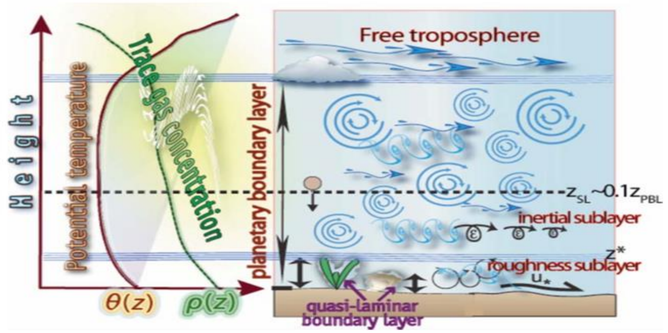
PARAMETRIZAÇÕES
Superfície

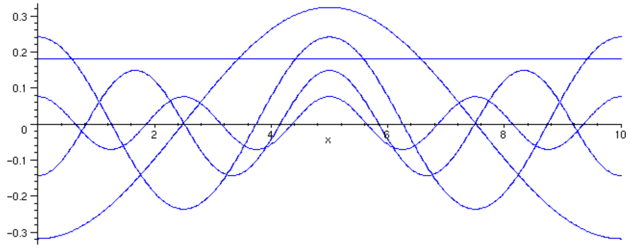
$$|\tau_z| = \rho\sqrt{[(\overline{w'u'})^2 + (\overline{w'v'})^2]}$$

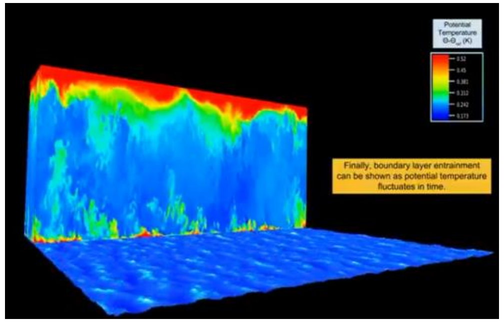
$$H = \rho_a c_{pd}\overline{w'\theta_v{}'}$$

$$\mathrm{Ef} = \rho_a L_v \overline{w'q'}$$

J. Sommar et al.







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Previsão Numérica de Tempo e Clima

lei do gas $\bar{p} = \bar{\rho} R_d \bar{T}_v$ $\qquad \overline{T}_v = T(1+0.61q_v - q_l)$

Temperatura virtual

Necessita ser parametrizado !

2nd ordem

Média de Reynolds

$$A = \overline{A} + A'$$

momentum

$$\frac{\partial \overline{u_i}}{\partial t} + \overline{u_j}\frac{\partial \overline{u_i}}{\partial x_j} = -\delta_{i3} g + f_c \varepsilon_{ij3} \overline{u_j} - \frac{1}{\overline{\rho}}\frac{\partial \overline{P}}{\partial x_i} + \frac{\nu \partial^2 \overline{u_i}}{\partial x_j{}^2} - \frac{\partial \overline{(u_i' u_j')}}{\partial x_j}$$

Advecção media | gravidade | Coriolis | Gradiente de Pressão | Estresse Viscoso | Transporte Turbulento

Eq. Continuidade

$$\frac{\partial \overline{u_i}}{\partial x_j} = 0$$

Calor

$$\frac{\partial \overline{\theta}}{\partial t} + \overline{u_j}\frac{\partial \overline{\theta}}{\partial x_j} = -\frac{1}{\overline{\rho} c_p}\frac{\partial \overline{F_j}}{\partial x_j} - \frac{\partial \overline{u_j' \theta'}}{\partial x_j} - \frac{L_v E}{\overline{\rho} c_p}$$

Advecção media | radiação | Transporte Turbulento | Liberação de Calor Latente

Agua Total

$$\frac{\partial \overline{q_t}}{\partial t} + \overline{u_j}\frac{\partial \overline{q_t}}{\partial x_j} = \frac{S_{q_t}}{\overline{\rho}} - \frac{\partial \overline{u_j' q_t'}}{\partial x_j}$$

Advecção media | precipitação | Transporte Turbulento

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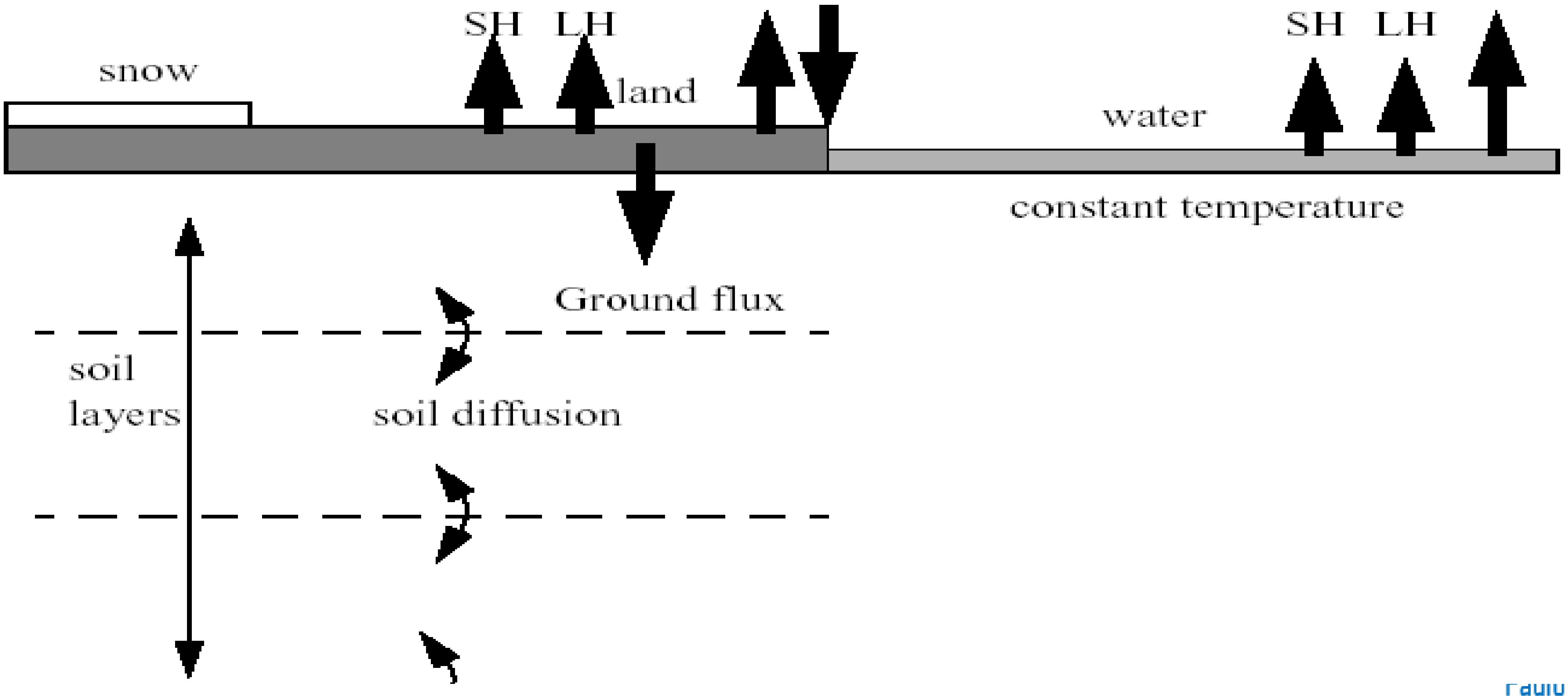
Processos na superfície



- Assume-se que o gradiente médio (temperatura ou umidade) dirige o fluxo turbulento (calor ou umedecimento)

Magnitude of Reynolds stress at ground surface (8.2)

$$|\tau_z| = \rho_a\left[\left(\overline{w'u'}\right)^2 + \left(\overline{w'v'}\right)^2\right]^{1/2}$$

Kinematic vertical turbulent momentum flux ($m^2\,s^{-2}$) (8.3)

$$\overline{w'u'} = -\frac{\tau_{zx}}{\rho_a}$$

$$\overline{w'v'} = -\frac{\tau_{zy}}{\rho_a}$$

Vertical turbulent sensible-heat flux ($W\,m^{-2}$) (8.4)

$$H_f = \rho_a c_{p,d}\overline{w'\theta'_v}$$

Kinematic vert. turbulent sensible-heat flux ($m\,K\,s^{-1}$) (8.5)

$$\overline{w'\theta'_v} = \frac{H_f}{\rho_a c_{p,d}}$$

Vertical turbulent water vapor flux ($kg\,m^{-2}\,s^{-1}$) (8.6)

$$E_f = \rho_a\overline{w'q'_v}$$

Kinematic vert. turbulent moisture flux ($m\,kg\,s^{-1}\,kg^{-1}$) (8.7)

$$\overline{w'q'_v} = \frac{E_f}{\rho_a}$$

Resistência aerodinâmica [r_a]

$$\therefore \frac{1}{r_a} = C_D U_r$$

$$H = \rho_a c_{pd}\overline{w'\theta_v{}'}$$

$$\mathrm{Ef} = \rho_a L_v \overline{w'q'}$$

Condições neutras

Verma-Rosenberg model

$$C_{DN} = \frac{k^2}{\left[\ln\left(\frac{z_r}{z_0}\right)\right]^2}$$

$$H = \rho_a c_{pd} K_h \frac{\partial\overline{\theta_v}}{\partial z}$$

$$\mathrm{Ef} = \rho_a L_v K_q \frac{\partial\bar{q}}{\partial z}$$

- Onde $K_H(z)$, m^2s^{-1} é a **difusividade turbulenta para calor**, γ_d é o lapse rate adiabático

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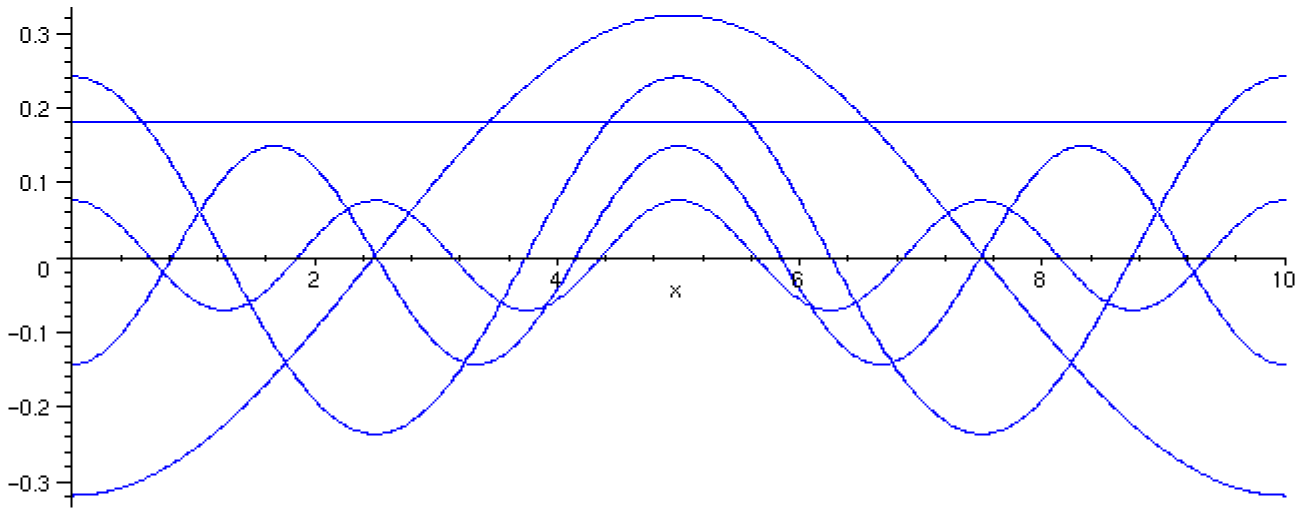
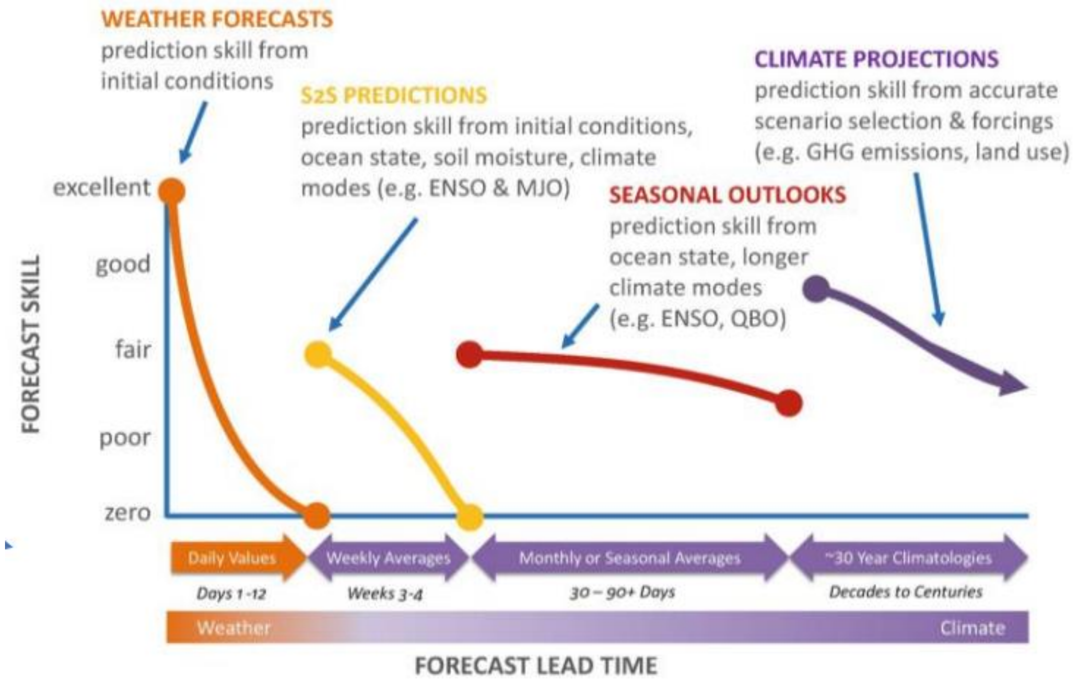
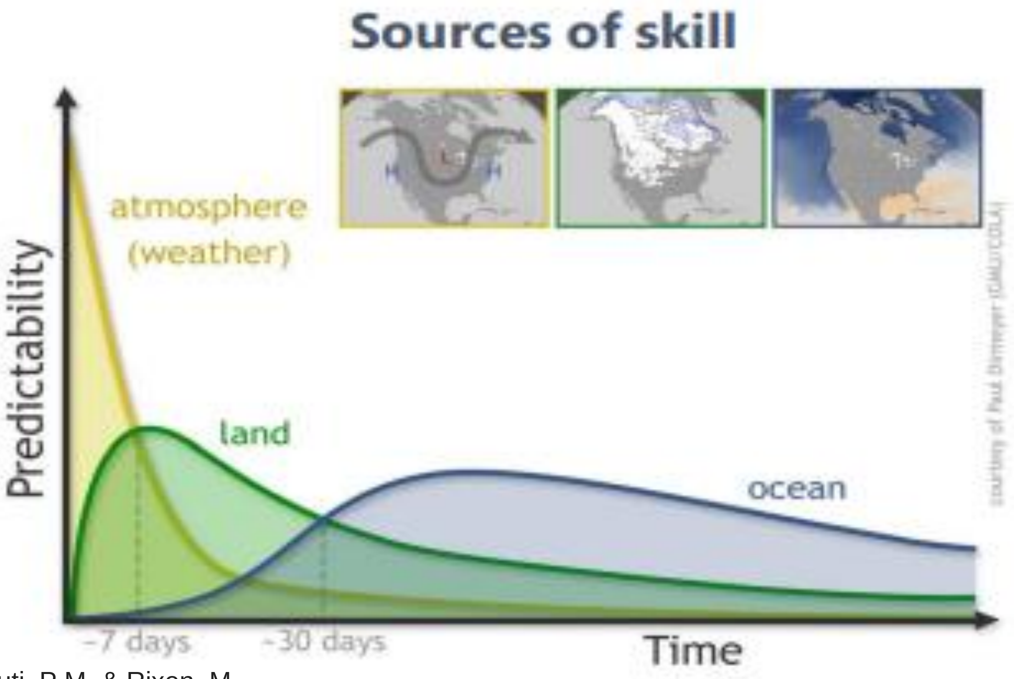
- Em outras palavras a influencia da fricção, aquecimento superficial e evaporação tem importância para previsões na escala sinótica, que aumenta com o tempo de integração (clima)





Source: Adapted from iri.columbia.edu/news/ qa-subseasonal-prediction-project.

- Fluxos superficiais são importantes no armazenagem de calor e umidade (clima) e na estabilidade (tempo e clima)
- Acredita-se que em previsões curtas é importante os prognósticos das variáveis de superfície



Source: NOAA CPO graphic adapted from original by Paul Dirmeyer, GMU/COLA

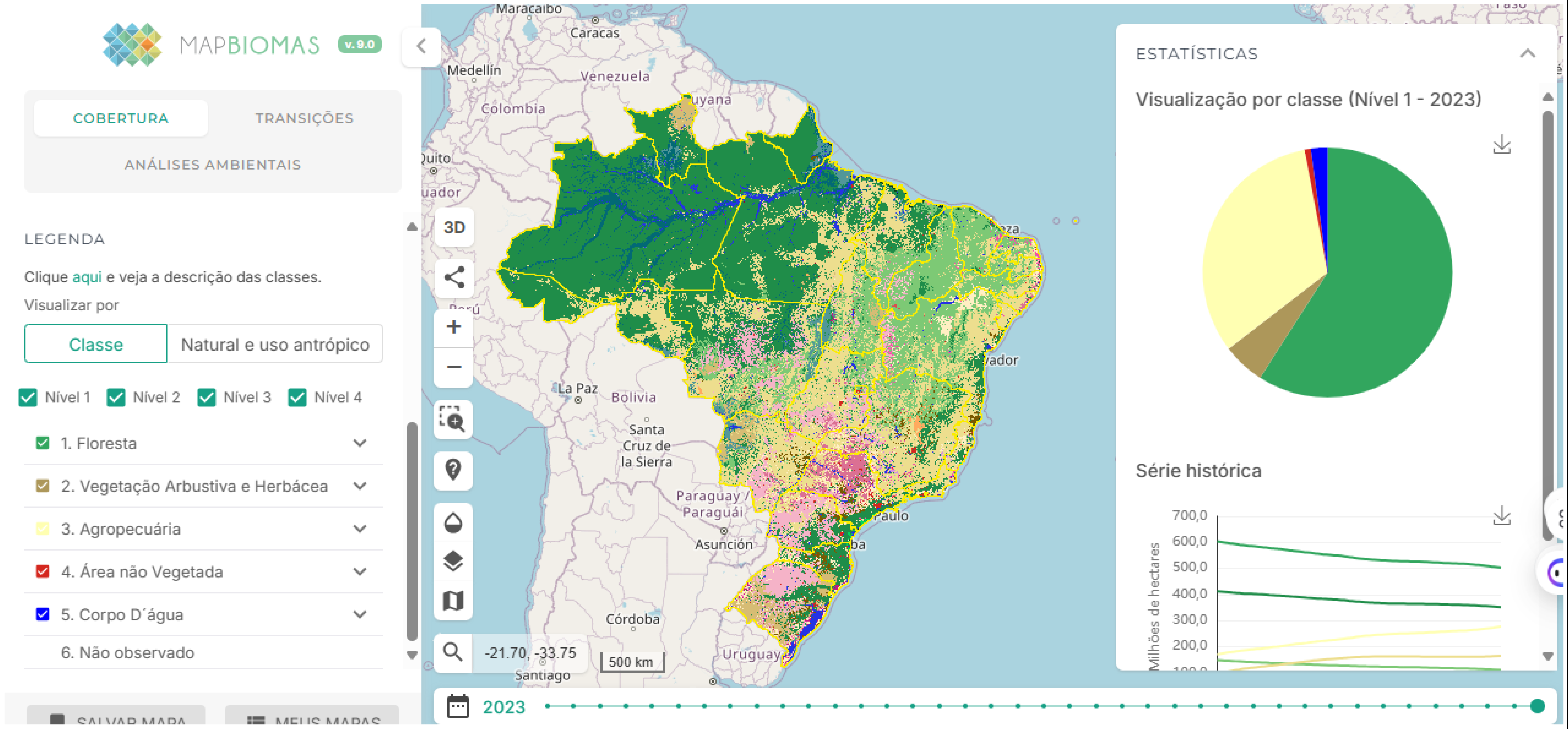
Mariotti, A., Ruti, P.M. & Rixen, M.

Source: Adapted from iri.columbia.edu/news/ qa-subseasonal-prediction-project.

Superfície

- A superfície do planeta corresponde à condição de contorno inferior para os movimentos atmosféricos;
- A absorção da energia solar na superfície é motor para os movimentos atmosféricos;
- As variações verticais mais abruptas nas variáveis atmosféricas ocorrem nas camadas próximas à superfície.

Previsão Numérica de Tempo e Clima



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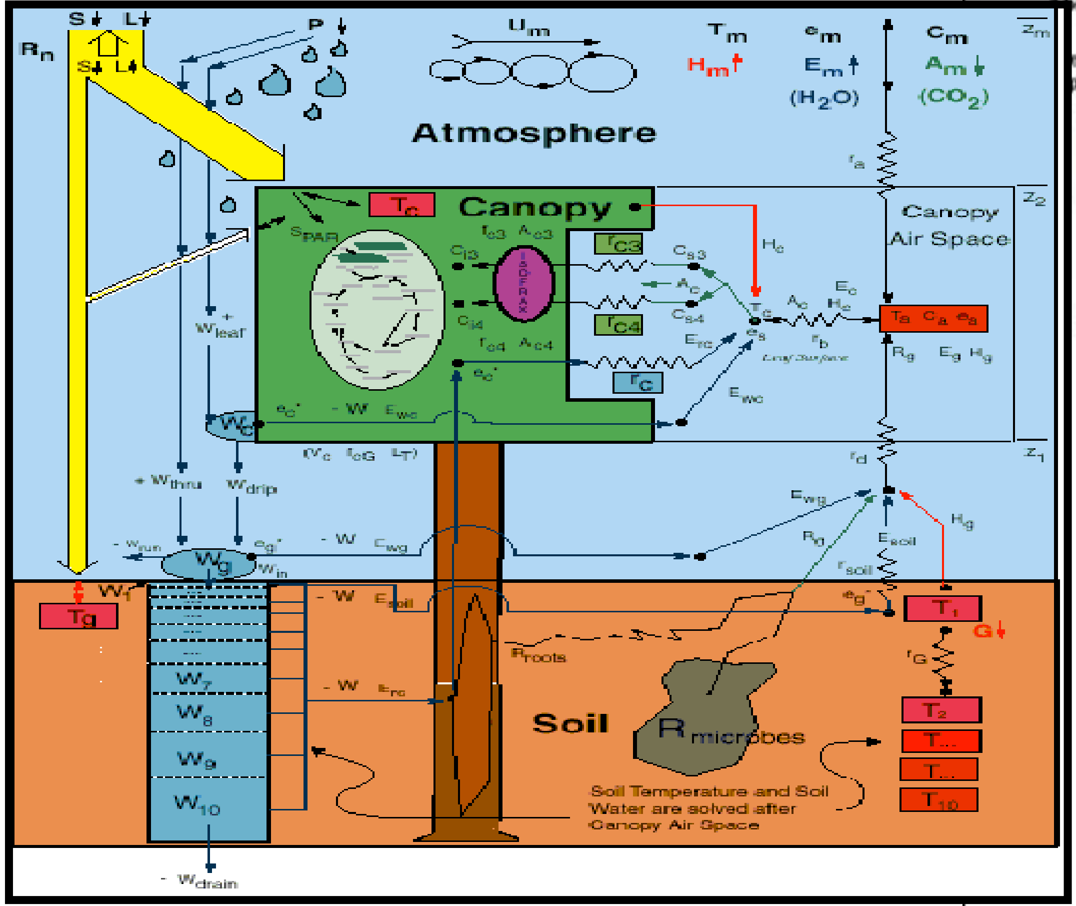
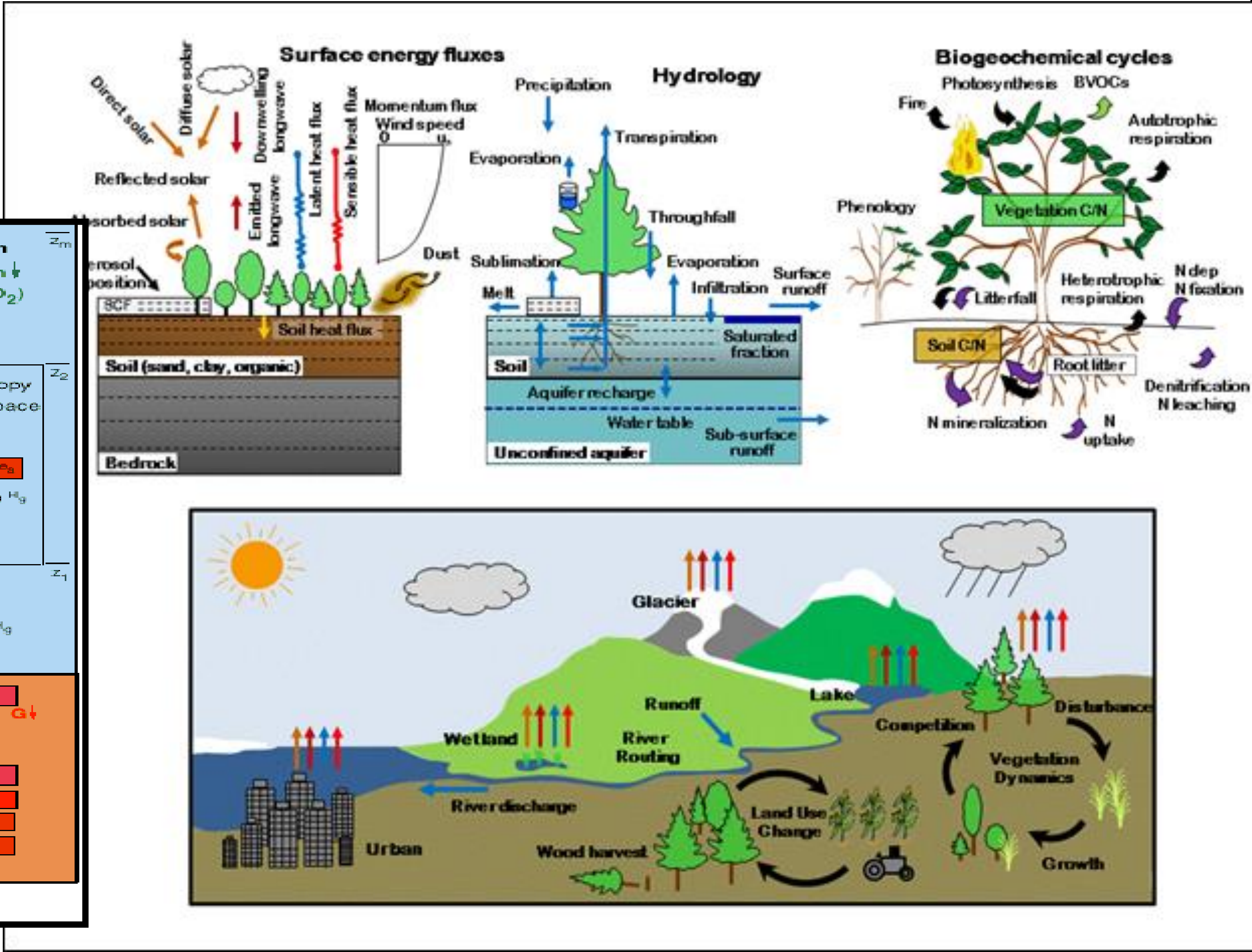
Superfície

- Umidade da superfície (fluxo de calor latente)
- Temperatura da superfície (fluxo de calor sensível)
- Radiação refletida na superfície
- Partição de energia
- Balanço de água no solo

Processos


Atmosphere
Canopy
Canopy Air Space
Soil
Soil Temperature and Soil Water are solved after Canopy Air Space


Surface energy fluxes
Hydrology
Biogeochemical cycles
Direct solar
Diffuse solar
Downwelling longwave
Latent heat flux
Sensible heat flux
Momentum flux
Wind speed
Reflected solar
Absorbed solar
Emitted longwave
Dust
Soil heat flux
Soil (sand, clay, organic)
Bedrock
Precipitation
Transpiration
Evaporation
Throughfall
Sublimation
Melt
Infiltration
Surface runoff
Saturated fraction
Soil
Aquifer recharge
Water table
Sub-surface runoff
Unconfined aquifer
Photosynthesis
BVOCs
Fire
Autotrophic respiration
Phenology
Vegetation C/N
Litterfall
Heterotrophic respiration
N dep
N fixation
Soil C/N
Root litter
Denitrification
N leaching
N mineralization
N uptake
Glacier
Lake
Runoff
Wetland
River Routing
Competition
Disturbance
Vegetation Dynamics
River discharge
Land Use Change
Urban
Wood harvest
Growth

Balanço de energia

- Temperatura à superfície:

$$(\rho C)_g D \frac{\partial T_s}{\partial t} = R_n + H + LE + G$$

$$C_g \frac{\partial T_g}{\partial t} = Rn_g - H_g - \lambda E_g - \omega C_g (T_g - T_d)$$

$$C_c \frac{\partial T_c}{\partial t} = Rn_c - H_c - \lambda E_c$$

$$C_d \frac{\partial T_d}{\partial t} = Rn_g - H_g - \lambda E_g$$

- R_n: saldo de radiação à superfície
- H: calor sensível
- LE: calor latente
- G: calor no solo
- T_s: temperatura do solo
- $(\rho C)_g$: capacidade calorífica do solo
- D: espessura da camada do solo

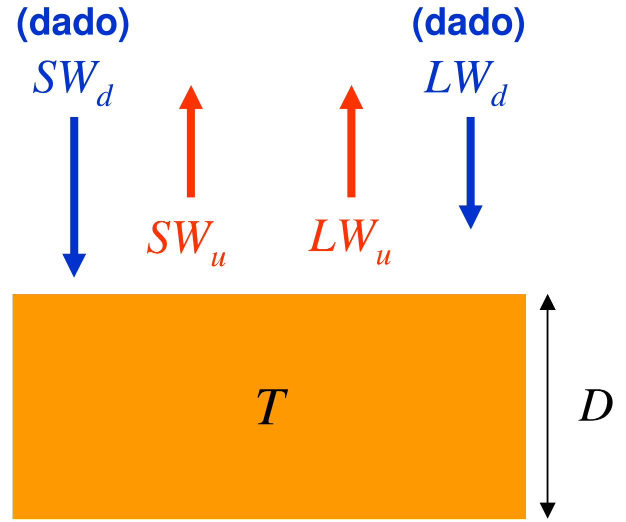
Saldo de radiação R_n

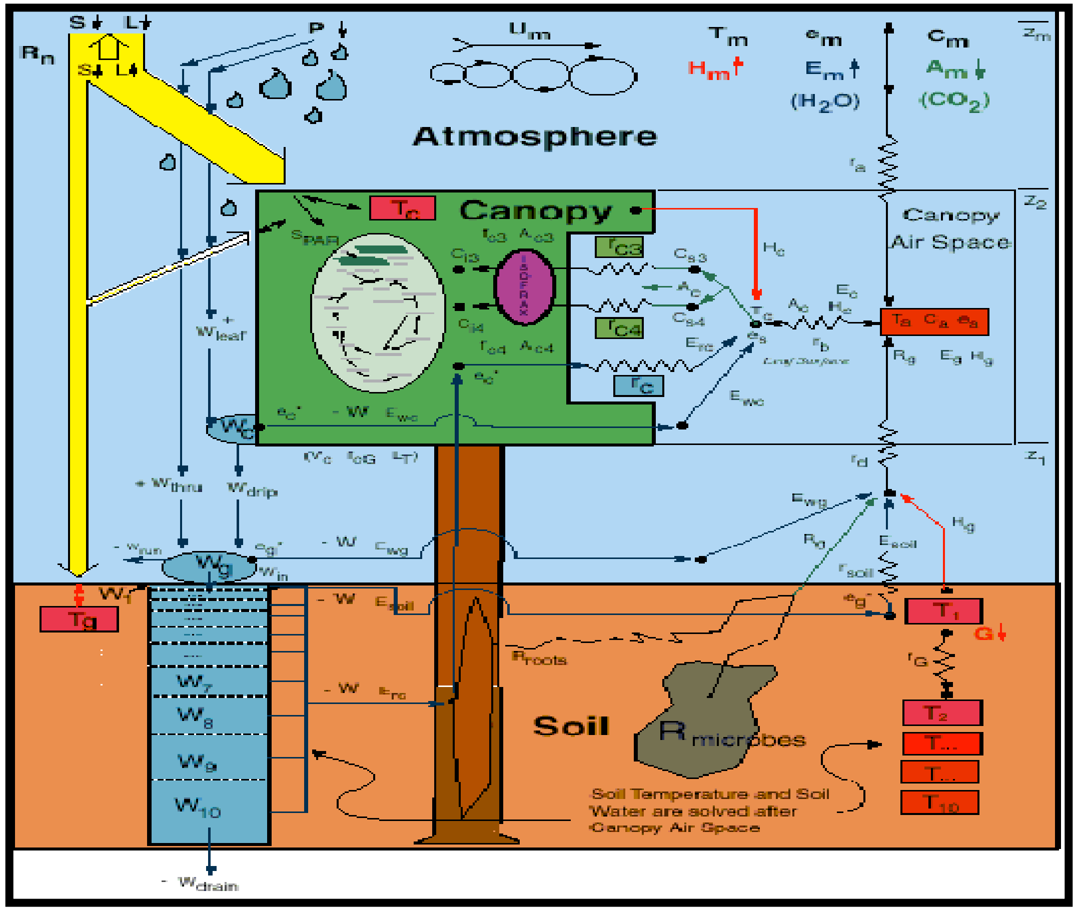
$$R_n = SW_d - SW_u + LW_d - LW_u$$

$$SW_u = \alpha SW_d$$

$$LW_u = \varepsilon\sigma T^4$$

$$R_n = (1-\alpha)R_s^{-} + \varepsilon_g R_T^{-} - \varepsilon_g \sigma T_{sk}^4$$

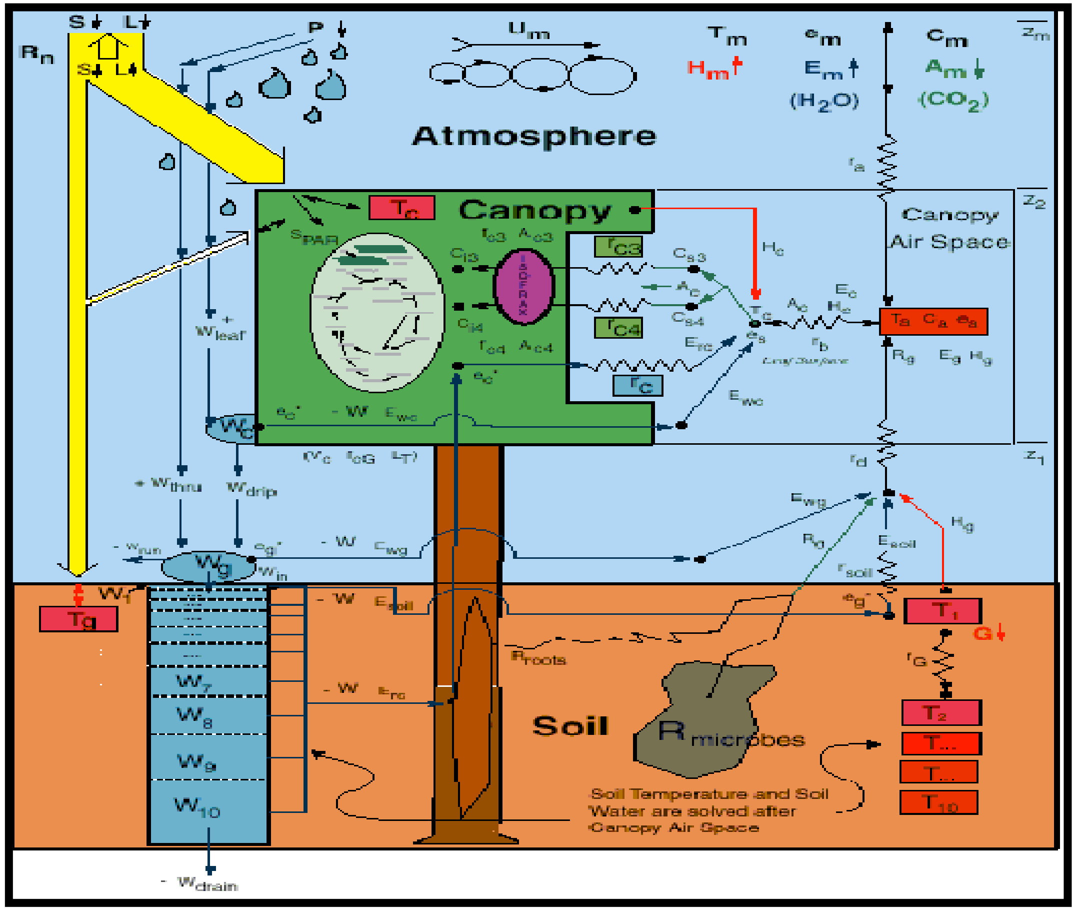




Balanço de água

$$\frac{\partial W_T}{\partial t} = P - E - (R_S + R_D)$$

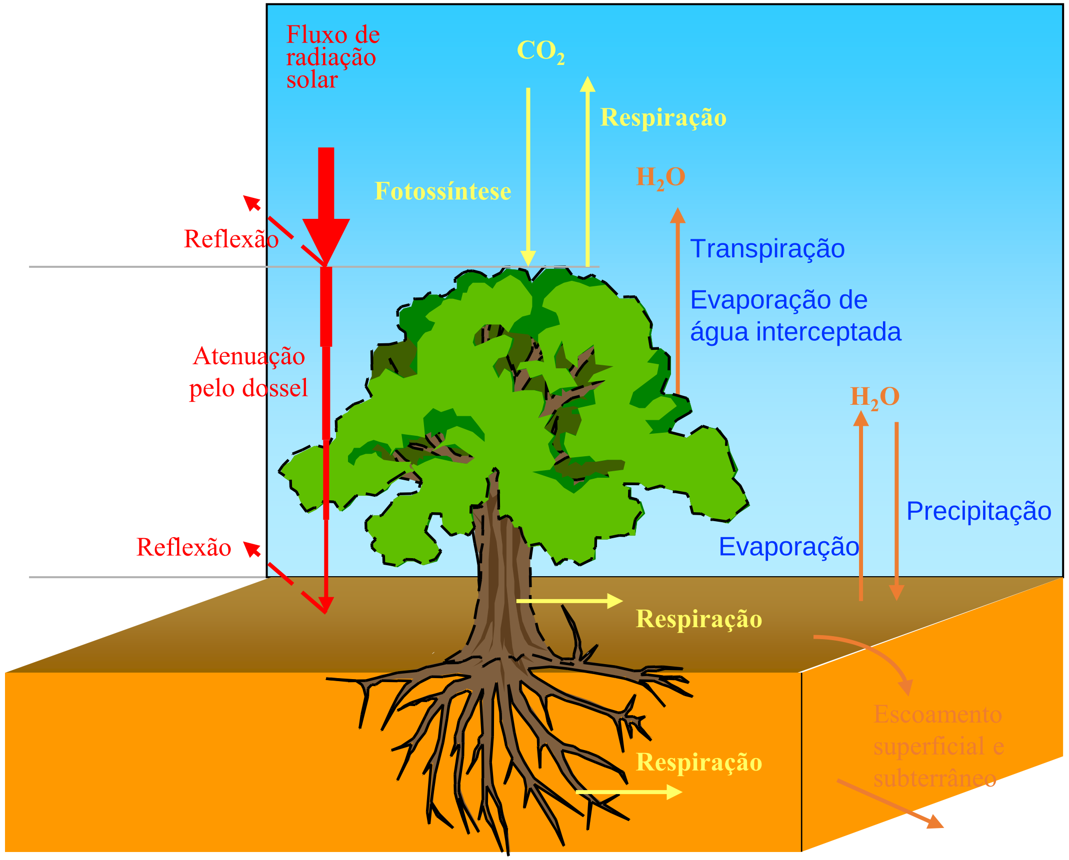
$$W_T = W + S + I$$



Balanço de água

- **Balanço Hídrico**
  - ✓ Toda água que evapora tem que precipitar em algum lugar, por essa razão a água circula continuamente entre grandes reservatórios na superfície terrestre e a atmosfera;

- **Balanço de Ciclo de Carbono**
  - ✓ Fotossíntese :processo pelo qual toda E entra na biosfera;
  - ✓ Respiração: liberação de CO_2, H_2O e energia para o meio;



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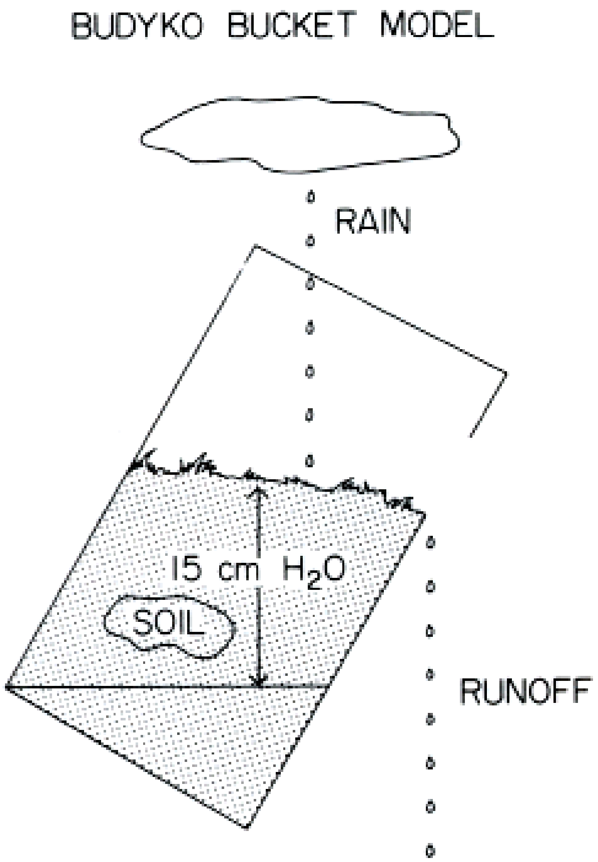
Key Model	Number Canopy Layers	Inter-ception Treated	Number of Layers Included for T	Θ	Roots	Canopy	Rationale for Temperature	Rationale for Soil moisture	Reference
A BATS1E	1	yes	2	3	2	Penman/Monteith	force-restore	Darcy's Law	Dickinson *et al* (1986, 1993)
B BEST	1	yes	3	2	2	Penman/Monteith	force-restore	Philip-de Vries	Pitman *et al* (1991) Cogley *et al* (1990)
C BUCKET	0	no	0	1	1	-	instantaneous surface heat balance	bucket + variation	Robock *et al* (1995)
D CLASS	1	yes	3	3	3	Penman/Monteith	heat diffusion	Darcy's Law	Verseghy (1991) Verseghy *et al* (1993)
E CSIRO	1	yes	3	2	1	aerodynamic	heat diffusion	force-restore	Kowalczyk *et al* (1991)
F GISS	1	yes	6	6	6	aerodynamic	aerodynamic	Darcy's Law	Abramopoulos *et al* (1988)
G ISBA	1	yes	2-3	2	1	aerodynamic	force-restore	force-restore	Noilhan and Planton (1989)
H TOPLATS	1	yes	1	2	1	Penman/Monteith	heat diffusion	Philip-de Vries	Famiglietti and Wood (1995)
I LEAF	1	yes	7	7	3	Penman/Monteith	heat diffusion	Darcy's Law	Avissar and Pielke (1989)
J LSX	2	yes	6	6	6	Penman/Monteith	heat diffusion	Philip-de Vries	-
K MAN69	0	no	1	1	1	-	-	bucket	Manabe (1969)
L MILLY	0	no	1	1	1	-	-	bucket	Manabe (1969)
M MIT	0	no	3	3	3	-	heat diffusion	Darcy's Law	Abramopoulos *et al* (1988) Entekhabi and Eagleson (1989)
N MOSAIC	1	yes	2	3	2	Penman/Monteith	-	Darcy's Law	Koster and Suarez (1992a)
O NMC-MRF	1	yes	1	1	1	lumped with soil	-	-	Pan (1990)
P CAPS	1	yes	2	2	1	Penman/Monteith	heat diffusion	diffusion	Mahrt and Pan (1984)
Q PLACE	1	yes	30	30	2	Ohm's law analogy	force-restore	force-restore	Wetzel and Chang (1988)
R RSTOM	-	no	0	1	1	-	-	bucket + variation	Milly (1992)
S SECHIBA	1	yes	2	2	1	Penman/Monteith	force-restore	Choisnel	Ducoudré *et al* (1993)
T SSIB	1	yes	2	3	1	Penman/Monteith	force-restore	diffusion	Xue *et al* (1991)
U UKMO	1	yes	4	1	1	Penman/Monteith	heat diffusion	diffusion	Warrilow *et al* (1986)
V VIC	1	yes	1	2	1	Penman/Monteith or full energy balance	heat diffusion	Philip-de Vries	Liang *et al* (1994)
W BIOME	1	yes	1	1	1	Penman/Monteith	force-restore	-	

Table 3.1 *Characteristics of several land surface parametrization schemes*

Modelo balde



Conteúdo de água muda pelo efeito da evaporação e precipitação

$$\frac{\partial W_t}{\partial t} = P - E - R_S$$

$$E = \beta E_{pot} \qquad (0 < \beta < 1)$$

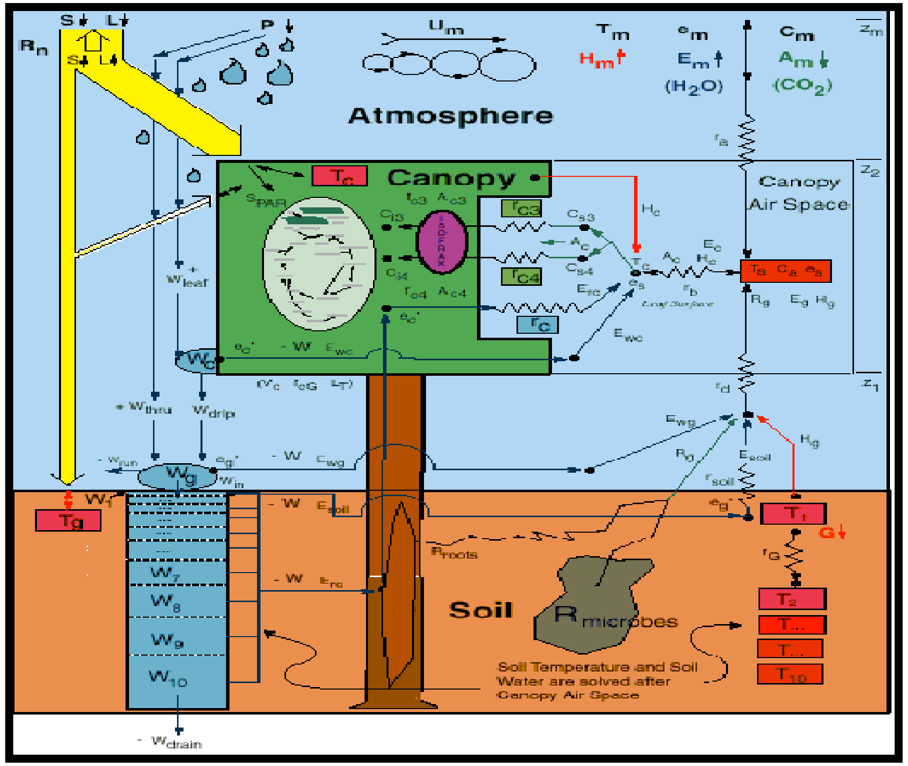
$$R = 0 \qquad (w < w_{crit})$$

$$R = P - E \qquad (w \geq w_{crit})$$

- Vantagens
  - Simples

- Limitações
  - Superestima a evaporação em condições úmidas
  - Resposta da evaporação à precipitação é lenta

Modelo com Várias Camadas de Solo



$$C\frac{\partial T}{\partial t} = \frac{\partial}{\partial z}\left(K\frac{\partial T}{\partial z}\right)$$

$$C(\tilde{\theta}_k)\frac{\partial \tilde{T}_k}{\partial t} = \frac{1}{\Delta z_k}\left[K(\theta_{k-1})\frac{\partial T}{\partial z}\Big|_{z_{k-1}} - K(\theta_{k-1})\frac{\partial T}{\partial z}\Big|_{z_k}\right]$$

$$\frac{\partial \theta}{\partial t} = \frac{\partial}{\partial z}\left(D(\theta)\frac{\partial \theta}{\partial z}\right) + \frac{\partial K(\theta)}{\partial z}$$

$$\frac{\partial}{\partial t}\int_{z_i}^{z_{i+1}} \theta\, dz = \int_{z_i}^{z_{i+1}} \frac{\partial}{\partial z}\left(D(\theta)\frac{\partial \theta}{\partial z}\right) dz + \int_{z_i}^{z_{i+1}} \frac{\partial K(\theta)}{\partial z} dz$$

Modelo com Várias Camadas de Solo

$$-\left[\frac{\Delta t}{C(\tilde{\theta}_k)}\frac{1}{(\Delta z)_k}\frac{K(\theta_{k-1})}{(\Delta\tilde{z})_{k-1}}\right](\tilde{T}_{k-1}^{n+1})+\left[1+\frac{\Delta t}{C(\tilde{\theta}_k)}\frac{1}{(\Delta z)_k}\frac{K(\theta_{k-1})}{(\Delta\tilde{z})_{k-1}}+\frac{\Delta t}{C(\tilde{\theta}_k)}\frac{1}{(\Delta z)_k}\frac{K(\theta_k)}{(\Delta\tilde{z})_k}\right]\tilde{T}_k^{n+1}-\frac{\Delta t}{C(\tilde{\theta}_k)}\frac{1}{(\Delta z)_k}\frac{K(\theta_k)}{(\Delta\tilde{z})_k}(\tilde{T}_{k+1}^{n+1})=\tilde{T}_k^n$$

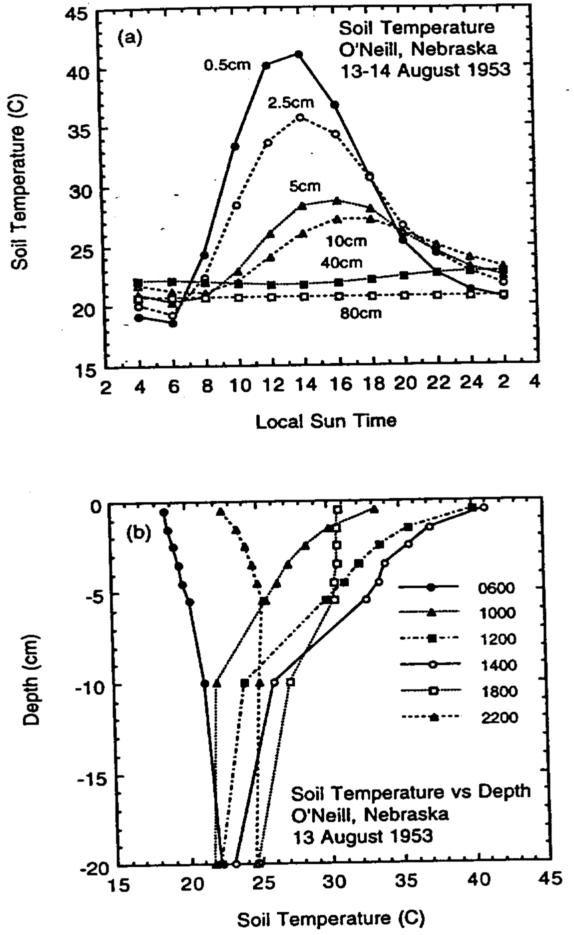
$$-C\phi_{j-1}^{n+1}+(1+C)\phi_j^{n+1}=\phi_j^n$$

$$\begin{pmatrix} 1+C & 0 & 0 & 0 & 0 & 0 & -C \\ -C & 1+C & 0 & 0 & 0 & 0 & 0 \\ 0 & -C & 1+C & 0 & 0 & 0 & 0 \\ 0 & 0 & -C & 1+C & 0 & 0 & 0 \\ \ddots & \ddots & \ddots & \ddots & \ddots & \ddots & \ddots \\ 0 & 0 & 0 & 0 & -C & 1+C & 0 \\ 0 & 0 & 0 & 0 & 0 & -C & 1+C \end{pmatrix}\begin{pmatrix} \phi_1^{n+1} \\ \phi_2^{n+1} \\ \phi_3^{n+1} \\ \phi_4^{n+1} \\ \vdots \\ \phi_{j-2}^{n+1} \\ \phi_{j-1}^{n+1} \end{pmatrix}=\begin{pmatrix} \phi_1^n \\ \phi_2^n \\ \phi_3^n \\ \phi_4^n \\ \vdots \\ \phi_{j-2}^n \\ \phi_{j-1}^n \end{pmatrix}$$

Modelo com Várias Camadas de Solo

Fluxo de calor no solo [G]

Fonte: adaptado de Hartmann, 1994



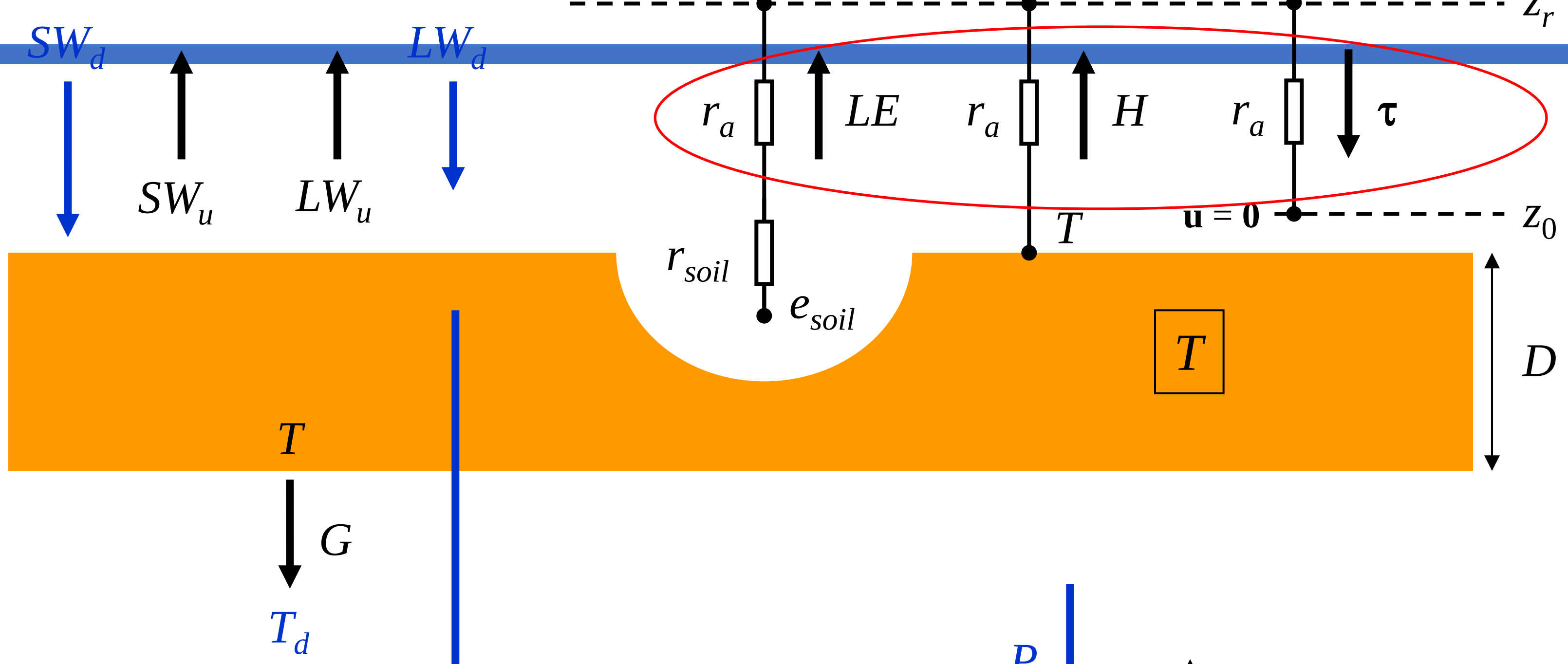
$$(1-\alpha)S^{\downarrow} + L^{\downarrow} - \sigma T_s^4 = G + H + LE$$

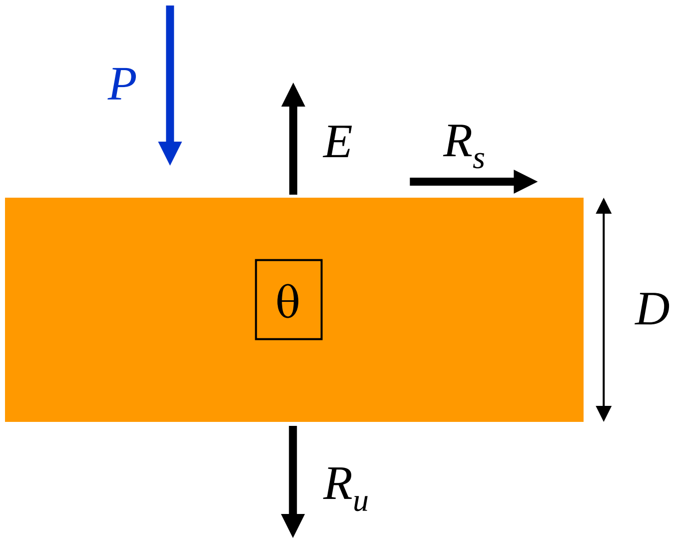
Maiores variações nas camadas mais superficiais

$$C\frac{\partial T}{\partial t} = \frac{\partial}{\partial z}\left(K\frac{\partial T}{\partial z}\right)$$

$$\frac{\partial \theta}{\partial t} = \frac{\partial}{\partial z}\left(D(\theta)\frac{\partial \theta}{\partial z}\right) + \frac{\partial K(\theta)}{\partial z}$$

balanço de radiação





balanço de energia

$$C_s D \frac{dT}{dt} = Rn - G - H - LE$$

balanço de água

$$D \frac{d\theta}{dt} = P - E - R$$

Fluxo de momentum

$$\boldsymbol{\tau} = \rho \mathbf{u_r} / r_a$$

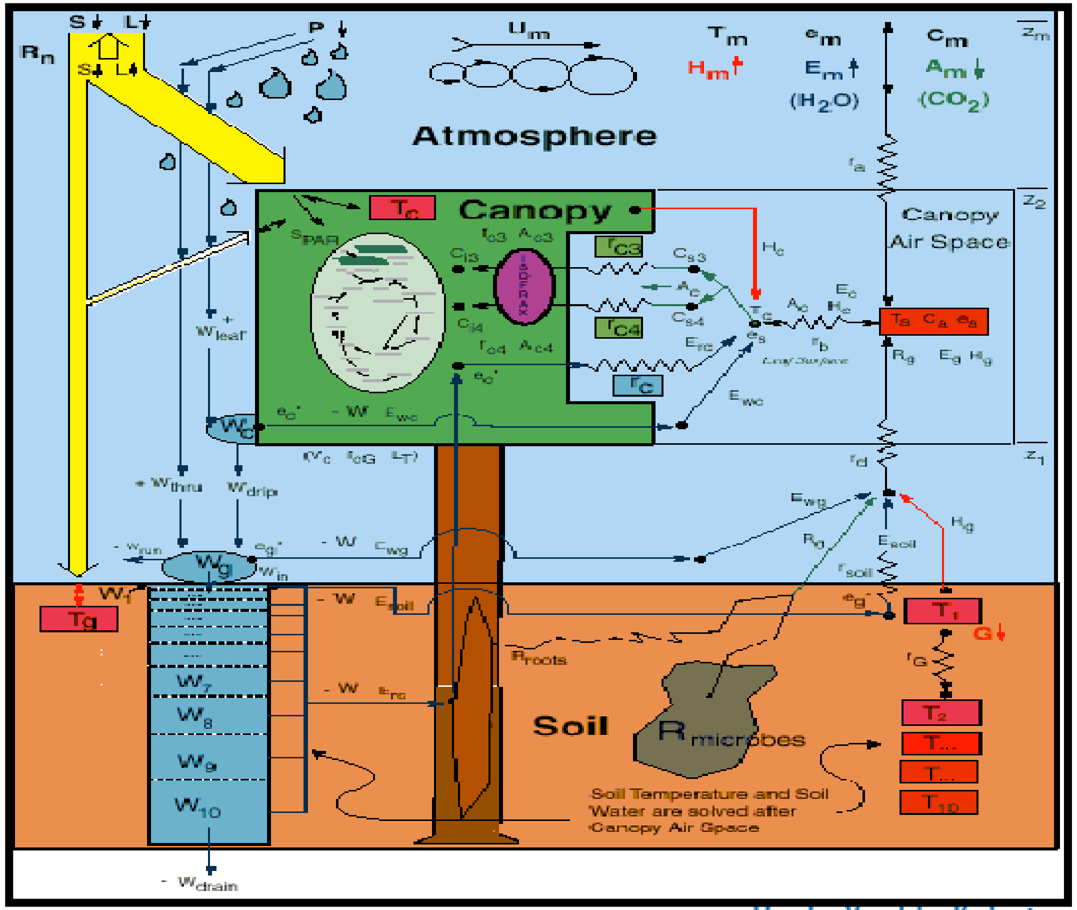
Resistência aerodinâmica [r_a]

A resistência aerodinâmica utilizada nos cálculos dos fluxos podem ser parametrizadas por Cd e Cdn

Verma-Rosenberg model $\therefore \dfrac{1}{r_a} = C_D U_r$

$$C_{DN} = \frac{k^2}{\left[\ln\left(\dfrac{z_r}{z_0}\right)\right]^2}$$

condições neutras



C_D = coeficiente de arrasto (adimensional)
C_{DN} = coeficiente (C_D) sob condições neutras
k = coeficiente de von Kárman = 0,4

$$C_s D \frac{dT}{dt} = Rn - G - H - LE$$

$$D \frac{d\theta}{dt} = P - E - R$$

$$\boldsymbol{\tau} = \rho \mathbf{u_r} / r_a$$

$$Rn = (1 - \alpha) SW_d + LW_d - \varepsilon\, \sigma T^4$$

$$G = C_s D (T - T_d) / \tau_d$$

$$H = \rho c_p (T - T_r) / r_a$$

$$LE = (\rho c_p / \gamma)[h e_s(T) - e_r] / (r_a + r_{soil})$$

Hipóteses*

α = constante ~ 0,30

ε = constante ~ 0,97

C_s = constante ~ 10^6 J m^{-3} K^{-1}

τ_d = constante ~ 1 dia / 2π

θ_s = constante ~ 0,50

z_0 = constante ~ 0,01 m

$$C_D = C_{DN} \rightarrow \frac{1}{r_a} = \frac{k^2 U_r}{[\ln(z_r / z_0)]^2}$$

$$r_{soil} = \exp[8{,}2 - 4{,}3(\theta / \theta_s)]$$

$$R = 38\ (\theta / \theta_s)^{11}$$

* Os valores se referem a solo nu.

$$C_s D \frac{dT}{dt} = Rn - G - H - LE$$

$$D \frac{d\theta}{dt} = P - E - R$$

$$\boldsymbol{\tau} = \rho \mathbf{u_r} / r_a$$

$$Rn = (1-\alpha) SW_d + LW_d - \varepsilon \sigma T^4$$

$$G = C_s D (T - T_d) / \tau_d$$

$$H = \rho c_p (T - T_r) / r_a$$

$$LE = (\rho c_p / \gamma) [h e_s(T) - e_r] / (r_a + r_{soil})$$

Magnitude of Reynolds stress at ground surface (8.2)

$$|\tau_z| = \rho_a \left[\left(\overline{w'u'}\right)^2 + \left(\overline{w'v'}\right)^2 \right]^{1/2}$$

Kinematic vertical turbulent momentum flux (m² s⁻²) (8.3)

$$\overline{w'u'} = -\frac{\tau_{zx}}{\rho_a}$$

$$\overline{w'v'} = -\frac{\tau_{zy}}{\rho_a}$$

Vertical turbulent sensible-heat flux (W m⁻²) (8.4)

$$H_f = \rho_a c_{p,d} \overline{w'\theta'_v}$$

Kinematic vert. turbulent sensible-heat flux (m K s⁻¹) (8.5)

$$\overline{w'\theta'_v} = \frac{H_f}{\rho_a c_{p,d}}$$

Vertical turbulent water vapor flux (kg m⁻² s⁻¹) (8.6)

$$E_f = \rho_a \overline{w'q'_v}$$

Kinematic vert. turbulent moisture flux (m kg s⁻¹ kg⁻¹) (8.7)

$$\overline{w'q'_v} = \frac{E_f}{\rho_a}$$

$$C \frac{\partial T}{\partial t} = \frac{\partial}{\partial z}\left(K \frac{\partial T}{\partial z}\right)$$

$$\frac{\partial \theta}{\partial t} = \frac{\partial}{\partial z}\left(D(\theta) \frac{\partial \theta}{\partial z}\right) + \frac{\partial K(\theta)}{\partial z}$$

$$C_g \frac{\partial T_g}{\partial t} = Rn_g - H_g - \lambda E_g - \omega C_g (T_g - T_d)$$

$$C_c \frac{\partial T_c}{\partial t} = Rn_c - H_c - \lambda E_c \qquad C_d \frac{\partial T_d}{\partial t} = Rn_g - H_g - \lambda E_g$$

$$\frac{\partial \overline{u_i}}{\partial t} + \overline{u_j} \frac{\partial \overline{u_i}}{\partial x_j} = -\delta_{i3} g + f_c \varepsilon_{ij3} \overline{u_j} - \frac{1}{\overline{\rho}} \frac{\partial \overline{P}}{\partial x_i} + \frac{\upsilon \partial^2 \overline{u_i}}{\partial x_j^2} - \frac{\partial (\overline{u'_i u'_j})}{\partial x_j}$$

$$\frac{\partial \overline{\theta}}{\partial t} + \overline{u_j} \frac{\partial \overline{\theta}}{\partial x_j} = -\frac{1}{\overline{\rho} c_p} \frac{\partial \overline{F_j}}{\partial x_j} - \frac{\partial \overline{u'_j \theta'}}{\partial x_j}$$

$$\frac{\partial \overline{q_t}}{\partial t} + \overline{u_j} \frac{\partial \overline{q_t}}{\partial x_j} = \frac{S_{q_t}}{\overline{\rho}} - \frac{\partial \overline{u'_j q'_t}}{\partial x_j}$$

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Mecanismos de *feedback*

- Albedo
- Evapotranspiração
- Rugosidade
- Umidade

Feedback = “realimentação”

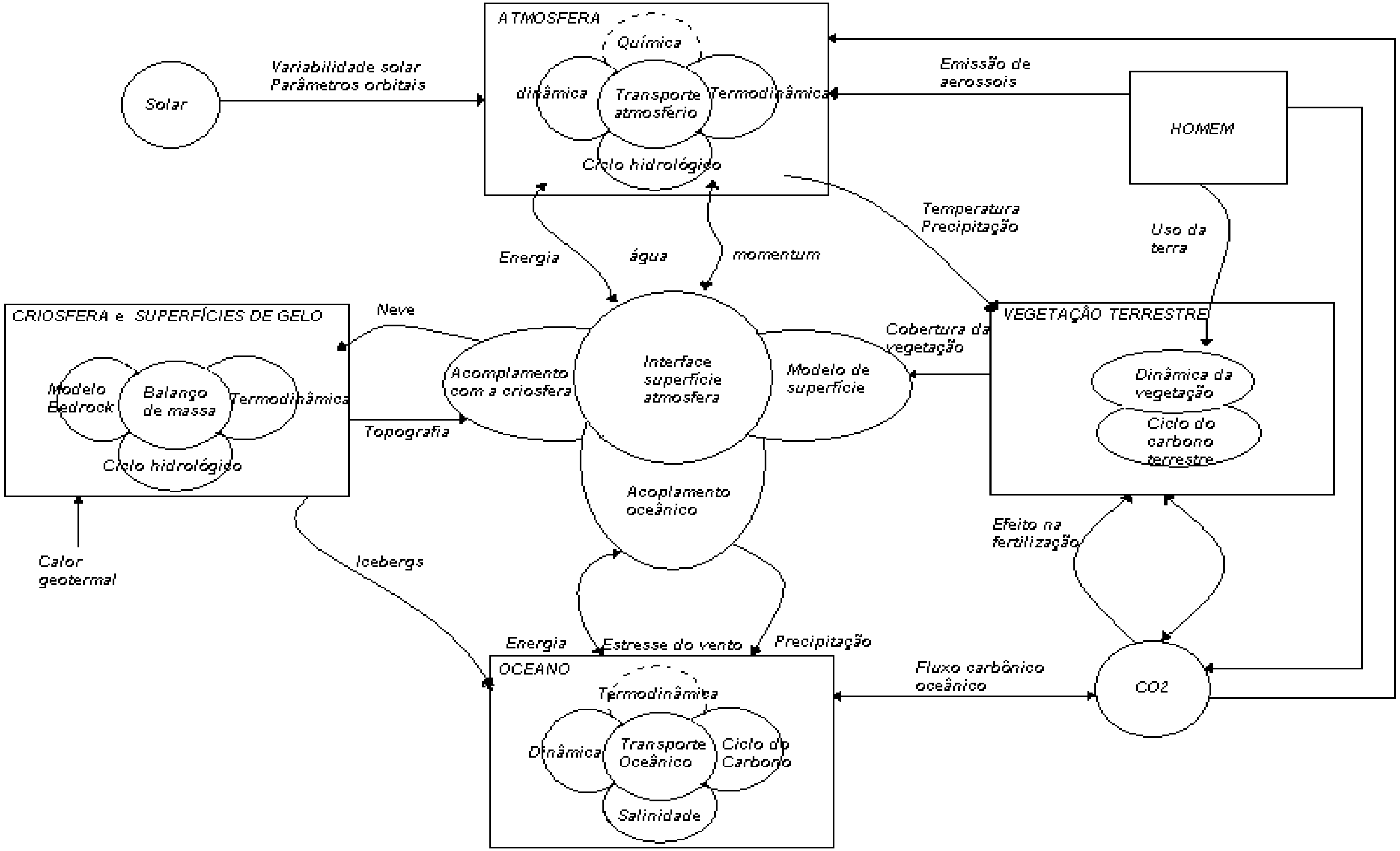
- Processo inicial influência um segundo processo que por sua vez influência o primeiro:

$$A_i \rightarrow B \rightarrow A_f$$

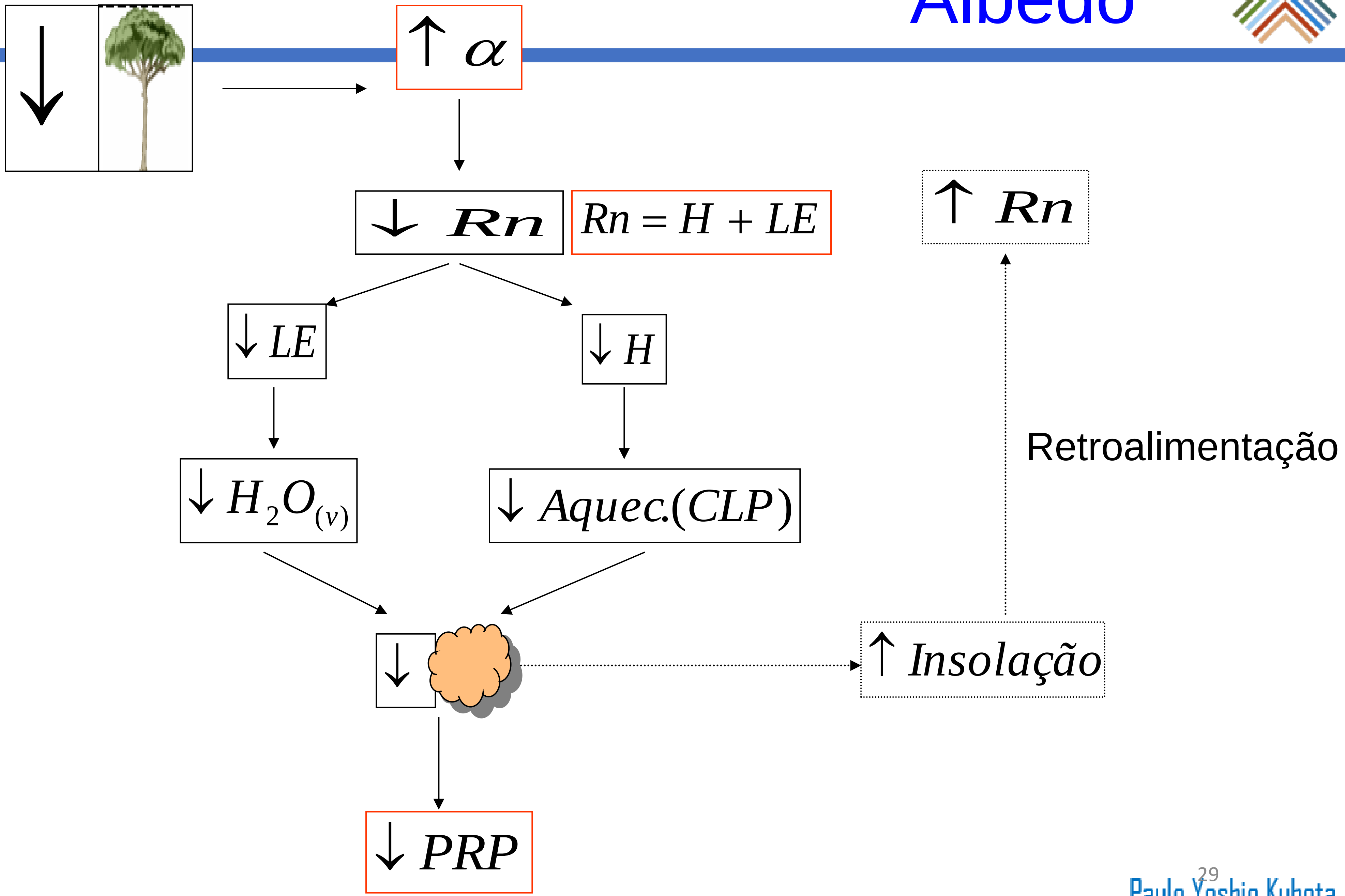
Se $A_i \uparrow \downarrow$ e $A_f \uparrow \downarrow$ Feedback positivo

Se $A_i \uparrow \downarrow$ e $A_f \downarrow \uparrow$ Feedback negativo

Sistema completo



Albedo



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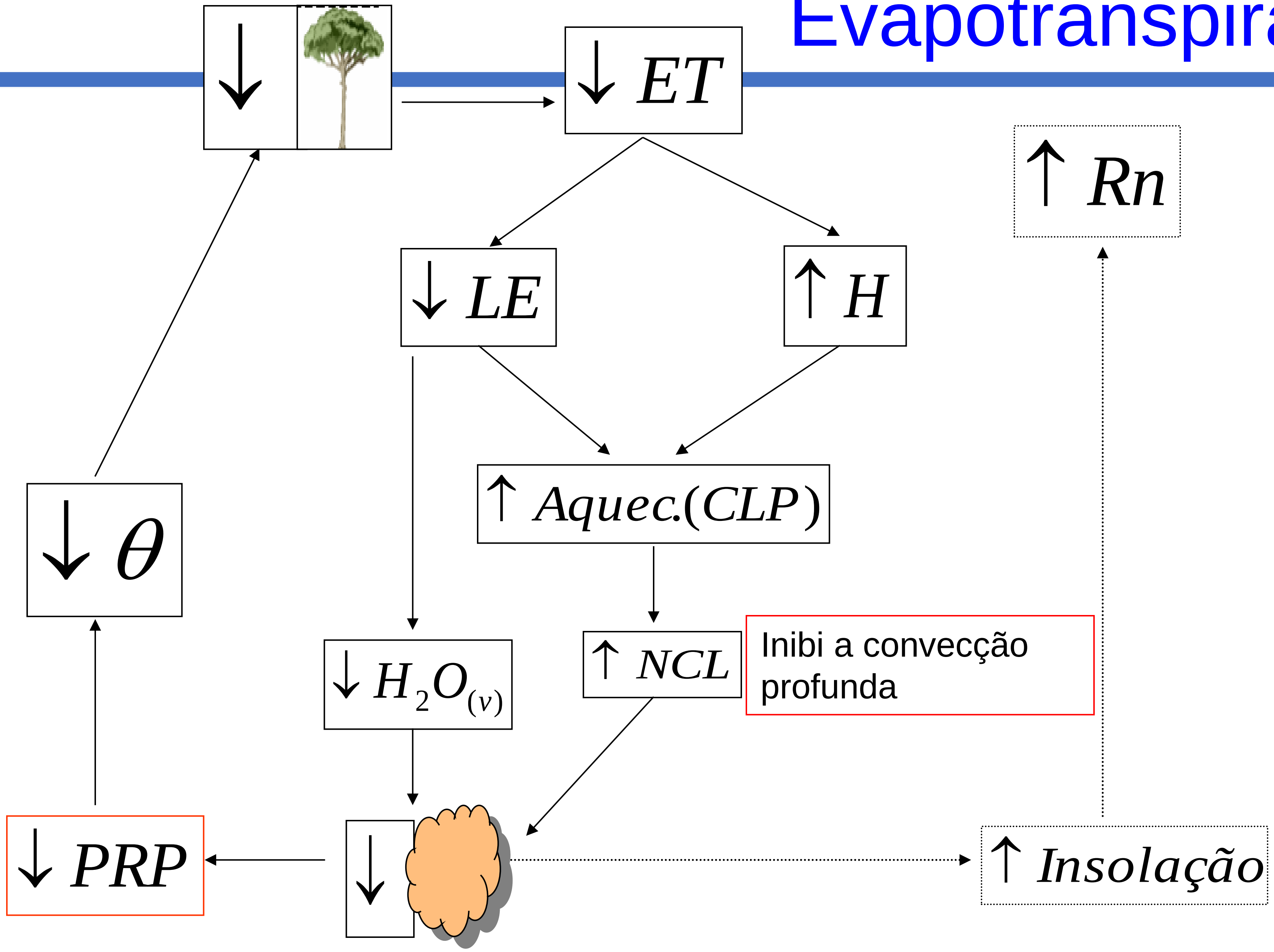
Evapotranspiração

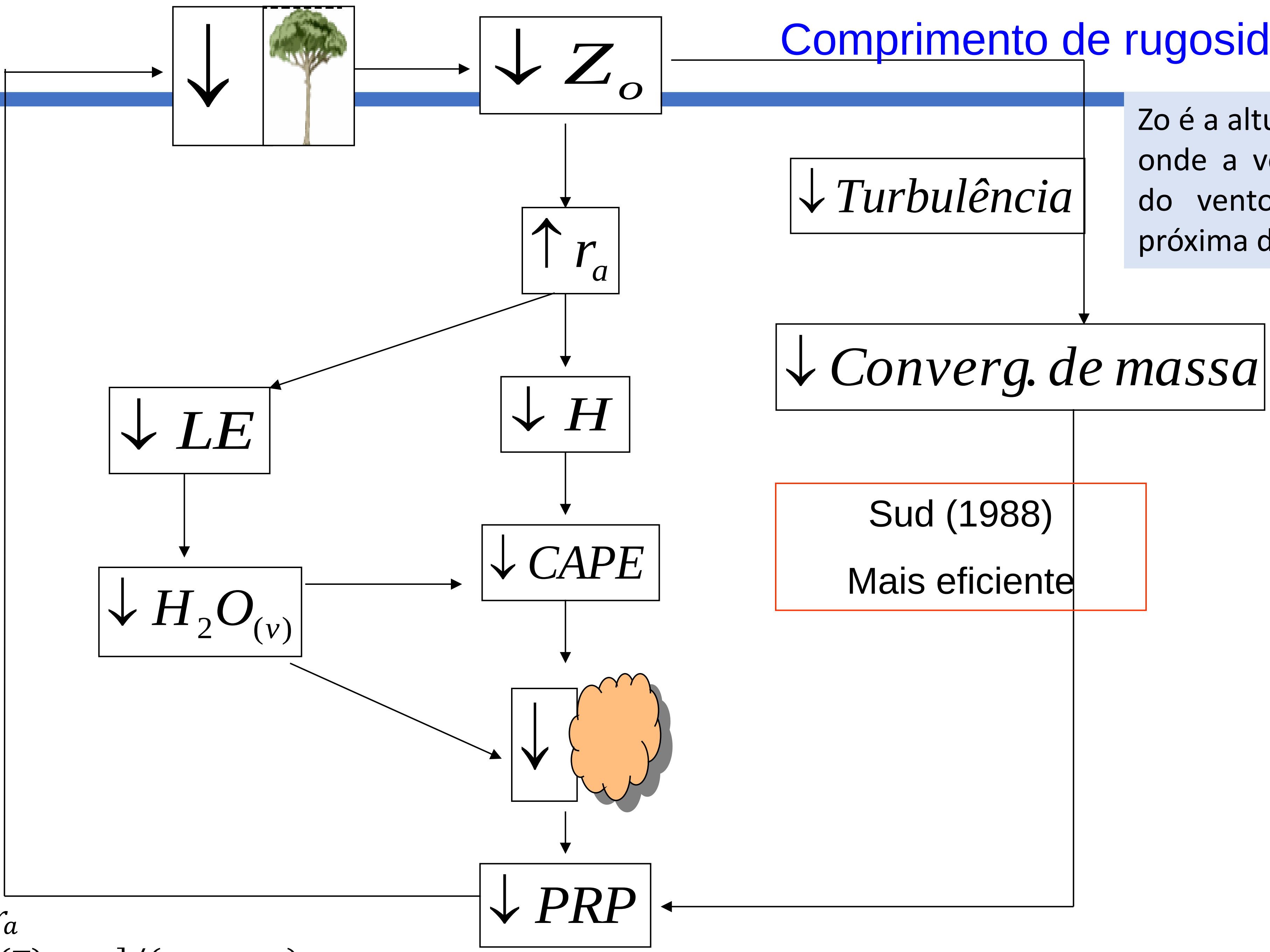


Comprimento de rugosidade - Zo

Zo é a altura média onde a velocidade do vento é bem próxima de zero.

$$\therefore \frac{1}{r_a} = C_D U_r$$

$$C_{DN} = \frac{k^2}{\left[\ln\left(\frac{z_r}{z_0}\right)\right]^2}$$



Sud (1988)

Mais eficiente

$$H = \rho c_p \, (T - T_r)/r_a$$

$$LE = (\rho c_p/\gamma)\,[h e_s(T) - e_r]/(r_a + r_{soil})$$

Mecanismo de umidade:

Anomalia de velocidade vertical devido a mudanças na cobertura vegetal em áreas adjacentes

Ramo Negativo

- mais umidade em baixos níveis
- mais instabilidade convectiva
- mais precipitação
- anomalia de velocidade ascendente

Ramo Positivo

- menos umidade em níveis médios
- inibição de convecção profunda (nuvens mais rasas)
- menos precipitação
- anomalia de velocidade subsidente

Modelos Biofísicos e Biogeoquímicos

No início as deficiências nos MCGA eram:

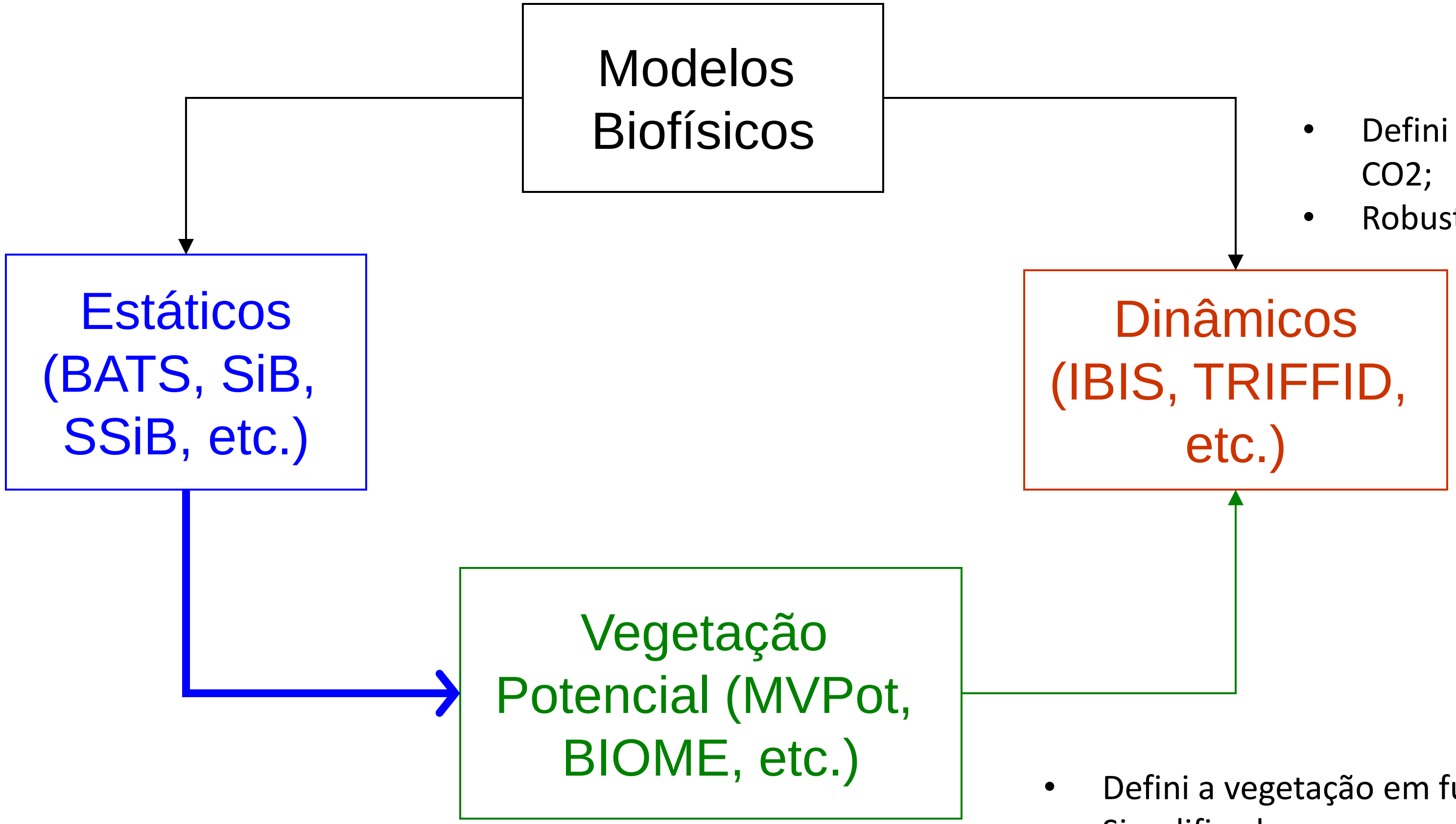
i) **Albedos não realistas**

ii) **Roughness lenght constante**

iii) **Bucket model com capacidade constante de 150 mm**

A partir da década de 80 foram criados os primeiros modelos biofísicos

Previsão Numérica de Tempo e Clima



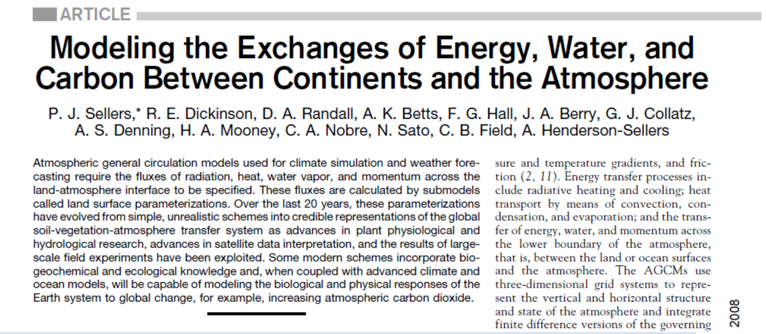
- Defini a vegetação da assimilação de CO_2;
- Robusto.

- Defini a vegetação em função do clima;
- Simplificado.

Tipos de modelos atuais de superfície de MCGA's:

- Simple Biosphere Model (SIB);
- Integrated Biosphere Simulator Model (IBIS);
- Community Land Model (CLM).

Evolução do modelo Simple Biosphere Model (SiB):


ARTICLE

Modeling the Exchanges of Energy, Water, and Carbon Between Continents and the Atmosphere

P. J. Sellers,* R. E. Dickinson, D. A. Randall, A. K. Betts, F. G. Hall, J. A. Berry, G. J. Collatz, A. S. Denning, H. A. Mooney, C. A. Nobre, N. Sato, C. B. Field, A. Henderson-Sellers

Atmospheric general circulation models used for climate simulation and weather forecasting require the fluxes of radiation, heat, water vapor, and momentum across the land-atmosphere interface to be specified. These fluxes are calculated by submodels called land surface parameterizations. Over the last 20 years, these parameterizations have evolved from simple, unrealistic schemes into credible representations of the global soil-vegetation-atmosphere transfer system as advances in plant physiological and hydrological research, advances in satellite data interpretation, and the results of large-scale field experiments have been exploited. Some modern schemes incorporate biogeochemical and ecological knowledge and, when coupled with advanced climate and ocean models, will be capable of modeling the biological and physical responses of the Earth system to global change, for example, increasing atmospheric carbon dioxide.

sure and temperature gradients, and friction (2, 11). Energy transfer processes include radiative heating and cooling; heat transport by means of convection, condensation, and evaporation; and the transfer of energy, water, and momentum across the lower boundary of the atmosphere, that is, between the land or ocean surfaces and the atmosphere. The AGCMs use three-dimensional grid systems to represent the vertical and horizontal structure and state of the atmosphere and integrate finite difference versions of the governing

2008

1986: Simple Biosphere Model – SiB (Sellers et al., 1986)

1991: Simplified Simple Biosphere Model – SSiB (Xue et al., 1991)

1996: Simple Biosphere Model 2 – SiB2 (Sellers et al., 1996)

2003: Simple Biosphere Model 2.5 SiB 2.5 (Baker et al., 2003)

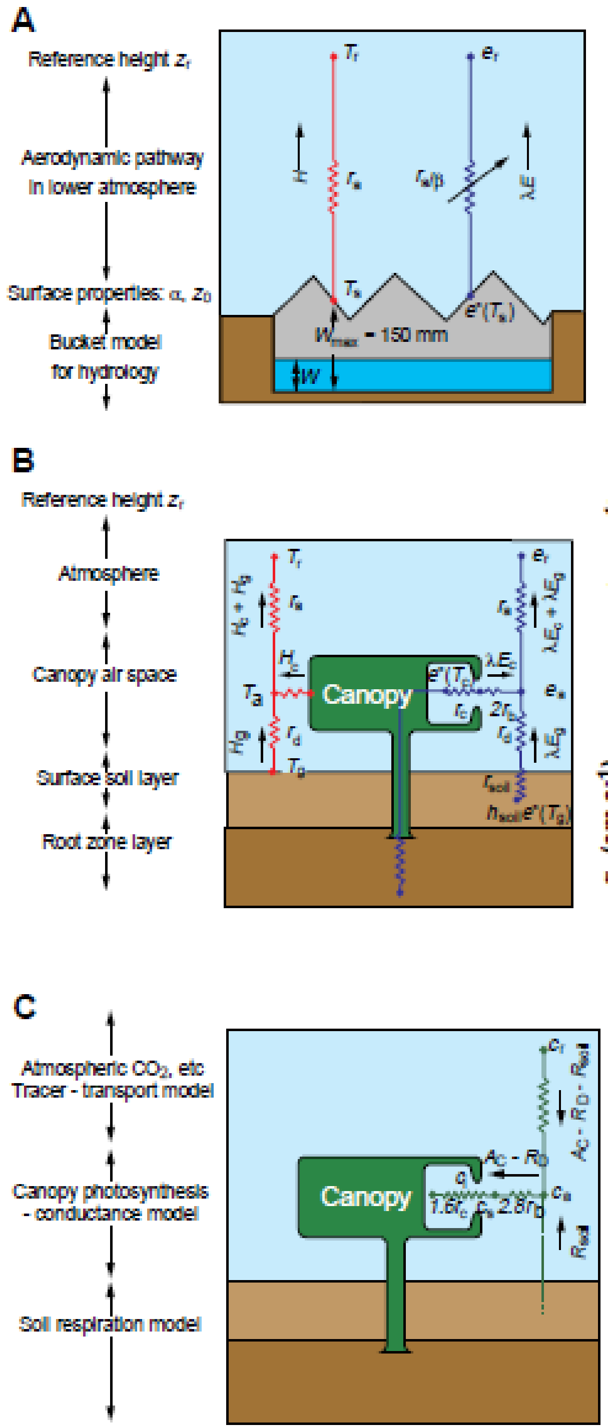
2003: Simplified Simple Biosphere Model 2 – SSiB2 (Zhan et al., 2003)

2003: Simplified Simple Biosphere Model 3 – SSiB3 (Sun e Xue, 2003)

2007: Simple Biosphere Model 3 – SiB3 (Baker et al., 2003)

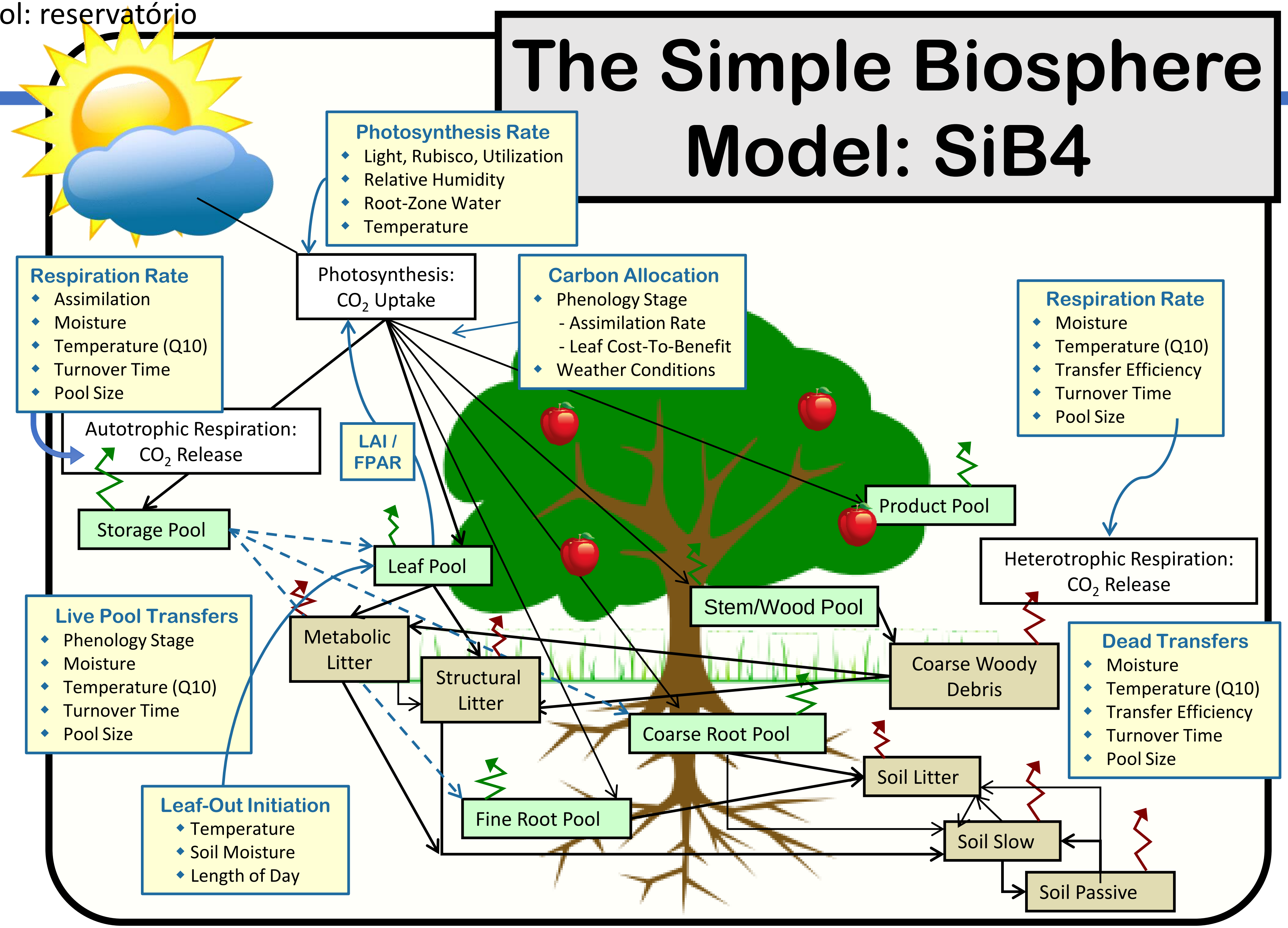
2008: Simplified Simple Biosphere Model 4 – SSiB4/TRIFFID (Xue et al., 2008)

2015: Simple Biosphere Model 4 – SiB4 (Haynes, K; Baker, I. Denning, S., 2015)



Pool: reservatório

The Simple Biosphere Model: SiB4



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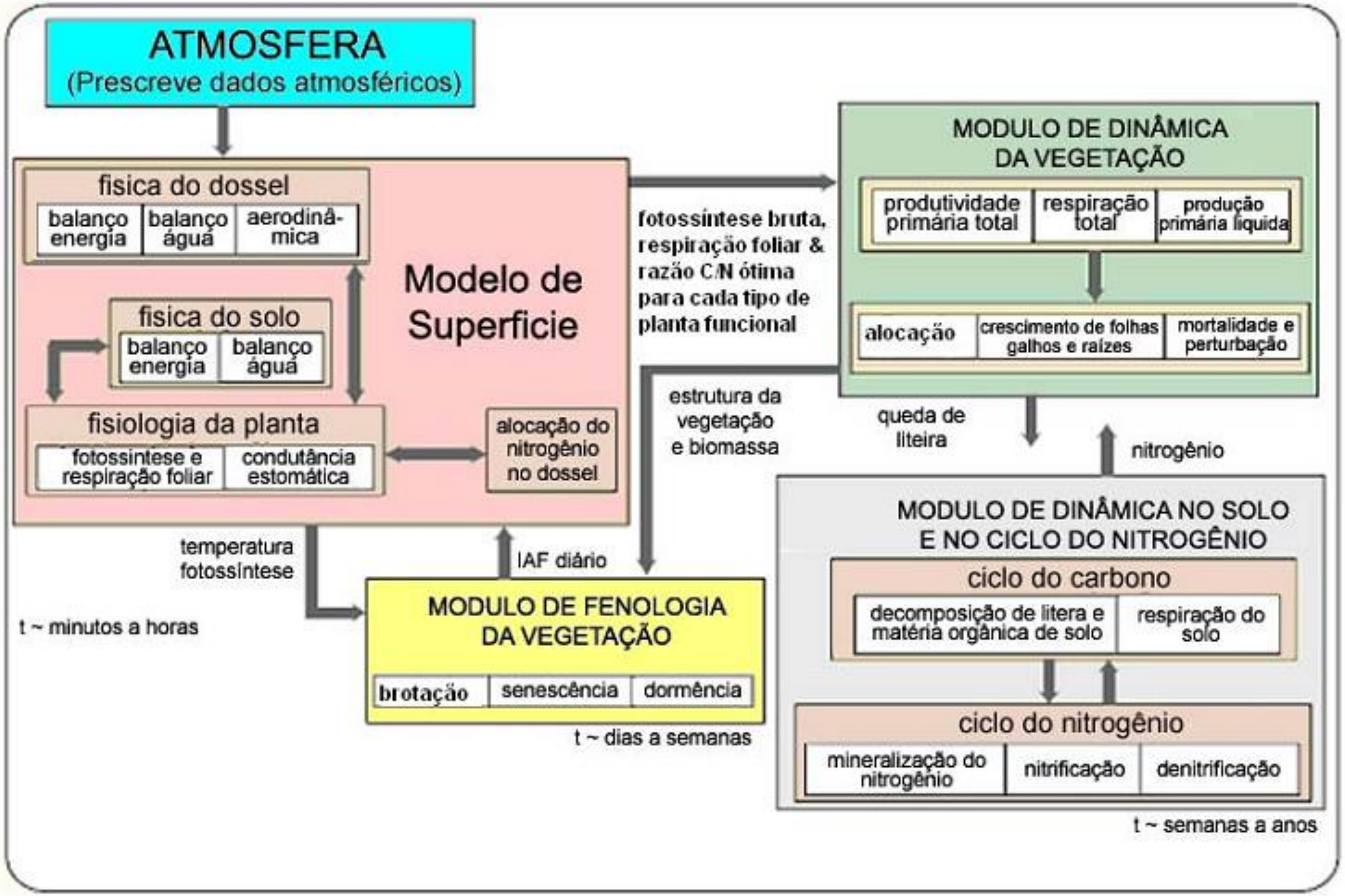
Integrated Biosphere Simulator Model (IBIS) (modelo com opção de vegetação dinâmica simples);

Estrutura básica do IBIS



Community Land Model (modelo mais sofisticado com opção de vegetação dinâmica);

CLM
COMMUNITY LAND MODEL

NCAR Earth System Laboratory (NESL)
a collaborative project between TSS and the CESM community

Overview | Model Components | Software and Documentation

UCAR > NCAR > NESL > CGD > TSS > *CLM Home*

Overview

Model Components
- Biogeophysics
- Hydrologic Cycle
- Biogeochemistry
- Dynamic Vegetation

Software and Documentation
- CLM 2.0
- CLM 2.1
- CLM 3.0
- CLM 3.5
- CLM 4.0

Welcome to the Community Land Model

The Community Land Model is the land model for the Community Earth System Model (CESM) and the Community Atmosphere Model (CAM).

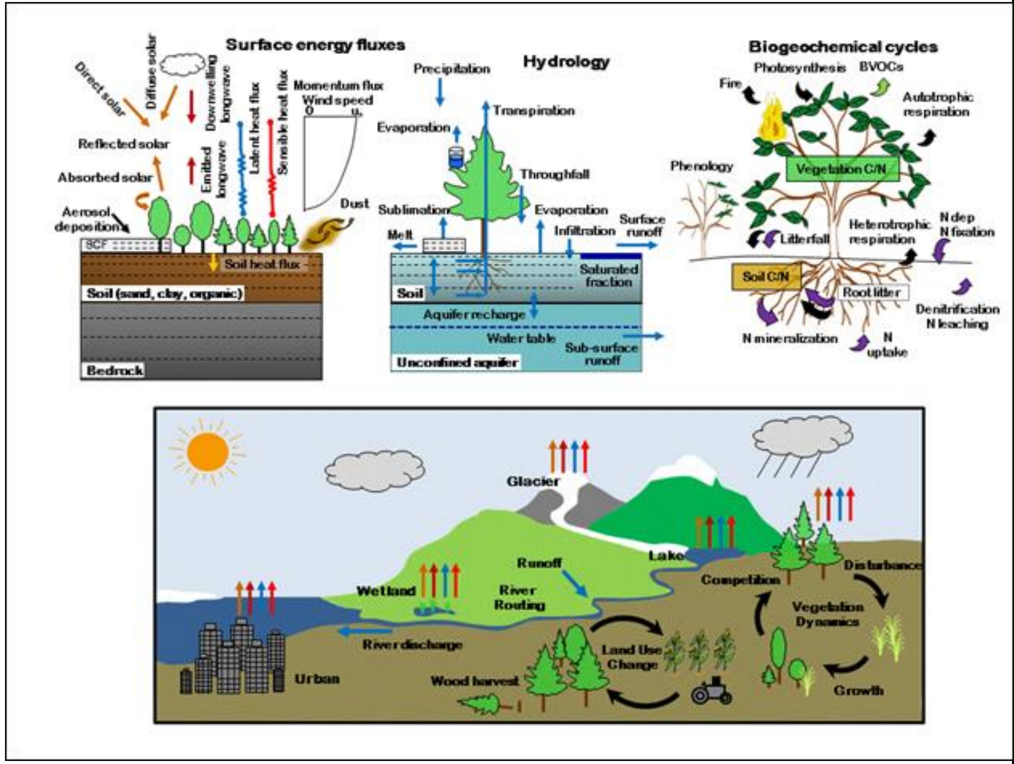
It is a collaborative project between scientists in the Terrestrial Sciences Section (TSS) and the Climate and Global Dynamics Division (CGD) at the National Center for Atmospheric Research (NCAR) and the CESM Land Model Working Group. Other principal working groups that also contribute to the CLM are Biogeochemistry, Paleoclimate, and Climate Change and Assessment.

The model formalizes and quantifies concepts of ecological climatology. Ecological climatology is an interdisciplinary framework to understand how natural and human changes in vegetation affect climate. It examines the physical, chemical, and biological processes by which terrestrial ecosystems affect and are affected by climate across a variety of spatial and temporal scales. The central theme is that terrestrial ecosystems, through their cycling of energy, water, chemical elements, and trace gases, are important determinants of climate.

Model components consist of: biogeophysics, hydrologic cycle, biogeochemistry and dynamic vegetation.

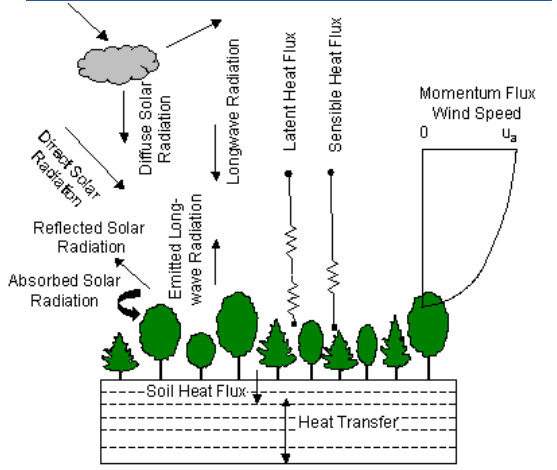
The land surface is represented by 5 primary sub-grid land cover types (glacier, lake, wetland, urban, vegetated) in each grid cell. The vegetated portion of a grid cell is further divided into patches of plant functional types, each with its own leaf and stem area index and canopy height. Each subgrid land cover type and PFT patch is a separate column for energy and water calculations.

The current version of the Community Land Model is CLM4.0

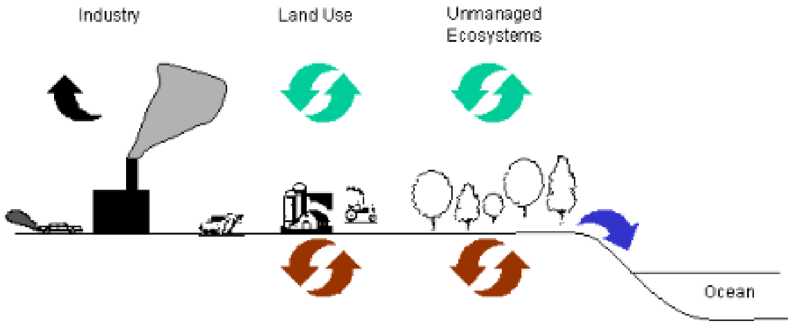


Community Land Model

Biogeophysics – Energy, Moisture, Momentum

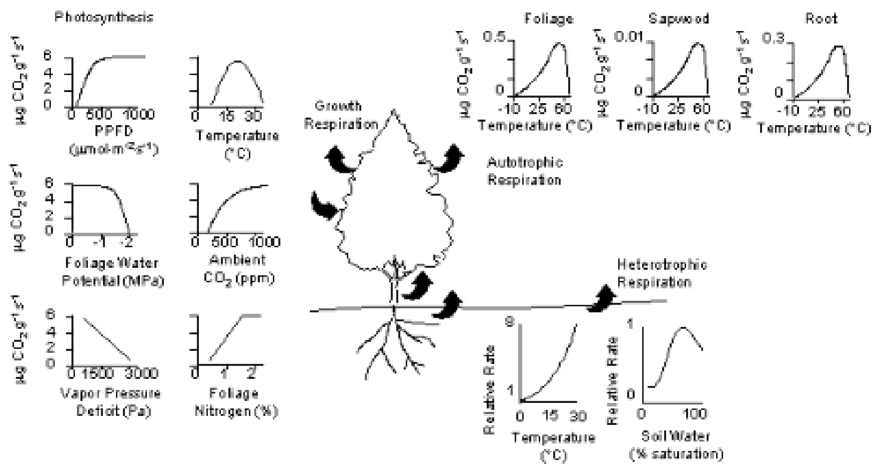


Biogeochemistry

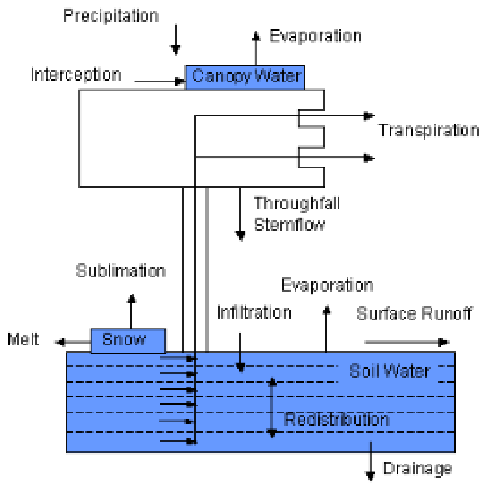


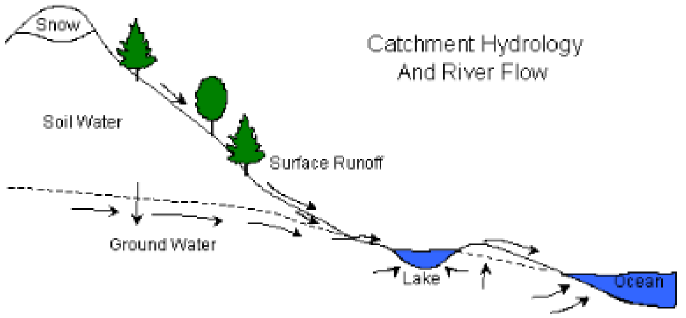
- Dust
- Biogenic volatile organic compounds
- Dry deposition

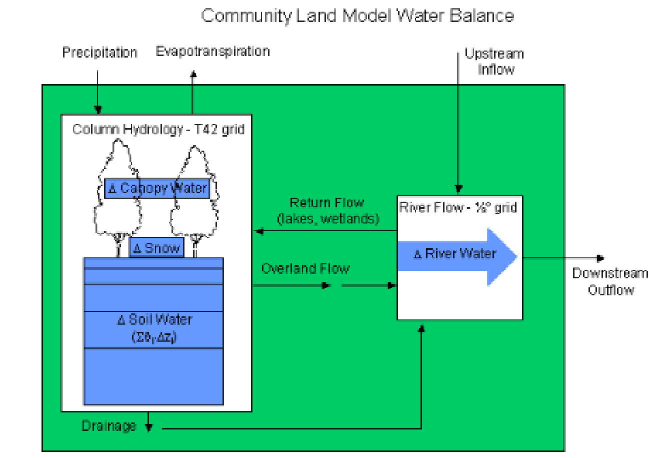
Ecosystem Carbon Balance



Hydrology



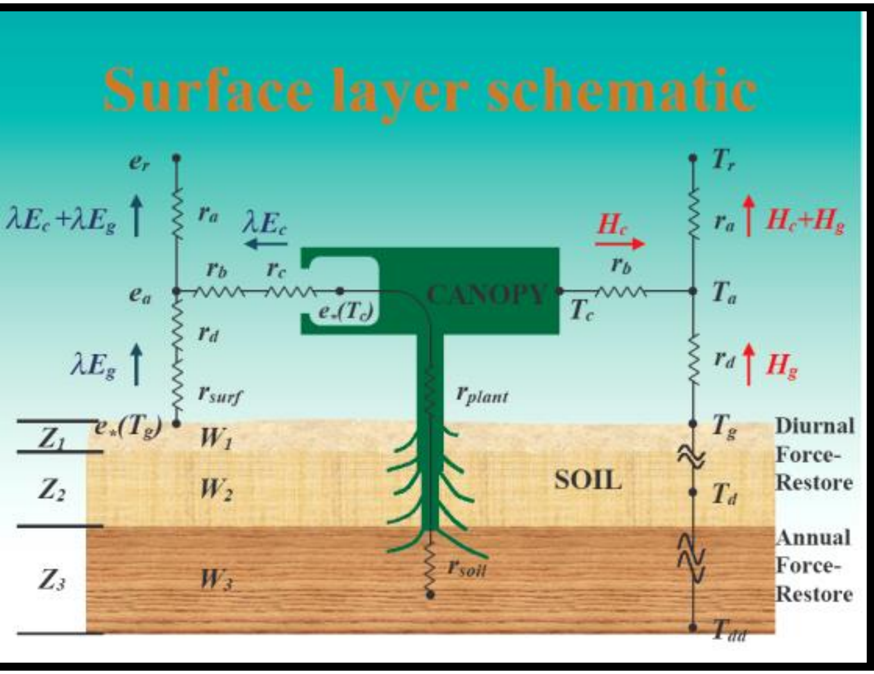




Column (T42): Precipitation + Return - Evapotranspiration - Total Runoff
River (½°): Inflow + Total Runoff - Return - Outflow
Grid Cell (T42): Precipitation + Inflow - Evapotranspiration - Outflow

Modelos de superfície

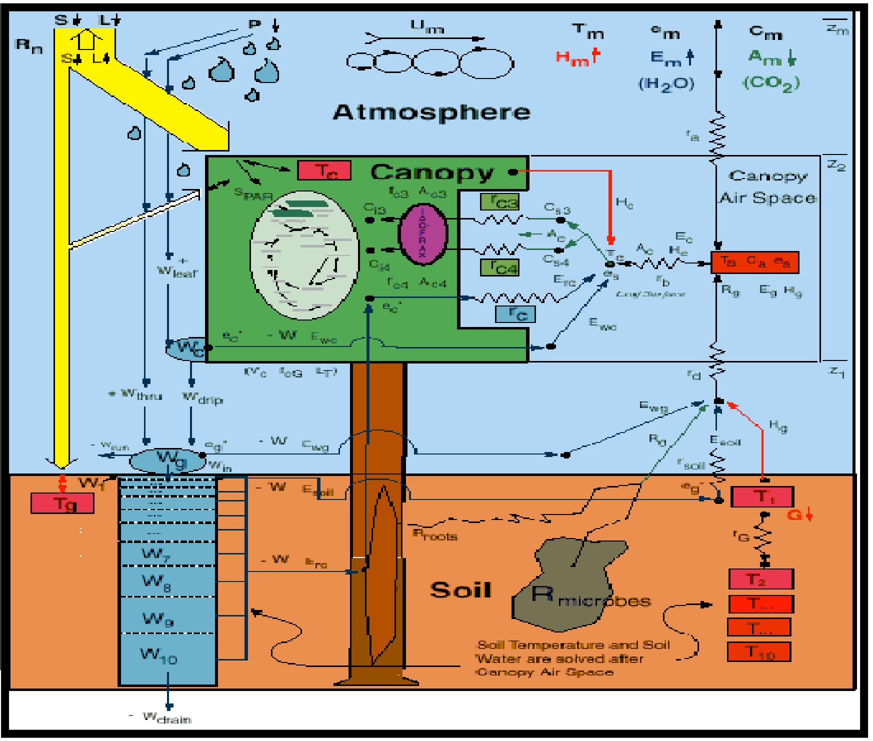
SSiB



SSiB (Xue et al., 1991)

3° geração

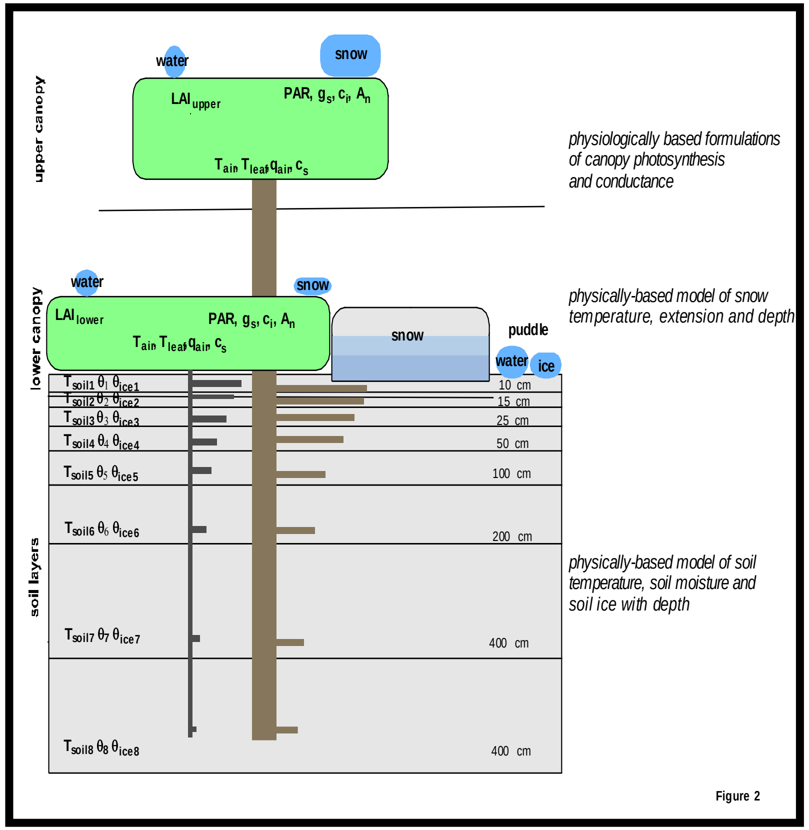
SiB 2.5



SiB 2.5 (Baker et al., 2003)

3° geração

IBIS



IBIS (Foley, J.A. et al., 2005)

Simplified Simple Biosphere Model 2 – SSiB2 (Zhan et al., 2003) em desenvolvimento>>> future SSIB4 (Haynes, K; Baker, I. Denning, S., 2015)

Paulo Yoshio Kubota

A Simplified Biosphere Model for Global Climate Studies

Y. XUE, P. J. SELLERS, J. L. KINTER AND J. SHUKLA

Center for Ocean–Land–Atmosphere Interactions, Department of Meteorology, University of Maryland, College Park, Maryland

(Manuscript received 8 February 1990, in final form 7 November 1990)

SSiB

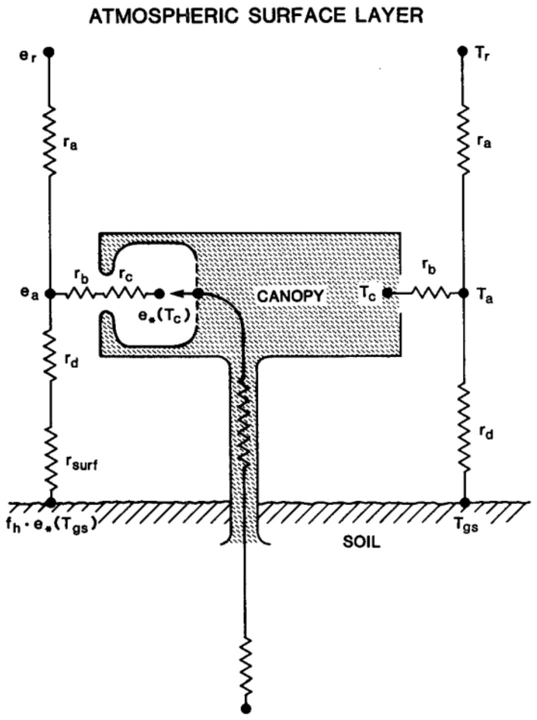


FIG. 3. Schematic diagram of SSiB. T_r is the air temperature at reference height, T_c the canopy temperature, T_a the air temperature within the canopy space, T_g the soil temperature, r_a the aerodynamic resistance between canopy air space and reference height, r_b the bulk boundary layer resistance, r_c the bulk stomatal resistance, r_d aerodynamic resistance between canopy air space and ground.

- A parametrização do ciclo diurno do albedo foi simplificada;
- Simplificação da dependência da resistência estomática em relação à na zona de raízes;
- Os fluxos de calor, umidade e momentum entre o dossel e a atmosfera foram parametrizados com base em uma linearização derivada a partir da teoria de similaridade de Monin-Obukhov;
- O nº de camadas de vegetação foi reduzido de dois para um.

Parâmetros morfológicos, fisiológicos e físicos

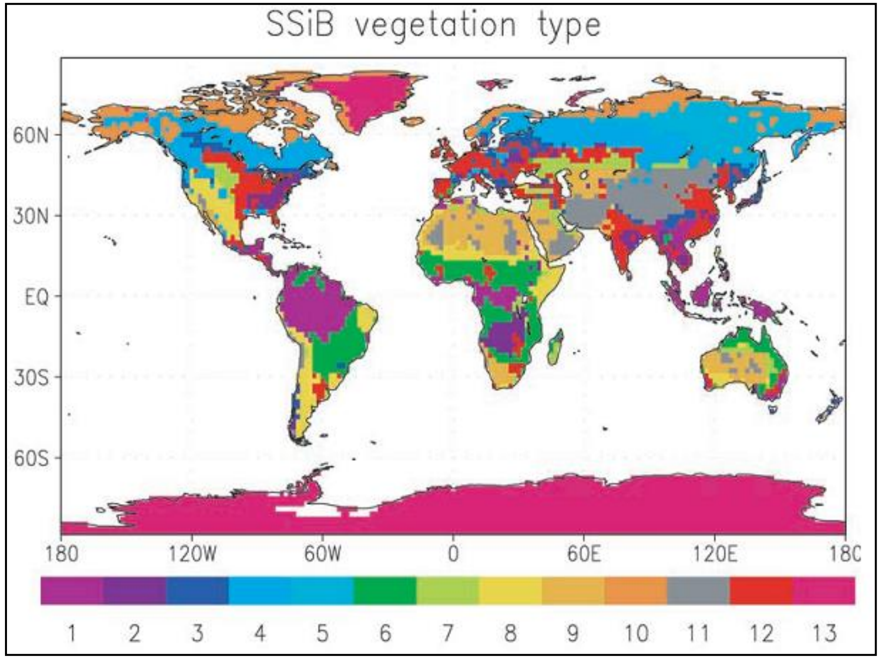
Definintion	SiB	SSiB
Vegetation cover	Vc, Vg	Vc
Leaf angle distribution	Oc, Og	Oc
Height of canopy top	z2	z2
Height of canopy bottom	z1	
Leaf index	Lc, Lg	Lc
Rooting depth	Zdc, Zdg	Zdc
Root length density	Dgc, Dgg	
Root cross section	Rcroc, Rcrog	
Thickness of 3 soil layers	D1, D2, D3	D1, D2, D3
Green fraction	Nc, Ng	Nc
rs coefficients	$(a, b, c)_c$, $(a, b, c)_g$	(a, b, c)
Constant for temperature adjustment	$(T1, Th, To)_c$ $(T1, Th, To)_g$	(T1, Th, To)
Constant for water vapor deficit adjustment	h5c, h5g	h5c
Constant for moisture adjustment	$(\psi_{c2}\psi_{c1})_c$ $(\psi_{c2},\psi_{c1})_g$	(C1, C2)
Root resistance	Rc, Rg	
Plant resistance	*r*(plant)	
Roughness length	zo	zo
Displacement height	*d*	*d*
Soil pore	Os	Os
Soil moisture potential	ψ_s	ψ_s
b parameter	*B*	*B*
Lengthscale of leaf	*l*	
Canopy source height	ha	
Slope	α	α
Parameter for *rd*	Cd	Cd
Parameter for *rb*	Cb	Cb
Parameter for aerodynamic resistance	G1, G2, G3, ZTZO	

- Parâmetros reduzidos de 44 para 21;
- mudanças na estrutura do modelo;
- simplificação das parametrizações;

SSiB (Xue et al., 1991)

Classificação dos Biomas Segundo Dorman e Sellers (1989)

Bioma	Características
0	Gelo perpétuo
1	Árvores latifoliadas perenes (florestas tropicais)
2	Árvores latifoliadas decíduas (floresta temperada)
3	Árvores latifoliadas/aciculadas (floresta mista)
4	Árvores aciculadas perenes (floresta conífera)
5	Árvores aciculadas decíduas (floresta de lariços)
6	Árvores latifoliadas com cobertura arbustiva/herbácea (savana)
7	Arbustos (campos extratropicais)
8	Arbustos latifoliados com cobertura herbácea (caatinga)
9	Arbustos latifoliados com solo exposto (semi-deserto)
10	Árvores anãs e arbustos com cobertura herbácea (tundra)
11	Solo exposto (deserto)
12	Cultivos (parâmetros iguais aos do tipo 7)*

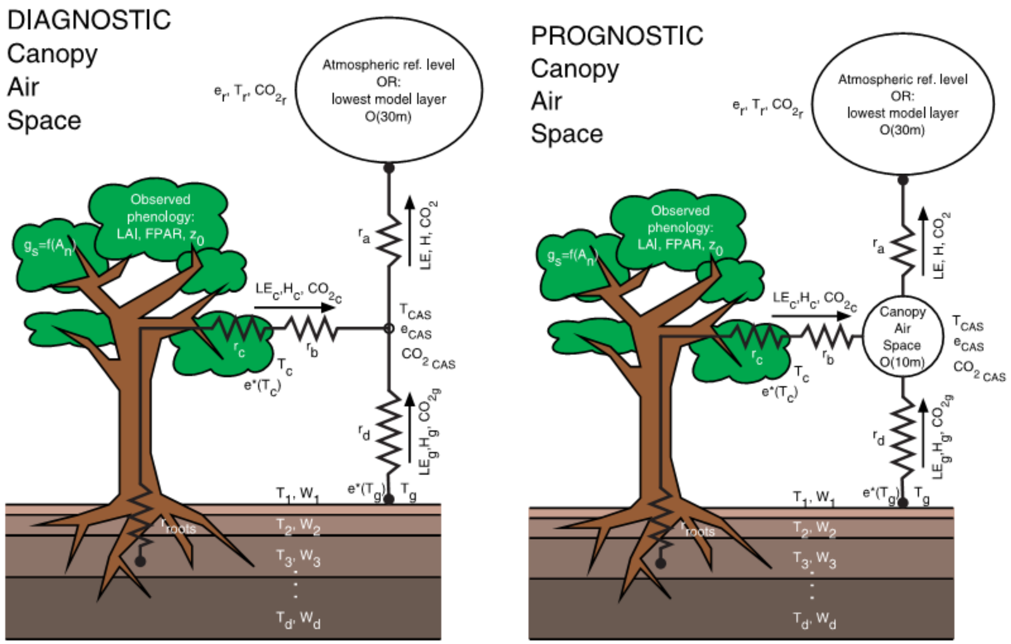


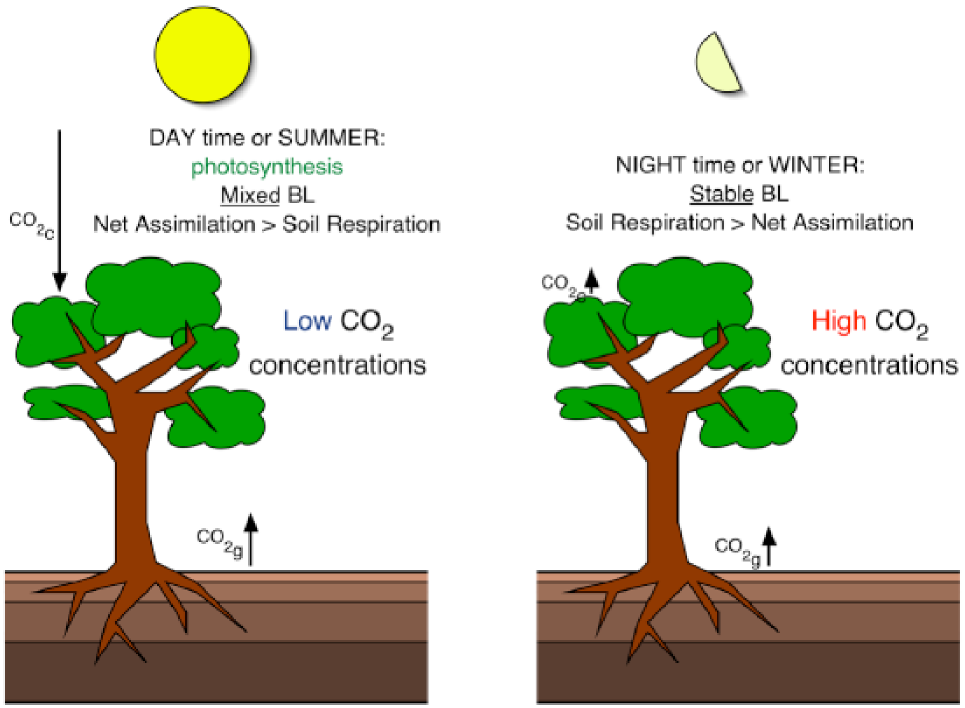
*cada vegetação corresponde a um tipo de solo

SiB2.5 (Baker et al., 2003)

- Seis camadas de solo;
- 13 tipos de vegetação e 12 tipos de solo independentes.

Assimilação de CO2





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IBIS *Integrated Biosphere Simulator*

➢ ***Filosofia***

- Modelo dinâmico da vegetação global;
- 15 tipos de vegetação e 12 tipos de solo;
- Considera mudanças ocorridas na composição e estrutura da vegetação em resposta à condições ambientais;
- Inclui:
  - ✓Interações superfície-atmosfera
  - ✓Ciclos de CO_2
  - ✓Nutrientes terrestres
  - ✓Efeitos fisiológicos do dossel
  - ✓Fenologia
  - ✓Dinâmica e competição da vegetação

- Maneiras típicas de considerar a fenologia num modelo de interação atmosfera-biosfera:

- ✓ IAF pré-definido (p. ex., LSM, CLM)
- ✓ IAF determinado por sensoriamento remoto (p. ex. SiB2)
- ✓ IAF simulado de acordo com regras (p. ex. IBIS)

	IAF pré-definido	IAF sens. remoto	IAF simulado
Vantagens	▪ modelo mais simples	▪ potencialmente mais preciso no curto prazo	▪ responde a variabilidade interanual do clima, mudanças climáticas ou mudanças no CO_2
Desvantagens	▪ não responde a variabilidade interanual do clima, mudanças climáticas ou mudanças no CO_2	▪ estudos de clima futuro ou fora da faixa de dados disponíveis têm que ignorar mudanças na fenologia	▪ modelo mais complexo

Problemas

- Não existem observações de temperatura e umidade em escala global, sendo derivadas das variáveis atmosféricas
- Erros sistemáticos devido as deficiências na forçante atmosférica e esquemas de superfície
- Previsões sensíveis as condições iniciais de umidade do solo

- Também podem existir inconsistências pela resolução do modelo: elevação, tipo de solo e vegetação
- O spin-up ocorre na temperatura e umidade do solo
- Evitado rodando off-line o modelo na mesma resolução
- Assimilação de dados cíclica uma alternativa?

Arrasto de ondas de gravidade

- Arrasto topográfico pelas ondas de gravidade
- Atua como um mecanismo de amortecimento nas equações de movimento
- Necessário quando a resolução > 10 km, simulações maiores a 5 dias e o domínio inclui montanhas
- Para seu calculo é necessária a variância da silhueta orográfica do modelo

Sugestões de leitura

Campbell, G.S.; Norman, J.M. *An Introduction to Environmental Biophysics*. Springer, 2nd edition, 1998. 286p.

Garrat, J.R. *The atmospheric boundary layer*. Cambridge University Press, 1992. 316p.

Monteith, J.L.; Unsworth, M. *Principles of Environmental Physics*. Arnold, 2nd edition, 1990.

Sellers, P.J.; Mintz, Y.; Sud, Y.C.; Dalcher, A. A Simple Biosphere model (SiB) for use within General Circulation Models. *J. Atmos. Sci.*, v.43, p.505-531, 1986. **[SiB1]**

_____; Randall, D.A.; Collatz, G.J.; Berry, J.A.; Field, C.B.; Dazlich, D.A.; Zhang, C.; Collelo, G.D.; Bounoua, L. A Revised Land Surface Parameterization (SiB2) for Atmospheric GCMs. Part I: Model Formulation. *J. Climate*, v.9, p.676-705, 1996. **[SiB2]**

Lista-3 de Exercício

a) Execute o modelo monan utilizando o arquivo x1.40962.static_natural.nc. Procedimento:
no diretório
/monan_Linux/monan/pre/databcs/meshes/quasi_uniform/
copie o arquivo x1.40962.static_natural.nc para x1.40962.static.nc
cp x1.40962.static_natural.nc x1.40962.static.nc
e execute os scripts:

```
./runPost.bash ${EXP_NAME} 40962 ${LABELI} ${LABELF} ${Domain} ${AreaRegion} ${TypeGrid}
./runPost.bash ${EXP_NAME} 40962 ${LABELI} ${LABELF} ${Domain} ${AreaRegion} ${TypeGrid}
./runPost.bash ${EXP_NAME} 40962 ${LABELI} ${LABELF} ${Domain} ${AreaRegion} ${TypeGrid}
```

b) Execute o modelo monan utilizando o arquivo x1.40962.static_bare.nc . Procedimento:
no diretório
/monan_Linux/monan/pre/databcs/meshes/quasi_uniform/
copie o x1.40962.static_bare.nc para x1.40962.static.nc
cp x1.40962.static_bare.nc x1.40962.static.nc
e execute os scripts:

```
./runPost.bash ${EXP_NAME} 40962 ${LABELI} ${LABELF} ${Domain} ${AreaRegion} ${TypeGrid}
./runPost.bash ${EXP_NAME} 40962 ${LABELI} ${LABELF} ${Domain} ${AreaRegion} ${TypeGrid}
./runPost.bash ${EXP_NAME} 40962 ${LABELI} ${LABELF} ${Domain} ${AreaRegion} ${TypeGrid}
```

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Lista-3 de Exercício

Os arquivos podem ser obtidos no link:

https://ftp.cptec.inpe.br/pesquisa/bam/paulo.kubota/externo/monan/pre/databcs/meshes/quasi_uniform/global/120_km/x1.40962.static_bare.nc

https://ftp.cptec.inpe.br/pesquisa/bam/paulo.kubota/externo/monan/pre/databcs/meshes/quasi_uniform/global/120_km/x1.40962.static_natural.nc

Discuta o comportamento dos resultados das duas simulações.