# Local Air Pollution Modeling AIM/Air

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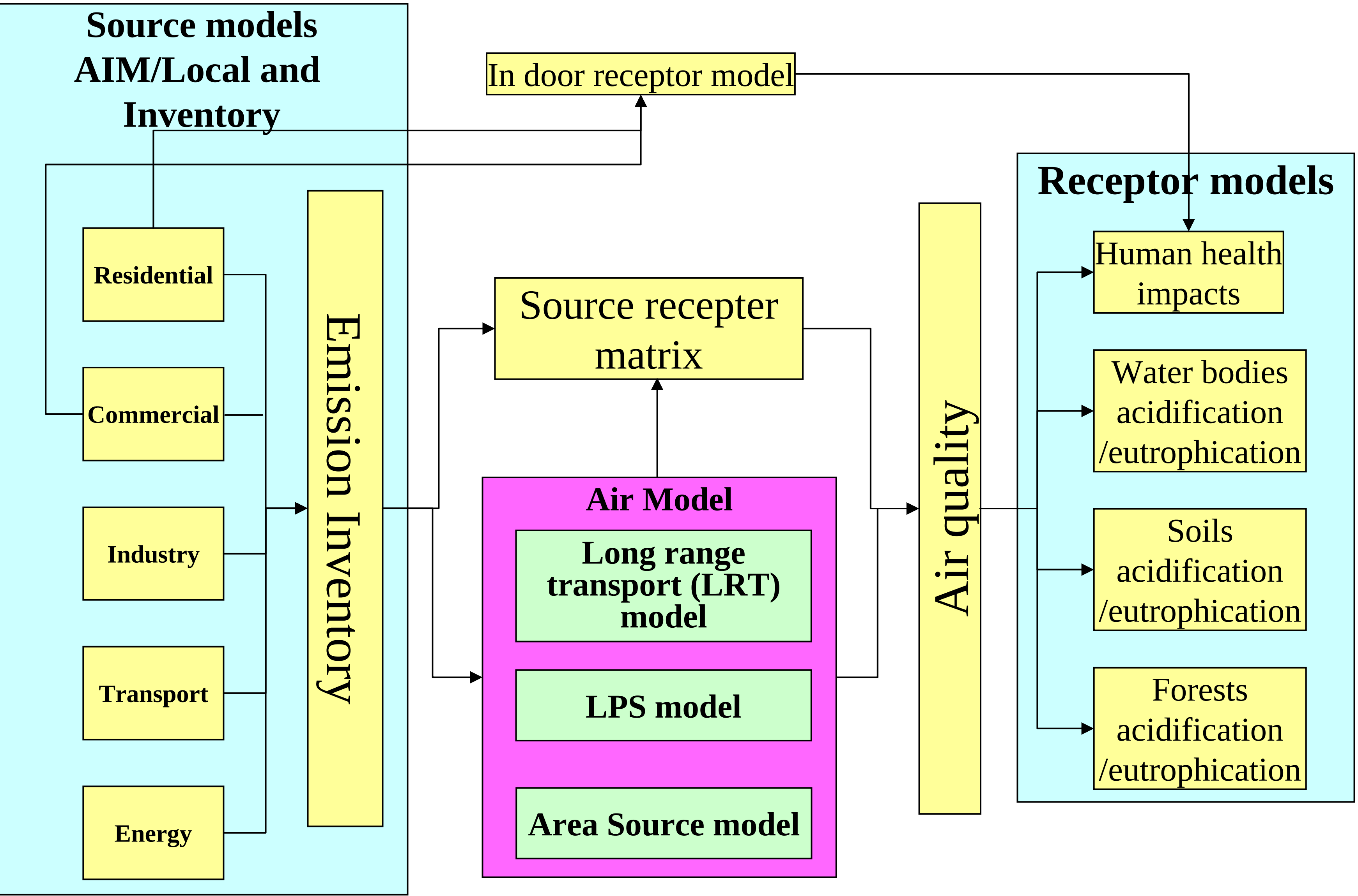
# AIM/Air

- Introduction of an air quality modeling in the framework of **AIM** family
- One of supplementary models of **AIM/Enduse**
- Consolidated with the emission inventory and energy bottom-up model, multi-scale multi-species model

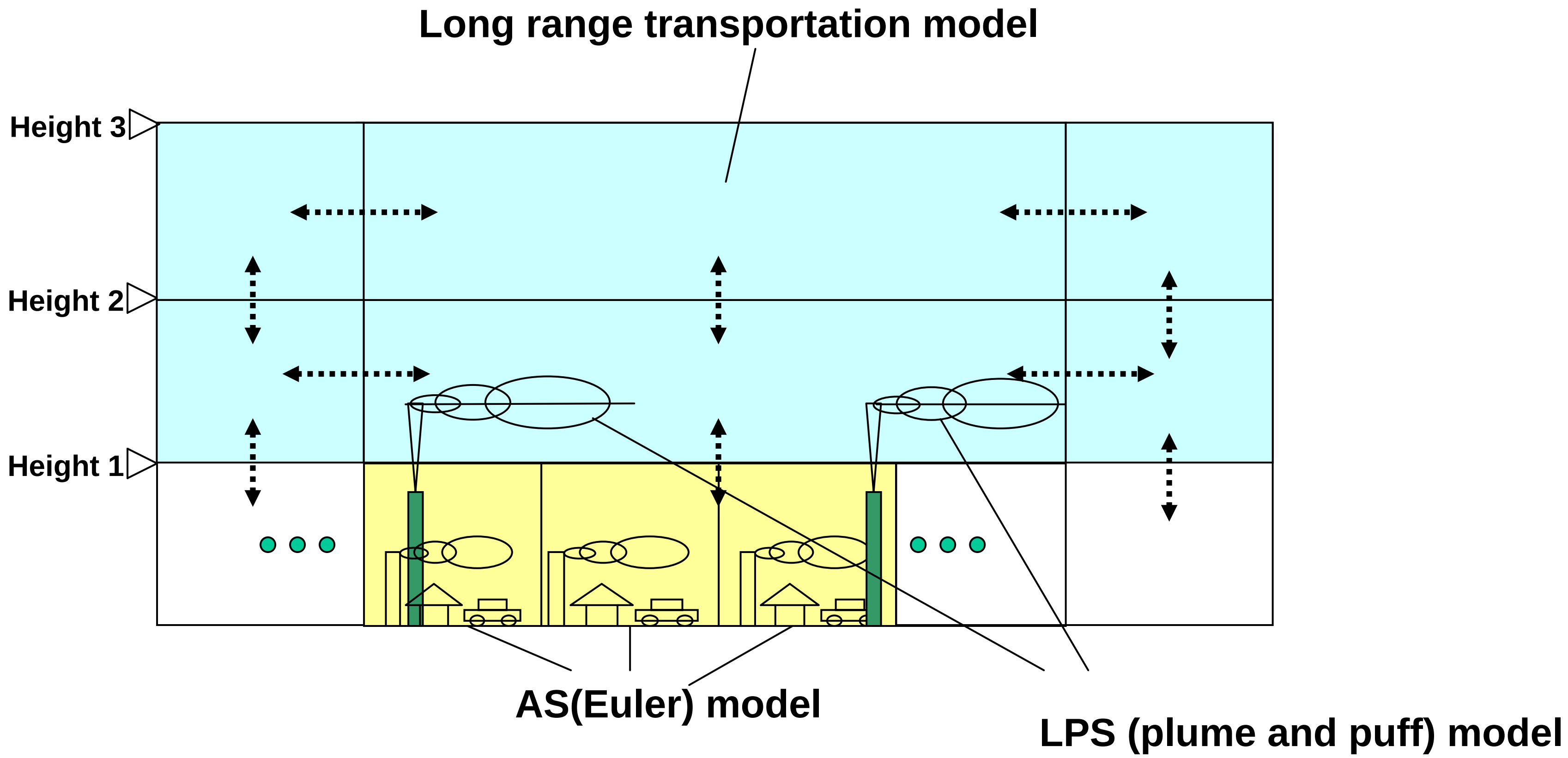
# Framework of AIM/Air



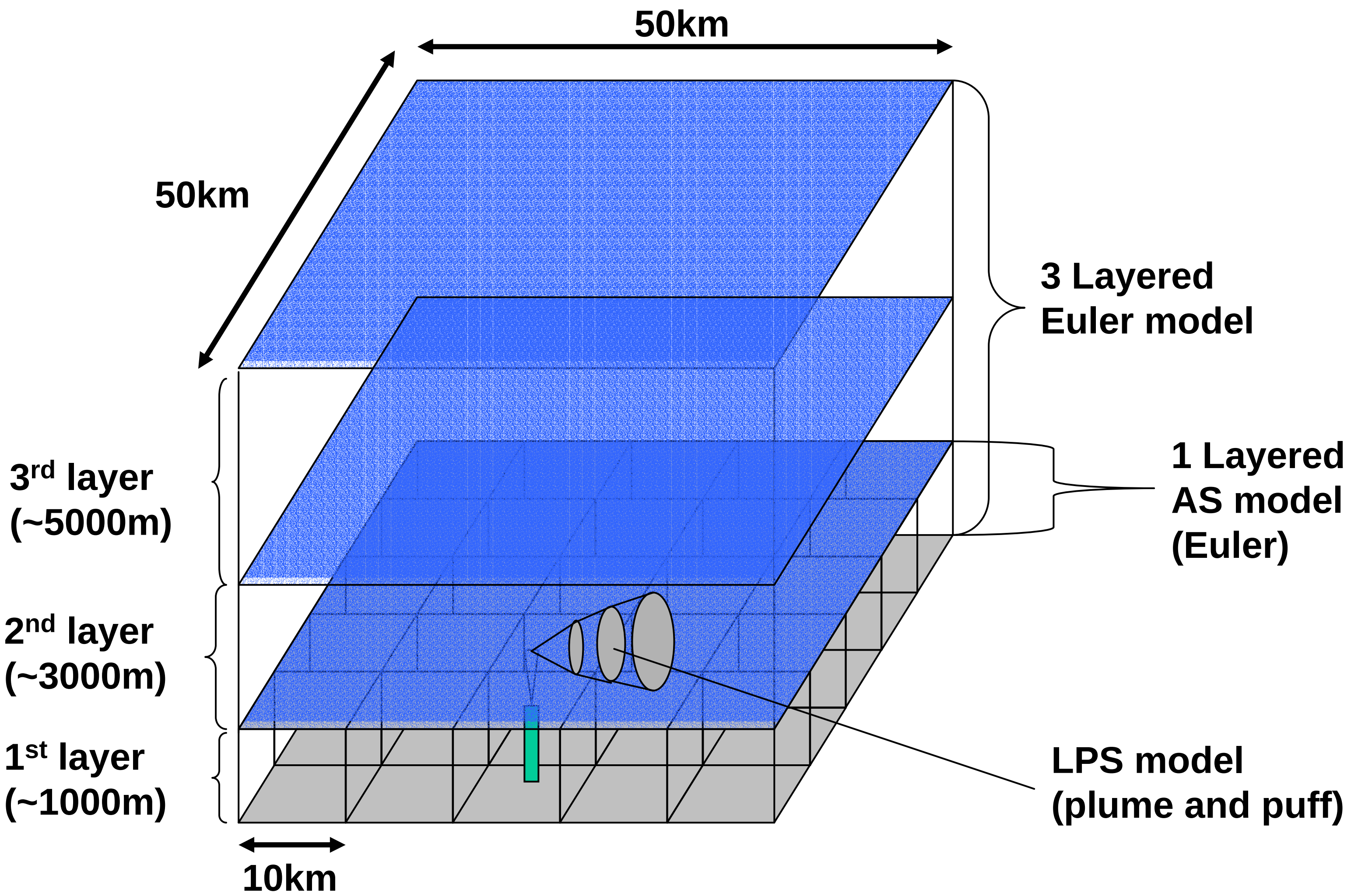
# Characteristics

- **Sources**: Large point sources (tall stack >200m) and area sources. Line sources are included in area sources.
- **Target pollutants**: $SO_2$, $NO_2$, SPM
- **Coupling of models**: Point source model (LPS), area source  model (AS) and long-range transport model(LRT)
- **Multi-scale description**: *x* km(LPS) + *m**x*** km(AS) + *mn**x*** km(LRT) grids (integer *m*,*n*)

# Modeling concept(1)

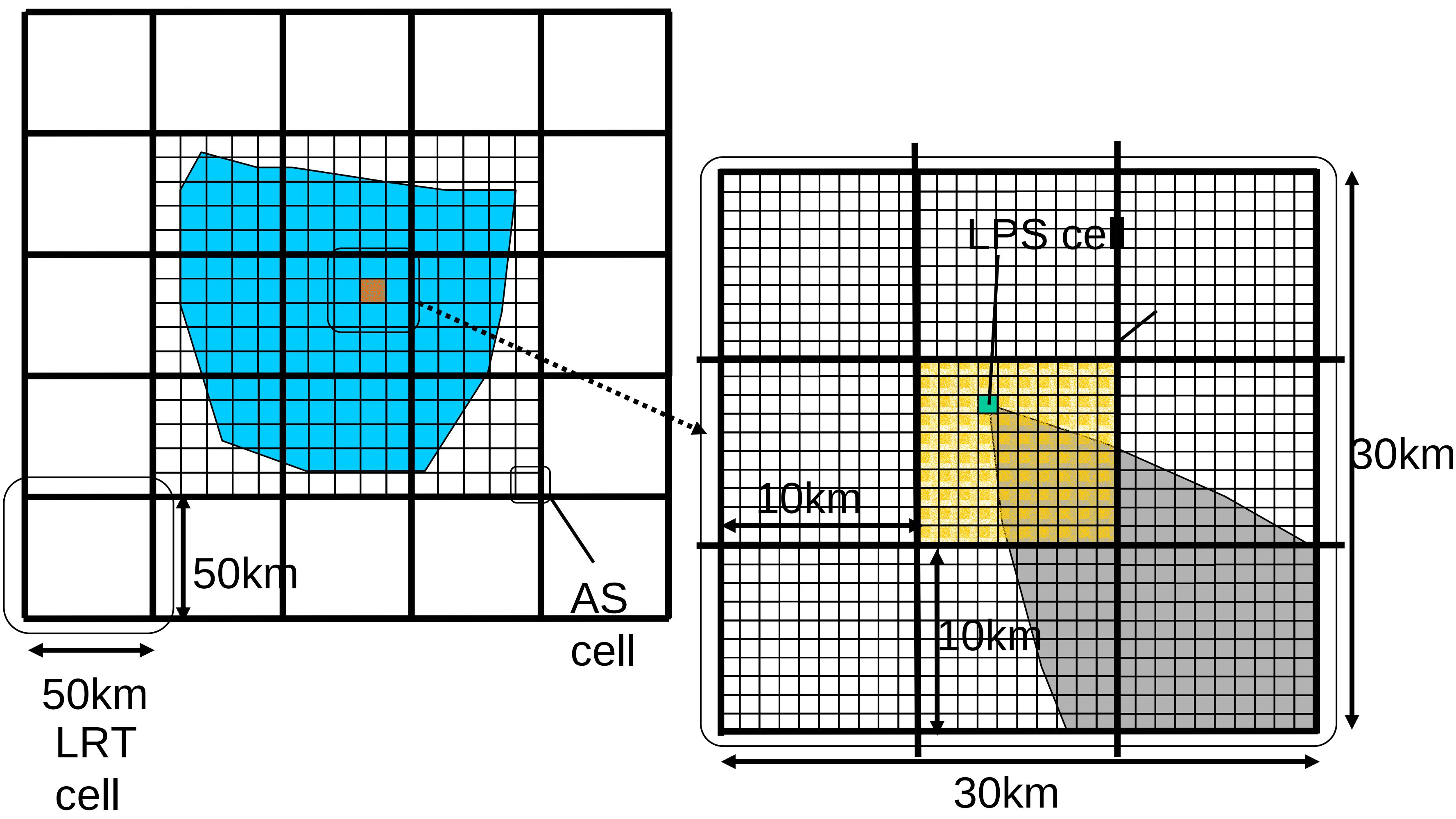


# Modeling concept(2)



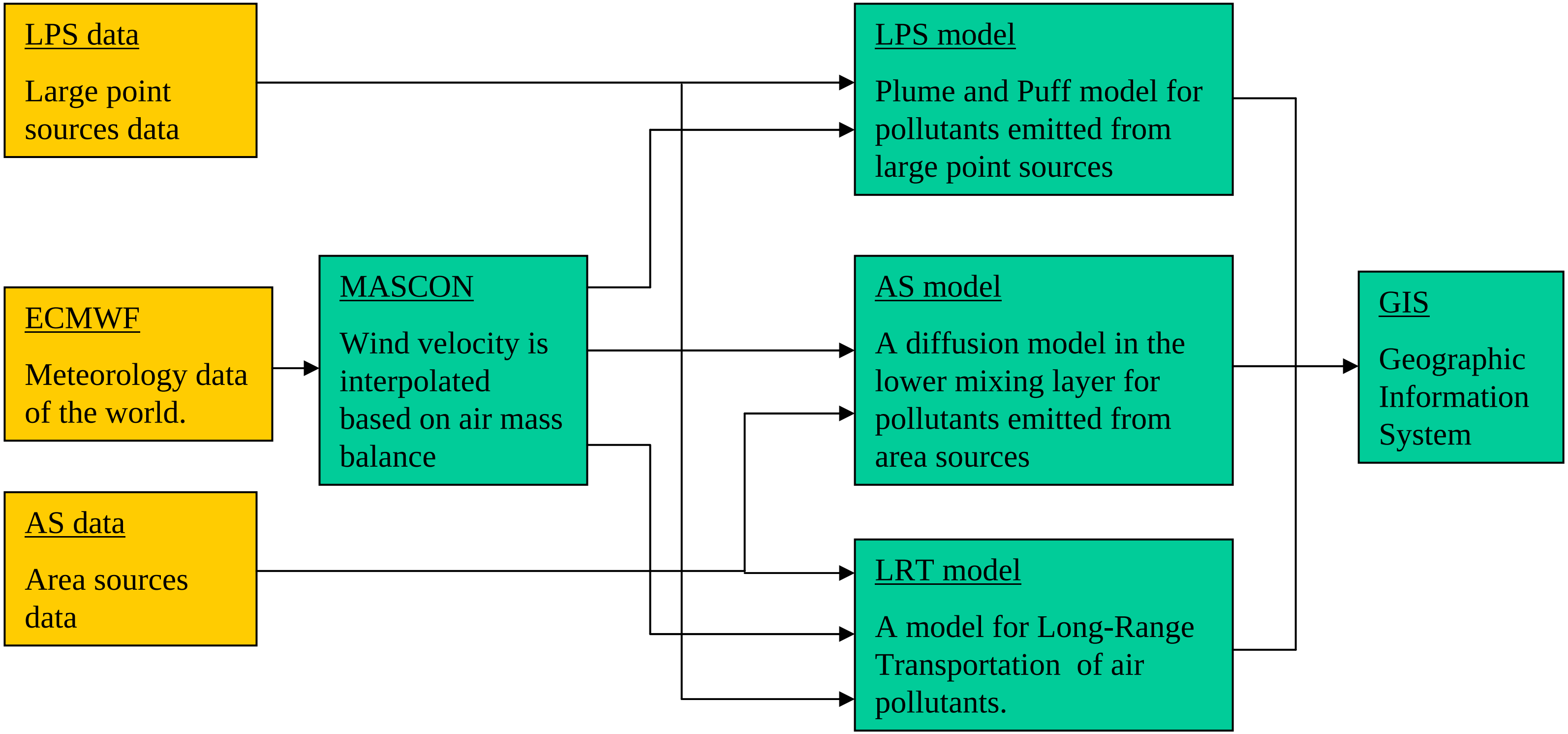

**Vertical Relation between AS model and LRT model**

# Modeling concept(3)

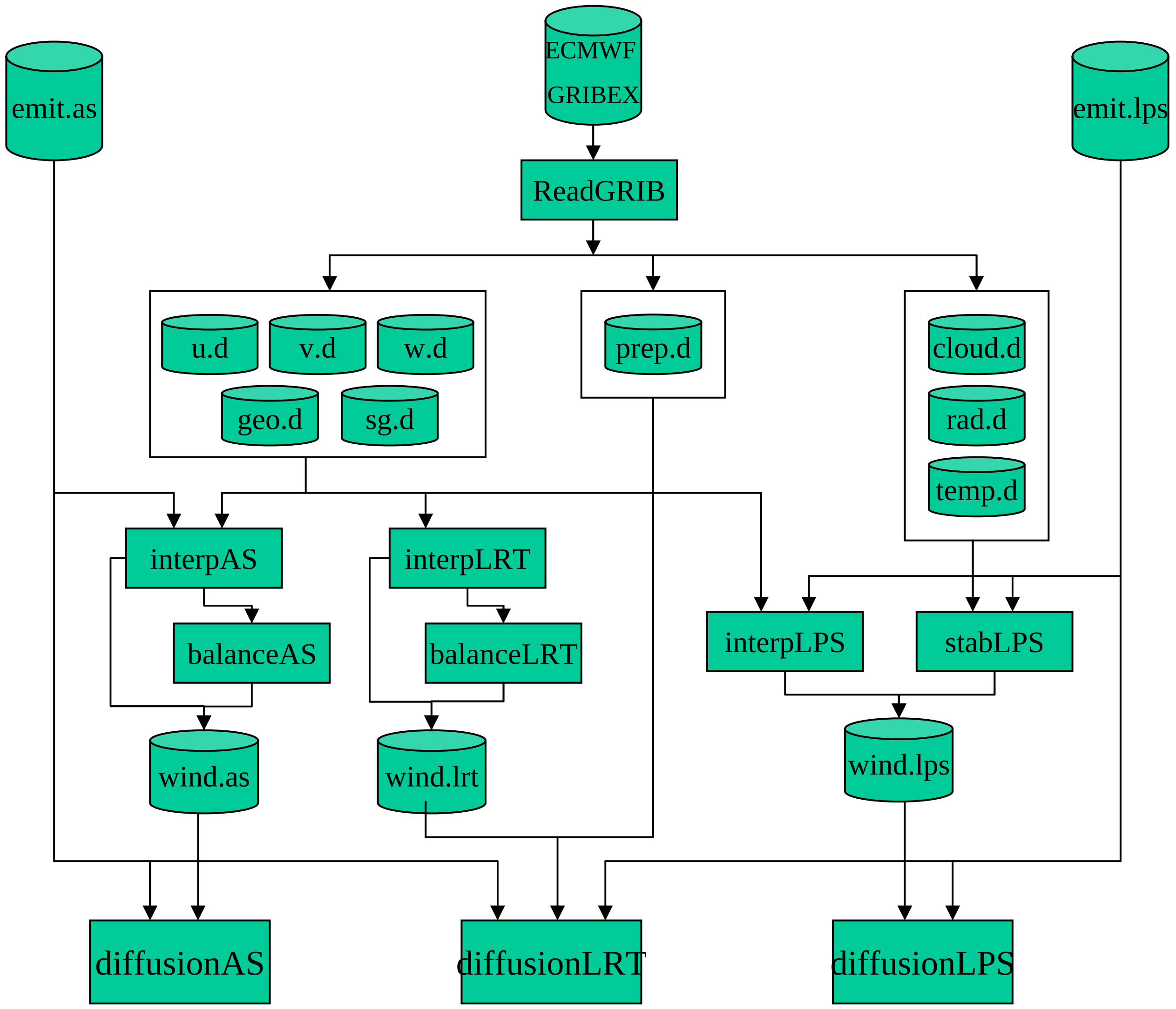



**Relation among LPS grid, AS grid and LRT grid**

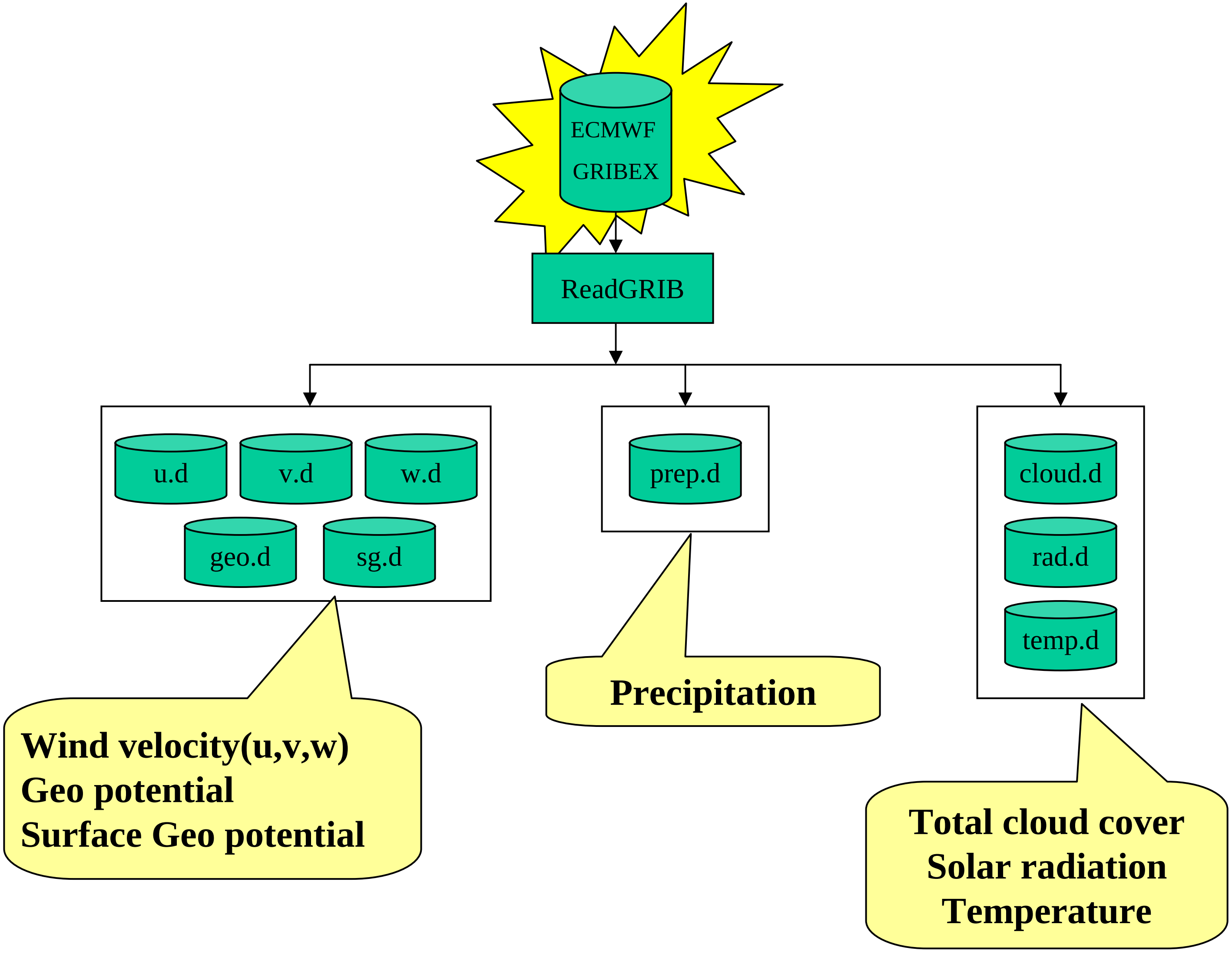
# General Flow of AIM/Air



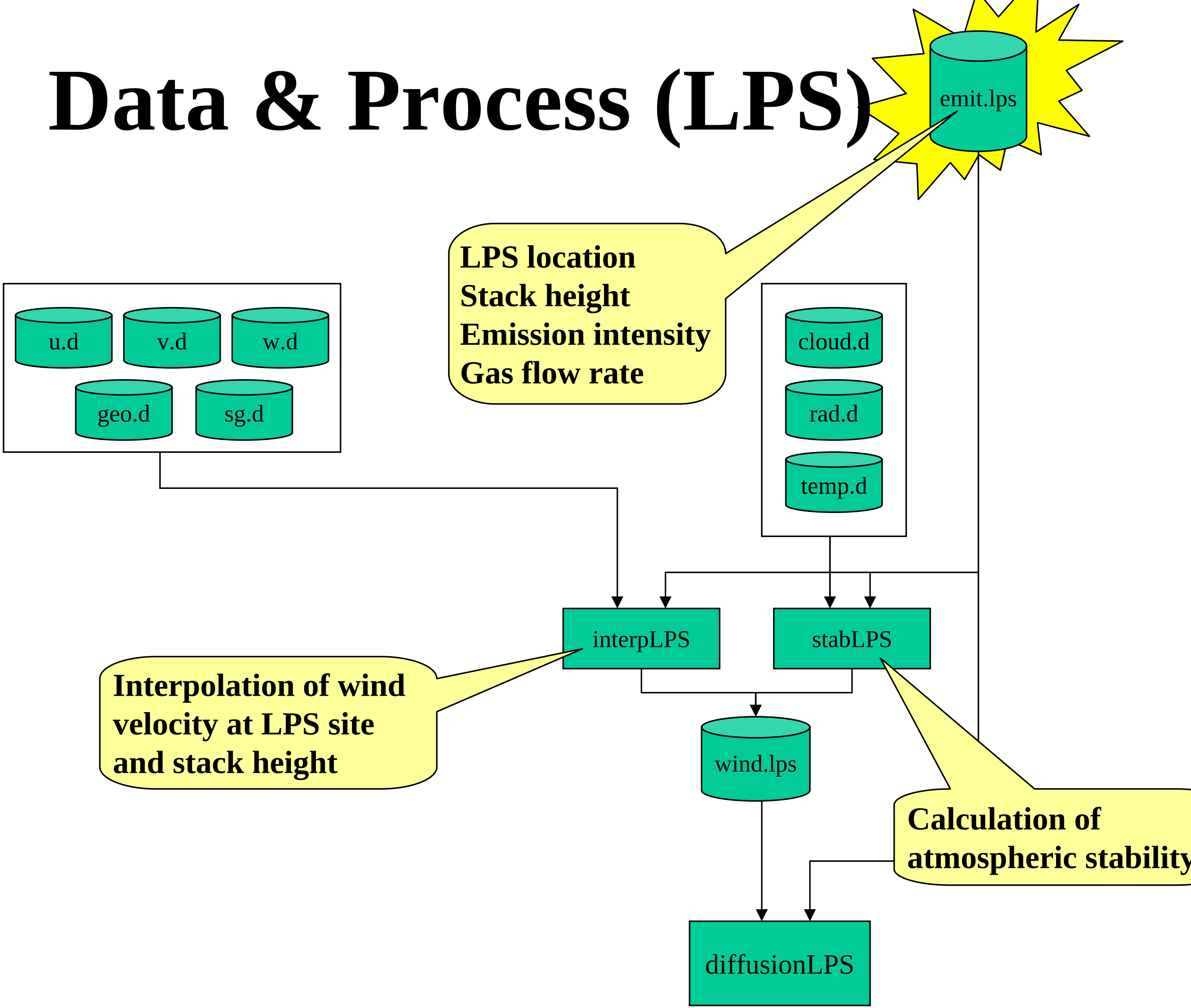
# AIM/Air Data & Process



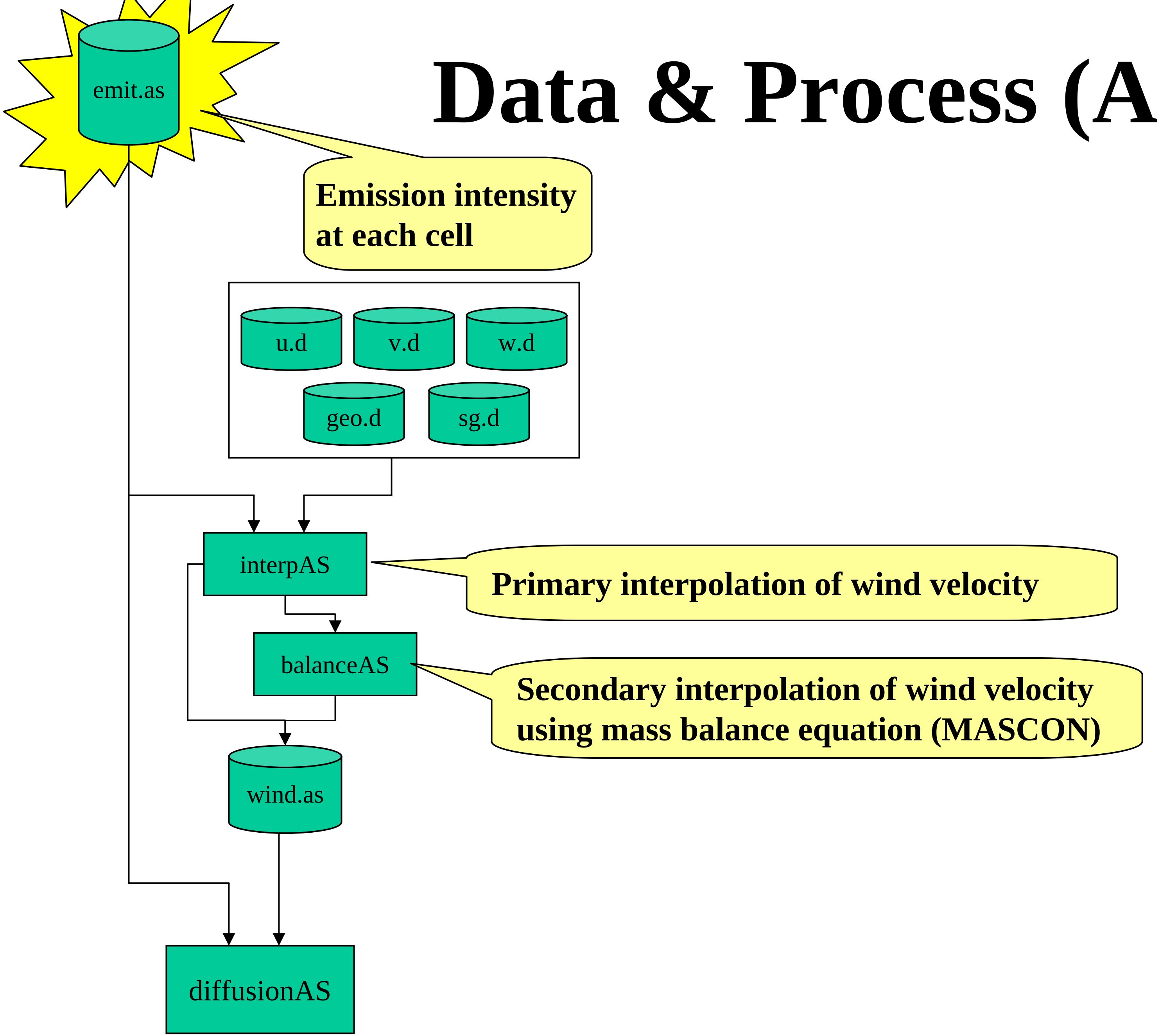
# Data & Process (Weather)



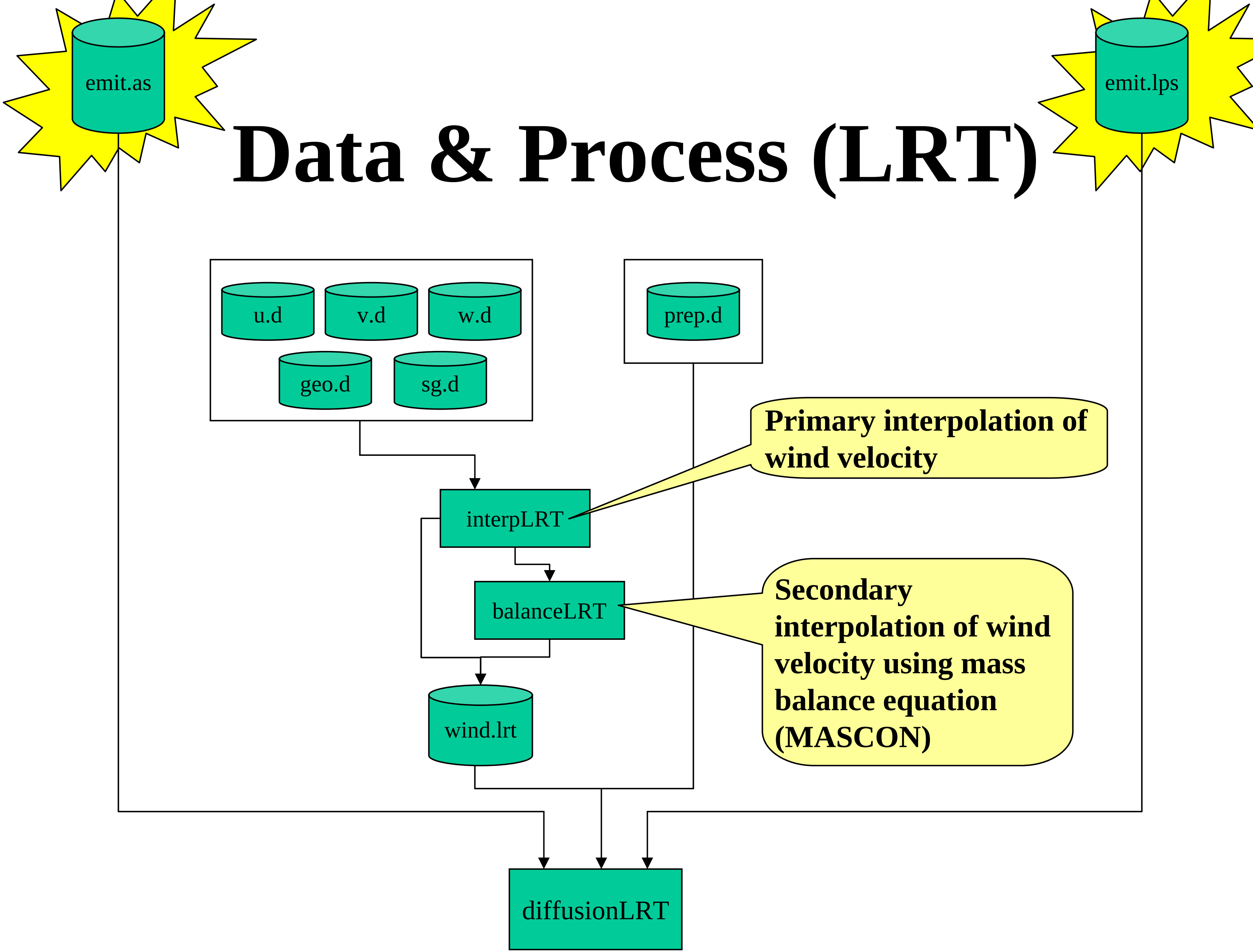
# Data & Process (LPS)



# Data & Process (AS)

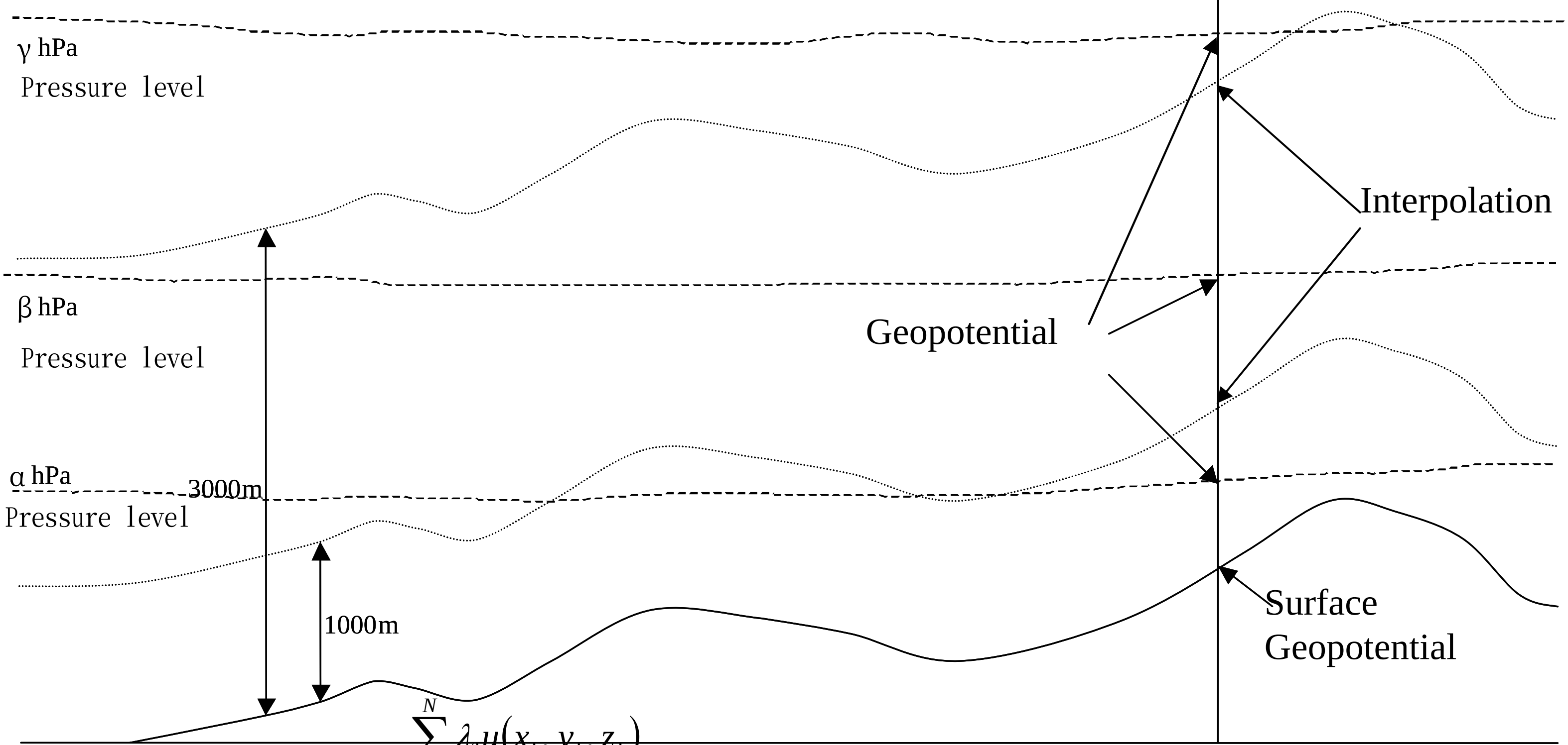


# Data & Process (LRT)



# Primary interpolation

$$u(a)=\frac{1}{E_{G,\beta hPa}-E_{G,\alpha hPa}}\times\left\{\left(E_{G,a}-E_{G,\alpha hPa}\right)\times u_{\beta hPa}+\left(E_{G,\beta hPa}-E_{G,a}\right)\times u_{\alpha hPa}\right\}$$




$$u(x,y,z)=\frac{\sum_{i=1}^{N}\lambda_i u(x_i,y_i,z_i)}{\sum_{i=1}^{N}\lambda_i},\quad \lambda_i=1\Big/\sqrt{(x_i-x)^2+(y_i-y)^2+(z_i-z)^2}$$

# LPS model (1)

- Corresponding to tall stack emissions (larger than 100～200m). Emission input to this LPS model is not included in the AS model.
- A plume model (windy) or puff model (no wind).
- Complex terrain modification is similar to EPA's ISC3.
- Calculate concentration at each cell (1km x 1km), within 10 km to every directions near the emission sites, hour by hour through a year.

# LPS model (2)

Plume model

$$C(x,y,z)=\frac{Q_P}{2\pi\sigma_y\sigma_z u}\exp\left(-\frac{y^2}{2\sigma_y{}^2}\right)\exp\left\{\left(-\frac{(z-H_e)^2}{2\sigma_z{}^2}\right)+\left(-\frac{(z+H_e)^2}{2\sigma_z{}^2}\right)\right\}$$

$x$: downstream coordinate, $y$: horizontally transverse coordinate, $z$: vertical coordinate (representative height=1.5m, $\sigma_y$, $\sigma_z$ : diffusion coefficients and calculated with the next equations, $Q_p$: emission from LPS, $u$: wind velocity, $H_e$: effective height of stacks

$$\sigma_y=\gamma_y\cdot x^{\alpha_y},\quad \sigma_z=\gamma_z\cdot x^{\alpha_z}$$

$\gamma_y$, $\gamma_z$, $\alpha_y$, $\alpha_z$: parameters given with Pasquill-Gifford diagram. He is given by the next CONCAWE equation.

$$H_e=H+\Delta H$$

$$\Delta H=0.175Q_H{}^{1/2}u_h{}^{-3/4}$$

$$Q_H=\rho C_p q_g(T_g-T_0)$$

$Q_H$ is a heat emission (cal/s), and $u_h$ is a wind velocity at the outlet

# LPS model (3)

Puff model in case of no wind/weak wind

$$C(x,y,z)=\frac{Q_P}{(2\pi)^{3/2}\gamma}\exp\left(-\frac{u^2}{2\alpha^2}\right)\left[\frac{1}{\eta_-^2}\left\{1+\frac{\sqrt{\pi/2}\cdot ux}{\alpha\eta_-}\exp\left(\frac{u^2x^2}{2\alpha^2\eta_-^2}\right)\mathrm{erfc}\left(-\frac{ux}{\sqrt{2}\alpha\eta_-}\right)\right\}\right.$$
$$\left.+\frac{1}{\eta_+^2}\left\{1+\frac{\sqrt{\pi/2}\cdot ux}{\alpha\eta_+}\exp\left(\frac{u^2x^2}{2\alpha^2\eta_-^2}\right)\mathrm{erfc}\left(-\frac{ux}{\sqrt{2}\alpha\eta_+}\right)\right\}\right]$$

$$\eta_-^2=x^2+y^2+\frac{\alpha^2}{\gamma^2}(z-H_e)^2$$

$$\eta_+^2=x^2+y^2+\frac{\alpha^2}{\gamma^2}(z+H_e)^2$$

$$\mathrm{erfc}(W)=\frac{1}{\sqrt{\pi}}\int_W^\infty e^{-t^2}dt$$

where **α** and **γ** is given with Pasquill stability classification. In this case, $H_e$ is given by Briggs equation.

$$\Delta H=1.4Q_H^{1/4}\left(\frac{d\theta}{dz}\right)^{-3/8}$$

$d\theta/dz$ is potential temperature gradient (K/m)

# Euler Model(AS & LRT)

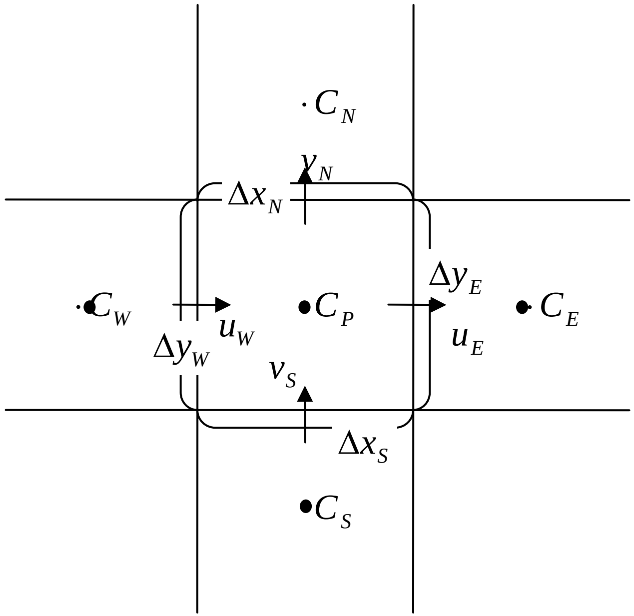
Equation

$$\frac{\partial c_i}{\partial t} = -\frac{\partial (u c_i)}{\partial x} - \frac{\partial (v c_i)}{\partial y} - \frac{\partial (w c_i)}{\partial z} + \frac{\partial}{\partial x}\left(k_h \frac{\partial c_i}{\partial x}\right) + \frac{\partial}{\partial y}\left(k_h \frac{\partial c_i}{\partial y}\right) + \frac{\partial}{\partial z}\left(k_v \frac{\partial c_i}{\partial z}\right) + R_i + Q_i$$

$c_i$ Concentration

$k_h$ $k_v$ Diffusion parameters

$R_i$ $Q_i$ Reaction terms




Input and output through a cell

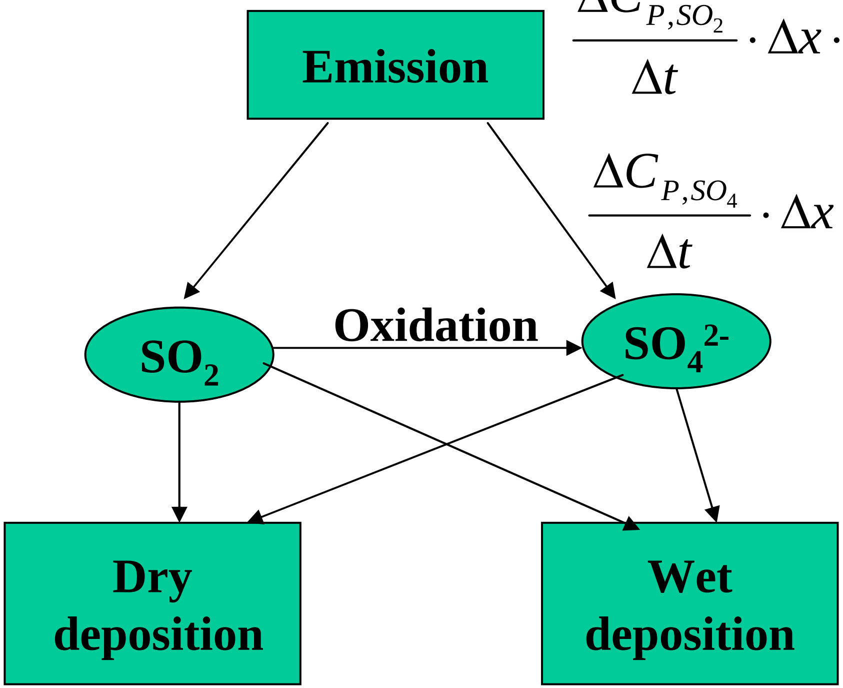
# Deposition of Sulfur

$$R_{P,SO_2} = \left\{ -\left( W_{P,SO_2} / \Delta z \right) - PR_{P,SO_2} \right\} \cdot C_{P,SO_2} \cdot \Delta x \cdot \Delta y \cdot \Delta z - \underline{kC_{P,SO_2} \cdot \Delta x \cdot \Delta y \cdot \Delta z}$$

$$R_{P,SO_2} = \underline{k \cdot C_{P,SO_2} \cdot \Delta x \cdot \Delta y \cdot \Delta z} + \left\{ -\left( W_{P,SO_4} / \Delta z \right) - PR_{P,SO_4} \right\} \cdot C_{P,SO_4} \cdot \Delta x \cdot \Delta y \cdot \Delta z$$

$$\frac{\Delta C_{P,SO_2}}{\Delta t} \cdot \Delta x \cdot \Delta y \cdot \Delta z = E_{in,SO_2} - E_{out,SO_2} + Q_{P,SO_2} + R_{SO_2}$$

$$\frac{\Delta C_{P,SO_4}}{\Delta t} \cdot \Delta x \cdot \Delta y \cdot \Delta z = E_{in,SO_4} - E_{out,SO_4} + Q_{P,SO_4} + R_{SO_4}$$




k: reaction rate of $SO2 \rightarrow SO4^{2-}$

W: dry deposition ratio

PR: wet deposition rate

# AIM/Air Program Package

- Programs in C language:
  - 20 programs including utility programs
  - 6410 lines including comment lines
- Graphics: X-window.
  - figcont: concentration
  - figarrow: wind direction and strength
- Convenient batch programs:
  - aircalc: menu of calculation
  - airview: menu of visualization

# Implementation Principles

- **Platform**: Linux and MS Windows
- **Emission projection and inventory**: Based on AIM/Database. With MS Access.
- **Weather database**: ECMWF data 0.5$^{o}$ grid, every 6 hours + local weather station information
- **Air Models**: C program worked on Linux and MS Windows. Complete programs and communicate with other modules by files.
- Complicate calculation with Linux, transport the aggregated output to MS Windows in order to use by end users.

# Conclusion

- AIM/Air software package was developed.
- AIM/Air includes LPS, AS, LRT models. Multi-scale diffusion simulation is supported.
- This tool becomes a powerful tool for studies on local air pollution of each country and global air pollution in the Asia.