PhD application

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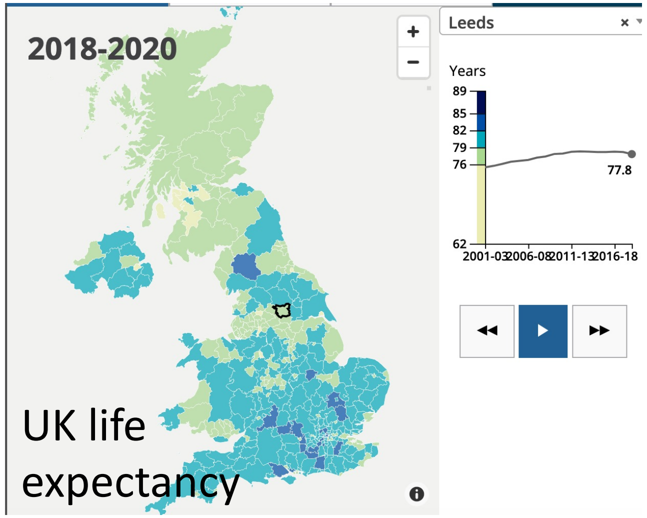
NERC Panorama DTP

https://panorama-dtp.ac.uk/research/

Application deadline: Friday 5th January 2024



Examining the changing inluence of global wildfires using new satellite observations of carbon monoxide

Dr Chris Wilson
Dr Ailish Graham
Dr Carly Reddington
Prof Martyn Chipperfield

https://panorama-dtp.ac.uk/research/theme/air-quality/#browse_tab

Other funding sources for PhDs in the UK!

My email: c.l.s.reddington@leeds.ac.uk

Air pollution in the UK

Carly Reddington

c.l.s.reddington@leeds.ac.uk

@CLSReddington

History of air pollution in the UK

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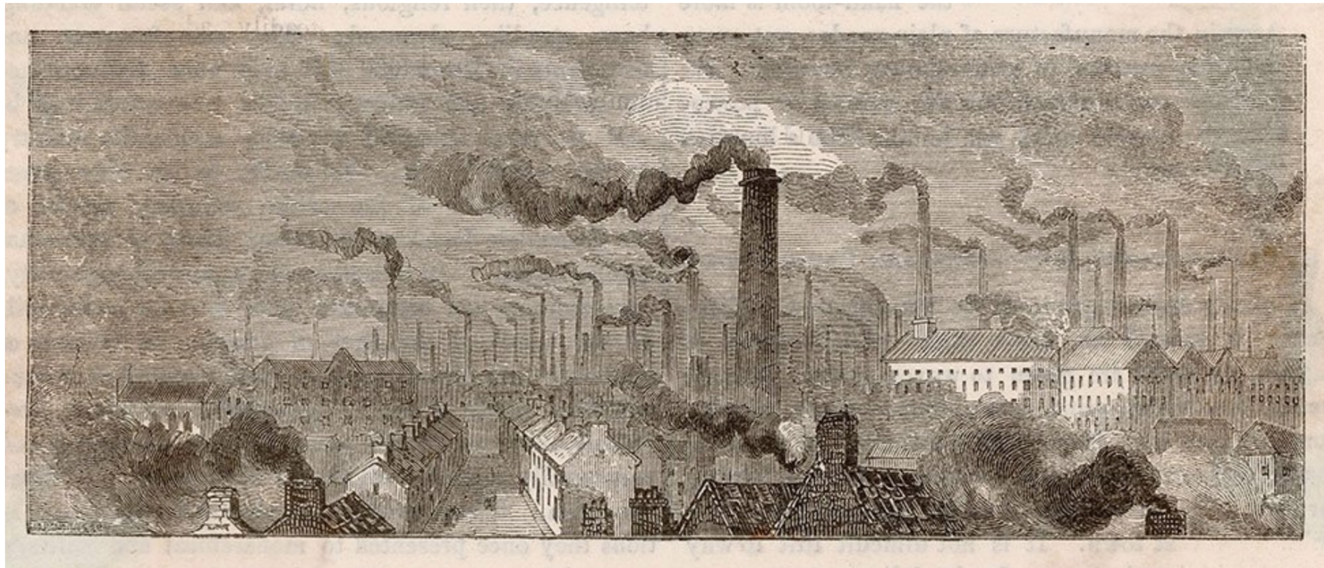
1760 – 1820

The industrial revolution saw an dramatic increase in the amount of air pollution.

- On cold calm winter days there is little mixing of the air.
- Pollutants collect close to the ground, causing **smog**.

Rickets and the crippled child: an historical perspective
Gibbs, 1994

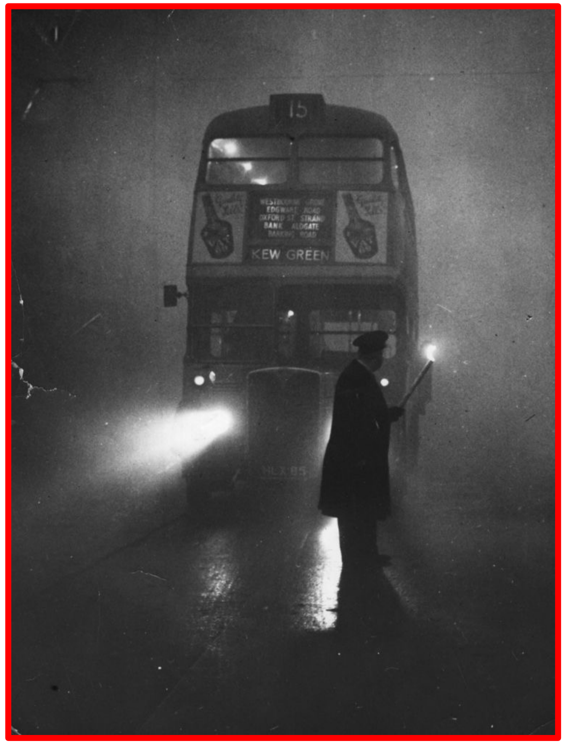
the association between rickets and air pollution functioning as a barrier to sunlight in industrial and high density domestic coal burning areas of Britain



MANCHESTER, FROM THE ENTRANCE TO THE LONDON AND NORTH-WESTERN RAILWAY.

https://www.scienceandindustrymuseum.org.uk/objects-and-stories/air-pollution

The Great London Smog (1952)

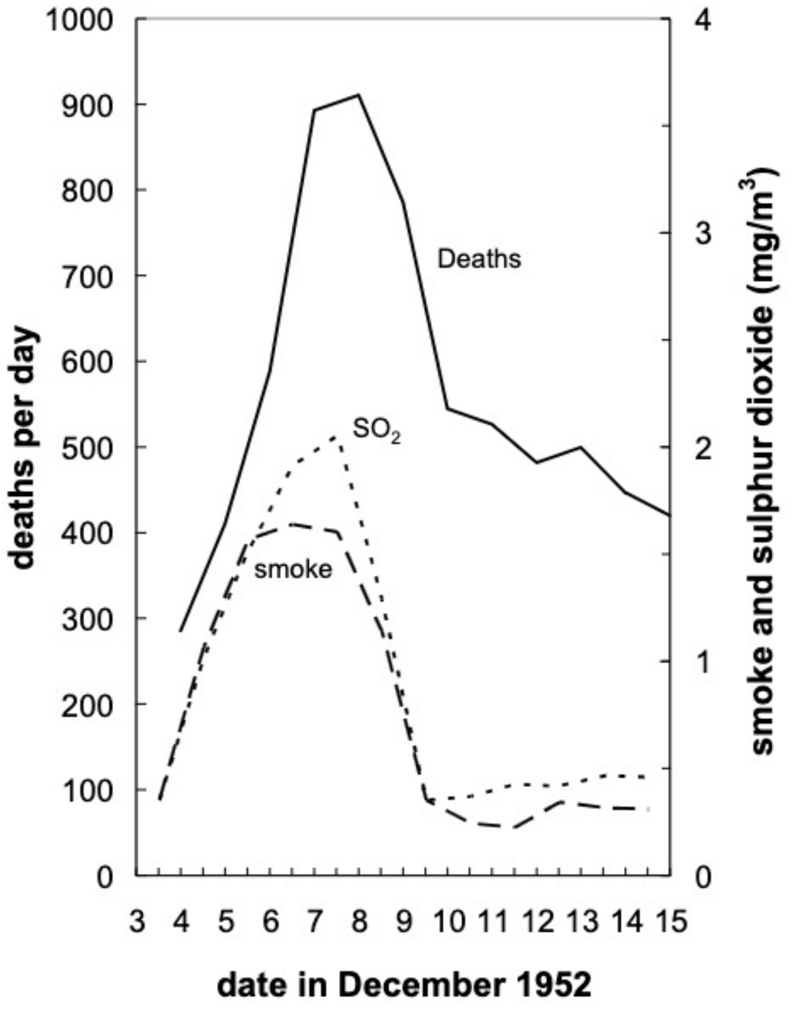


"There is one thing I remember most vividly about the smog. I travelled by Underground and regularly saw a blind man who lived nearby. When the smog was at its worst he would collect a queue of people who followed him from the Tube station along the main road and so home."

Joy Riley Radley, Oxfordshire
(The Telegraph Letters)

The Great London Smog (1952)

- Between 1948 and 1962 eight air pollution episodes occurred in London.
- The Great Smog between 5th and 9th December 1952 was the most significant.
- Visibility was so bad that people could not see their own feet.
- **At least 4,000 people are believed to have died during the smog and in the following weeks.**



Death rate, smoke and SO_2 concentration (daily average) during the Great Smog in December 1952[1].

Source: https://www.parliament.uk/globalassets/documents/post/pn188.pdf

UK Clean Air Acts of 1956 and 1968

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- Established as a **response to public pressure** arising from the mass mortality caused by the great smog event.

- The acts focused on local emission of smoke:

    - Introduced smoke control areas
    - Controlled chimney heights
    - Moved industry out from the city centre

Establishment of the first UK air quality monitoring network which monitored black smoke and SO_2.

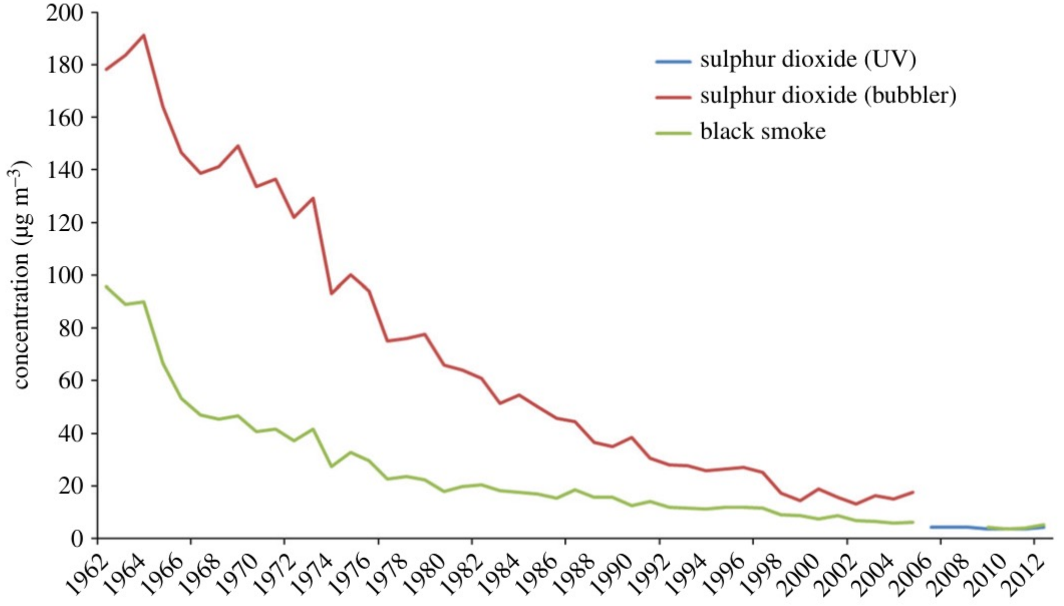

Figure 2. The decline in SO_2 and smoke in London following the Clean Air Act (1956), including data from the 'bubbler method'

Fowler et al., Phil. Trans. R. Soc. A, 2020

Decline in heavy industry and the location of power stations with high stacks outside cities has led to an over 90% decrease in national average SO_2 levels

Current air pollution in the UK

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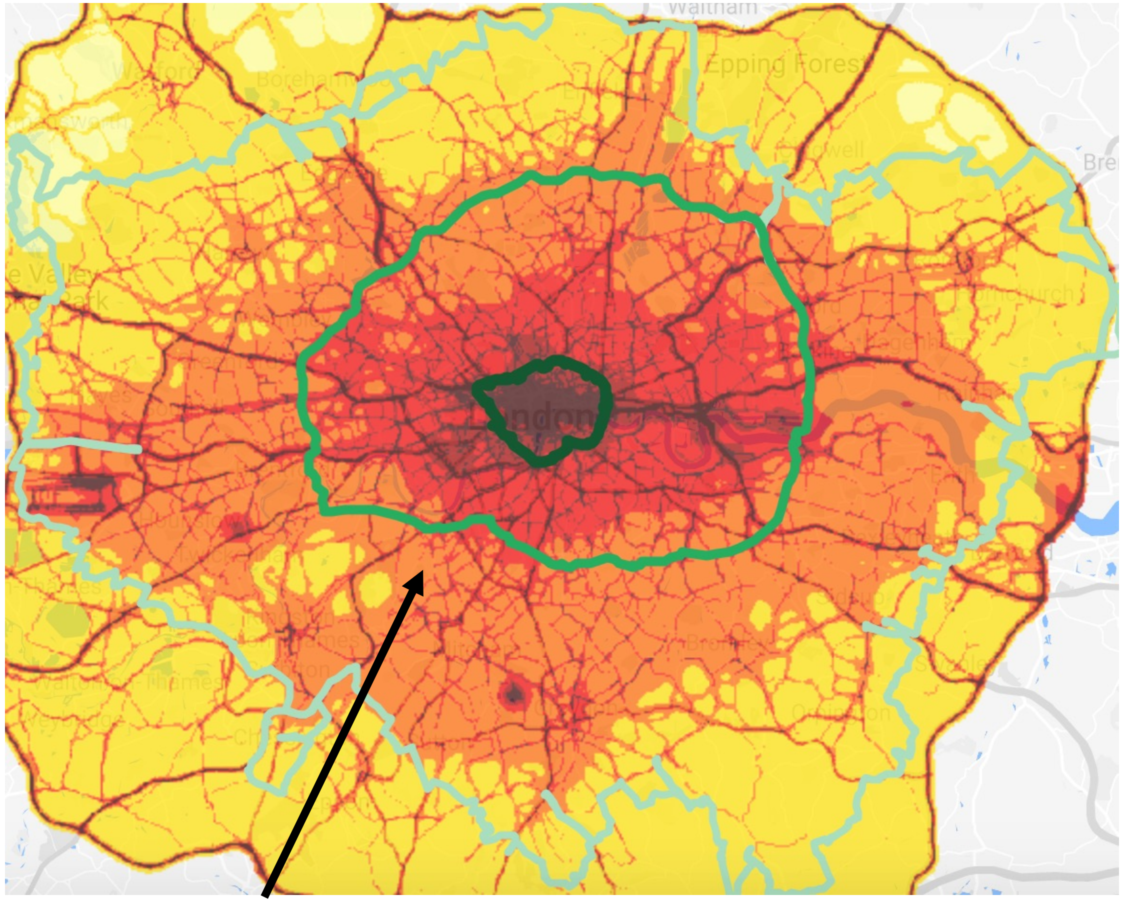
Annual Mean Concentration, 2019 ($\mu g/m^3$)

	0 - 10
WHO AQG (NO_2)	10 - 20
	20 - 30
	30 - 40
UK Legal Limit (NO_2)	40 - 50
	50 - 60
	60+

Modelled annual mean NOx concentrations for 2019



Expanded ULEZ

Modelling air pollution: a brief introduction

Carly Reddington

c.l.s.reddington@leeds.ac.uk

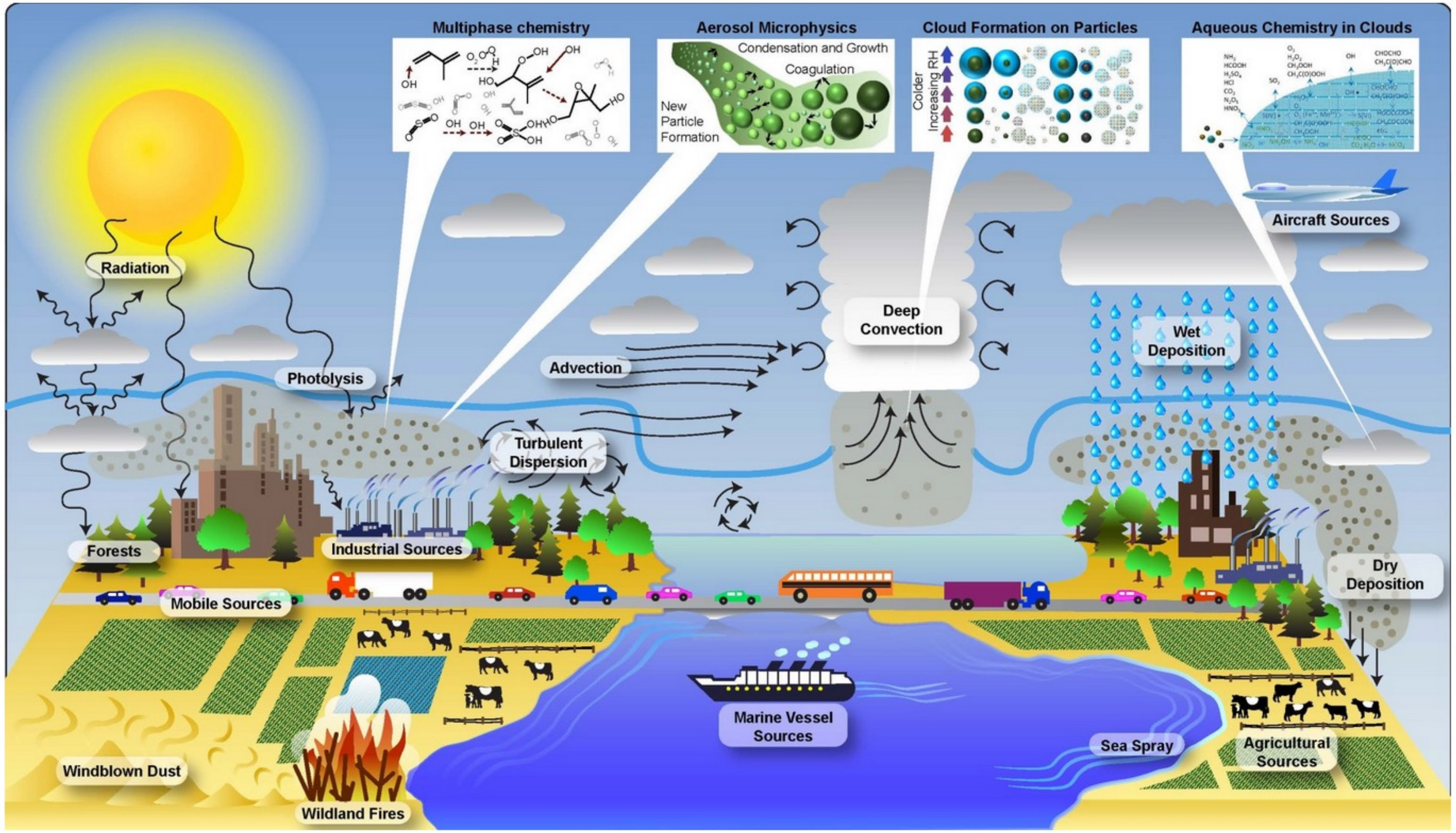
@CLSReddington

"All models are wrong, but some are useful”

George Box, 1976

Atmospheric processes in a model relevant for air pollution

Air quality models use mathematical and numerical techniques to simulate the physical and chemical processes that affect air pollutants as they disperse and react in the atmosphere.



ADMS 6

CAMx Ozone Particulates Toxics

Met Office UKCA

UKESM

WRF-Chem

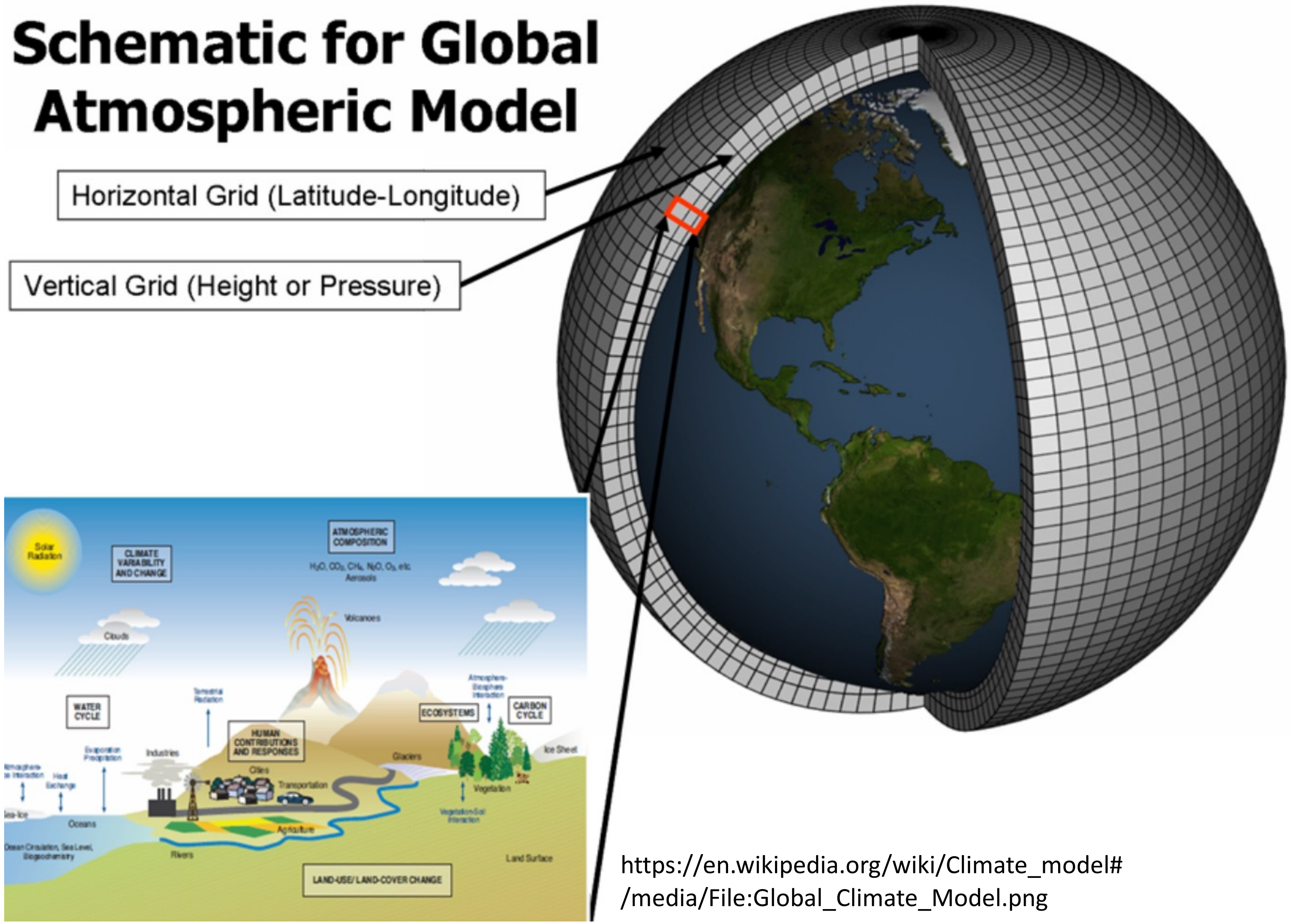
CMAQ EPA

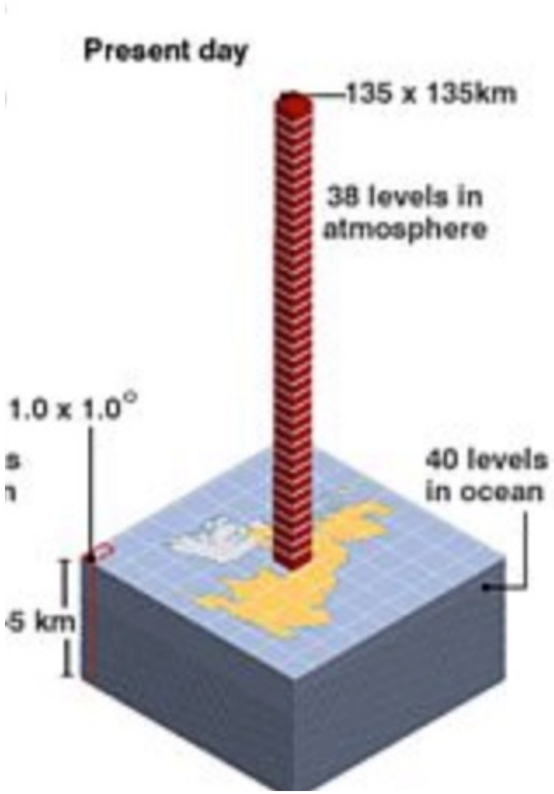
NCAR | COMMUNITY EARTH SYSTEM MODEL CESM

GLOMAP Global Model of Aerosol Processes

MUSICA Multiscale Infrastructure for Chemistry and Aerosols

The model grid

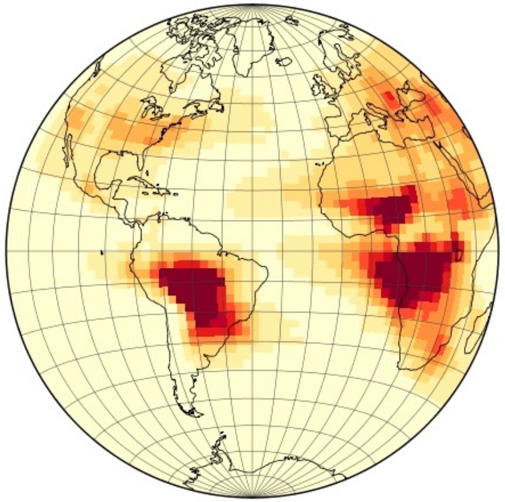




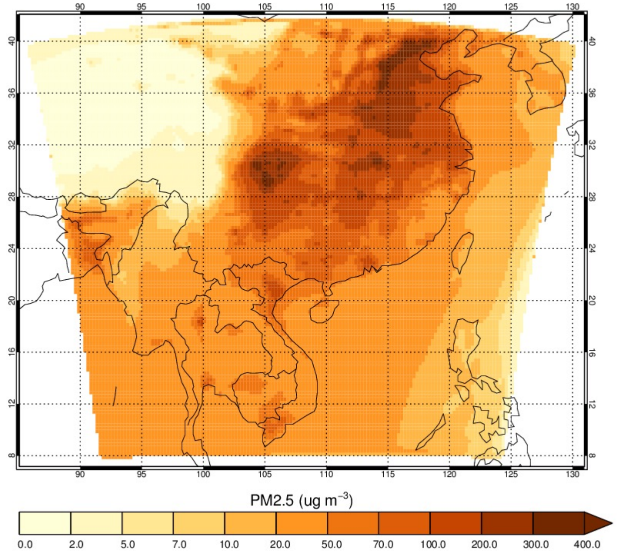
https://en.wikipedia.org/wiki/Climate_model#
/media/File:Global_Climate_Model.png

Model resolution and domain size

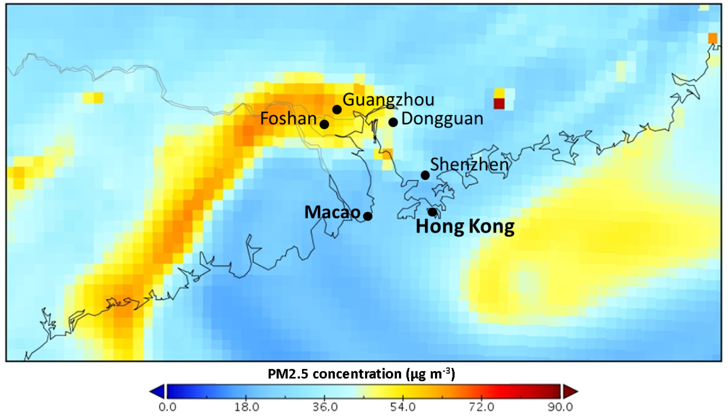
Global model:
50 - 300 km simulation

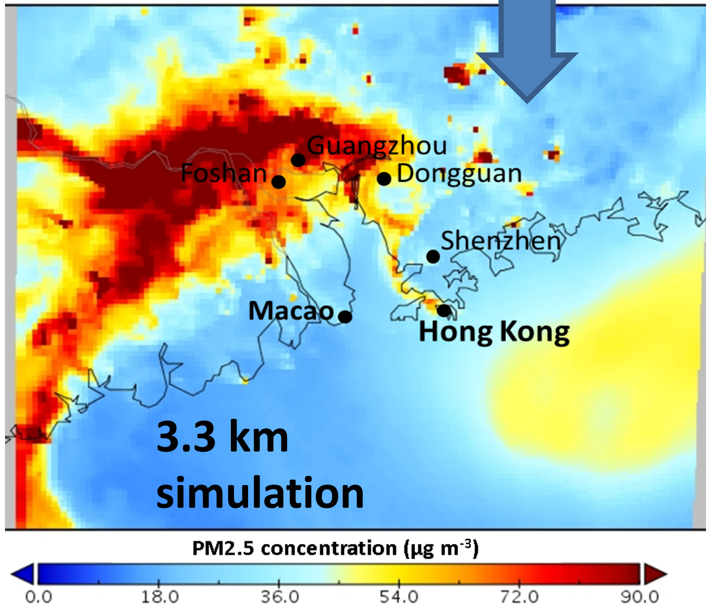


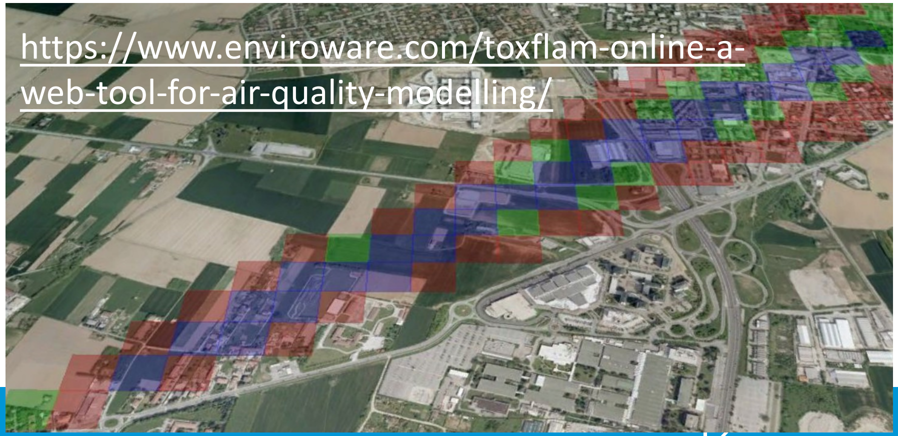
Region model:
30 km simulation



10 km simulation







Model resolution and computational cost

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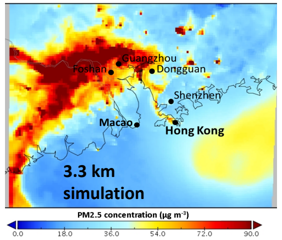
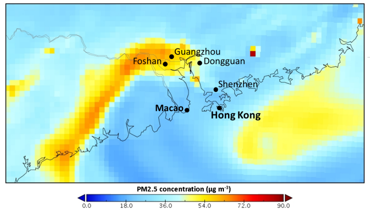
Computational cost

Make some compensations

Reduce domain size and use boundary conditions

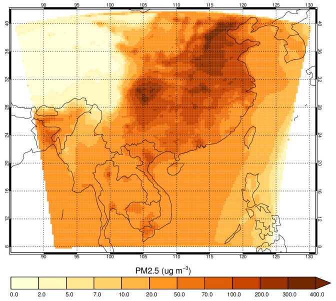


10 km simulation



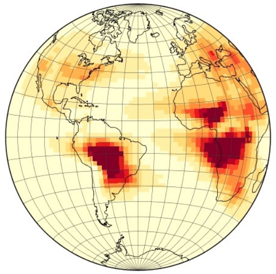
Run model for few days

Region model: 30 km simulation



Run model for 10's of years

Global model: 50 - 300 km simulation

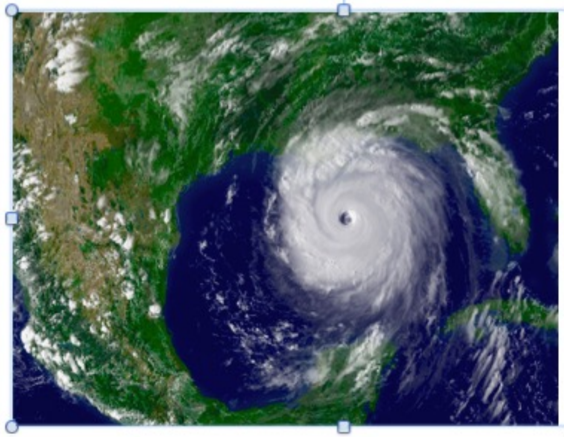


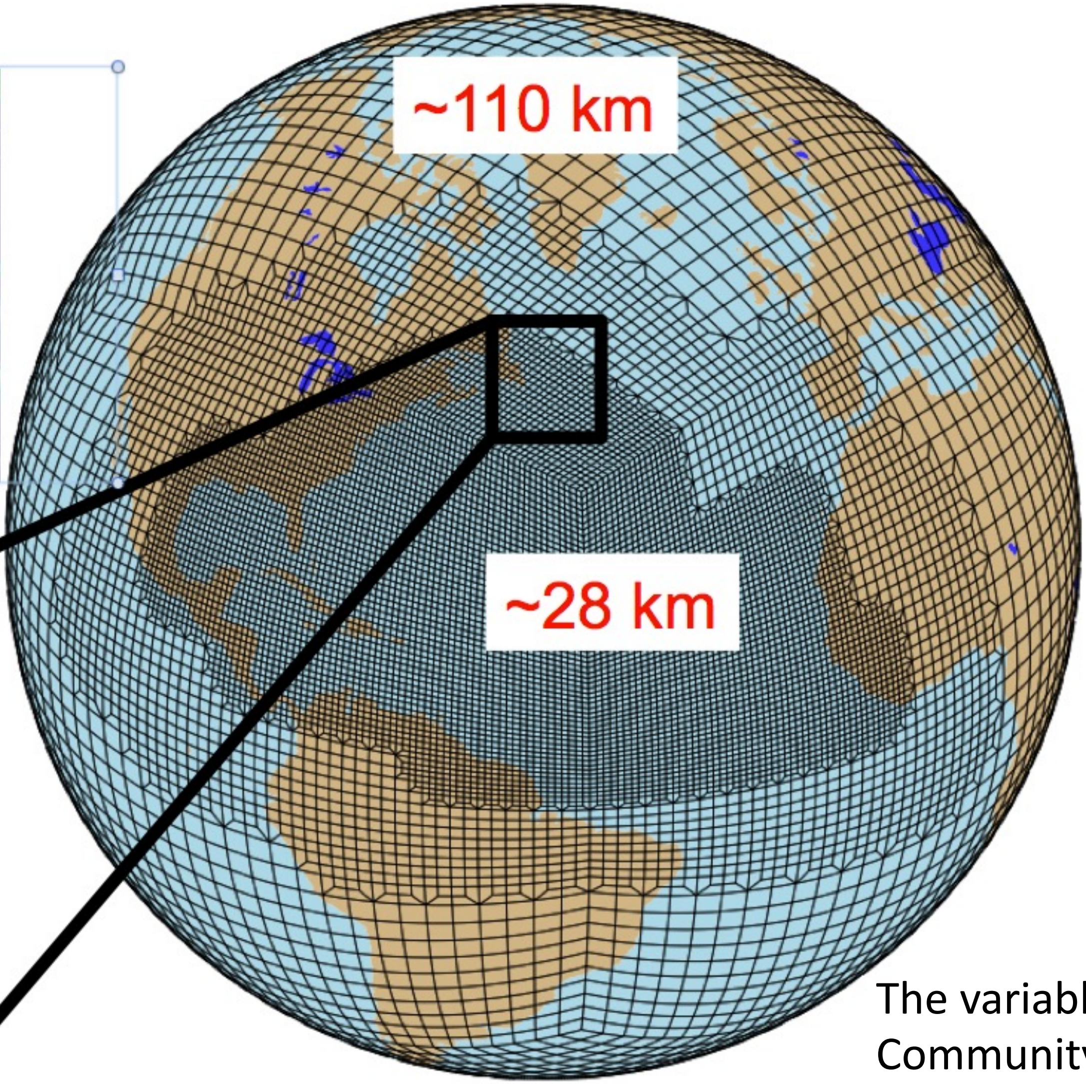
- Reduce complexity (parameterise some processes).
- Use Machine Learning techniques to represent model processes or emulate model outputs.

  e.g. Carslaw et al., Nature, 2013

Resolution

Models with variable grid resolution





The variable-resolution grid of the Community Atmosphere Model (CAM)

Quantifying impact of emission sources on air quality

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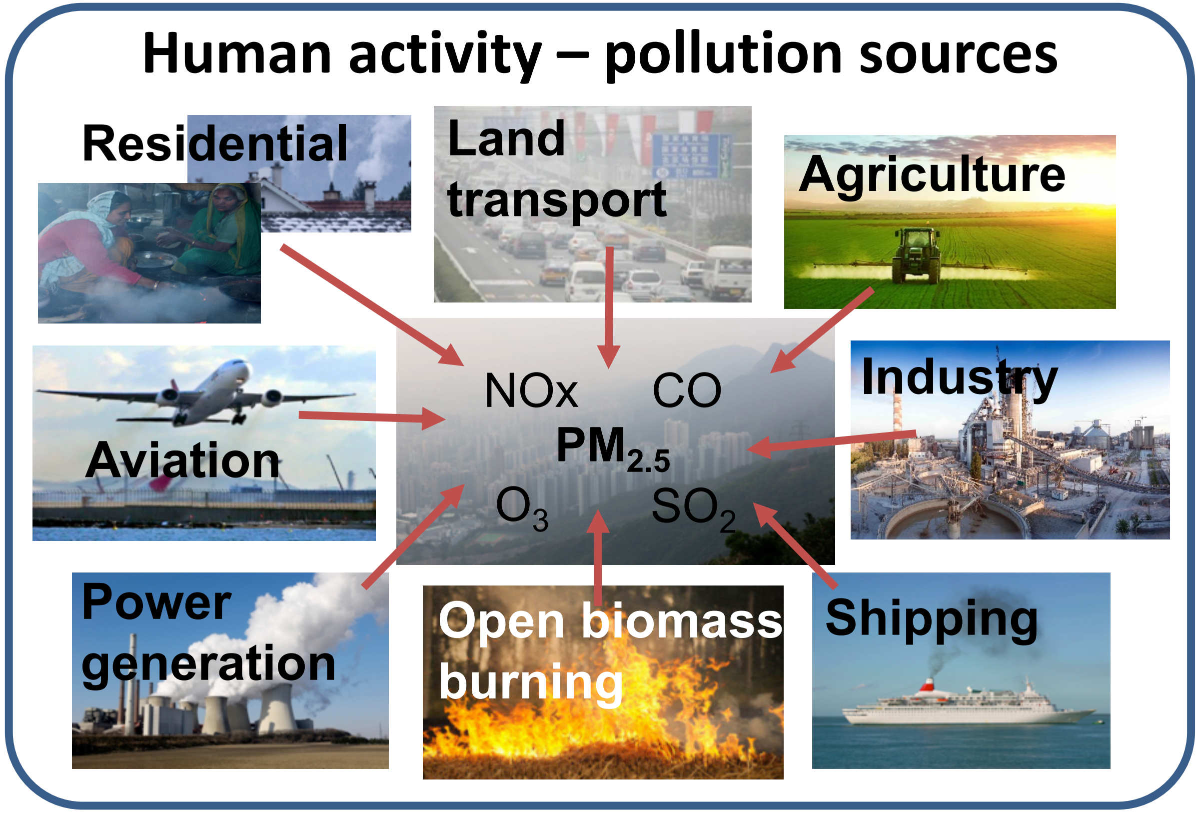
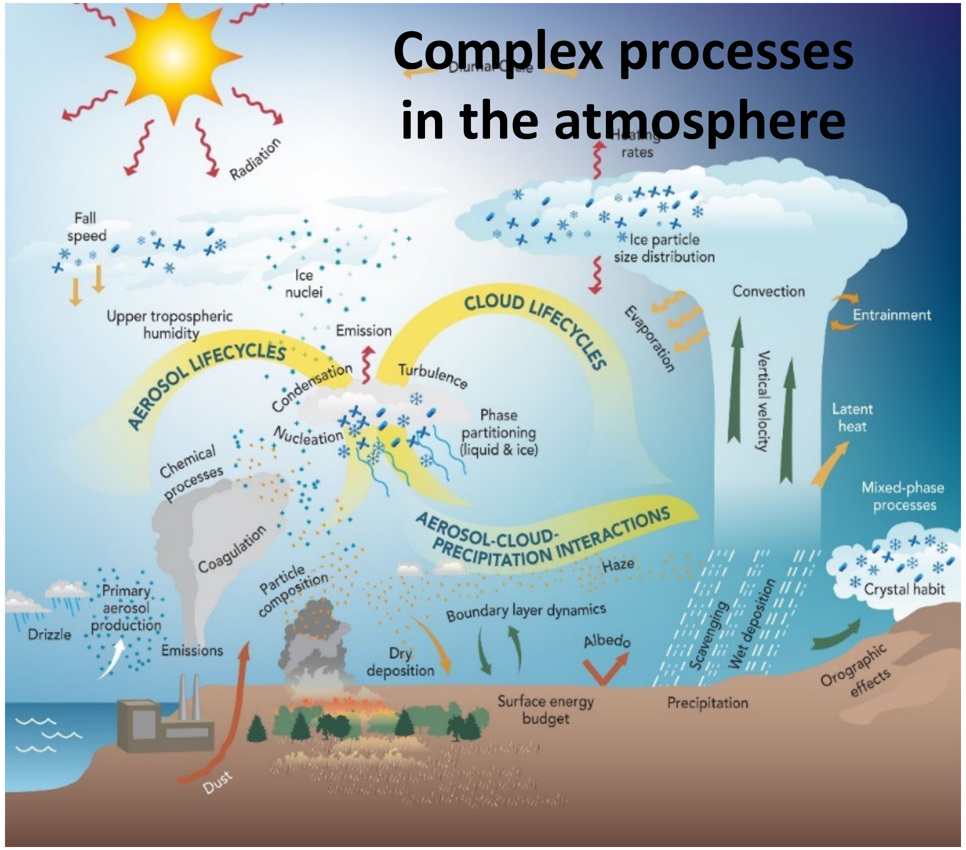
⇒ To improve air quality it is vital to better understand **pollution sources** and **processes that lead to unhealthy air**.





Modelling air pollution

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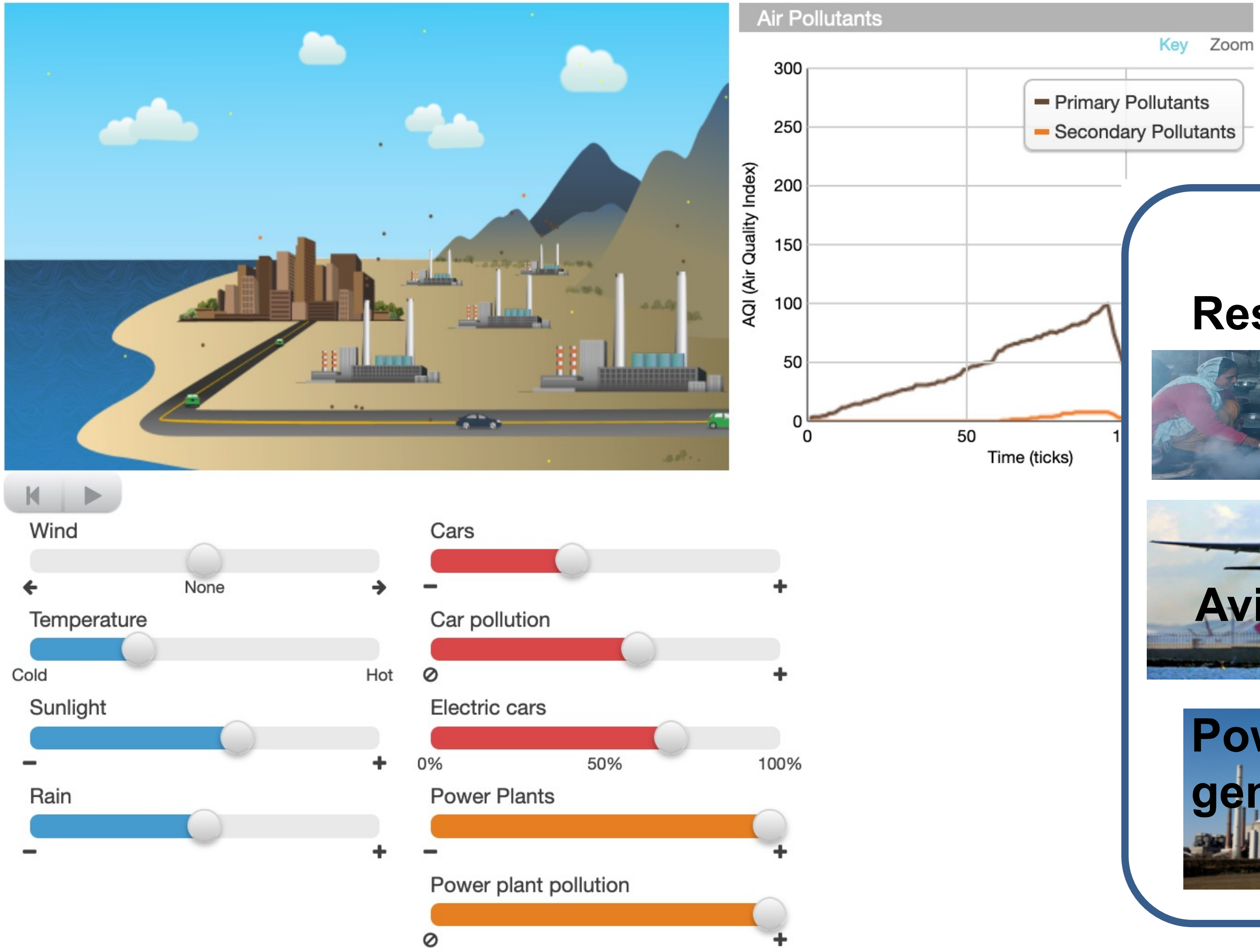
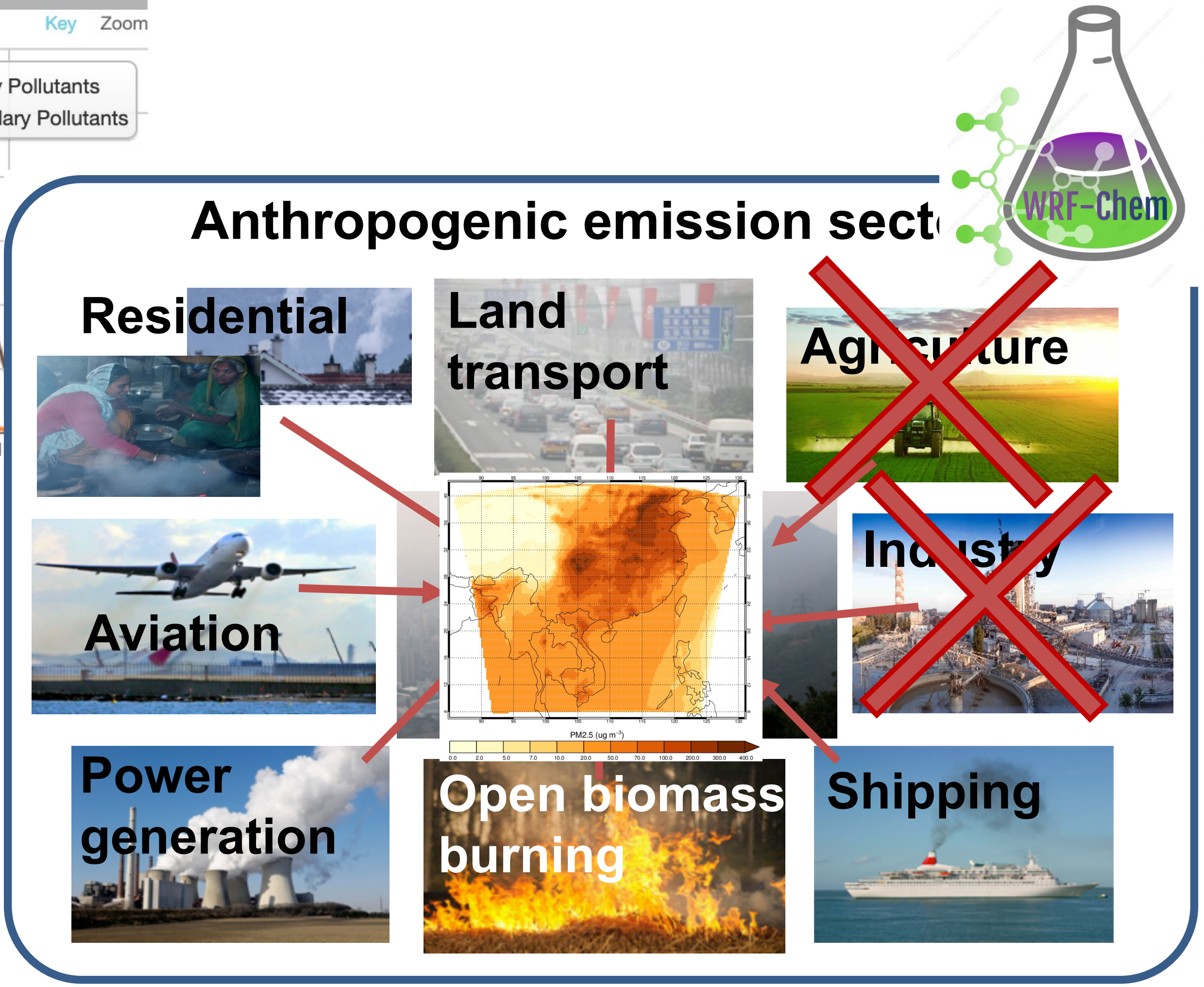


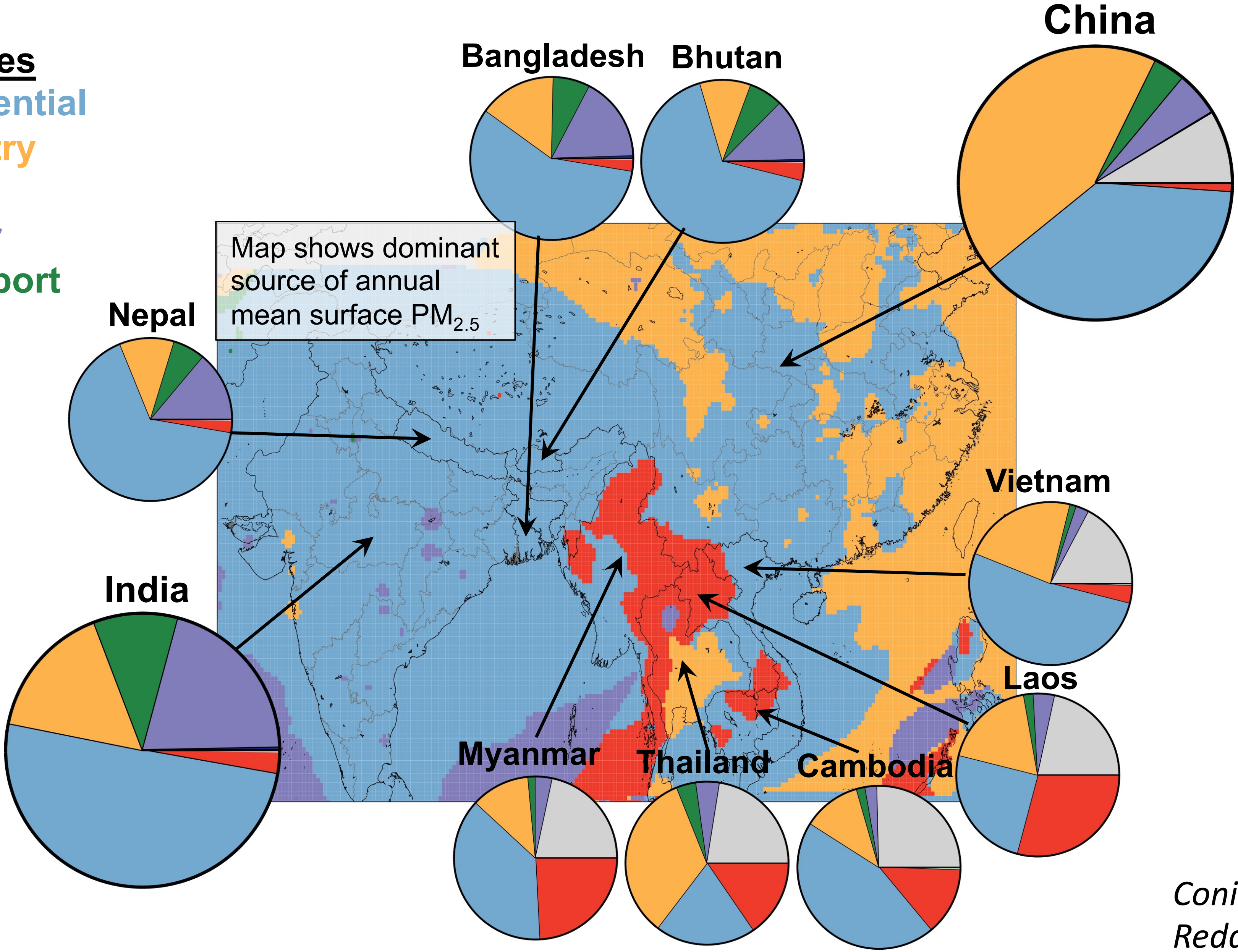


http://lab.concord.org/embeddable.html#interactives/air-pollution/air-pollution-master.json

https://www2.acom.ucar.edu/wrf-chem

What sources contribute most to $PM_{2.5}$ pollution in South and East Asia?

Sources
Residential
Industry
Fires
Power
Transport
Other



Pie charts show relative contributions to population-weighted annual mean $PM_{2.5}$

Conibear et al., Nat Comm., 2018
Reddington et al. Atmos. Chem. Phys, 2019

Quantifying impact of fires on air quality

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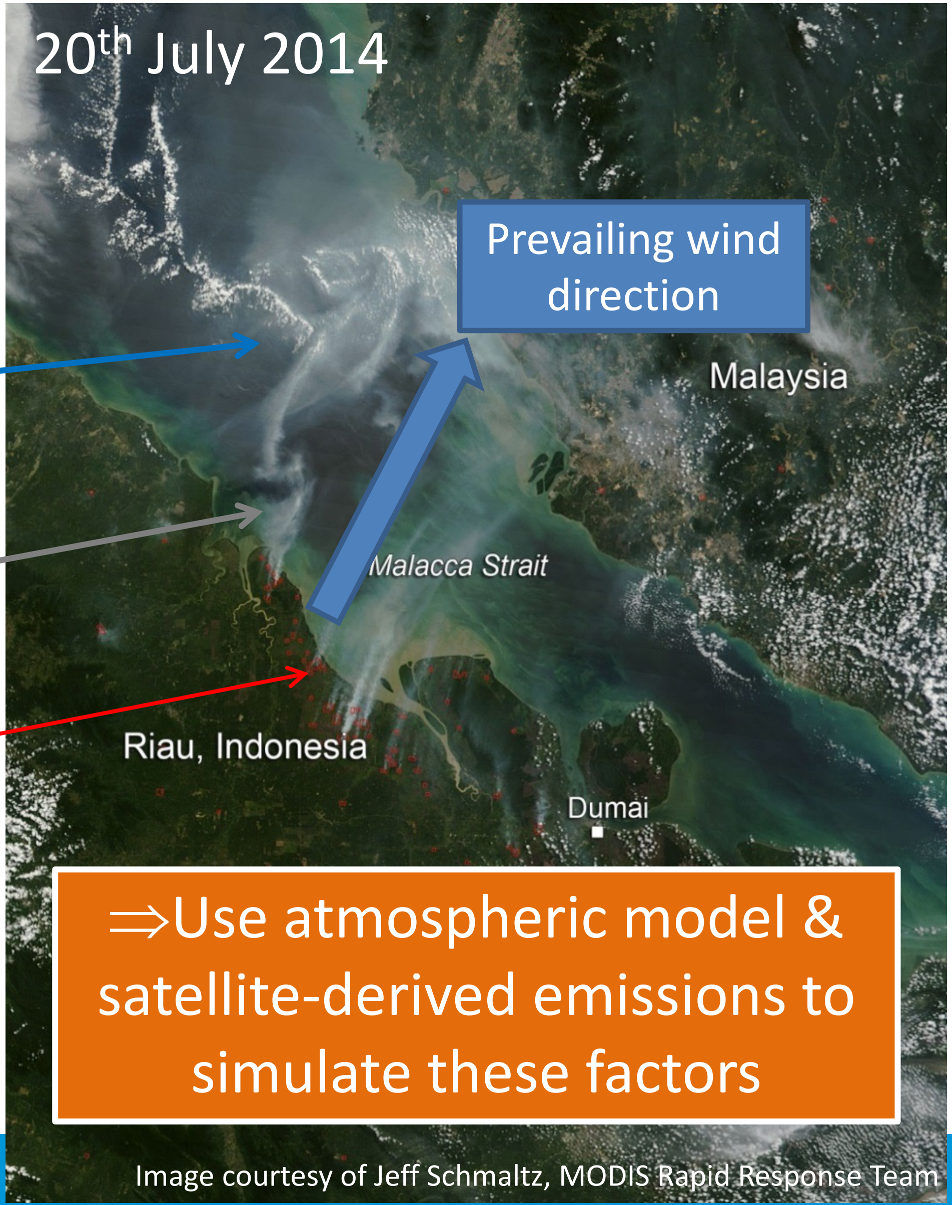
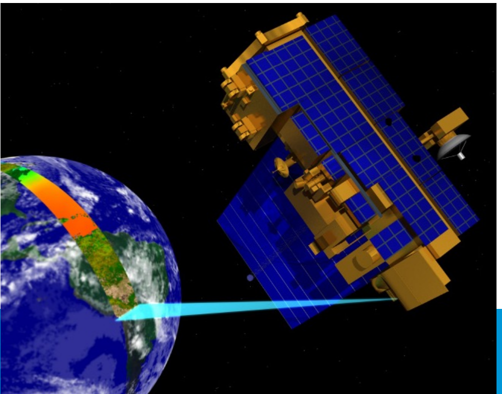
Satellite image of fire hotspots in Indonesia

Atmospheric transport and ageing of smoke plume

Amount of smoke emitted

Fire location





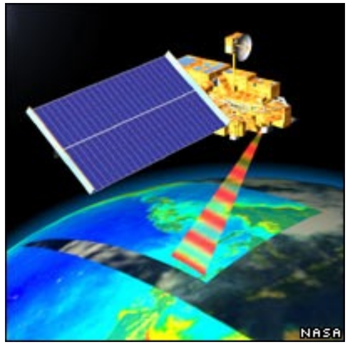
Reddington et al., ERL, 2014

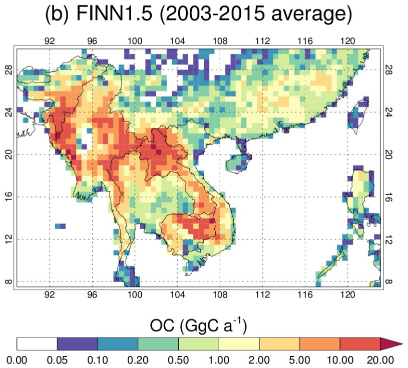
Aim: To explore the impact of forest and vegetation fires on air quality and public health in Mainland SE Asia and SE China.

Part 1: Simulate multi-year (2003-2015) PM concentrations to evaluate the performance of three fire emissions datasets against observations.

Satellite-derived fire emissions

GFED4.1s *(van der Werf et al., 2017)*
GFASv1.2 *(Kaiser et al., 2012)*
FINNv1.5 *(Wiedinmyer et al., 2011)*





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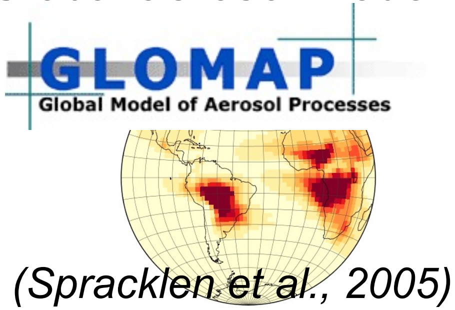
Global aerosol model



(Spracklen et al., 2005)

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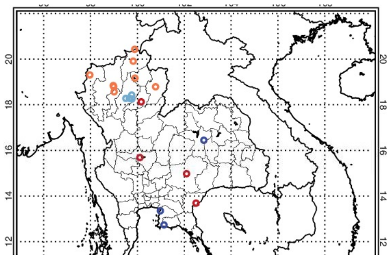
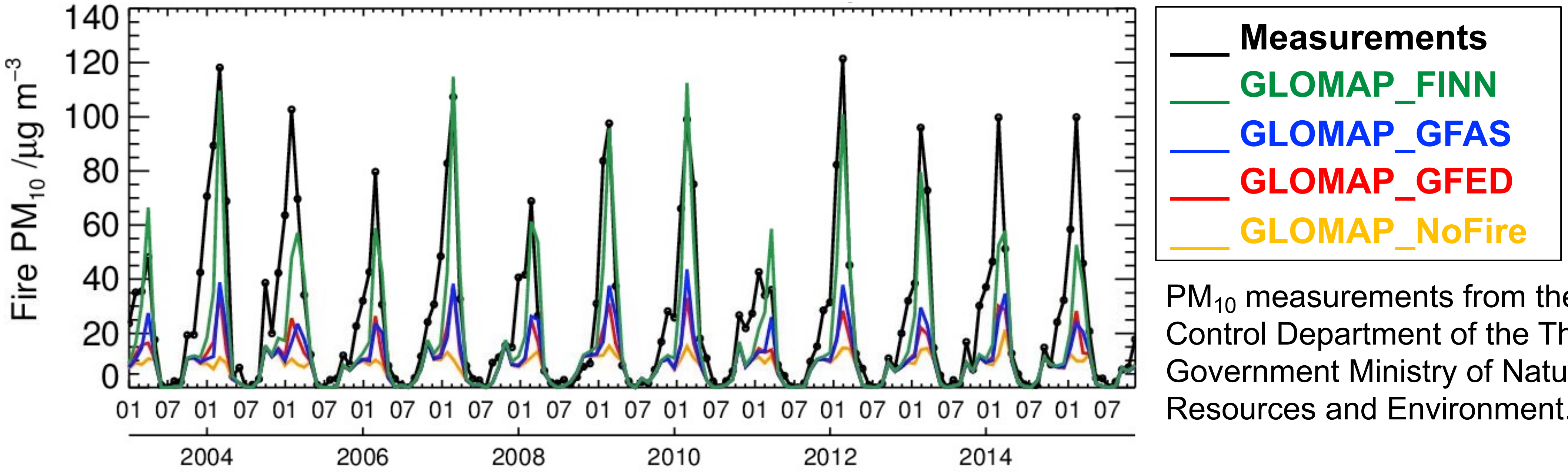
PM_{10} measurements



Thailand Pollution Control Department monitoring data

Global model captures observed magnitude and variability in fire-derived PM_{10} best with FINN dataset.

Multi-annual (2003-2015) monthly mean "fire-derived" PM_{10} in Thailand



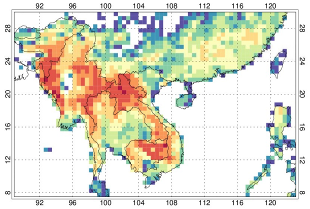
PM_{10} measurements from the Pollution Control Department of the Thailand Government Ministry of Natural Resources and Environment.

Reddington et al., GeoHealth, 2021

Aim: To explore the impact of forest and vegetation fires on air quality and public health in Mainland SE Asia and SE China.

<u>Part 2</u>: Simulate high-res PM concentrations for one year (2014) and quantify the public health impacts.

Fire emissions; **FINNv1.5**



(Wiedinmyer et al., 2011)

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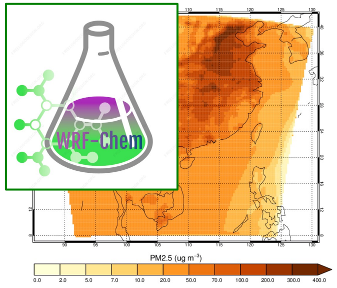
High-res regional model; **WRFChem**



(Grell et al., 2005)

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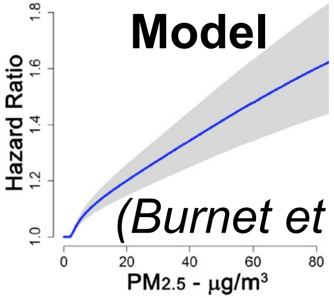
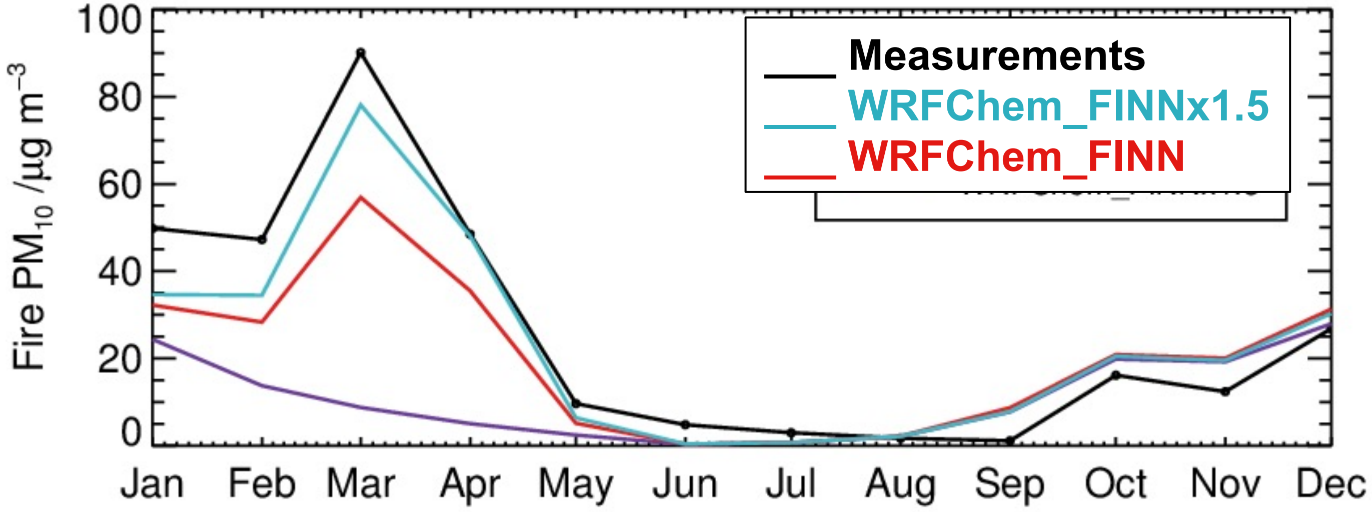
Health Impact Assessment; **Global Exposure Mortality Model**



(Burnet et al., 2018)

Regional model using FINN best simulated measured PM_{10} when particulate fire emissions were scaled upwards by a factor 1.5.

2014 monthly mean "fire-derived" PM_{10} in Thailand



- Model well simulates monthly mean variation in measured fire PM_{10} but underestimates the magnitude.
- Increasing fire emissions by a factor 1.5 improves agreement.

Reddington et al., GeoHealth, 2021

Poorer populations are exposed to greater levels of fire-derived $PM_{2.5}$ pollution than wealthier populations.

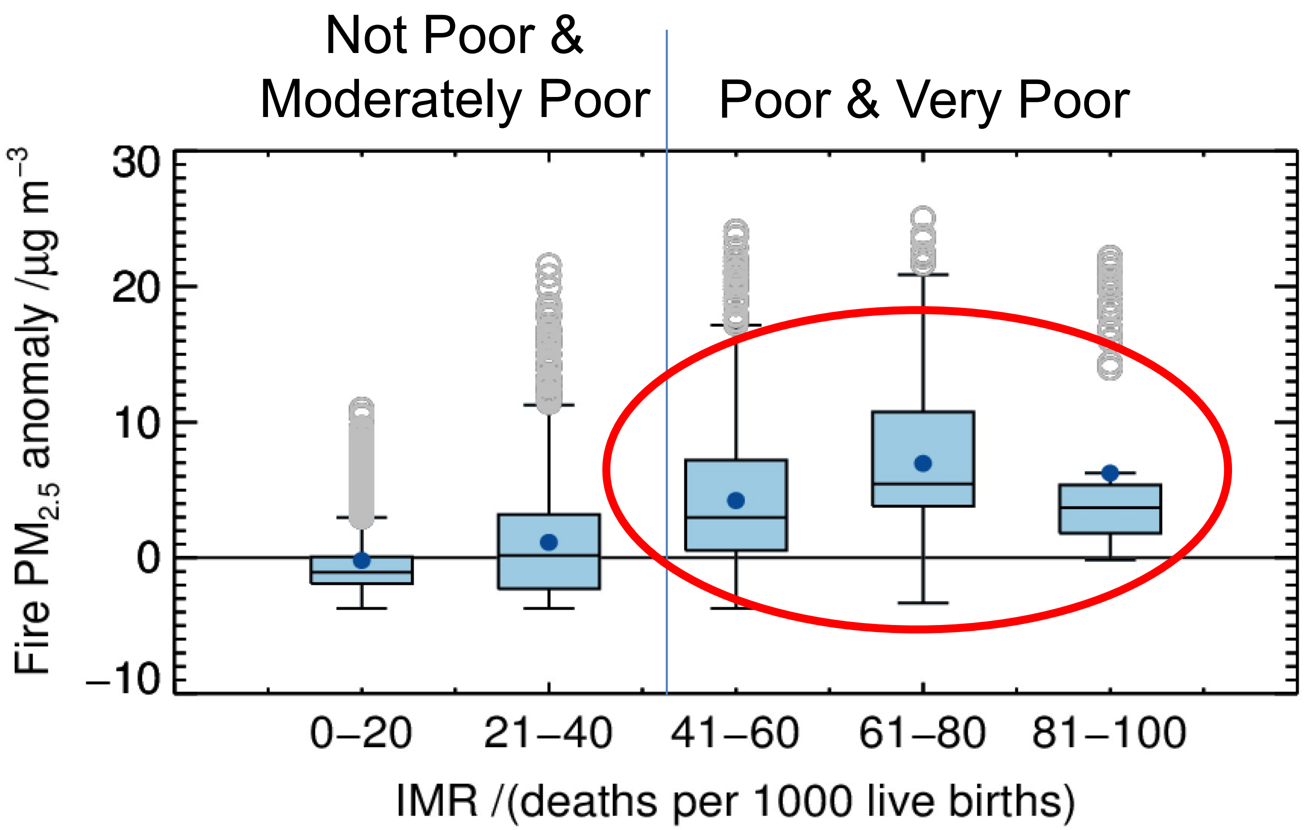
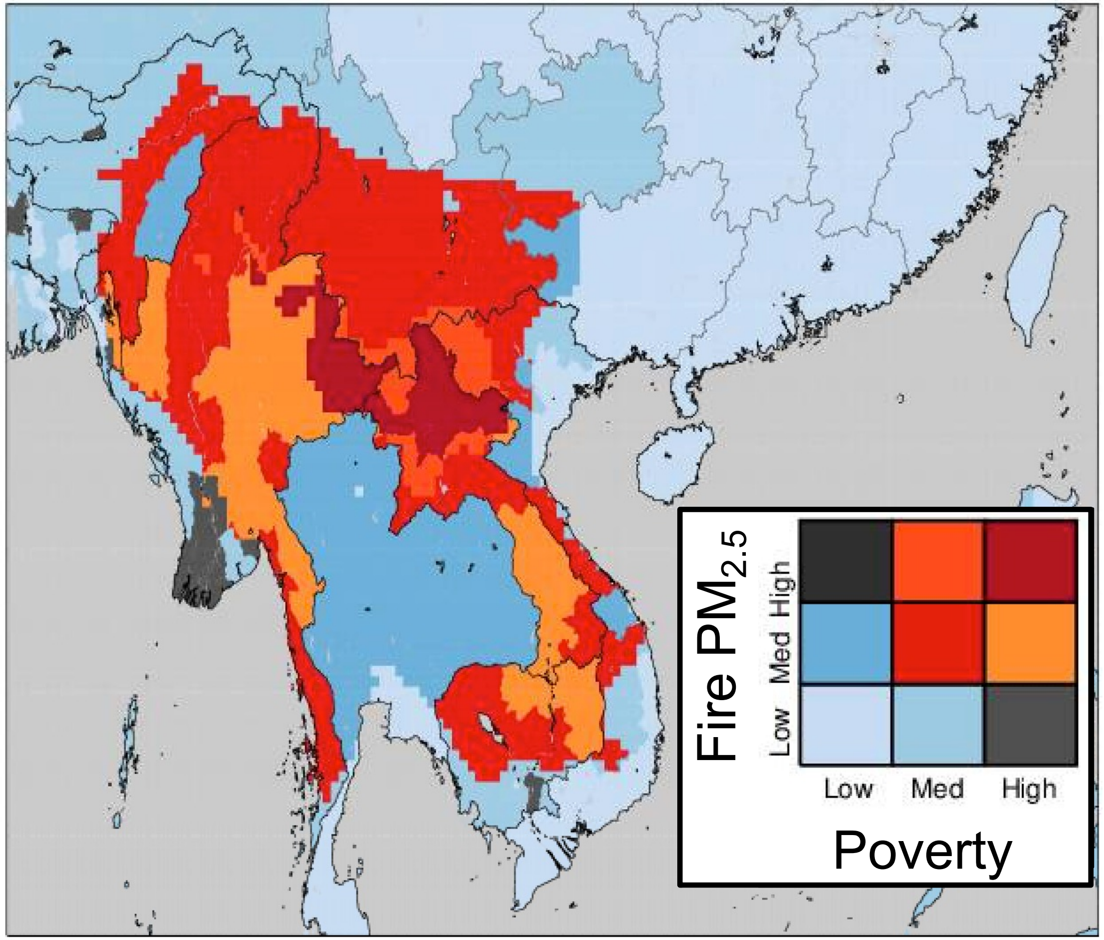


Figure: Simulated exposure to **fire-derived $PM_{2.5}$ concentrations** for populations across SE Asia with different poverty levels.

Anomaly = difference of the $PM_{2.5}$ exposure in each IMR bin from the mean $PM_{2.5}$ exposure across all IMR bins.

Reddington et al., GeoHealth, 2021

Regions with high levels of poverty coincide with exposure to relatively high concentrations of $PM_{2.5}$ from fires.



Spatial distribution of relative poverty levels and simulated fire-derived $PM_{2.5}$ exposure across Southeast Asia.

Reddington et al., GeoHealth, 2021

Free atmospheric models / model data online

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HYSPLIT
AIR RESOURCES LAB

Trajectory and dispersion models

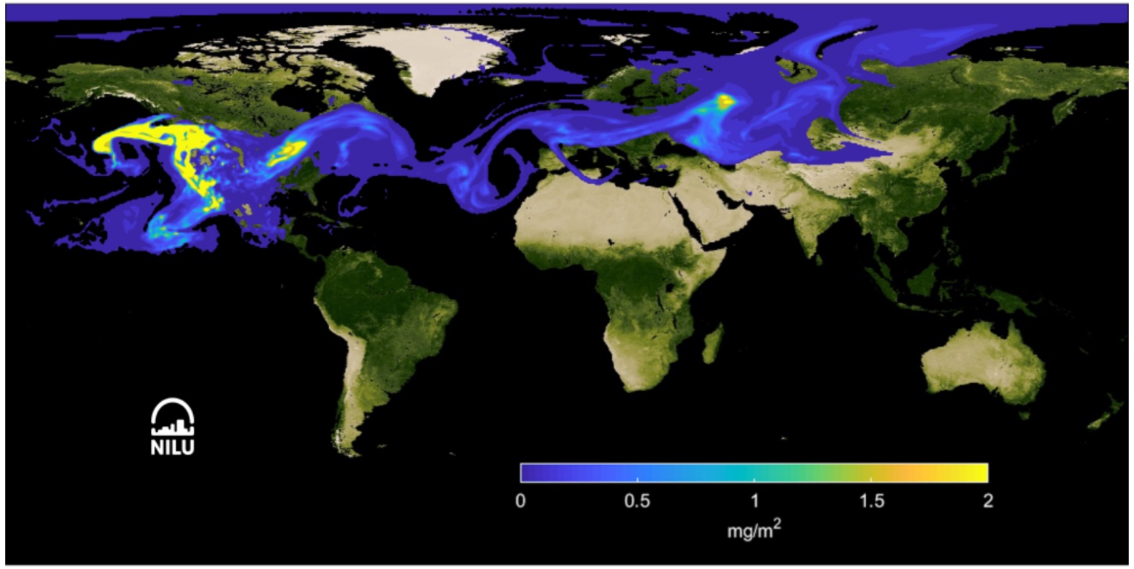
https://www.ready.noaa.gov/HYSPLIT.php

Graz Lagrangian Model GRAL

https://gral.tugraz.at/features.html

FLEXPART

Model for atmospheric transport representing the Lagrangian trajectories of a large number of particles in the atmosphere.



FLEXPART forward simulation on 13.09.2020 of the total column density of aerosols emitted from forest fires in North America

http://flexpart.eu

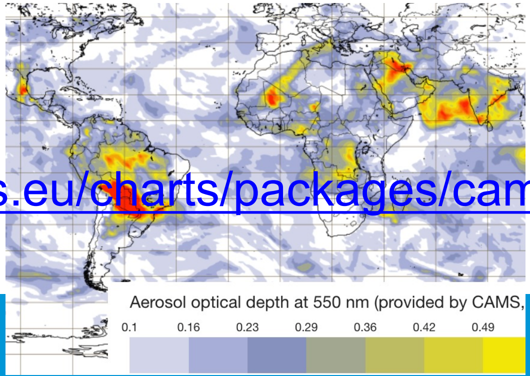
ECMWF CAMS Reanalysis

https://www.ecmwf.int/en/research/climate-reanalysis/cams-reanalysis

https://acp.copernicus.org/articles/19/3515/2019/

CAMS Forecasts

https://atmosphere.copernicus.eu/charts/packages/cams/



Having a go at HYSPLIT

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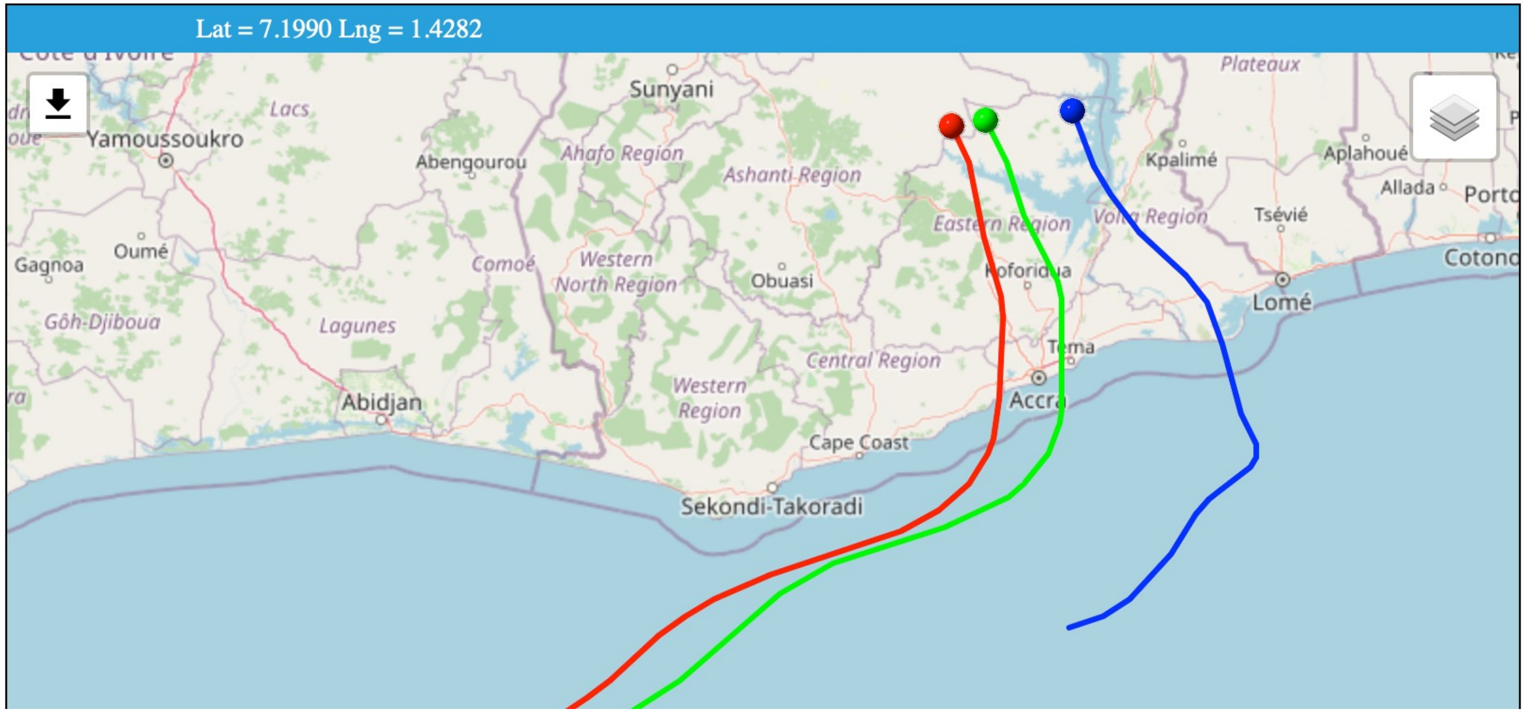
https://www.ready.noaa.gov/HYSPLIT.php

HYSPLIT MODEL RESULTS FOR JOB NUMBER 16677

Model Status:

```
Thu Oct 26 04:23:15 EDT 2023
The model and graphics are now complete.
Finished generating graphics for job 16677.
  adding: greenball.png (deflated 1%)
```



One example of using HYSPLIT Trajectory Model

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https://www.ready.noaa.gov/HYSPLIT_traj.php

HYSPLIT Trajectories
AIR RESOURCES LAB

- Compute *forecast* trajectories
- Compute *archive* trajectories
- Retrieve previous model results
- Restart user session (clear user inputs)

Type of Trajectory(ies)

Number of Trajectory Starting Locations ○ 1 ○ 2 ◉ 3

Note: By choosing just one source location, mor the next page, such as choosing by latitude/lon locations limit the input to just latitude/longitud ensemble and frequency.

Type of Trajectory ◉ Normal ○ Matrix ○ Ensemble ○ Frequency

Meteorology & Starting Location(s)

Trajectory Calculation

Meteorology: GDAS (1 degree, global, 2006-present)

Source Location

Source 1 Latitude:	7.013668	N
Source 1 Longitude:	0.703125	W
Source 2 Latitude:	7.100000	N
Source 2 Longitude:	-0.000000	W
Source 3 Latitude:	7.050000	N
Source 3 Longitude:	0.500000	W

Model Run Details

Request trajectory

The archived data file (GDAS1) has data beginning at 10/22/23 0000 UTC.

Model Parameters

Trajectory direction: ○ Forward ◉ Backward (Change the default start time!) More info

Vertical Motion: ◉ Model vertical velocity ○ Isobaric ○ Isentropic More info

Start time (UTC): Current time: 10:45 — year 23, month 10, day 22, hour 8 More info

Total run time (hours): 48 More info

...t a new trajectory every: 0 hrs Maximum number of trajectories: 0 More info

Start 1 latitude (degrees): 7.013668 More info

Start 1 longitude (degrees): -0.703125 More info

Start 2 latitude (degrees): 7.100000

Start 2 longitude (degrees): 0.000000

Start 3 latitude (degrees): 7.050000

Start 3 longitude (degrees): -0.500000

Display Options

GIS output of contours? ○ None ◉ Google Earth (kmz) ○ GIS Shapefile More info

The following options apply only to the GIF, PDF, and PS results (not Google Earth)

Plot resolution (dpi):	96					More info
Zoom factor:	70					More info
Plot projection:	◉ Default	○ Polar	○ Lambert	○ Mercator		More info
Vertical plot height units:	○ Pressure	◉ Meters AGL	○ Theta			More info
Label Interval:	○ No labels	○ 1 hour	◉ 6 hours	○ 12 hours	○ 24 hours	More info
Plot color trajectories?	◉ Yes	○ No				
Use same colors for each source location?	◉ Yes	○ No				More info
Plot source location symbol?	◉ Yes	○ No				
Distance circle overlay:	◉ None	○ Auto				More info