Linking in situ radical observations to pollution production in megacities

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Workshop on a Pilot Design for Air Quality in Africa

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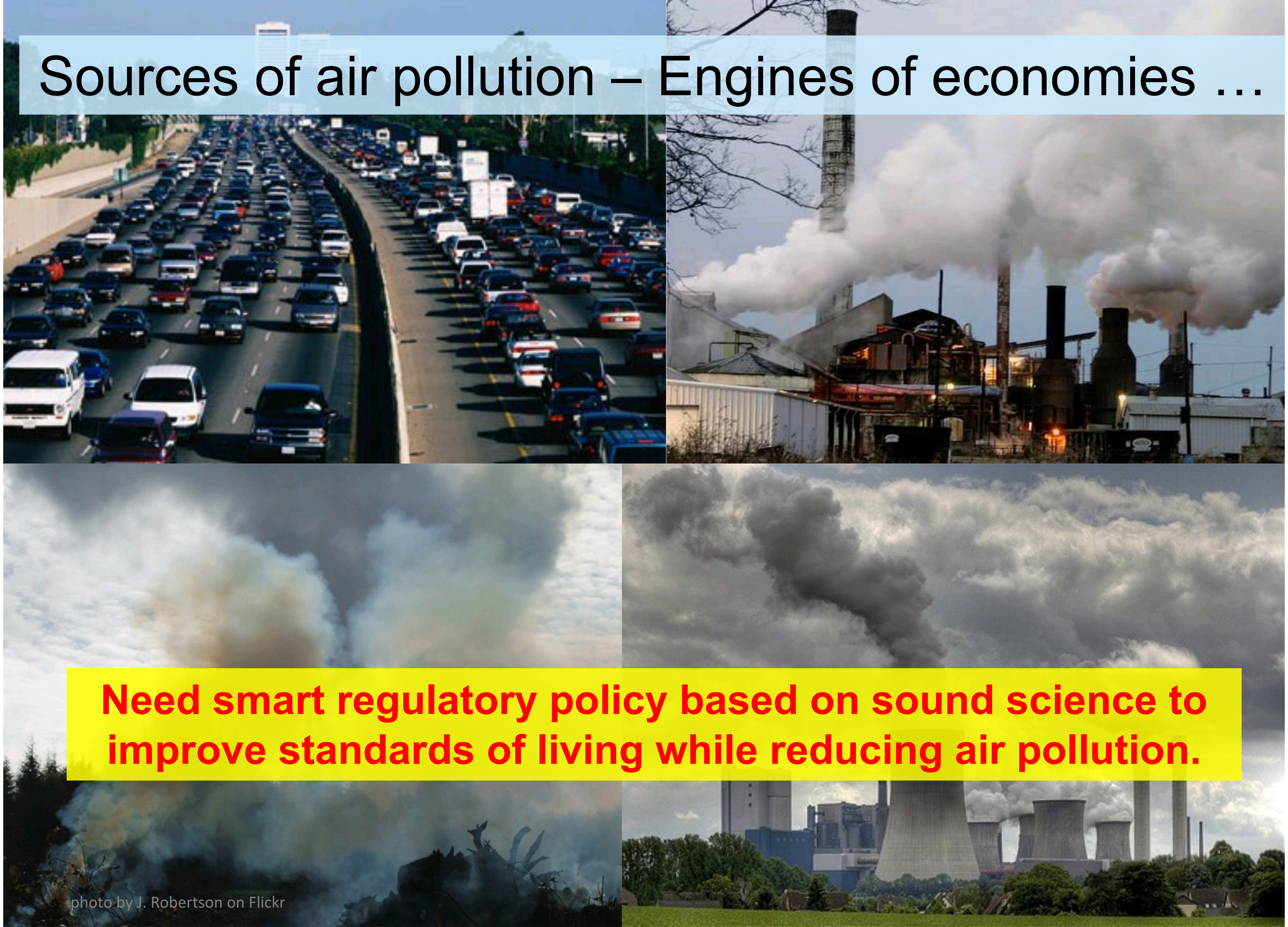
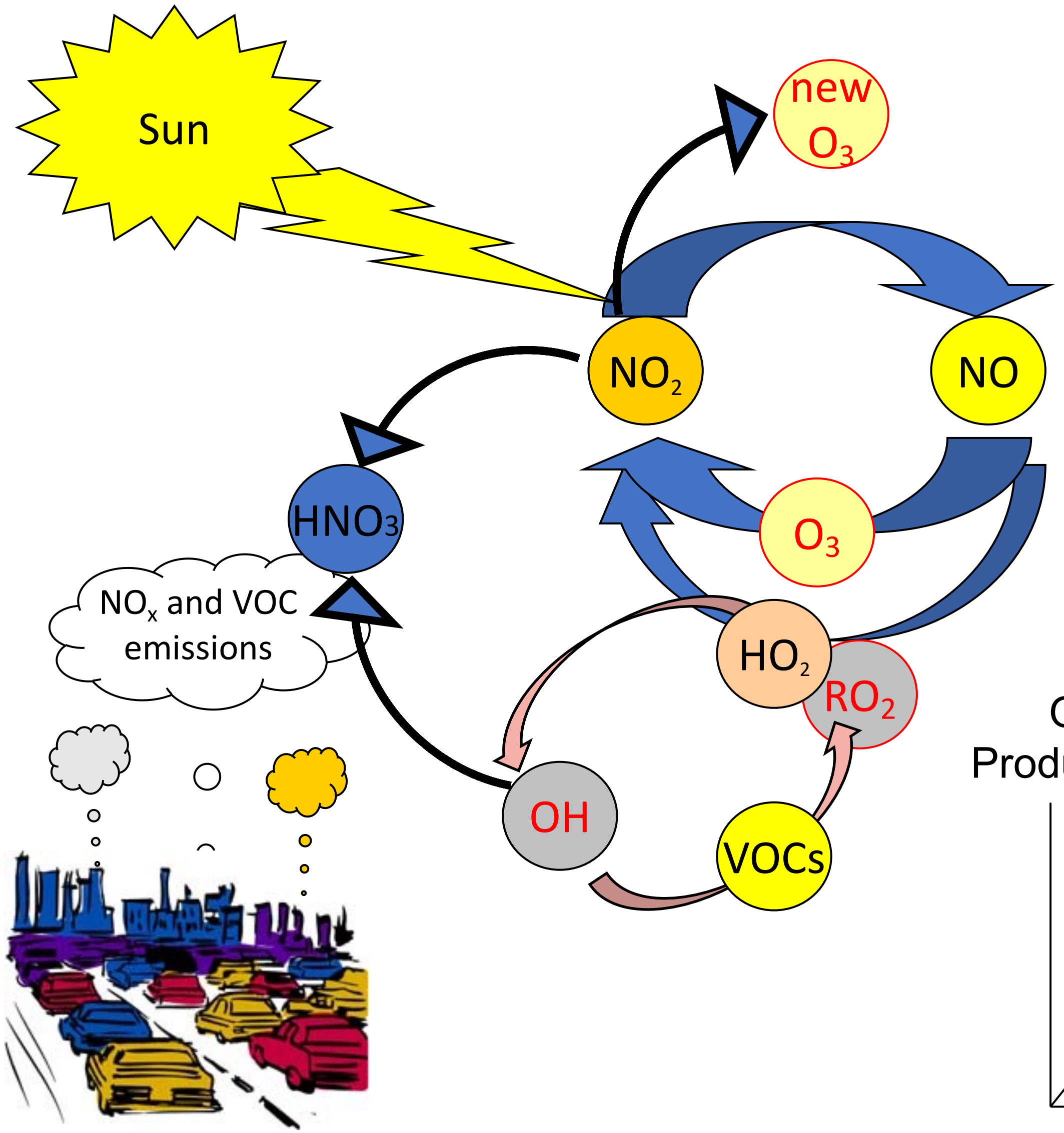
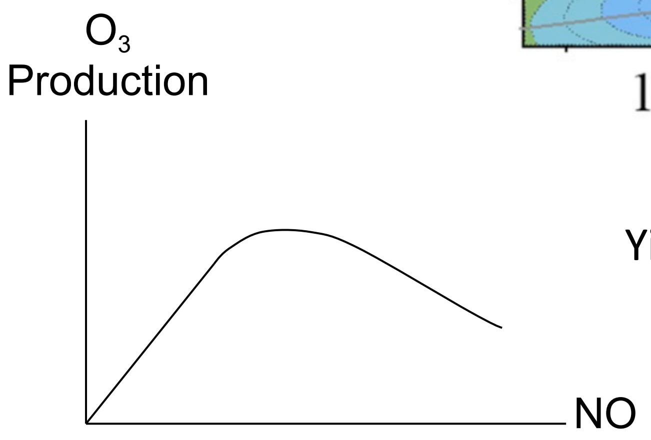
Sources of air pollution – Engines of economies …

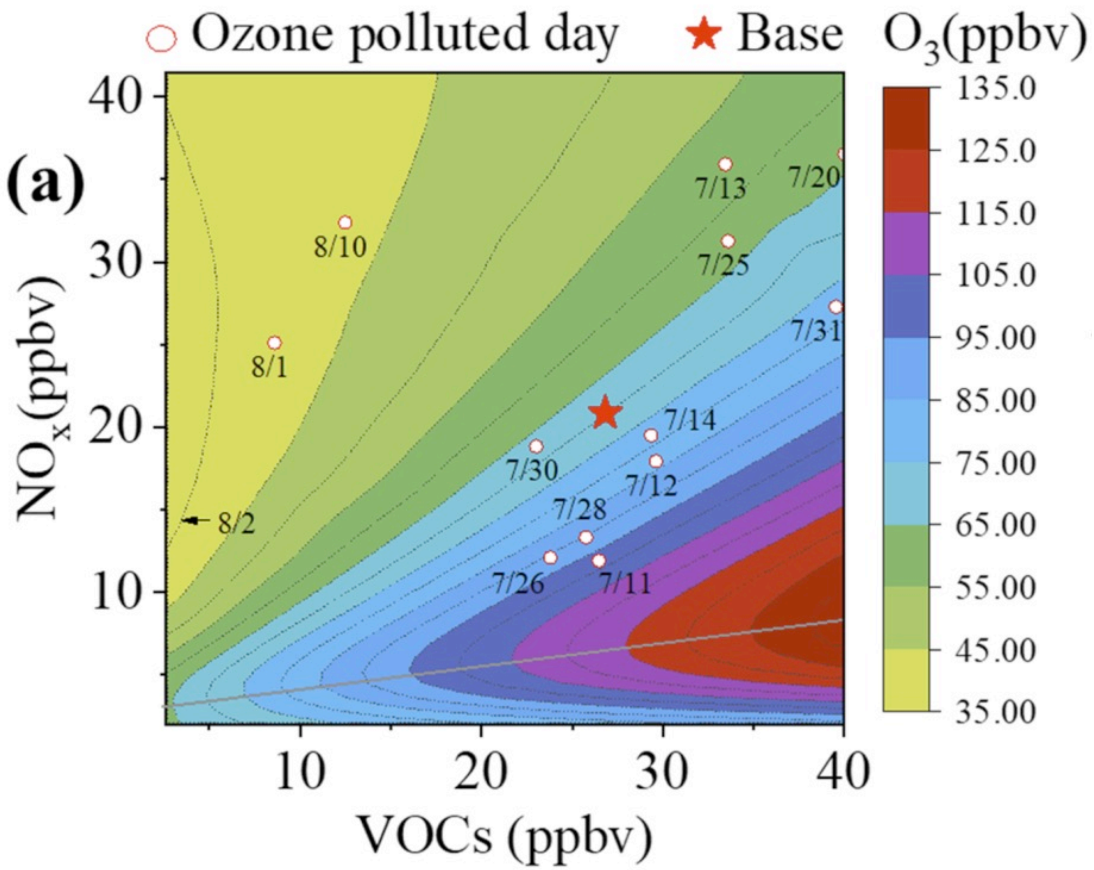


Need smart regulatory policy based on sound science to improve standards of living while reducing air pollution.

Ozone (O_3) pollution – focus on net production

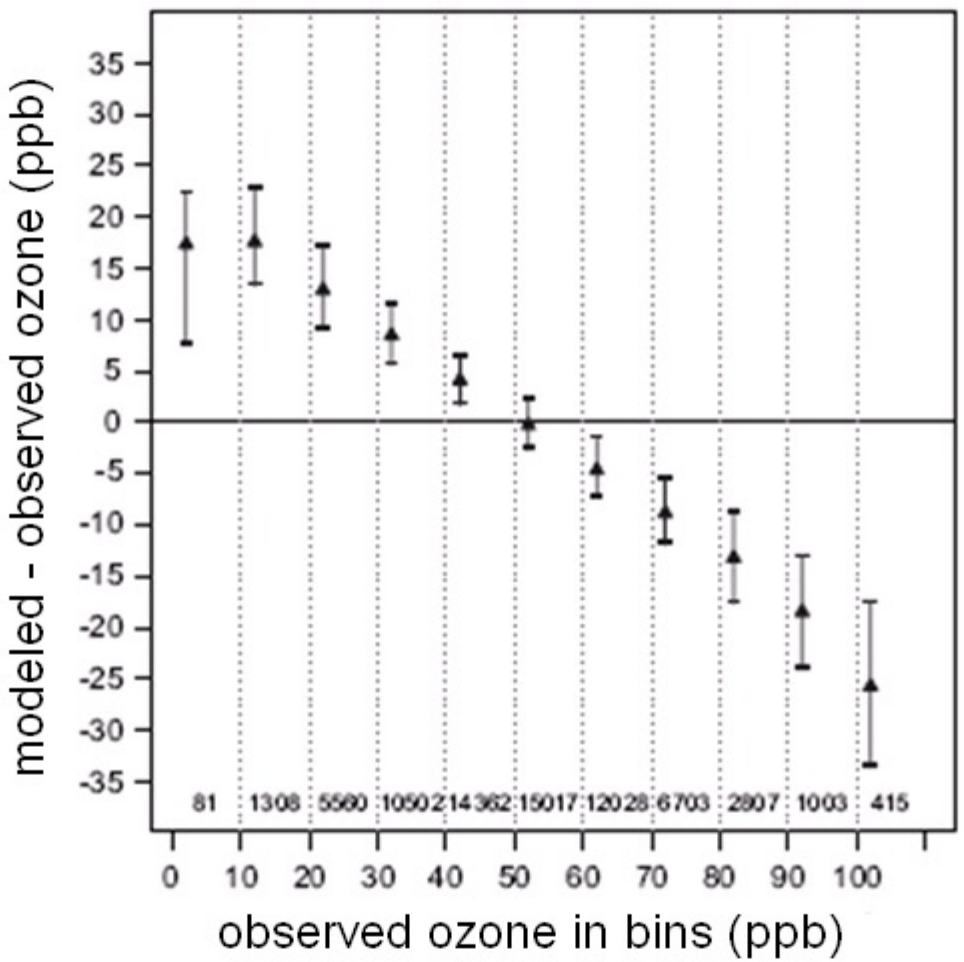




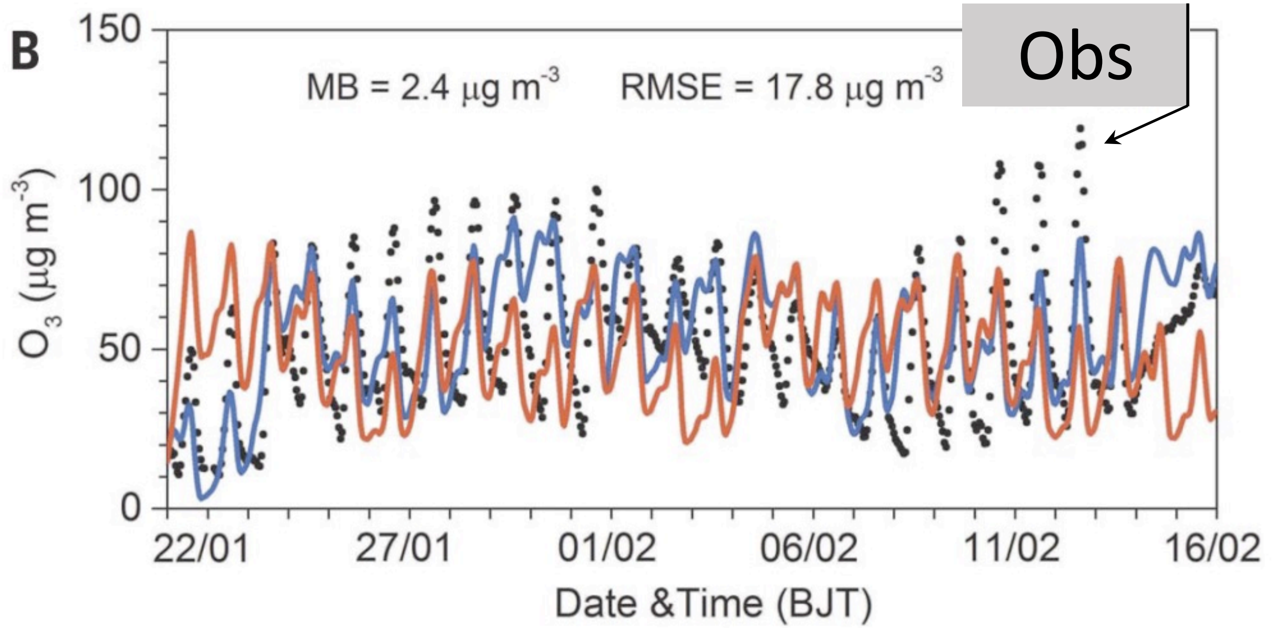


Yin et al., O_3 in Yulin, China, Peerj, 2021

A problem: Most models underpredict unhealthy O_3 levels



Aggregated EPA CMAQ model O_3.
K.W. Appel (NOAA), et al., Atmospheric Environment, 41, 9603–9615, 2007.



WRF-Chem model for Beijing O_3 during the COVID lockdown.
T. Le et al., Science, 369, 702-706, 2020.

What does this underprediction say about model guidance for O_3 mitigation strategies involving NO_x and VOC reduction?

For mitigation, considering O_x (=O_3+NO_2) is better than considering O_3 alone.

- O_3 and NO_2 readily adjust to move toward photostationary state equilibrium during the day.

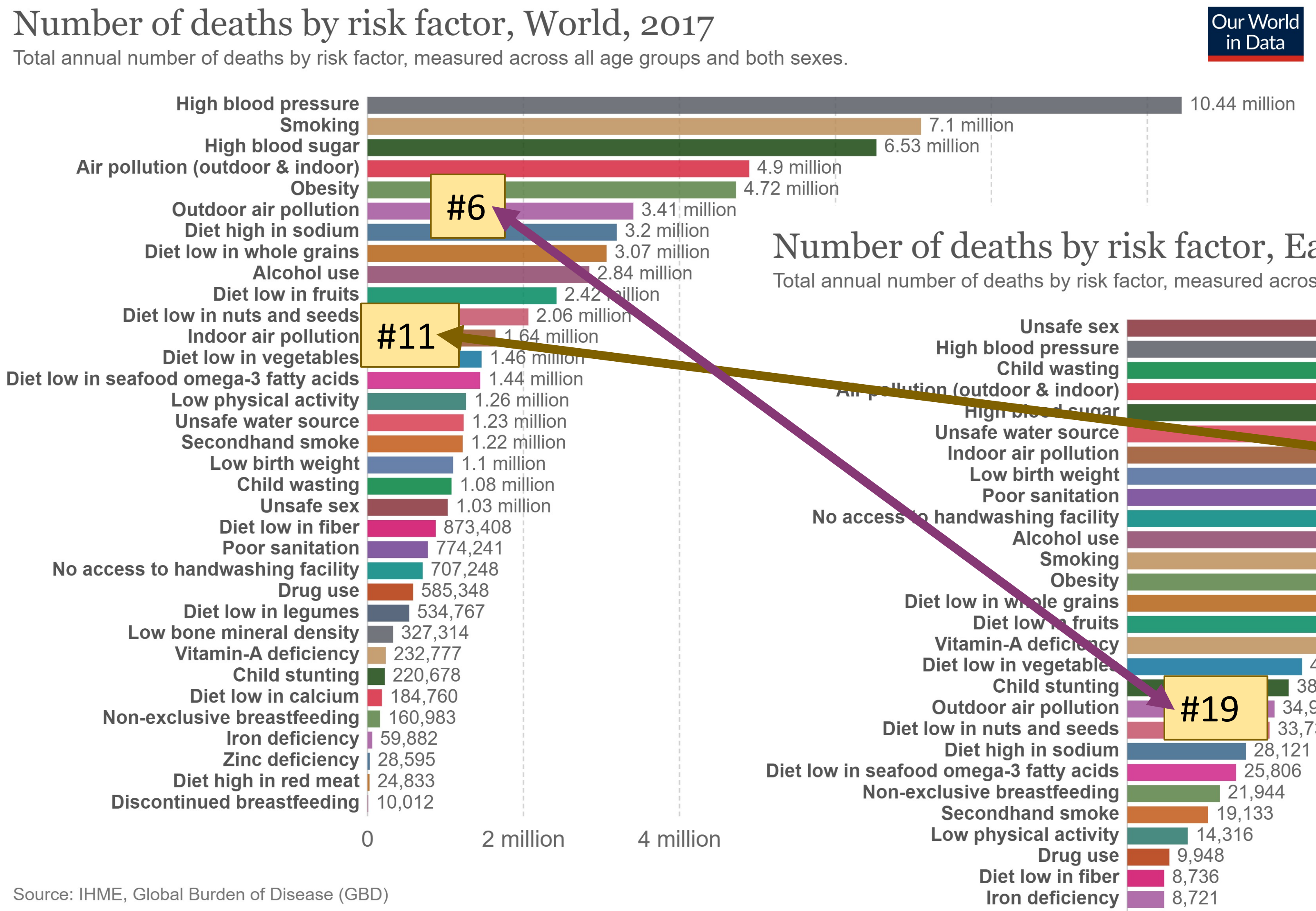
$$[NO_2] = (k_1[NO] + k_2[HO_2 \; and \; RO_2])[O_3]/J_{NO2}$$

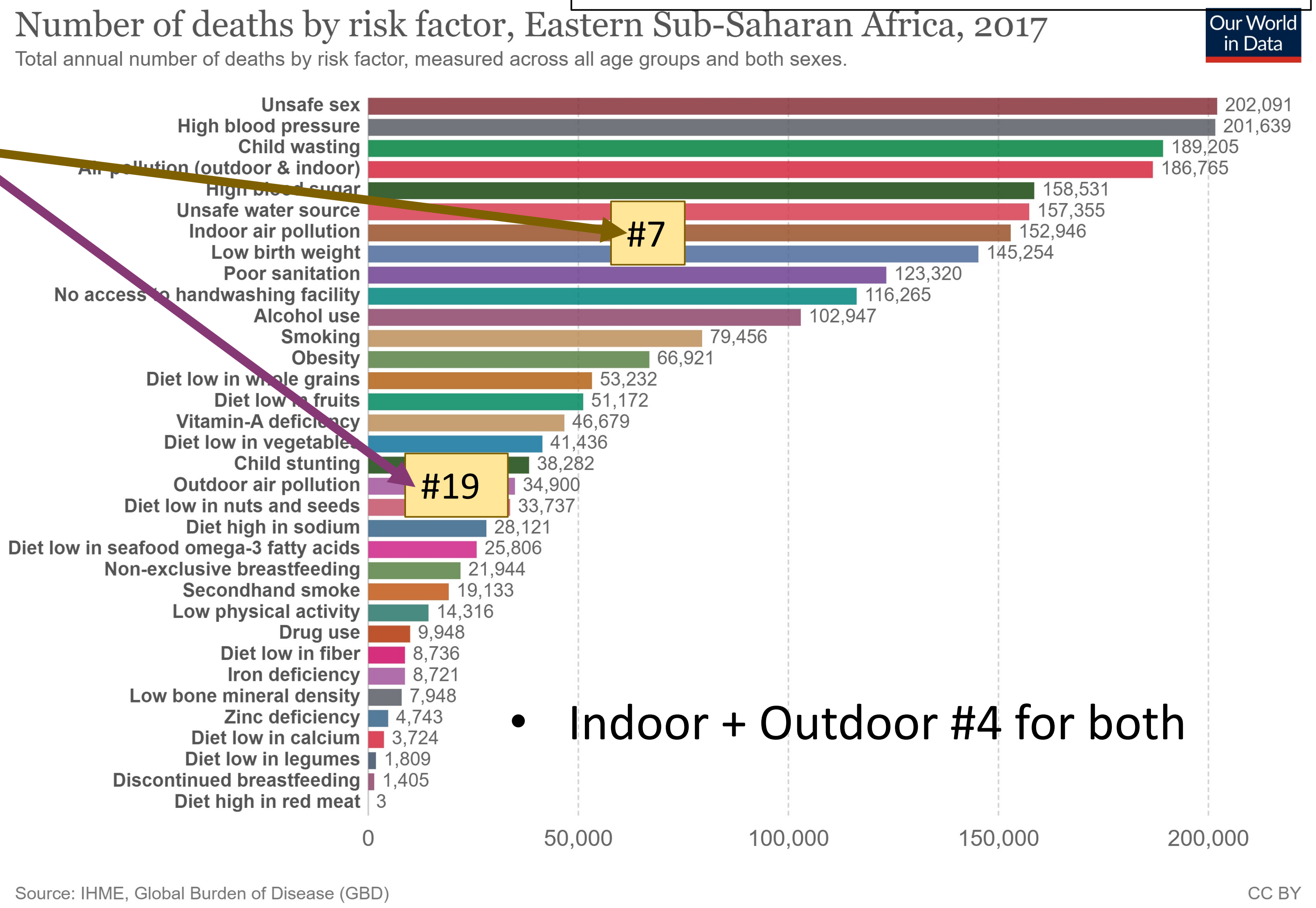
- Diesel vehicles emit ~(20-70)% of their NO_x as NO_2, and thus are another O_3 source.
- O_3 and NO_2 have similar air quality standards.

US EPA NAAQS				
Nitrogen Dioxide (NO_2)	primary	1 hour	100 ppb	98th percentile of 1-hour daily maximum concentrations, averaged over 3 years
	primary and secondary	1 year	53 ppb [(2)]	Annual Mean
Ozone (O_3)	primary and secondary	8 hours	0.070 ppm [(3)]	Annual fourth-highest daily maximum 8-hour concentration, averaged over 3 years

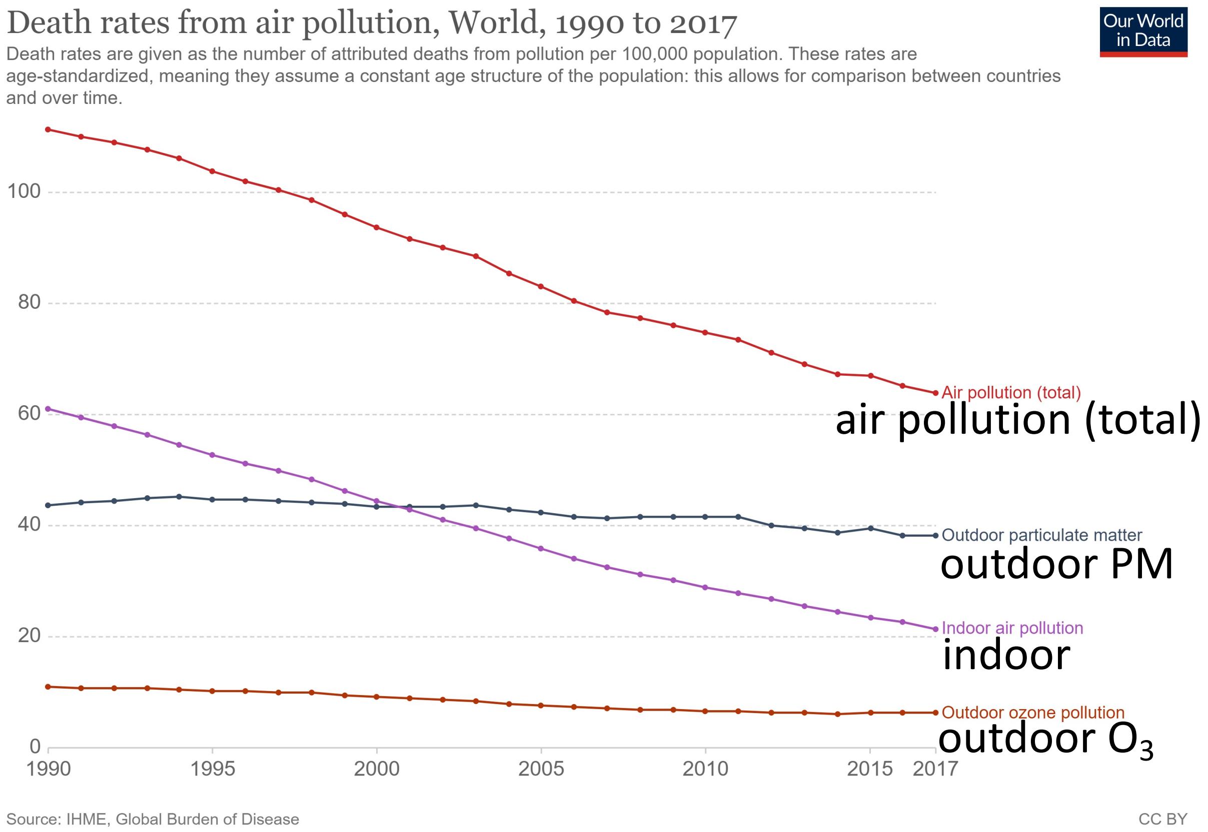
NO_2 also increases PM2.5. Need to weigh O_3 and PM2.5 risks together.

Some perspective on air pollution in Eastern Sub-Saharan Africa



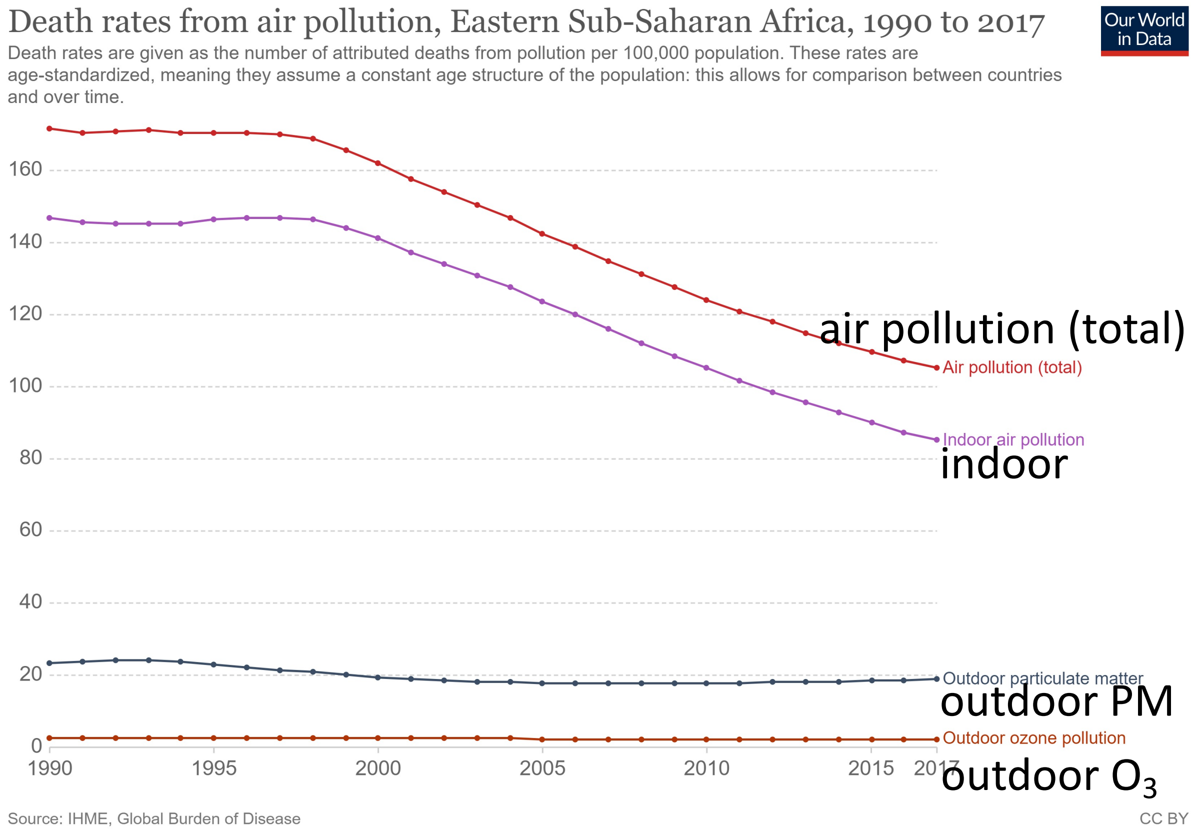


- Indoor + Outdoor #4 for both

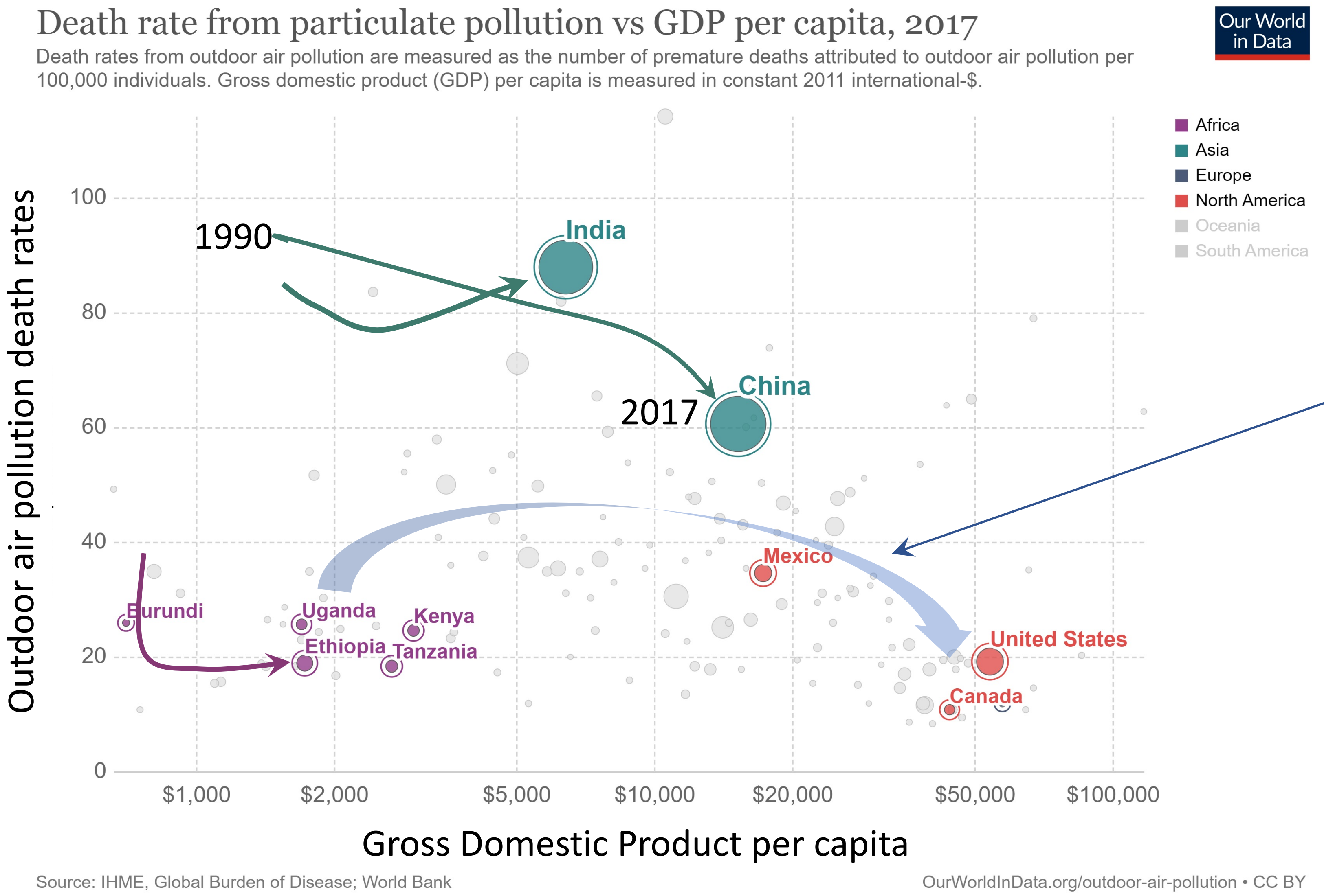


Take care of indoor air pollution first, then outdoor PM, and then outdoor O_3?

If indoor air pollution deaths decrease, will outdoor air pollution deaths rise?



How to achieve a higher standard of living?



Typical Path

Can Sub-Saharan East Africa follow a different path?

In Sub-Saharan East Africa, O_3 levels are not high, even though NO_x and VOCs are fairly high. Why?

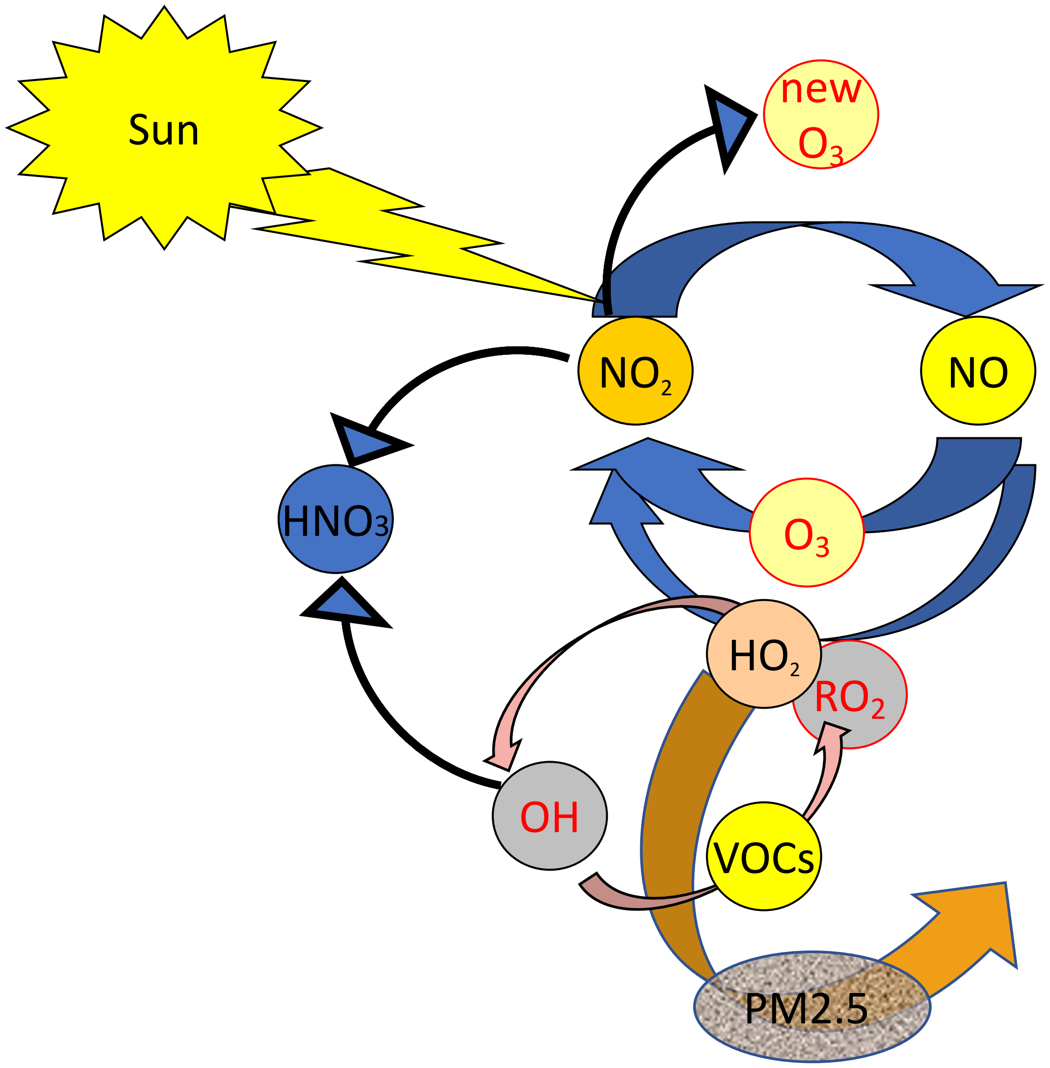
24-hr Averages for Select Cities						
Location	Year	O_3 (ppbv)	NO (ppbv)	NO_2 (ppbv)	O_x (ppbv)	CO (ppmv)
Nairobi, Kenya*	2015	4-14	6-18	1-55	5-69	0.5-1.7
Seoul, S. Korea	2016	36	7.9	32	68	0.46
Mexico City, Mex.	2003	28	2.4	28	56	0.72
Bakersfield, CA	2010	42	0.65	6.4	48	0.16
Houston, TX	2006	30	1.2	6.4	36	0.21
Houston, TX	2009	37	0.32	5.1	42	0.18
New York City	2004	23	4.2	28	51	0.38

* From 6 different sites in and around Nairobi. deSouza, Air Quality, Atmosphere & Health (2020) 13:1487–1495

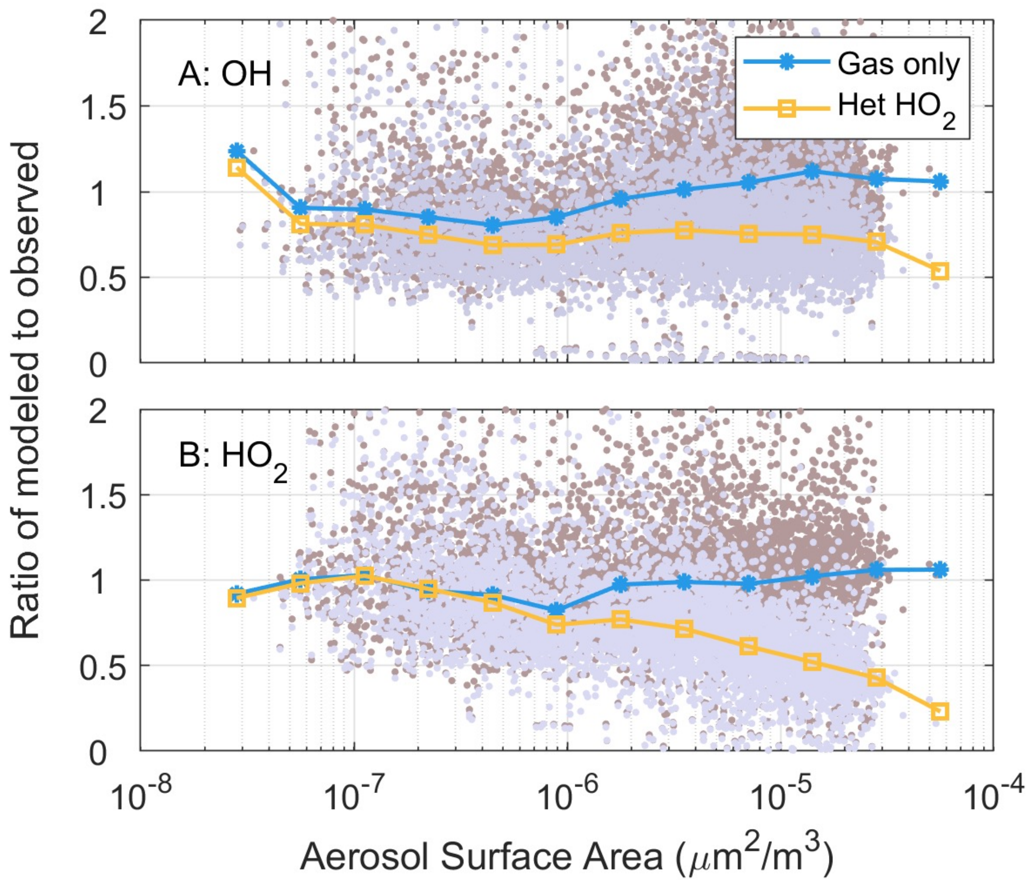
In China, why is O_3 going up when PM2.5 is going down?

Li et al., Anthropogenic drivers of 2013-2017 trends in summer surface ozone in China, PNAS, doi/10.1073/pnas.1812168116, 2018

- GEOS-Chem global model study of China O_3 from 2013-2017
- PM2.5 goes down, but O_3 goes up over standard in eastern China (8-hr 82 ppbv)
- Reductions in a combination of NO_x and VOCs required to bring O_3 down as PM2.5 levels decline
- Claim: PM2.5 a sink for HO_2 … Add HO_2 aerosol uptake (lost in 20% of collisions)
- PM2.5 down means HO_2 up and thus O_3 up



Airborne observations from South Korea: KORUS-AQ (2016)



Observed HO_2 inconsistent with HO_2 uptake on PM2.5

Conclusions for Sub-Saharan East Africa

- There appears to be enough NO_x and VOCs to make much O_3.
- Reducing PM2.5 could increase in O_3 to unhealthy levels, although the chemical mechanism is not clear. However, it may be worth it.
- Simultaneously reducing NO_2 sources and VOCs that form O_3 and PM2.5 should reduce PM2.5 while keeping O_3 low.
- Model guidance for O_3 mitigation should be trusted only if it can demonstrate the ability to consistently simulate: (1) unhealthy O_3 values and (2) an O_3 increase with decreasing PM2.5 in megacities.
- Hourly measurement of O_3, NO_x, CO, and VOC/OH reactivity needed
- My recommendation: start restricting trash fires and diesel use.