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Session 7 Data Management

Design of Georeference-Based Emission Activity Modeling System (G-BEAMS) for Japanese Emission Inventory Management

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Outlines

1. Background
2. Objective
3. Materials and Methods
    - System functions
    - System configuration
    - Emission calculation
    - Spatial distribution
    - Temporal distribution
4. Conclusions

Background

A systematic emission inventory is needed

- to improve accuracy of emission inventory
- to manage data and methodologies on emission estimations, and
- to quantify effect of countermeasure to reduce pollutants.

Objective

- The aims of this study are to design a methodology for systematizing an emission inventory building and to develop the emission inventory system actually.

Necessities for emission inventory

For emission management and analysis

・Macro total emission
・Source contribution
・Annual change
・Emission projection
・Quantification of emission reduction measures (fuels change, new tech.)
・Pollutants to be managed (GHG, Air pollutants)

Different concerns

For environmental fate models

・Emission within calculation domain
・Spatial emission distribution
・Temporal emission distribution
・emitted media (air, water, soil)
・emission condition (height, temp. , velocity)
・Chemical species and physical properties of pollutants

Needs for emission inventory system

・Inventories for various types of environmental burdens
・Easy update of emission factors and activity data
・Use of top-down and bottom up methods for emission estimation
・Combination of existing emission data with estimation
・Finding of data to be modified for accuracy improvement
・Open access to data and methods

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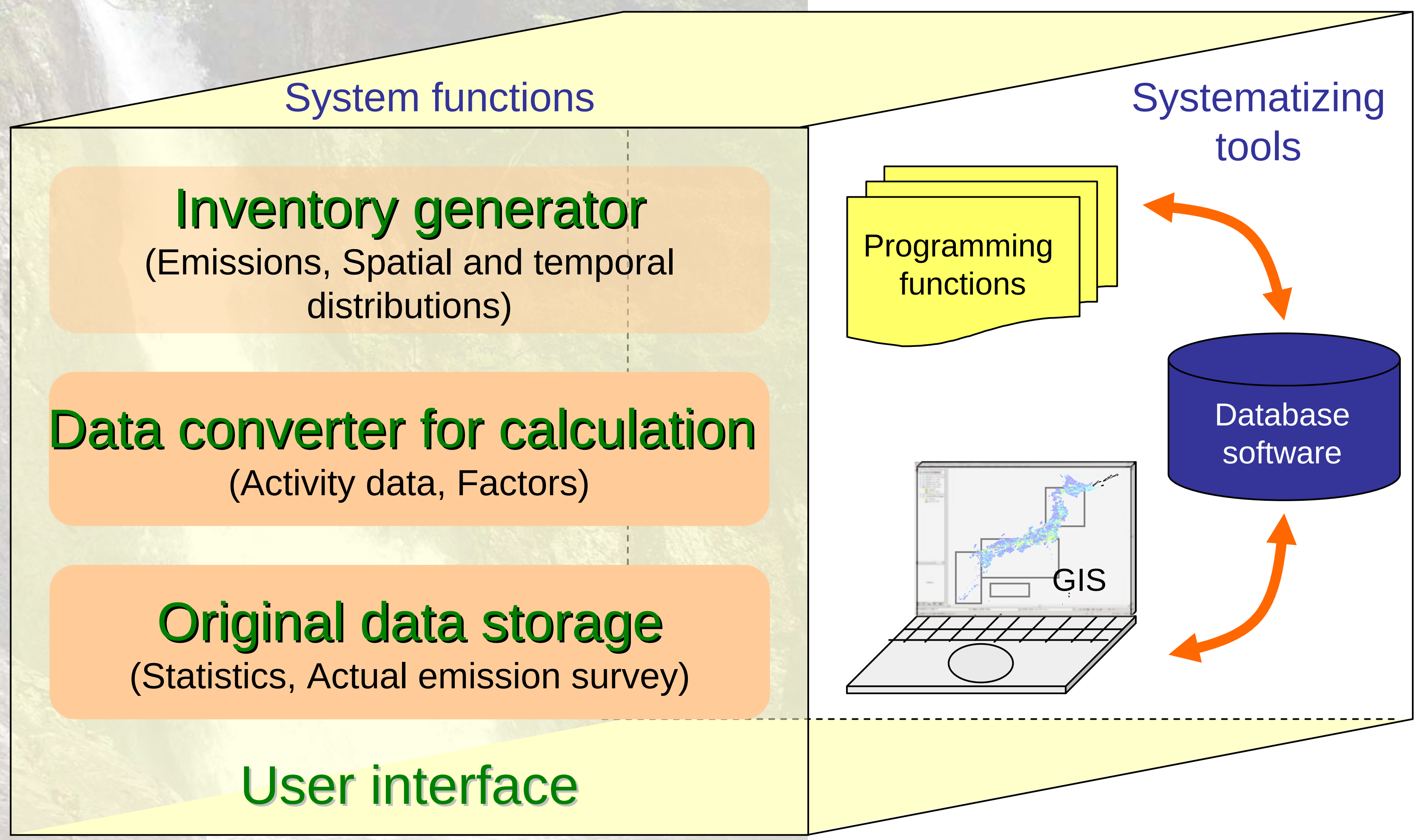
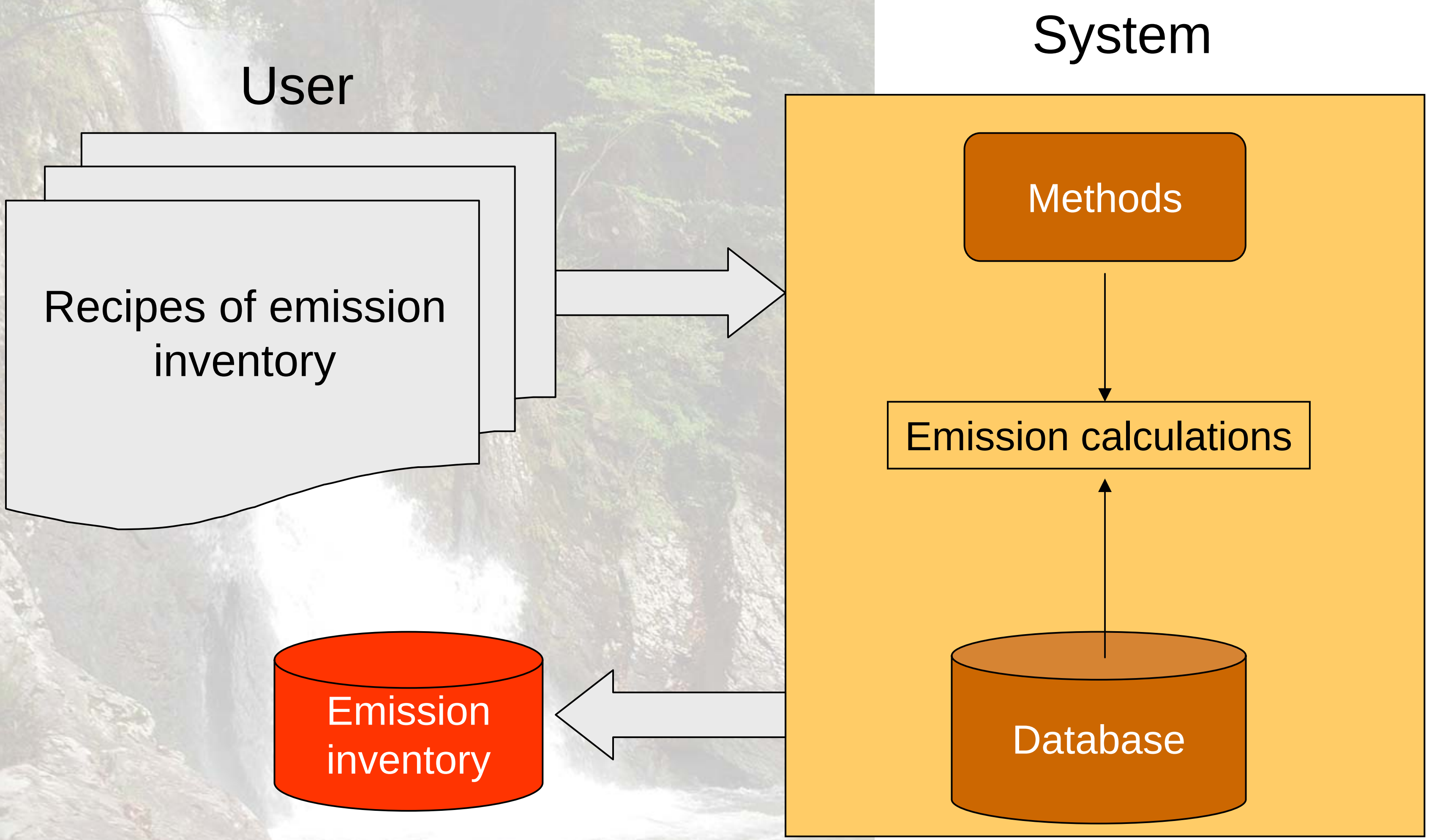
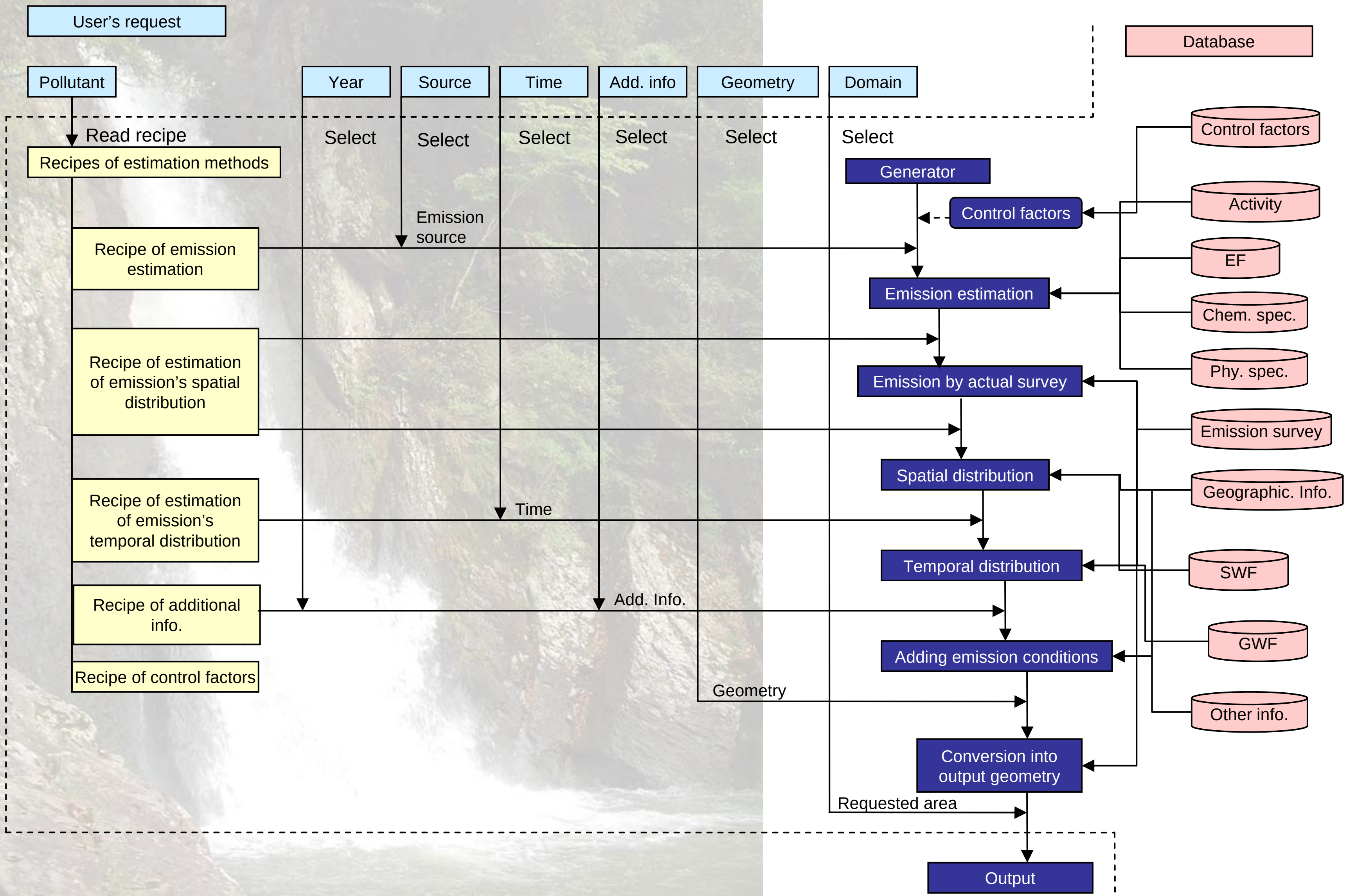
System functions and tools



Recipe of emission inventory



Flow of building emission inventory



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System configuration

1. Emission activity (Database software)

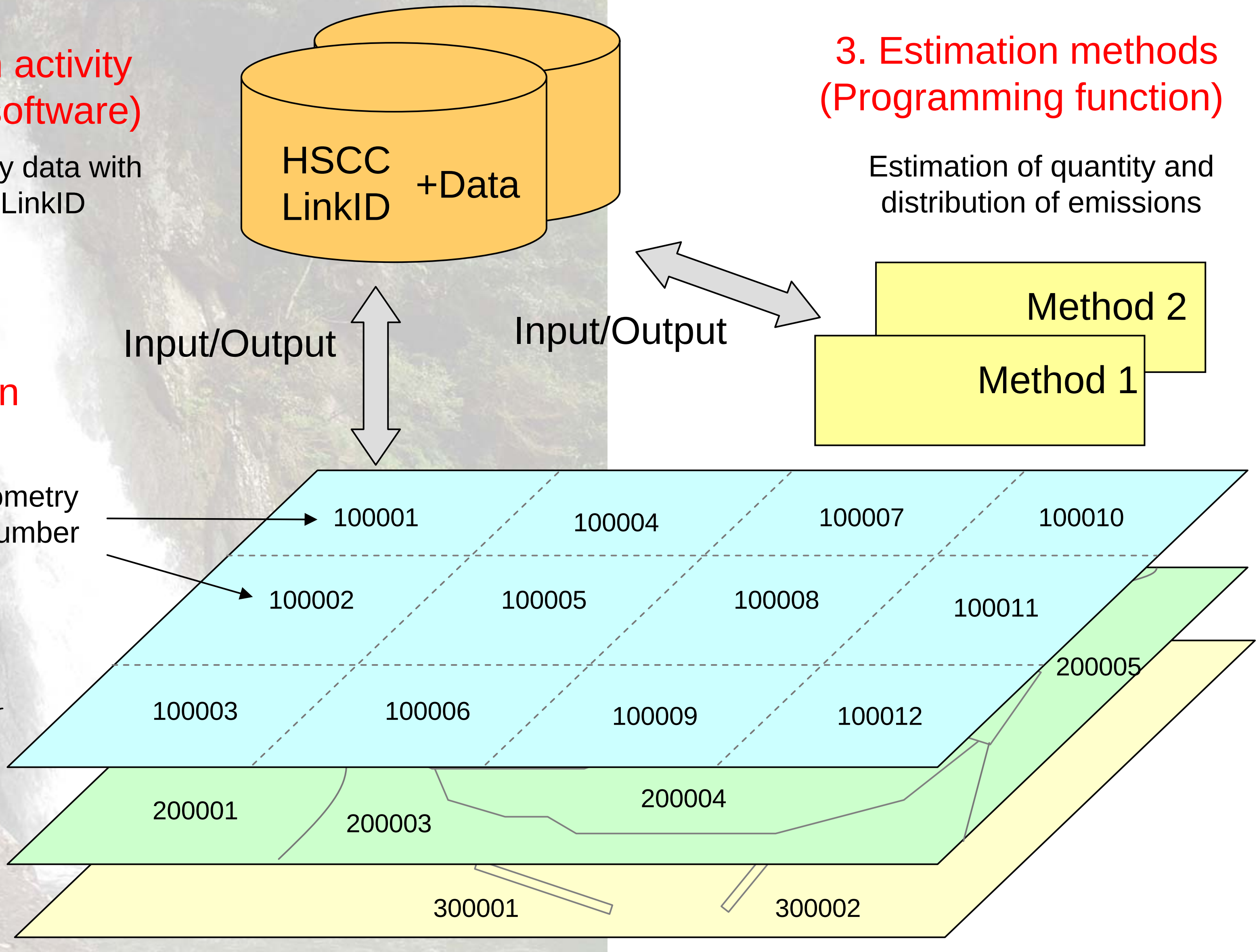
Emission activity data with HSCC and LinkID

3. Estimation methods (Programming function)

Estimation of quantity and distribution of emissions

2. Location (GIS)

Predefined geometry given unique number (LinkID)

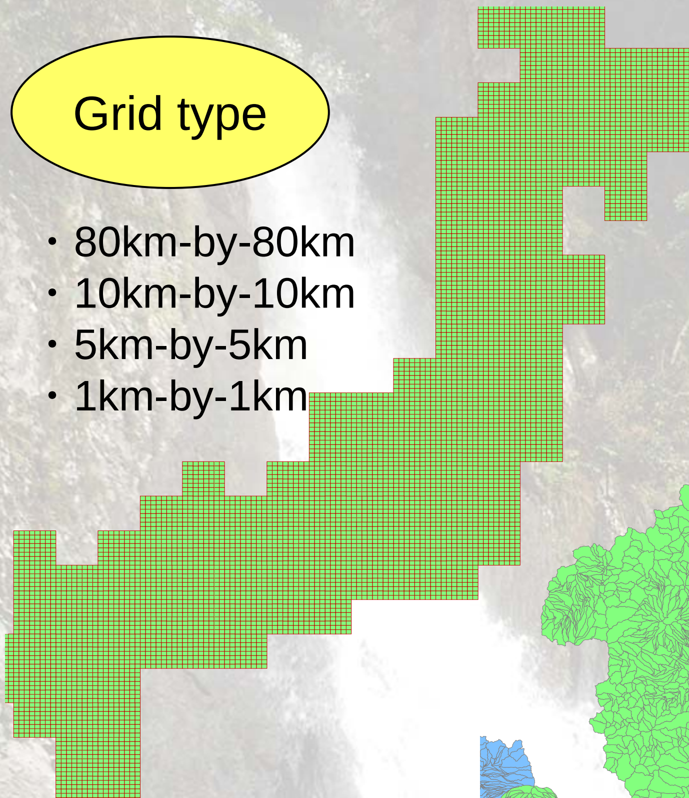


13 standard layers

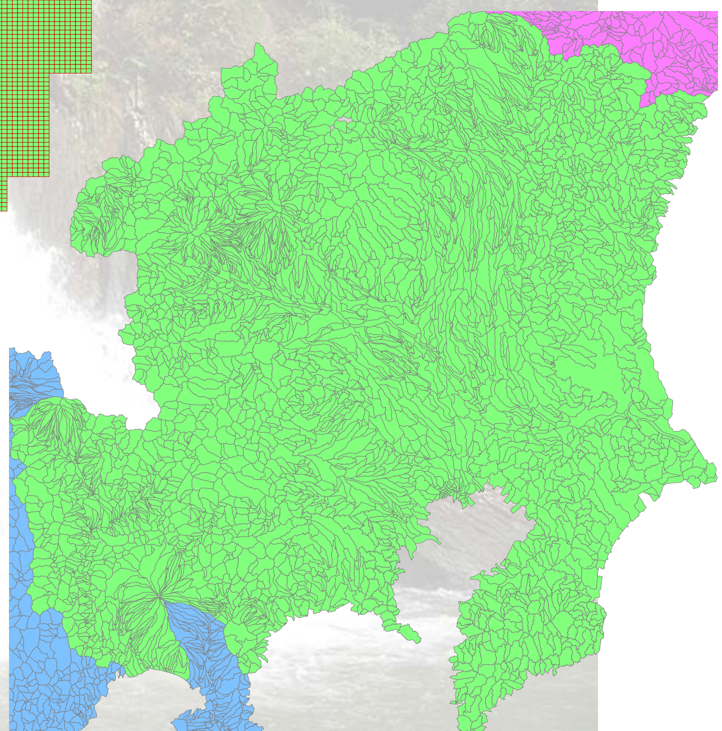
The standard layers

Grid type

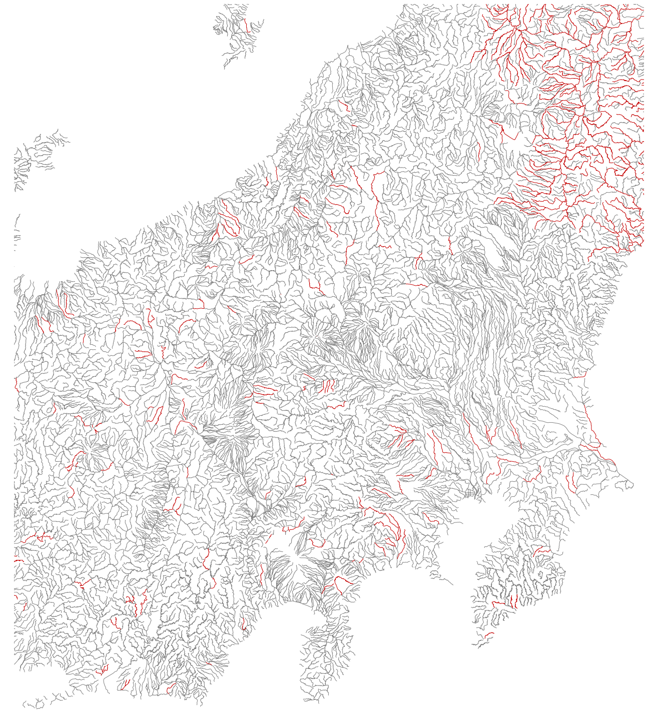
- 80km-by-80km
- 10km-by-10km
- 5km-by-5km
- 1km-by-1km



- Prefecture
- City
- Basin
- Agricultural village
- Sea
- Lake



Polygonal type



- River
- Road

Linear type

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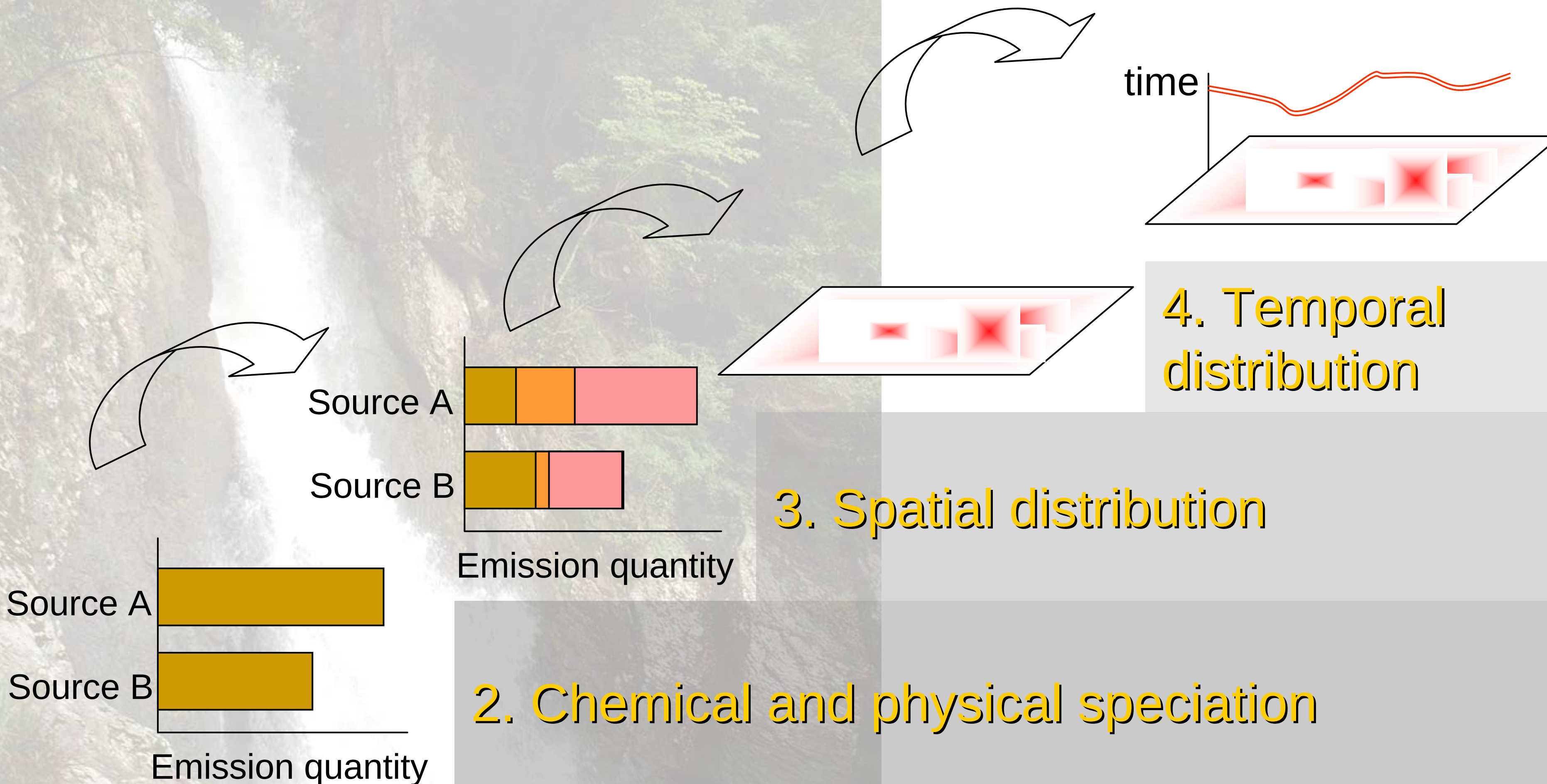
Main steps of emission inventory



1. Emission by source

2. Chemical and physical speciation

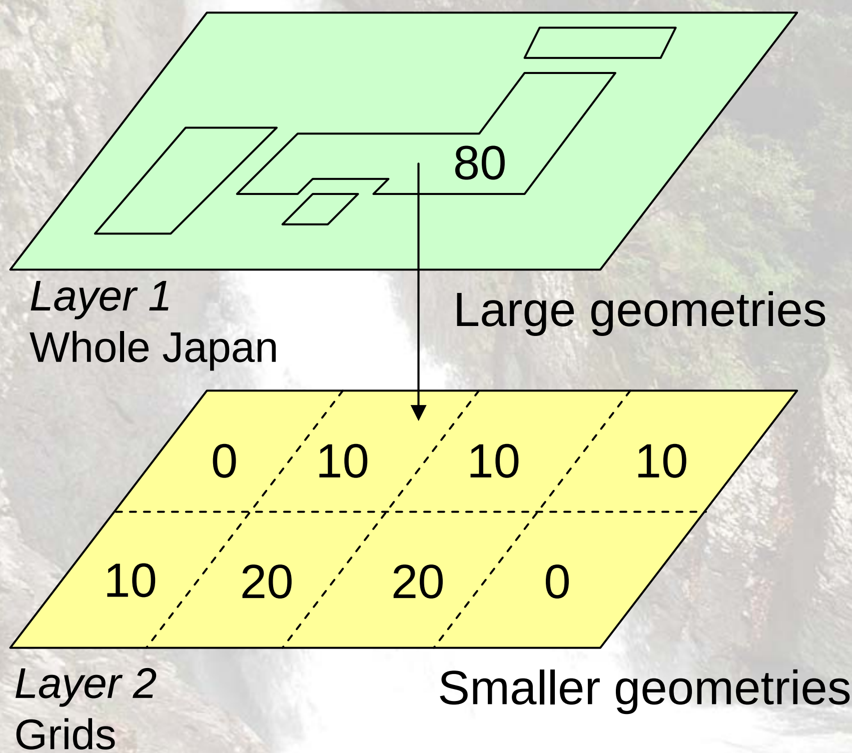
3. Spatial distribution

4. Temporal distribution

Two approaches to building an emission inventory

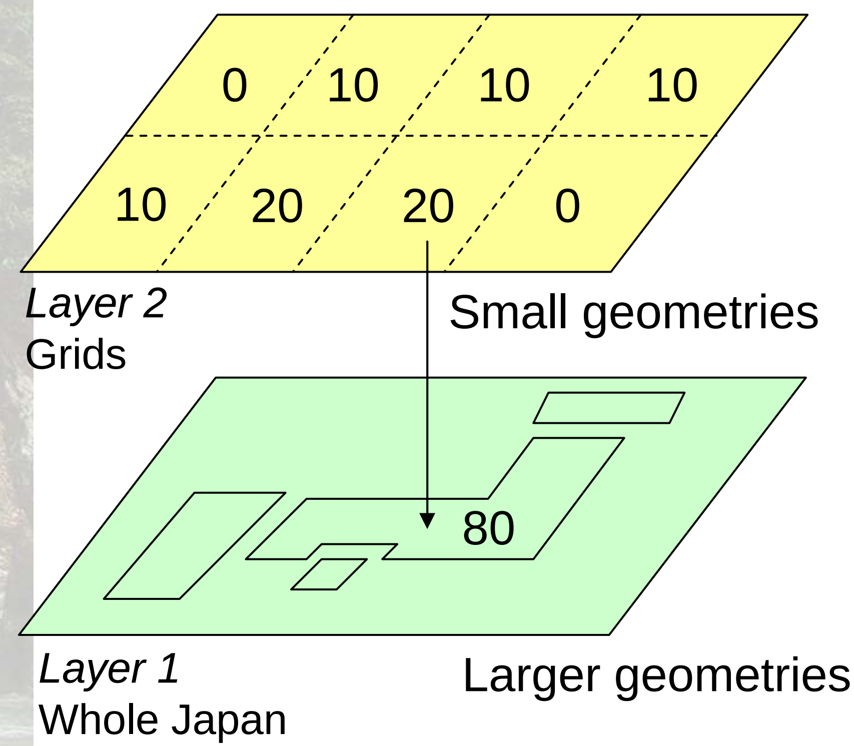
Top-down approach

Conversion of emissions on large geometries basis into emissions on smaller geometries basis



Bottom-up approach

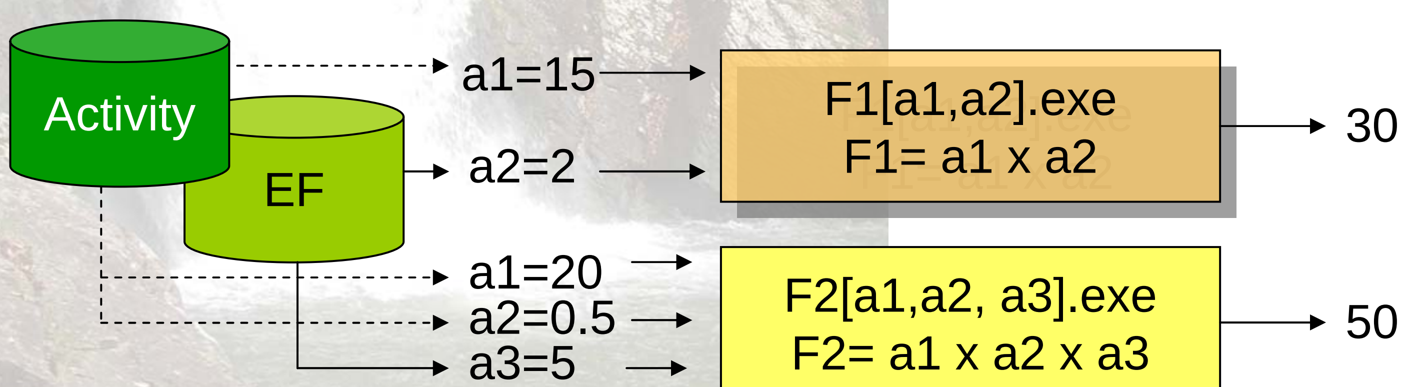
Conversion of emissions on small geometries basis into emissions on larger geometries basis



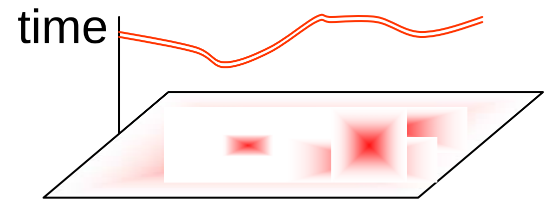
Recipe for emission calculation

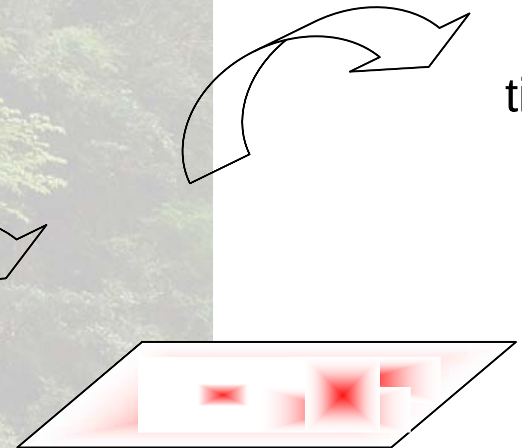
The inventory recipe format applicable to the top-down and bottom-up approaches

<Source>	<Location>	<Method>	<Variations order>	<Database>	
HSCC	**LinkID**	**Emission Function**	**Input order**	**File name**	**Table name**
100100100	25	F1.exe	1	Activity.mdb	Coal
100100100	25	F1.exe	2	EF.mdb	NOxEF
100100200	25	F2.exe	1	Activity.mdb	Naphtha
100100200	25	F2.exe	2	Activity.mdb	BurnRt
100100200	25	F2.exe	3	EF.mdb	NOxEF



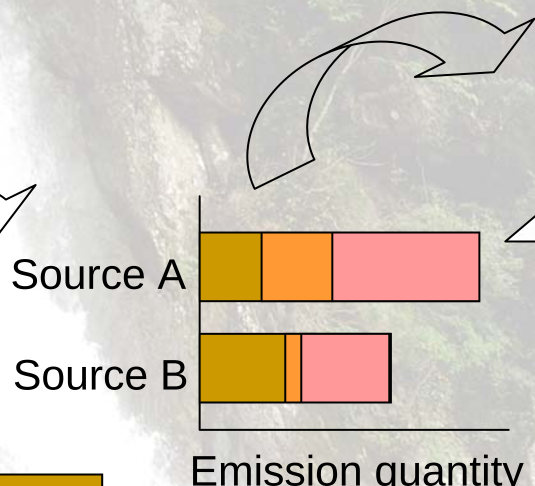
Main steps of emission inventory



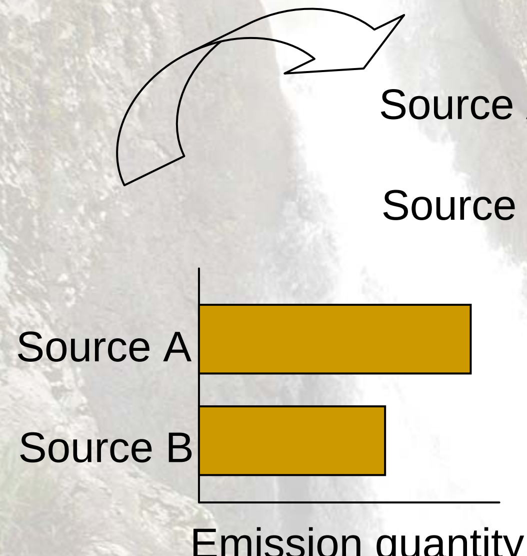


4. Temporal distribution

3. Spatial distribution



2. Chemical and physical speciation



1. Emission by sources

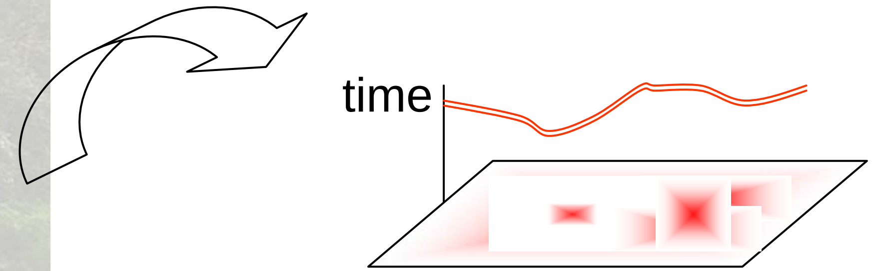
Speciation of pollutant

Emissions

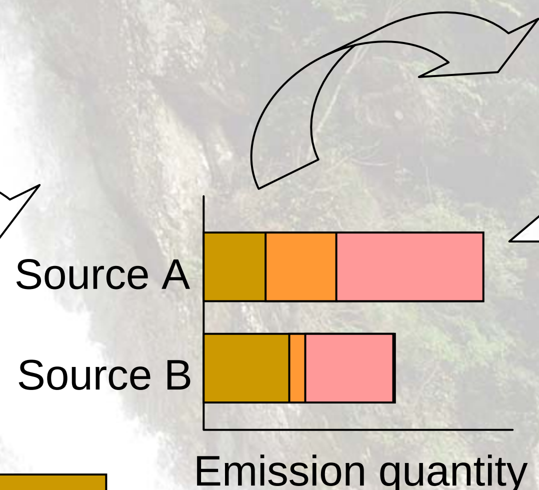
	X	Chemical property A (0.3)	=	200 x 0.3 = 60
Pollutant [200]	X	Chemical property B (0.6)	=	200 x 0.6 = 120
	X	Chemical property C (0.1)	=	200 x 0.1 = 20

Sum (0.3+0.6+0.1) = 1

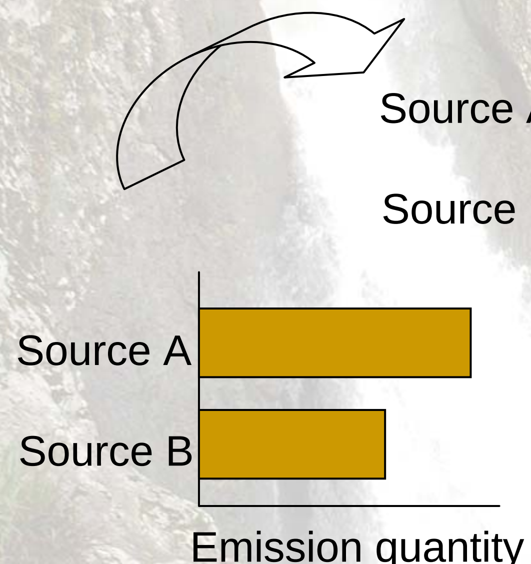
Main steps of emission inventory



4. Temporal distribution



3. Spatial distribution



2. Chemical and physical speciation

1. Emission by sources

Spatial distribution

Characteristics of calculation method

- Emission conversion based on the spatial weighting factor (SWF)
  - SWF is defined by geometry on a layer.
  - SWF is normalized value in each standard layer, or the sum of SWF for all geometries on the layer equals 1.
  - SWF represents the magnitude of emission activity for a geometry.

- The cascade weighting method
  - It considers the relationship between geographical resolution and uncertainty of public statistics.
  - It enables us to convert estimated emission based on a layer to emission based on other layer using SWF for each geometry.

- The hybrid weighting method
  - Emissions from actual emission survey, existing emission inventory and emission report can be used as emissions at a geometry in preference to emission estimated by the cascade weighting method.

Uncertainty and resolution

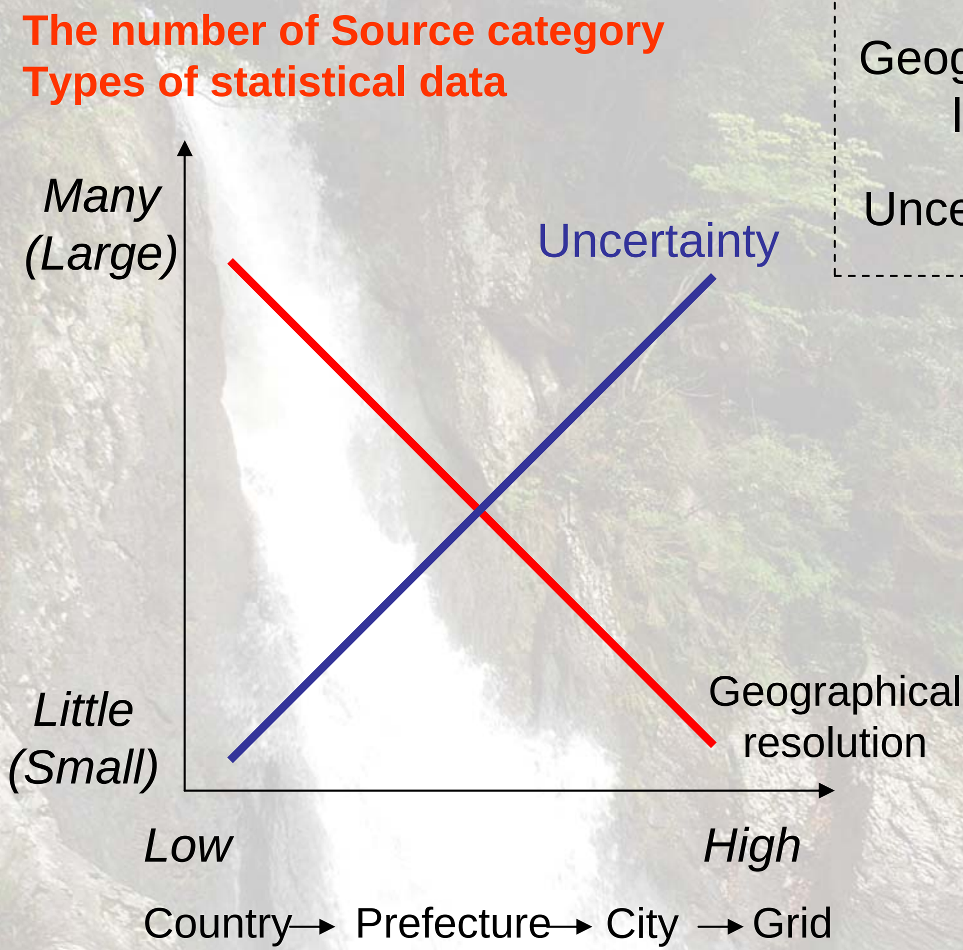


Fig. Relationship between types, sector categories and geographical resolution of Japanese statistics applicable as emission activity data

Geographical level	Country		City		Grid
Uncertainty (%)	0	20 % decrease	20	20 % decrease	40

1. Direct conversion from country level into gird level

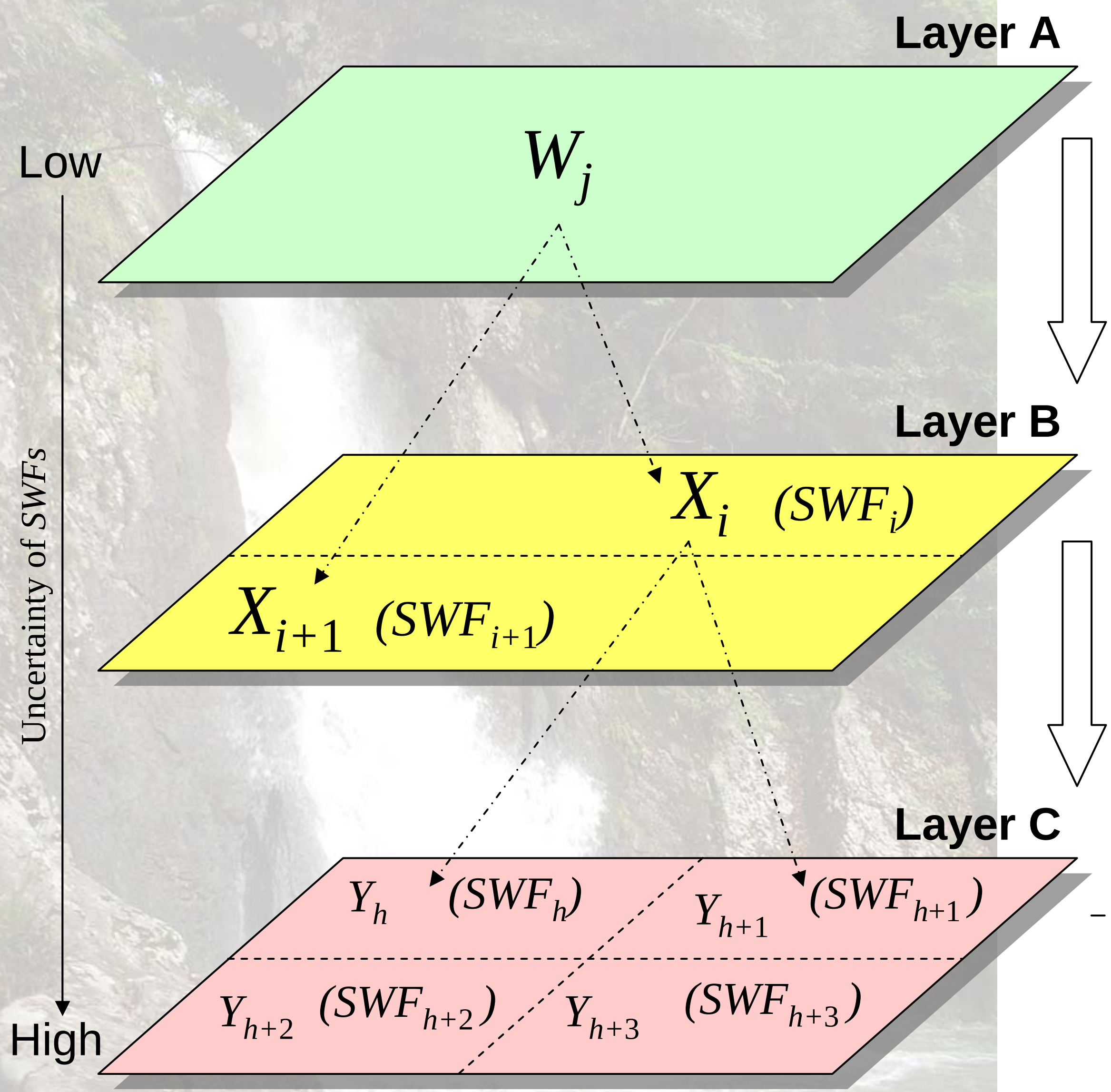
1 x (1-0.4) = 0.6 (60 %)

2. Cascading conversion from country level into gird level

1 x (1-0.2) x (1-0.2) = 0.64 (64%)

Where, original information quantity is 1

The cascade weighting method



1. Conversion of emissions on layer A into emissions on layer B

$$X_i = W_j \cdot \frac{SWF_i}{\sum_{m=i \in j} SWF_m}$$

2. Conversion of emissions on layer B into emission on layer C

$$Y_h = X_i \cdot \frac{SWF_h}{\sum_{n=h \in i} SWF_n}$$

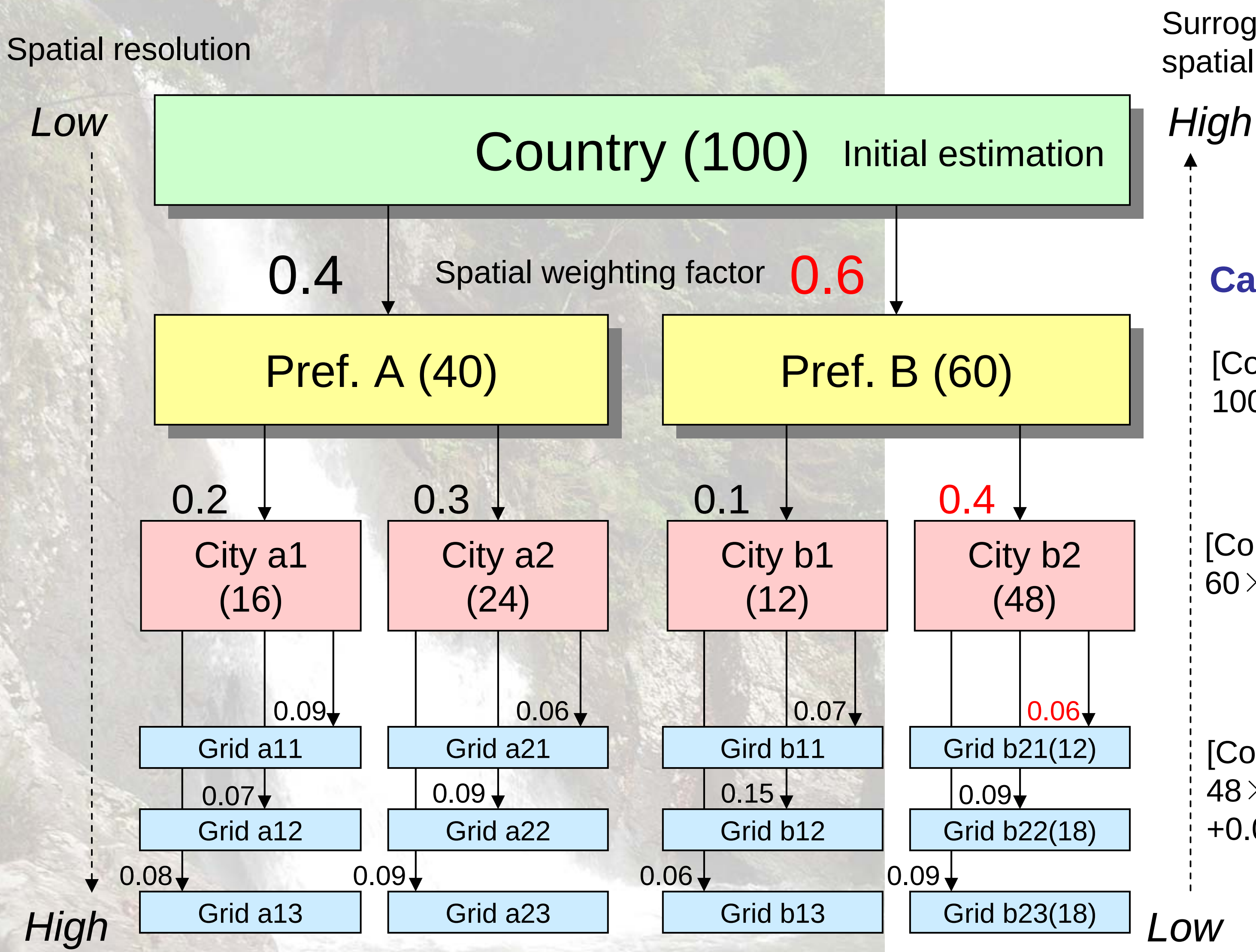
$$= W_j \cdot \frac{SWF_i}{\sum_{m=i \in j} SWF_m} \cdot \frac{SWF_h}{\sum_{n=h \in i} SWF_n}$$

W, *X*, *Y*: Emissions for each geometry

SWF: Spatial weighting factor

$i \in j$: Geometry *i* geographically overlaps geometry *j*

Example of the cascade weighting method



Cascade weighting

[Conversion to pref. B]
100×0.6/(0.4+0.6) = 60

[Conversion to City b2]
60×0.4/(0.4+0.1) = 48

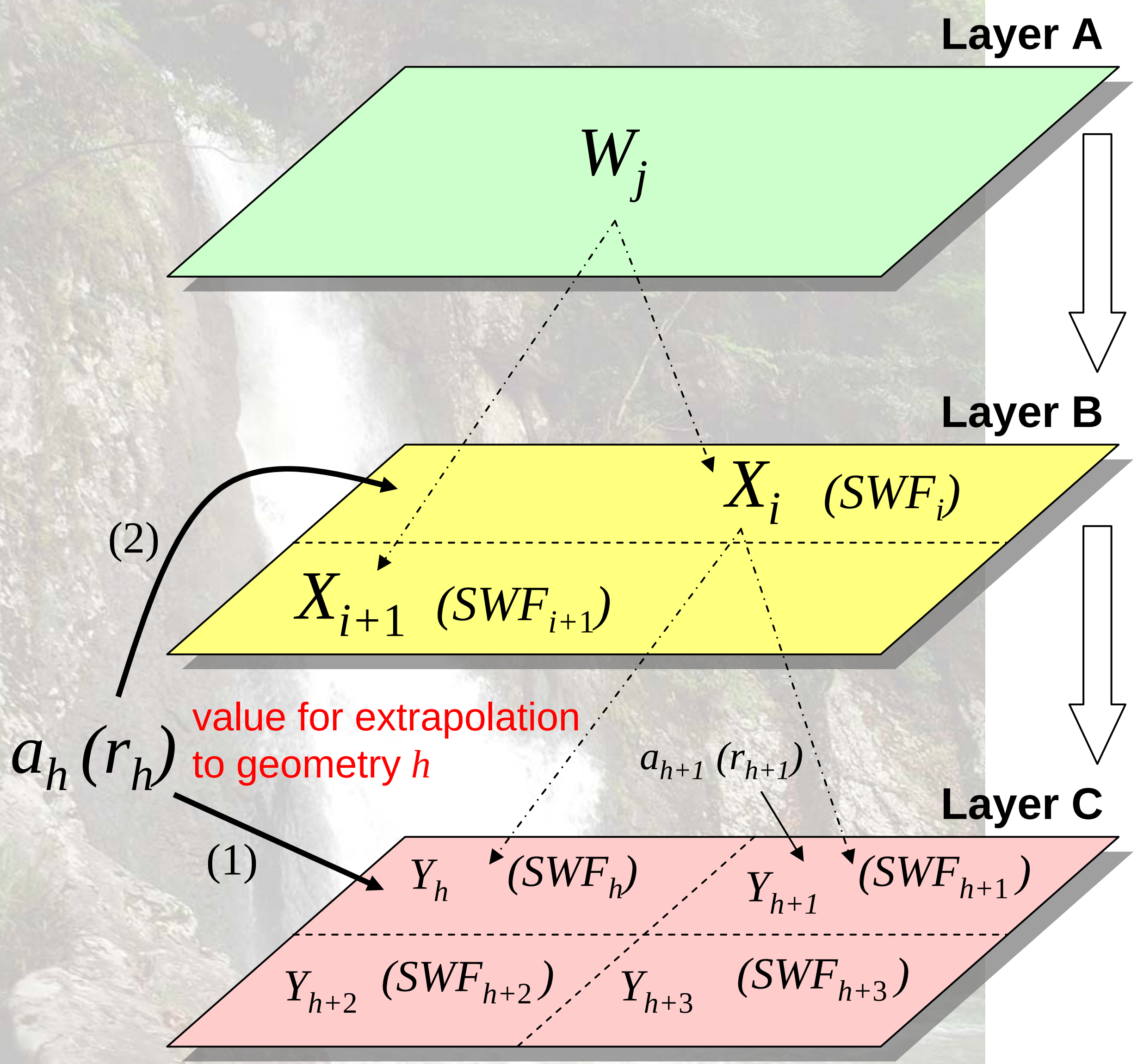
[Conversion to Grid b21]
48×0.06/(0.06+0.09+0.09) = 12

Spatial distribution

Characteristics of calculation method

- Emission conversion based on the spatial weighting factor (SWF)
  - SWF is defined by geometry on a layer.
  - SWF is normalized value in each standard layer, or the sum of SWF for all geometries on the layer equals 1.
  - SWF represents the magnitude of emission activity for a geometry.
- The cascade weighting method
  - It considers the relationship between geographical resolution and uncertainty of public statistics.
  - It enables us to convert estimated emission based on a layer to emission based on other layer using SWF for each geometry.
- The hybrid weighting method
  - Emissions from actual emission survey, existing emission inventory and emission report can be used as emissions at a geometry in preference to emission estimated by the cascade weighting method.

The hybrid weighting method



(1) when $X_i - \sum_{n=h\in i} a_n \geq 0$

$$Y_h = a_h + \left(X_i - \sum_{n=h\in i} a_n \right) \cdot \frac{SWF_h(1-r_h)}{\sum_{n=h\in i} SWF_n(1-r_n)}$$

(2) when $X_i - \sum_{n=h\in i} a_n < 0$

$$X_i = \sum_{n=h\in i} a_n + \left(W_j - \sum_{n=h\in i} a_n \right) \cdot \frac{SWF_i(1-r_i)}{\sum_{m=i\in j} SWF_m(1-r_m)}$$

$$r_i = \frac{\sum_{n=h\in i} r_n SWF_n}{\sum_{n=h\in i} SWF_n} \qquad Y_h = X_i \cdot \frac{SWF_h}{\sum_{n=h\in i} SWF_n}$$

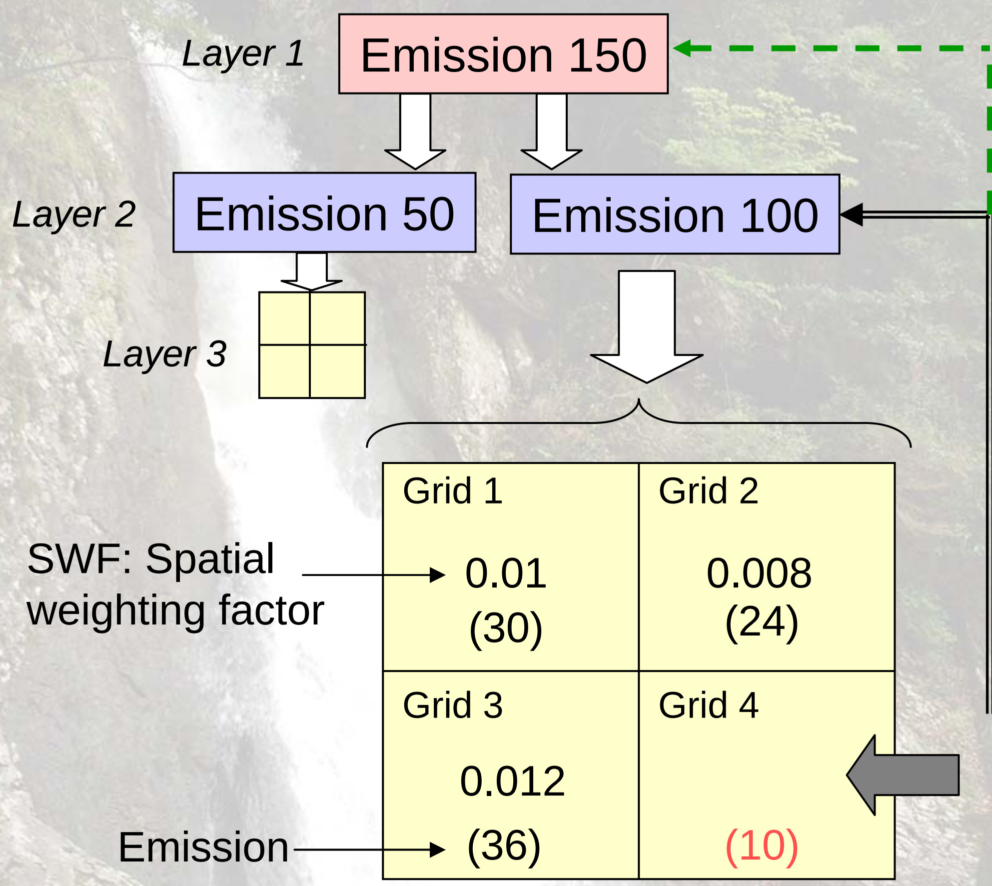
a: Extrapolated emissions

r: Rate of domination of SWF related to extrapolated emissions to total SWF of the extrapolated geometry

$i \in j$: Geometry *i* geographically overlaps geometry *j*

W, *X*, *Y*: Emissions for each geometry   *SWF*: Spatial weighting factor

Example of the hybrid weighting method



Extrapolating emission of 10 obtained by actual survey to Grid 4

Note

In the case that extrapolated emission is more than the total emission to be allocated on the layer 2, the extrapolated emission is deducted from the total emission of the larger geometry in the layer 2 layers above layer 3.

<Calculation process>

Emission allocated to Grid 1
(100-10) × 0.01/(0.01+0.008+0.012) = 30

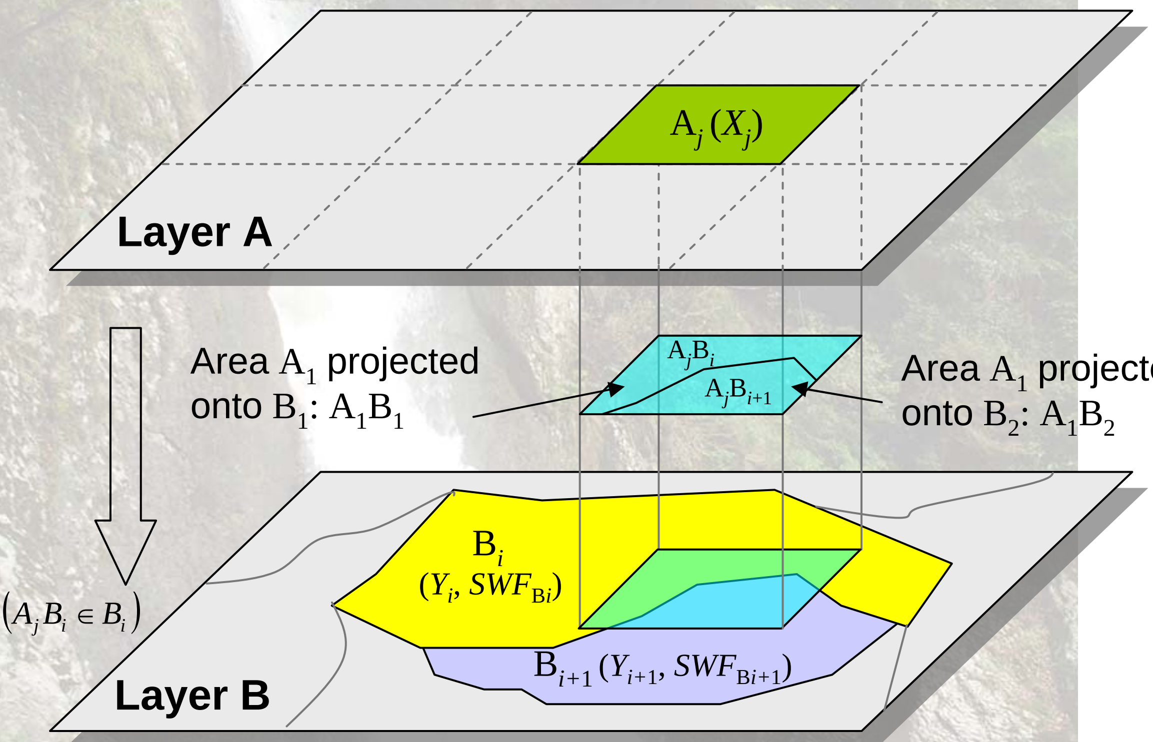
Emission allocated to Grid 2
(100-10) × 0.008/(0.01+0.008+0.012) = 24

Emission allocated to Grid 3
(100-10) × 0.012/(0.01+0.008+0.012) = 36

Note

Preferentially 10 is determined as emission of Grid 4 within the total 100, assuming that the ratio of SWF of extrapolated emission to SWF of the total emission at Grid 4 is 1.

Method of transforming spatial weighting factors between polygonal geometries



1. Transformation of SWFs

$$SWF_{A_jB_i} = SWF_{B_i} \cdot Ar\left(A_jB_i / B_i\right)$$

$$SWF_{A_jB_{i+1}} = SWF_{B_i} \cdot Ar\left(A_jB_{i+1} / B_{i+1}\right)$$

2. Emission x_jy_i of projected area A_jB_i

$$x_jy_i = X_j \cdot \frac{SWF_{A_jB_i}}{\sum_{k=i\in j} SWF_{A_jB_k}}$$

3. Emission Y_i of geometry B_i

$$Y_i = \sum_{p=j\in i} x_py_i$$

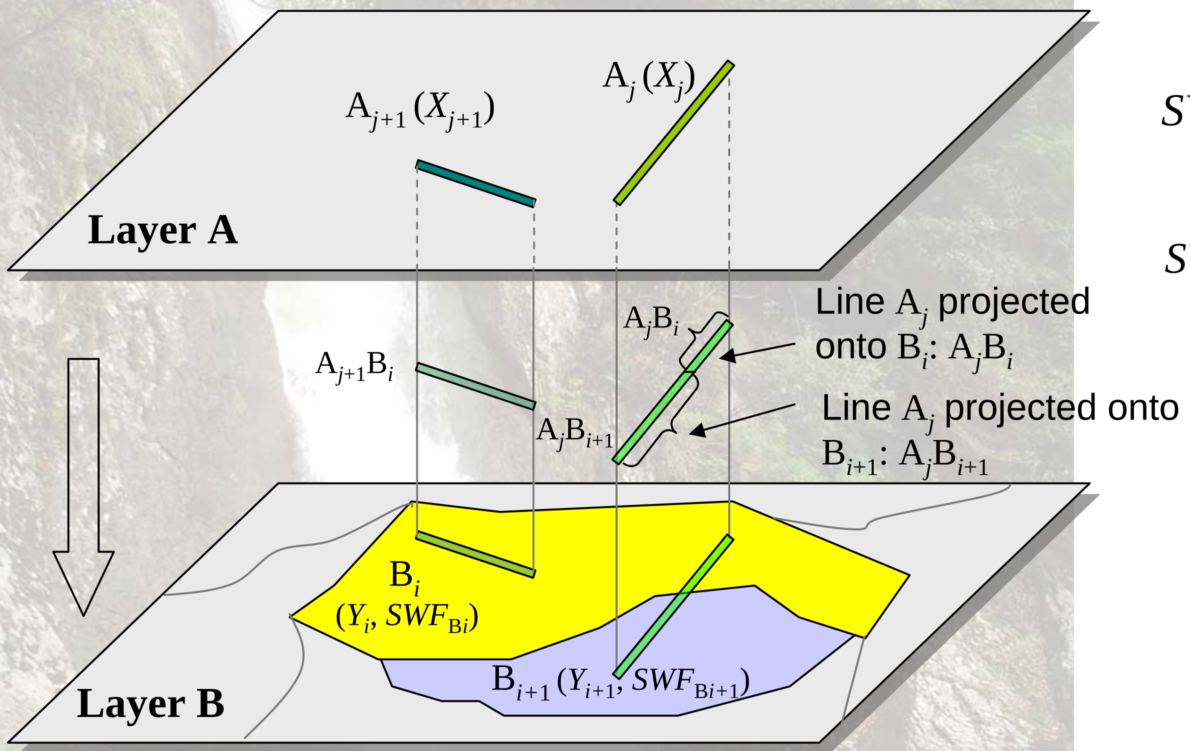
X, Y: Emissions for each geometry

SWF: Spatial weighting factor

$i \in j$: Geometry i geographically overlaps geometry j

$Ar(G_1/G_2)$: Area ratio of geometry G_1 to geometry G_2

Method of transforming spatial weighting factors between polygonal and linear geometries



X, *Y*: Emissions for each geometry

SWF: Spatial weighting factor

$i \in j$: Geometry *i* geographically overlaps geometry *j*

$Lr(G_1/G_2)$: Length ratio of geometry G_1 to geometry G_2

1. Transformation of SWFs

$$SWF_{A_jB_i} = SWF_{B_i} \cdot Lr\left(A_jB_i \Big/ \sum_{s=j\in i} A_sB_i \right)$$

$$SWF_{A_jB_{i+1}} = SWF_{B_{i+1}} \cdot Lr\left(A_jB_{i+1} \Big/ \sum_{t=j\in i+1} A_tB_{i+1} \right)$$

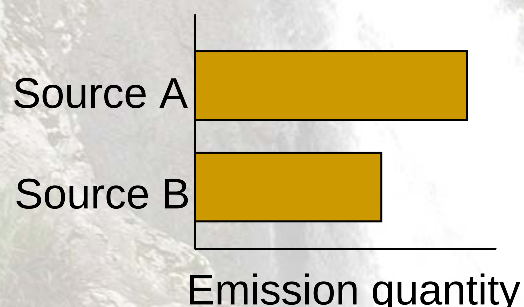
2. Emission x_jy_i of projected line A_jB_i

$$x_jy_i = X_j \cdot \frac{SWF_{A_jB_i}}{\sum_{k=i\in j} SWF_{A_jB_k}}$$

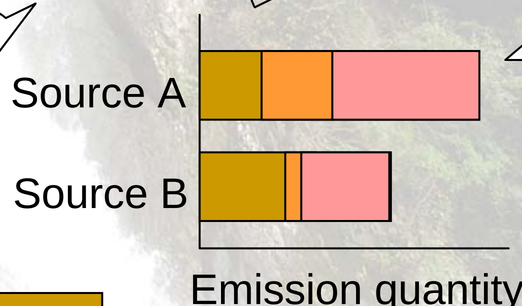
3. Emission Y_i of geometry B_i

$$Y_i = \sum_{p=j\in i} x_py_i$$

Main steps of emission inventory

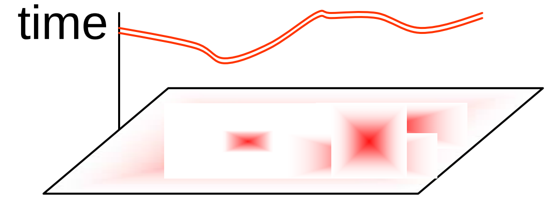


1. Emission by sources



2. Chemical and physical speciation

3. Spatial distribution



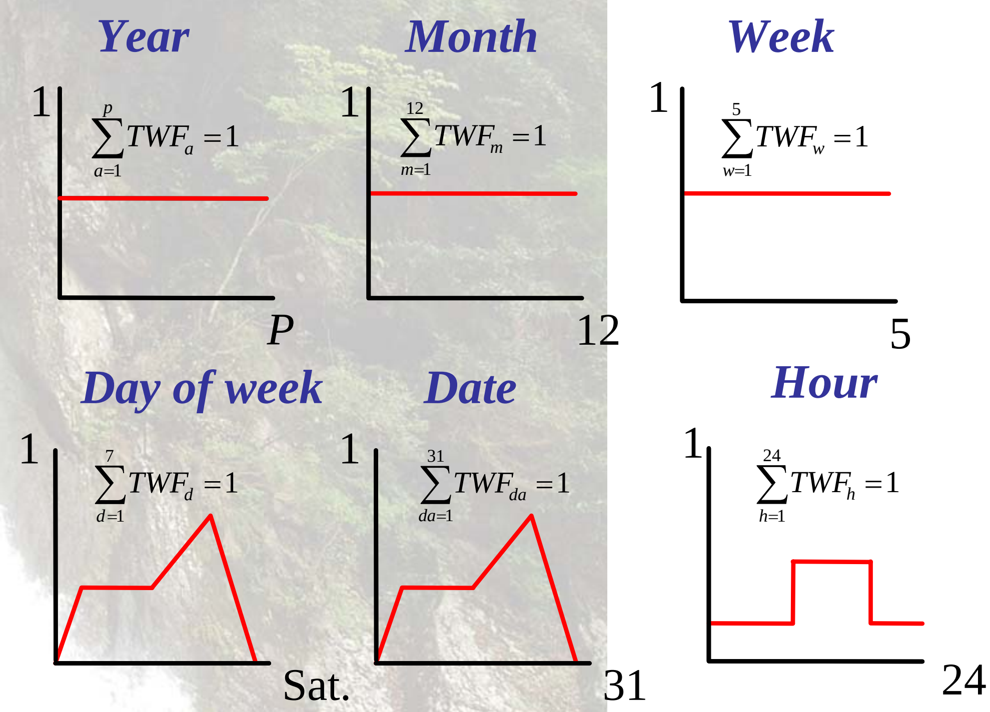
4. Temporal distribution

Temporal distribution

Characteristics of calculation method

- Emission allocation based on the temporal weighting factor (TWF)
  - Fundamental methodology is the same as the US EPA's method (Ryan, 2003).
  - TWF is defined by time unit (year, month, week, day, hour).
  - TWF is normalized value in each time unit, or the sum of TWF for each time unit equals 1.
  - SWF represents the magnitude of emission activity for the time.

Schematic graphs of temporal weighting factors by time unit



1. Emission on h hour of d day of w week in m month

$$X_{m,w,d,h} = X_p \cdot TWF_a \cdot TWF_m \cdot TWF_w \cdot TWF_d \cdot TWF_h$$

2. Emission on h hour of da date in m month

$$X_{m,da,h} = X_p \cdot TWF_a \cdot TWF_m \cdot TWF_{da} \cdot TWF_h$$

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Conclusions

1. This study proposed methodologies to systematize emission inventory with GIS and database software.

2. Defining geographical position by geometries on a layer of GIS is useful to systematize main procedures of emission estimations.

3. The cascade weighting method and the hybrid weighting method using SWFs were developed to determine spatial emission distribution.

4. In our system, temporal emission distribution is calculated by the same method as the US EPA using TWFs.

Thank you for your attention!

Questions by slowly speaking and easy words!

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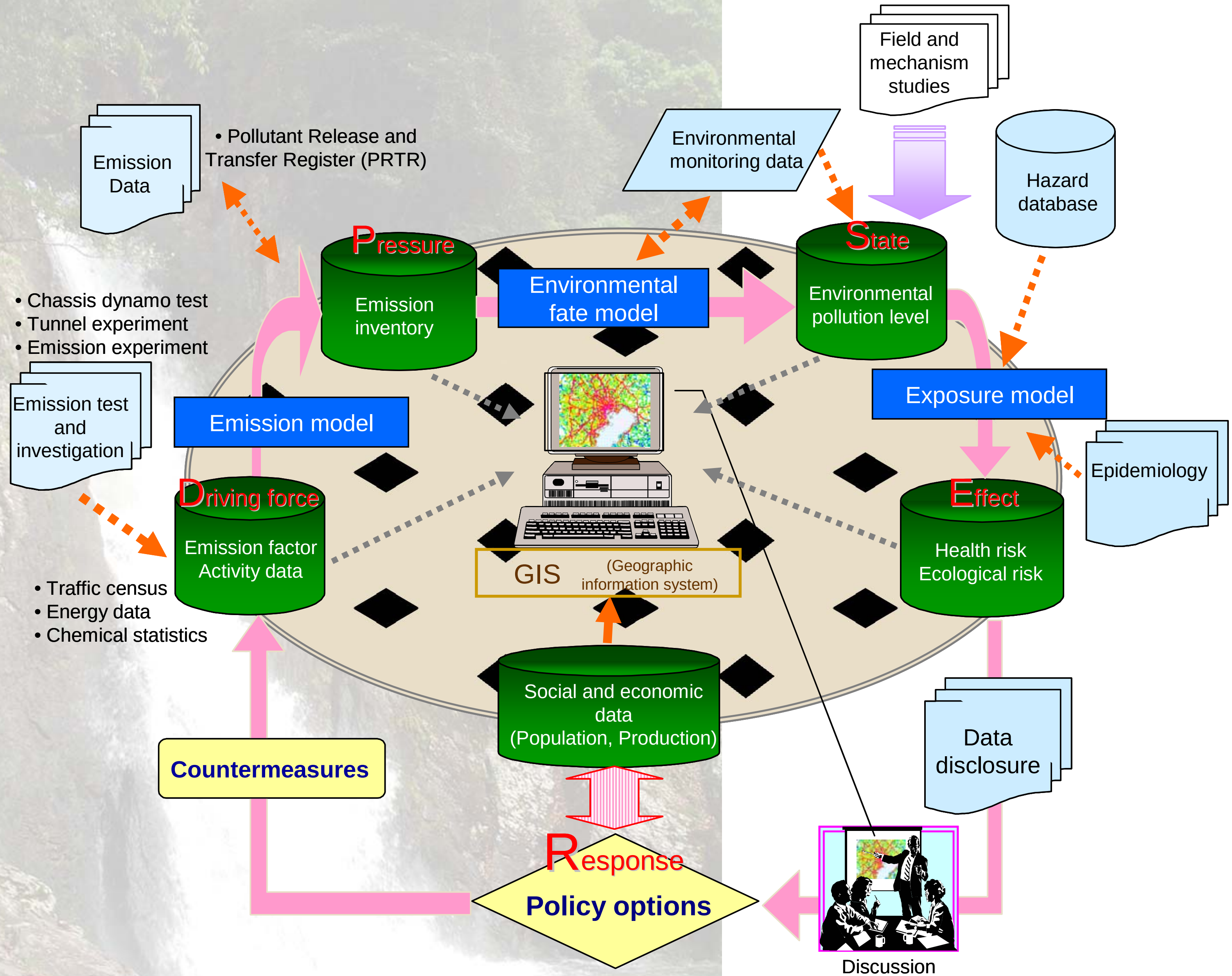

Fig. Schematic of the Virtual World