Input data needed by MATCH

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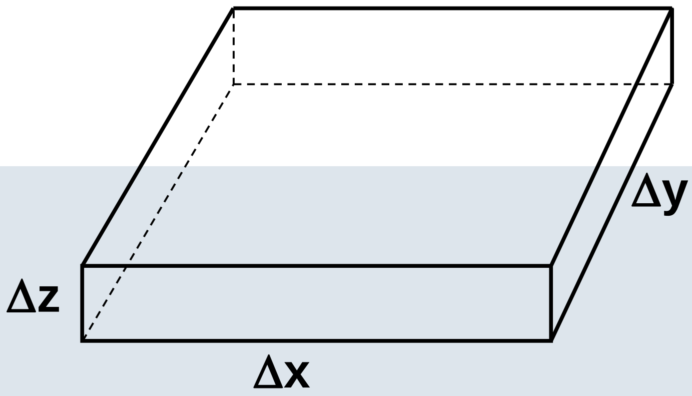
- Three-dimensional meteorology
- Fields with area emissions, list of large point sources
  - Temporal variation of emissions, stackheight etc. of emissions
- Field of surface fysiography
- Boundary fields

Three-dimensional meteorology

- Taken from meteorological models
- Plenty of information, take up large amount of disk-space (5-10 Gbyte $year^{-1}$)
- The meteorology is valid for a certain time interval
- It is also possible to use forecasted meteorology, as well as data from climate models

Meteorological data for MATCH



From weather forecast or analysis model

Use data from ECMWF's global model

Horizontal resolution (Δx×Δy): 100 km × 100 km, 50 km × 50 km

Possible to interpolate to higher resolution (1–5 km) in MATCH

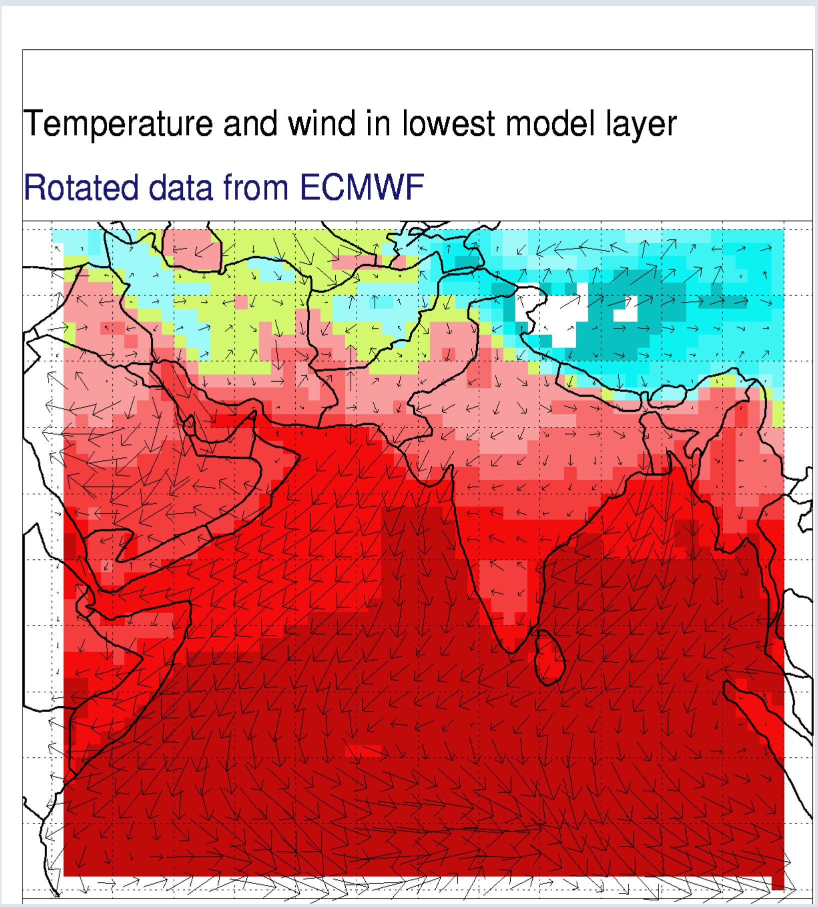
Vertical resolution (Δz) ca. 20-60 meters near the surface, increasing to ~500 m at 10 km

Temporal resolution 3 or 6 hours

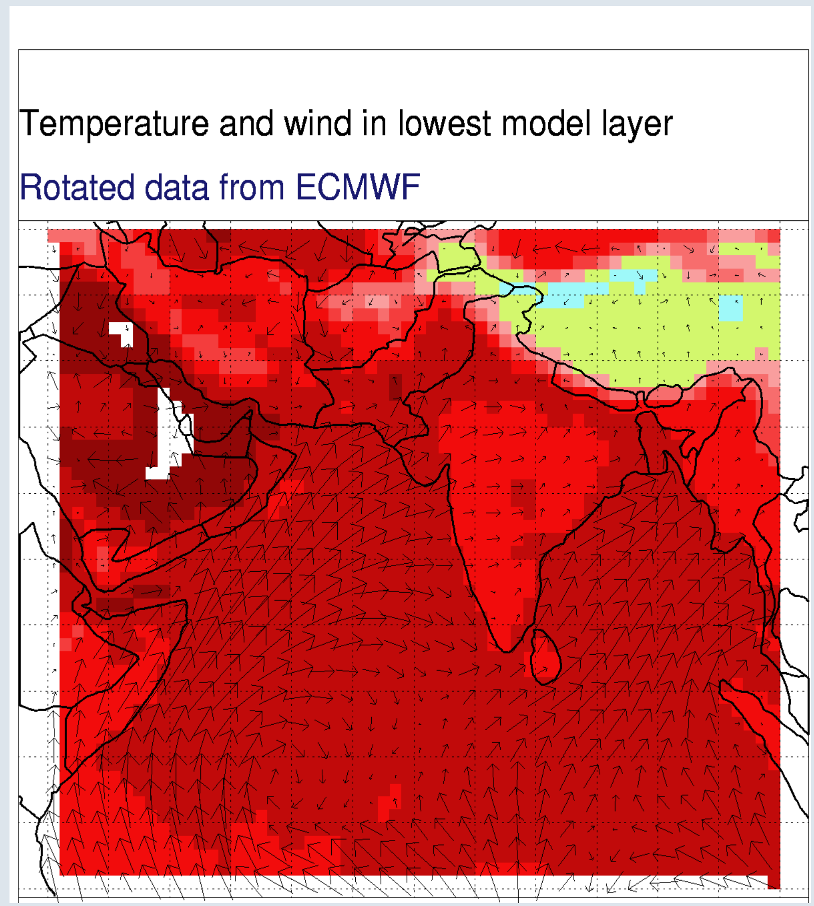
Interpolated to 1 hour in MATCH

High resolution (25 km or better) can be used if running regional weather forecast models for the area.

Illustration of Malé model domain and type of meteorology available



15 February, 2000 00Z



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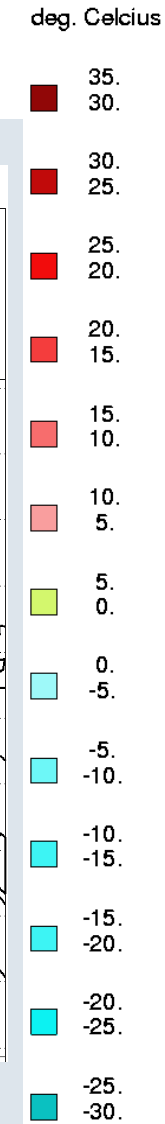
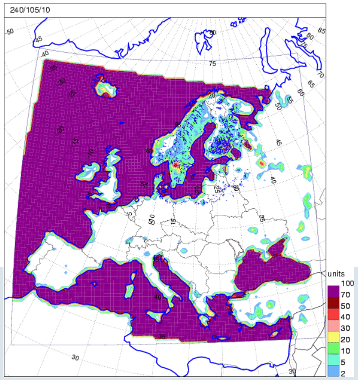
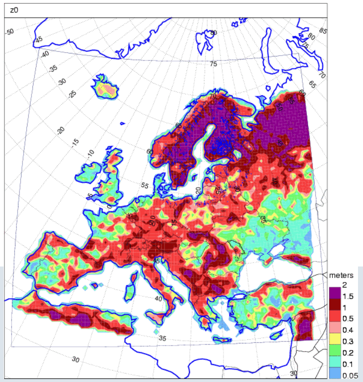


Physiography



Water



z_0

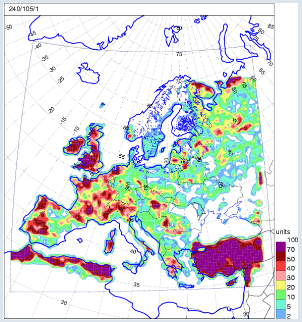
- Land or Sea
- Surface type (forest, pasture, …, urban, … etc)
- Surface roughness (z_0)

Needed to

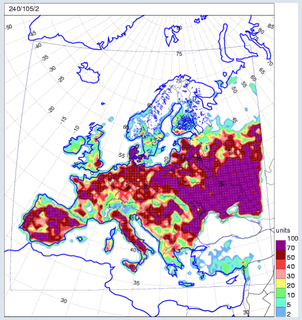
(i) deduce near-surface turbulence in MATCH, including boundary layer height

(ii) calculate drydeposition to different surfaces

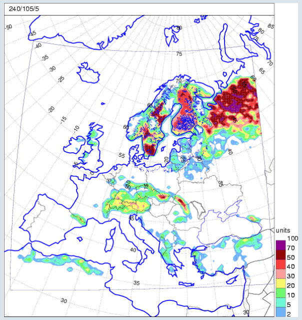
Etc.



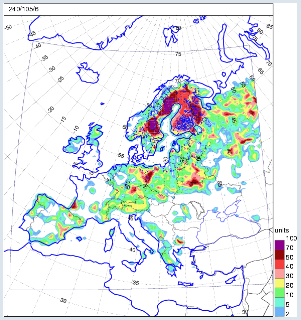
Pasture



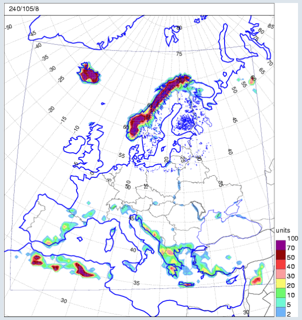
Arable



Spruce

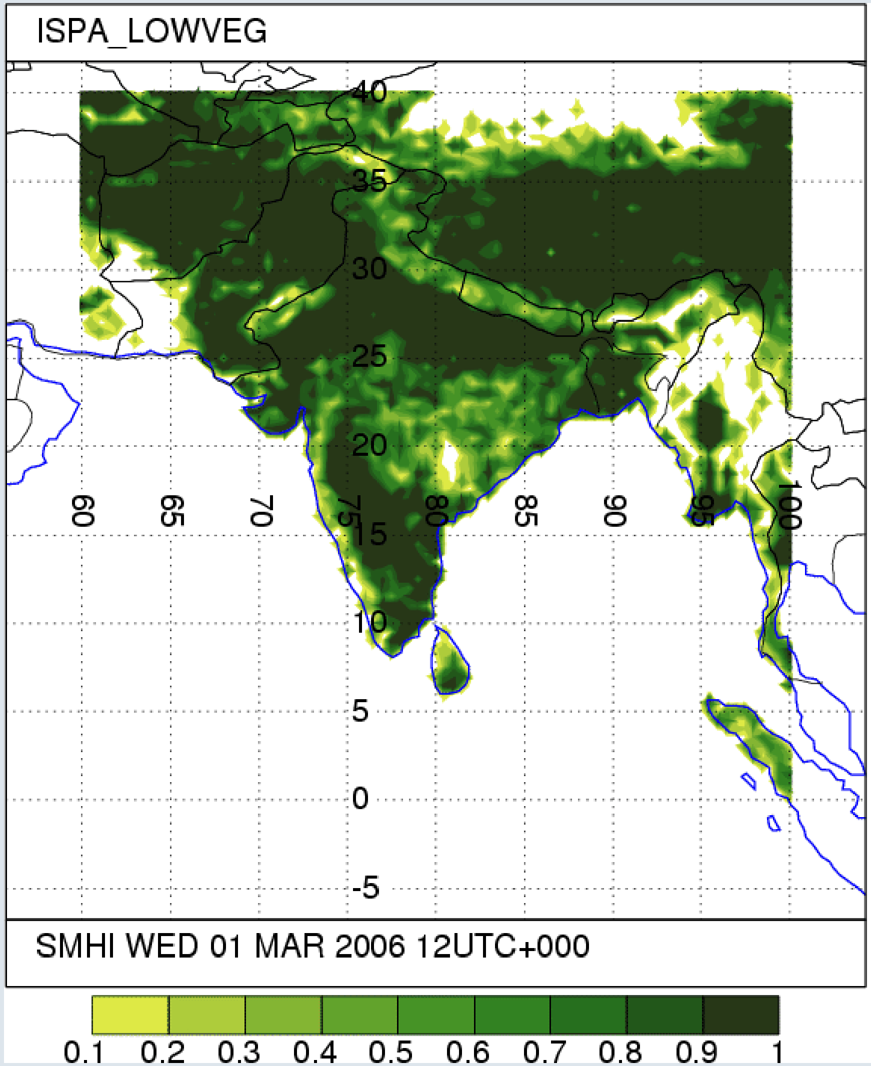


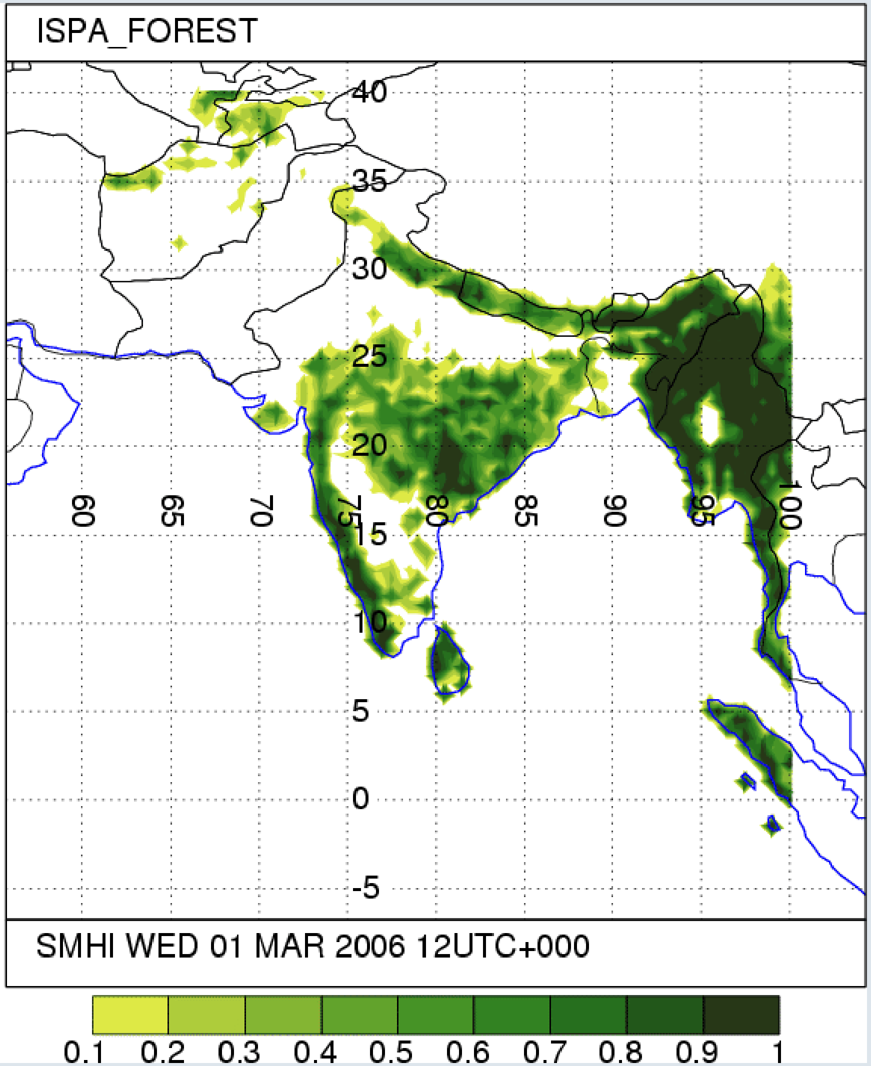
Pine



Mountain

Four surface types: (1) low vegetation; (2) forest; (3) dry land; (4) ocean





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Input meteorological data required by MATCH

Minimum set of input meteorological and "*physiographical*" (surface characterisation; land-sea mask, surface roughness and surface albedo) parameters needed to run MATCH. Note the distinction between single level parameters (two-dimensional) and multi level parameters (three-dimensional). The meteorological data is updated at regular intervals, e.g. every 6 hours.

Parameter	Comment
Land-sea mask[1]	Used for calculation of near-surface turbulence, and discrimination between different surface types in the calculation of dry deposition.
Topography[1]	Needed for setting up the vertical domain.
Surface roughness[1]	Used for calculation of near-surface turbulence.
Surface albedo	Used for calculation of near-surface turbulence.
Surface pressure	Used for setting up the vertical co-ordinates, and for calculating pressure tendency (important when calculating vertical wind).
Surface temperature	Used for calculation of near-surface turbulence.
2 m temperature	Mean temperature in lowest model layer can also be used. Used for calculation of near-surface turbulence.
2 m dew point temperature	Can also use e.g. specific humidity in lowest model layer. Used for calculation of near-surface turbulence.
10 m u-component of wind	Mean u-wind in lowest model layer can also be used. Used for calculation of near-surface turbulence.
10 m v-component of wind	Mean v-wind in lowest model layer can also be used. Used for calculation of near-surface turbulence.
Total cloud cover	Used for calculation of near-surface turbulence, and chemical reaction rates.
Total surface precipitation	Used for wet deposition calculations.
Fraction of ice-covered ocean	Used for calculation of near-surface turbulence.
Fraction of snow-covered land	Used for calculation of near-surface turbulence.
Mean layer temperature[2]	Used for calculating air density and layer thickness etc.
Mean layer u-component of wind[2]	Used for the calculating the horizontal advection of tracers.
Mean layer v-component of wind[2]	Used for the calculating the horizontal advection of tracers.
Mean layer moisture content[2]	Needed if Tiedtke's cumulus scheme is adopted.
Mean layer cloud cover[2]	Needed if more advanced wet-phase chemistry, or photochemistry is adopted.
Mean layer liquid-water content[2]	Needed if more advanced wet-phase chemistry is adopted.
Mean layer ice-water content[2]	Needed if more advanced wet-phase chemistry is adopted.

[1]Only read in once (at start of simulation)
[2]Must be provided for all layers (three-dimensional fields).

Boundary concentrations

Boundary fields may be necessary when modelling chemistry in a limited region

In some cases boundary concentrations can be neglected or are irrelevant

Boundary concentrations in MATCH

In MATCH boundary concentrations can be specified in a few different ways. They can be defined as:

- **constant for all boundaries**

- **For each of the "five boundaries" (the four sides and the top of the model domain) a concentration (ctop, cwest, ceast, csouth, cnorth) can be assigned.**

  Ctop represents the concentration at the top surface boundary, while the four lateral boundary concentrations represent the ground level concentrations *at the midpoints* of the four sides. Linear interpolation is used to get boundary values between these points.

- **Latitude dependent boundary concentration profiles (height dependent) can also be specified**

- **Three-dimensional boundary concentrations can be read from grib-files at arbitrary time-intervals**

- **These values are also used for setting initial conditions**

Fields of oxidants

Concentration of oxidants are needed for some of the chemical schemes

- **H_2O_2 (and O_3) for aqueous sulphur chemistry**
- **O_3 for NO_X chemistry**
- **OH for NO_X and SO_X chemistry**
- **CO, CH_4, for O_3 chemistry**

Emissions in MATCH

Two types:

•***Areasources***

gridded data (interpolated to the same resolution as the transport model)

•***Large Point Sources***

Pointsources are given with exact location, and other individual details, and may be followed in a separate plume model during a number of timesteps

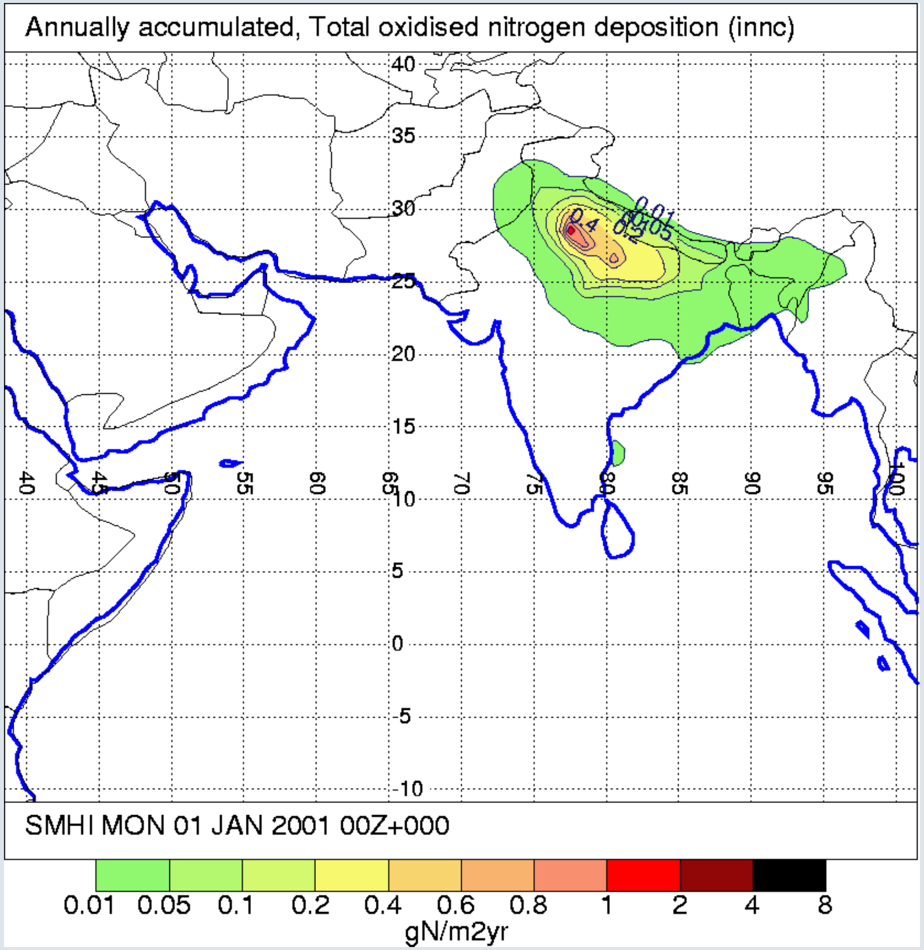
Several emission files (for each pollutant) are possible

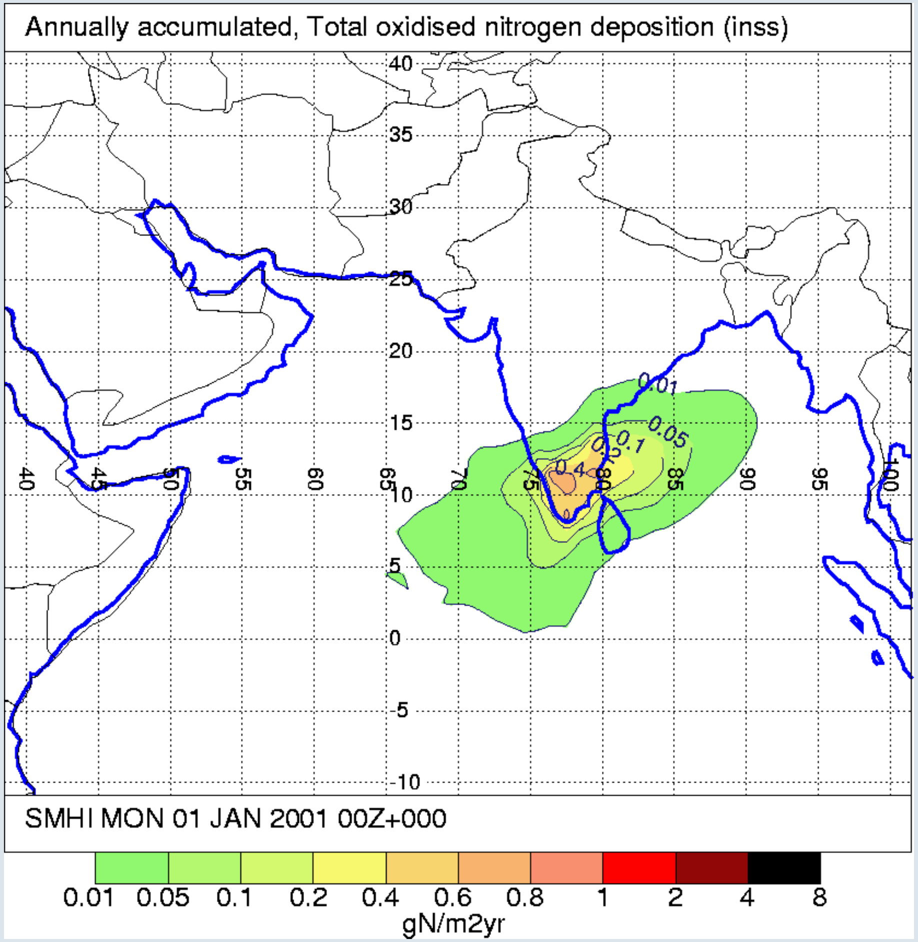
A particular area source has to be given one emission configuration (stackheight, effluent temperature and velocity etc.)

Emissions may be released at different layers

Example of results when only using a subset of the total emissions available

Total NO_X deposition in Malé domain, only emissions from Northern and Southern India, respectively

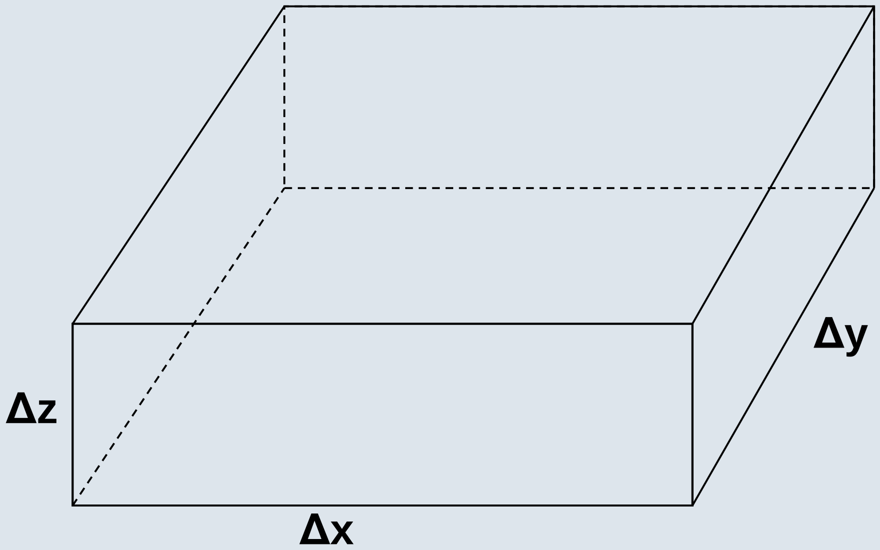




Area sources

Area sources immediately change the concentration in the whole gridbox:

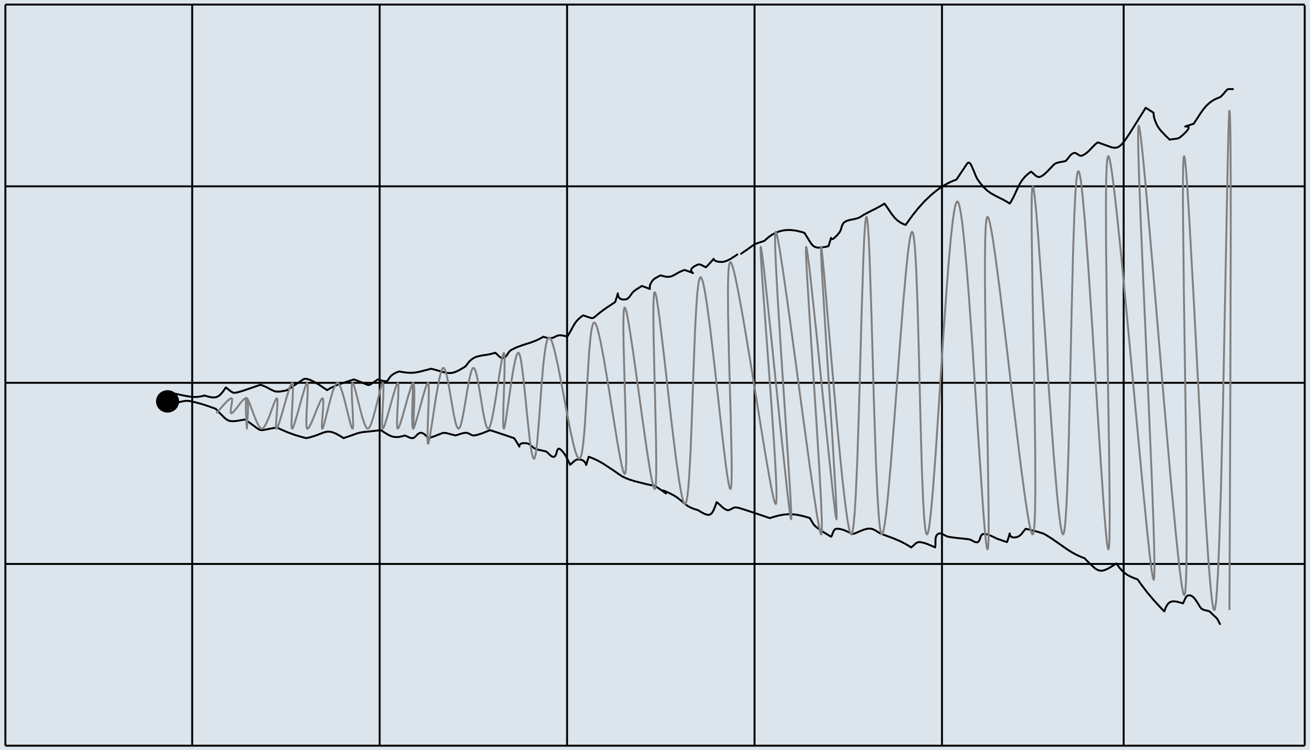
$$\Delta c = \frac{\Delta M}{V} = \frac{q\ [g/s] \times \Delta t\ [s]}{\Delta x\ \Delta y\ \Delta z\ [m^3]} \quad [g\ m^{-3}]$$



Pointsource emissions vs. Area-emissions

Emissions from point-sources may be traced separately in a plume model until the plume each the size of a grid-box

The embedded plume models in MATCH are “time-consuming”. Only consider the 10-20 largest pointsources. Treat the rest as area-emissions.

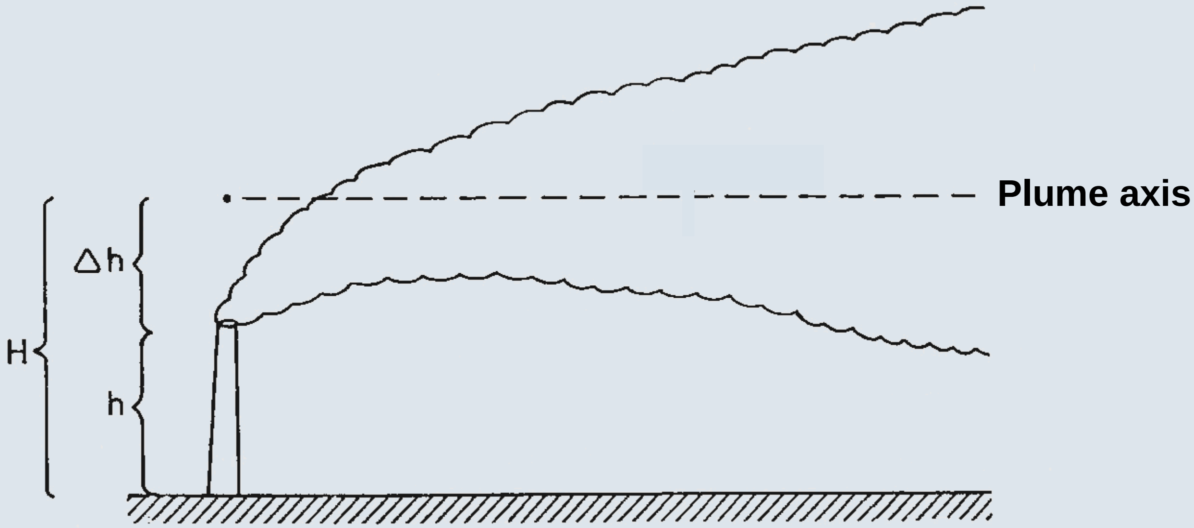


Certain characteristics should be given to the Area- and Large Point source

Characteristics include:

- **Height of emissions**
- **Temporal variations**
- **Volume, and temperature of gases…**

Plumerise



H – Effective stackheight

h – Stackheight

Δh – Plumerise

Δh dependent on the effluents exit temperature, velocity, volume flux; orifice diameter; ambient wind and stability; …

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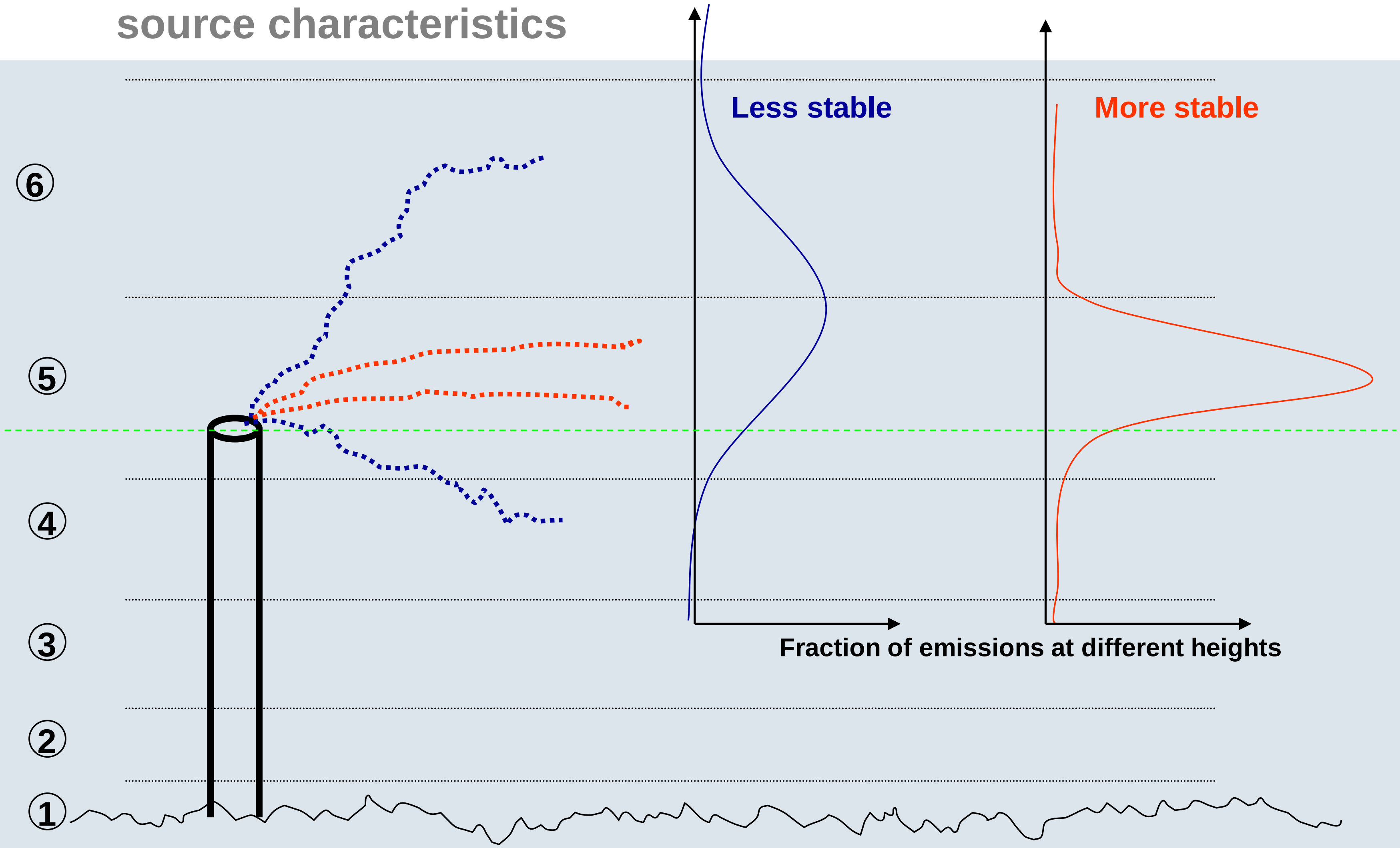
In MATCH, are the emissions distributed between different layers (with different plumerise) depending on ambient stability and source characteristics



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Why is it important to distribute the emissions realistically in the vertical?

More dilution if the emissions are released at higher heights (model layers are thicker aloft)

Tracer in the lowest model layer may be drydeposited at the ground

Different wind speed and direction at different heights

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Temporal variation of the emissions

The emissions may have:

Seasonal-
Weekly-
Diurnal-

} variations

Each species may be emitted from a number of sectors, e.g.:

Private cars

Heavy duty transport (lorries etc.)

Heating

Factories

Shipping

Diffuse emissions from soils or landfills

Natural emissions

Etc. …

Sectoral emissions

Each sector may have different:

Temporal variation

Effective stack height

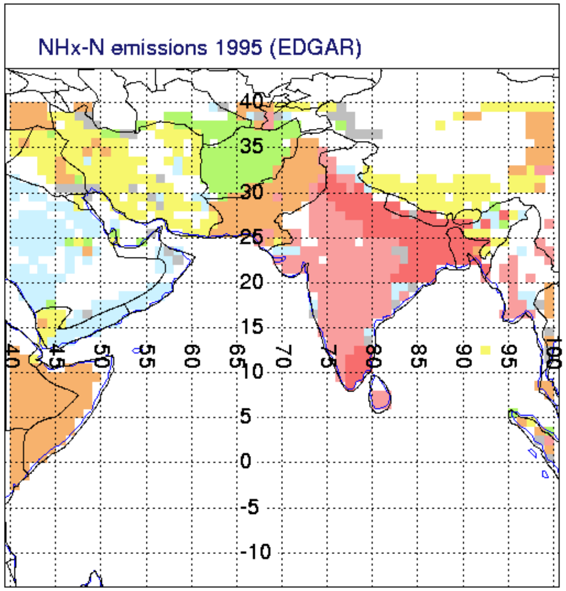
In MATCH, we may treat the emissions in a simplified manner, i.e. read in the emissions once, then apply different scaling functions

Alternative, read in new emissions every 1 hour after the appropriate temporal variation has already been applied.

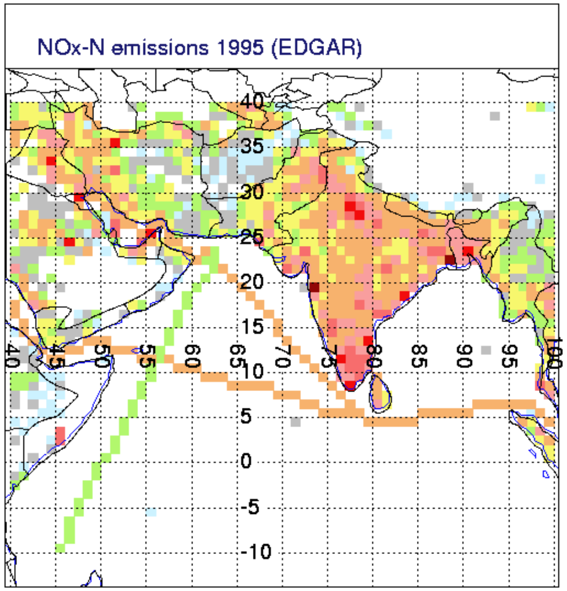
The emissions in each sector should be released at the appropriate level

Emissions from EDGAR database

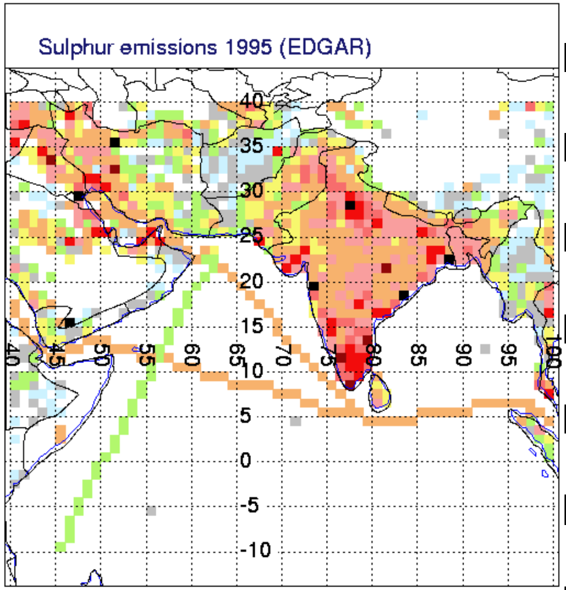
(Inventory valid for 1995; includes all anthropogenic sources)



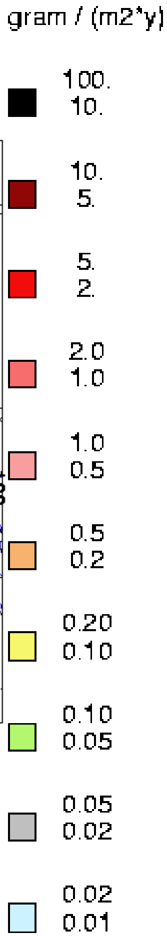
Reduced nitrogen



Oxidised nitrogen



Total sulphur



Horizontal distribution of total emissions in a country/region

- Area sources = Total emission – Point Sources

From "workbook" or other sources

- Point source emissions have known positions

- Area sources can be distributed based on e.g. population density or land usage classification

- We can also scale new area-sources according to previous distribution

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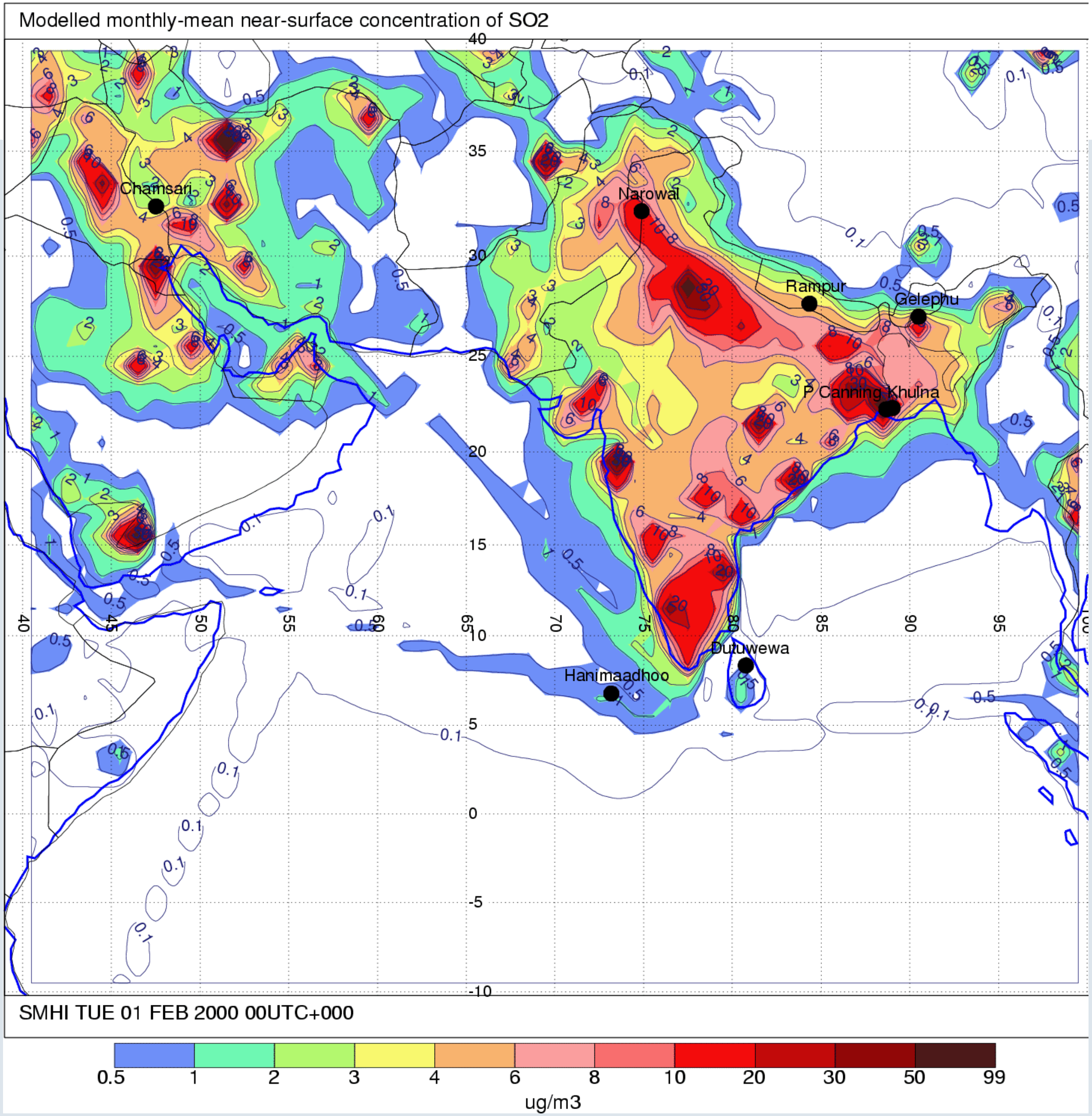
How certain are the results?

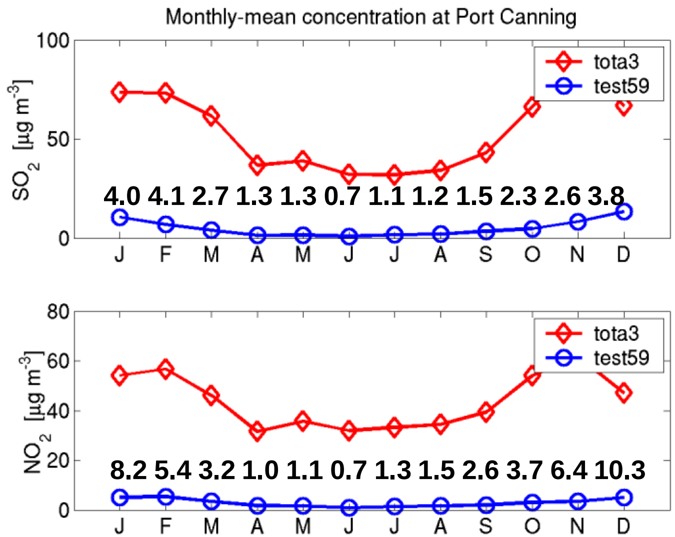


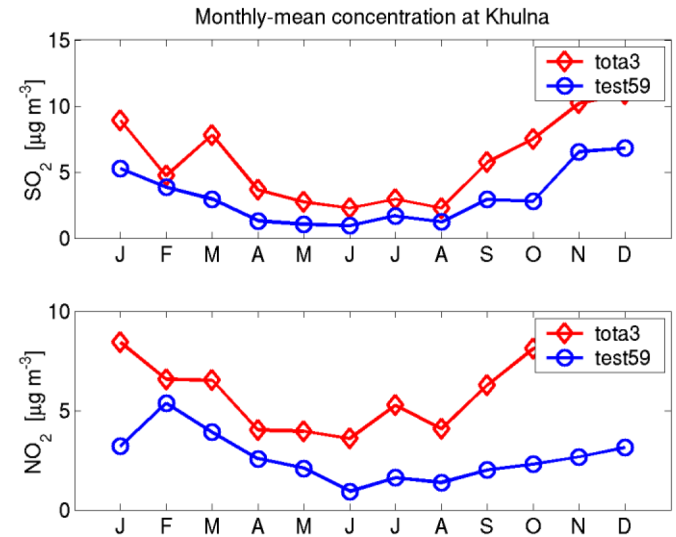
Modelled near-surface SO_2 concentration in Malé domain during January 2000 using EDGAR emissions valid for 1995

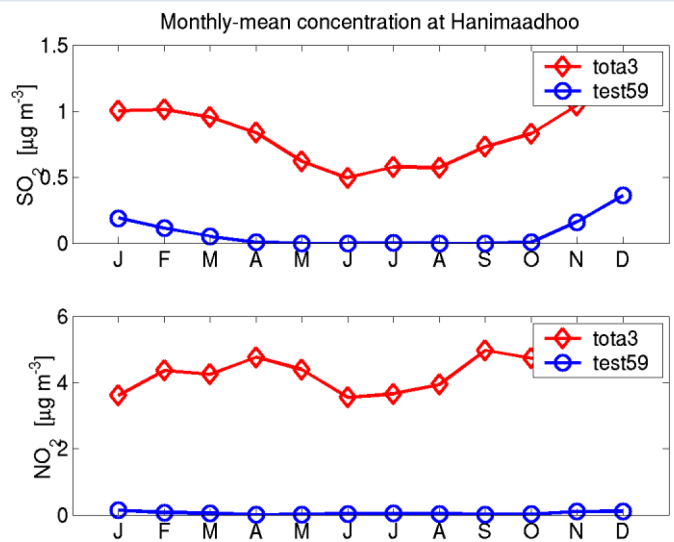
Modelled monthly-mean concentrations of SO_2 and NO_2 using two different emissions inventories

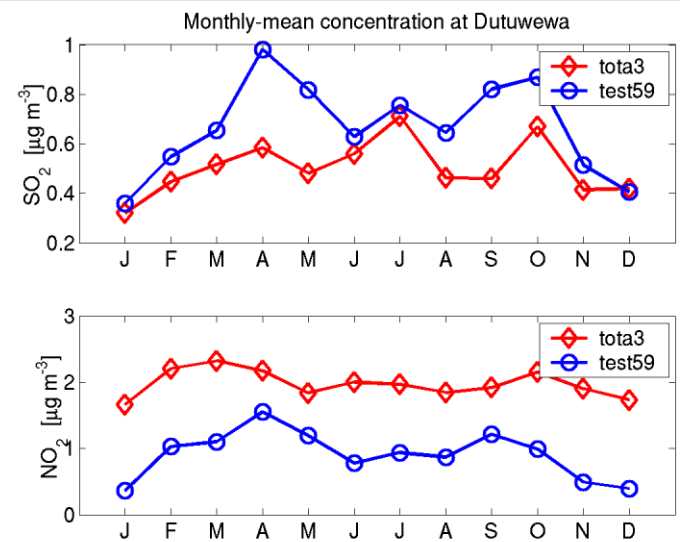
EDGAR emissions; 1°×1° resolution

TRACE-P emissions; 0.5°×0.5° resolution









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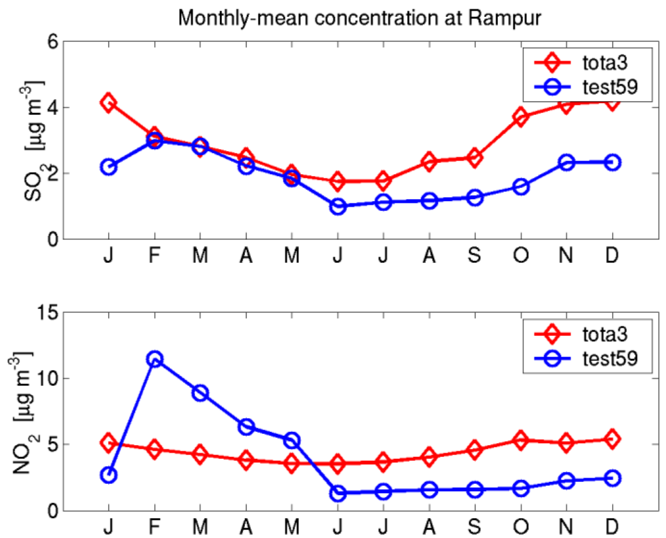
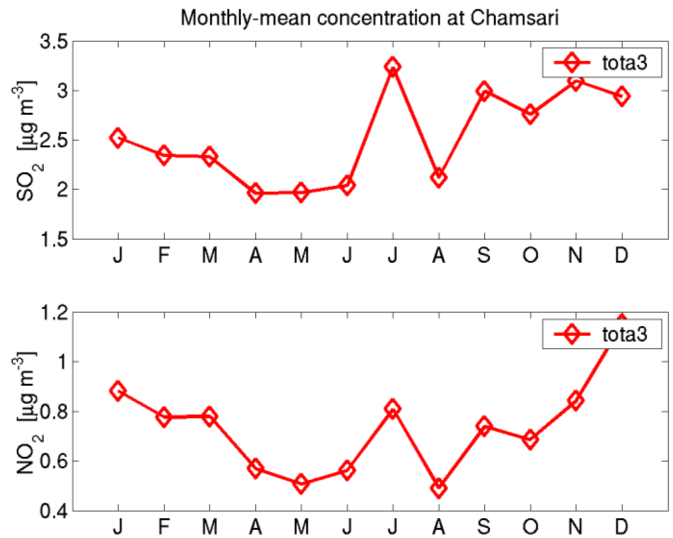
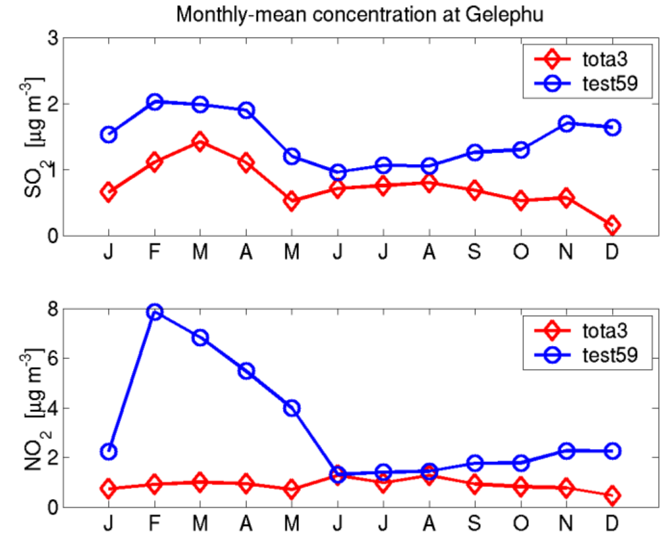
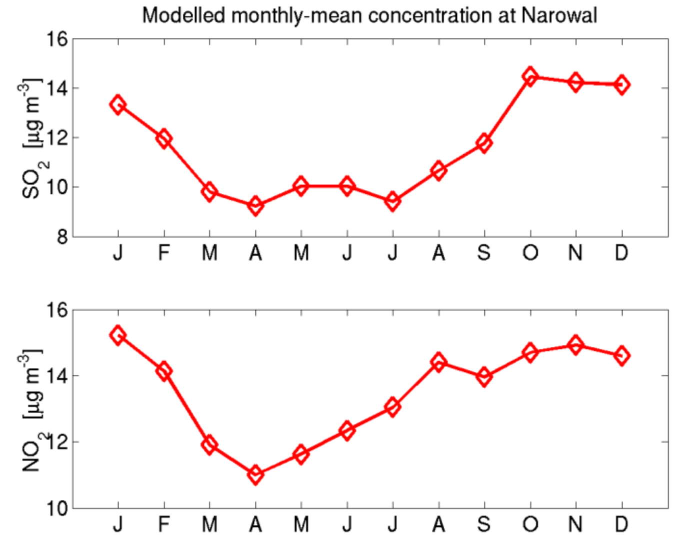
EDGAR emissions; 1°×1° resolution

TRACE-P emissions; 0.5°×0.5° resolution



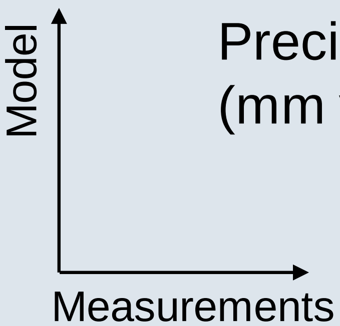






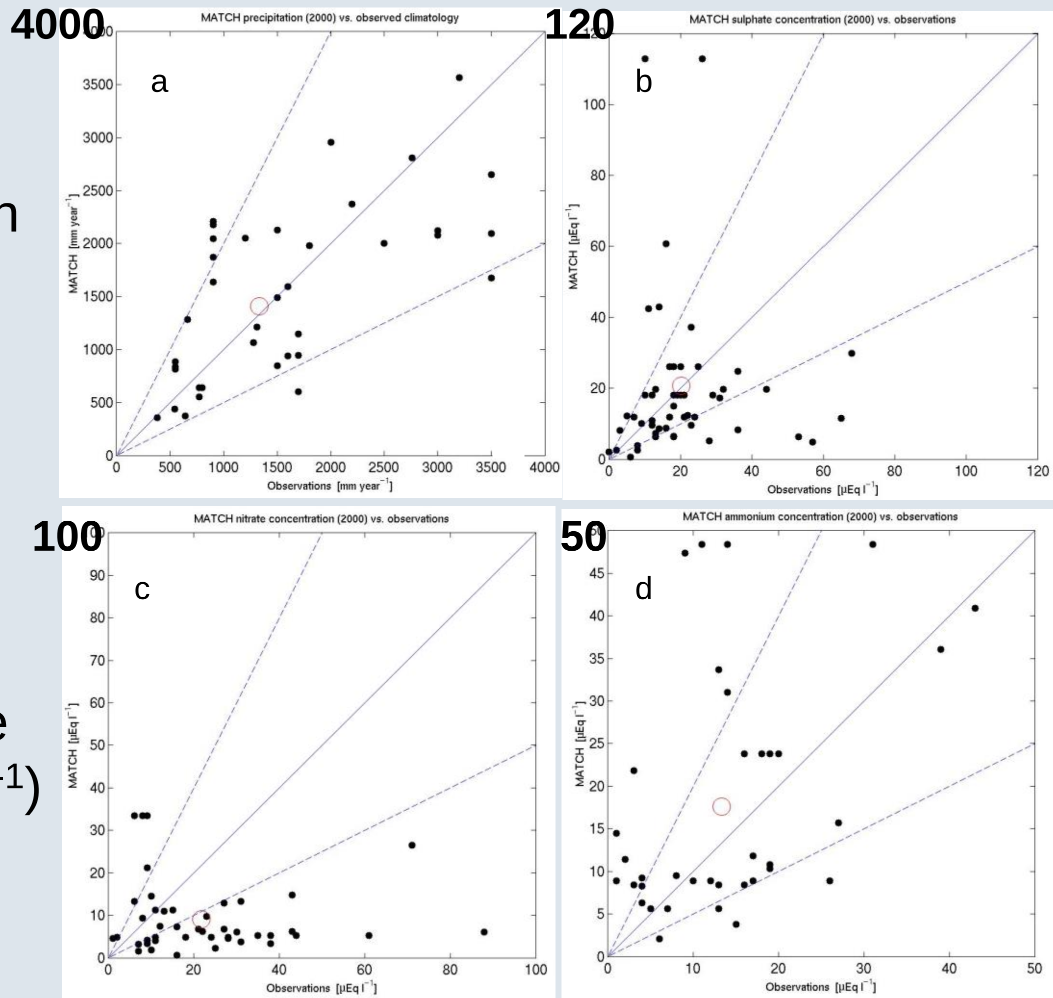
Sample results. Annual-mean concentration in precipitation

(Kulshrestha et al., Atm. Environ. 2005, 7403-7419)



Precipitation ($mm\ year^{-1}$)

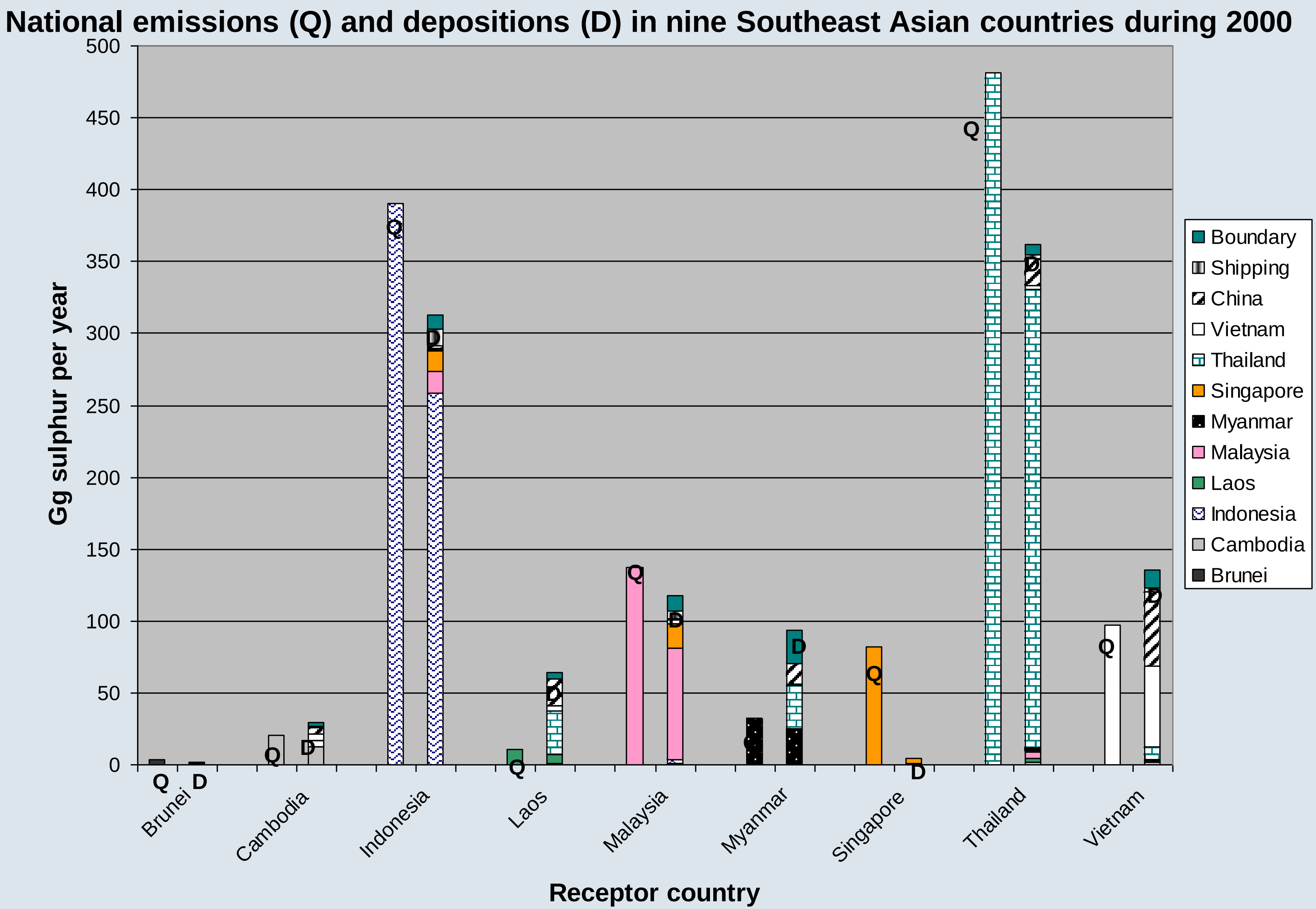
Sulphate ($\mu Eq\ l^{-1}$)



Nitrate ($\mu Eq\ l^{-1}$)

Ammonium ($\mu Eq\ l^{-1}$)

Source-receptor calculations of anthropogenic sulphur in Southeast Asia using the MATCH model



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Sensitivity tests

Test the robustness of the results by varying model parameters and emission configurations

Annually accumulated deposition (in 10^9 g sulphur $year^{-1}$) on nine Southeast Asian receiver countries from emissions from Thailand during different model set-ups. The accuracy of the values is far less than indicated by some of the entries in the table, typically only 1 or 2 significant digits.

Receiver → / Experiment ↓	Brunei	Cambodia	Indonesia	Laos	Malaysia	Myanmar	Singapore	Thailand	Vietnam	other areas
Standard	0.0	4.3	1.2	30.6	3.2	30.2	0.0	319.3	9.5	82.8
Oxidation rate halved	0.0	4.3	1.2	30.3	3.1	30.3	0.0	318.0	9.3	84.6
Decreased wet scavenging	0.0	3.6	3.3	22.5	3.2	31.5	0.0	237.5	9.3	170.2
No rain in domain	0.0	2.5	1.9	12.6	2.7	14.7	0.0	204.8	4.6	237.3
Decreased dry deposition	0.0	4.8	1.6	33.8	3.1	33.0	0.0	290.7	11.1	103.0
Increased dry deposition	0.0	3.8	0.9	27.5	3.2	27.4	0.0	344.0	8.1	66.2
Emissions higher during May-Oct	0.0	4.6	1.0	32.4	3.1	29.7	0.0	327.9	9.6	72.8
Emissions lower during May-Oct	0.0	4.0	1.4	28.8	3.3	30.6	0.0	310.7	9.4	92.9
Emission height increased	0.0	5.9	1.7	37.5	2.9	34.8	0.0	274.2	12.2	111.9
Emission height decreased	0.0	4.3	1.2	25.8	3.1	22.6	0.0	342.8	8.1	73.2