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Hydrological Improvement of the Land Surface Process Scheme Using the CEOP Observation

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2. A hydrologically enhanced land-surface process model

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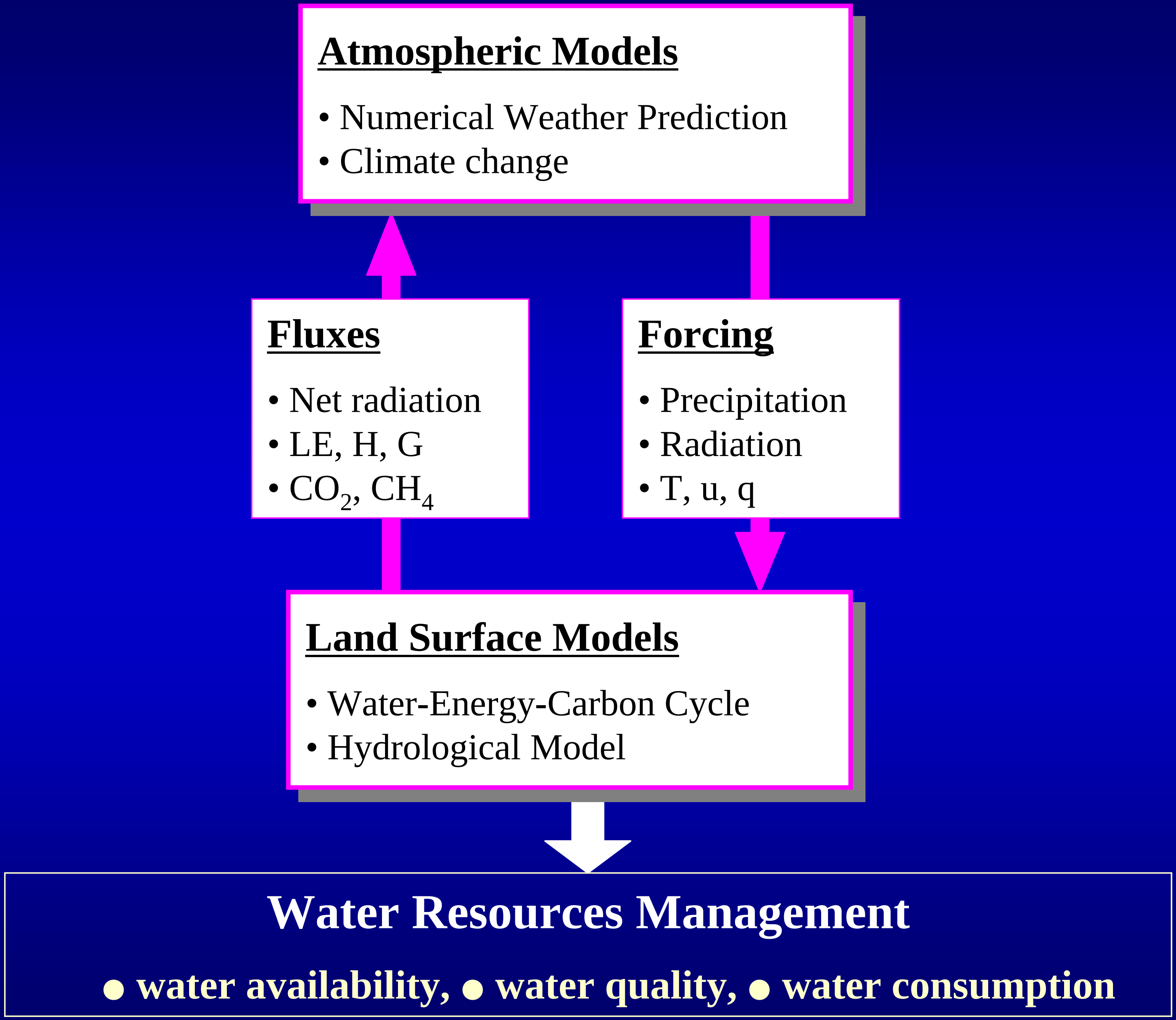

Atmospheric Models
• Numerical Weather Prediction
• Climate change
Fluxes
• Net radiation
• LE, H, G
• CO_2, CH_4
Forcing
• Precipitation
• Radiation
• T, u, q
Land Surface Models
• Water-Energy-Carbon Cycle
• Hydrological Model
Water Resources Management
● water availability, ● water quality, ● water consumption

Several Urgent Issues in Hydrological Application

- Impacts of human activity to the hydrological processes and its induced spatial and temporal variability of water resources.

- Hydrological responses to the climate changes and its induces possible variability in water resources.

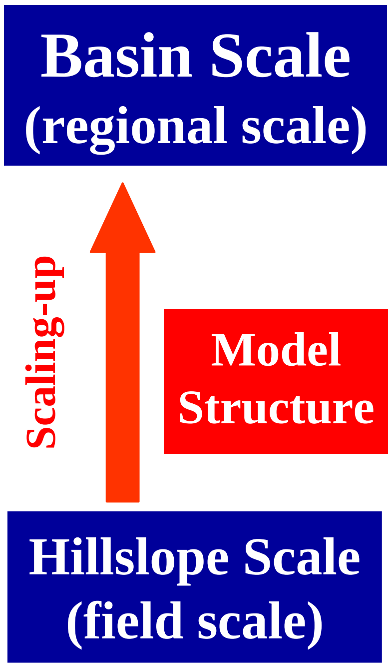
- Role of vegetation in the hydrological cycle for the integrated basin management.

- Managing water quality together with water quantity.

The Distributed Hydrological Model

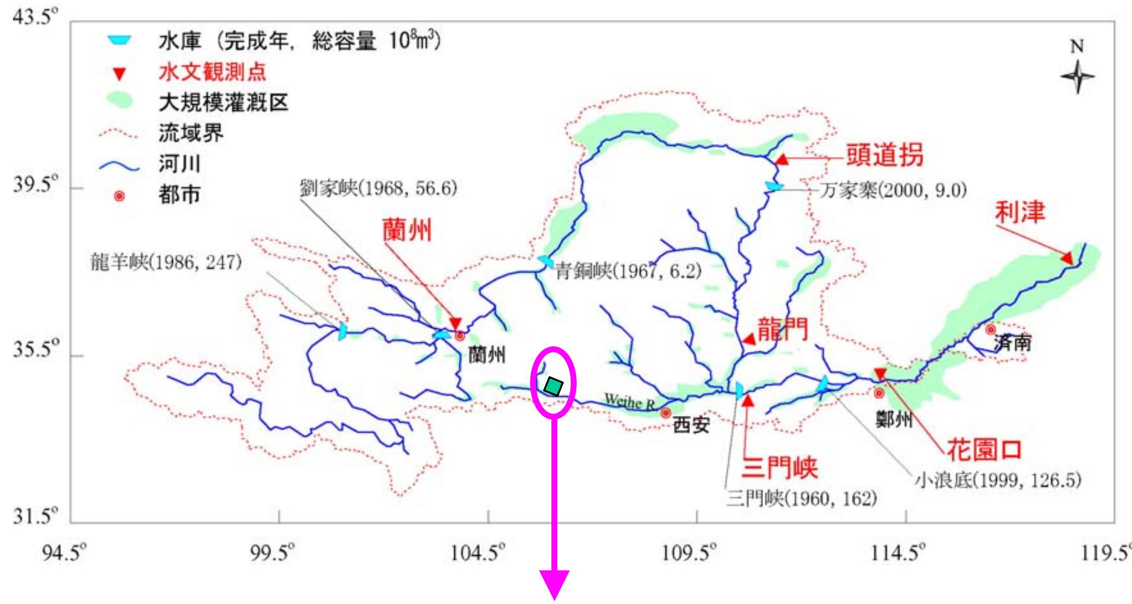
On the Basin Scale

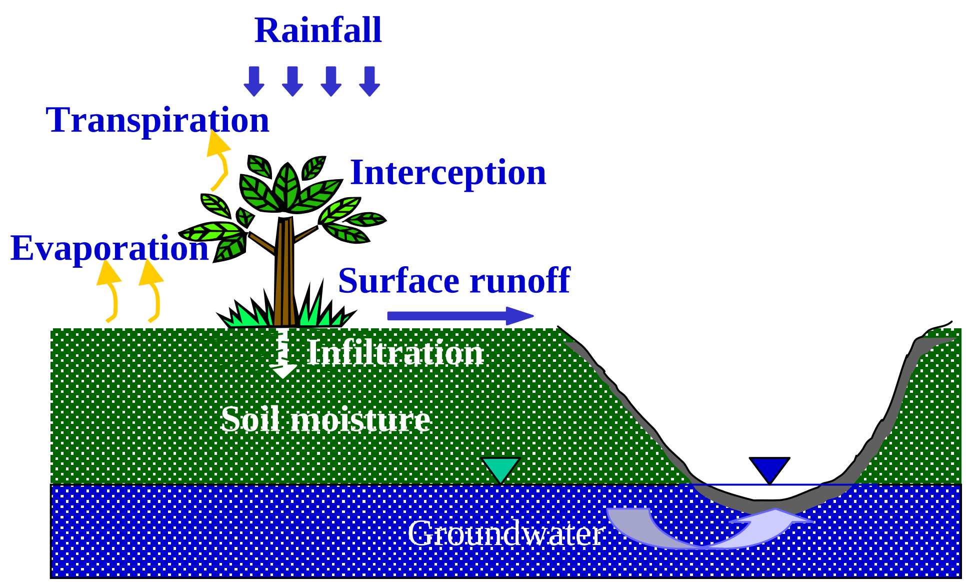
- River flow routing
- Groundwater flow



On the Hillslope (field) Scale

- Hydrological Processes：rainfall-infiltration-runoff
- Potential E_p → Actual E_a





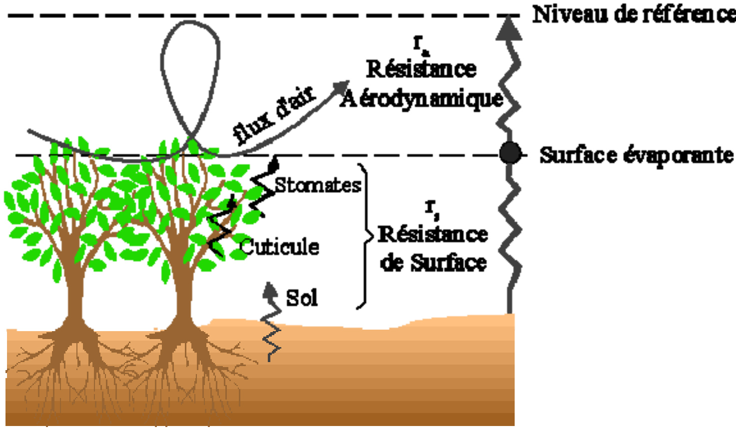
Net radiation → potential evaporation → actual evapotranspiration

Penman equation for potential evaporation:

$$E = \frac{\Delta}{\lambda(\Delta+\gamma)}(R_n - G) + \frac{\rho c_a (e_s - e_{za})/r_a}{\lambda(\Delta+\gamma)}$$

Penman-Monteith equation for the actual evapotranspiration:

$$E_a = \frac{\Delta(R_n - G) + \rho c_a (e_s - e_{za})/r_a}{\lambda[\Delta + \gamma(1+\frac{r_s}{r_a})]}$$



Reference crop evaporation:

r_s=70 s/m , r_a= 208/u2 s/m, the Penman-Monteith equation become:

$$E_{rc} = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273}(e_s - e_{za})u_2}{\Delta + \gamma(1+0.34u_2)}$$

Net Radiation: $R_n = S_n + L_n$

$$S_n = S_t(1-\alpha)$$

$$S_t = \left(a_s + b_s \frac{n}{N}\right) S_0$$

$$S_0 = 15.392 d_r (\omega_s \sin\phi \sin\delta + \cos\phi \cos\delta \sin\omega_s)$$

$$L_n = -f\varepsilon'\sigma (T_a + 273.15)^4 / (\lambda\rho_w \cdot 10^{-3})$$

$$f = \left(a_c \frac{b_s}{a_s + b_s}\right)\frac{n}{N} + \left(b_c + \frac{a_s}{a_s + b_s} a_c\right)$$

$$\varepsilon' = a_e + b_e \sqrt{e_d}$$

Parameters:

(1) albedo (α): seasonal and regional characteristics

(2) a_s, b_s, a_c, b_c, a_e, b_e: with regional characteristics

Actual Evapotranspiration

(Kristensen and Jensen 1975)

Calculating the actual transpiration E_{at} as :

$$E_t = f^1_{(\theta)} f_{(LAI)} f_{(RDF)} E_{rc}$$

$$\begin{cases} f_{(LAI)} = C_2 + C_1 LAI \rightarrow if \cdot LAI < \dfrac{(1-C_2)}{C_1} \\ f_{(LAI)} = 1 \rightarrow else \end{cases}$$

{C_1,C_2 are constants}

$$f^1_{(\theta)} = 1 - \left(\frac{\theta_f - \theta}{\theta_f - \theta_w} \right)^{\frac{C_3}{E_{rc}}}$$

C_3 :empirical parameter(mm/day)

θ_f: volumetric moisture content at field capacity

θ_w: volumetric moisture content at wilting point

θ: volumetric moisture content of the layer

And actual evaporation from upper layer E_s as:

$$E_s = (E_{rc} - E_t) f^1_{(\theta)}$$

Infiltration and Unsaturated Zone

Governing Equation for 1-D Flow

Momentum Equation (Darcy's law)

$$q = -K(\theta)\frac{d(\psi + z)}{dz}$$

Continuity equation

$$\frac{\partial \theta}{\partial t} = -\frac{\partial q}{\partial z}$$

Soil-water properties:

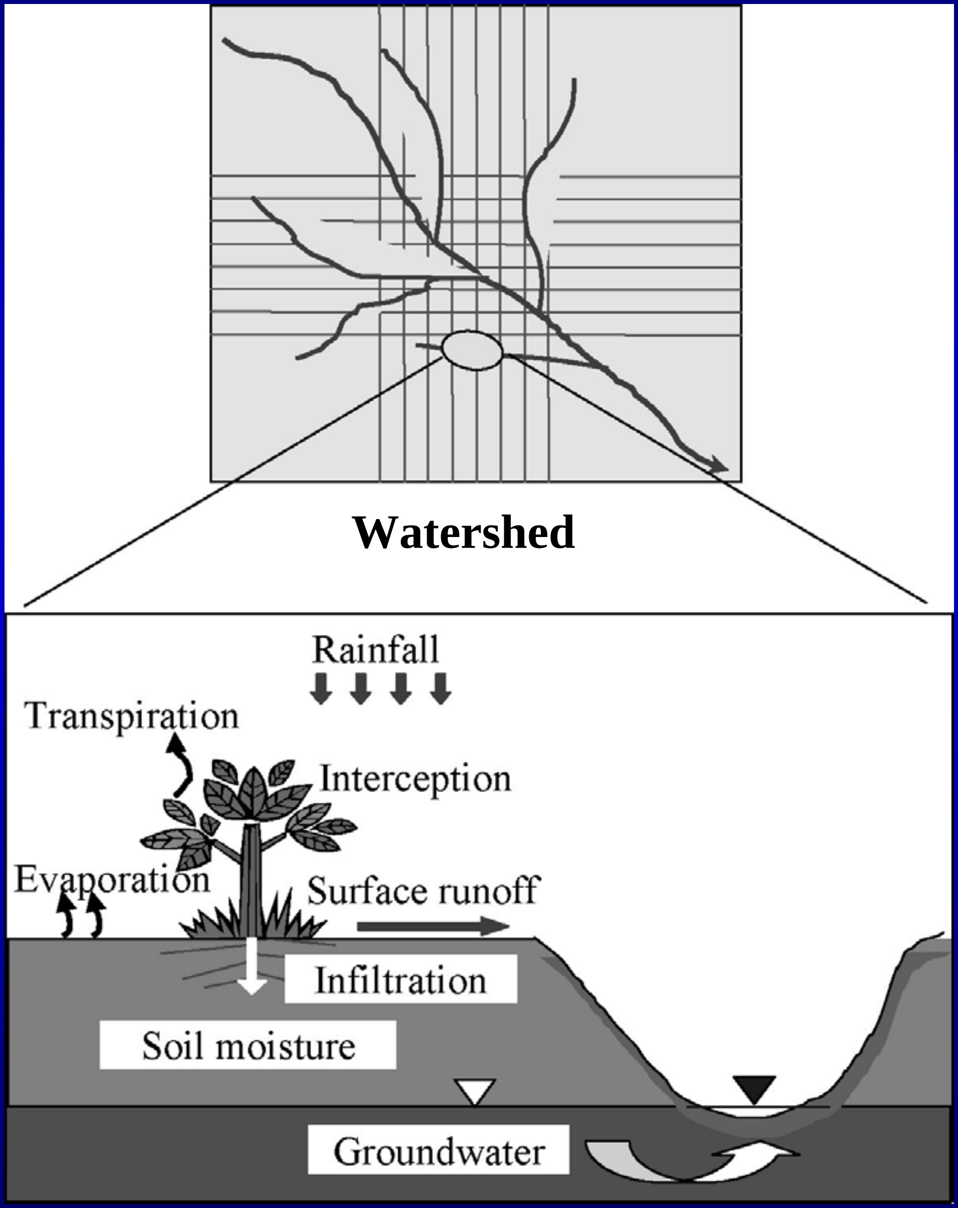
- porosity (saturated moisture)
- water retention: θ–φ
- unsaturated hydraulic conductivity: k–θ

By combining them, Richards' equation is obtained

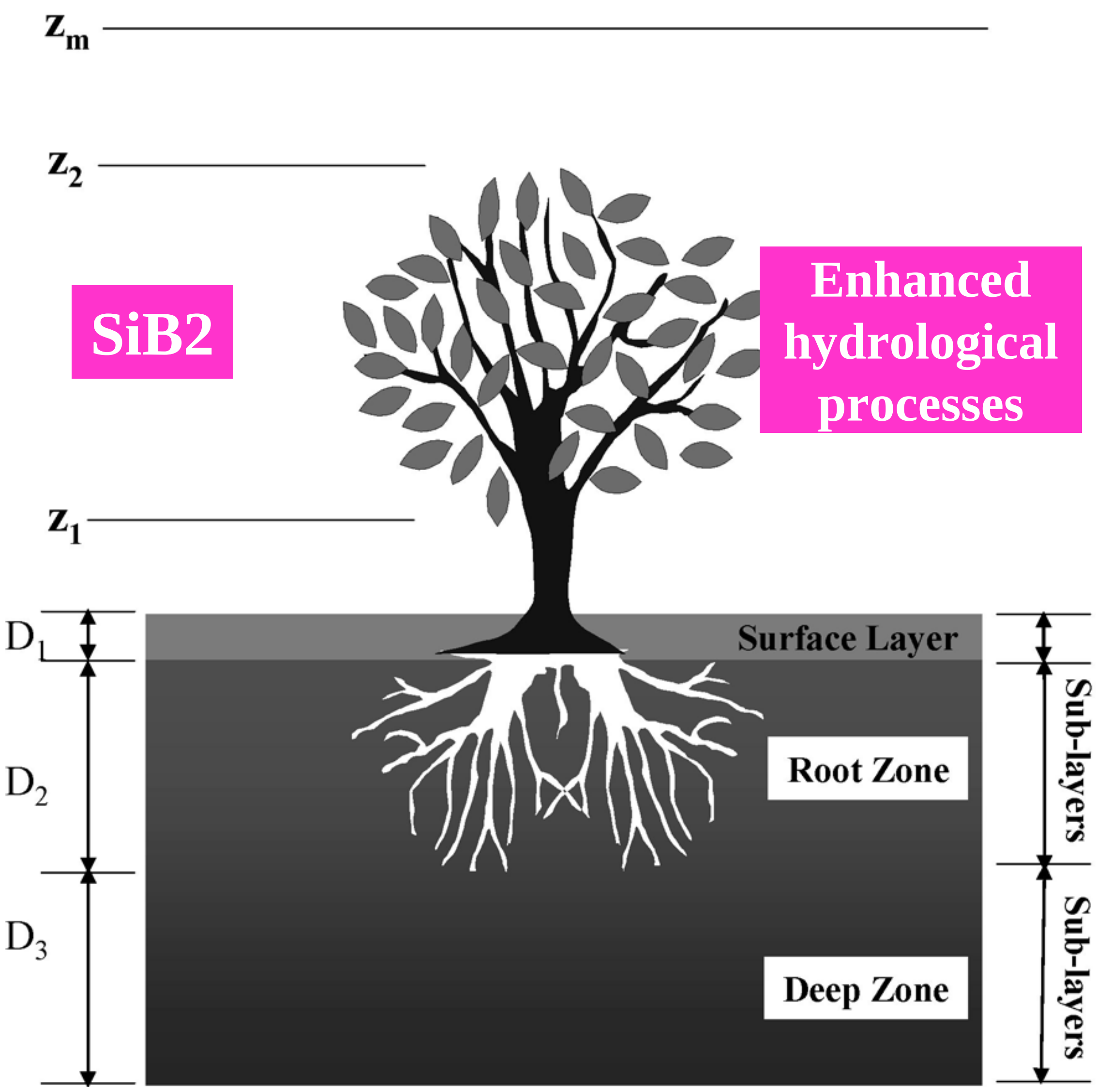
$$\frac{\partial \theta}{\partial t} = \frac{\partial}{\partial z}\{K(\theta)\frac{\delta \psi}{\delta z} + 1\}$$

Hydrologocally Enhanced Land-surface Model

1. Using distributed hydrological model;
2. Including radiation transfer processes;
3. Including biophysical processes;
4. Including biochemical processes.



Hydrologically Enhanced Land-surface Process Model (HELP)

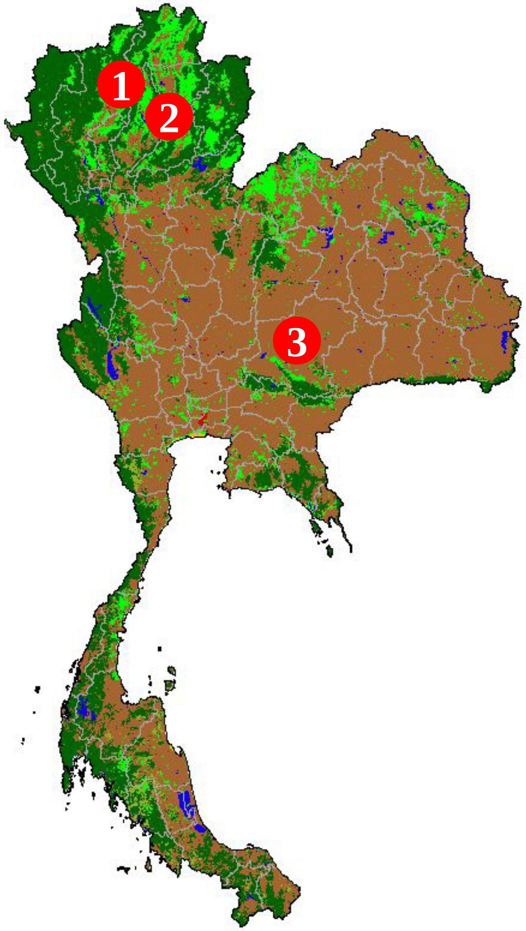


(1) Using more reliable formulation for soil-water property by replacing the Campbell's formula with Von Genuchten's formula.
(2) Using quasi 2-dimensional unsaturated zone model
(3) Including the dynamic interaction between groundwater level and the unsaturated zone and the exchange between the groundwater and river.
(4) Including surface routing along the hillslope.

10 soil layers:

- The first layer is fixed to be 0.05 m
- The root zone is subdivided
- The deep zone is subdivided

Validation using the CEOP Thailand Site Observation

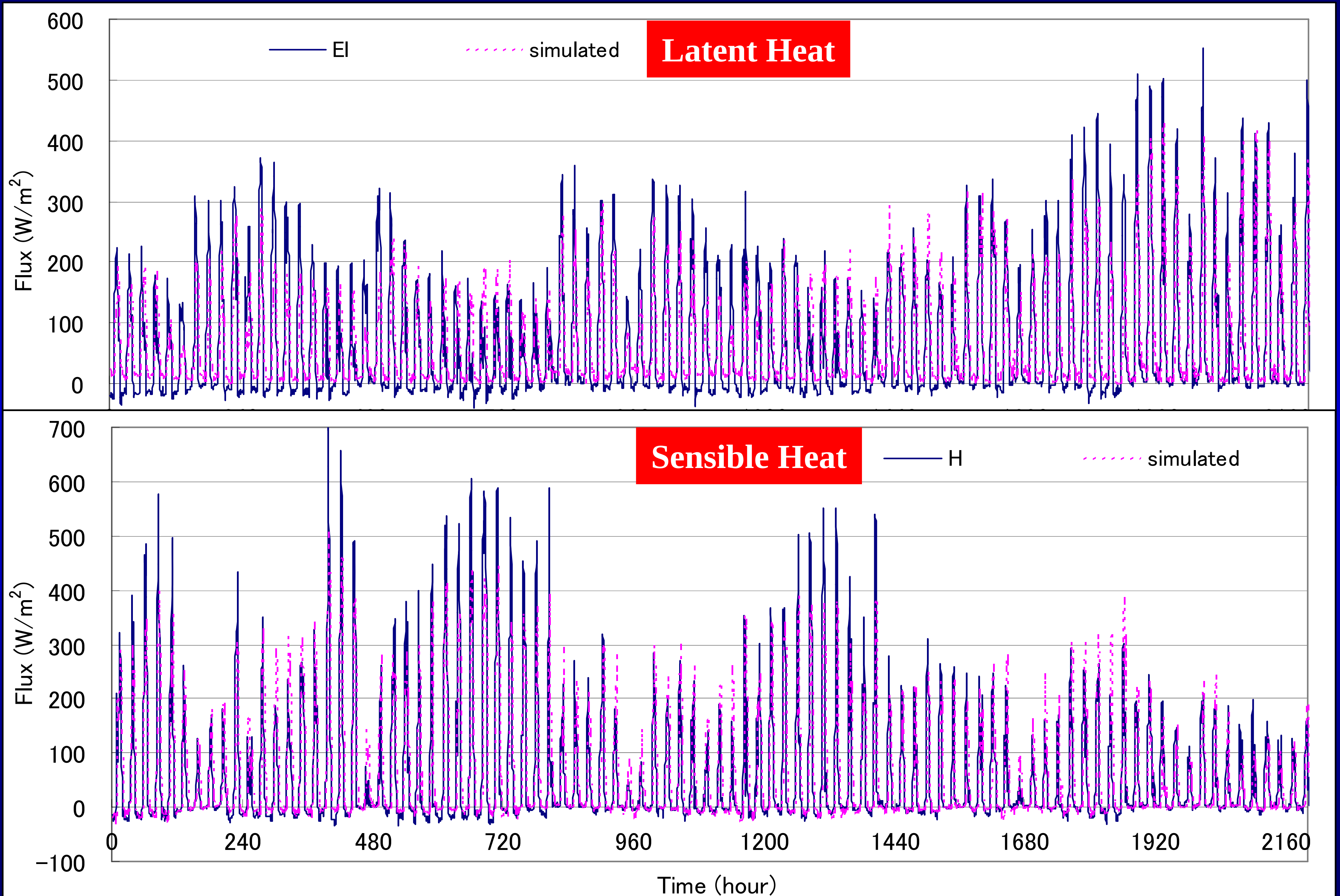


1 Ever-green Forest

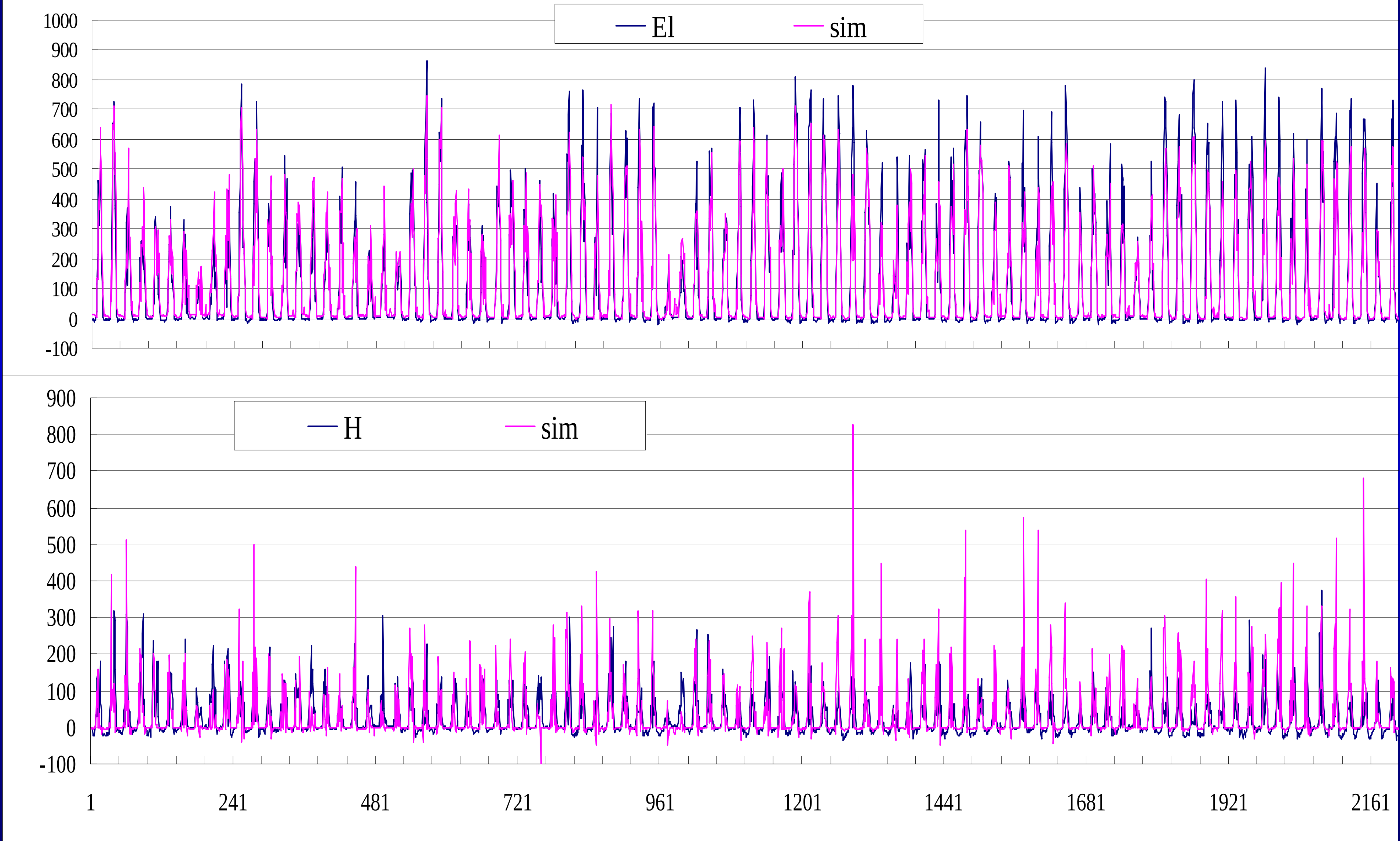
2 Deciduous Forest

3 Cassava

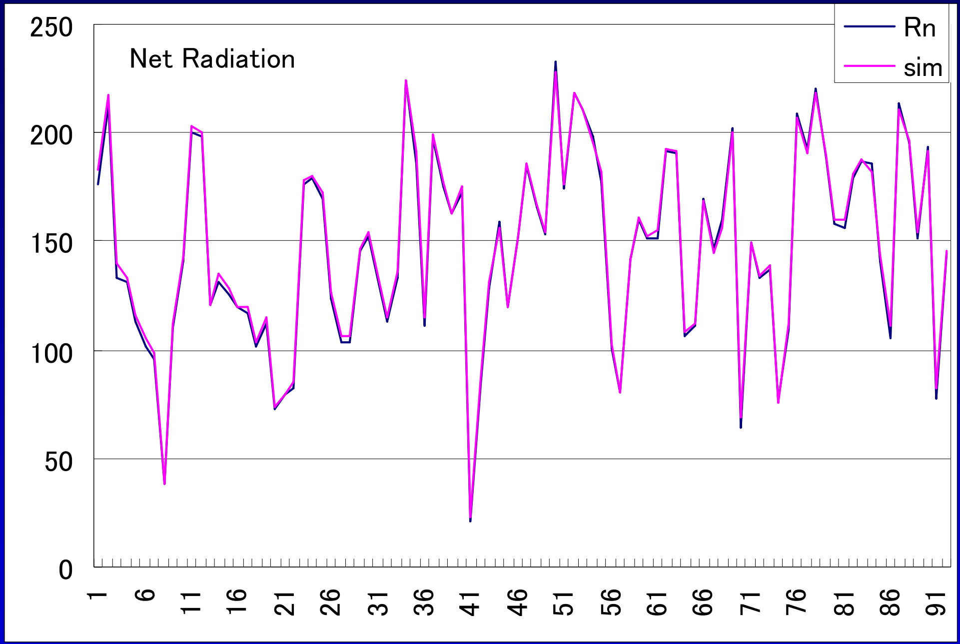
Validation at one-D: the Cassava Site (July 2nd ~ Oct. 1st, 2001)

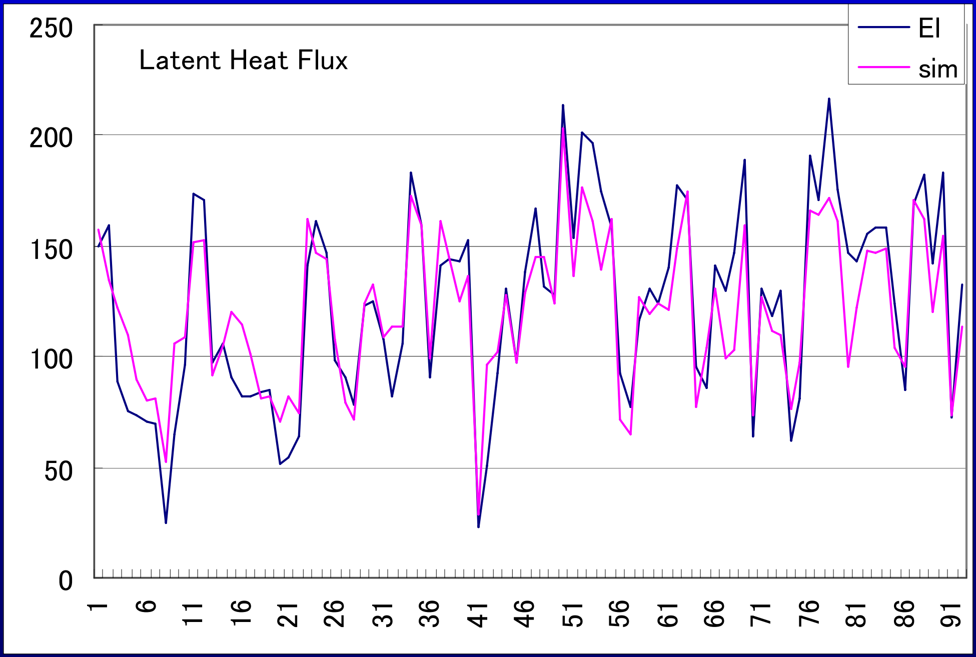


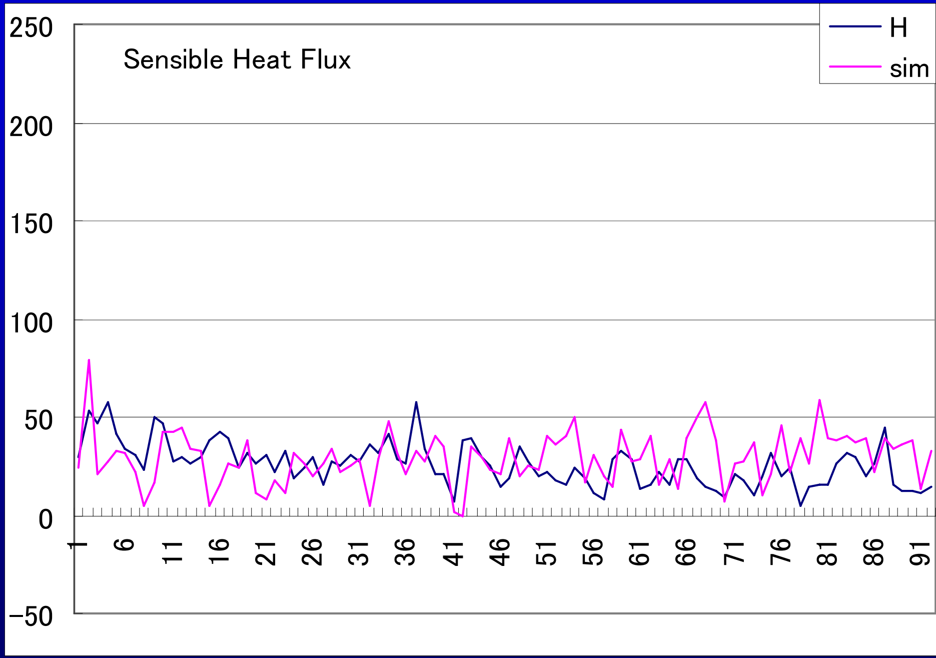
Validation at one-D: the Deciduous Forest Site (July 2nd ~ Oct. 1st, 2001)



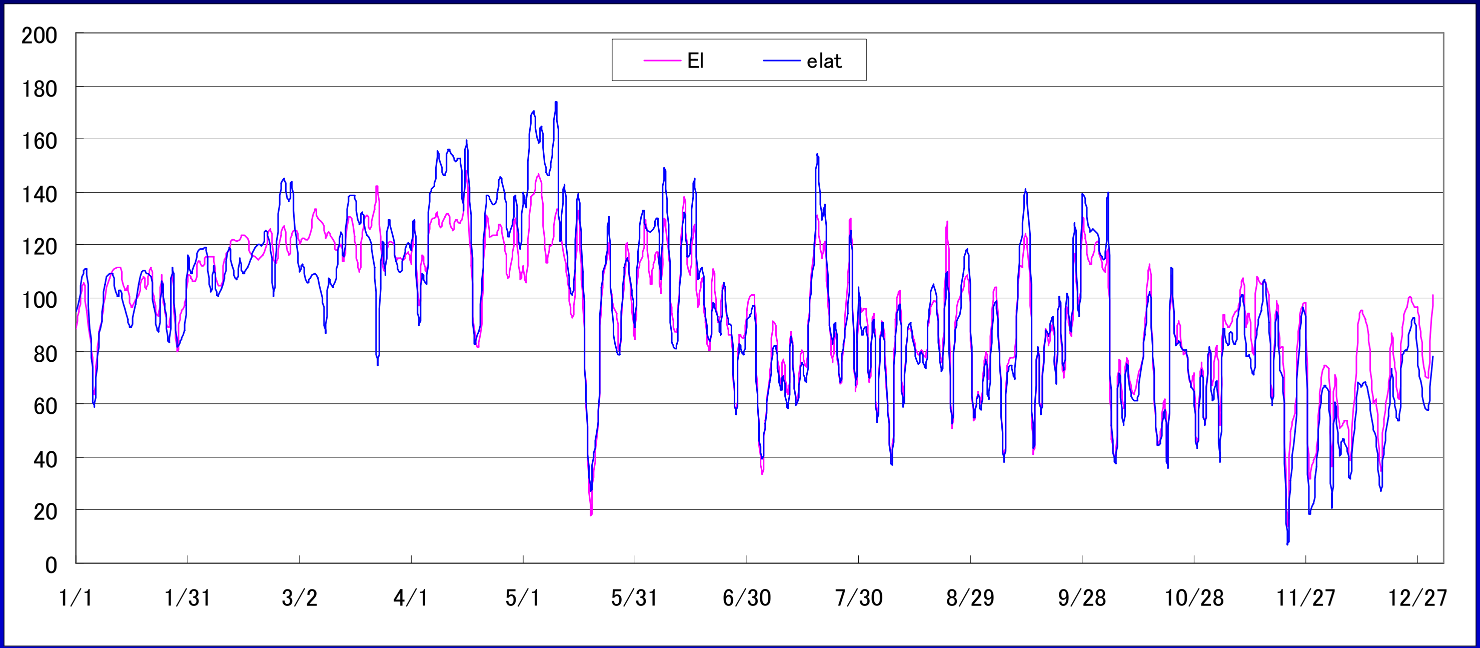
Validation at one-D: the Deciduous Forest Site (July 2nd ~ Oct. 1st, 2001)

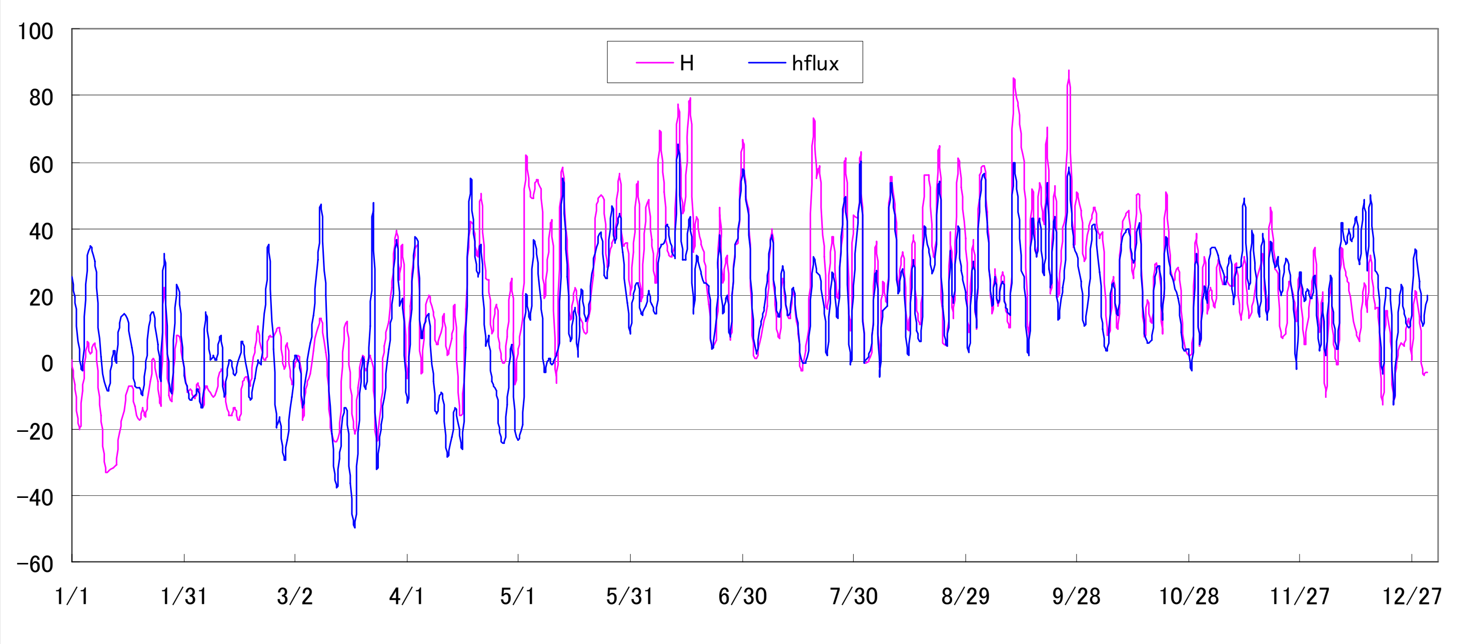






Validation at one-D: the Deciduous Forest Site (Jan. 1st ~ Dec. 31st, 1998)





Conclusion

- Soil - vegetation – atmosphere transfer processes could be the the key to simulating the water cycle specially in many water-stressed regions
- From the viewpoint of water resources management, it needs a basin-scale land surface model that can deal with the river discharge and groundwater flow
- The present research showed a potential possibility of developing a common Land Surface Model for more wider uses for atmospheric and hydrological purposes

Thank You !