If you don't like your result change your approach!

Satellite based Characterization of Emissions

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Outline

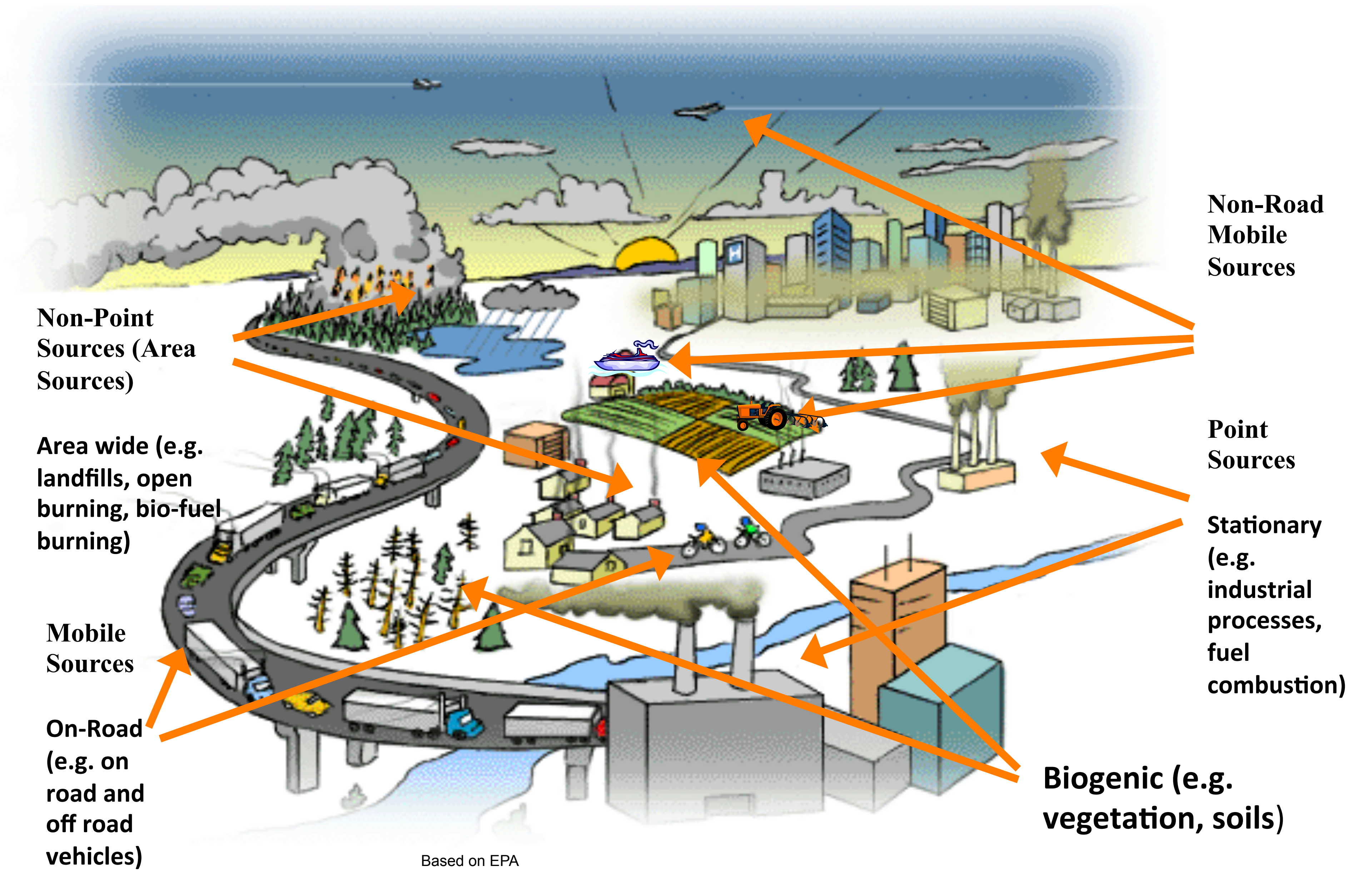
1. **What is an Emissions Inventory and why do we need one?**
    1. Building and bottom up emission inventory
    2. Calculation of emissions from the T sector fro Delhi
2. **Satellite measurements and top down emission inventory**
3. **Data base for Global and regional Emission Inventory data sources**

What is an Emission Inventory?

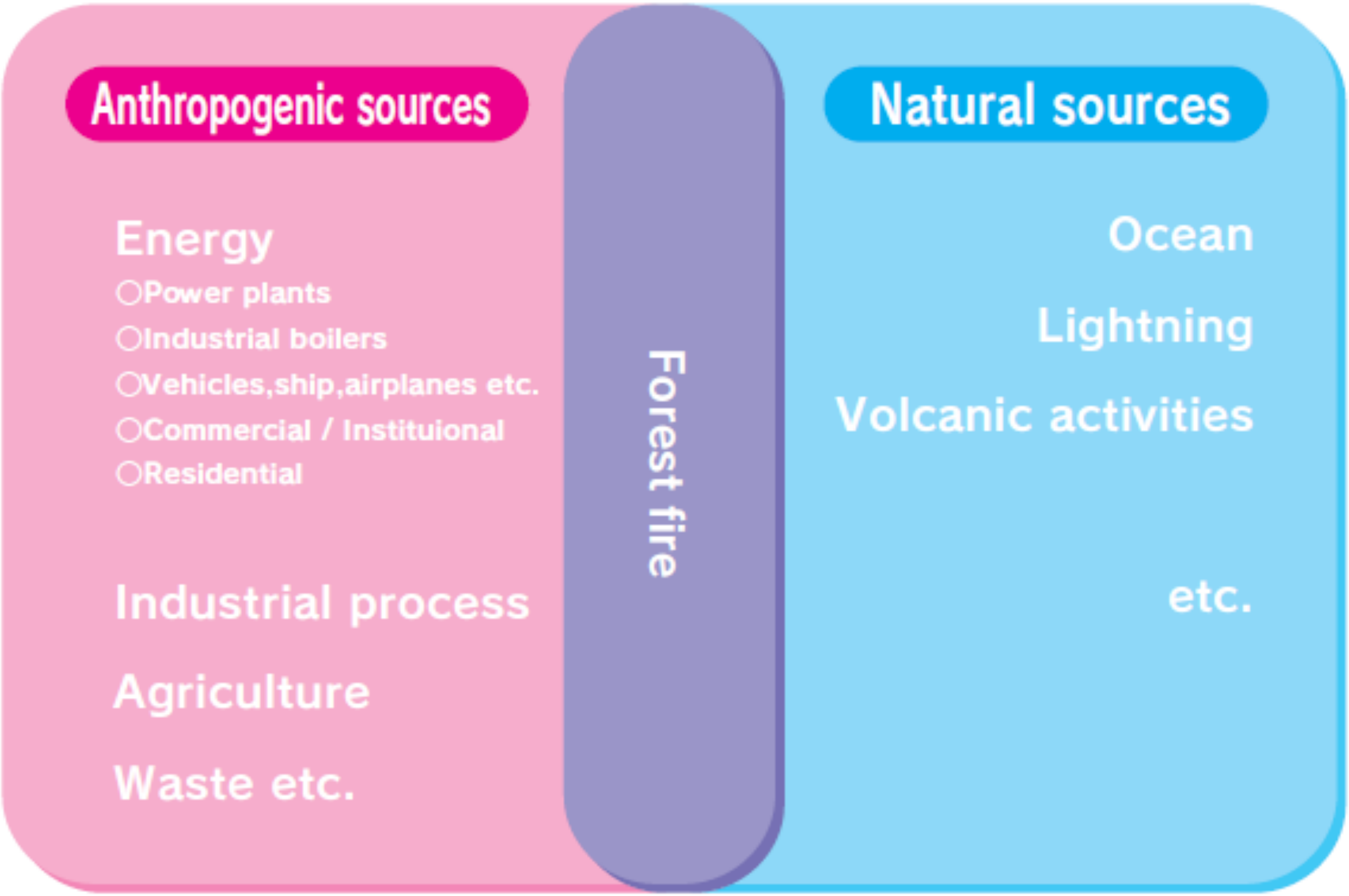
Is a comprehensive listing of sources of estimated air pollutant emissions within a specific geographic area during specific time period

- Covers a specific geographic area
- Covers a specific period of time
- Organized by type of data (e.g., point, area, mobile, biogenic)

What are Emission Sources?



Sources of Emissions



What can Emission Inventory tell you?

- **Where air pollution is emitted**

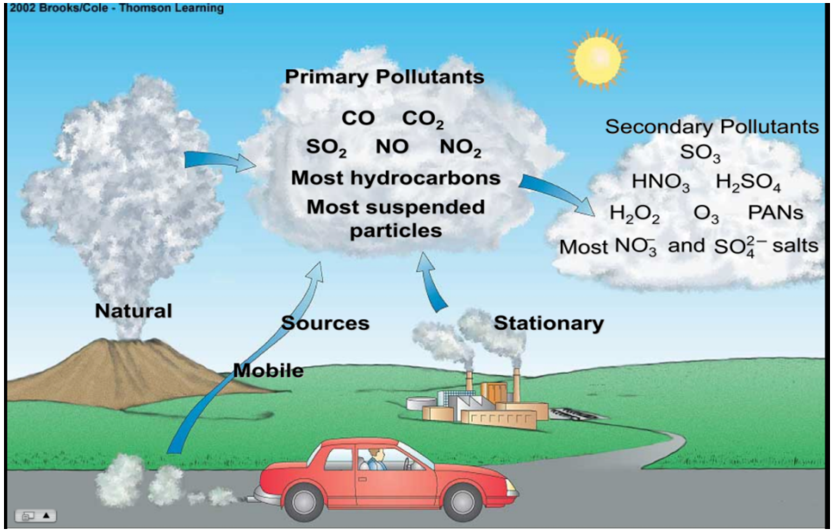
(**at surface:** e.g. from mobile and st. sources, ocean, biomass,
non- surface: e.g. Air craft, lightening, etc, Indoor activity or outdoor activity)

- **How much is emitted from each source**

- **What sources would be most effective to control**

What can Emission Inventory NOT tell you?

- The distance that air pollutant emissions are transported
- The amount of air pollution to which people are exposed
- The health risk from the air pollution

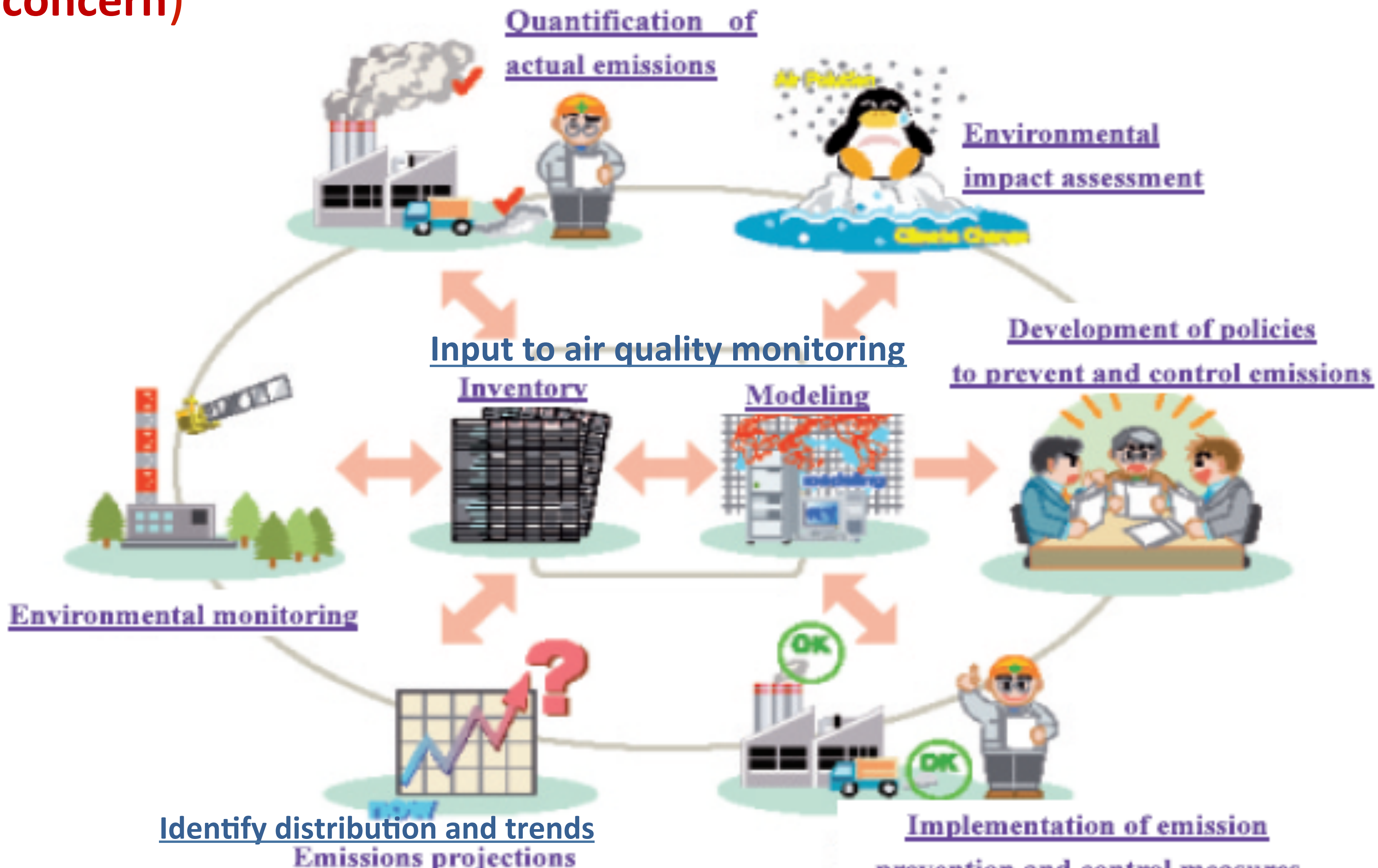


Formation of secondary pollutants (e.g. ozone, PAN, HNO3).

Windblown dust

Why is emission inventory needed?

Air quality management (Identify sources of pollution and pollutants of concern)



How are EI data used?

- Air quality management tool
  - Collect baseline data
  - Develop & track emissions control and management strategies
- Regulations development
- Air quality modeling and assessment
- Permits
  - Do you have facilities that need permits?
  - Conditions (potential to emit)
  - Fees
- Emissions trading
- Regulatory compliance

How is Emission Inventory used?

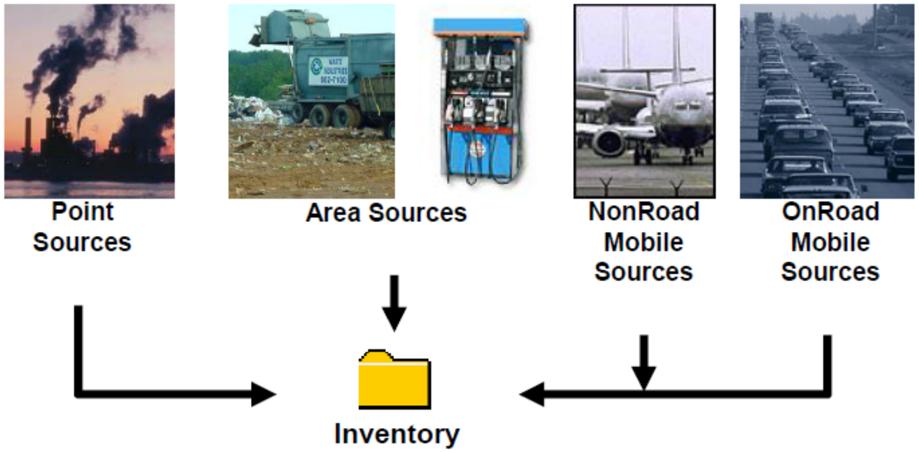
- Identifying and planning for allocation of source contributors;
- Developing an emissions control strategy
- Permitting sources and imposing emission fees
- Public information and awareness
- Monitoring and tracking of emissions trends

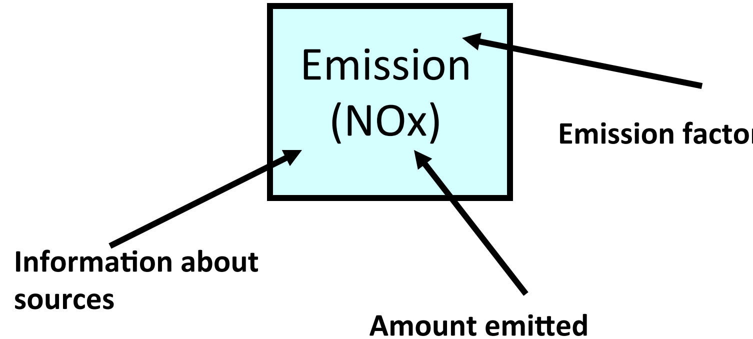
Types of Inventories

- **Bottom up EI** (emissions → concentrations)
- **Top Down** (concentrations → emissions)
  1. Direct estimate
  2. Combination of satellite and bottom up

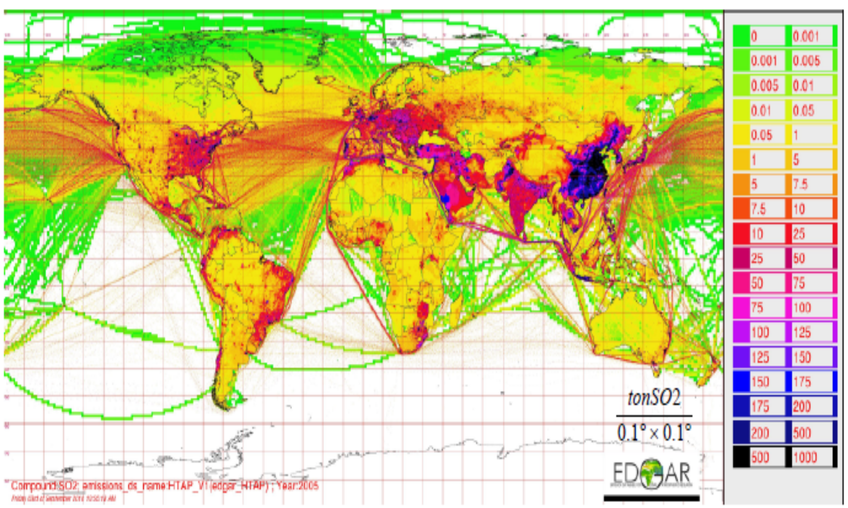
- Annual average
- Seasonal inventories
- Forecasted - future estimates
- Gridded / Modeling

Building an bottom up Emission Inventory



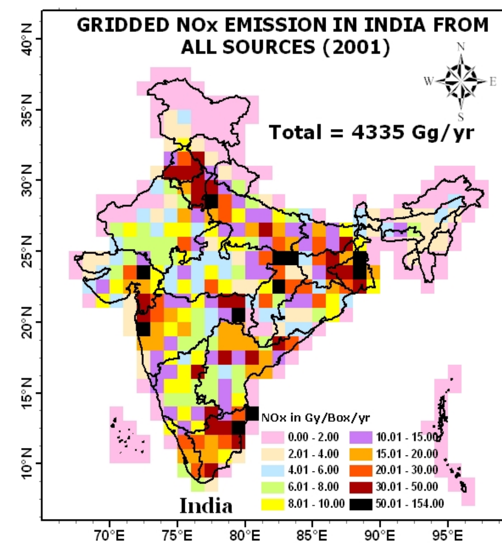


Edgar (global)



EDGAR-HTAPV1 SO_2 total emissions in ton per 0.1°x0.1°

India (regional)



Level of Detail

- Simple summary: Small reservation, few on-reservation sources
  - Compiled from existing data sources
  - Includes only large sources

- Comprehensive accounting: Large reservation, many and/or large sources
  - Large on-reservation sources–permitting
  - "Problem" emissions (agricultural burning, small industries, road dust, traffic emissions)

Types of Sectors

Industrial, Energy, Transportation, Biomass burning, Residential, Aviation, etc

Types of Sources

- Point sources = Stationary sources
- Area sources = Non-Point sources
- Mobile sources
  - On-Road (cars, motorcycles, trucks, buses)
  - Non-Road (trains, heavy equip.)
- Biogenic sources

Pollutants

Criteria (Particle matter (PM_{10} and $PM_{2.5}$), Sulfur dioxide: SO_2 , Carbon monoxide: CO, Lead: Pb)

Ozone precursors (Nitrogen oxides: No_x, Volatile Organic Compounds: VOCs)

Greenhouse gases (CH_4, N_20, CO_2)

Activity data and emission factors

◎Emission factors

Emission factors are the average rate of emission of a pollutant per unit of activity data for a given sector.

When there is no emission factor reflecting the actual local situation, default values in manuals are used. However, if the default factor is considered to be inappropriate, it is preferable to obtain an emission factor that reflects the real situation by direct measurement.

The rates of reduction and propagation of technical measures have to be reflected in the factor or the formula, because introduction of countermeasures reduces the emission.

◎Activity Data

Activity data give a measure of the scale of activity causing the emissions.

The necessary data basically can be collected from statistics and surveys

Emission = Emission Factor x Activity Data

Examples:

Emission Factor:

- SOx emission per the amount of fuel burnt, calculated based on the sulfur content of fuel, the sulfur retained in the ash and the reduction achieved by emission control technology (fuel combustion)
- NOx emission per distance (exhaust gas emissions from vehicles)
- SOx emission per the amount of copper smelted (copper smelting)

Activity Data:

- the amount of fuel burnt (fuel combustion)
- the distance of vehicle travelled (exhaust gas emissions from vehicles)
- the rates of the production of the commodity (industrial process without combustion)

Bottom-Up:(Source specific estimation)

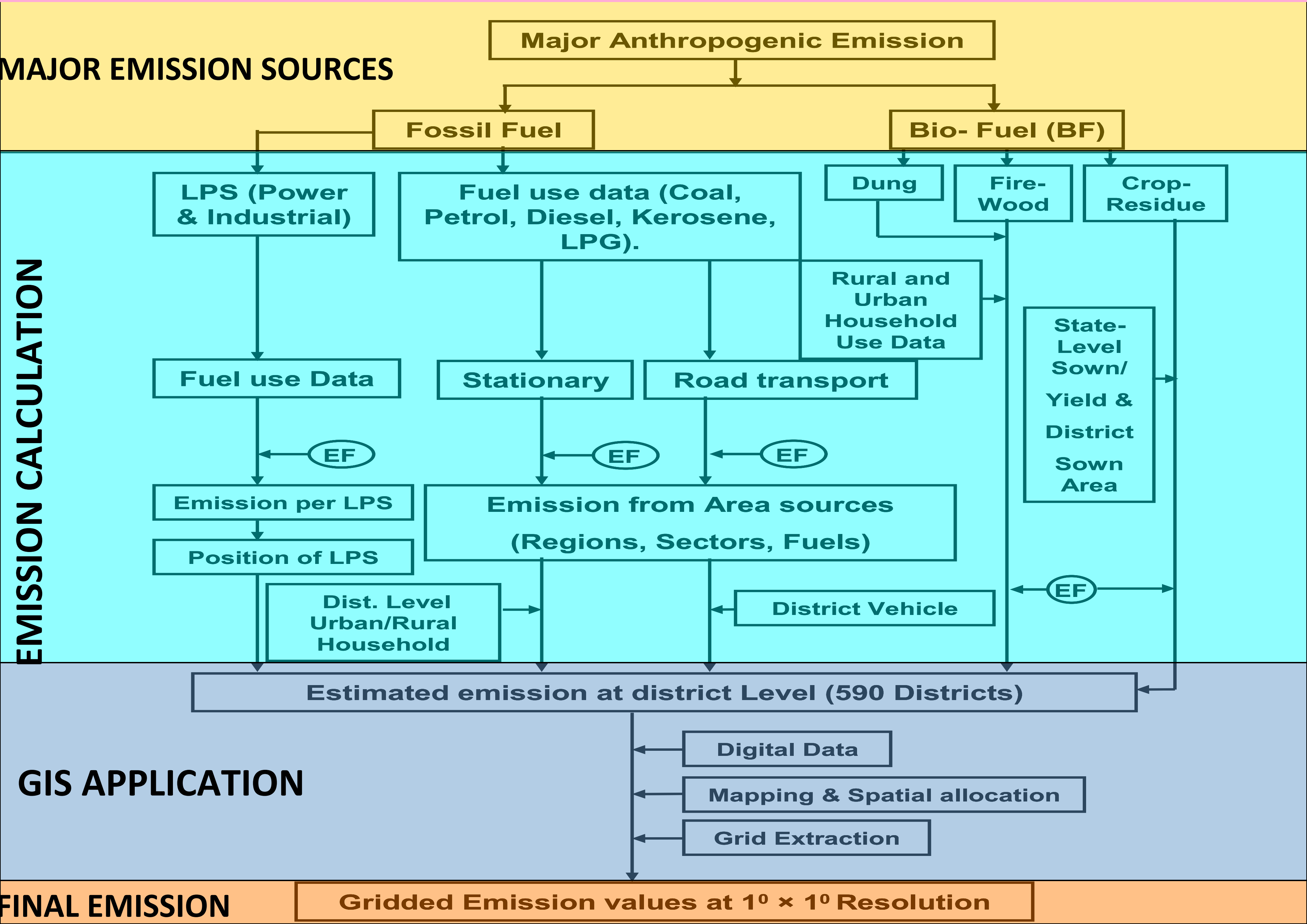
- **Emission estimated for individual sources is summed to obtain domain level inventory.**

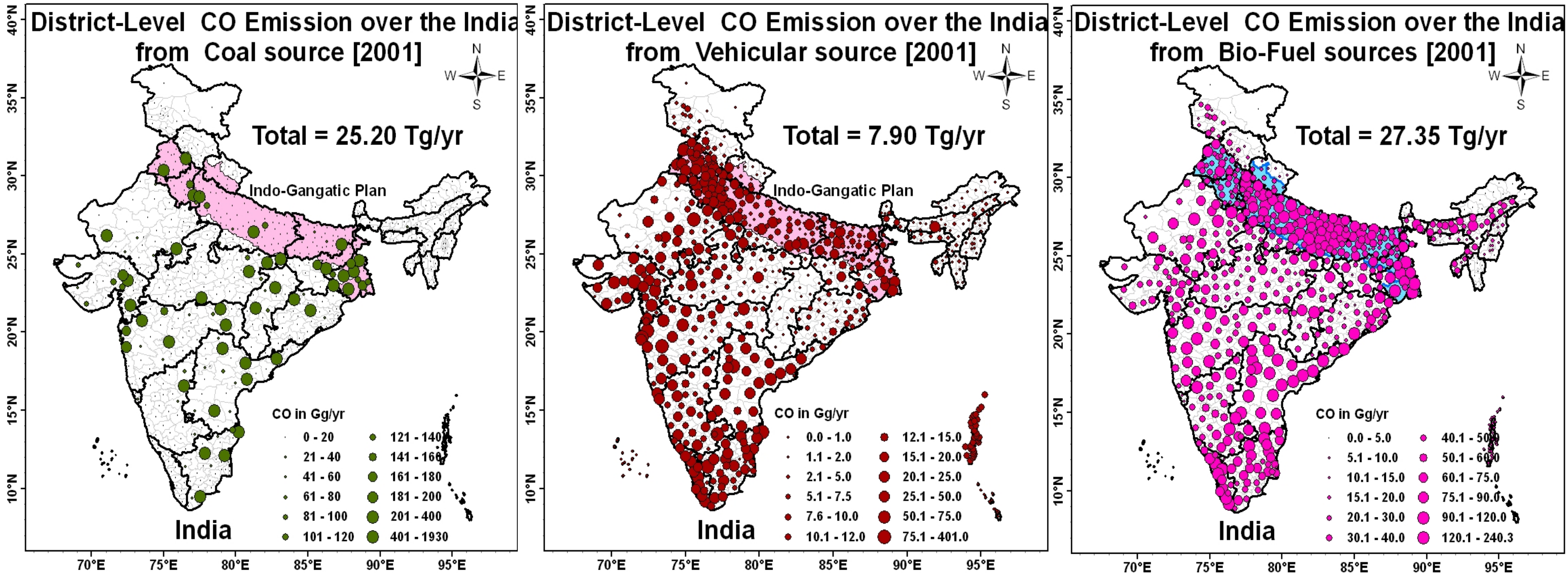
- Emission Inventories are estimated as per the most widely used emission factor approach.

$$Em_{j,k} = \sum_{l} \sum_{m} FC_{k,l,m} \left[\sum_{n} EF_{j,k,m,n} X_{k,l,m,n} \right]$$

- ***j,k,l,m,n*** **=Species, country, sector, fuel type, Technology**
- **Em = Total Emission**
- **FC = Fuel consumption , Kg/yr**
- **EF = Emission factor specific to fuel/Technology**
- **X = Fraction of fuel for this sector consumed by a specific technology,**

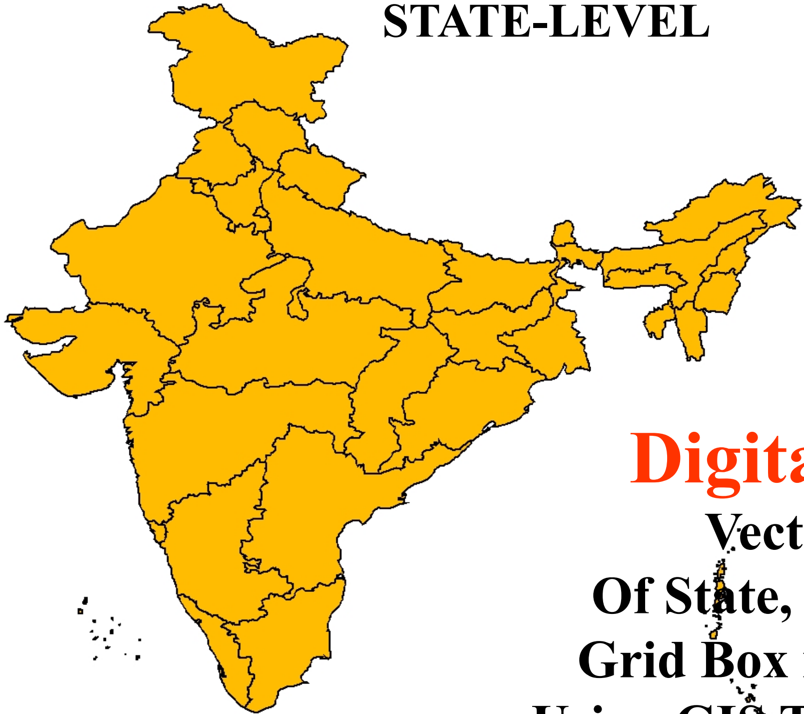
Schematic Methodology for the Development of Indian emission estimation



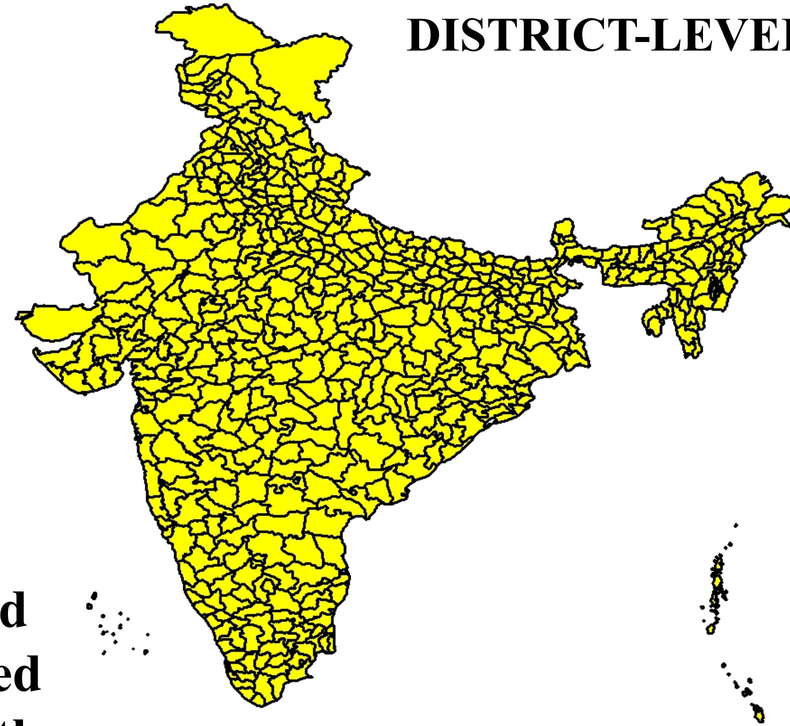


District-Level CO Emission over the India
from Coal source [2001]
Total = 25.20 Tg/yr
Indo-Gangatic Plan
CO in Gg/yr
0 - 20
21 - 40
41 - 60
61 - 80
81 - 100
101 - 120
121 - 140
141 - 160
161 - 180
181 - 200
201 - 400
401 - 1930
India
District-Level CO Emission over the India
from Vehicular source [2001]
Total = 7.90 Tg/yr
Indo-Gangatic Plan
CO in Gg/yr
0.0 - 1.0
1.1 - 2.0
2.1 - 5.0
5.1 - 7.5
7.6 - 10.0
10.1 - 12.0
12.1 - 15.0
15.1 - 20.0
20.1 - 25.0
25.1 - 50.0
50.1 - 75.0
75.1 - 401.0
India
District-Level CO Emission over the India
from Bio-Fuel sources [2001]
Total = 27.35 Tg/yr
CO in Gg/yr
0.0 - 5.0
5.1 - 10.0
10.1 - 15.0
15.1 - 20.0
20.1 - 30.0
30.1 - 40.0
40.1 - 50.0
50.1 - 60.0
60.1 - 75.0
75.1 - 90.0
90.1 - 120.0
120.1 - 240.3
India
N
S
E
W
70°E
75°E
80°E
85°E
90°E
95°E
10°N
15°N
20°N
25°N
30°N
35°N
40°N

STATE-LEVEL

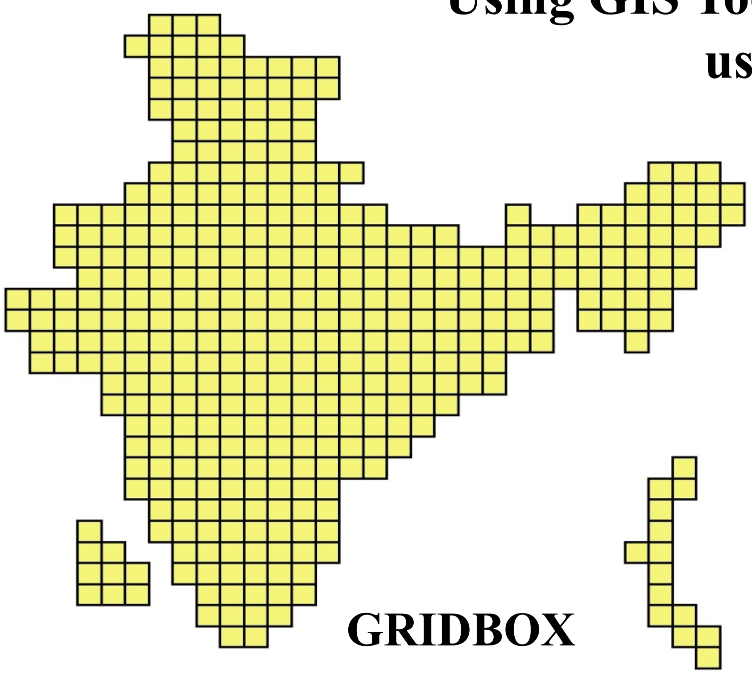


DISTRICT-LEVEL

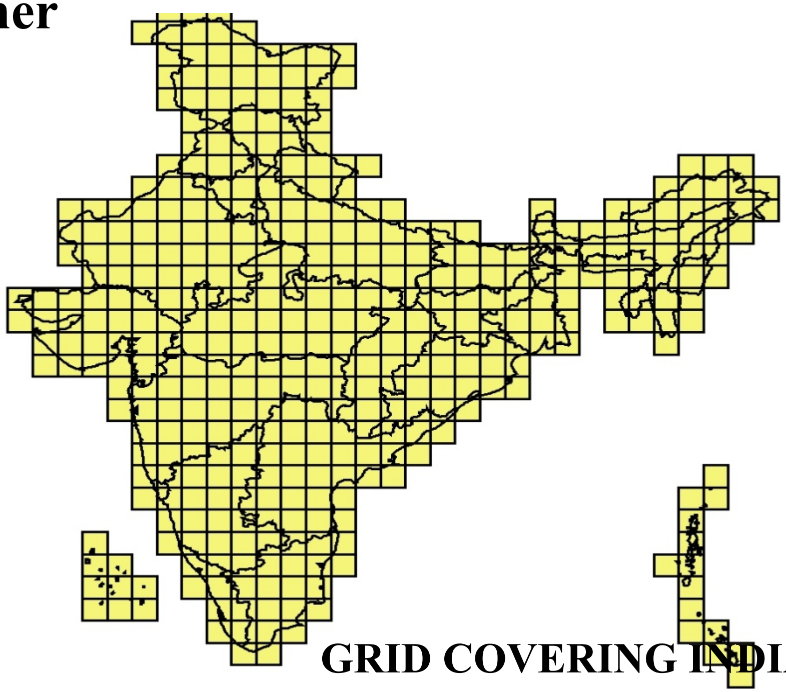


Digital Data:

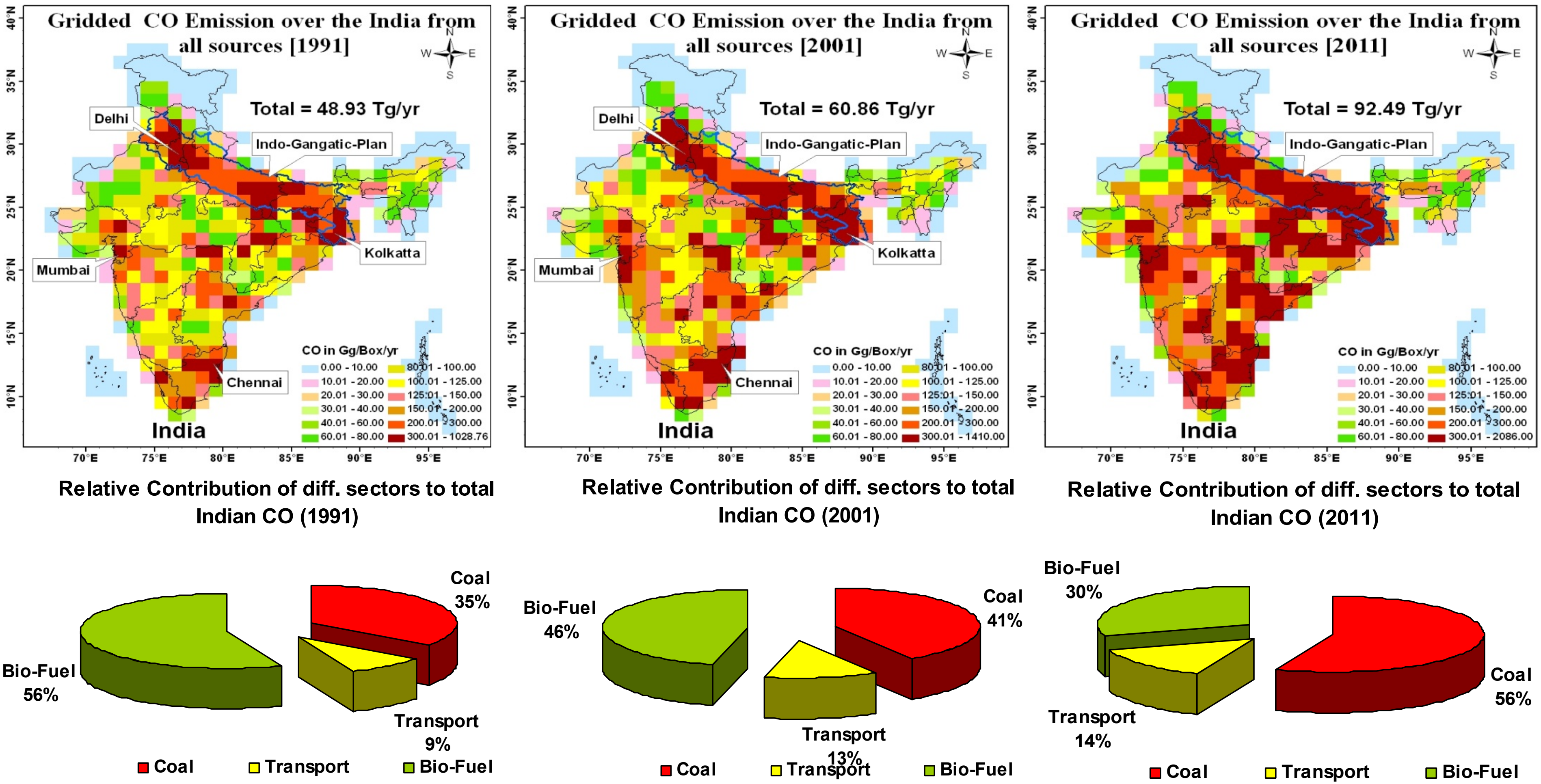
Vector-Map
Of State, District and
Grid Box is Generated
Using GIS Tool for further
use.



GRIDBOX



GRID COVERING INDIA



Gridded CO Emission over the India from all sources [1991]
Total = 48.93 Tg/yr
Delhi
Indo-Gangatic-Plan
Kolkatta
Mumbai
Chennai
India
CO in Gg/Box/yr
0.00 - 10.00
10.01 - 20.00
20.01 - 30.00
30.01 - 40.00
40.01 - 60.00
60.01 - 80.00
80.01 - 100.00
100.01 - 125.00
125.01 - 150.00
150.01 - 200.00
200.01 - 300.00
300.01 - 1028.76
Gridded CO Emission over the India from all sources [2001]
Total = 60.86 Tg/yr
Delhi
Indo-Gangatic-Plan
Kolkatta
Mumbai
Chennai
India
CO in Gg/Box/yr
0.00 - 10.00
10.01 - 20.00
20.01 - 30.00
30.01 - 40.00
40.01 - 60.00
60.01 - 80.00
80.01 - 100.00
100.01 - 125.00
125.01 - 150.00
150.01 - 200.00
200.01 - 300.00
300.01 - 1410.00
Gridded CO Emission over the India from all sources [2011]
Total = 92.49 Tg/yr
Indo-Gangatic-Plan
India
CO in Gg/Box/yr
0.00 - 10.00
10.01 - 20.00
20.01 - 30.00
30.01 - 40.00
40.01 - 60.00
60.01 - 80.00
80.01 - 100.00
100.01 - 125.00
125.01 - 150.00
150.01 - 200.00
200.01 - 300.00
300.01 - 2086.00
70°E 75°E 80°E 85°E 90°E 95°E
10°N 15°N 20°N 25°N 30°N 35°N 40°N
Relative Contribution of diff. sectors to total Indian CO (1991)
Coal 35%
Transport 9%
Bio-Fuel 56%
Relative Contribution of diff. sectors to total Indian CO (2001)
Bio-Fuel 46%
Coal 41%
Transport 13%
Relative Contribution of diff. sectors to total Indian CO (2011)
Bio-Fuel 30%
Coal 56%
Transport 14%
Coal
Transport
Bio-Fuel

Emission Exercise ---- Transportation Sector (Delhi)

Categories of vehicles

1. Two stroke two-wheeler (2W2S)
2. Four stroke two-wheeler (2W4S)
3. Two stroke three-wheeler (3W2S)
4. Four stroke three-wheeler (3W4S)
5. Four wheeler gasoline (4WG)
6. Four wheeler diesel (4WD)
7. Heavy Duty Diesel Low sulfur (HDDLS)
8. Heavy Duty Diesel High sulfur (HDDHS)

Pollutants for which Emission Factors have been determined

1. Carbon dioxide (CO_2)
2. Carbon monoxide (CO)
3. Oxides of Nitrogen (NO)

Computed Mass Emission Factors for Different Vehicles

Species		2W2S	2W4S	3W2S	3W4S	4WG	4WD	HDDLS	HDDHS
FC	g/km	11.0	9.7	22.1	25.9	84.3	92.7	195.2	195.2
	G/hr	254.9	225.2	511.2	599.8	1576.5	1733.2	3649.9	3649.9
CO_2	g/km	26.6	28.3	60.3	78.5	223.6	208.3	515.1	515.2
	G/hr	617.0	655.6	1397.2	1817.1	4181.3	3896.4	9633.3	9634.8
CO	g/km	2.0	1.4	5.25	2.0	24.8	2.0	4.7	4.7
	G/hr	46.4	33	121.6	46.9	462.9	36.8	88.4	87.4
NO	g/km	0.8	1.4	1.2	2.0	3.3	116.9	354.3	405.3
	G/hr	20.5	32.9	28.1	46.0	62.4	2185.5	6626.6	7579.2

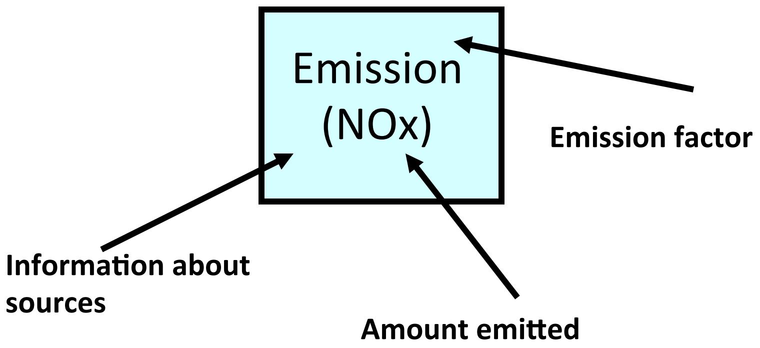
Area of Delhi: 36 km x 36 km

Number of total vehicles : 4.5 million

1.	Two stroke two-wheeler (2W2S): 10%	25km /day
2.	Four stroke two-wheeler (2W4S) : 10%	25km /day
3.	Two stroke three-wheeler (3W2S): 15%	50km /day
4.	Four stroke three-wheeler (3W4S):5%	50km /day
5.	Four wheeler gasoline (4WG): 30%	25km /day
6.	Four wheeler diesel (4WD): 10%	25km /day
7.	Heavy Duty Diesel Low sulfur (HDDLS): 10%	10km /day
8.	Heavy Duty Diesel High sulfur (HDDHS): 10%	10km /day

Calculate total annual emissions from the transportation sector

Drawbacks of bottom-up inventories



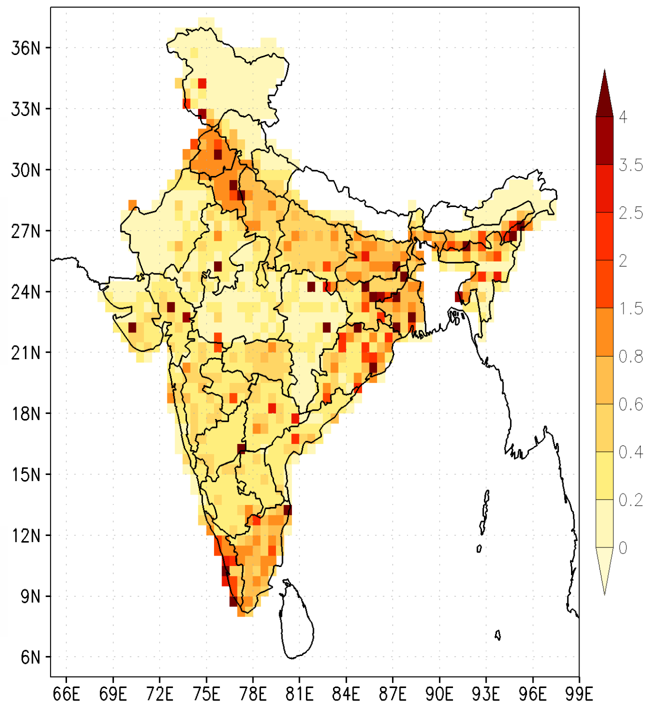
- Depend on the availability and reliability of the statistical information.
- Depend on historic information: easily out-dated.
- Uncertainties in spatial resolution if only area totals are available.

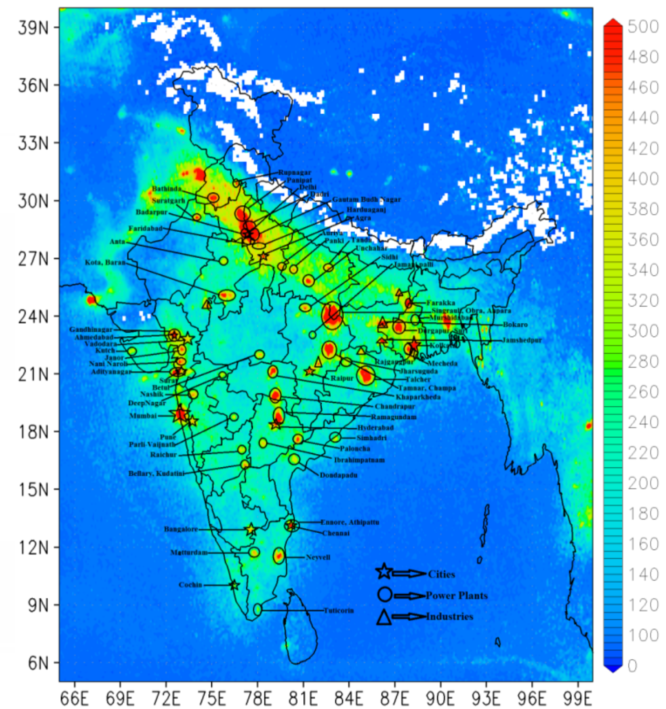
Constraining emissions with satellite observations

- Satellites have world-wide, homogeneous coverage.
- Correcting inventory for emission trends
- Detecting new (unknown) emission sources
- Emission trend analysis reveals effectiveness of air pollution policy
- Up-to-date emission inventories improve air quality forecasting

Top Down Approach

Emissions ← **Concentrations**

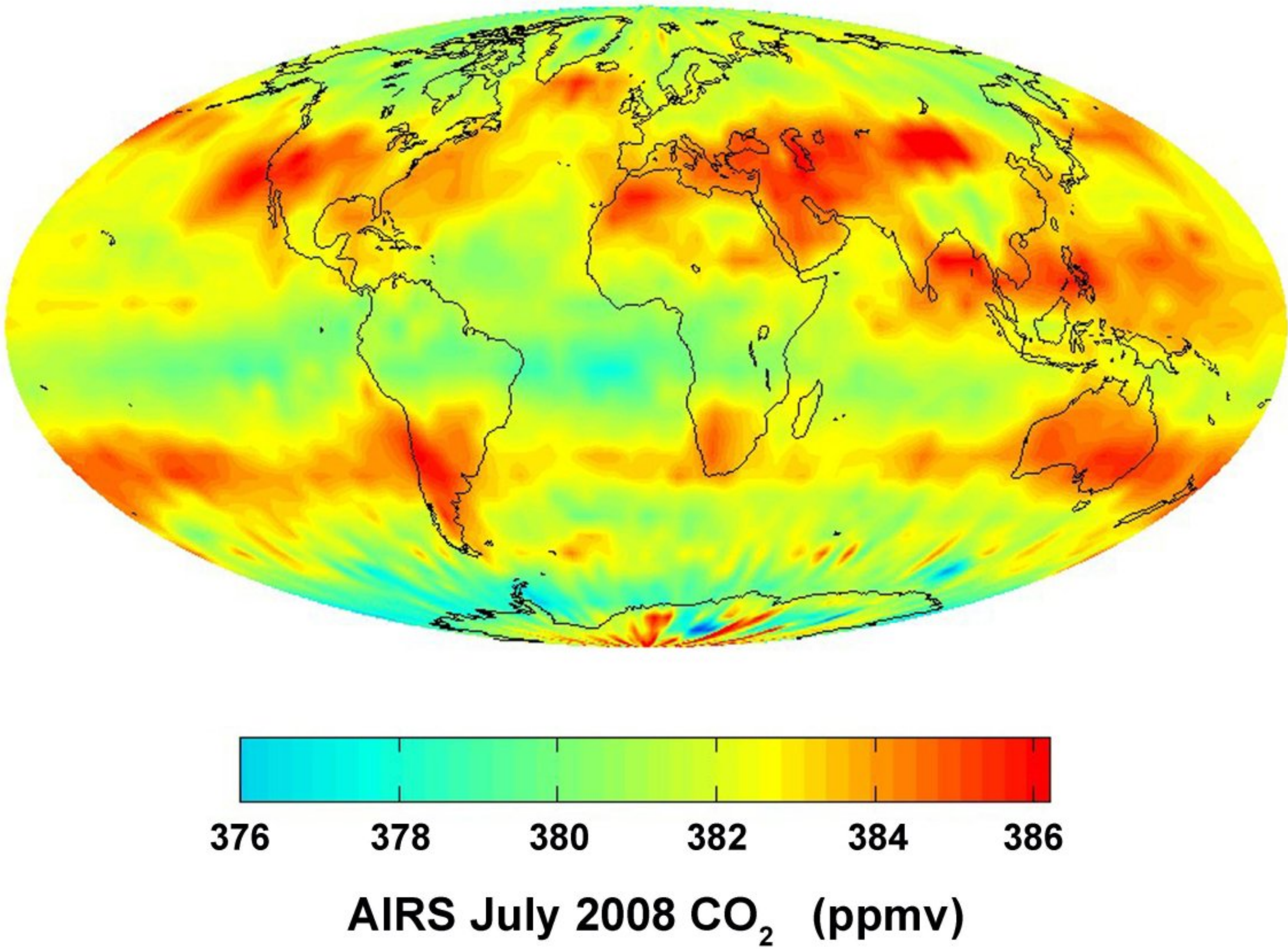




- **Top Down** **(concentrations → emissions)**

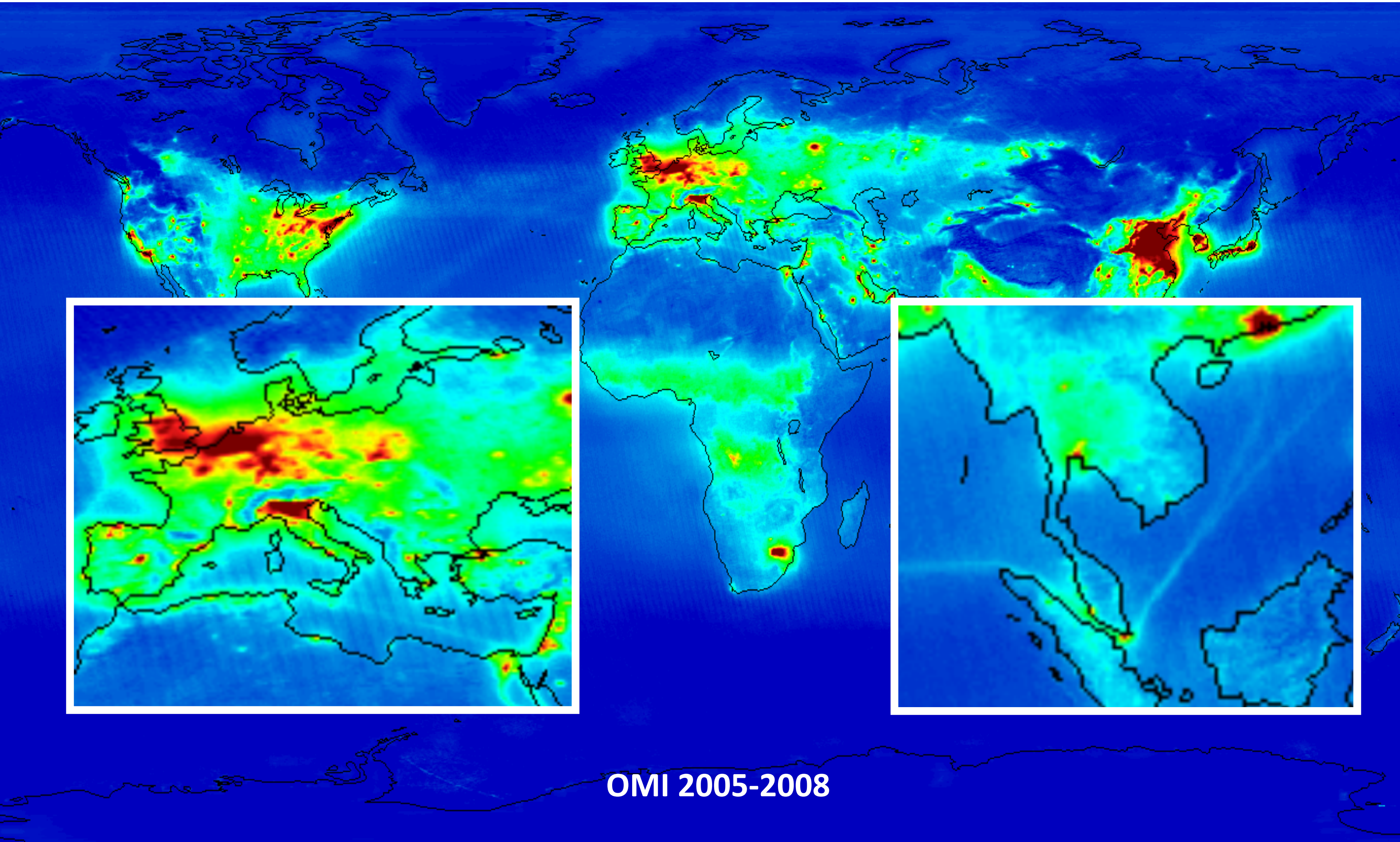
  1. Direct estimate
  2. Combination of satellite and bottom up

Lifetime example (1): CO_2



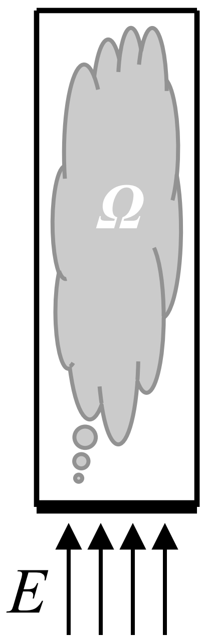
Lifetime example (2): NO_2

tropospheric NO_2 in summer: ~4h, in winter: ~10h



Local, linear relation concentration and emission

Martin et al. (2006) Space-based constraints on NOx emission, J. Geophys. Res.
Jaeglé et al. (2005) Global partitioning of NOx sources using (...), Faraday Discuss.



Assume linear relation between NO_x emission and NO_2 concentration:

Direct Approach

$$E_t = \alpha \Omega_{obs} \quad , \quad \alpha = (\Omega_{NO_X} / \Omega_{NO2}) / \tau_{NO_X}$$

Combine Approach

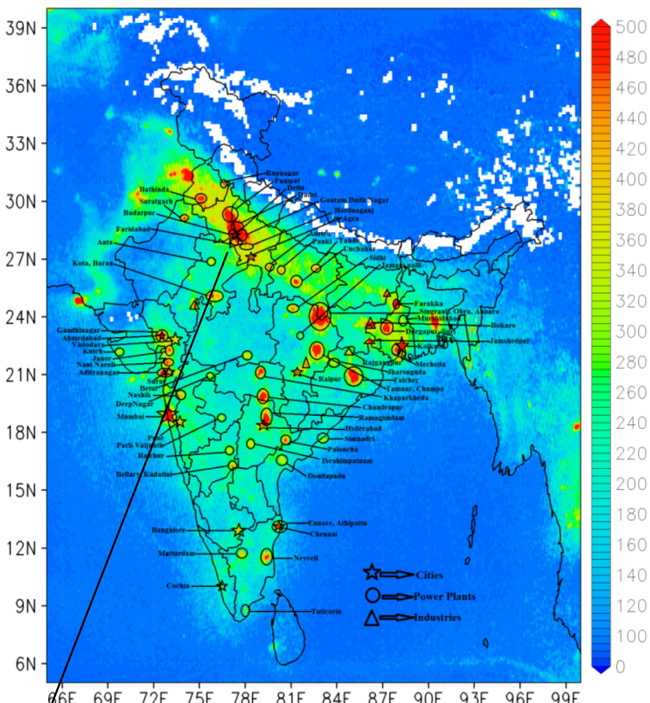
$$E = \alpha \Omega_{obs} \, , \quad \alpha = E_{a\,\mathrm{mod}} / \Omega_{No2m}$$

Local, linear relation concentration and emission

Direct Approach

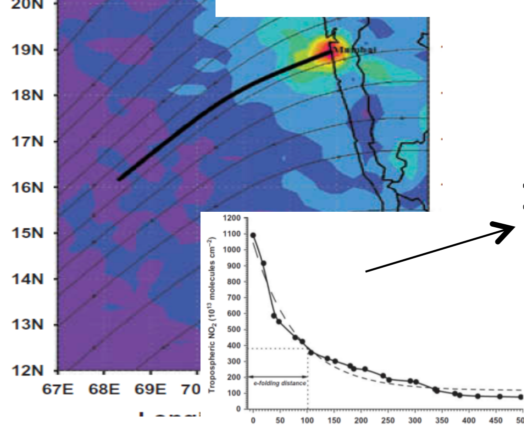
$$E_t = \alpha \Omega_{obs} \quad , \quad \alpha = (\Omega_{NO_X} / \Omega_{NO2}) / \tau_{NO_X}$$

From literature, measurements



1.7 x 10^{15} mole/c m^2
(25km x 25 km)

$$T_{NO_2} = \Omega_{NO_2} \times \exp(-t/\tau_{NO_x}),$$



11.2 hours = 11.2*3600 sec

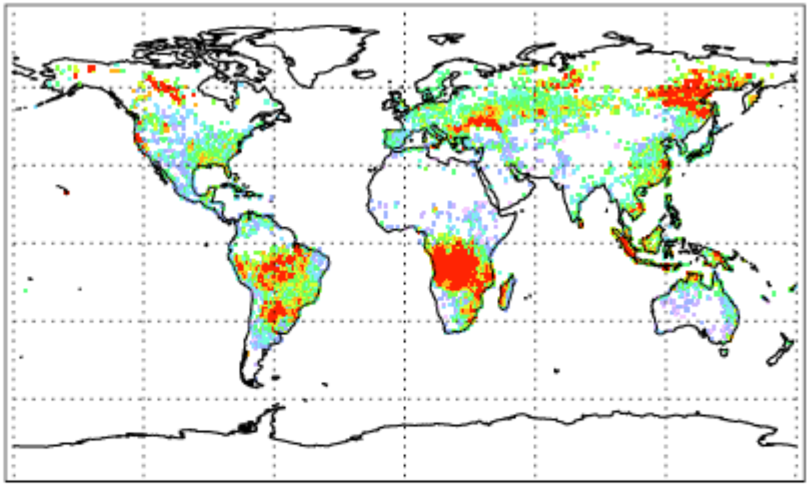
Et = (0.31/11.2)*1.7 x 10^{15} mole/cm^2

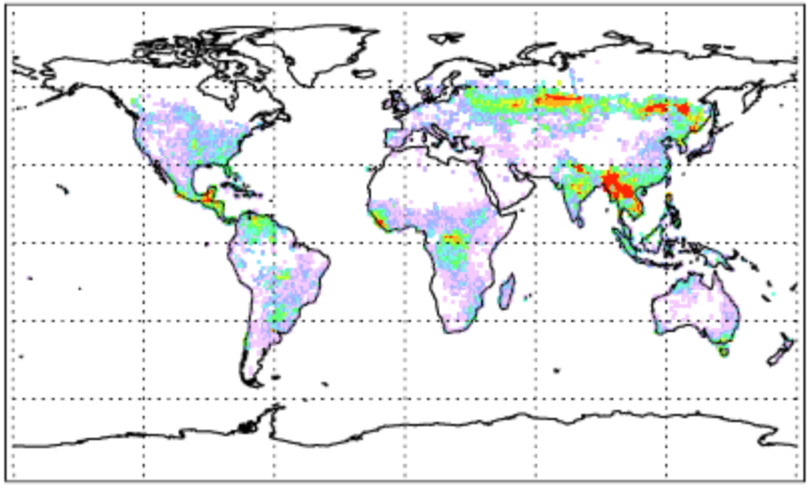
Combine Approach

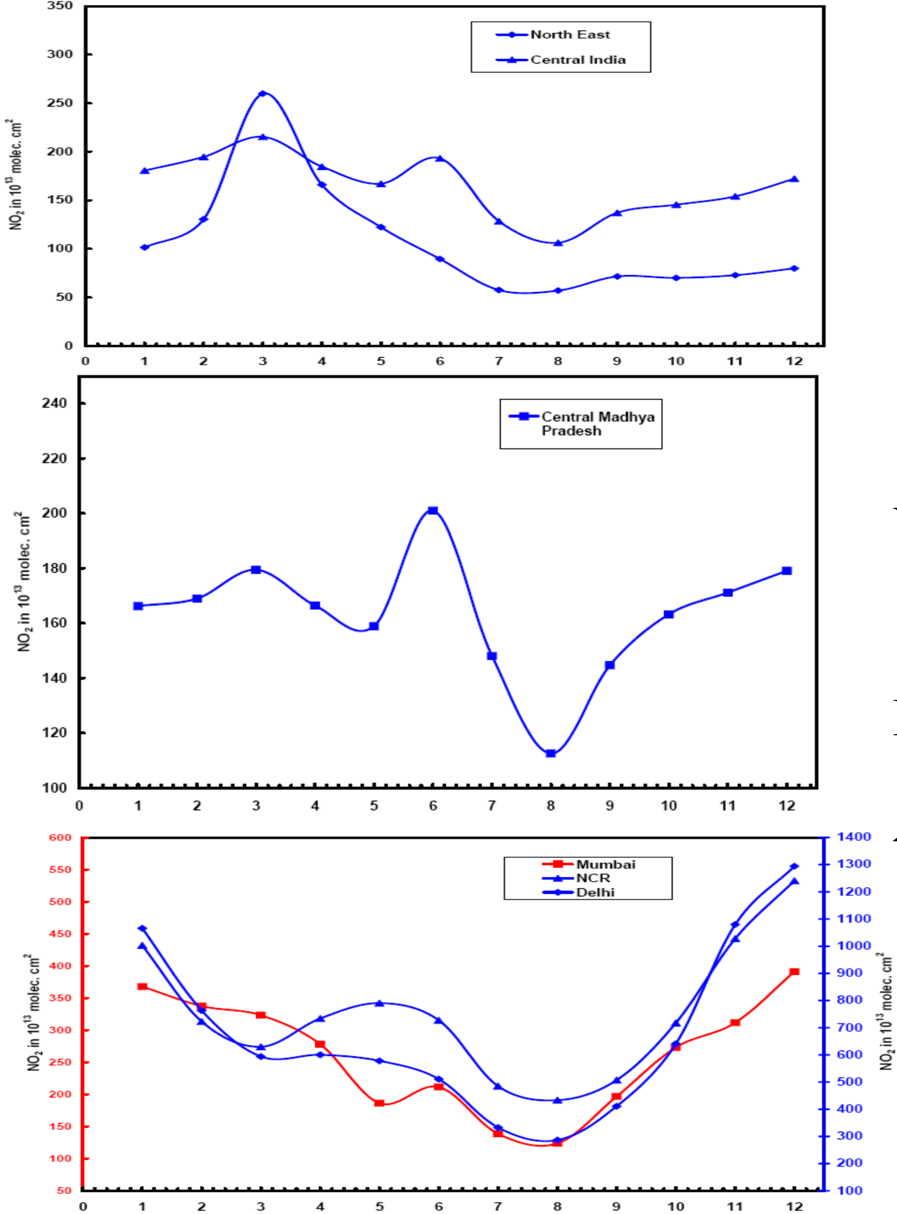
Satellite based estimates of Fire emission

$$E_i = A(x,t) \times B(x) \times \mathrm{FB} \times \mathrm{ef}_i$$

Use of fire hot spots
Burnt area at location x and time t: A(x,t)
land cover maps (identify vegetation type)
Biomass loading : B(x)
consumption estimates at location x: FB
Emission factors (emission factors from filed lab experiment): ef_i





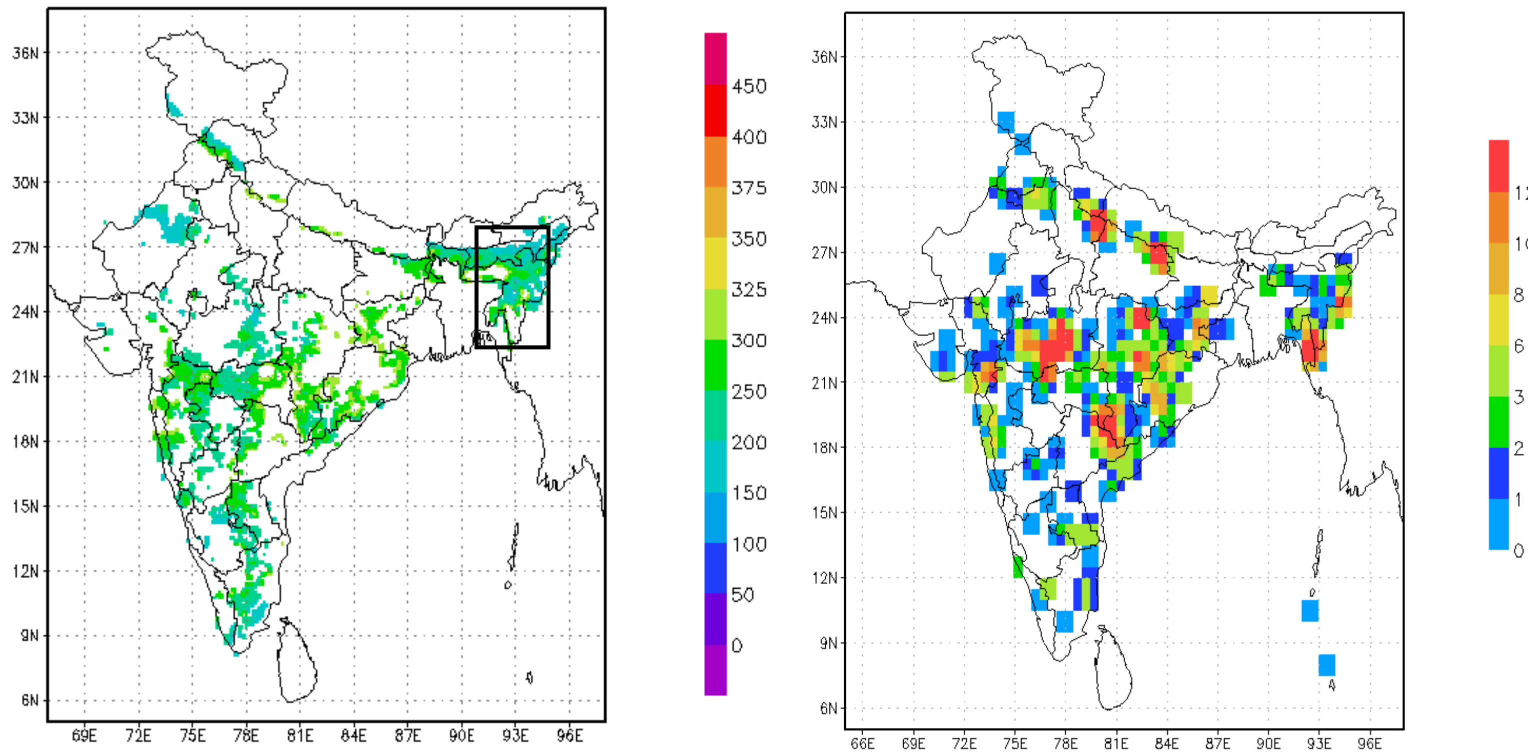


Methodology

$$[OMI_{NO2\_max}] - [OMI_{NO2}]_1^{12} = 0$$

Where $[OMI_{NO2\_max}]$ is the maximum tropospheric NO_2 amount at every grid cell between the January to December months in that year and $[OMI_{NO2}]_1^{12}$ is the monthly tropospheric NO_2 in that year.

Mean seasonal variation (2005-2010) of OMI tropospheric NO_2 column averaged over selected regions dominated by **(a)** biomass burning, **(b)** soil and **(d)** anthropogenic NOx emission.



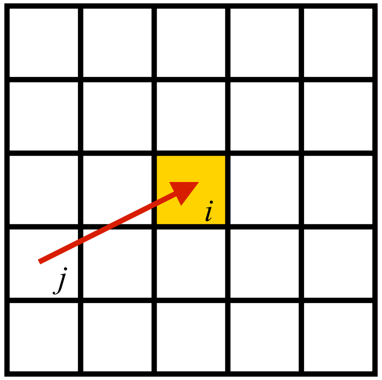
(a) Spatial distribution of OMI NO_2 (1×10^{13} molecules cm^{-2}) for 2005 for regions with a maximum in the seasonal cycle in tropospheric NO_2 during March-April. In these regions the dominant source type is estimated as biomass burning. **(b)** ATSR fire counts over the India region during March-April 2005 averaged over $0.5^{o} \times 0.5^{o}$.

Local, linear relation concentration and emission

Advantages

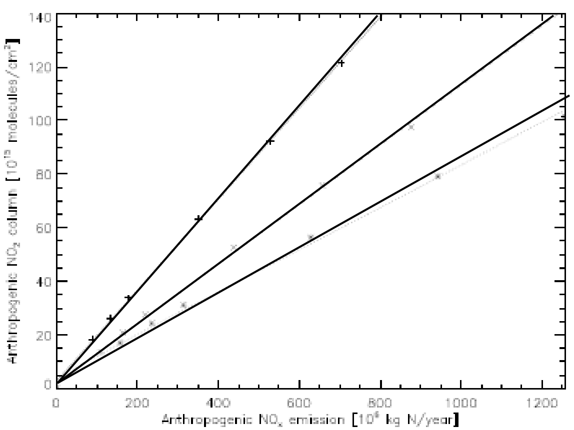
- Fast, no inverse modeling needed
- Emission update gives also new error estimates

Disadvantages

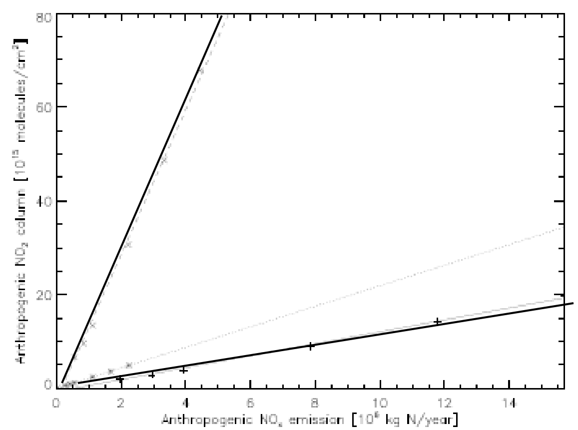


- Transport to neighbouring grid cells neglected
- Only one emission update possible
- No new sources detected if *a priori* emission is 0

Urban



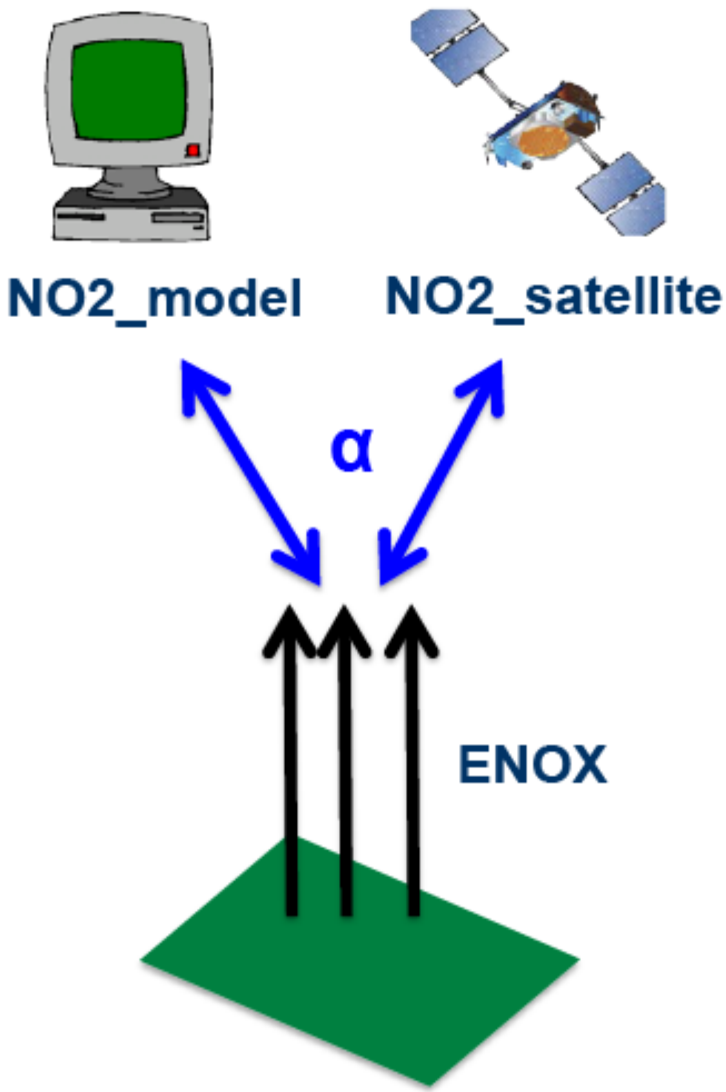
Rural



If you don’t like your result change your approach

Local, linear relation applied iteratively

Martin et al. [2003, 2006]
Lamsal et al. [2011]



= Adjustment of the emissions with satellite observations to reduce the disagreement between model and observation.

Assuming that horizontal transport of NOx is negligible, a posteriori emissions can be derived as following:

α = **ENOX_apriori / NO2_model**

=> **ENOX_aposteriori** = α x **NO2_satellite**

$$E_{i+1} = \alpha\Omega_{obs,i} \quad , \quad \alpha = E_i / \Omega_i$$

ENOX = anthropogenic NOx emissions
NO2_model= Modeled NO2 Tropospheric Column
NO2_satellite= Satellite NO2 Tropospheric Column

Local, linear relation applied iteratively

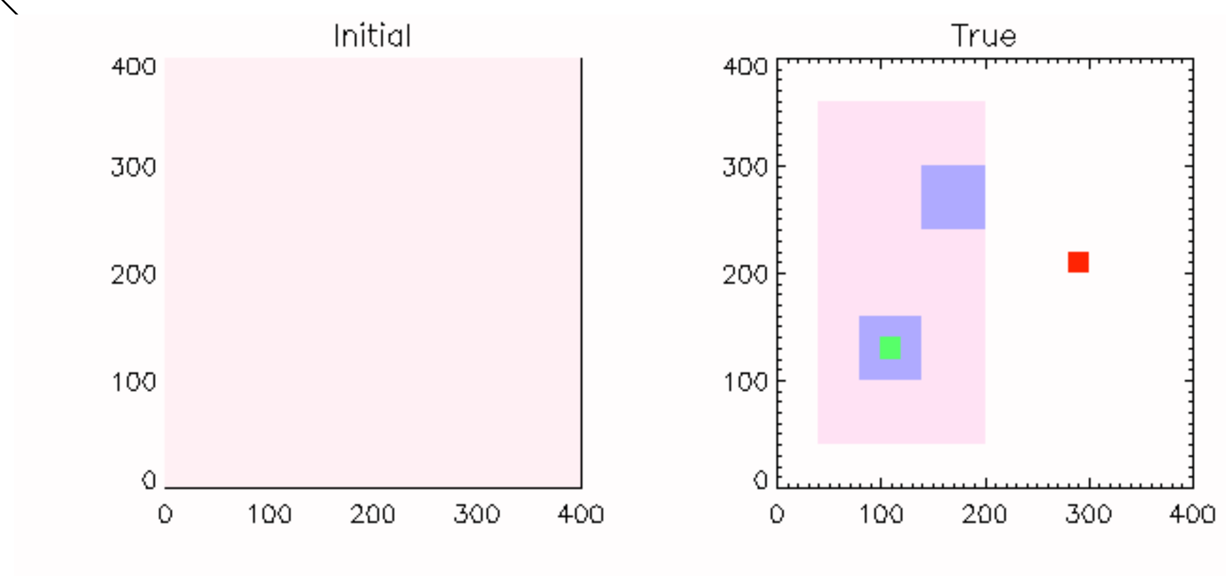
Advantages

- Iteration compensates for transport to neighbouring grid cells
- Accuracy of emissions improves

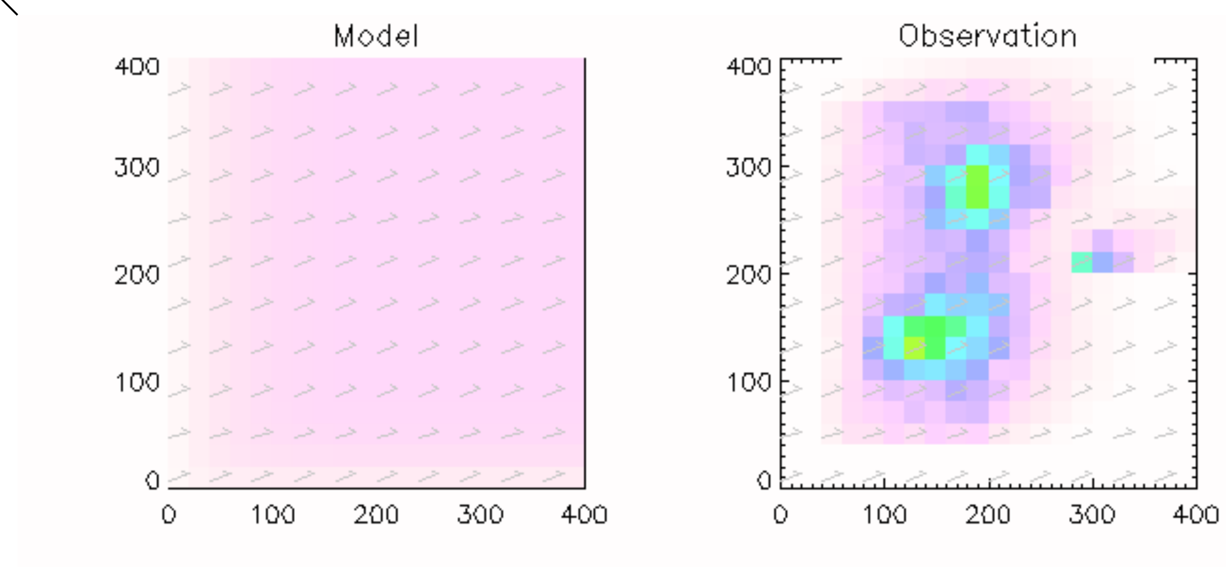
Disadvantages

- No error estimates of inventory
- No new sources detected if *a priori* emission is 0

emissions

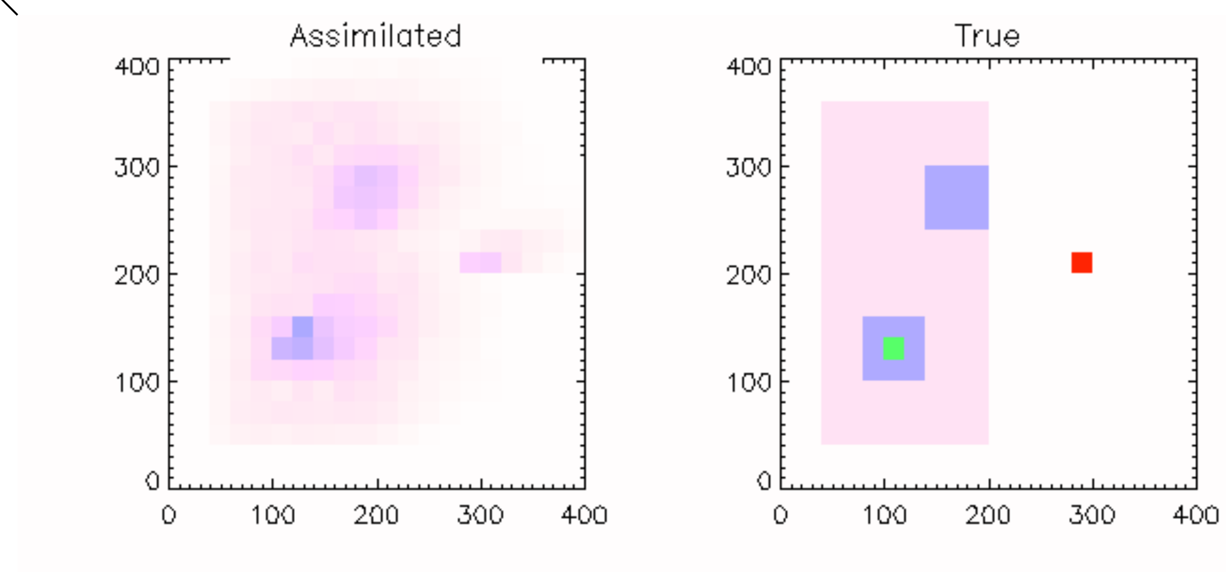


concentrations

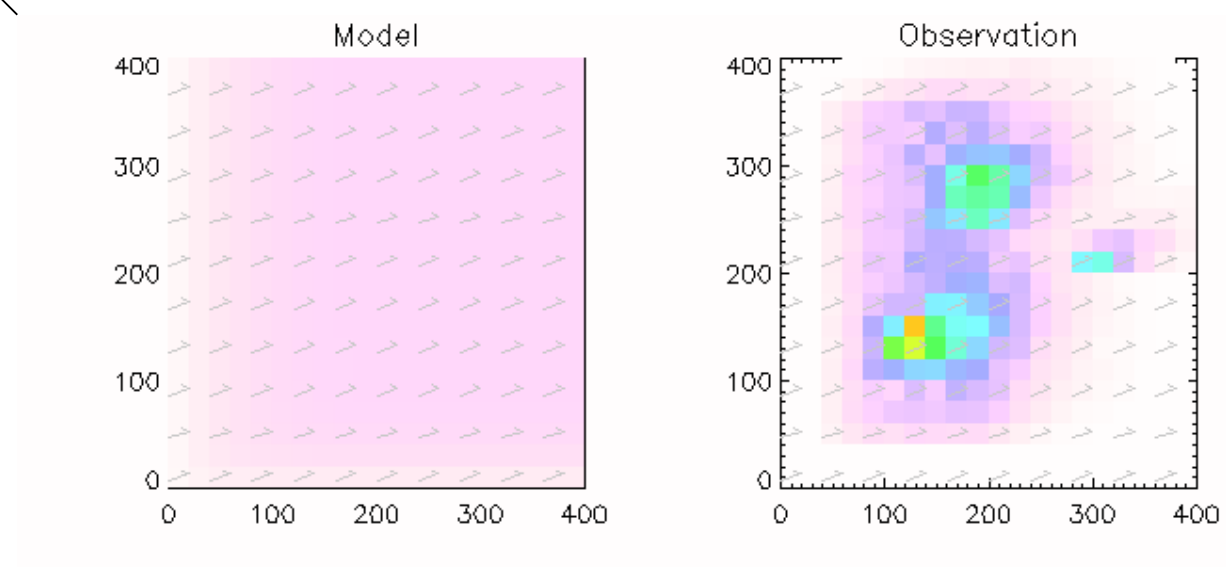


Local, linear

emissions



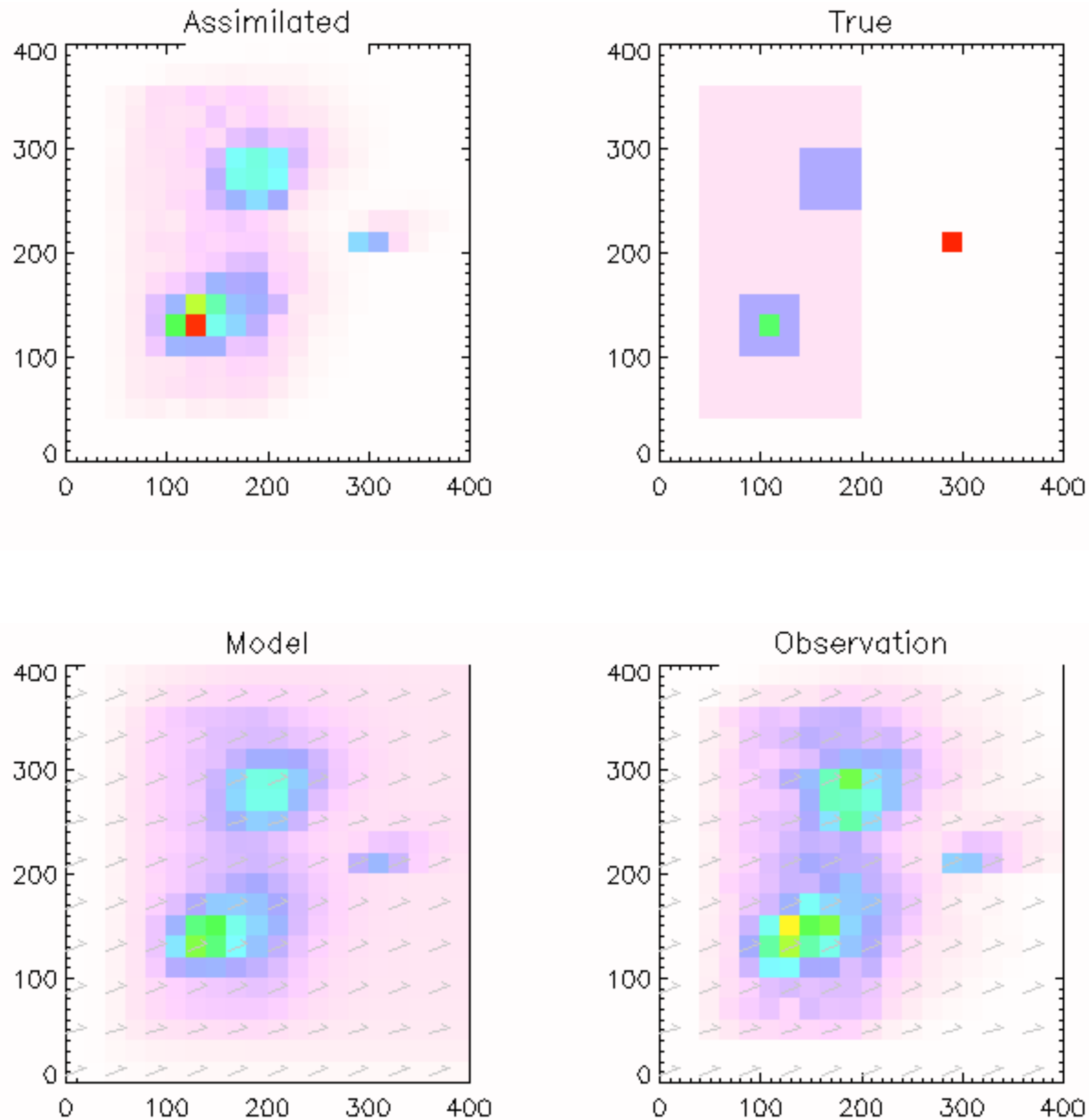
concentrations



Local, linear

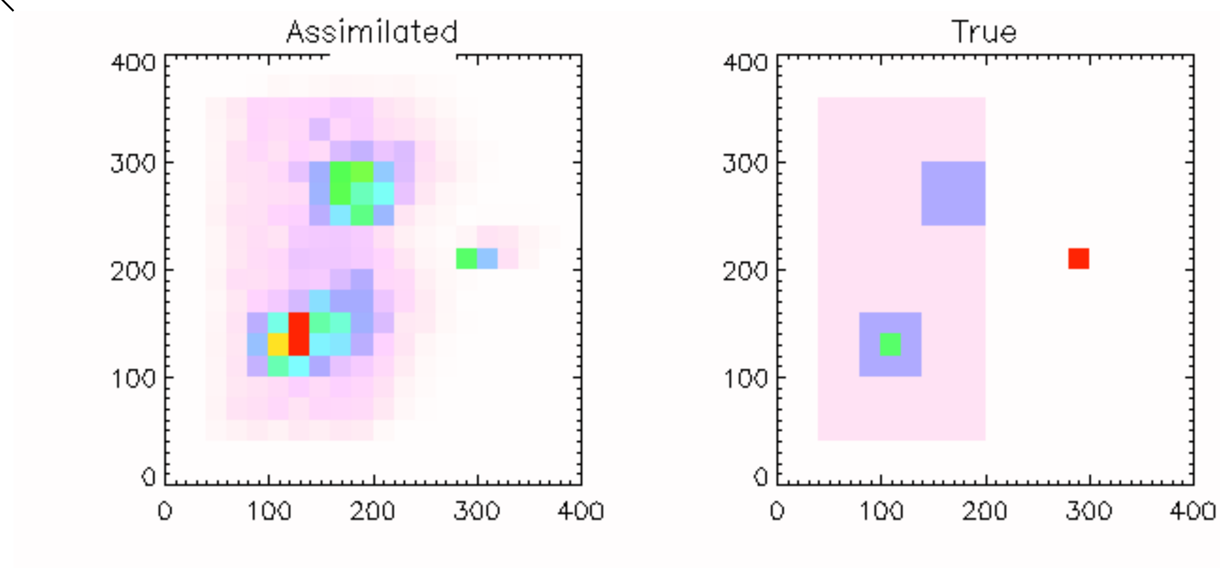
emissions

concentrations



Local, linear

emissions



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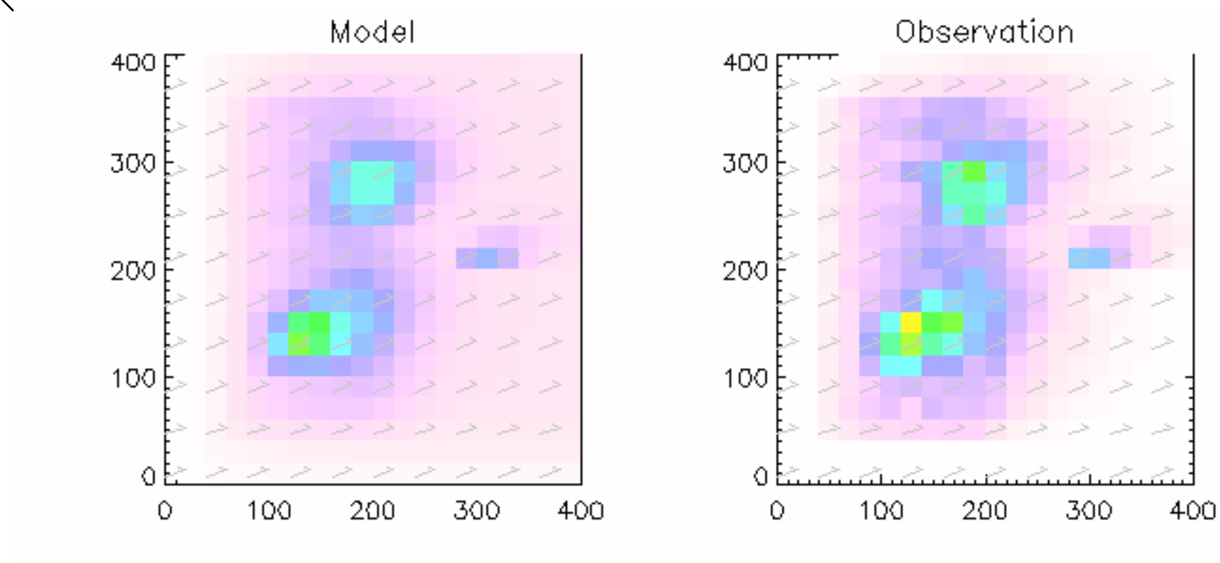
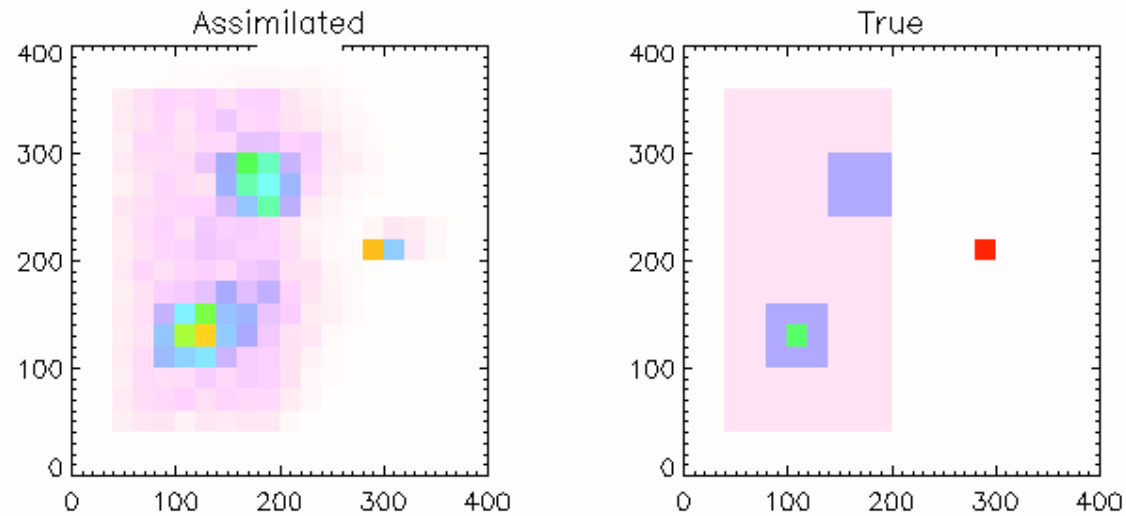


Local, linear

emissions



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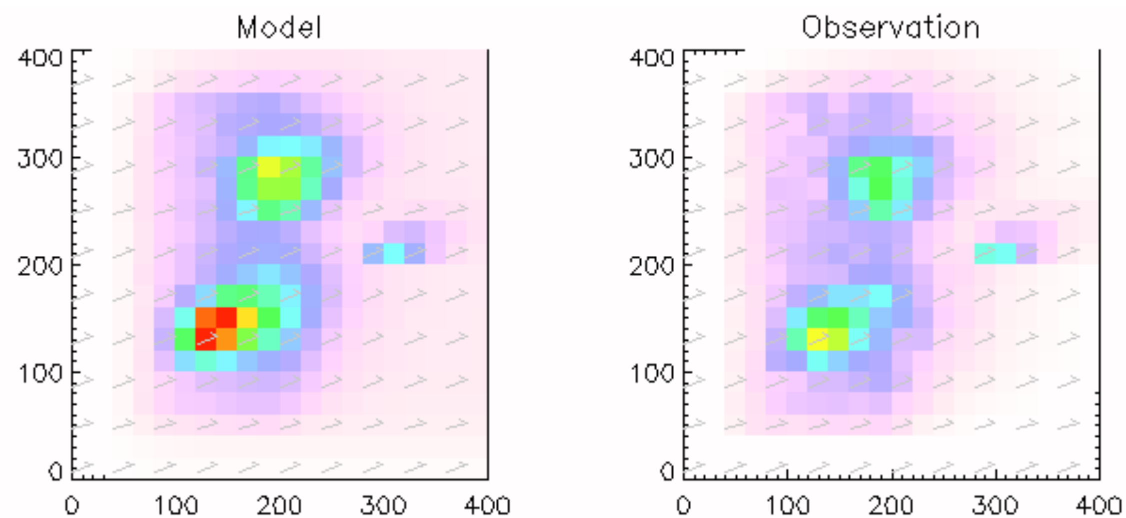

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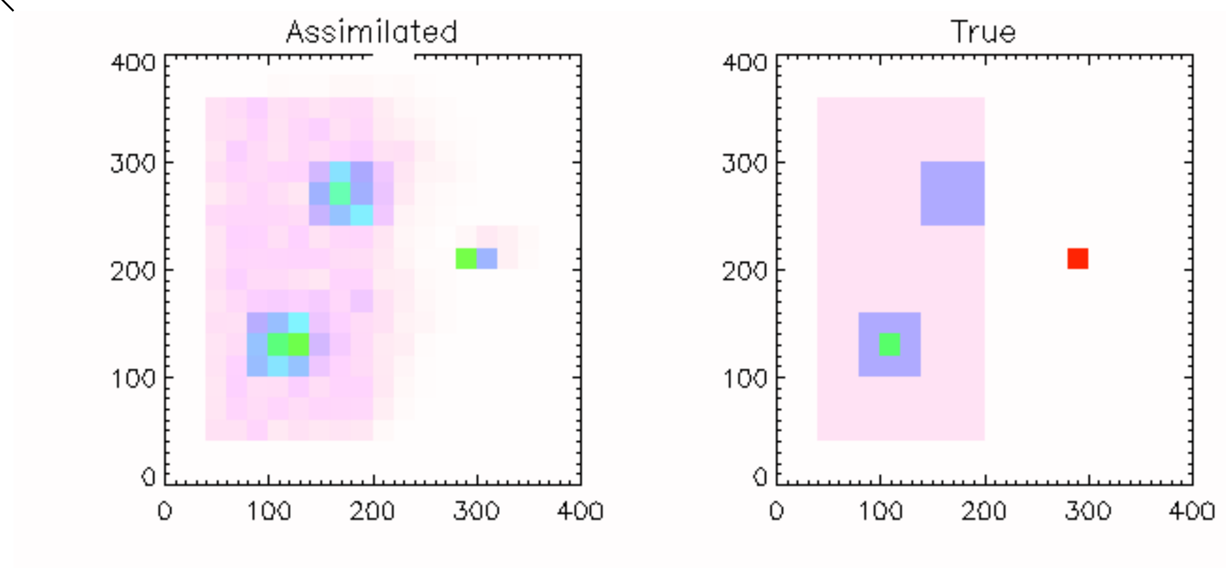
emissions



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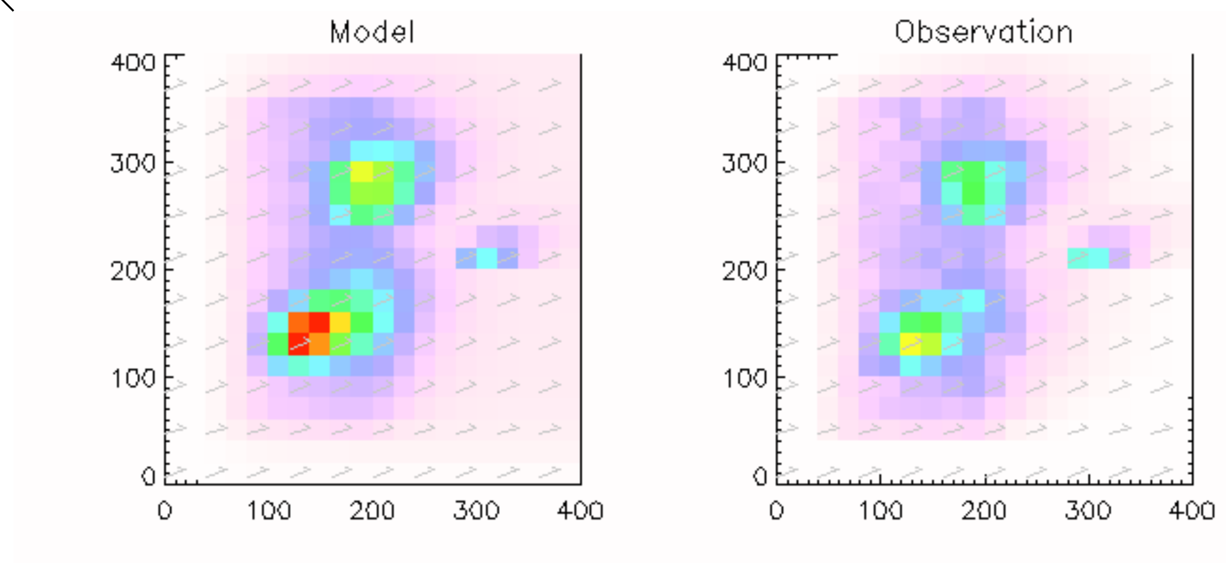
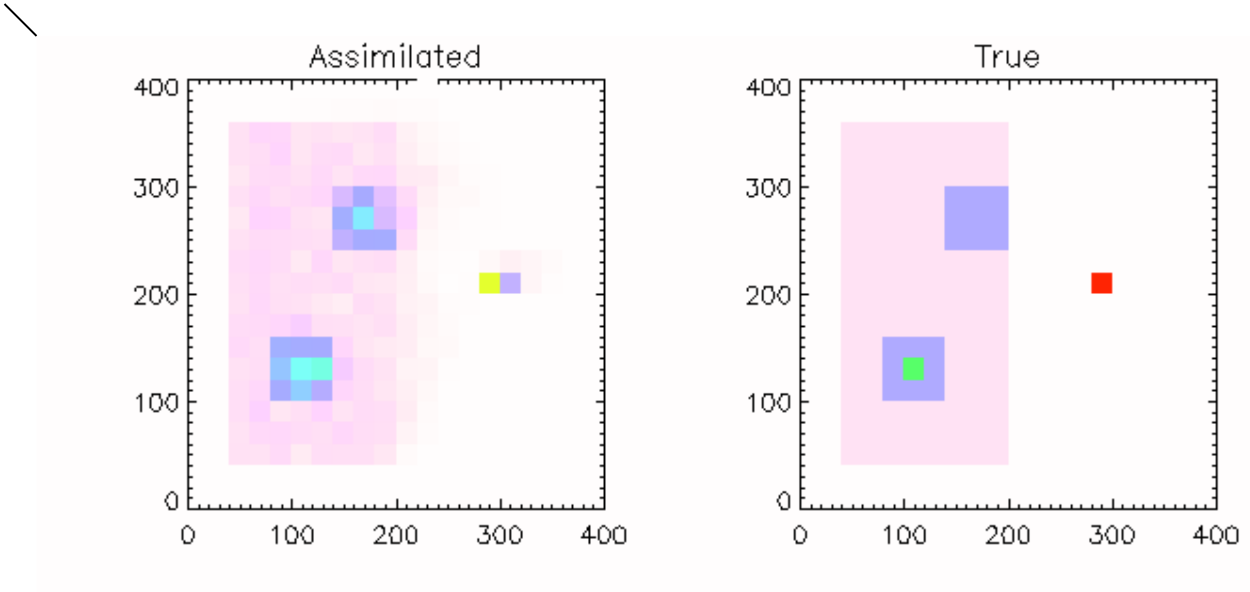
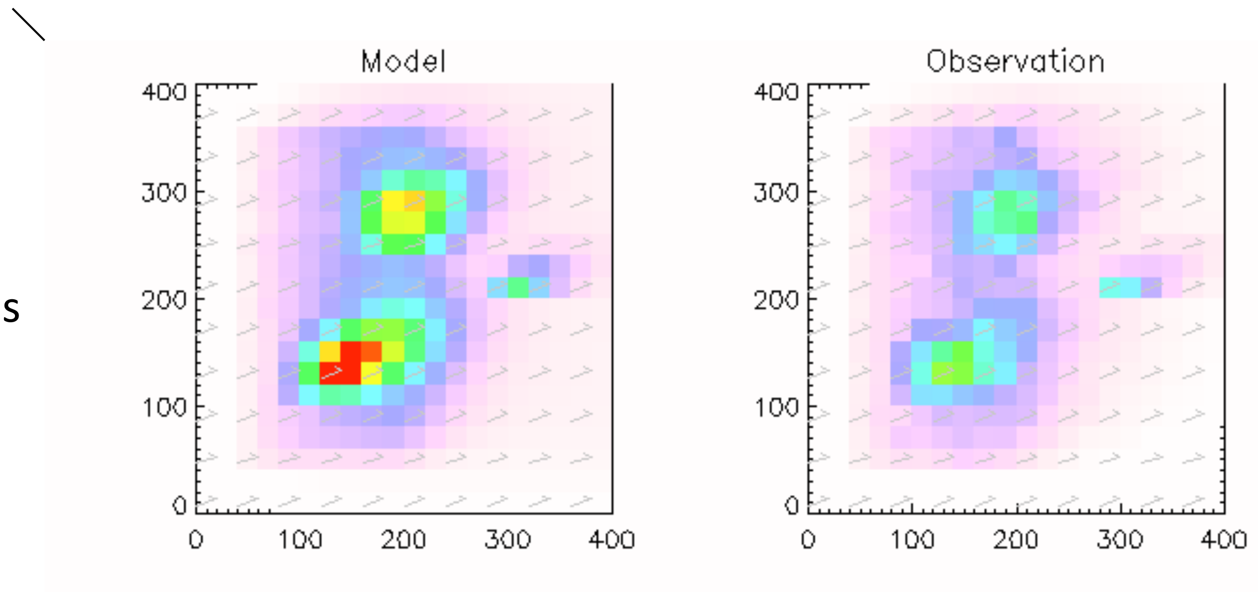


Local, linear

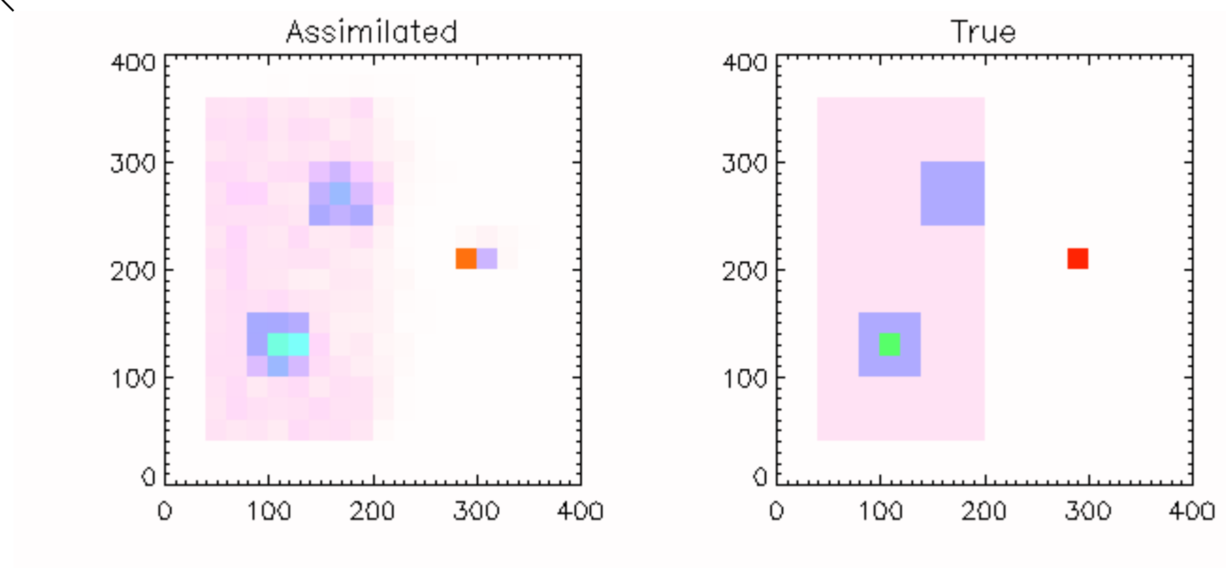
emissions



concentrations



Local, linear



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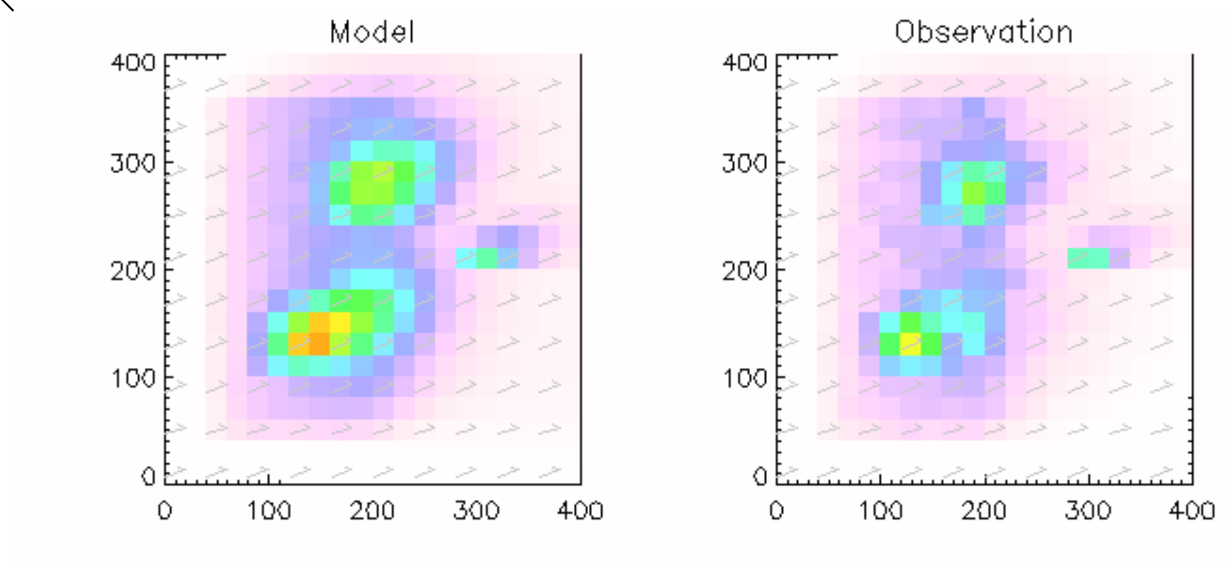
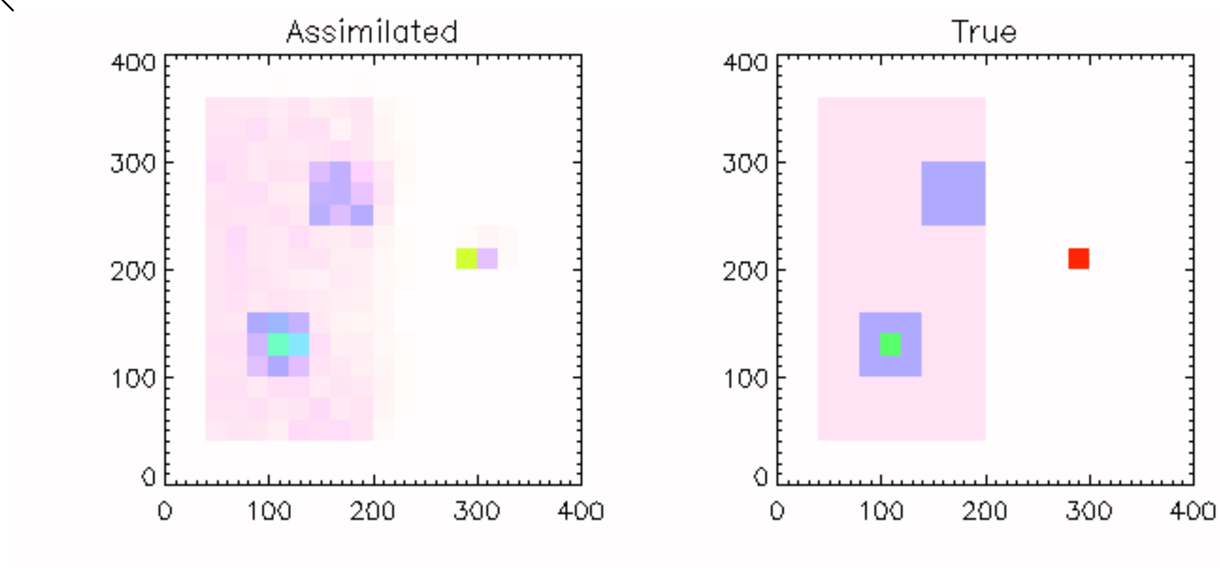


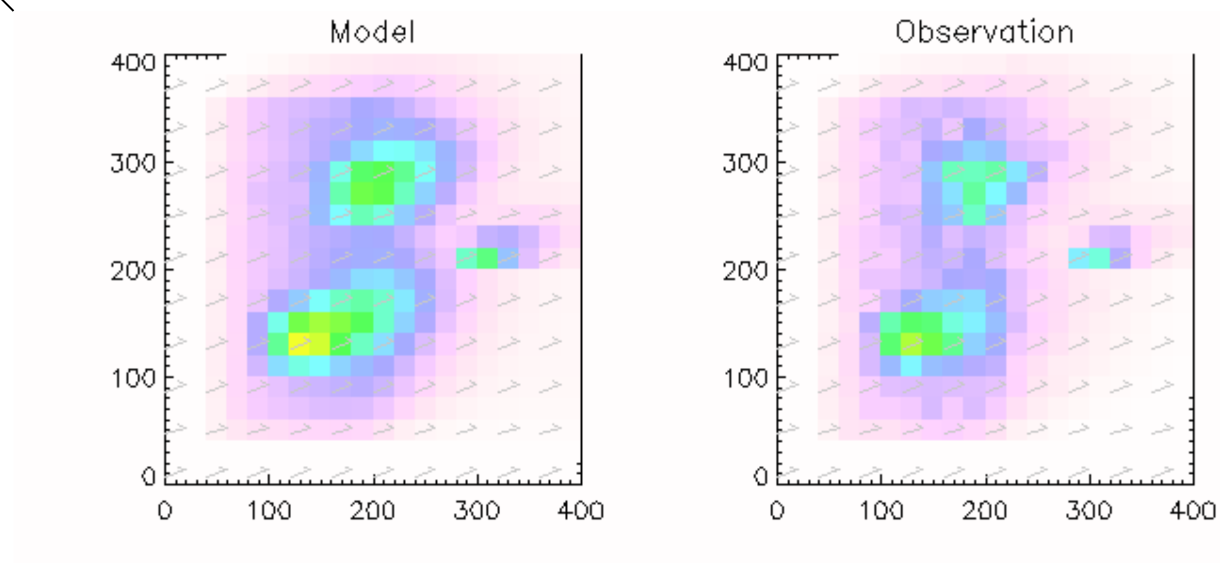
concentrations

Local, linear

emissions

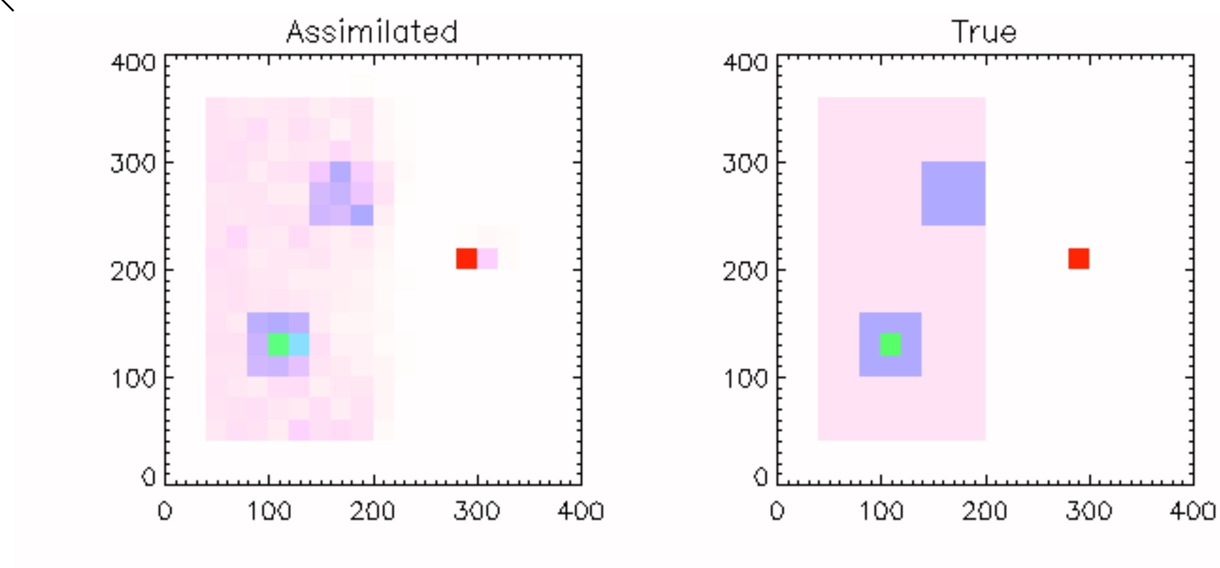


concentrations

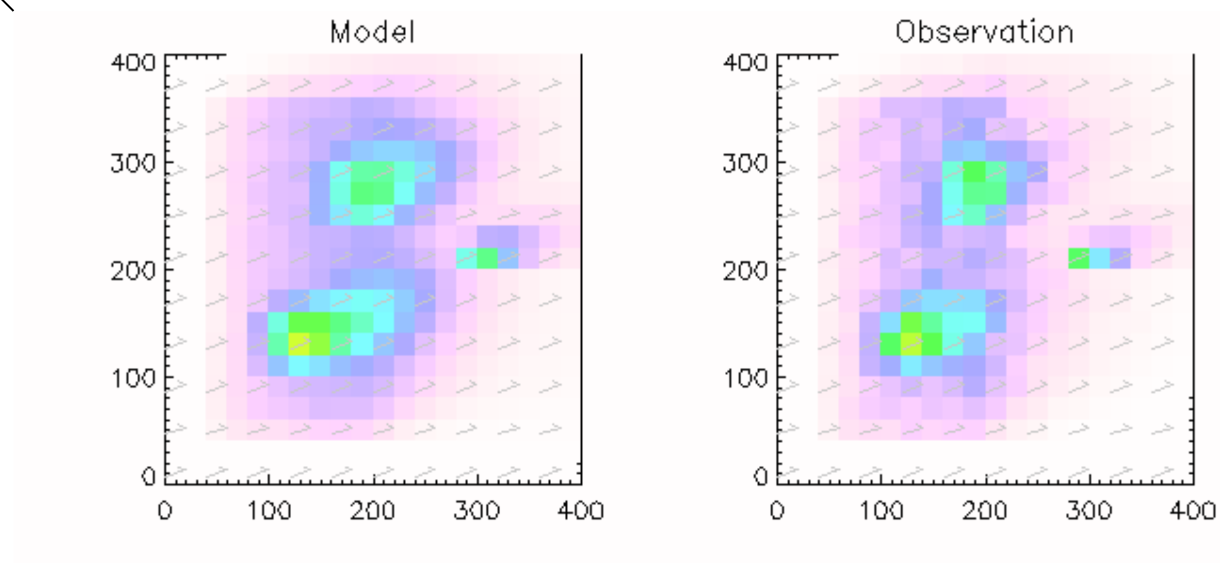


Local, linear

emissions

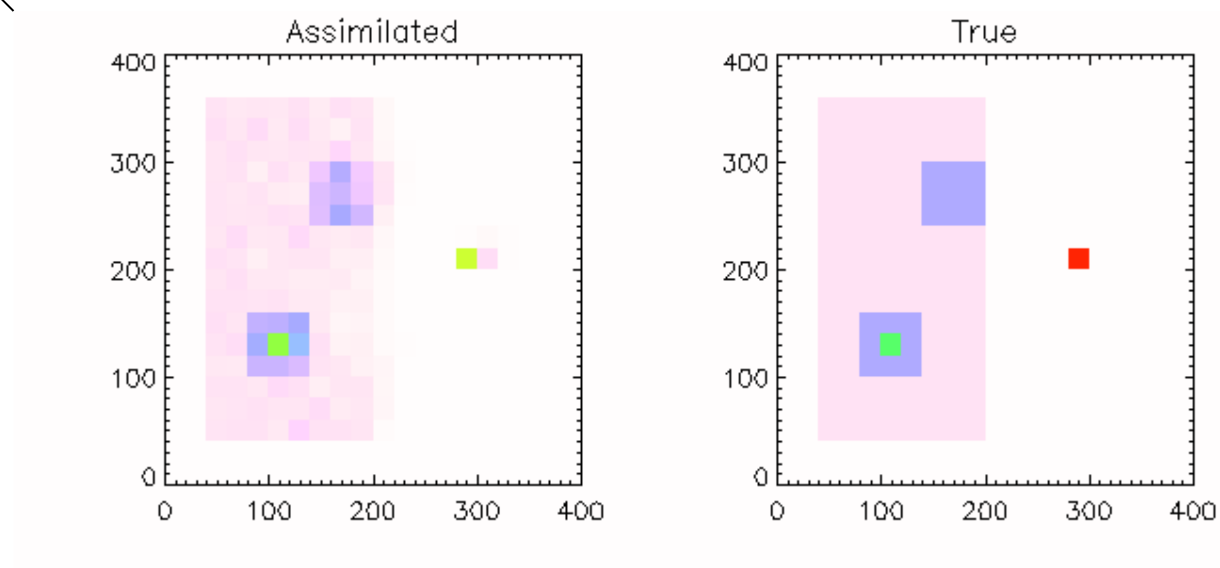


concentrations

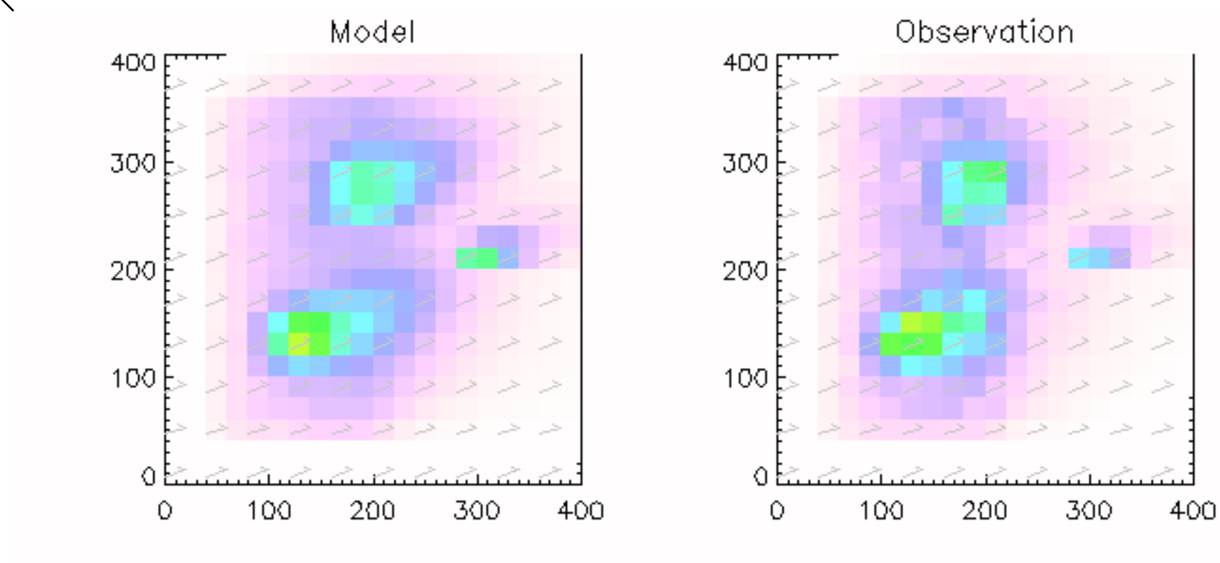


Local, linear

emissions

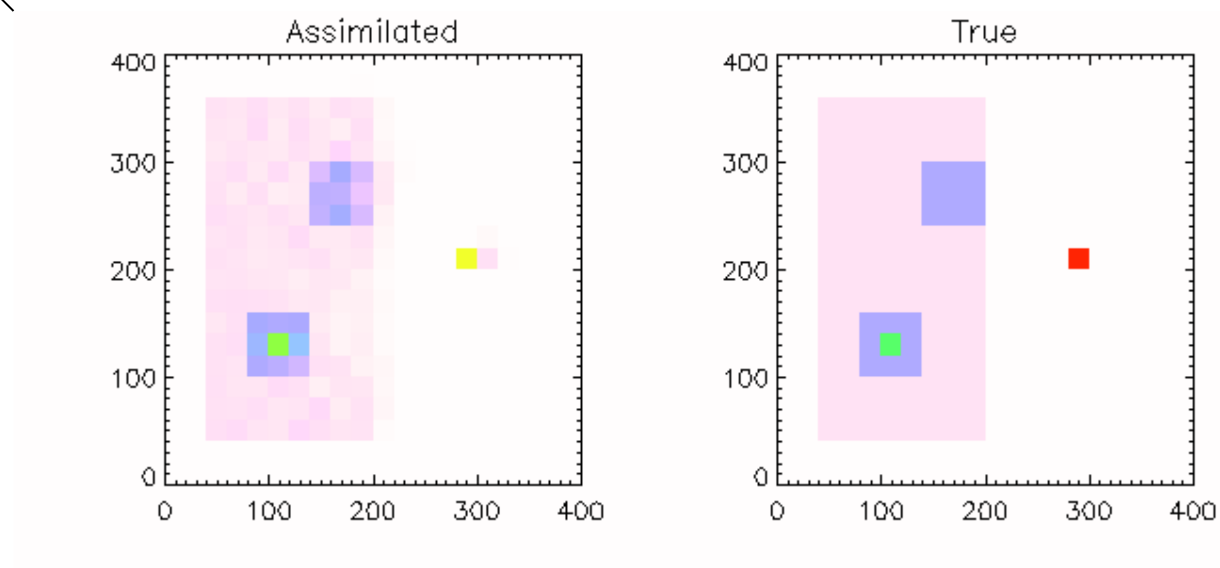


concentrations

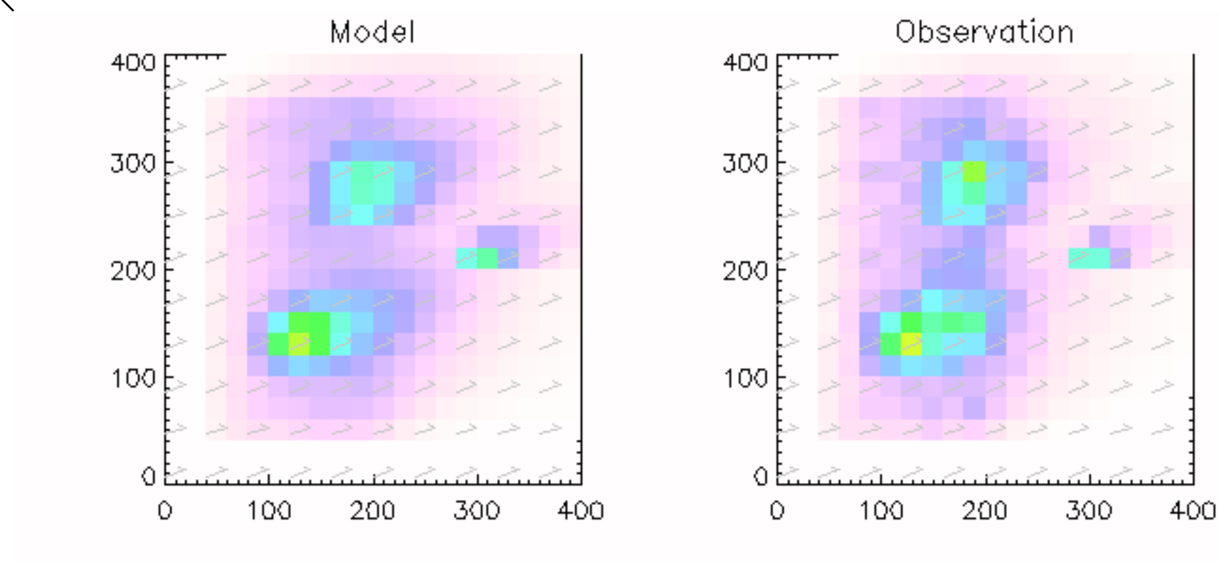


Local, linear

emissions



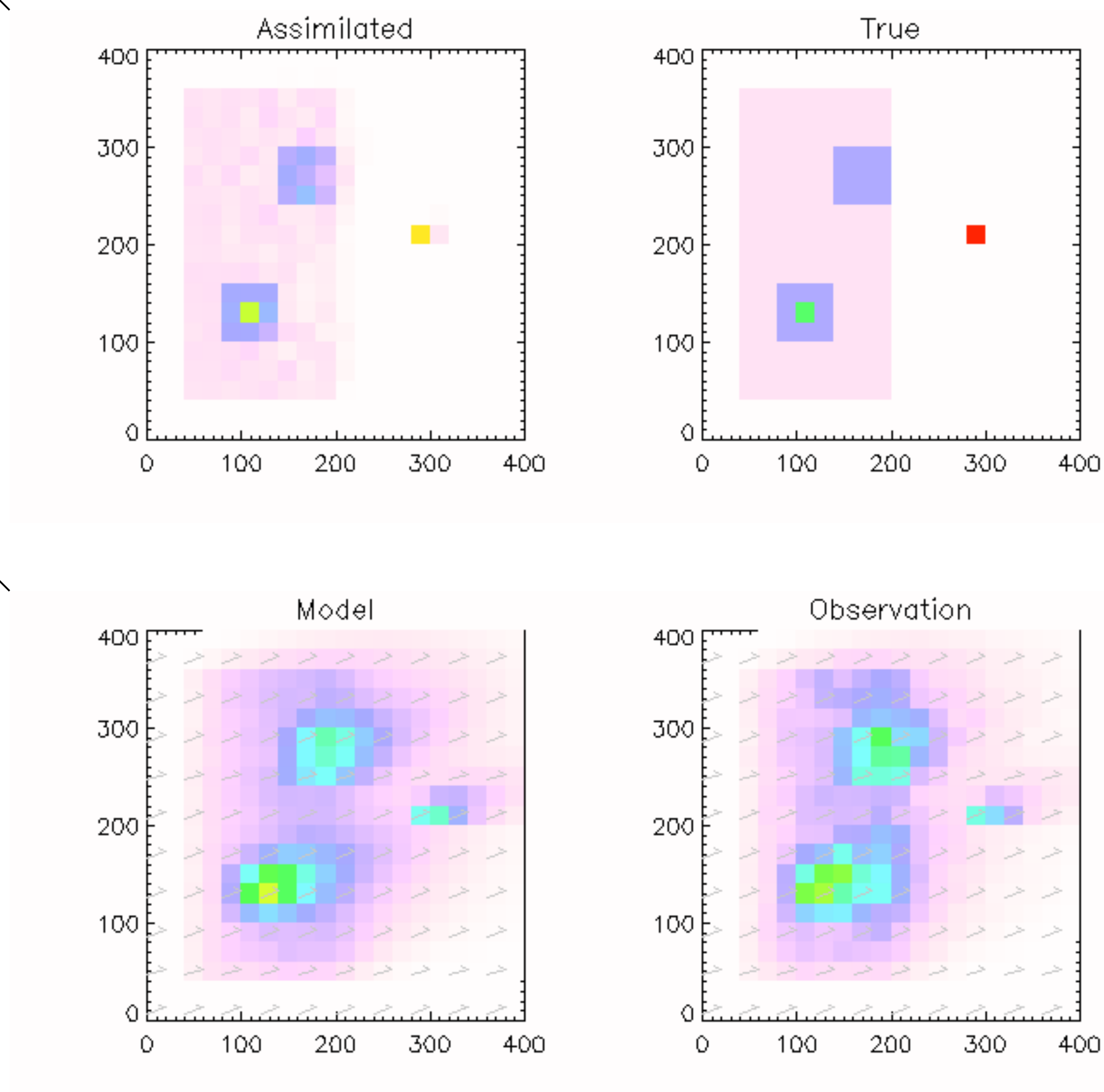
concentrations



Local, linear

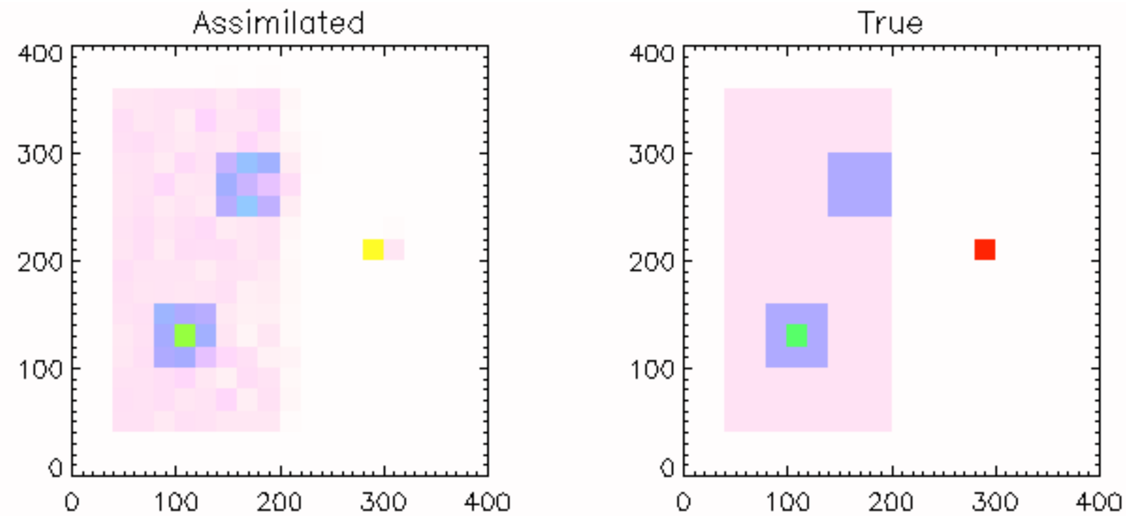
emissions

concentrations

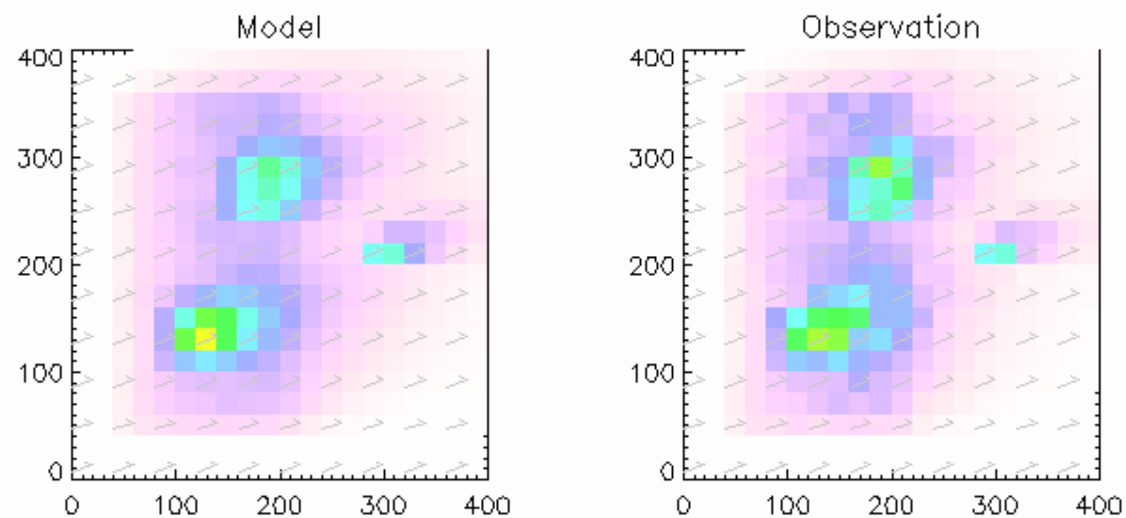


Local, linear

emissions

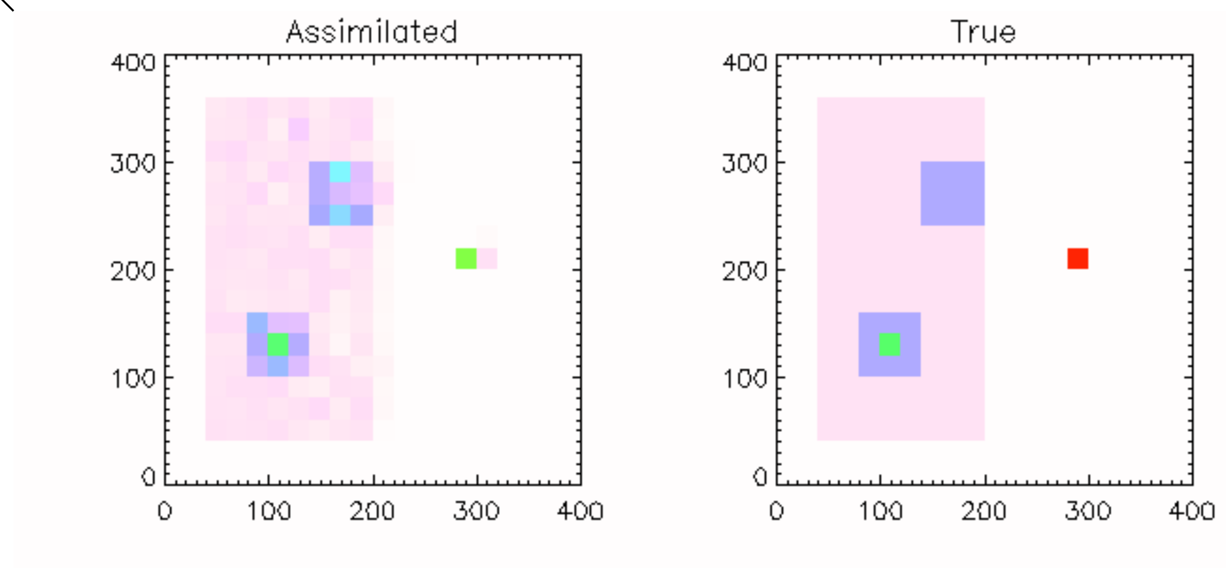


concentrations

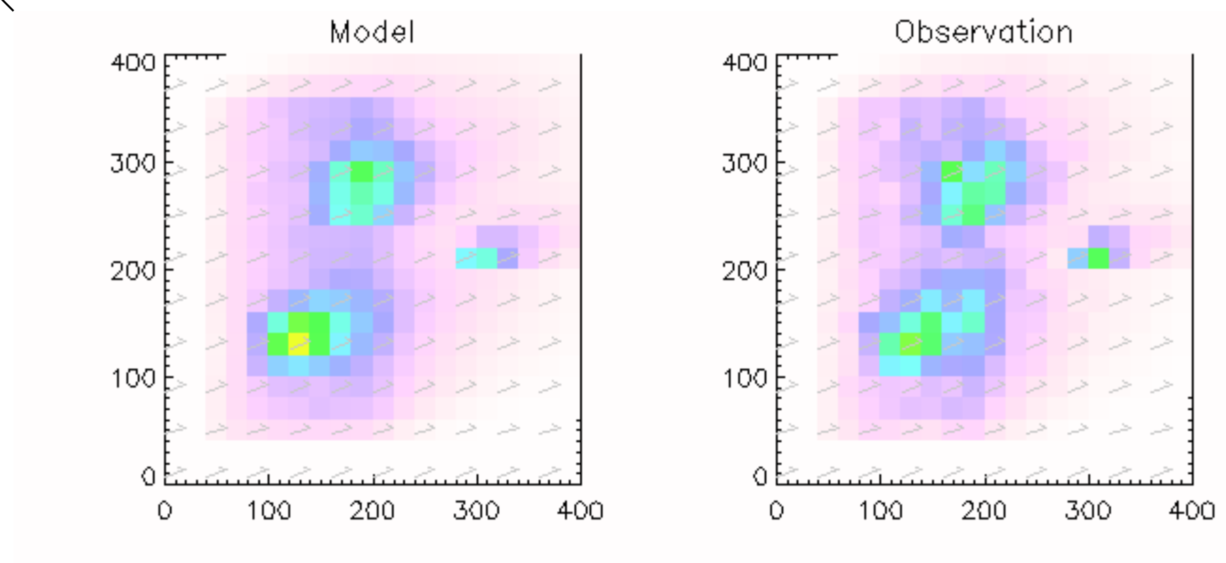


Local, linear

emissions

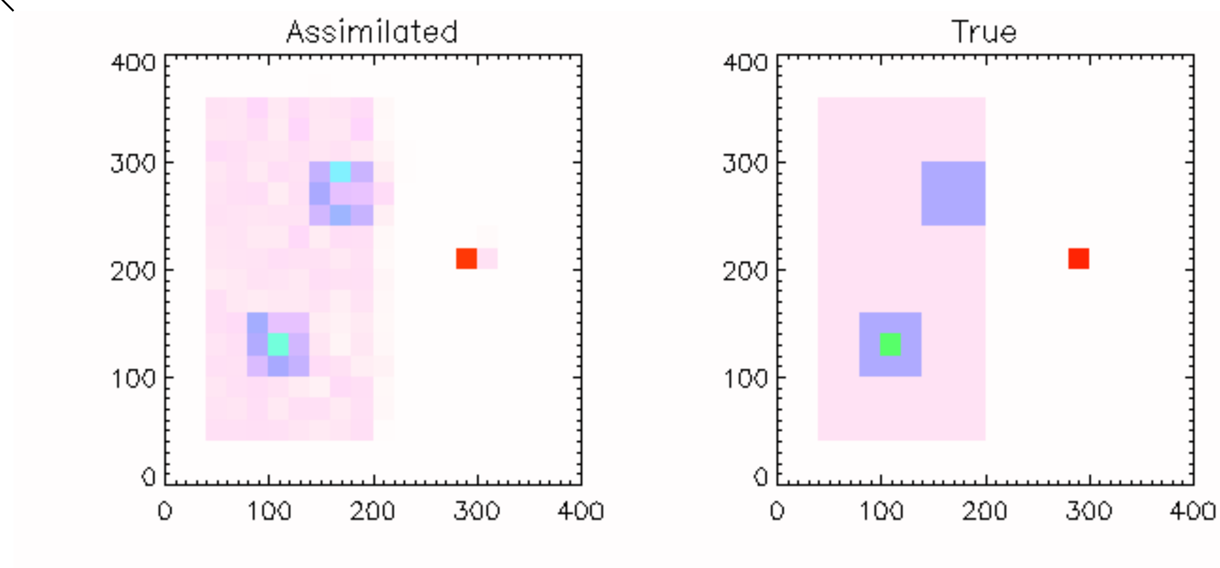


concentrations

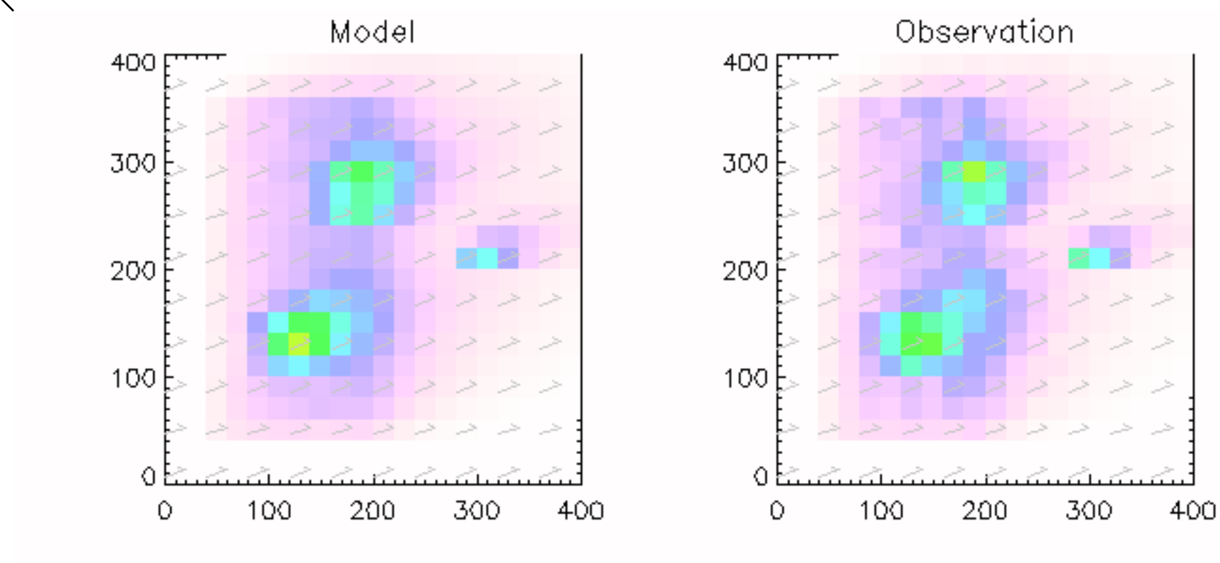


Local, linear

emissions

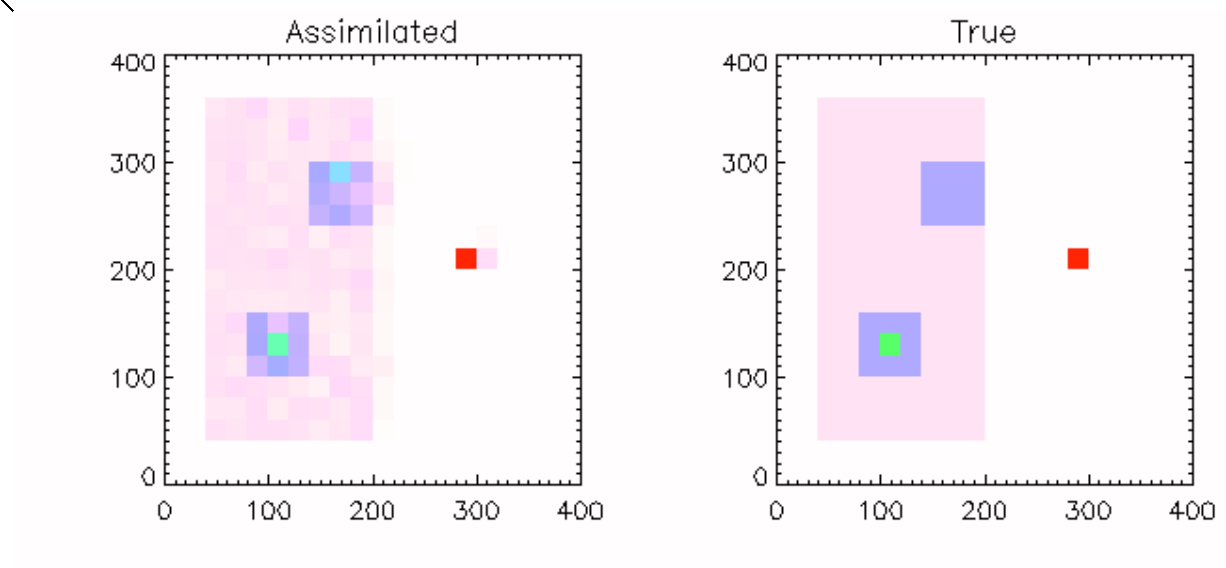


concentrations

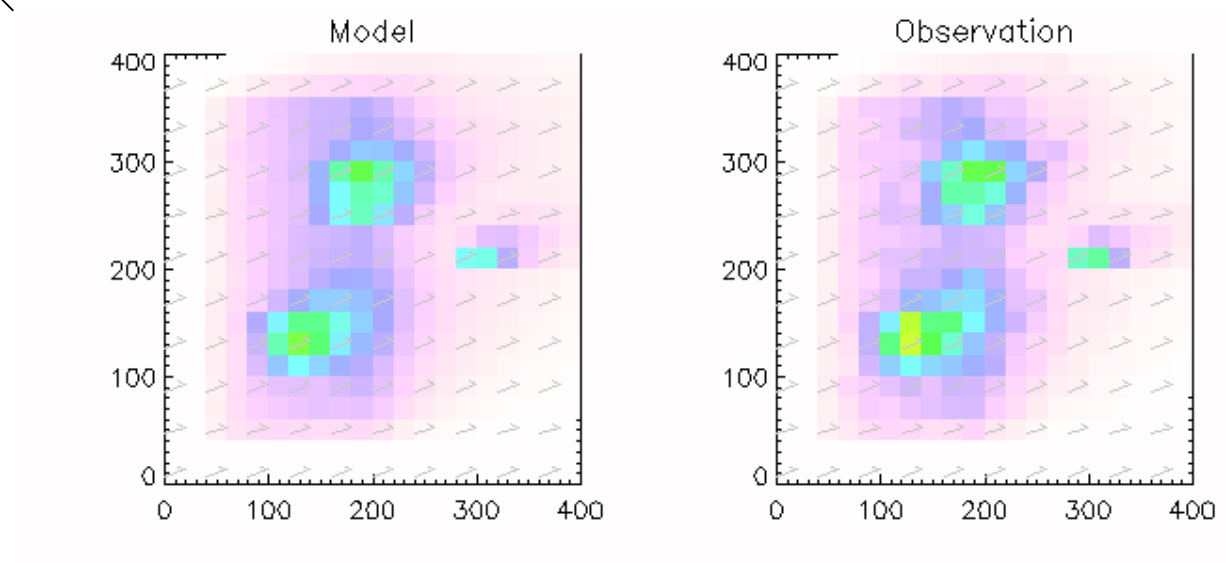


Local, linear

emissions

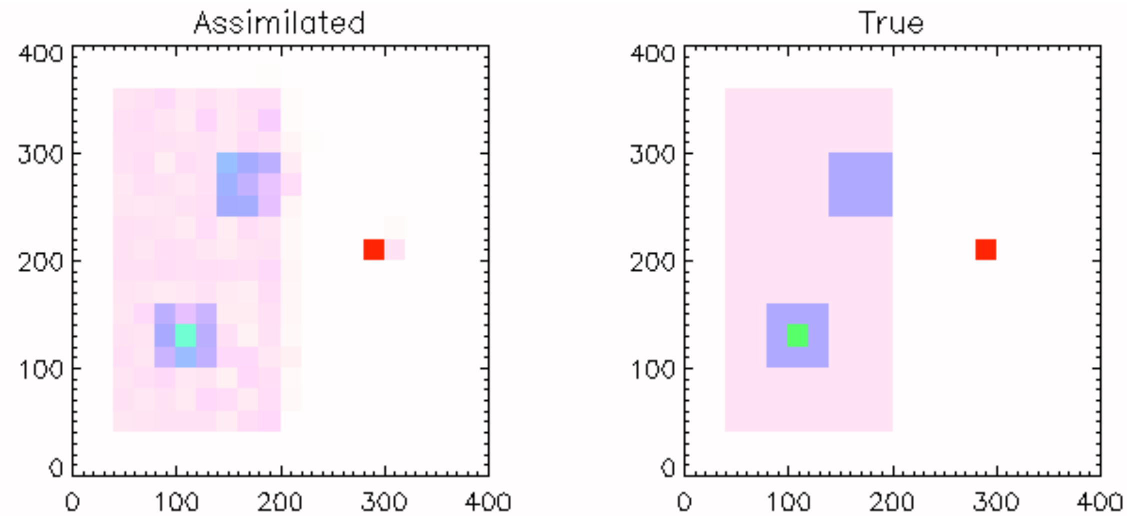


concentrations

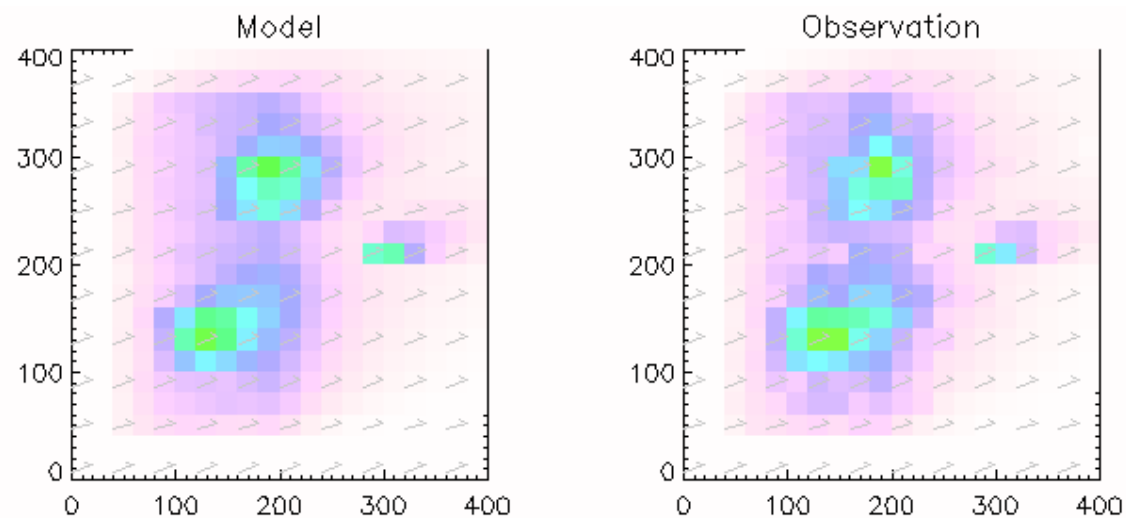


Local, linear

emissions

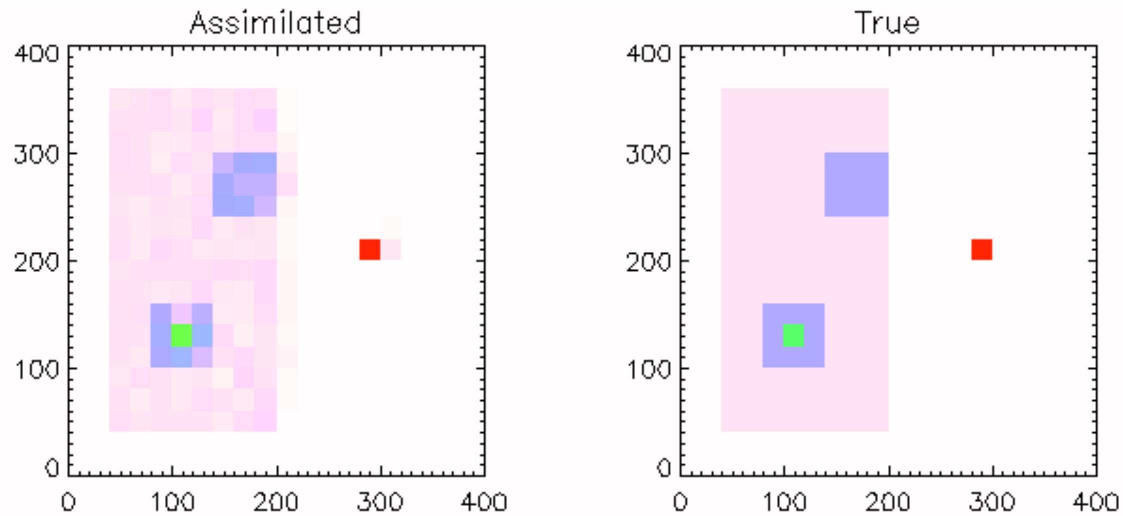


concentrations



Local, linear

emissions



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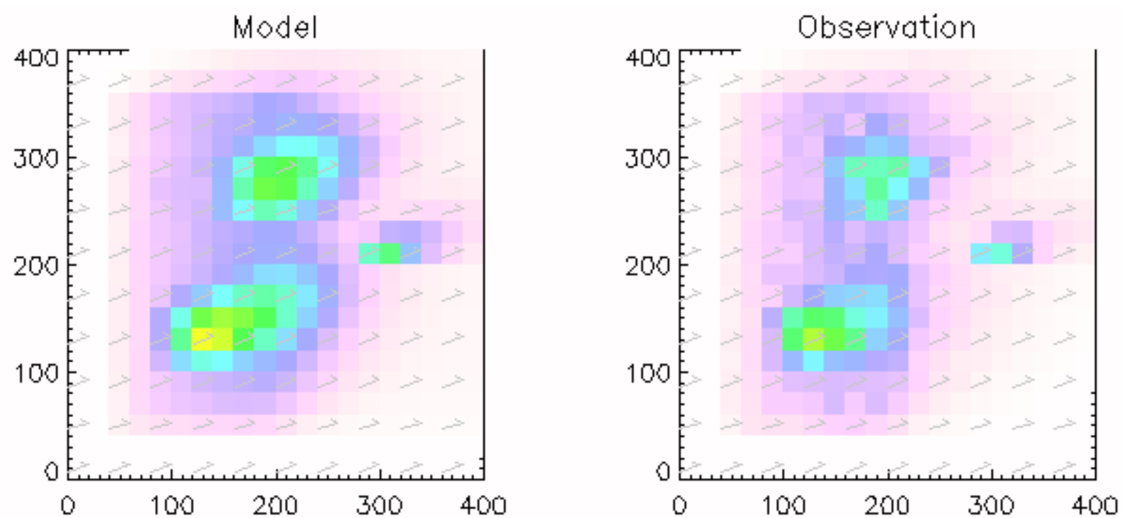
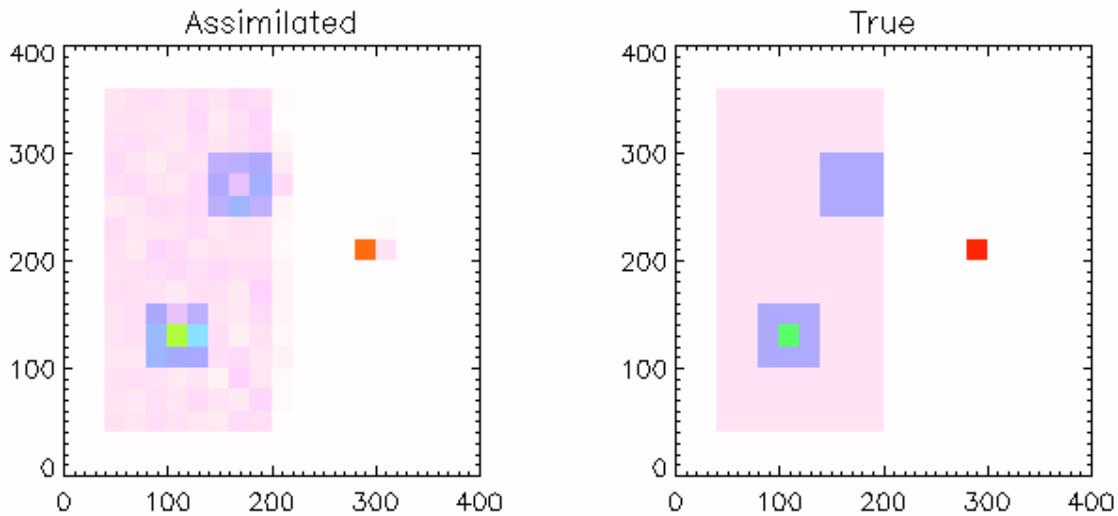
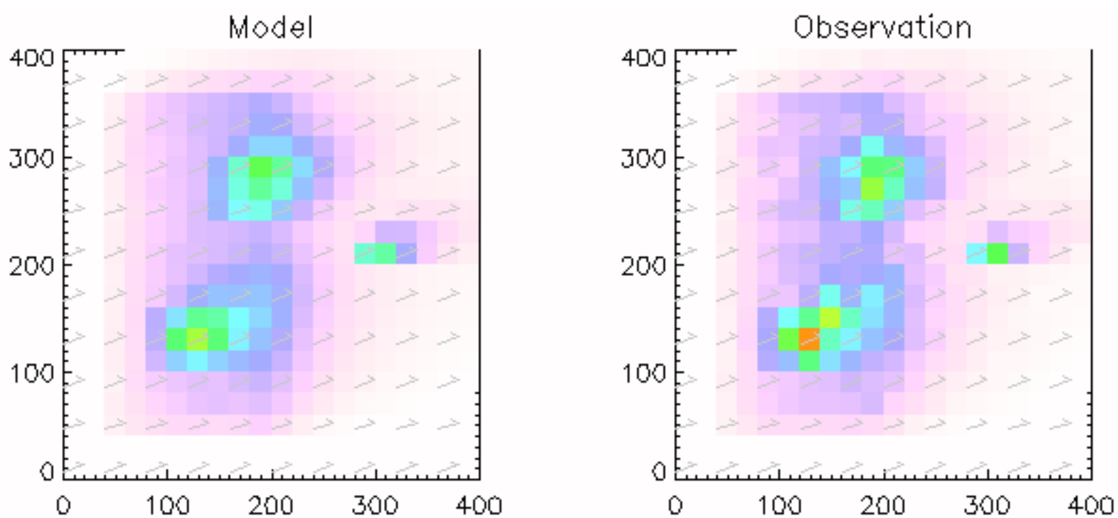


Local, linear

emissions



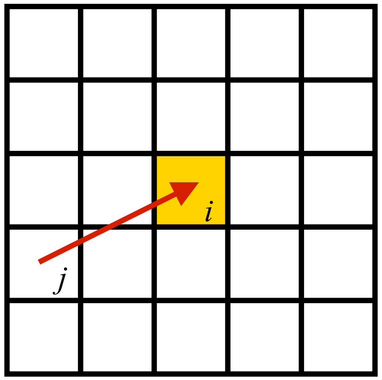
concentrations



Local, linear

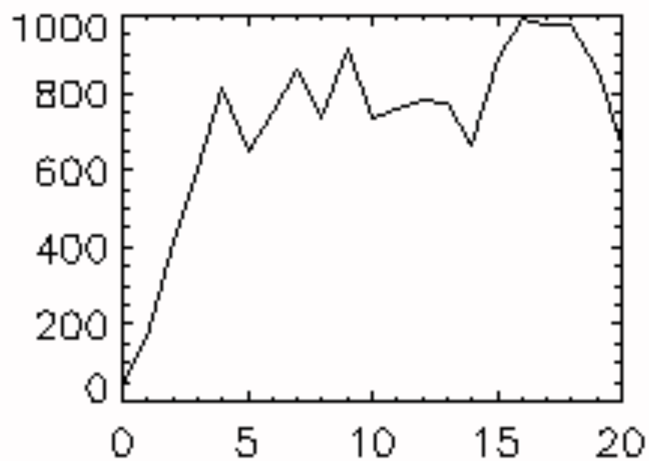
More realistic inversion: Sensitivities

When transport is taken into account, emissions in all grid cells can contribute to the observed concentration:

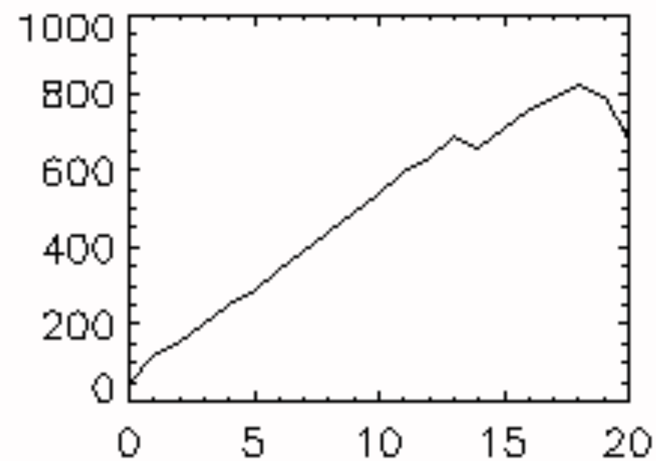


$$\Delta\Omega_i = \sum_j \alpha_{j\to i} \Delta E_j \quad , \quad \alpha_{j\to i} = \frac{\partial \Omega_i}{\partial E_j}$$

Convergence behaviour

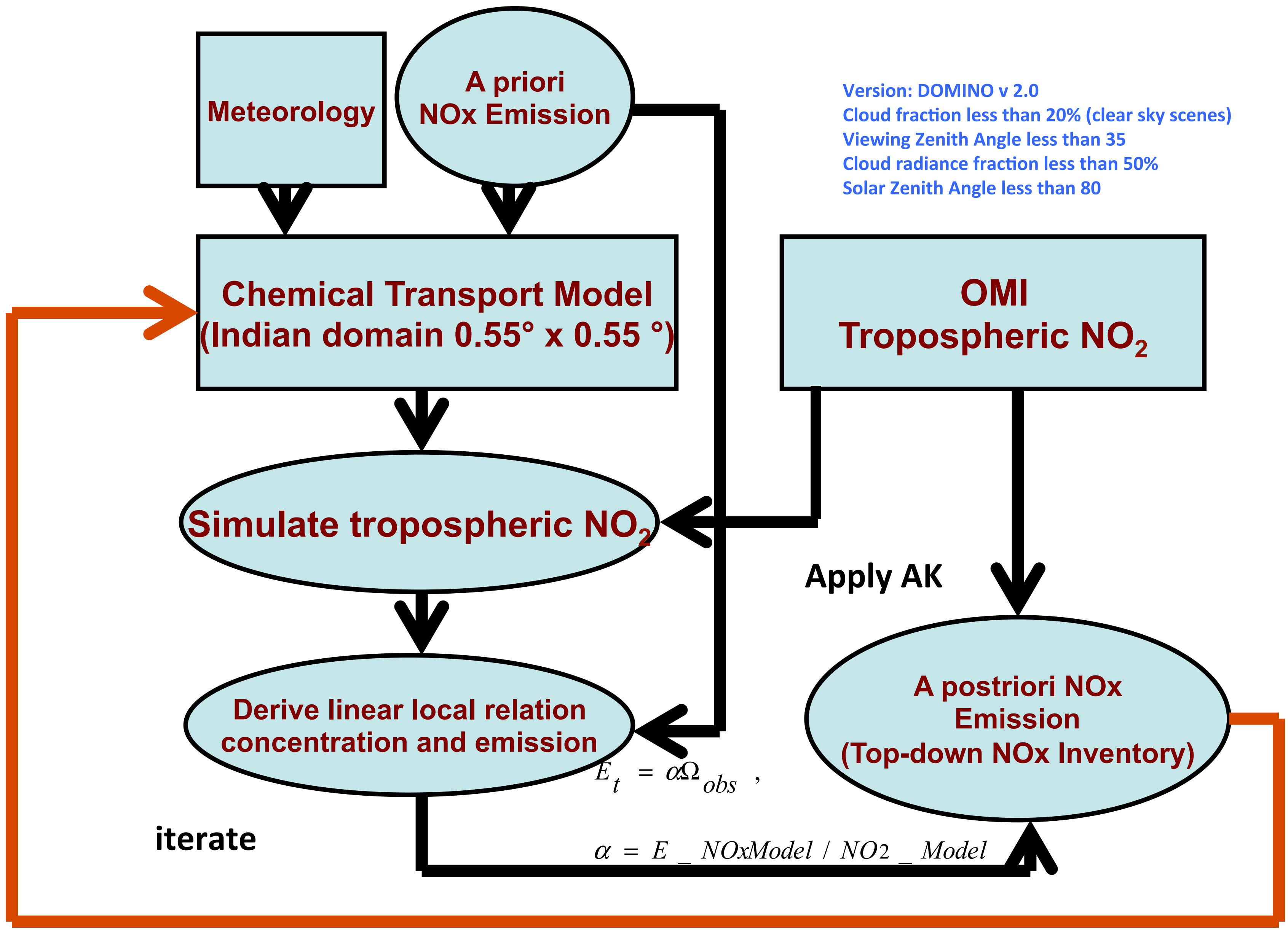


Local, linear



Kalman

Top-Down Approach for NOx- emission over India



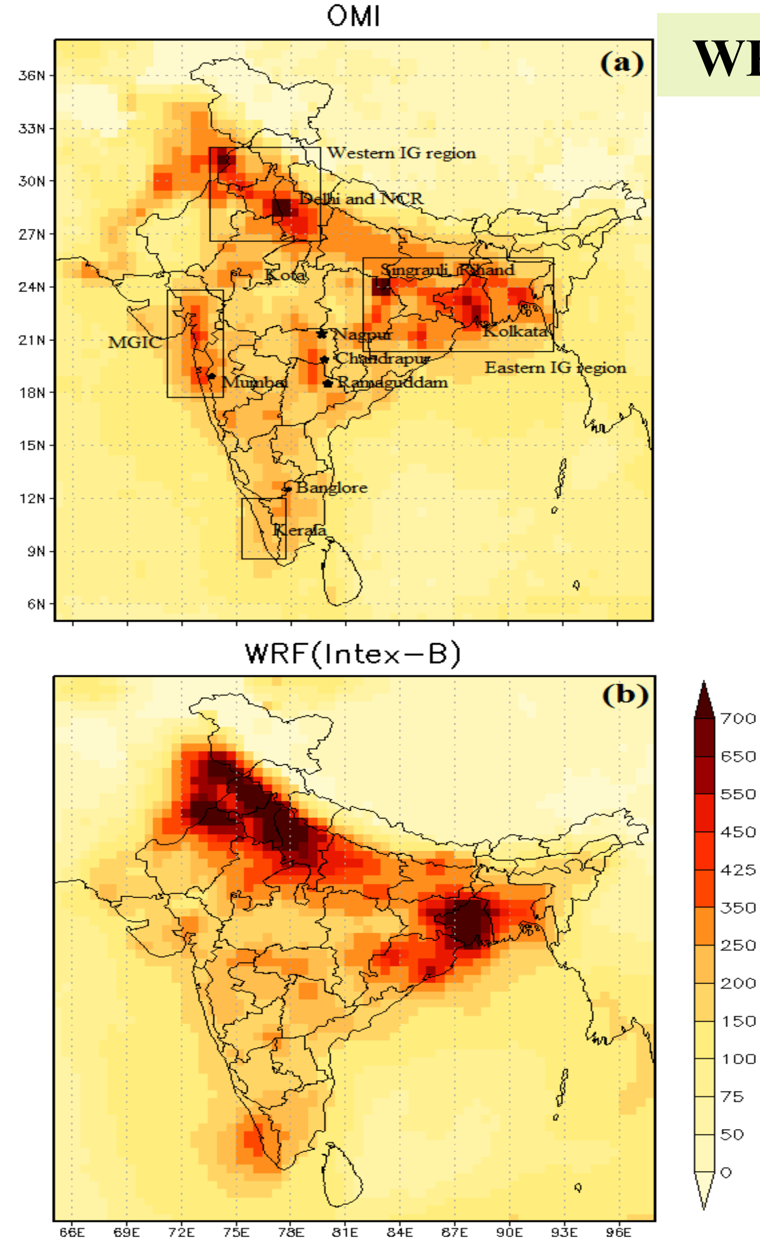
OMI Tropospheric NO_2 columns for the year 2005 Over India

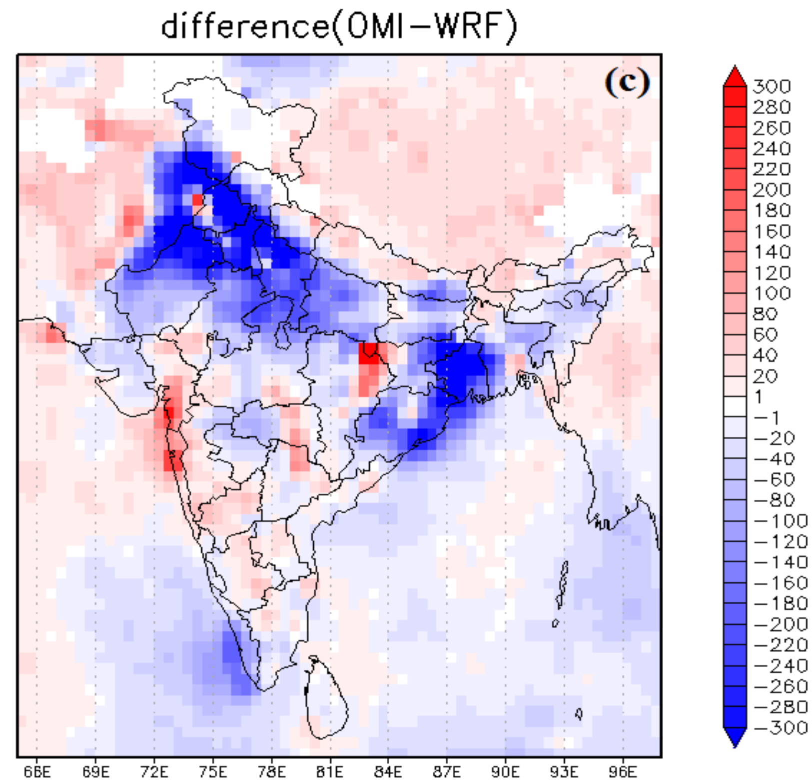
Version: DOMINO v 2.0 (Level 2 data set)
Cloud fraction less than 20% (clear sky scenes)
Viewing Zenith Angle less than 35 (pixel size smaller than $34x14km^2$)
Cloud radiance fraction less than 50%
Solar Zenith Angle less than 80

WRF-Chem Simulation for Jan 2005

Domain	: South Asia (0 - 45° N, 55 -110 ° E)
Period	: 2005
Resolution	: 55 km x 55 km
Emissions	: INTEX-B (A Priori)
Fire Emission	: NCAR Fire Inventory (FINN)
Biogenic	: MEGAN
Gas Ph. Chem	: MOZART
Aerosol Ph. Chem	: GOCART

WRF simulation with *a priori* emission (Intex-B)





With OMI Averaging Kernel

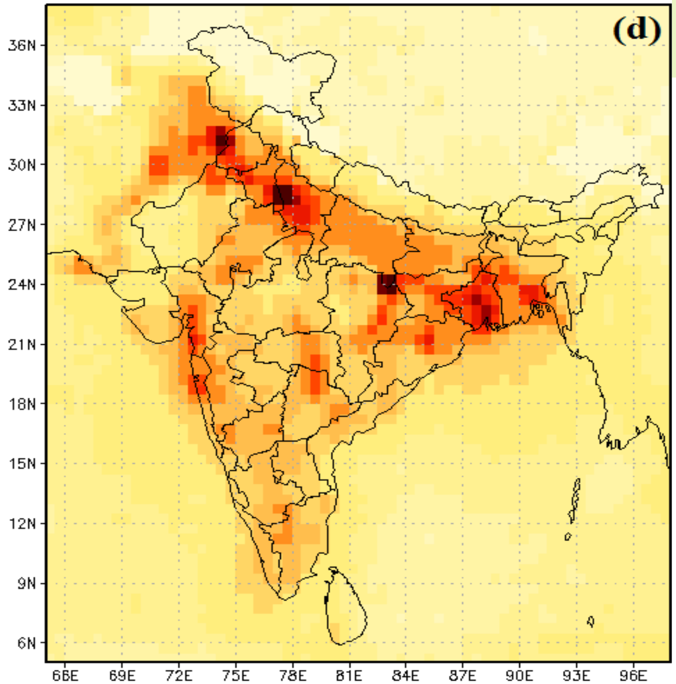
Correlation R^2 = 0.68

Spatial distribution of OMI and WRF-Chem tropospheric NO_2 column for 2005 and its difference. Tropospheric column NO_2 unit is 10^{13} molecules/cm^2/s.

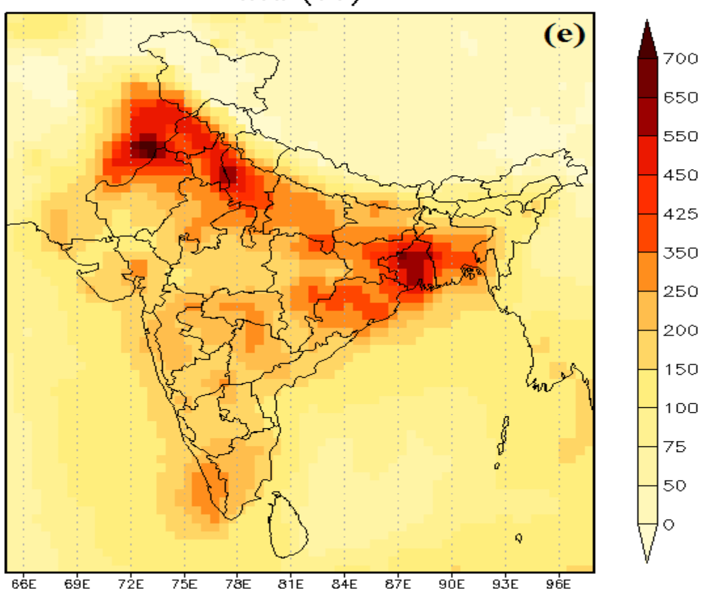
Ghude S.D., Pfister G. G., **Chinmay Jena** et al., GRL, 2013

WRF simulation with *a postrioro* emission (T1)

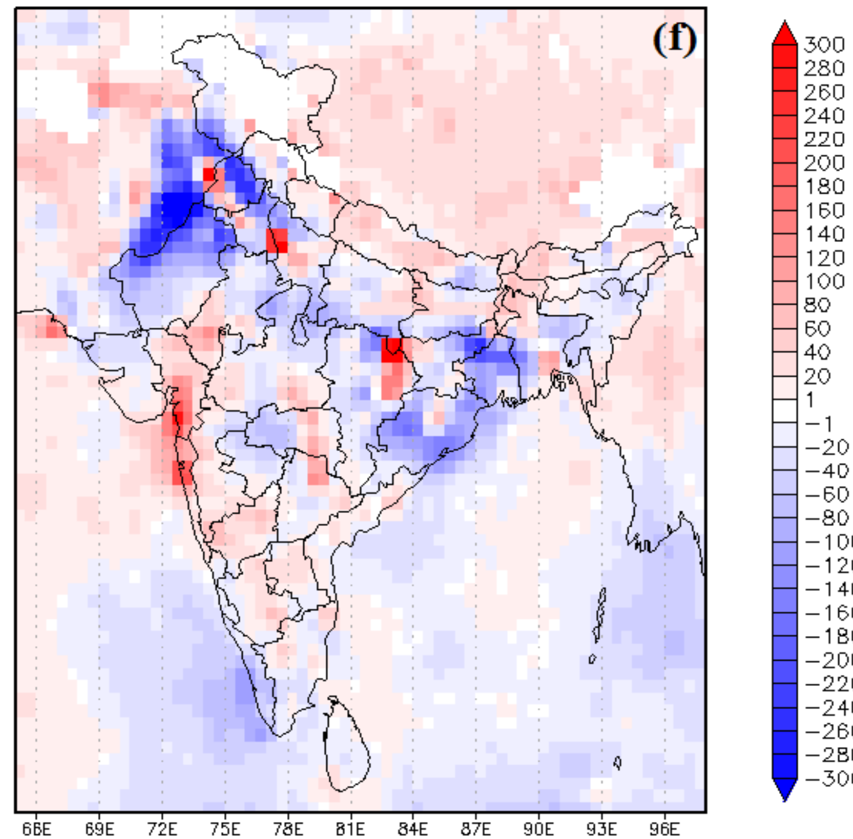
OMI



WRF(T1)



difference(OMI−WRF)

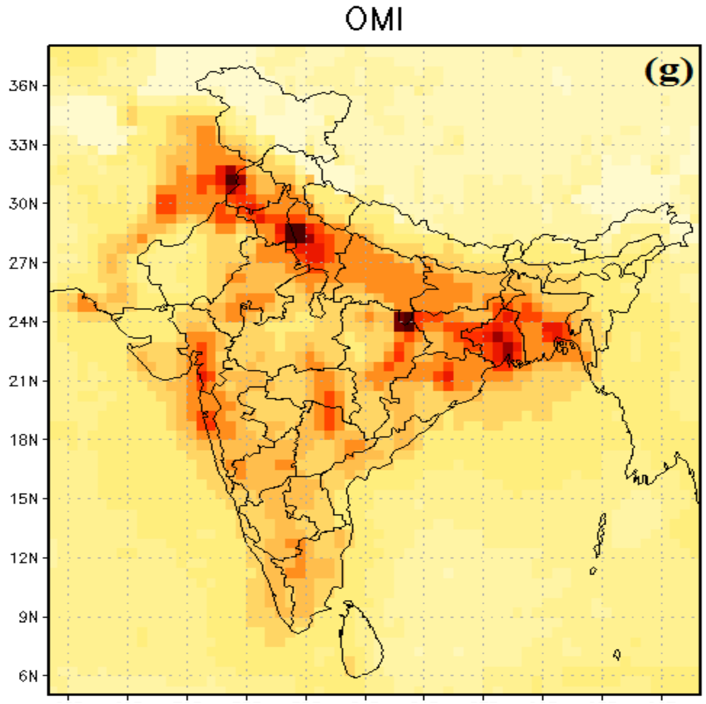


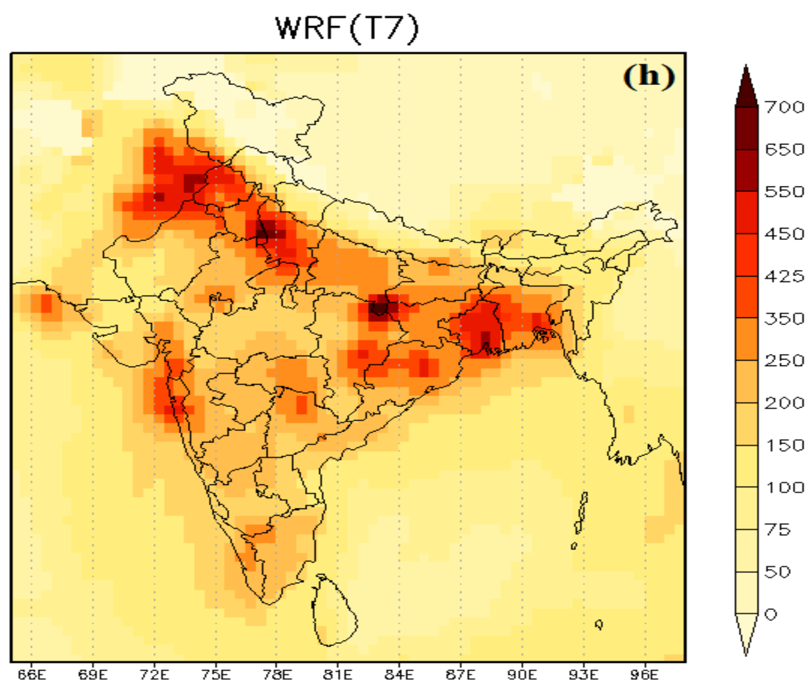
With OMI Averaging Kernel ←

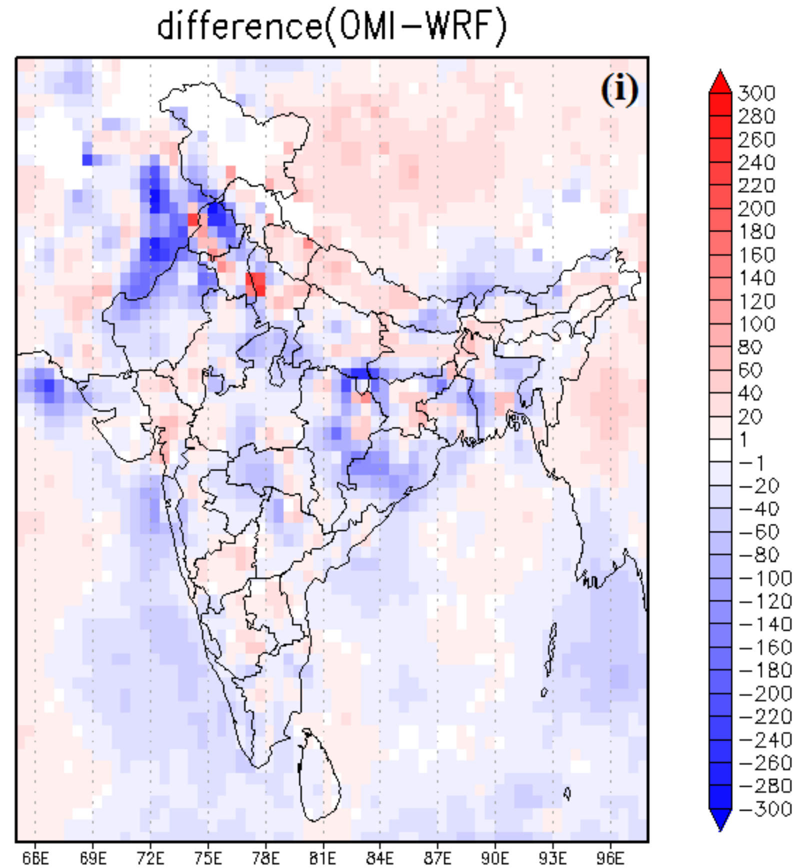
Correlation R^2 = 0.76

Ghude S.D., Pfister G. G., **Chinmay Jena** et al., GRL, 2013

WRF simulation with *a postrioro* emission (T7)





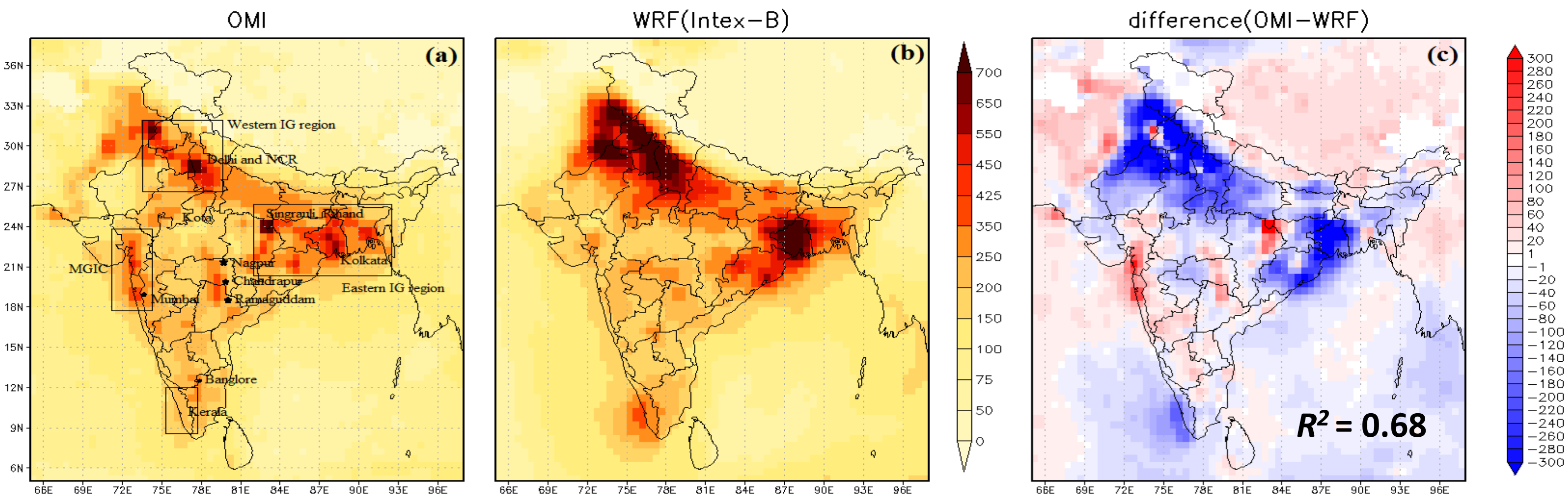


With OMI Averaging Kernel

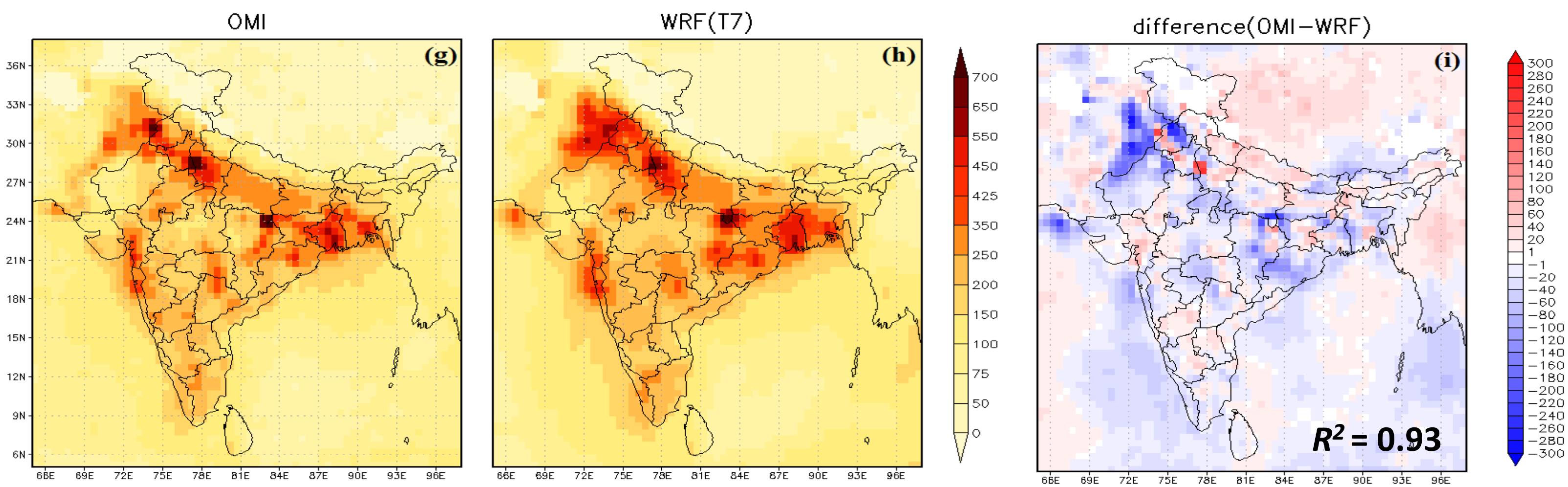
Correlation R^2 = 0.93

Ghude S.D., Pfister G. G., **Chinmay Jena** et al., GRL, 2013

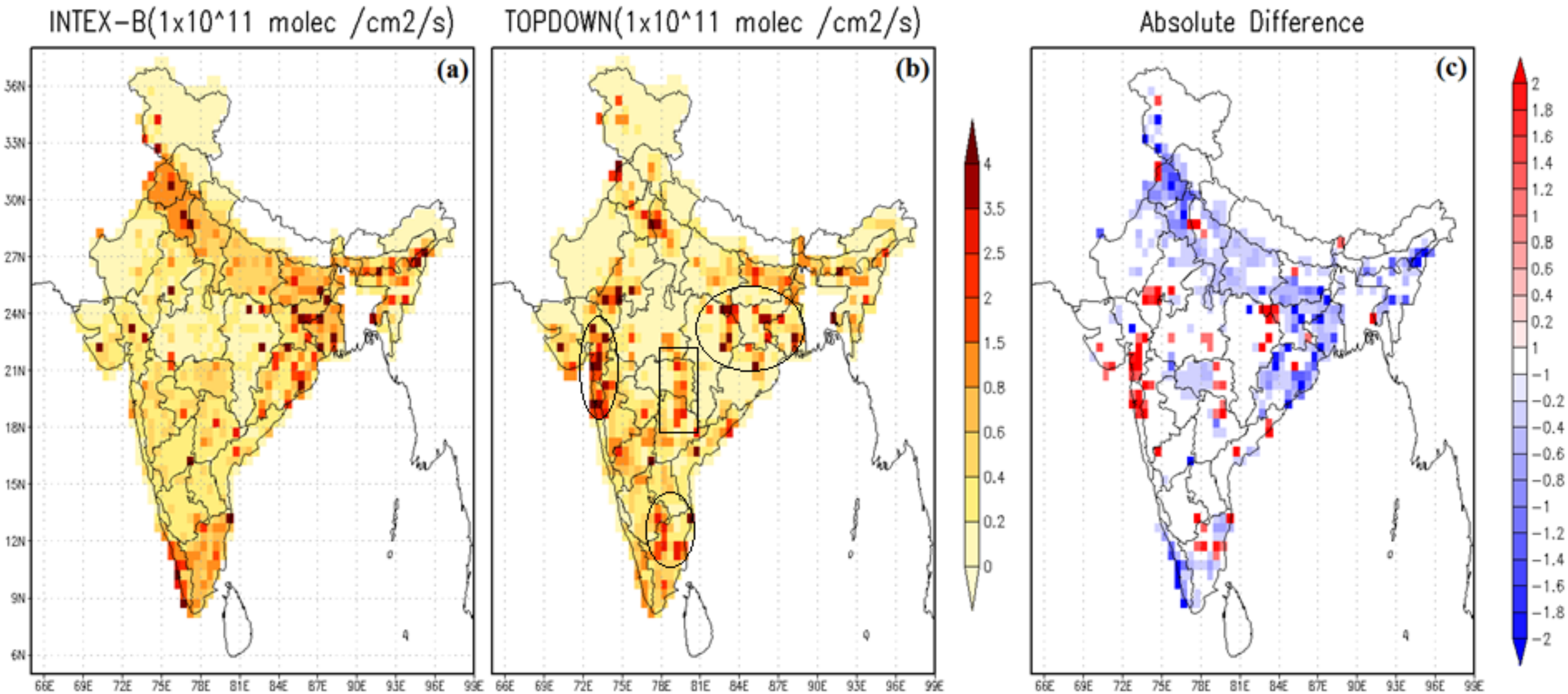
WRF simulation with *a priori* emission (Intex-B)



WRF simulation with *a postrioro* emission (T7)



A priori versus A posteriori Emissions

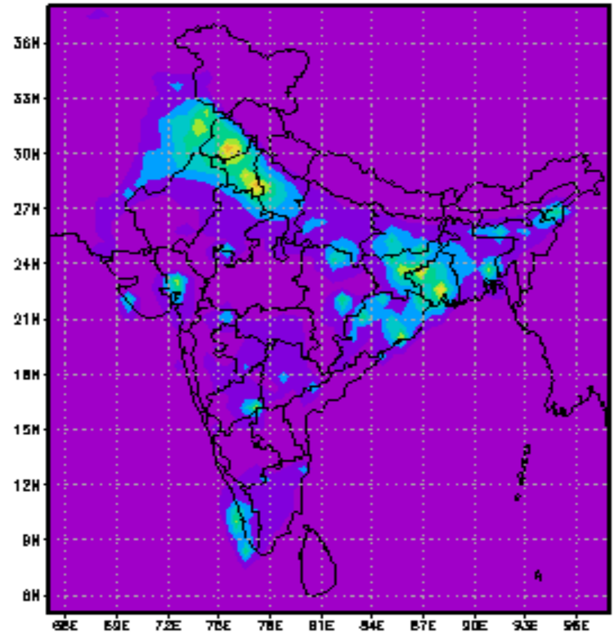


Spatial distribution of NO_X emission from (a) INTEX-B inventory, (b) optimized top-down Inventory and (c) their difference (emission unit is 10^{11} NO molecules/cm^2/s)

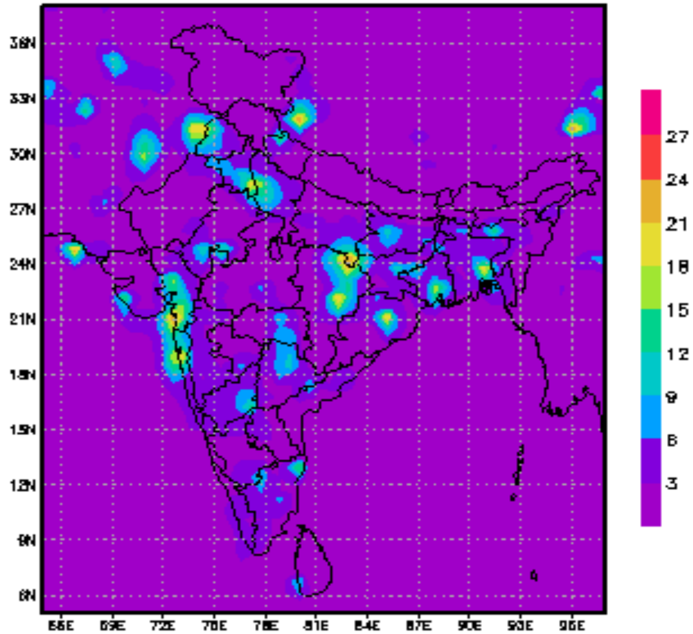
A priori emission	A posteriori emission
1.56Tg N /year	**1.42Tg N /year**

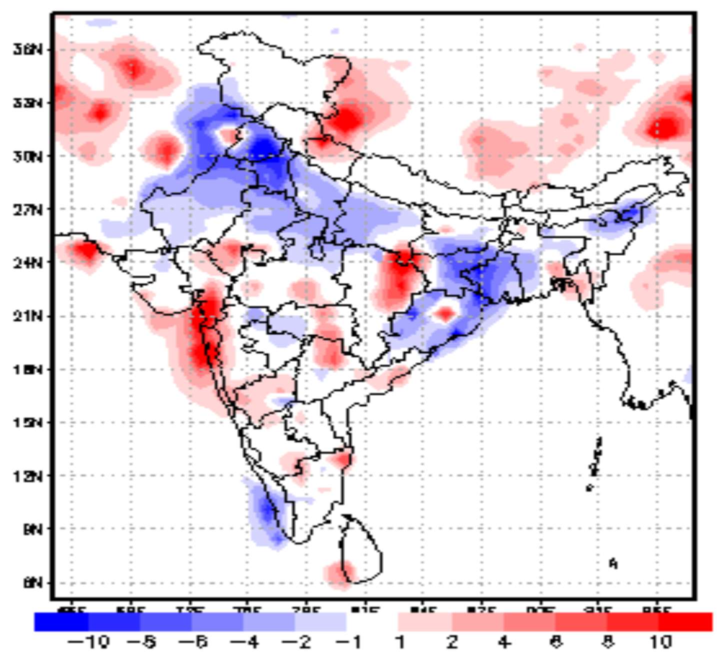
Ghude S.D., Pfister G. G., **Chinmay Jena** et al., GRL, 2013

Surface NO_2 (ppb) Intex-B



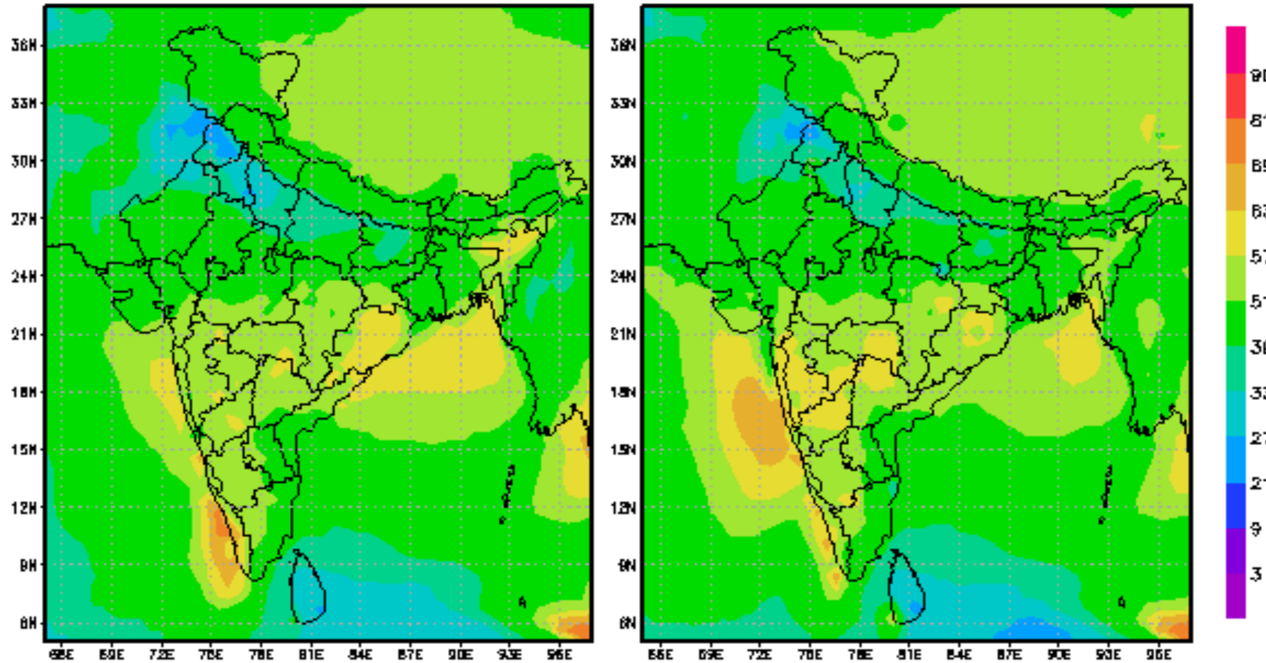
Surface NO_2 (ppb) T7



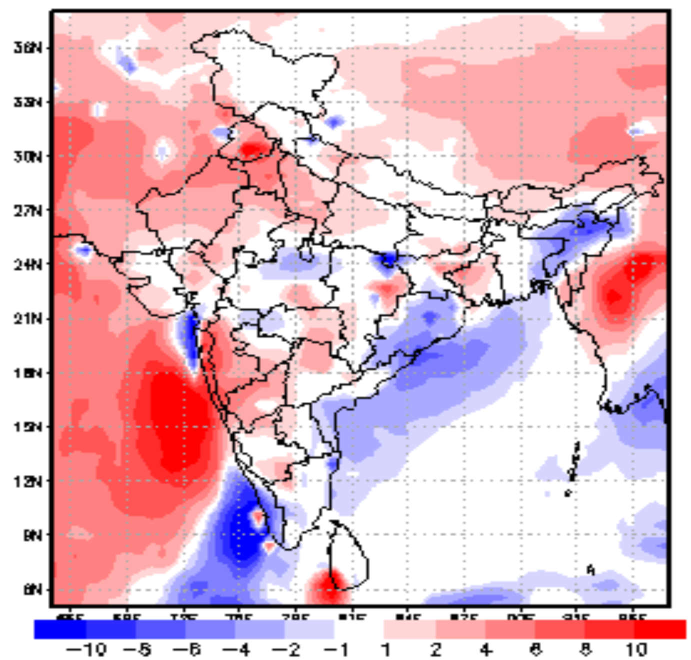


Difference in Surface NO_2 (ppb) (T7-Intex-B)

Mean daily max O_3 (ppb) Intex-B **Mean daily max O_3 (ppb) T7**



Difference in daily Max O_3 (ppb) (T7 - Intex-B)



Sources of Uncertainties in Top-Down Inventory:

1. Uncertainty in satellite retrievals

OMI filtering error,
Air Mass Faction (clod fraction, cloud pressure, NO2 Profile shape, aerosols calculation, Stratospheric corrections, etc)

2. Model Uncertainties

- Error in model metrology
- Model profile shape
- Simulation of fate of Nitrogen emitted into the atmosphere
- (chemical mechanism and heterogeneous aerosol
- NOx reactions)
- dry and wet deposition

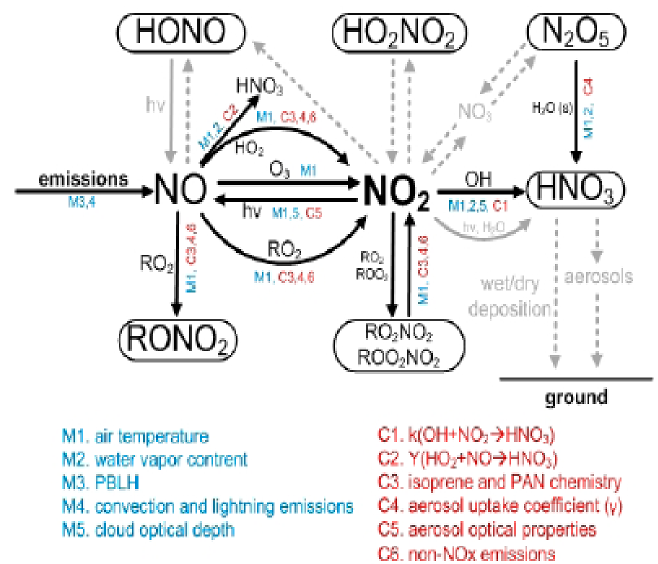


Fig. 1. Tropospheric chemistry involving NO_x and impacts of meteorological and chemical parameters evaluated in the present study. Processes shown in solid grey arrows are discussed without sensitivity simulations. Processes shown in dashed grey arrows are not discussed explicitly. Note that PBL mixing and convection affect vertical distributions of NO_x and related species. Heterogeneous uptake on aerosols depends on the amount of aerosol surfaces as well. Evaluation on the $RONO_2$ pathway is focused mainly on isoprene nitrates. Clouds and water vapor have indirect influences on radicals through effects on solar radiation.

Lin et al 2012

Conclusions

Every advantage has its disadvantage

Emission inventories in Asia and the World

RAINS·GAINS

This database is developed by International Institute for Applied System Analysis (IIASA) to estimate emission of air pollutants including greenhouse gases.

EDGAR

EDGAR database is developed by National Institute for Public Health and the Environment (RIVM) to estimate emission of air pollutants and greenhouse gases.

GEIA

As part of International Geosphere - Biosphere Programme (IGBP), GEIA has been developing inventories of global gas and aerosol emissions.

LTP

LTP is a joint research program among China, Japan and Korea. Its purpose is the monitoring/modeling of Air pollutants to improve understanding of transboundary air pollutants in Northeast Asia.

ACESS

ACESS is developed by Argonne National Laboratory to support the Aerosol Characterization Experiments and Transport and Chemical evolution over the Pacific Experiments.

REAS

REAS is developed by Frontier Research Center for Global Change and National Institute for Environmental Studies to understand the role of trace constituents in the atmosphere.

EA-Grid

EA-Grid is developed by the Ministry of the Environment in Japan to understand transboundary air pollutants in Northeast Asia.

Substances targeted by inventories

		SOx,SO_2	NOx	VOC	NH_3	CO	BC	OC	PM_{10}	Hg	CO_2	CH_4	N_2O	HFCs	PFCs	SF_6
UNFCCC		○	○	○		○					○	○	○	○	○	○
RAINS・GAINS		○	○	○	○	○	○	○	○		○	○	○			
EDGAR		○	○	○	○	○					○	○	○	○	○	○
GEIA		○	○	○	○	○	○	○		○	○	○	○			
LTP	China	○	○	○	○											
	Japan	○	○	○	○	○			○							
	R.of Korea	○	○	○	○	○			○							
ACESS		○	○	○	○	○	○	○			○	○				
REAS		○	○	○	○	○	○	○			○	○	○			
EA-Grid		○	○	○	○	○			○	○						

Main characteristics of inventories

Inventory		Area	Years	Categories	Spatial resolution	Temporal resolution
UNFCCC		Global	mainly 1990～ or 1994～ depends on the country	anthropogenic	Country	annual
RAINS・GAINS		Global	1990～2030	anthropogenic	Country・Administrative unit (China・India・Russia)	annual
EDGAR		Global	depends on the compound	anthropogenic/natural	Country, Region 1°×1°	annual
GEIA		Global	depends on the compound	anthropogenic/natural	1°×1°	annual (season, monthly)
LTP	China	China	mainly 1998	anthropogenic/natural	mainly 1°×1°	annual
	Japan	Japan	mainly 1998	anthropogenic/natural	mainly 1°×1°	monthly, annual
	Korea	Korea	mainly 1998	anthropogenic/natural	mainly 1°×1°	annual
ACESS		South Asia, Southeast Asia, East Asia	2000	anthropogenic/natural	Country, Region (China, Japan, Korea) 1°×1°	annual
REAS		South Asia, Southeast Asia, East Asia	1980～2020	anthropogenic/natural	0.5°×0.5°	annual
EA-GRID		China, South Korea, North Korea, Taiwan, Mongolia, Japan	2000	anthropogenic/natural	0.5°×0.5°	biogenic sources：monthly other emissions：annual

Access to information on emissions:

The ECCAD Emissions Database

ECCAD = Emissions of Chemical Compounds and Compilation of Ancillary Data

Goal of ECCAD

Provide access to surface emissions and associated ancillary data to support many projects:

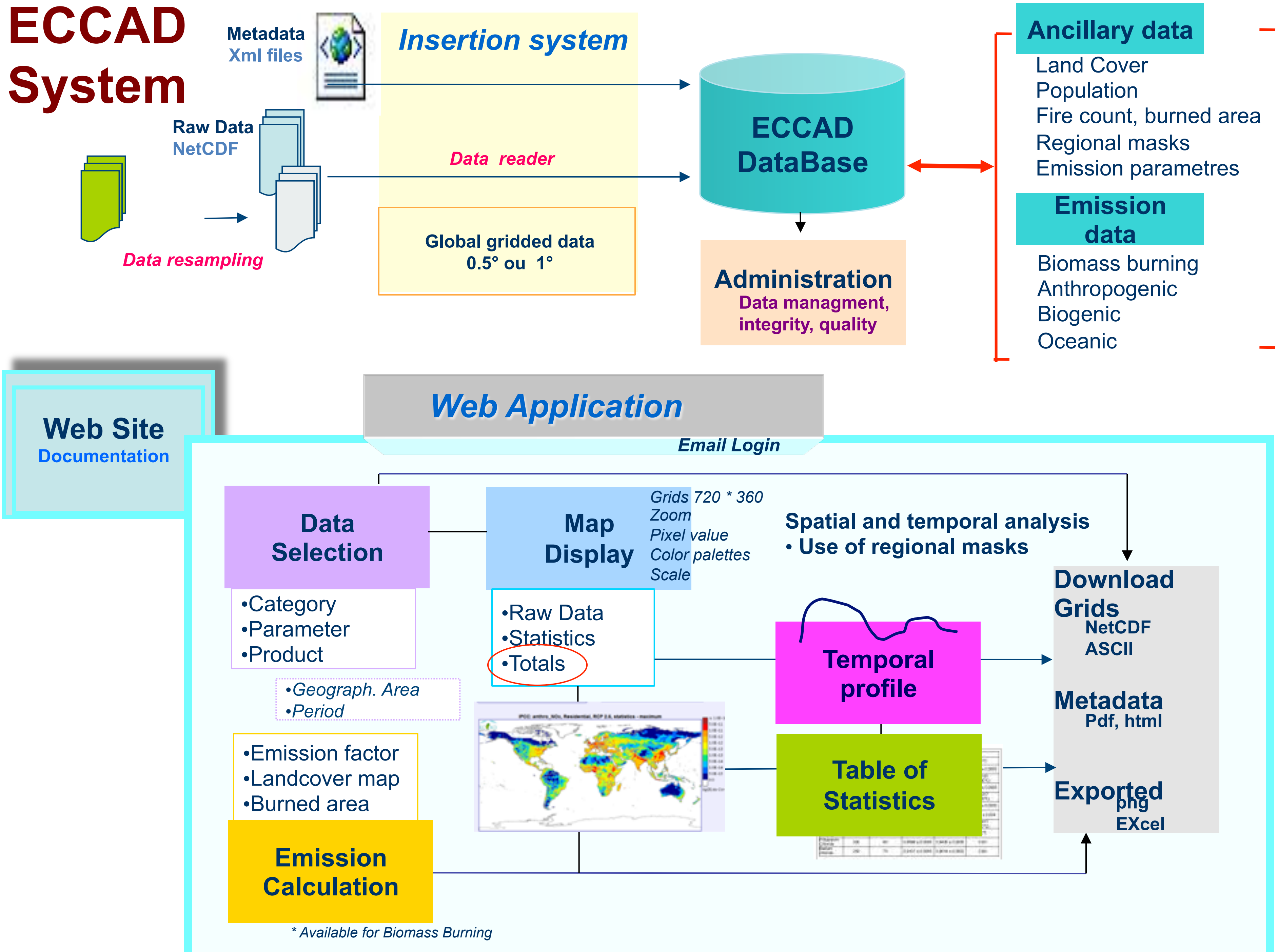
- International projects such as:
  - **GEIA** (Global Emission Inventories Activity)
  - **IGAC** (International Global Atmospheric Chemistry Project)
  - **CCMI, AEROCOM, , CMIP5/CMIP6, etc.**
- European research projects such as:
  - **MACC-II** (Monitoring of the Atmospheric Composition and Climate)
  - **PANDA** (Forecasting Air Pollution in China)
  - **ChArMEx** (The Chemistry-Aerosol Mediterranean Experiment)
  - **ECLIPSE, PEGASOS, PANDA, ACCESS, etc.**

Website: pole-ether.fr/eccad

From the ECCAD website

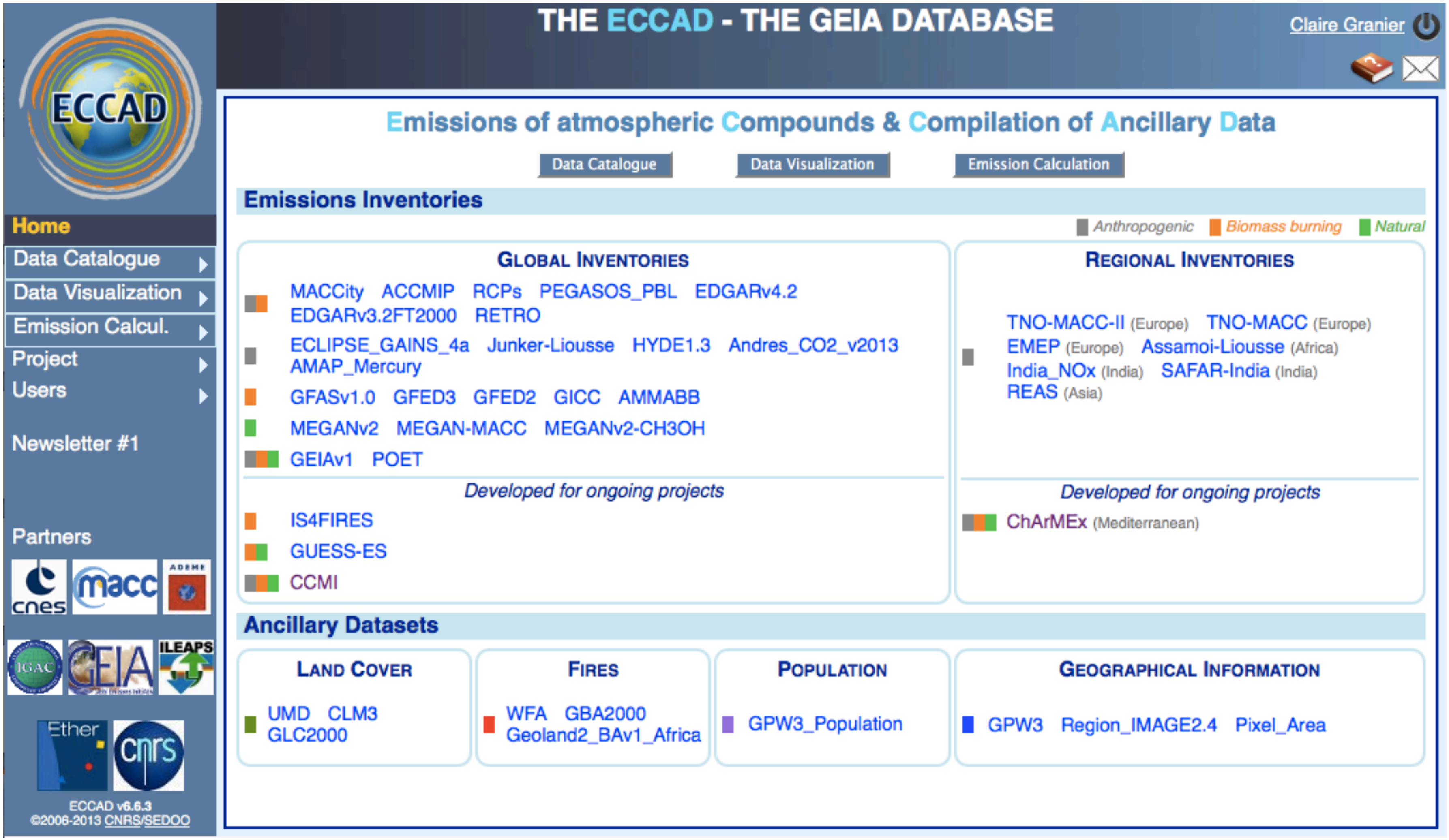
The ECCAD database includes currently a large diversity of datasets, which provide global and regional surface emissions for a large set of chemical compounds. All the data are at a 0.5x0.5 or 1x1 degree resolution. ECCAD provides detailed metadata for each dataset, including information on complete references and methodology, and links to the original inventories.
Several tools are available for the visualization of the data, for computing global and regional totals and for an interactive spatial and temporal analysis. The data can be downloaded as NetCDF CF-compliant files.

NetCDF-CF = Climate and Forecast (CF) Metadata Convention
See http://cfconventions.org/



ECCAD System
Metadata
Xml files
Insertion system
Raw Data
NetCDF
Data reader
Data resampling
Global gridded data
0.5° ou 1°
ECCAD DataBase
Administration
Data managment, integrity, quality
Ancillary data
Land Cover
Population
Fire count, burned area
Regional masks
Emission parametres
Emission data
Biomass burning
Anthropogenic
Biogenic
Oceanic
Web Site
Documentation
Web Application
Email Login
Data Selection
•Category
•Parameter
•Product
•Geograph. Area
•Period
•Emission factor
•Landcover map
•Burned area
Emission Calculation
* Available for Biomass Burning
Map Display
Grids 720 * 360
Zoom
Pixel value
Color palettes
Scale
•Raw Data
•Statistics
•Totals
Spatial and temporal analysis
• Use of regional masks
Temporal profile
Table of Statistics
Download
Grids
NetCDF
ASCII
Metadata
Pdf, html
Exported
png
EXcel

ECCAD = Emissions of Atmospheric Compounds and Compilation of Ancillary Data



ECCAD is the GEIA emissions database

Product *release year*	Temporal Coverage	Time resolution	Category *Hover to see Species*	Grid size	Data provider	Metadata
Global Inventories (22)						
MACCity *2010*	1960 - 2020	Monthly	Anthropogenic Biomass burning	0.5°	macc City	PDF
ACCMIP *2010*	1850 - 2000	Decadal Decadal-Monthly	Anthropogenic Biomass burning	0.5°	ACCMIP	PDF
RCPs *2010*	2005 - 2100	Decadal Decadal-Monthly	Anthropogenic Biomass burning	0.5°	RCPs	PDF
PEGASOS_PBL *2013*	1990 - 2100	Yearly	Anthropogenic Biomass burning	0.5°	PEGASOS	PDF
EDGARv4.2 *2011*	1970 - 2008	Yearly	Anthropogenic Biomass burning	0.5°	EDGAR	PDF
EDGARv3.2FT2000 *2005*	2000	Yearly	Anthropogenic Biomass burning	1°	EDGAR	PDF
RETRO *2005*	1960 - 2000	Monthly	Anthropogenic Biomass burning	0.5°	R3TRO	PDF
ECLIPSE_GAINS_4a *2013*	2005 - 2050	Yearly	Anthropogenic	0.5°	ECLIPSE	PDF
Junker-Liousse *2008*	1860 - 2003	Decadal/Yearly	Anthropogenic	1°		PDF
HYDE1.3 *2001*	1890 - 1990	Decadal	Anthropogenic	1°	EDGAR	PDF
Andres_CO2_v2013 *2013*	1751 - 2010	Yearly	Anthropogenic	1°	CDIAC	PDF
AMAP_Mercury *2005*	1995 - 2000	Half-decadal	Anthropogenic	0.5°	AMAP	PDF
GFASv1.0 *2012*	2003 - 2013	Daily	Biomass burning	0.5°	macc	PDF
GFED3 *2010*	1997 - 2010	Monthly	Biomass burning	0.5°	GFED	PDF
GFED2 *2005*	1997 - 2005	Monthly	Biomass burning	1°	GFED	PDF
GICC *2010*	1900 - 2005	Decadal-Monthly/ Monthly	Biomass burning	0.5°	LATMOS GICC	PDF
AMMABB *2009*	2000 - 2006	Daily	Biomass burning	0.5°		PDF
MEGAN-MACC *2012*	1980 - 2010	Monthly	Biogenic	0.5°	NCAR macc	PDF
MEGANv2 *2009*	2000	Monthly	Biogenic	0.5°	NCAR	PDF
MEGANv2-CH3OH *2011*	2003 - 2009	Yearly (seasonal)	Biogenic	0.5°		PDF
GEIAv1 *1990*	1984 - 1990	Yearly Monthly : NOx Lightning, NOx from Soils, BC Biom. Burn.	Anthropogenic Biomass burning Biogenic Oceanic Lightning Volcanic Total	1°	GEIA Global Emissions InitiAtive	PDF
POET *2003*	1990 - 2000	Yearly Monthly Monthly Yearly	Anthropogenic Biomass burning Biogenic Oceanic	1°	POET	PDF

Many different inventories, including global and regional datasets

Global Inventories developed for ongoing projects (3)						
IS4FIRES *2012*	2000 - 2011	Daily	Biomass burning	0.5°		PDF
GUESS-ES *2011*	1970 - 2009	Monthly	Biomass burning Biogenic	1°		PDF
CCMI *2013*	2000	Yearly/Monthly	Anthropogenic Biomass burning Biogenic Volcanic Total	0.5°	ccmi chemistry-climate model initiative	PDF

Regional Inventories (7)						
TNO-MACC-II **Europe** *2013*	2003 - 2009	yearly	Anthropogenic	0.5°	TNO innovation for life	PDF
TNO-MACC **Europe** *2009*	2003 - 2007	Yearly	Anthropogenic	0.5°	TNO innovation for life	PDF
EMEP **Europe** *2007*	1980 - 2020	Yearly	Anthropogenic	0.5°	Convention on Long-range Transboundary Air Pollution emep	PDF
Assamoi-Liousse **Africa** *2012*	2005 - 2030	Decadal	Total	0.5°	LA	PDF
India_NOx **India** *2012*	2005	Yearly	Anthropogenic	0.5°		PDF
SAFAR-India **India** *2012*	1991 - 2011	Decadal	Anthropogenic	1°		PDF
REAS **Asia** *2007*	1980 - 2020	Yearly	Anthropogenic	0.5°	REAS	PDF
Regional Inventories developed for ongoing projects (1)						
ChArMEx **Mediterranean** *2012*	2000	Varied	Anthropogenic Biomass burning Biogenic Oceanic Volcanic	0.25/0.5/1°	ChArMEx MISTRALS	PDF

Many different inventories, including global and regional datasets

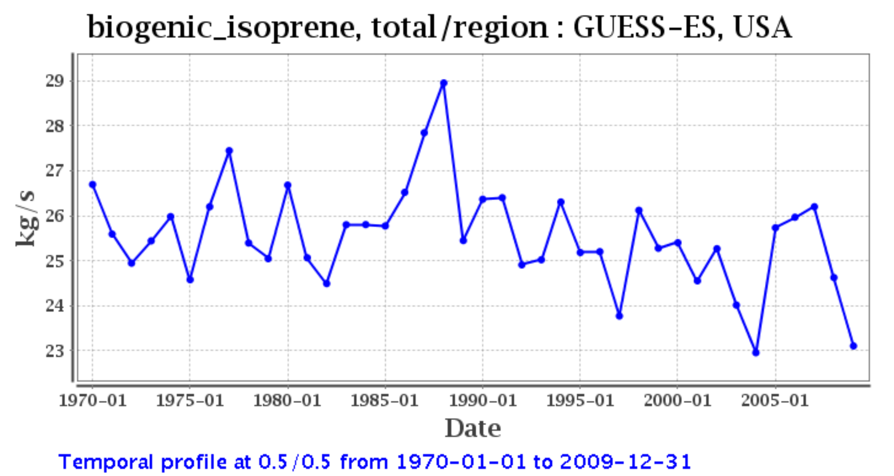
Only gridded inventories can be inserted currently in the database

New version under development (Thanks to EPA)

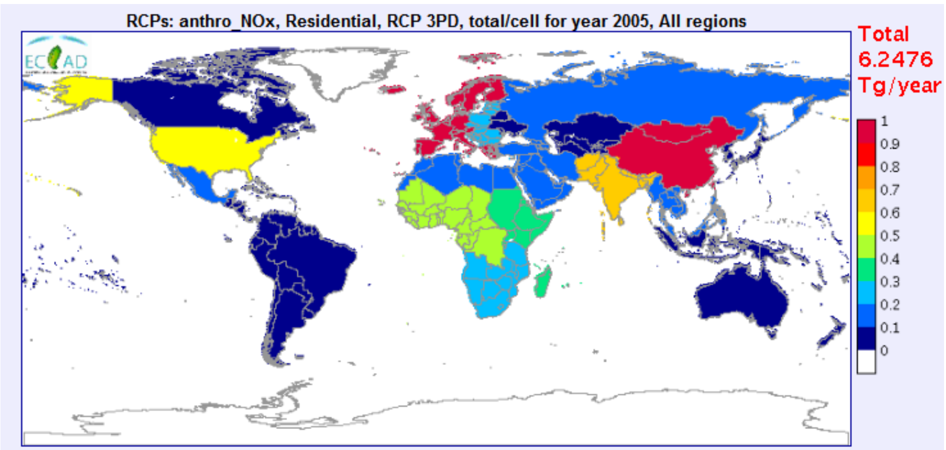
→ data at any resolution can be included

ECCAD tools

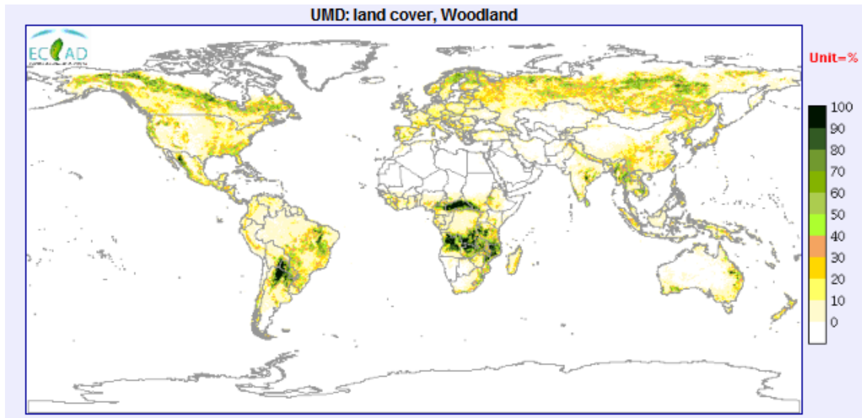
Temporal variation for a country over a period of time



Total emitted for different regions



Ancillary data



Currently under development: comparisons of maps with algrebraic calculations, scattered plots

Examples of exercices using ECCAD

1. Go to pole-ether.fr/eccad

2. If you don't have registered yet, go to registration

3. A look at the home page

4. Go to "data catalogue"
   - categories, years,….
   - Metadata

5. List of species

6. Totals/methodology/temporal coverage

1. Make a plot of the emissions of a species

2. Change the scale, the colors, country lines

3. 2 plots on 1 page

4. Table statistics

5. Calculate totals : world, one region, one country

6. Table of totals

7. Temporal profile

ECCAD users:

1940 across the world from more than 740 institutions

Note: The ECCAD database is being fully rewritten:

→ Accommodate data in all resolutions (degrees only)

→ Better graphics, more tools

→ More links to the GEIA website

http://eccad2.sedoo.fr/eccad2/

Site under construction, changes all the time

https://www2.acd.ucar.edu/gcm/tools

A substance discharged into the air, especially by an internal combustion engine.

Measure of the average amount of a specific pollutant or material discharged into the atmosphere by a specific process, fuel, equipment, or source. It is expressed as number of pounds (or kilograms) of particulate per ton (or metric ton) of the material or fuel.