

**Mitigating the greenhouse effect**

**The carbon market**

## IPCC: Intergovernmental Panel on **Climate Change (CC)**

- · created in 1988 by WMO (World Meteorological Organization) and UNEP (United Nations Environmental Programme) to assess science, impacts, economics, mitigation and adaptation of (for) CC
- · advice the **COP (Conference of the Parties)** to the issues of CC conducted by the UNFCCC (United Nations Framework Convention on CC)

## **Kyoto Protocol: established by the COP in 1997**

- · Article 3.1 – Annex I countries (developed) agree to limit greenhouse gases (GHG) emissions to 5% below 1990 levels in the commitment period 2008-2012
- · Article 3.3 – Provides net fluxes of GHG resulting from **direct human-induced activities** of Land Use, Land Use Change & Forestry – **LULUCF** - limited to afforestation, reforestation and deforestation since 1990, measured as verified changes in C stocks... to meet the commitments
- · Article 12.2 – The purpose of the clean development mechanism (**CDM**) shall be to assist non-Annex I parties (...developing countries) in achieving **sustainable development** and contribute to the objectives of Convention ...
- · Article 12.5(b) – Real, **measurable**, and **long-term** benefits related to the mitigation of CC
- · Article 12.5(c) – Reduction in emissions that are **additional** to any that would otherwise occur in the absence of project

The Subsidiary Body for Scientific and Technological Advice (SBSTA),  
at COP-9 meeting, 1-9 December 2003, Milano, Italy

establishes the **Methodological Issues of LULUCF under the CDM**

1. Confirms and give full effect of any action of modalities for  
**afforestation and reforestation project (AR)**

Annex A: defines

baseline = sum of C changes in the absence of AR (business as usual)

leakage = increase in C emissions outside the project boundary

actual net C increase = sum of C changes with AR minus the baseline  
minus the leakage

Project is **additional** if actual net C increase is **greater than baseline**

Annex A: defines accreditation

and the **Certified Emission Reduction (CER)** as

tCER = temporary, expires at the end of commitment period

lCER = long term, expires at the end of AR project

defines

Small-scale AR project = expected to result actual net C increase **less than 8000 tons CO<sub>2</sub> per year**

**Only additional and small-scale AR projects are eligible for CERS**

## Designated operational entities and steps:

- 1. Validation:** evaluation of AR project by an independent entity  
(in accordance with procedures required by host Party national authority)  
includes assessment of environmental impact (hydrology, soils, biodiversity, etc..) and socio-economic (participation of local communities) and a **MONITORING PLAN**
- 2. Registration** at the Executive Board of CDM (accepts or not)
- 3. Monitoring:** archiving all data necessary for measuring C changes
- 4. Verification:** periodic independent review of proposed achievements
- 5. Certifier:** written assurance by another entity

Therefore LULUCF - CDM projects shall comprise:

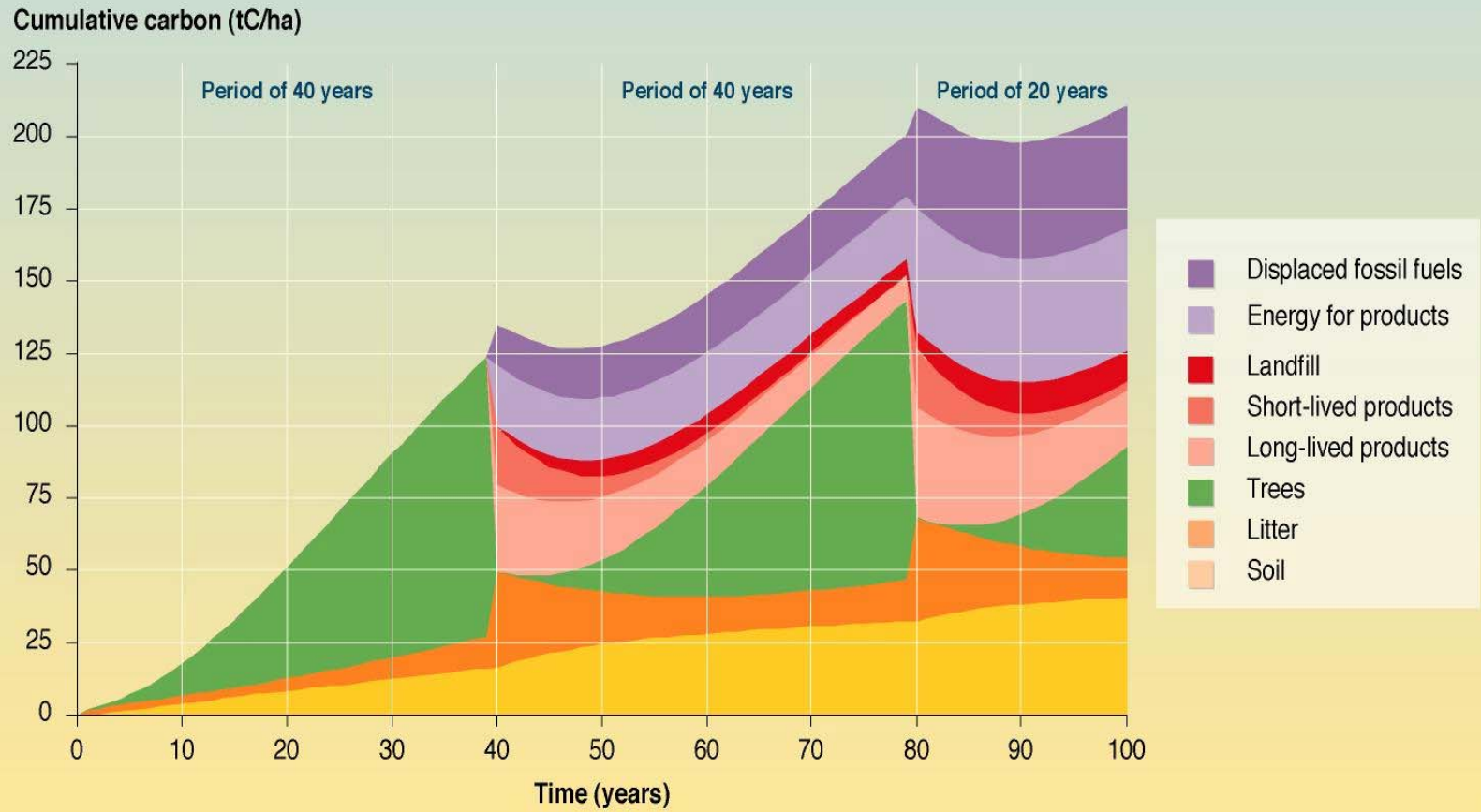
- Sustainability
- Additionality
- Longevity
- Measurability
- Externalities (environment, socio-economic issues)

Measurability (C accounting) shall be

- transparent
- consistent
- comparable
- complete
- accurate
- verifiable
- efficient recording
- reporting changes ... of C stocks

The Kyoto Protocol is not ratified so far (we are waiting for Russia).

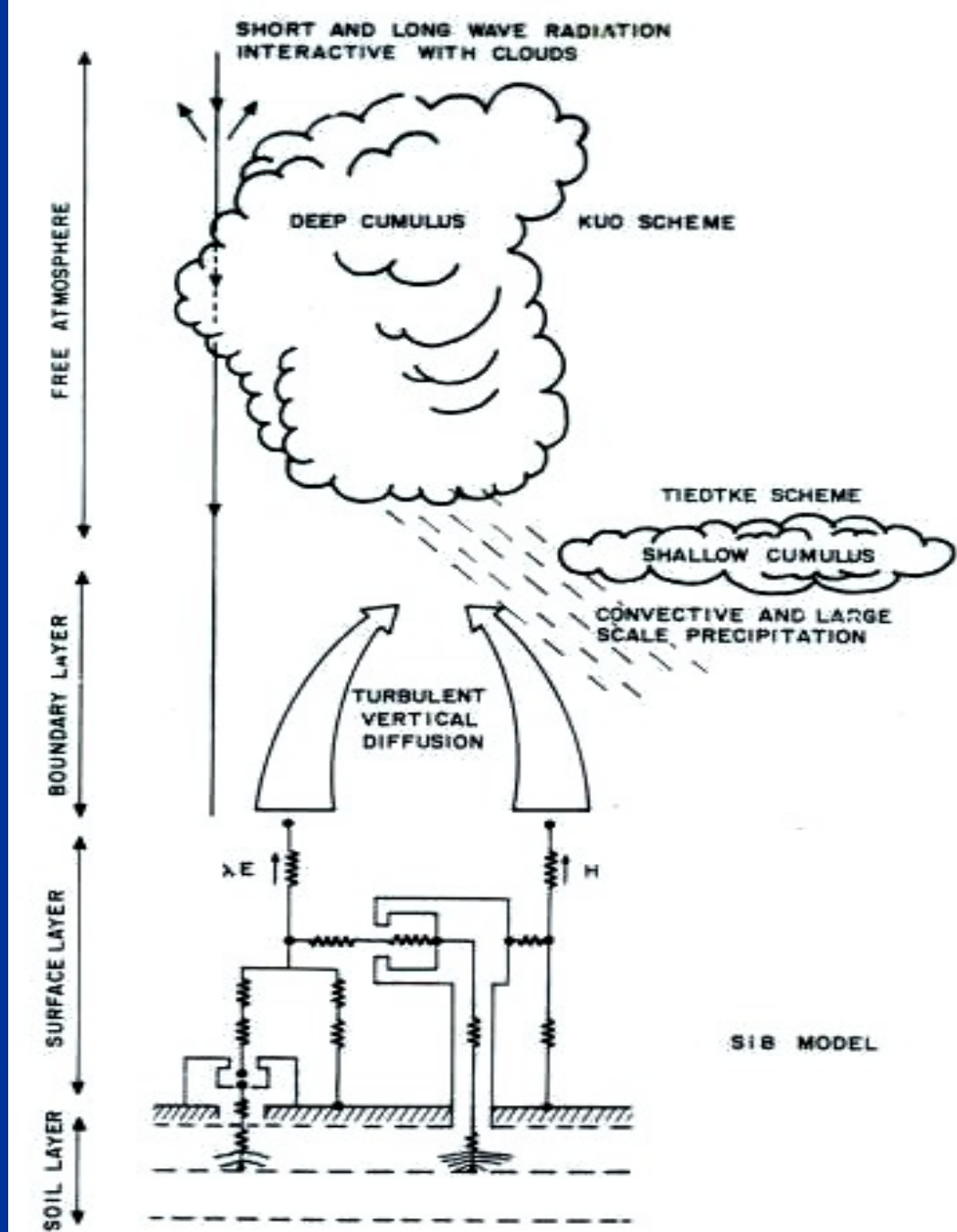
# Carbon balance from a hypothetical forest management project



WG3 - FIGURE TS-6

# Coupled ecosystem and climate models

# Physical processes in the column of an atmospheric circulation model



Rocha et al. 1996

# Physical and dynamical processes in an general circulation atmospheric model

## GCM (3D MODEL)

$$\frac{\partial \bar{V}}{\partial t} + \bar{V} \frac{\partial \bar{V}}{\partial x_i} = -\bar{k}g - \Omega \times \bar{V} - \frac{1}{\rho} \nabla p + \frac{1}{\rho} \frac{\partial \zeta}{\partial x_i}$$

wind

$$\frac{\partial q}{\partial t} + \bar{V} \frac{\partial q}{\partial x_i} = v \nabla^2 q + \frac{\delta q}{\rho}$$

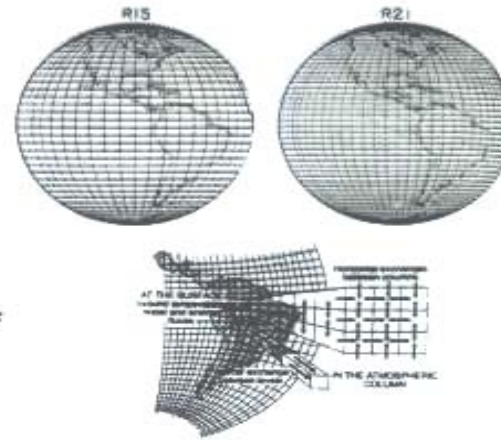
humidity

$$\frac{\partial \theta}{\partial t} + \bar{V} \frac{\partial \theta}{\partial x_i} = v \nabla^2 \theta - \frac{1}{\rho c_p} \frac{\partial Q}{\partial x_i} - \frac{\lambda E}{\rho c_p}$$

temperature

$$\frac{d\rho}{dt} + \rho \nabla \cdot \bar{V} = 0$$

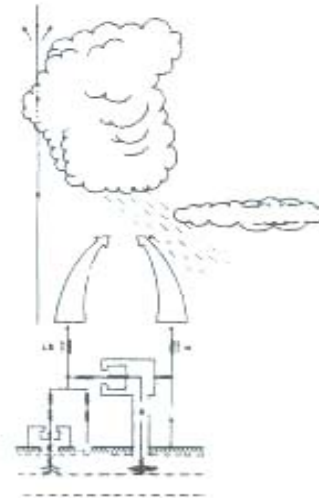
mass



## COLUMN (1D MODEL)

Radiative transfer  
Deep and shallow convection  
Large scale precipitation

CLP turbulent diffusion  
Surface (vegetation, ocean)



# Land surface parameterization

## SOIL-VEGETATION MODEL

$$C \frac{\partial T}{\partial t} = R_n - \lambda E - H - G - A_n$$

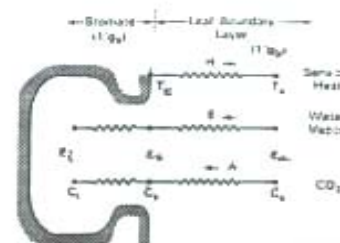
energy balance

$$\frac{\partial M}{\partial t} = P - D - \frac{E}{\rho}$$

interception

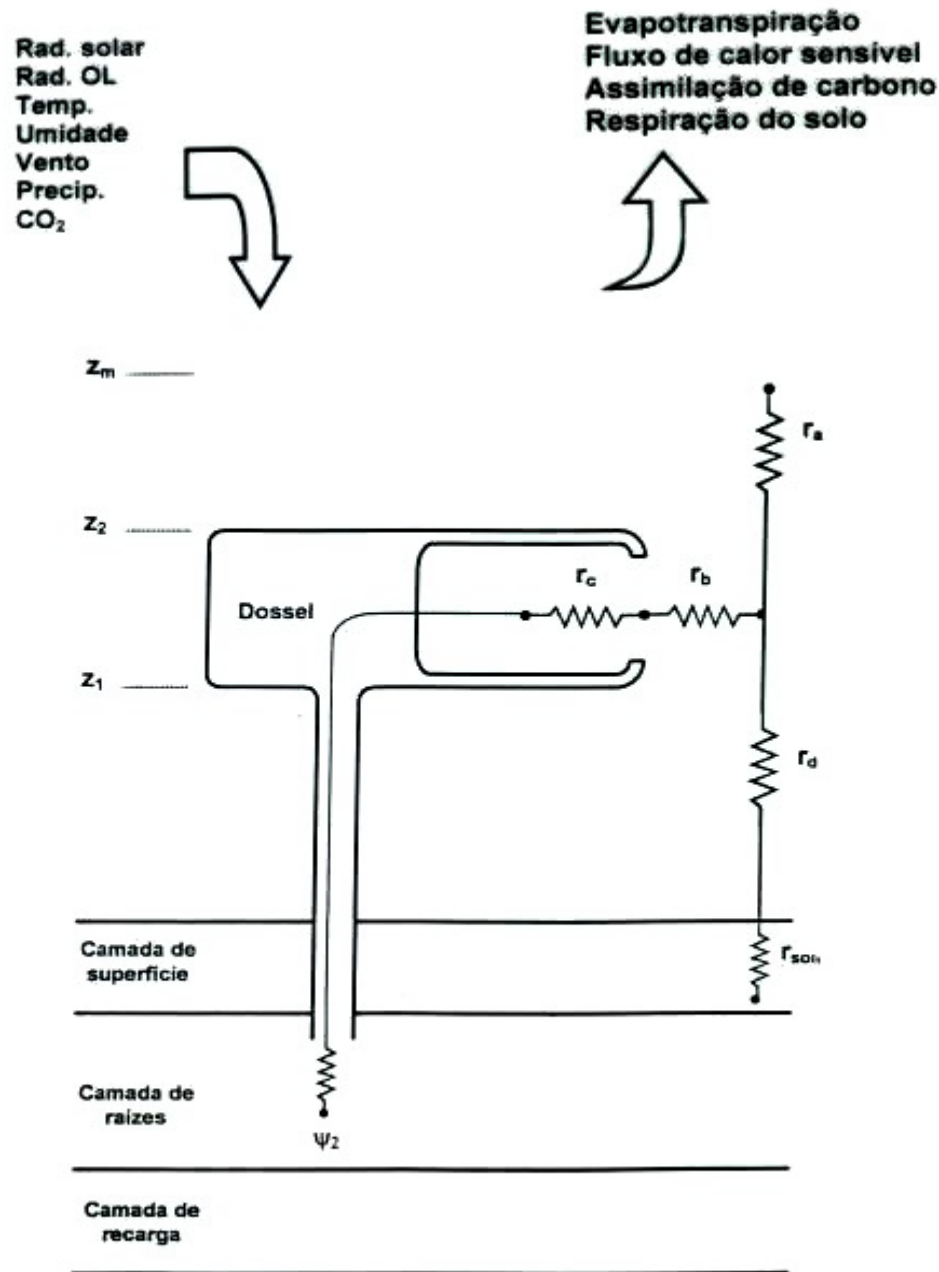
$$\frac{\partial W}{\partial t} = \frac{1}{\Theta_s D} (P + Q - \frac{E_d}{\rho} - R)$$

soil moisture



# The Simple Biosphere Model (SiB2) Sellers 1996

Aerodynamic drag  
Canopy radiative transfer  
Soil hydraulic diffusion  
Stomatal conductance  
CO<sub>2</sub> assimilation



Modelo SiB2 (Simple Biosphere Model)

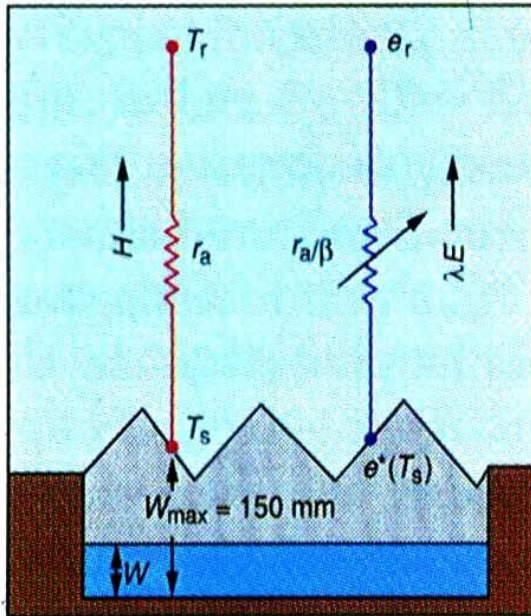
A

Reference height  $z_r$

Aerodynamic pathway  
in lower atmosphere

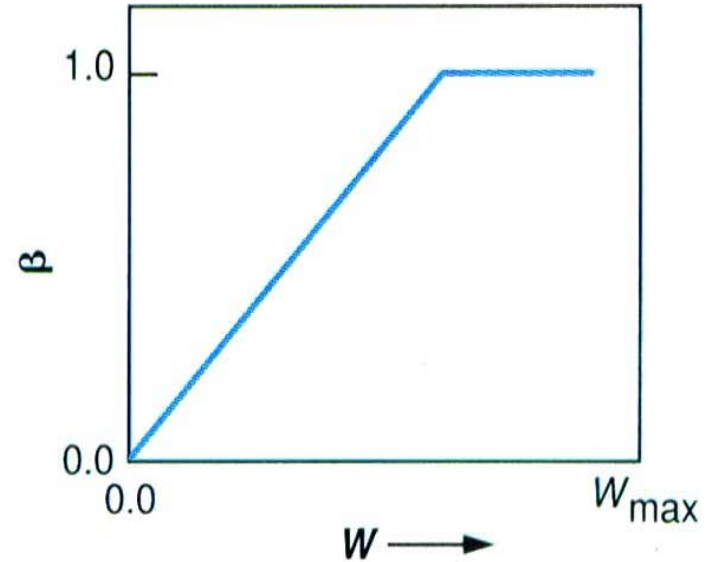
Surface properties:  $\alpha, z_0$

Bucket model  
for hydrology



$$H = \frac{T_s - T_r}{r_a} \rho c_p$$

$$\lambda E = \beta \left[ \frac{e_s(T_s) - e_r}{r_a} \right] \frac{\rho c_p}{\gamma}$$

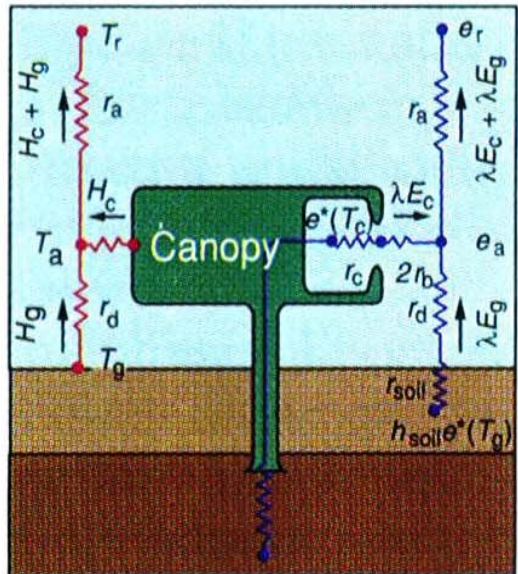


Bucket hydrology

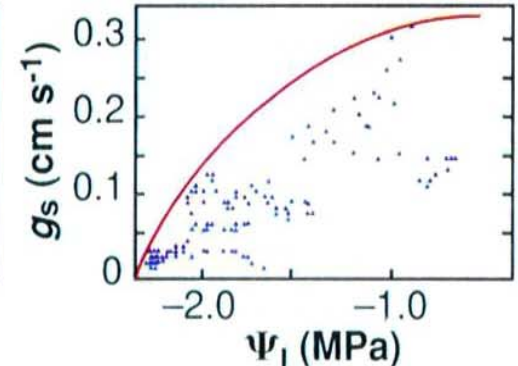
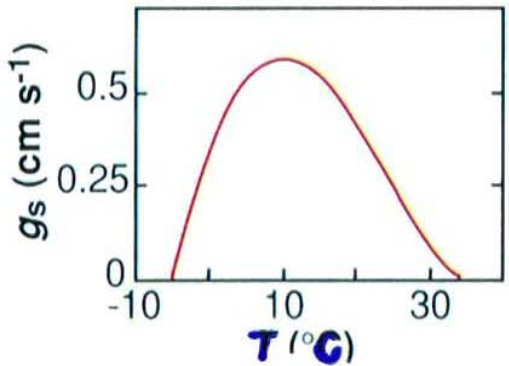
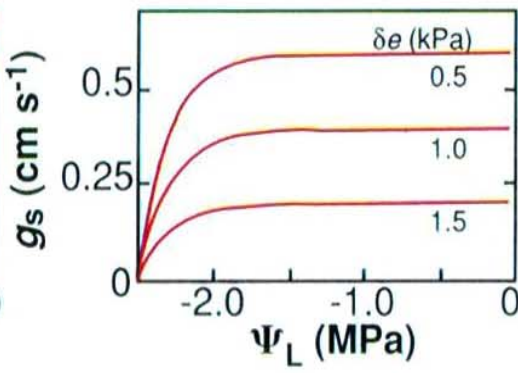
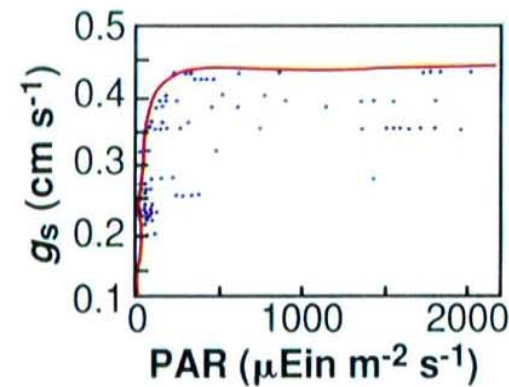
Sellers et al. (1997)

**B**

Reference height  $z_r$   
 Atmosphere  
 Canopy air space  
 Surface soil layer  
 Root zone layer



$$\lambda E = \left[ \frac{e_s(T_s) - e_a}{r_a + r_c} \right] \frac{\rho_c p}{\gamma}$$

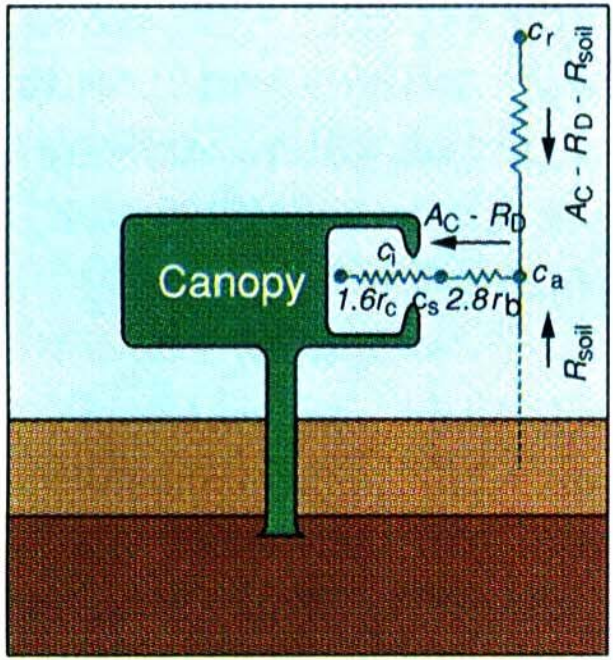
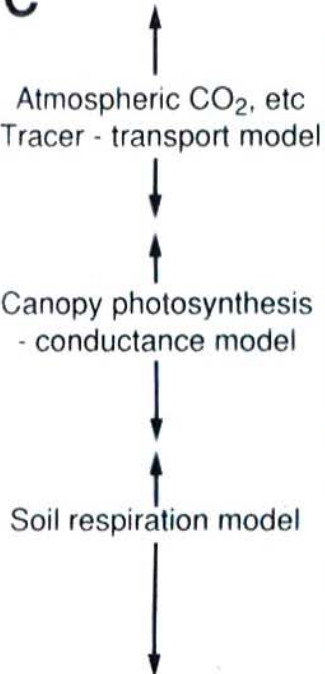


$$g_s = g_s(\text{PAR}) \left[ f(\delta e) f(T) f(\psi_r) \right] \text{ (Jarvis)}$$

Sellers et al. (1997)

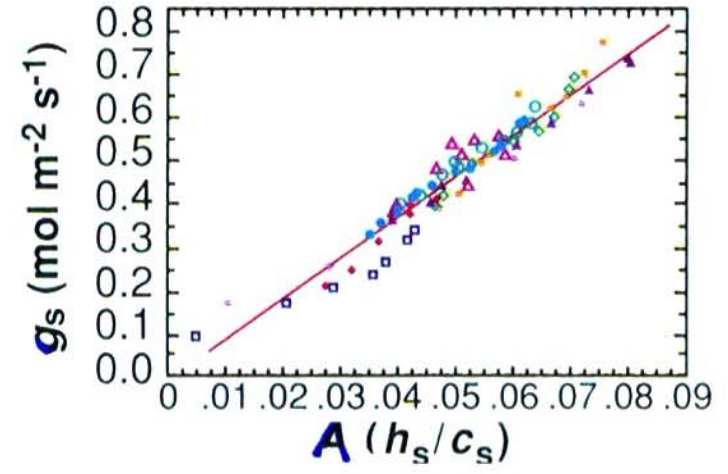
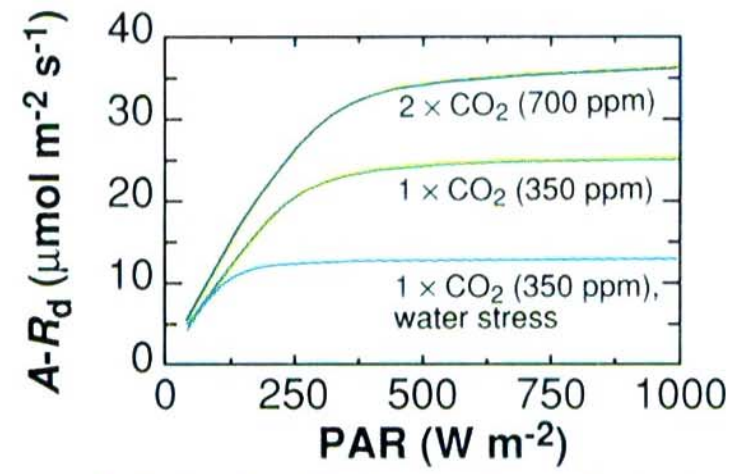
Second generation of models 1980's

C



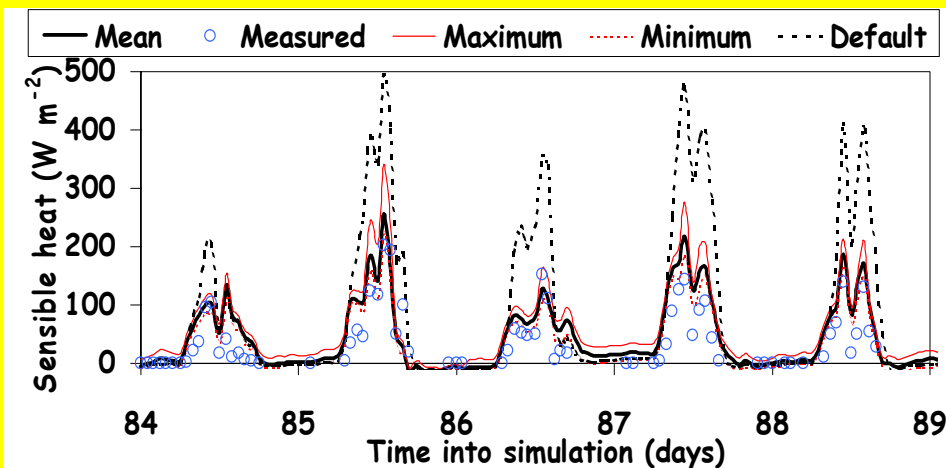
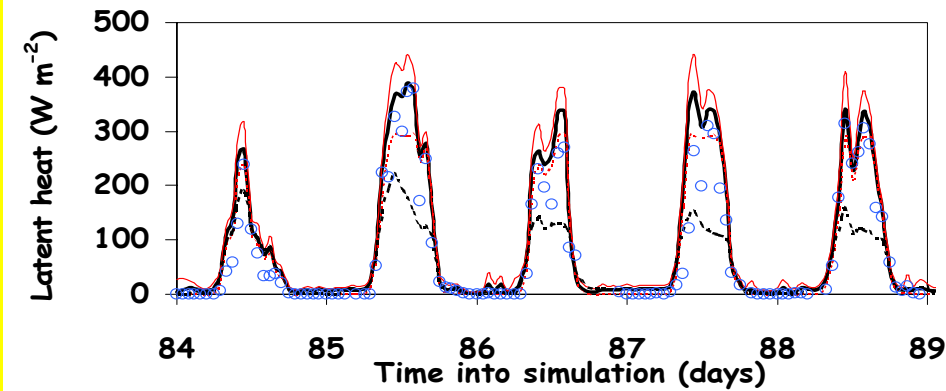
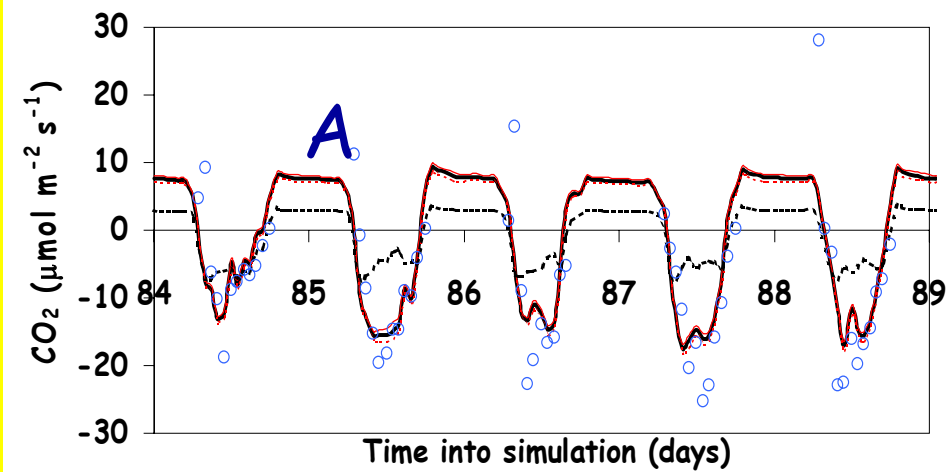
$$A_c, g_c = \left[ V_{max\theta}, PAR_{\theta} \right] \frac{FPAR}{R} [\beta_1 \dots \beta_6] \quad \text{--- } \pi$$

$$\pi \propto SR = \frac{a_N}{a_V}$$



Sellers et al. (1997)

Third generation of models 1990's



- Calibration of the Simple Biosphere Model (SiB2) for Amazon tropical forest site
- Measured fluxes fall well within the range of the optimized simulations. Simulations made using the default parameters significantly over-estimate the sensible heat flux and under-estimate the latent heat flux and the magnitude of the  $CO_2$  flux.

Time series of measured, modeled, and minimum and maximum possible fluxes for a selected 5-day period. **A** shows  $CO_2$  flux with the night time data filtered. There are still some positive fluxes early in the morning that cannot be described by the model.