IFIN-HH planned work on plant-soil modelling

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IFIN-HH Romania

MYPC-FDMH upgrade

- RODOS-FDMH documented
- Some upgrade published
- No major change for Exchange velocity-

  Jacobs-Calvet-Ronda (preferred and tested) BUT more work on **cuticle resistance** (night uptake)
- Check of parameters for leafy vegetable and grass (C3 and C4)
- Major change in soil model (was piston flow- stupid)
- Add a compartmental model for long term

Jacobs-Calvet-Ronda (preferred and tested)

- assumes that C conductance is determined by ratio between photosynthetic rate and the concentration difference of CO_2 for leaf surface and leaf interior

$$g_{l,c} = g_{\min,c} + \frac{a_1 A_g}{(C_s - \Gamma)\left(1 + \frac{D_s}{D_*}\right)},$$

$$\frac{C_i - \Gamma}{C_s - \Gamma} = f_0\left(1 - \frac{D_s}{D_0}\right) + f_{\min}\frac{D_s}{D_0},$$

$g_{\min,c}$ - the cuticular conductance
A_g - the gross assimilation rate- leaf
D_s - the vapour pressure deficit at plant level
C_s - the CO_2 concentration at the leaf surface
C_i - the CO_2 concentration in the plant interior
f_0 - the maximum value of $(C_i - \Gamma)/(C_s - \Gamma)$
D_0 - the value of Ds at which the stomata close
Γ – CO_2 compensation point

$$g_{l,c} = \frac{g_{l,w}}{1.6} \Rightarrow g_{c,c} = \frac{g_{c,w}}{1.6}.$$

$g_{l,c}$ – leaf C conductance;
$g_{l,w}$ – leaf water conductance;
$g_{c,c}$ – C canopy conductance;
$g_{c,w}$ - water canopy conductance

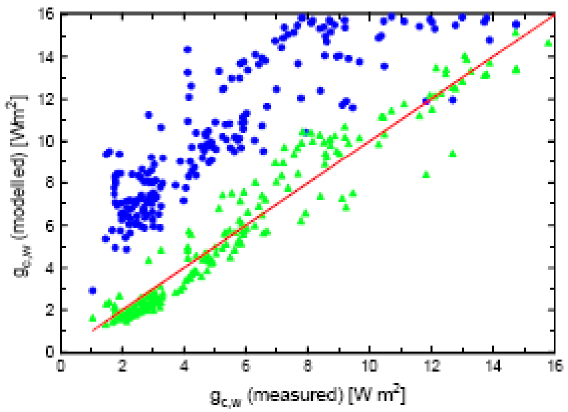


Figure 1: Scatter plot of modelled against measured canopy conductance for FIFE-KANSAS: simulated with physiology based model (green) and with JS-model (blue).

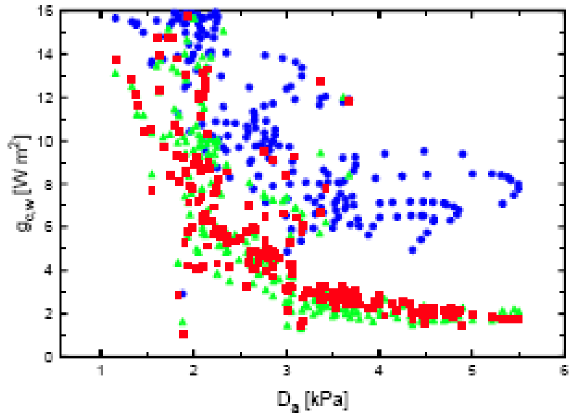


Figure 2: Scatter plot giving the canopy conductance as function of D_a; measurements (red), physiologically based model (green) and JS-model (blue).

For canopy - integrate on LAI
We use gross canopy photosynthesis rate from WOFOST;
Data base exist → advantage

Water vapor deficit and soil water deficit

$$\frac{C_i - \Gamma}{C_s - \Gamma} = f_0 - a_d D_s,$$

$$D_0 = \frac{f_0 - f_{\min}}{a_d}.$$

Vegetation type	f_o	a_d (kPa^{-1})
Low vegetation C3	0.89	0.07
Low vegetation C4	0.85	0.015
Lobos	0.093	0.12
Rice and phalaris grass	0.89	0.18
Forest temperate	0.875	0.06
Boreal forest	0.4	0.12

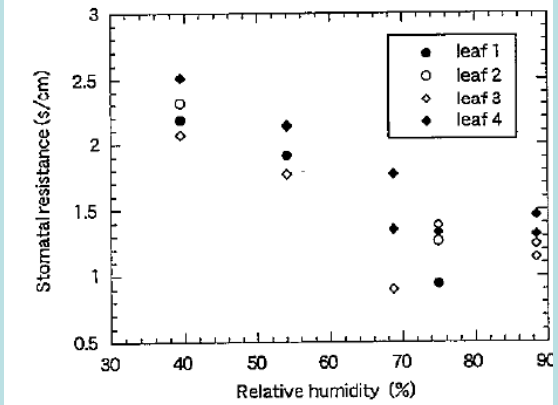
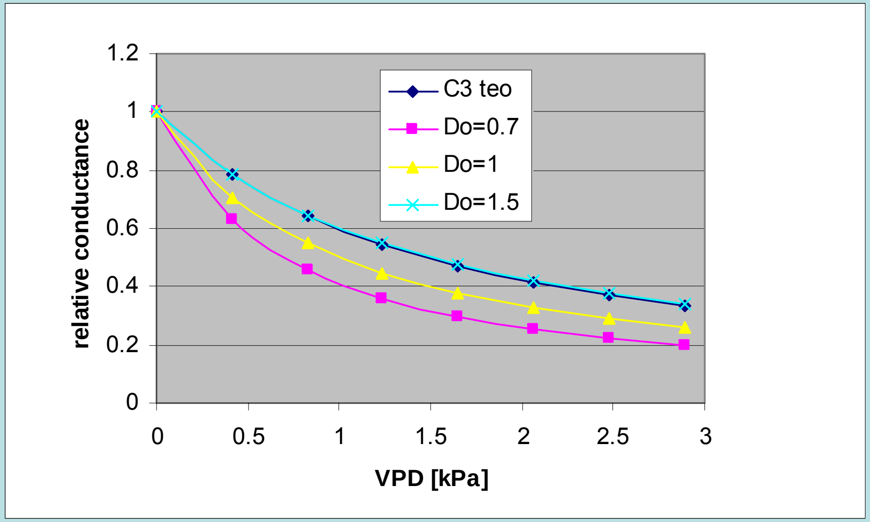
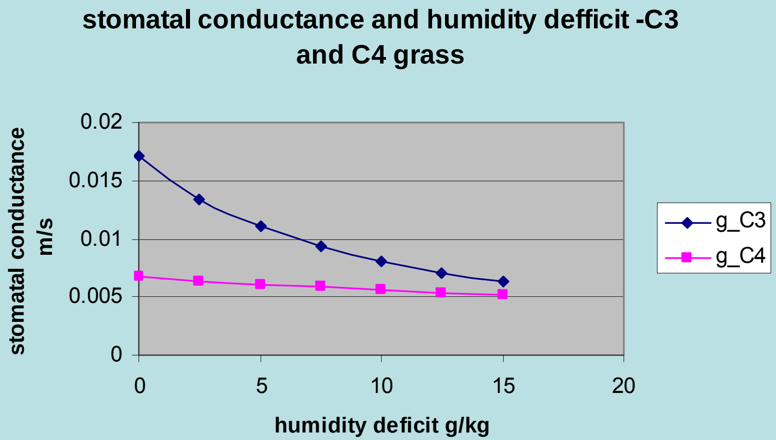


Fig. 4 Stomatal resistance of radish leaves



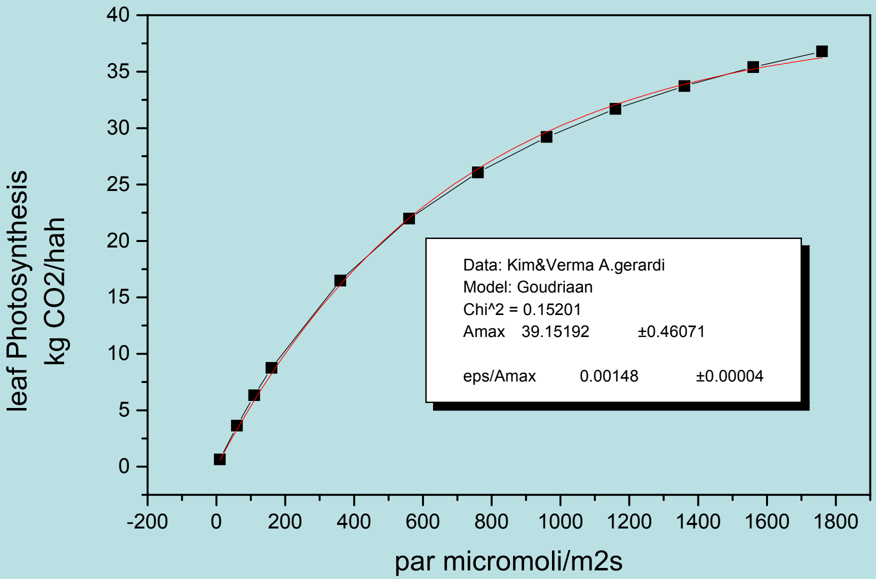


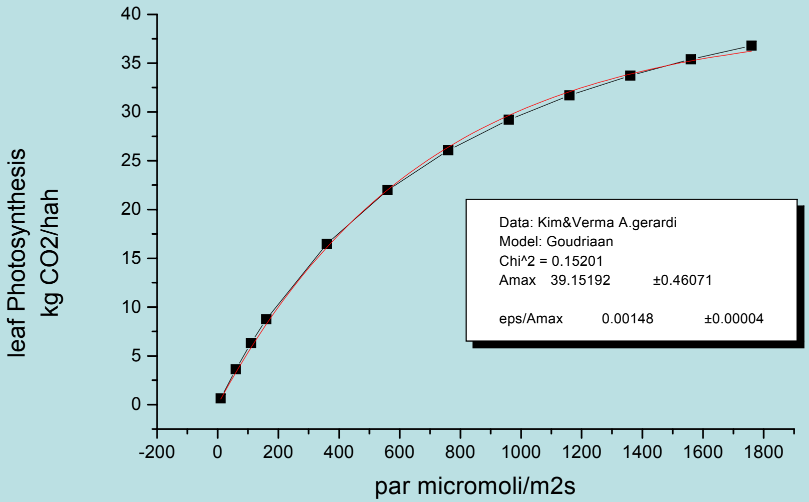
$$A_g = A_g^*[2\beta(\overline{\theta}) - \beta^2(\overline{\theta})].$$

$$\beta(\overline{\theta}) = \max\left[0, \min\left(1, \frac{\overline{\theta} - \mathrm{WP}}{\mathrm{FC} - \mathrm{WP}}\right)\right].$$

$$\overline{\theta} = R_1\theta_1 + R_2\theta_2 + R_3\theta_3 + R_4\theta_4.$$

GRASS C3 and C4





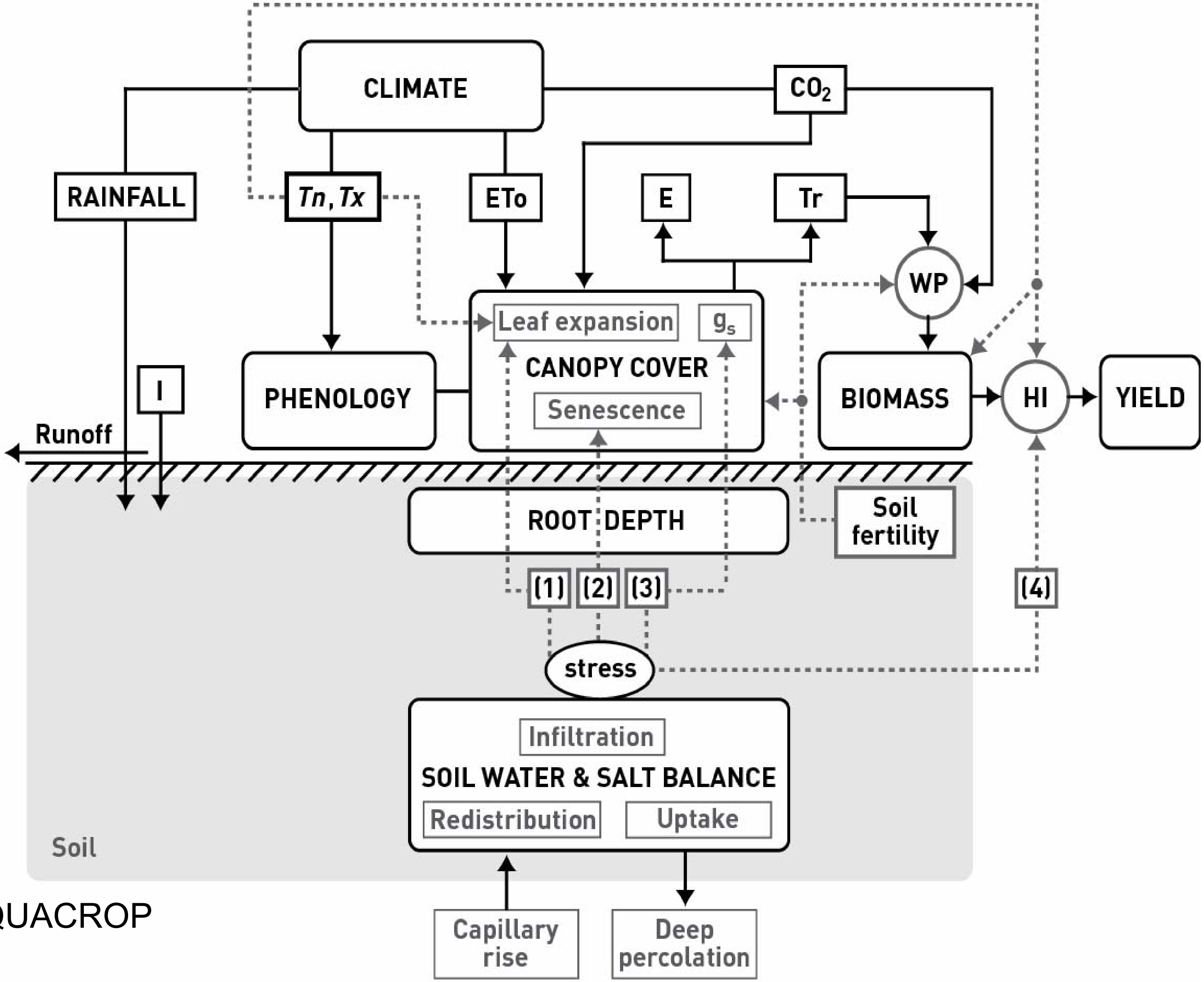
WOFOST for C4 grass, ambient temperature 40 C and for generic C4 (Kim and Verma data)

In the special grass version of WOFOST, the parameters are given: SLA between 0.0015 (day 80) to 0.002 (day 300), Kdif = 0.6, eps=0.5 amax = 40 (day 95) 35 (day 200) and 25 (day 275). The amax and eps are in good agreement with ryegrass data (J Woledge). Kdif is compatible with the effective daily mean of extinction coefficient (Blomback) but SLA is questionable (Blomback give 0.003). The model value for sla is in divergence also with Lucerne (also close to 0.003, cf Woodward). Also Johnson gives SLA near 0.0025 and amax near 22.

For hay a senescence loss can be added for OBT, using the senescence rate of 0.02 per day (cf Dowle) after day 200 and half this value before. For grass, we introduce a grazing loss for OBT following the procedure for mass loss (Dowle) but using, conservatively, a low livestock density. The grazing loss rate used is 0.02 per day and is effective only in the period of grazing (defined for a grass LAI bigger than 4, or a yield)

Soil HTO

- Initially piston flow in FDMH !
- Tuned by Drainage function (AQUACROP,CERES)
- UFOTRI variant
- CHEMFLO (use Haverkamp et al.(1977)), experienced in BIOMASS
- Campbell, tested
- HIDRUS1D, partially tested
- PICARD method, tested
- Celia method for water tested in BIOMASS (but from groundwater to top soil!)
- Tritium simple and method of characteristic
- To test more methods and to optimize-



From AQUACROP

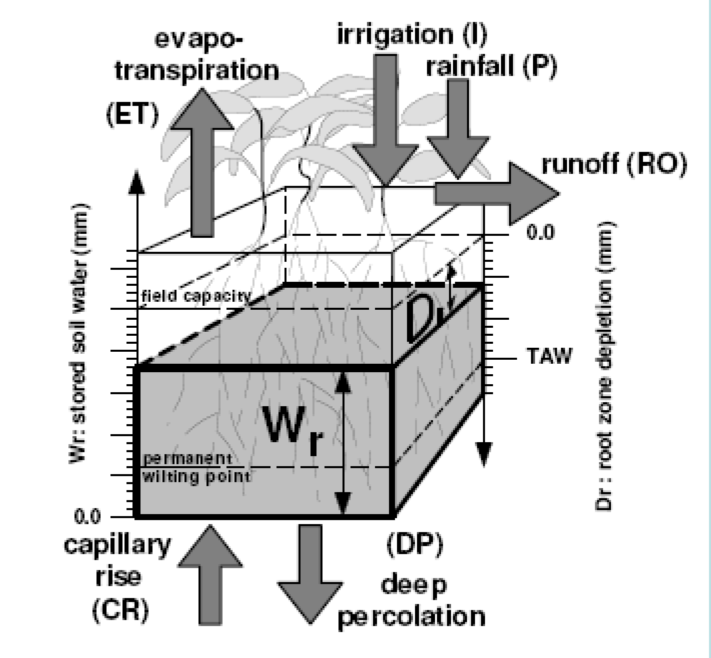


Figure 3.1a
The root zone as a reservoir.

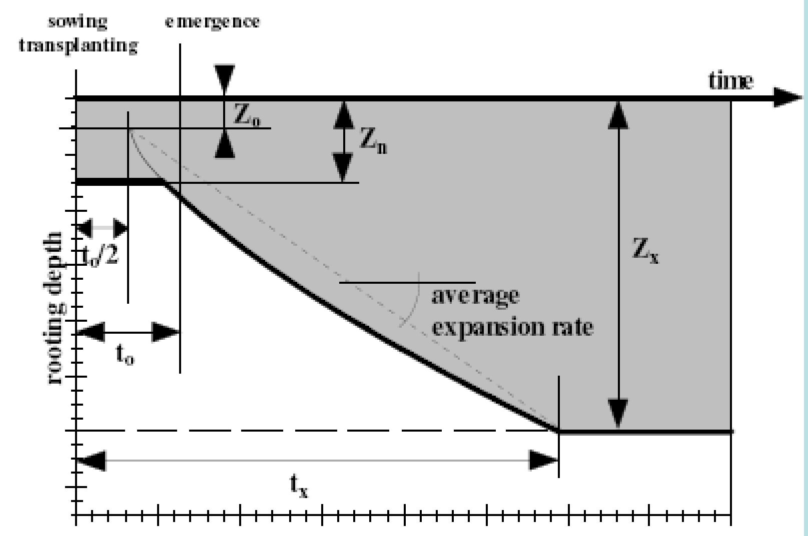


Figure 3.5a
Development of the effective rooting depth (shaded area)

From AQUACROP

TO COMPLETE PLANT DATA BASE WITH MIN AND MAX ROOTH LENGTH
Rice 0.6, wheat, potato>1. maize~2, but grass and lettuce <0.4

We must first solve the dynamic equation for soil water, with a space grid (z) extending below roots →This gives soil water content, water flux and soil water extraction, at various depths:

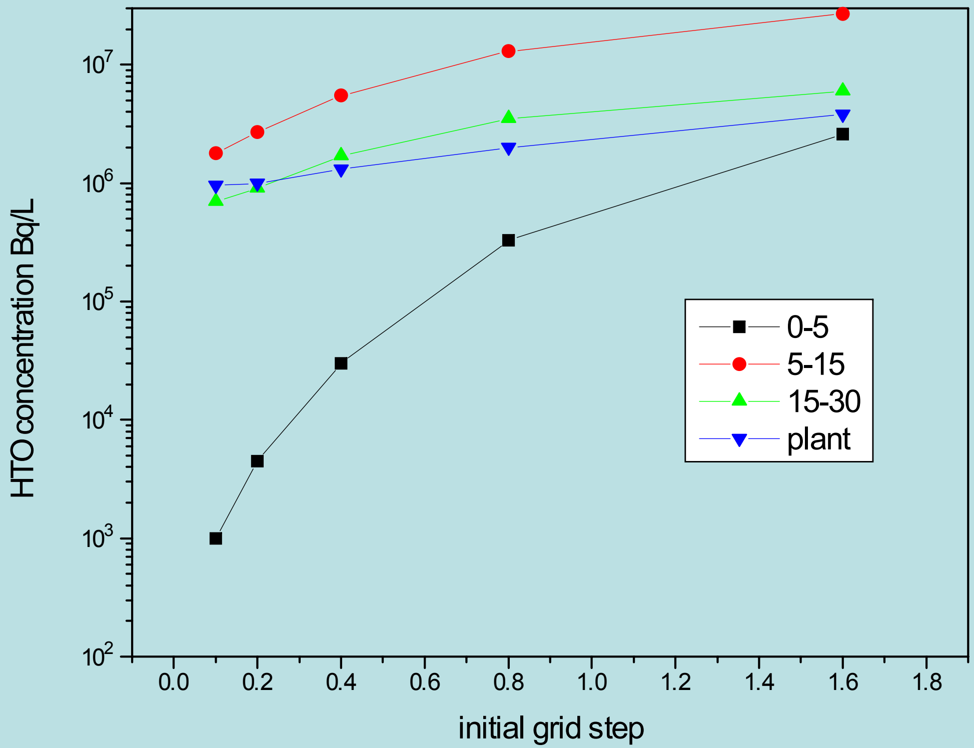
$$\frac{\partial \theta}{\partial t} = -\frac{\partial q_w}{\partial z} + s_w \qquad q = k\left(\frac{\partial \psi}{\partial z} + 1\right)$$

ψ is the soil matric potential,
k the hydraulic conductivity
and z the depth

Next we solve the HTO in soil and obtain the concentration of HTO at various depths and the concentration in transpiration water:

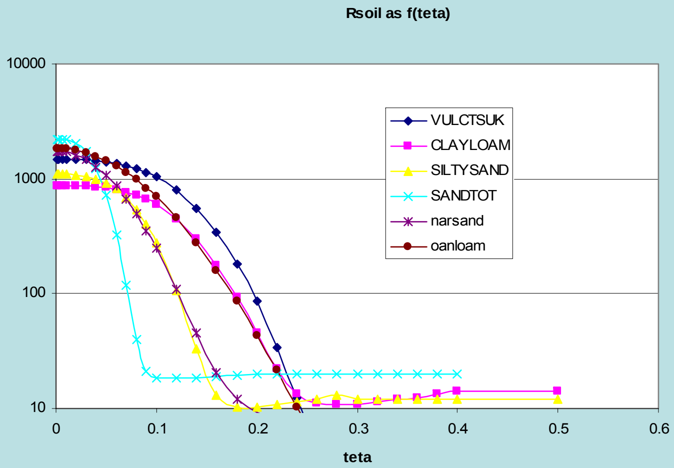
$$\frac{d(\theta c)}{dt} = -\frac{d(qc)}{dz} + \frac{d[\theta(D_{dif} + D_{dis})\frac{dc}{dz}]}{dz} - Sc$$

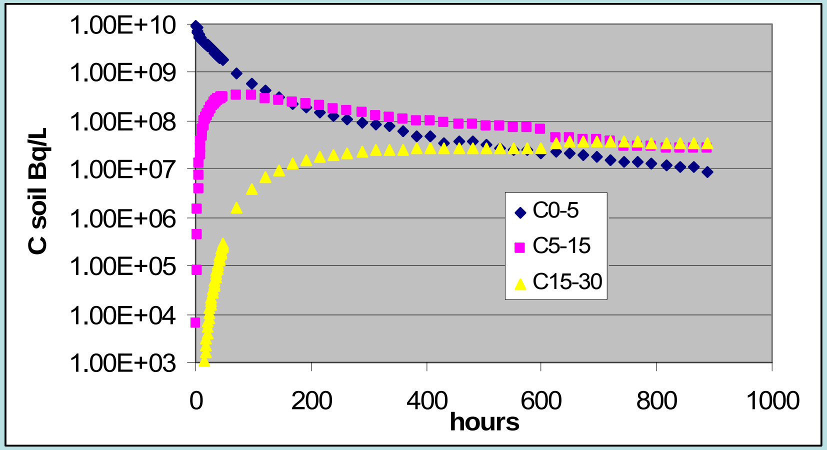
The space grid is important and increases from surface to deeper zone.
Optimization must minimize the error in the plant water concentration (after cloud passage).

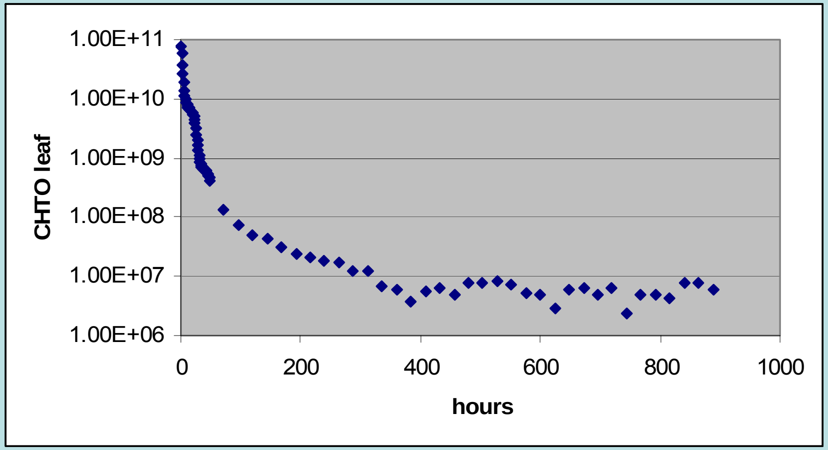


Effect of soil grid size on the HTO concentration in soil layers and plant (geometric grid)

Past results, to be upgraded







Soil resistance (upper left)
HTO concentration in soil
Layers (upper right)
HTO concentration in grass
(lower left)

Soil pedofunction

- PF log10 of matric head in cm water
- **Field Capacity (FC)** - is the moisture content in the soil after the excess water from a saturating rainfall has drained by gravity
- **Permanent Wilting Point (PWP)** - is the moisture content in the soil below which plants wilt beyond recovery

Table 2.1. Generally used soil-water retention and hydraulic conductivity relationships in the LSMs.

Model	Function	Parameters
Brooks-Corey (1964)	$\theta(h) = \begin{cases} \theta_s & if \quad h \ge h_b \\ \theta_r + (\theta_s - \theta_r)\left(\frac{h_b}{h}\right)^{\lambda} & if \quad h < h_b \end{cases}$	θ_r = residual water θ_s = saturated water or porosity h_b = air entry potential λ = pore-size index S_e = degree of saturation
	$K(S_e) = \begin{cases} K_s & if \quad h \ge h_b \\ K_s S_e^{\frac{2}{\lambda}+3} & if \quad h < h_b \end{cases}$	$S_e = \frac{\theta - \theta_r}{\theta_s - \theta_r}$
Campbell (1974)	$\theta(h) = \begin{cases} \theta_s & if \quad h \ge h_b \\ \left(\frac{h_b}{h}\right)^{1/b} & if \quad h < h_b \end{cases}$	b = constant
	$K(\theta) = \begin{cases} K_s & if \quad h \ge h_b \\ K\left(\frac{\theta}{\theta_s}\right)^{2b+3} & if \quad h < h_b \end{cases}$	
van Genuchten (1980)	$\theta(h) = \theta_r + \frac{\theta_s - \theta_r}{\left(1 + (\alpha h)^n\right)^m}$	α = constant n = constant $m = 1 - 1/n$
	$K(S_e) = K_s S_e^{0.5}\left[1 - \left(1 - S_e^{1/m}\right)^m\right]^2$	

Campbell soil parameters

	psie	b	tetas	ksat	robulk	FC	PWP
	J/kg		%vol	Kg*s/m ^3)	g/cm3		
clay	-9	9	0.5	8.00E-05	1.33	0.43	0.28
loam	-1.1	4.5	0.49	3.00E-04	1.35	0.23	0.1
sand	-1.5	2.35	0.407	4.00E-03	1.57	0.11	0.02
peat	-9	3.02	0.717	1.00E-03	0.75	0.47	0.13

Van Ghenuhten also considered.

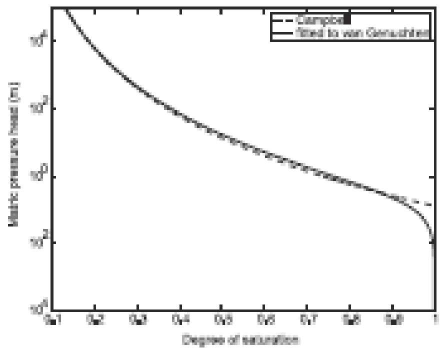
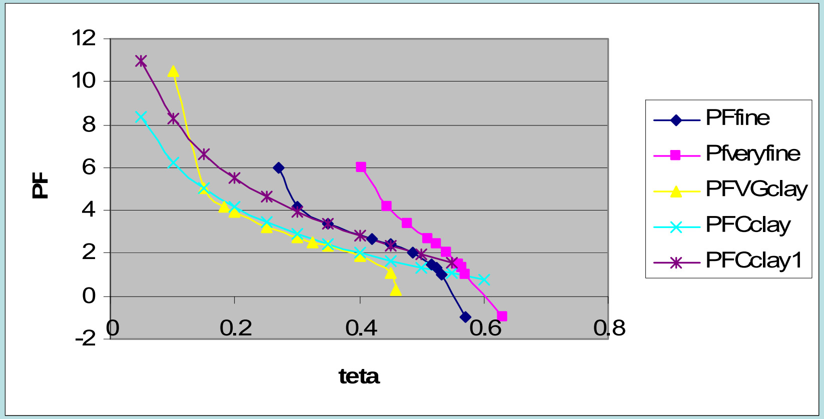
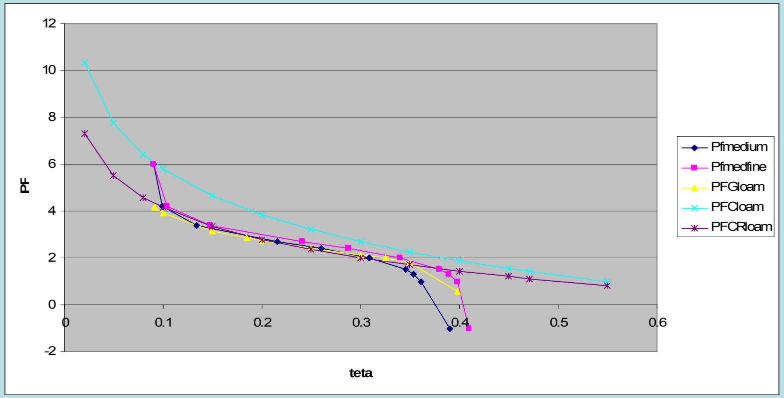


Figure 1. Water retention curve by Campbell (dashed) and that fitted to van Genuchten (solid).

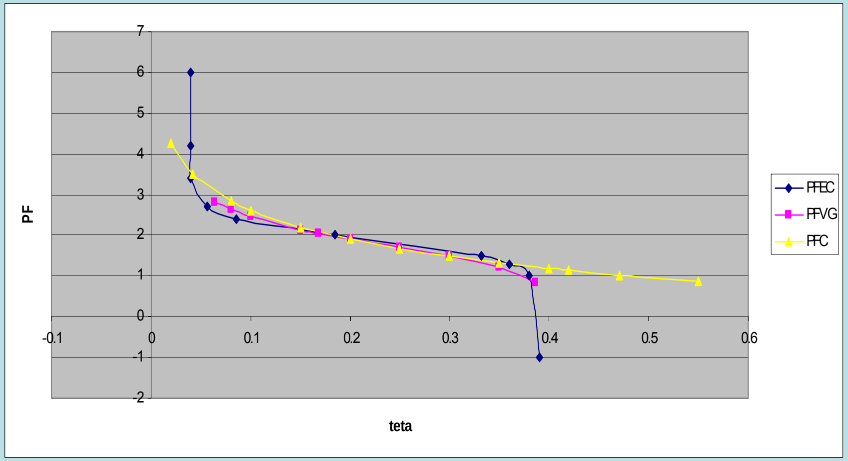
clay



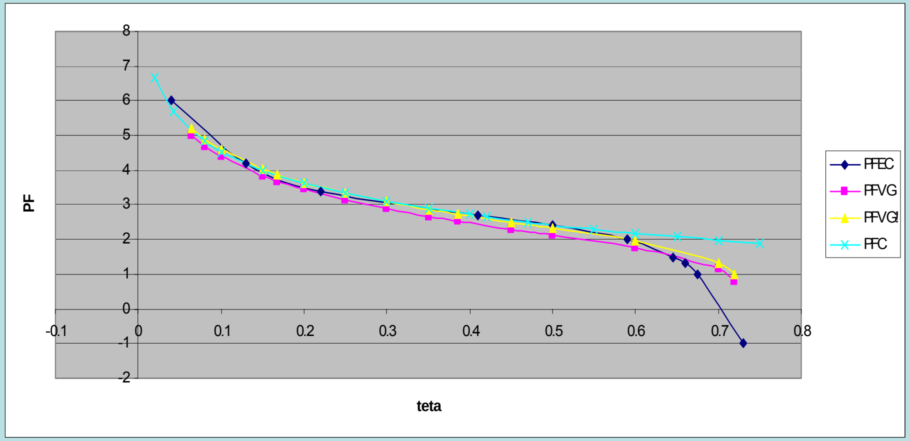
loam



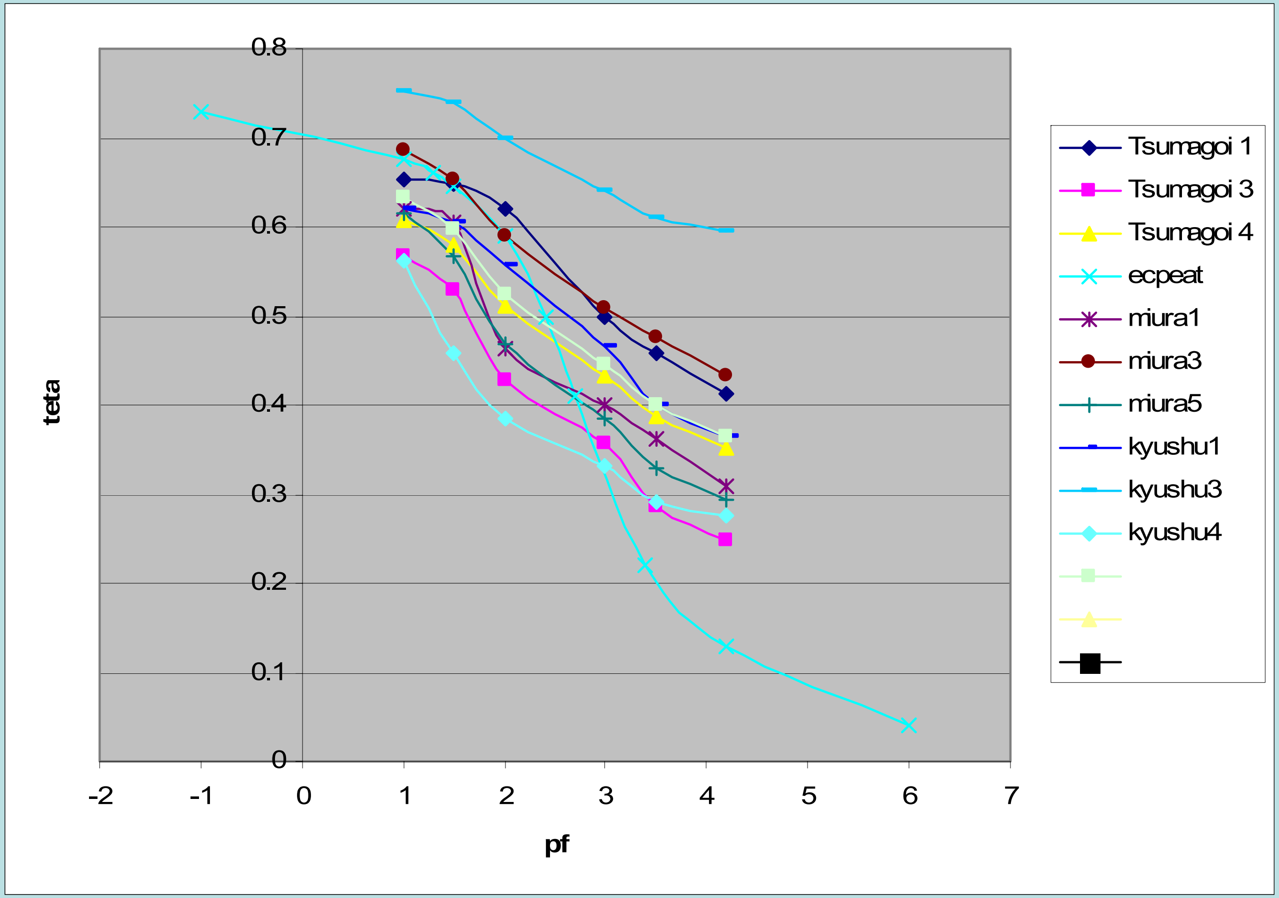
sand



peat

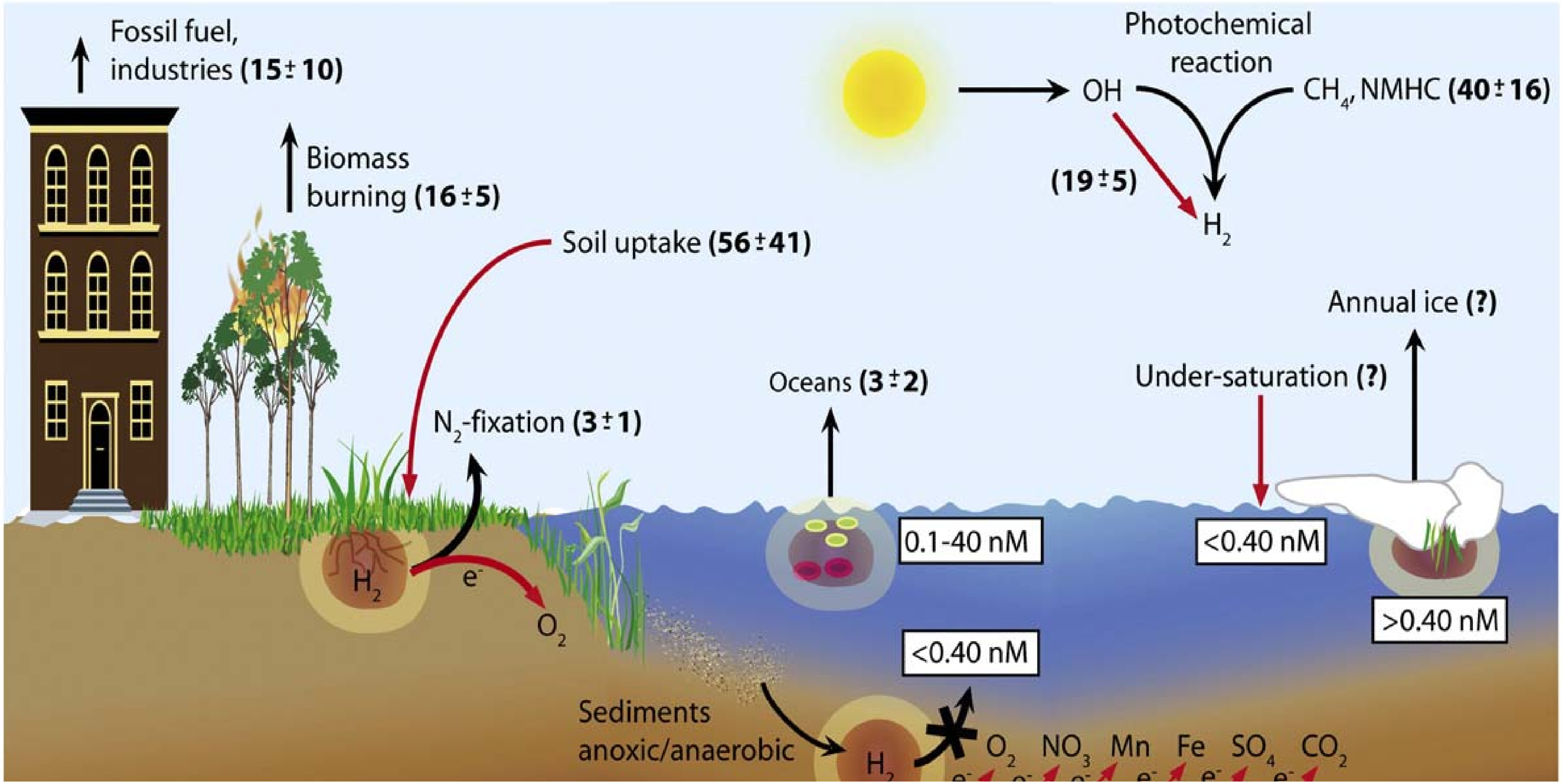


ANDOSOL



teta
pf
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-2
-1
0
1
2
3
4
5
6
7
Tsumagoi 1
Tsumagoi 3
Tsumagoi 4
ecpeat
miura1
miura3
miura5
kyushu1
kyushu3
kyushu4

Hydrogen balance>>HT deposition and conversion to hto



Previously we ignored HT deposition but it is planed a detritiation facility At CERNAVODA, and HT emission is considerated

$$\frac{d(\varepsilon C)}{dt} = \frac{d}{dz}[Deff * \frac{dC}{dz}] - \Lambda\varepsilon C$$

If the actual soil water volumetric content is θ and the maximum content at saturation is θs we have :

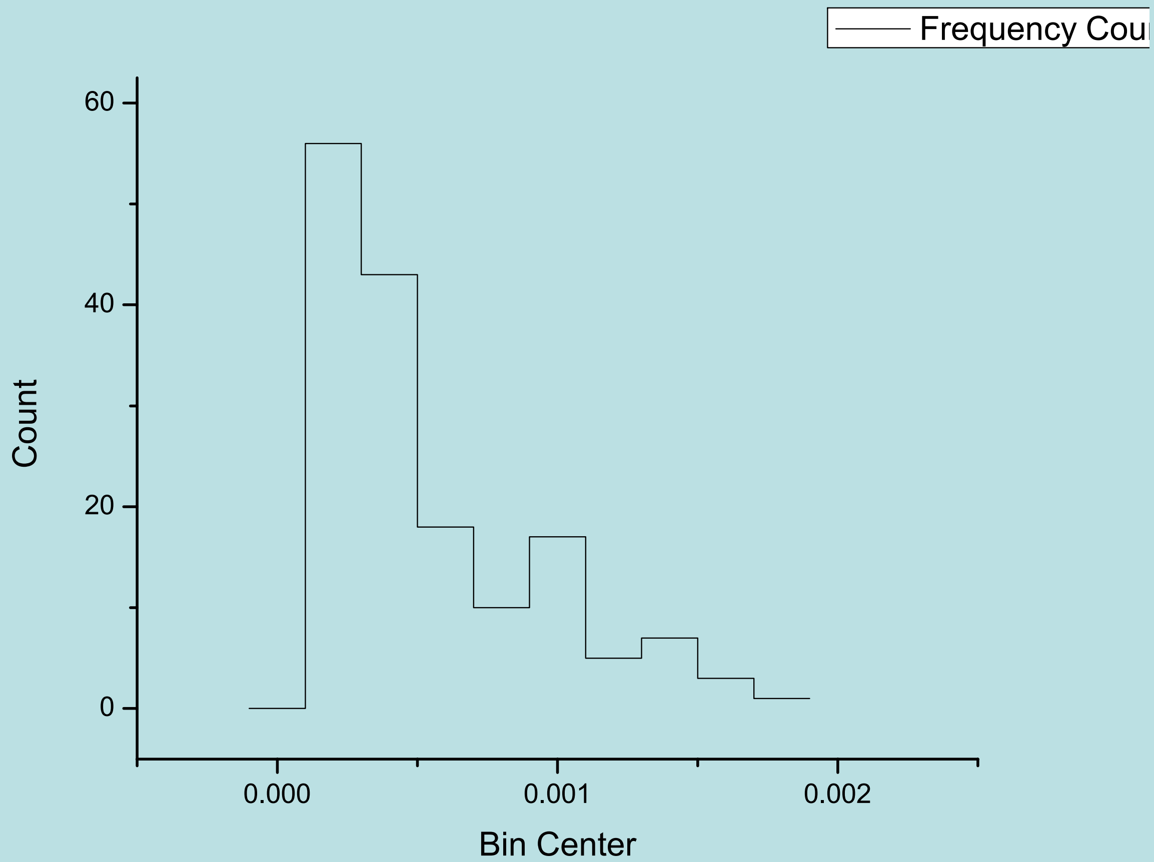
$\varepsilon = \theta s - \theta$

With Λ the oxidation rate (s-1) and Deff the effective diffusion coefficient [m2/s] given by

Defff= ε*Dsa [3]

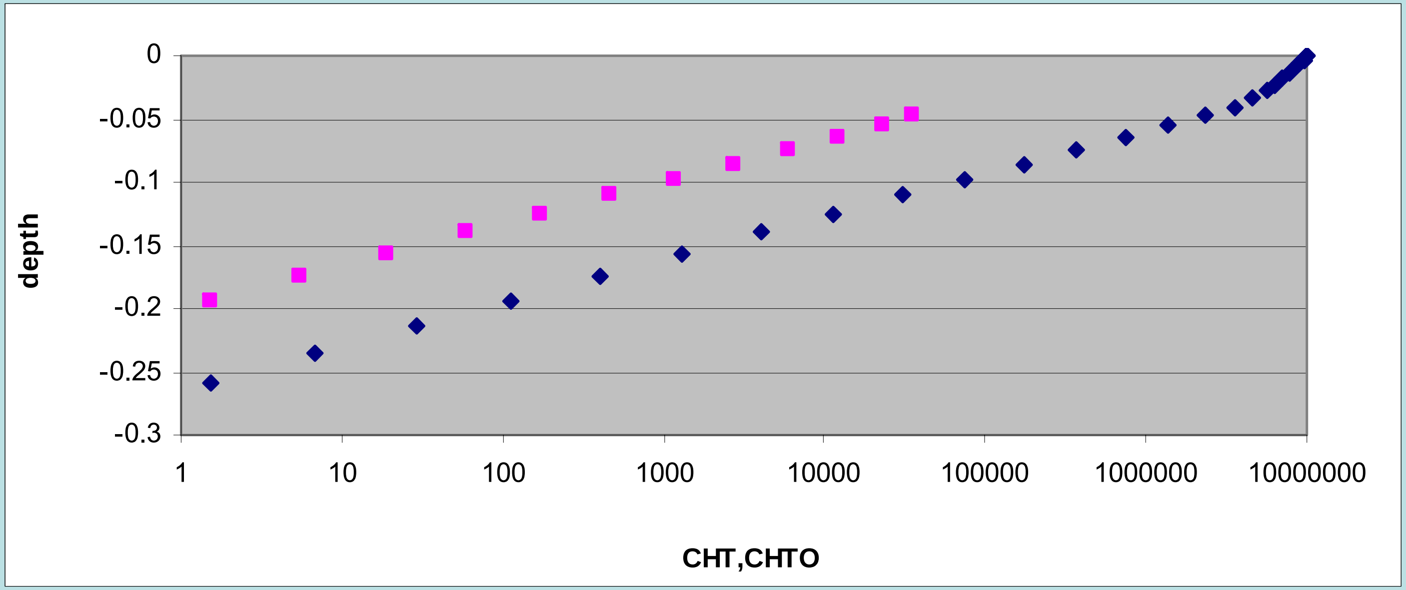
Where Dsa is the diffusion coefficient in the soil air

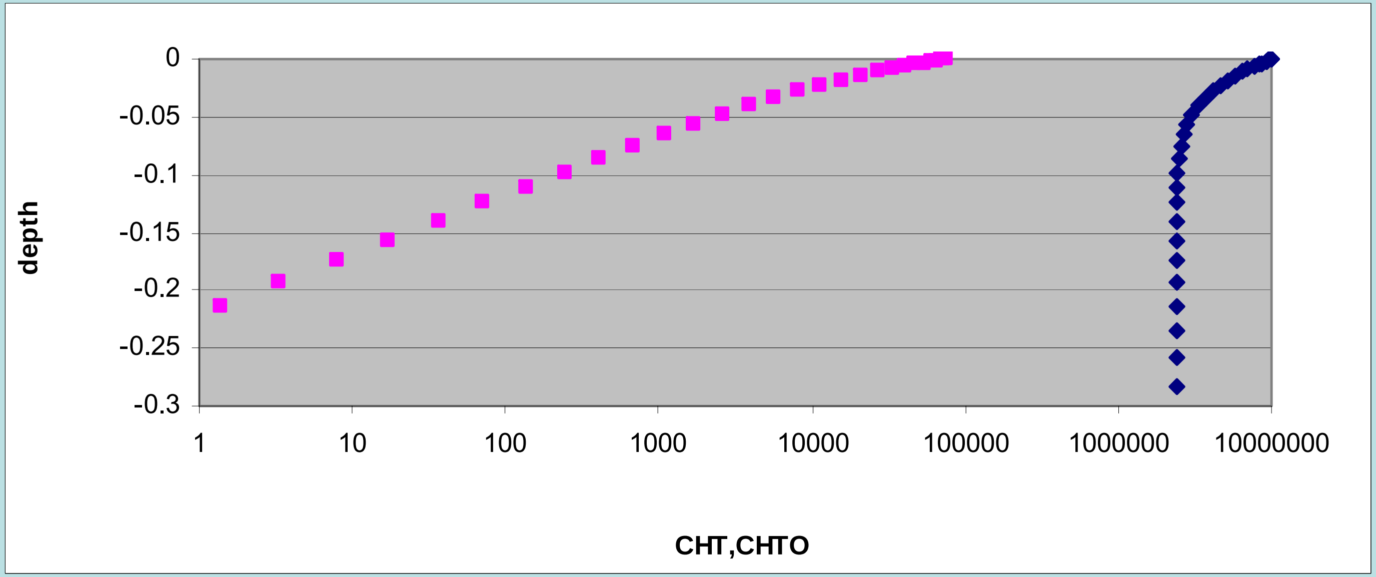
HT Deposition velocity distribution (m/s)- experimental data



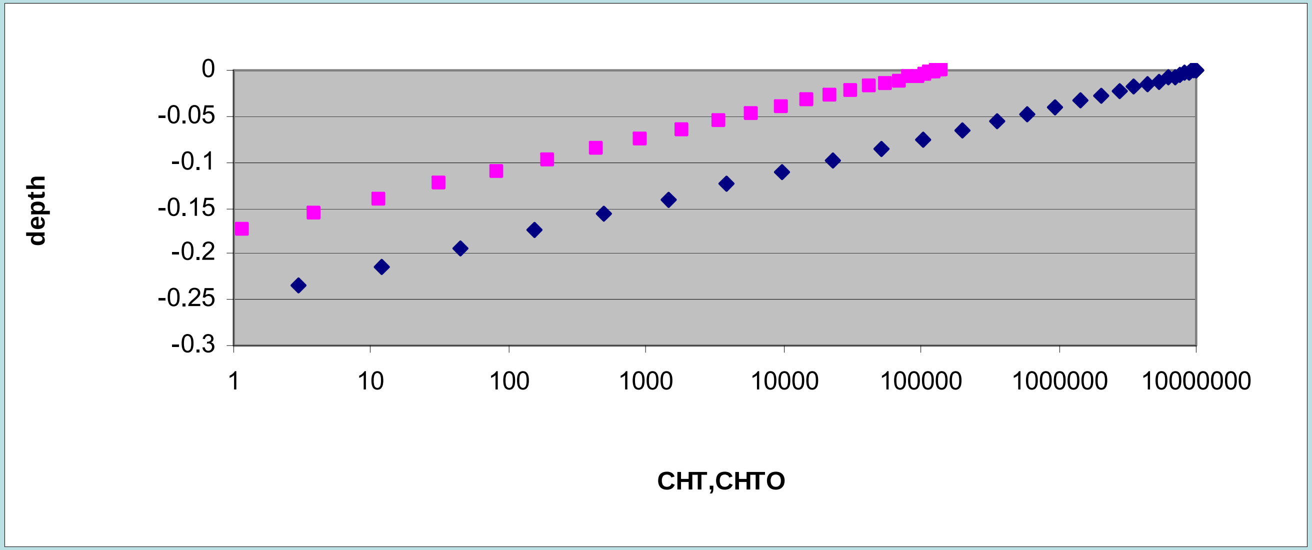
MAXIMUM H2 Deposition velocity 0.0033 m/s !!

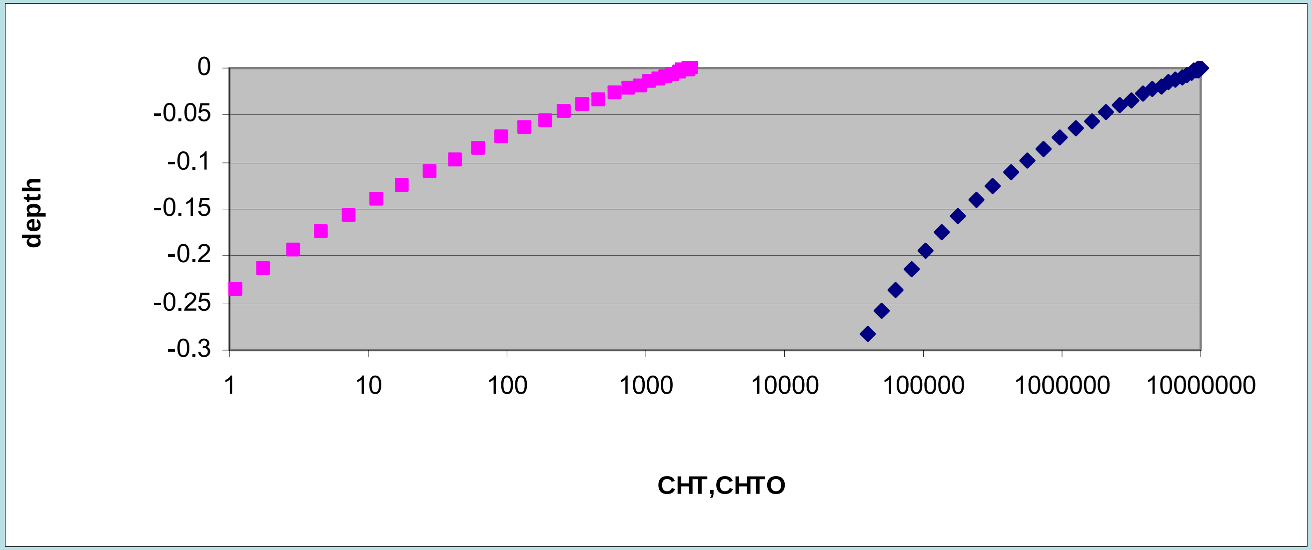
HT deposition Sand , dry season (up)
wet season (down)





HT deposition clay , dry season (up) wet season (down





- Soil water, HTO and transpiration - minimal complexity.
- Predominant soil type in the area

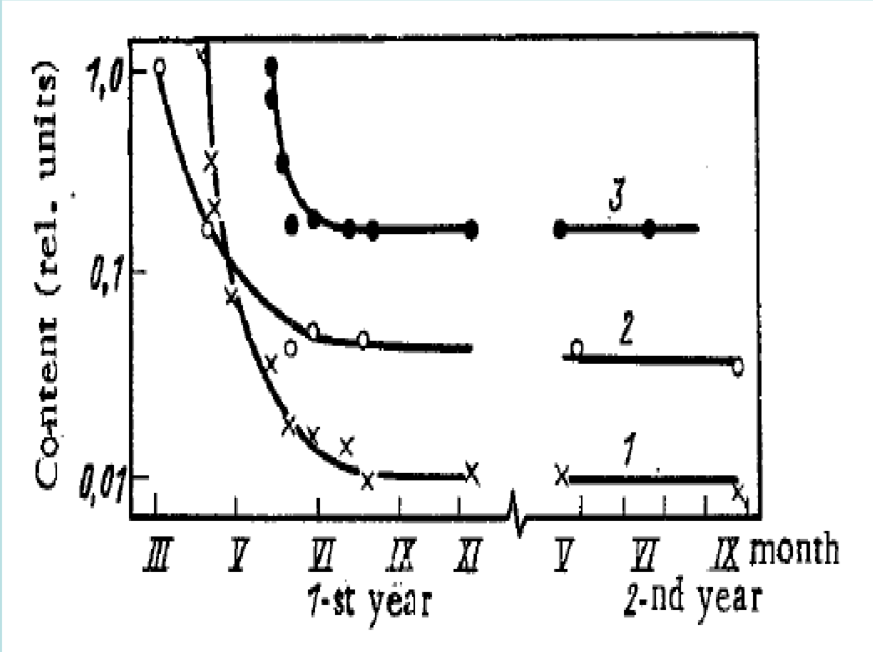
→ soil texture important for HTO remanence and site precipitation)

LONG term:

- Only soil HTO is driving
- Compartmental model with site adapted transfer parameters, seasonal dependence.
- Based on process simulation at one day time step.
- Body HTO loss rate

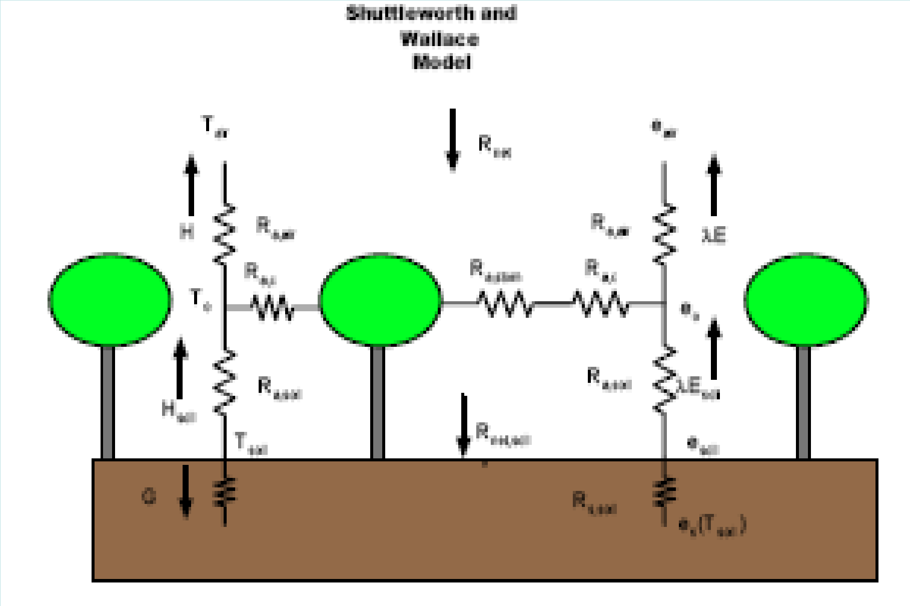
$loss=0.846*humsat*V_{ex}*3.600/watmass \ [h^{-1}]$

- V_{ex} computed for neutral atmosphere and season average PG
- Transpiration rate at average seasonal value for the crop



Changing of tritium content in 3 soil types

Soil – vegetation coupling and tritium transfer



The Shuttleworth-Wallace model defines fluxes from the vegetative and soil components with a resistance network.
With the Shuttleworth-Wallace model, there is need to define values of the humidity deficit, temperature and vapour pressure at the canopy source height, D_0, T_0, e_0.

By analogy, for HTO:

$$F_c(R_{aa} + R_{ab} + R_{ac}) + F_s R_a = C_a - C_c$$

$$F_c R_a + F_s(R_{aa} + R_{as} + R_{ss}) = C_a - C_s$$

C_a – HTO concentration in air;
C_c – HTO concentration in vegetation;
C_s – HTO concentration in soil;
R_{aa} – atmospheric resistance between reference level and canopy source height;
R_{ac} – boundary layer resistance;
R_{sc} – canopy resistance;
R_{as} – atmospheric resistance between canopy source height and soil surface;
R_{ss} - soil resistance;
F_c - flux atmosphere – vegetation;
F_s - flux atmosphere – soil.

$$F_c = V_{ex}(C_a - C_{va}) - V_{ex2}(C_a - C_{sa})$$

$$F_s = V_{ex1}(C_a - C_{sa}) - V_{ex2}(C_a - C_{va})$$

Details are given elsewhere

(A. Melintescu, D. Galeriu, “A versatile model for tritium transfer from atmosphere to plant and soil”, *Radioprotection*, Suppl. 1, Vol. 40 (2005), S437-S442, May 2005)

Time schedule

- June optimized soil HTO implemented in PCFDMH- budget assured
- September compartmental model for long term prediction-budget to be find
- December documentation – budget to be find