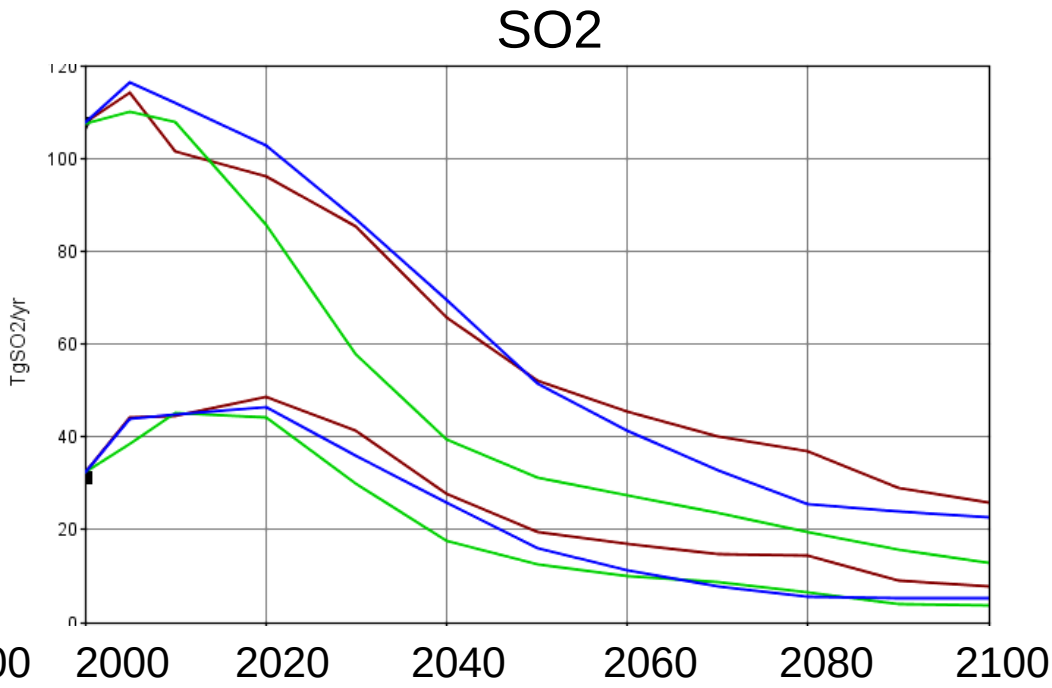
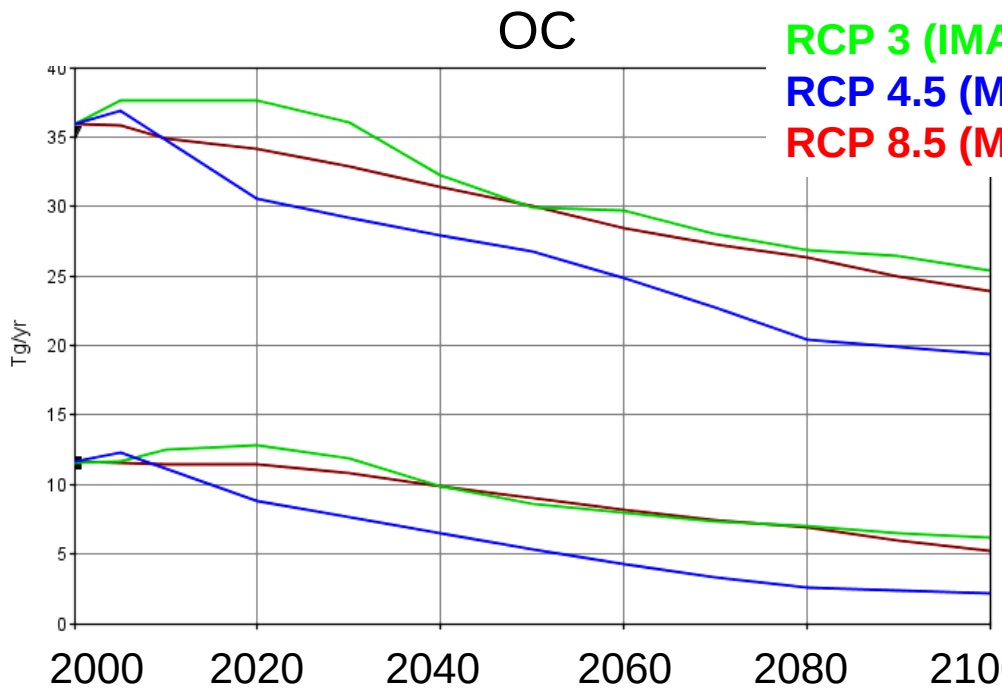
photo source: http://earthobservatory.nasa.gov/IOTD/view.php?id=40139&src=eoa-iotd

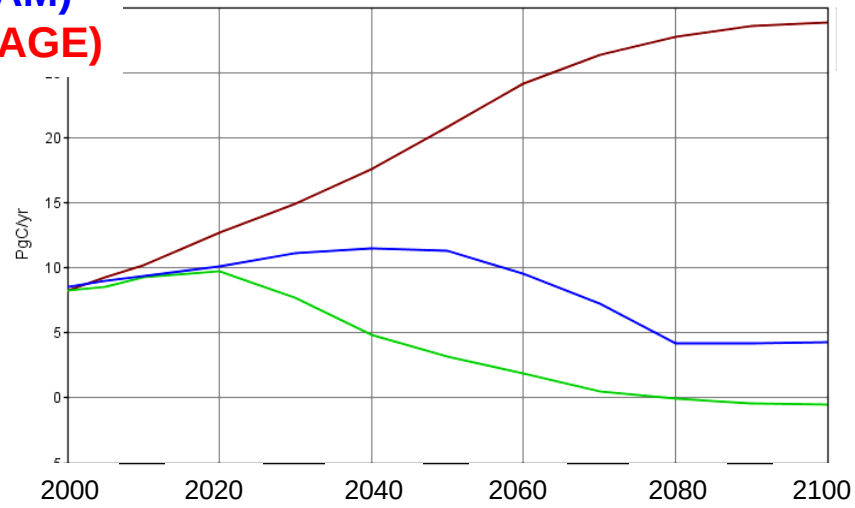
Representative Concentration Pathways (RCPs)





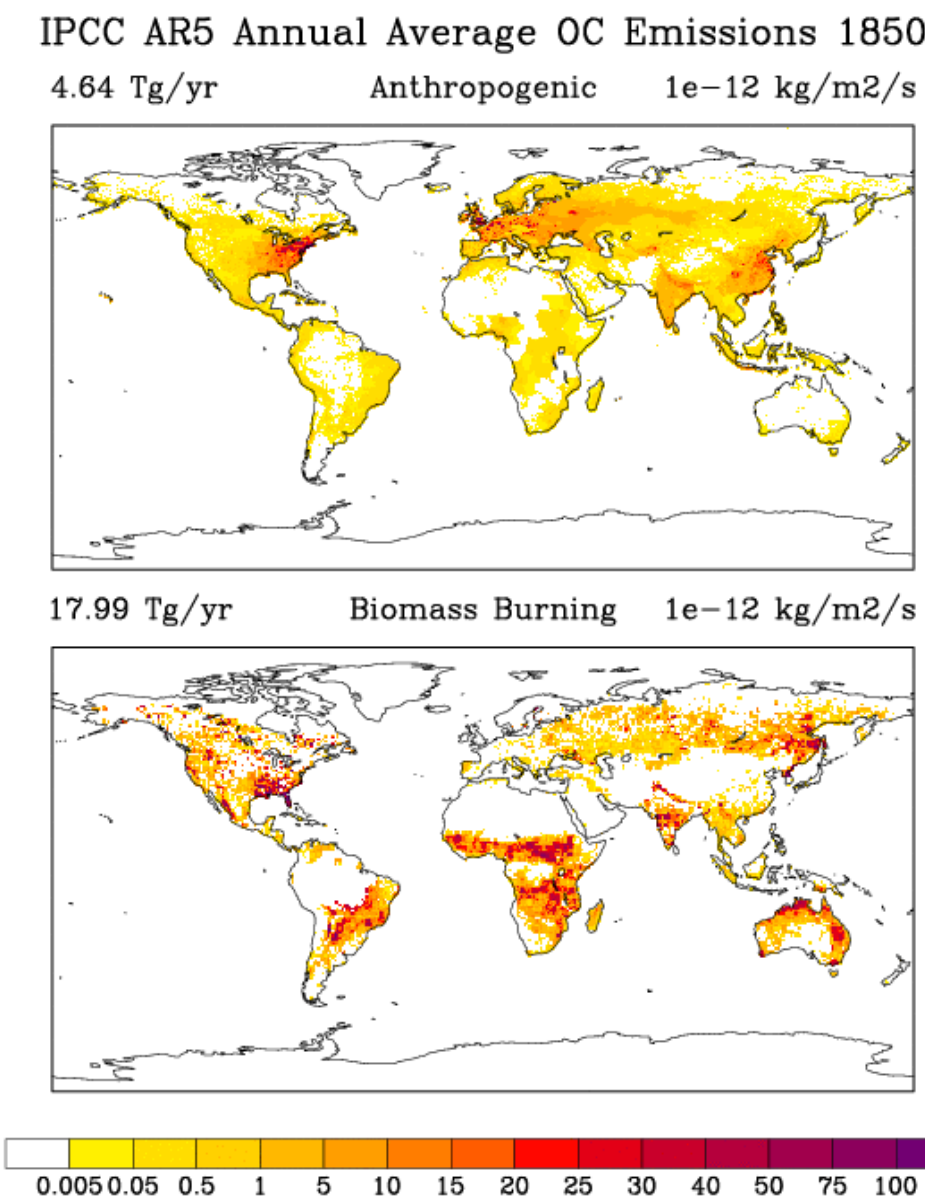


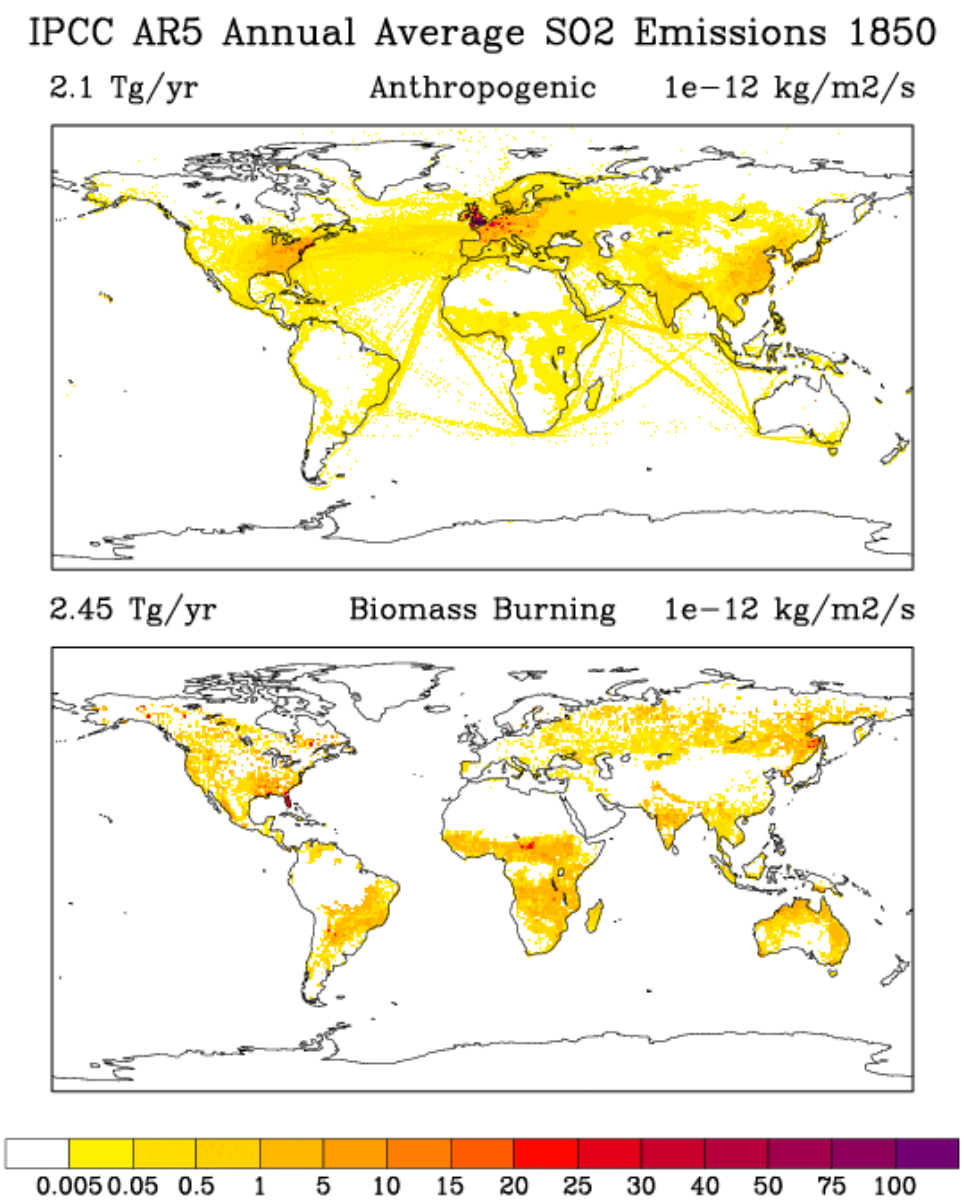
RCP 3 (IMAGE)
RCP 4.5 (MiniCAM)
RCP 8.5 (MESSAGE)



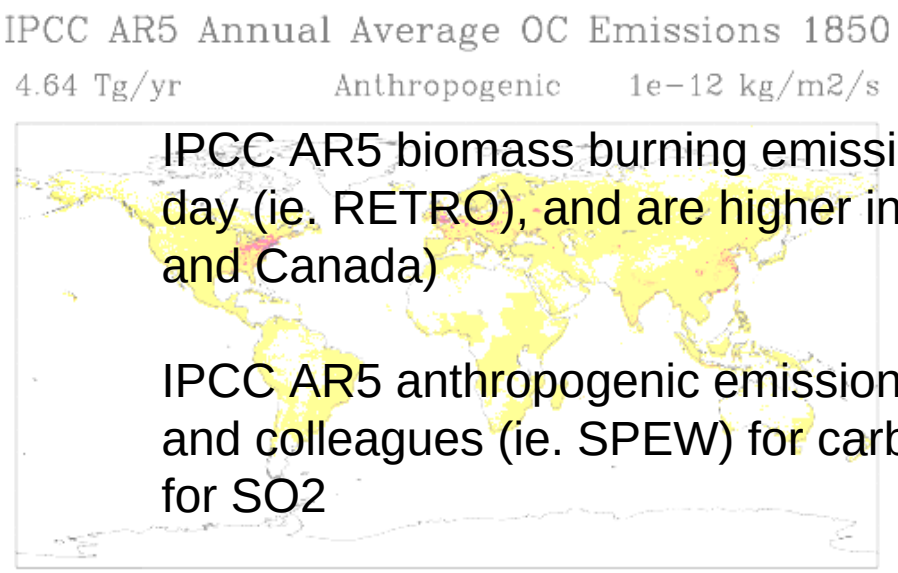
Reference: **http://www.iiasa.ac.at/web-apps/tnt/RcpDb/ (search RCP database in google);** RCP 3, van Vuuren et al. (2007); RCP 4.5, Clarke et al. (2007), Smith and Wigley (2006), Wise et al. (2009); RCP 8.5, Riahl et al. (2007)

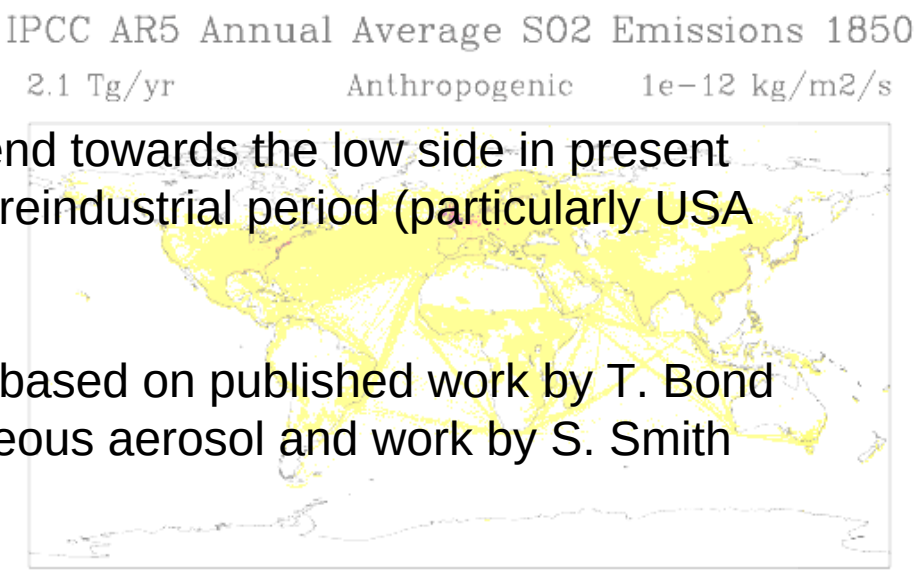
Emissions Animation





Conclusions



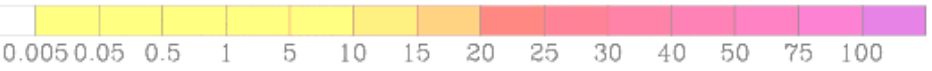


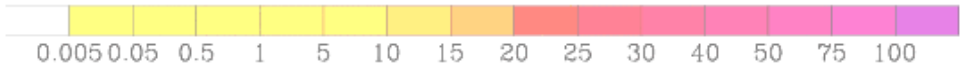
IPCC AR5 biomass burning emissions tend towards the low side in present day (ie. RETRO), and are higher in the preindustrial period (particularly USA and Canada)

IPCC AR5 anthropogenic emissions are based on published work by T. Bond and colleagues (ie. SPEW) for carbonaceous aerosol and work by S. Smith for SO2

For BB and anthro: AeroCom emissions are much lower during preindustrial

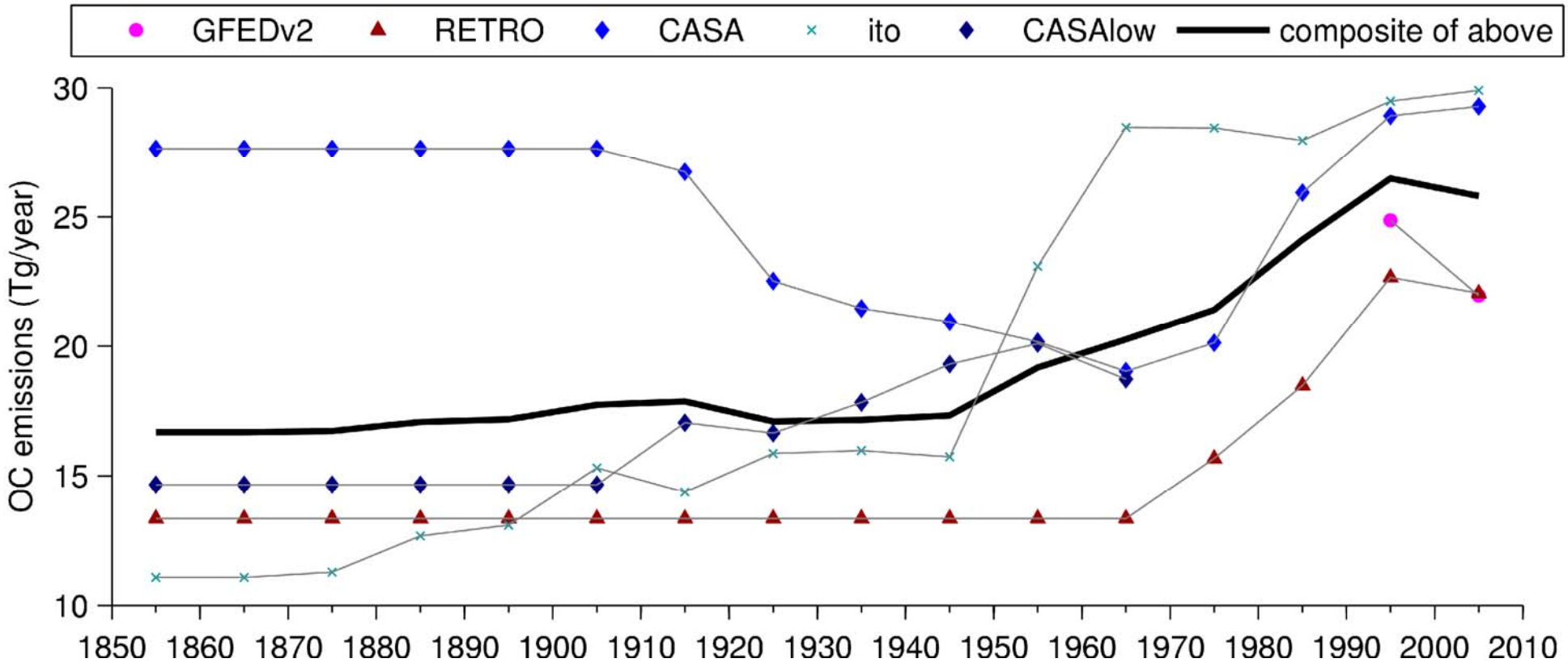
Things IPCC AR5 did not do:
Volcano, natural, SOA emissions
Microphysical properties (size, density)
Chemical properties (refractive indices of BC and BB OC)





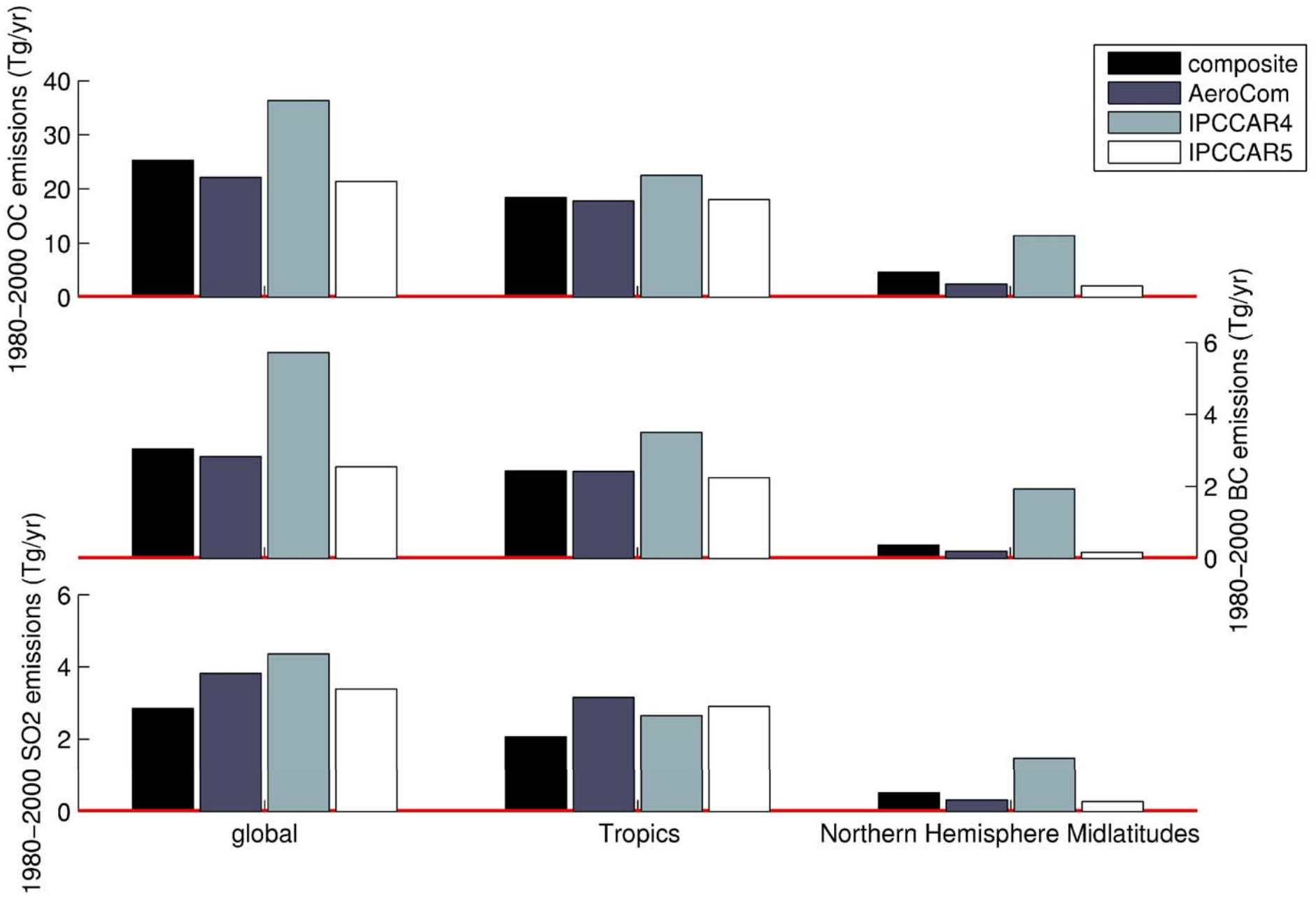
Extra slides

Historical Biomass Burning Emissions Estimates

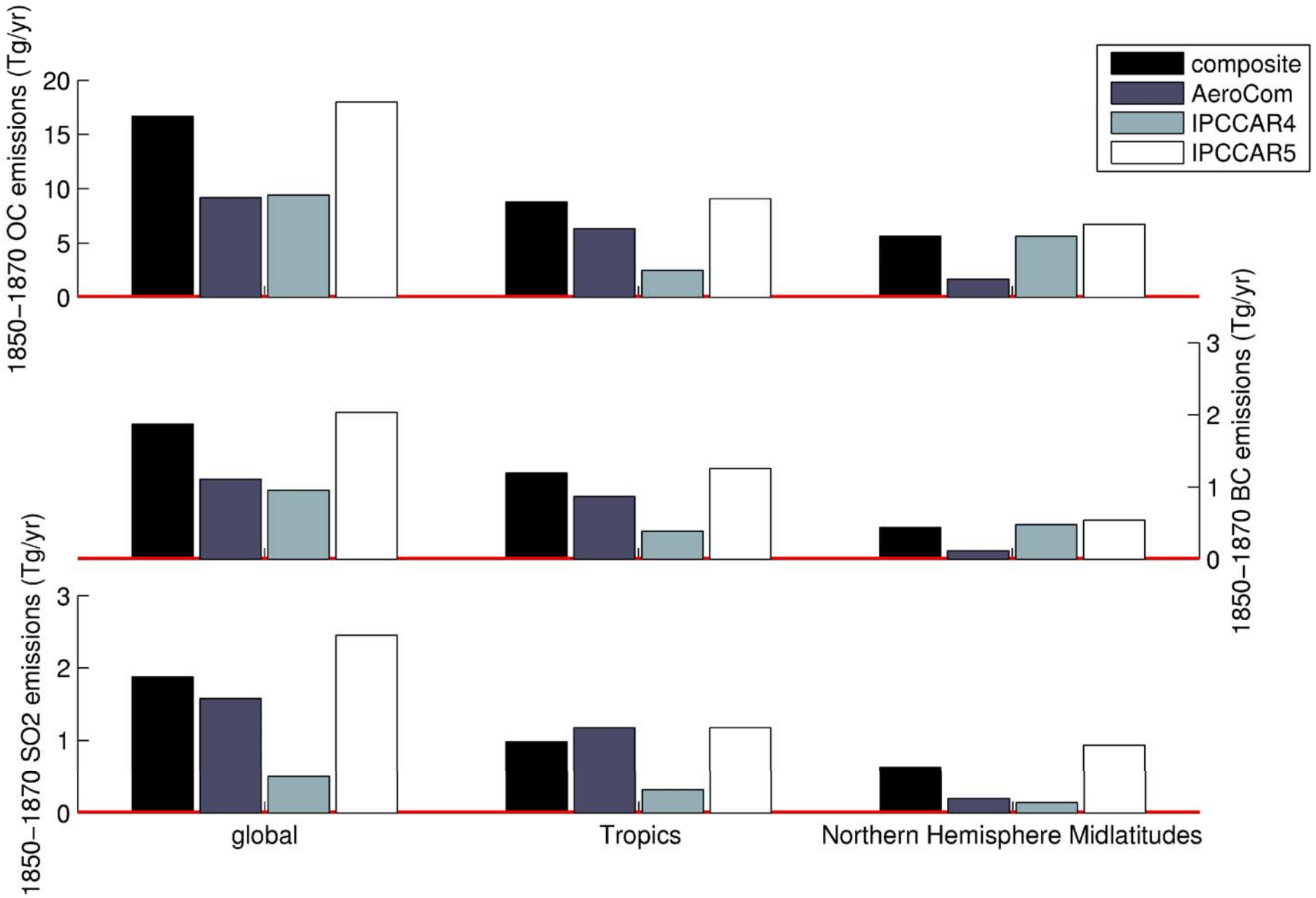


References: GFEDv2, van der Werf et al. (2006); RETRO, Schultz et al. (2008); CASA, Mouillot et al. (2006); ito, Ito and Penner (2005)

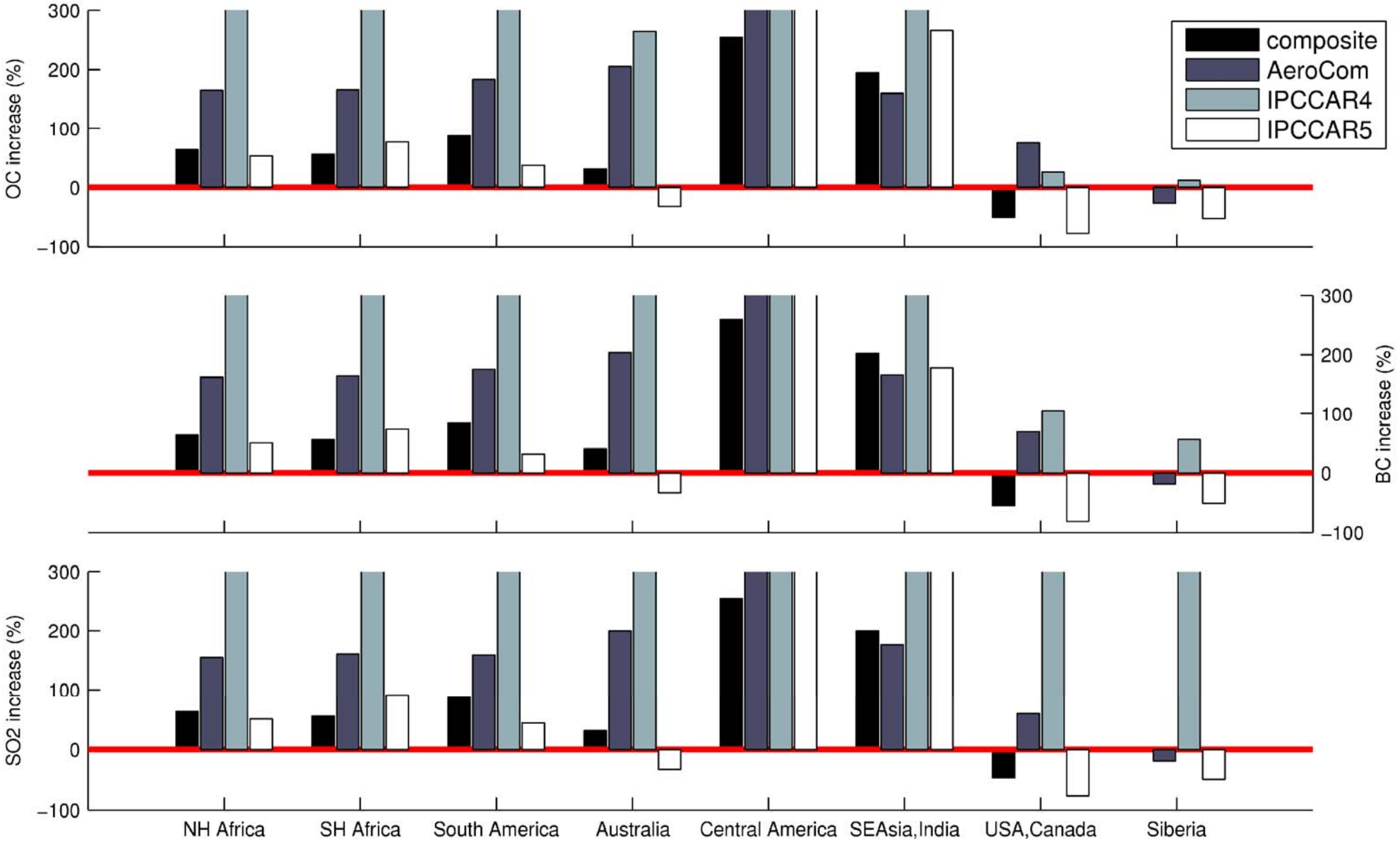
Present Day Biomass Burning Emissions



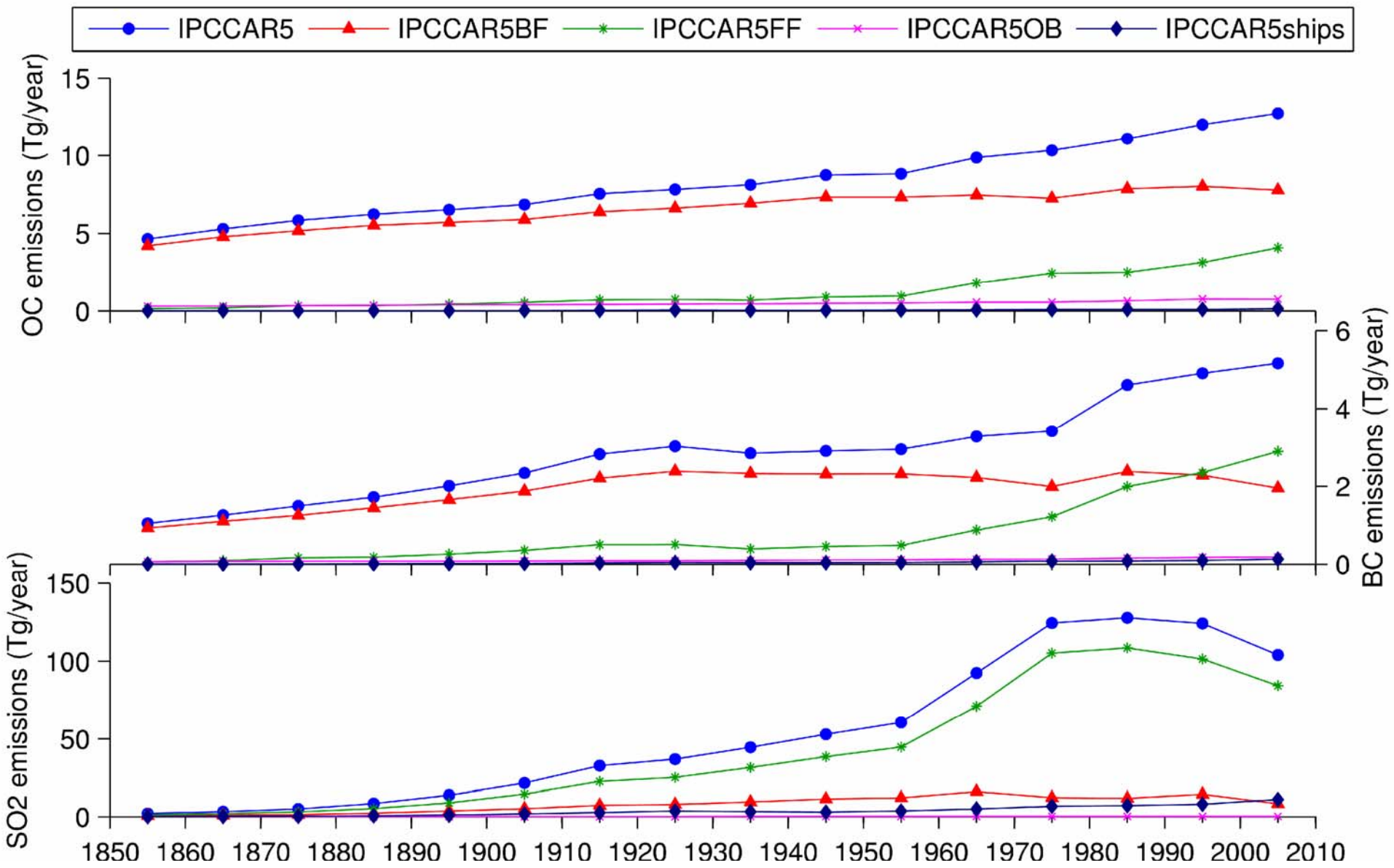
Preindustrial Biomass Burning Emissions



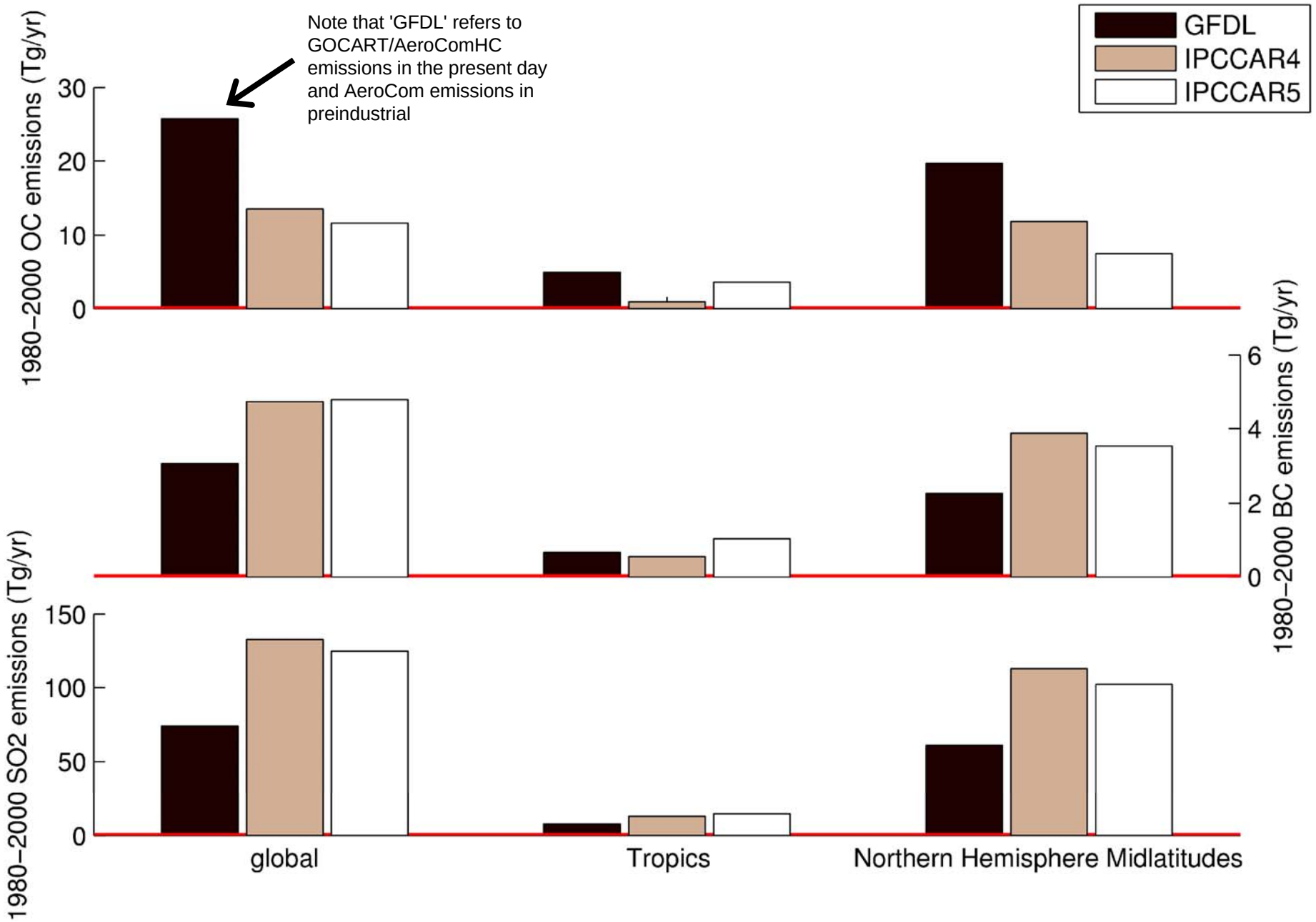
Increase in Biomass Burning Emissions since Preindustrial



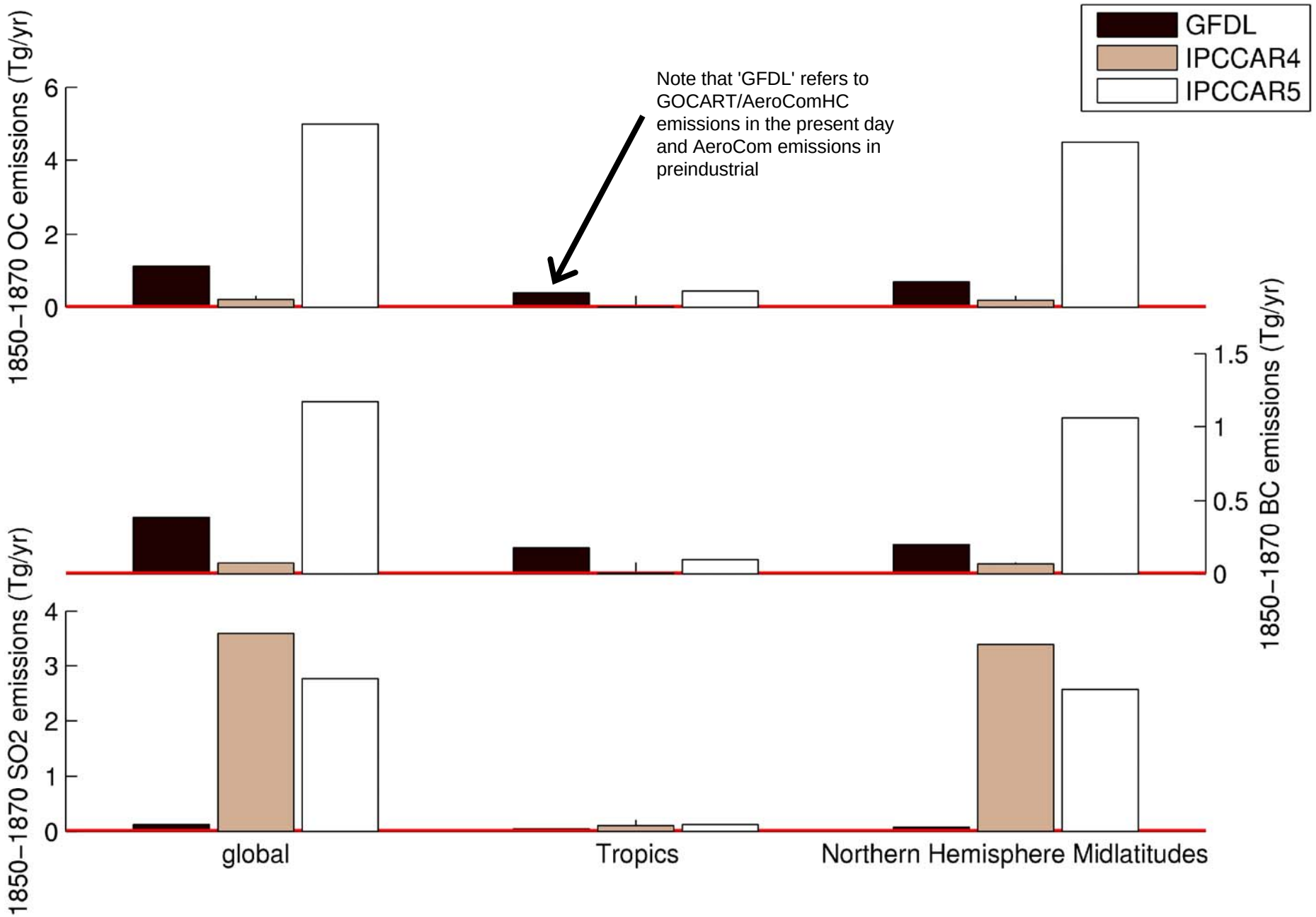
IPCC AR5 Anthropogenic Sectors



Present Day Anthropogenic Emissions



Preindustrial Anthropogenic Emissions



Historical Trend – IPCC AR5 **BC** Emissions (Tg/yr)