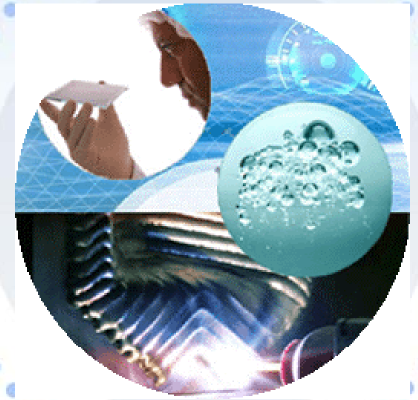

Plant submodel in OURSON

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From discharge in water to man : EDF dynamic models

- Dispersion/transport in river or sea
- Transfer to aquatic organisms
- Transfer through irrigation to agricultural products

Why are we interested in dynamic models for the dose assessment of liquid releases ?

- Some processes cannot be described by steady-state models : discontinuous process such as sediment deposit and resuspension

- Steady state models, used to demonstrate compliance with regulatory dose limits, are difficult to validate in the environment where concentrations change according to time in the day, season, river discharge,…Case of NPP liquid releases, discontinuous process and time-dependent pathways (irrigation)
  Validation is possible by :

  - Comparing dynamic models to field data

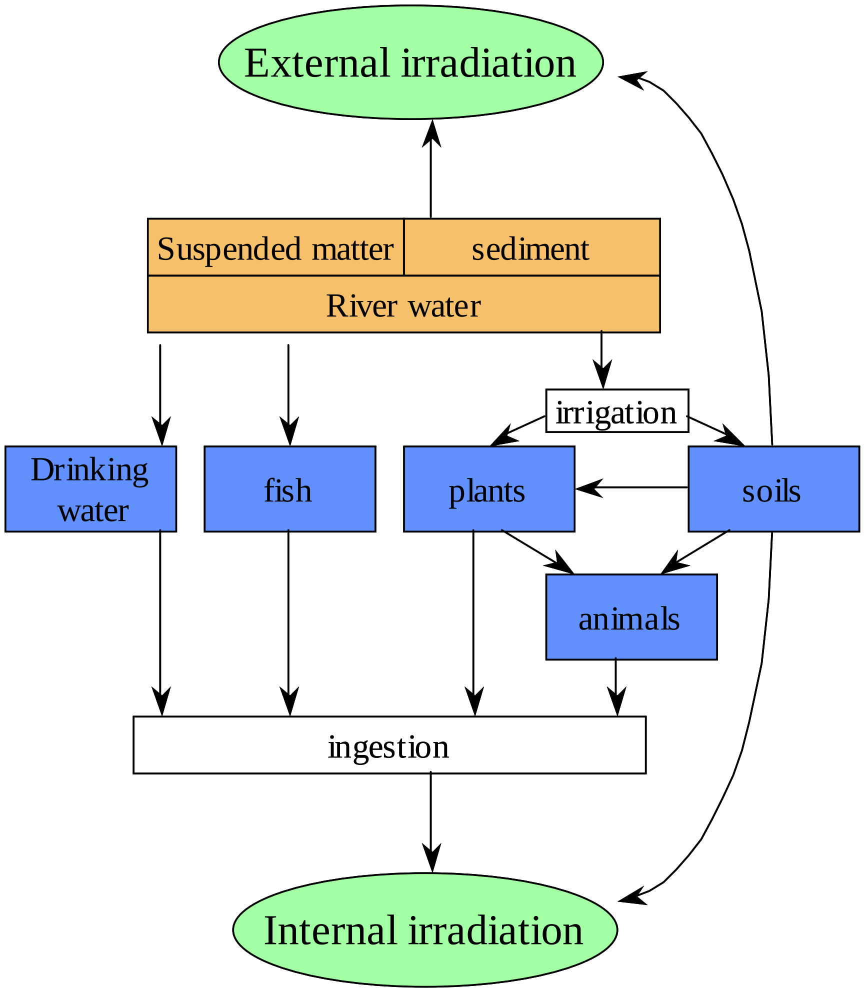
  - Running dynamic models on a longer time range (year) and comparing yearly average results with steady state model to check that they are conservative

- Dynamic models useful to demonstrate that different turn-over rates for HTO and OBT can explain observed OBT/HTO >1

Presentation of OURSON

- OURSON : a dynamic model developed to evaluate radionuclide transfer from surface water to man –
  - different submodels for tritium, carbone 14, and other radionuclides (Cs, Sr, Co, …)
  - some common processes (plant growth, plant water requirement, water movement in soil)
- Source term : liquid discharge in rivers, with time-dependent water flows (for more information on hydraulic models see Goutal et al 2008)
- Pathways : contamination of aquatic ecosystems, contamination of agricultural products through irrigation
- End point : dose to man

Main pathways of the OURSON model



OURSON Tritium aquatic sub-model

- HTO in fish
  - Rapid equilibrium between HTO in the organism and HTO in the surrounding media
  - Turn-over rate controlled by ratio between water intake and body water content (biological half-life lower than one day)
  - TFWT can be calculated with $A_{fish}^{HTO} = A_{water}^{HTO}$
- OBT in fish
  - same general equation for OBT and carbon 14 in phytoplancton, fish, terrestrial plants and animals: dynamics based on food intake rate or carbon assimilation rate for photosynthetic organisms (Sheppard et al 2006)
  - in the case of fish, feeding on phytoplancton, specific activity of OBT can be calculated with :

$$\frac{dA_{fish}^{OBT}(t)}{dt} = -k_{ing} A_{fish}^{OBT}(t) + k_{ing}.DF_{phyto}.\frac{H_{phyto}}{H_{fish}}.A_{eau}^{HTO}(t)$$

OURSON Tritium plant sub-model

See Ciffroy ,Siclet et al , 2006, *Journal of Environmental Radioactivity*

- HTO concentration in plants grown on irrigated soils
  - contamination is due to root uptake of soil water
  - HTO concentration in soil water
    - Function of precipitation, evapotranspiration (calculated from meteorological data), and irrigation rate (can be fixed or calculated for optimal crop growth)
    - Soil divided in 3 layers : ploughing zone, cultivable zone, deep soil
  - Plant TFWT(t) = $HTO_{ploughing\ zone}(t)$

  or

  Plant TFWT(t) = $(HTO_{ploughing\ zone}(t) + HTO_{cultivable\ zone}(t))/2$

  } depending on crop type

- OBT concentration in vegetative parts of plants (leaves, stems)
  - Same biota general equation : carbon assimilation through photosynthesis for plants

$$\frac{dOBT_{plant}(t)}{dt} = -g_r OBT_{plant}(t) + g_r TFWT(t)$$

g_r=relative growth rate = growth rate (assumed to be linear)/vegetative biomass

OURSON Tritium plant sub-model

- OBT in storage organs
  - Translocation from OBT formed in vegetative part from anthesis to harvest– irreversible accumulation in storage organs
  - Translocation index

$$TLI_t = \frac{\text{OBT in storage organs at harvest}}{\text{HTO root uptake at time of exposure / plant water content}}$$

With OBT in storage organs at harvest (Bq/L)

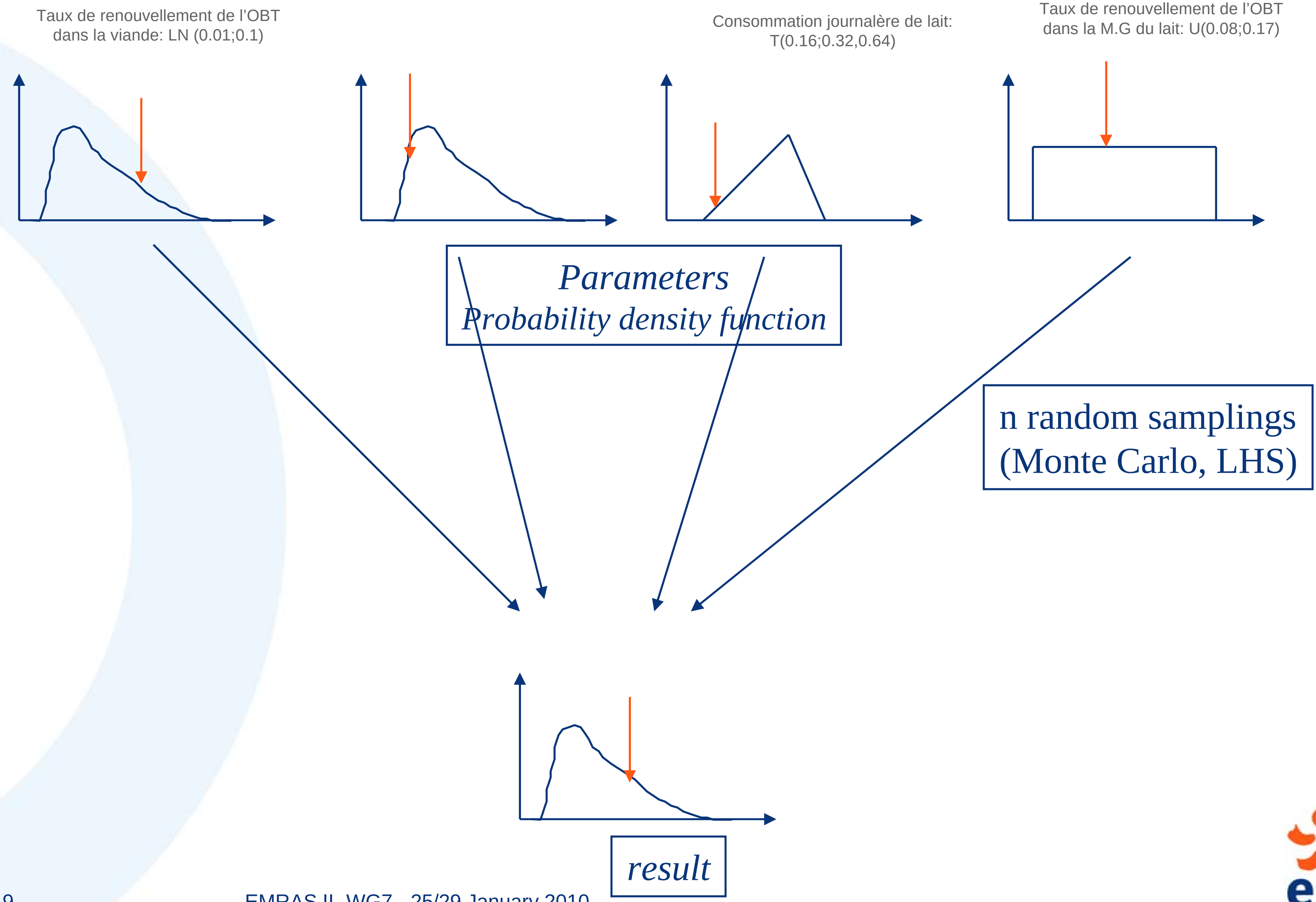
HTO root uptake at time of exposure ($Bq.m^{-2}.day^{-1}$)

plant water content ($L.m^{-2}$)

  - 3 stages with different TLI : anthesis, grain growth, maturity
  - OBT in storage organs at harvest : sum of daily translocation

$$OBT_{storage}(harvest) = \sum_t \frac{TLI_t.ETM.HTO_{soil}(t)}{H2O_{veg}(t)}$$

Uncertainty analysis



Uncertainty of mean annual dose (Sv/an) on Rdioecologie Loire scenario (OURSON results)

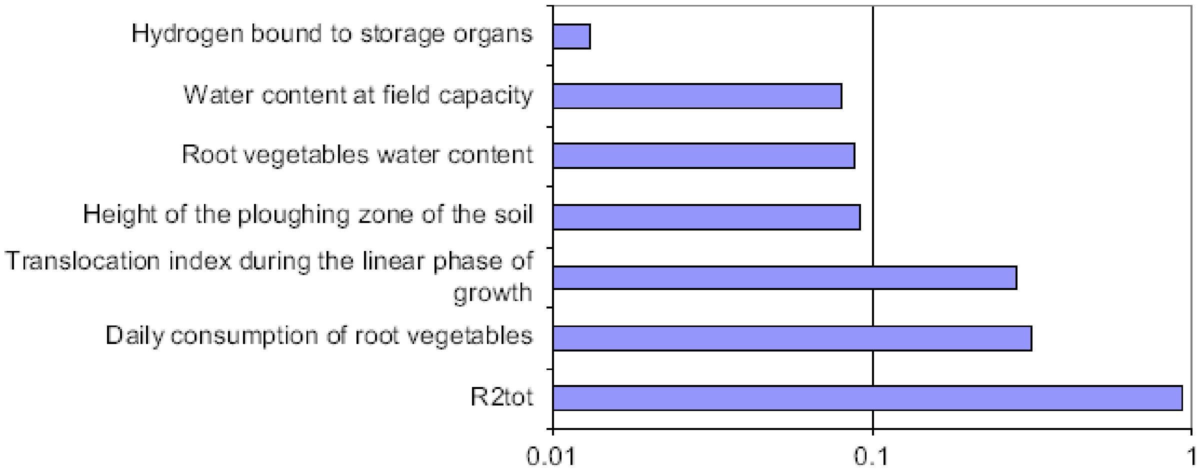
Output	Fifth percentile	95th percentile	Ratio 95th percentile/fifth percentile
Dose − ingestion of milk	9.9×10^{-9}	4.1×10^{-8}	4.1
Dose − ingestion of meat	1.3×10^{-9}	4.4×10^{-9}	3.4
Dose − ingestion of leaf vegetables	8×10^{-10}	2.7×10^{-9}	3.4
Dose − ingestion of fruit vegetables	6.6×10^{-9}	1.7×10^{-8}	2.6
Dose − ingestion of root vegetables	1.9×10^{-9}	8.8×10^{-9}	4.6

Source : Ciffroy ,Siclet et al , 2006, *Journal of Environmental Radioactivity*

Sensitivity analysis performed on Radioecologie Loire scenario

- Dose due to ingestion of root vegetables – sensitivity index

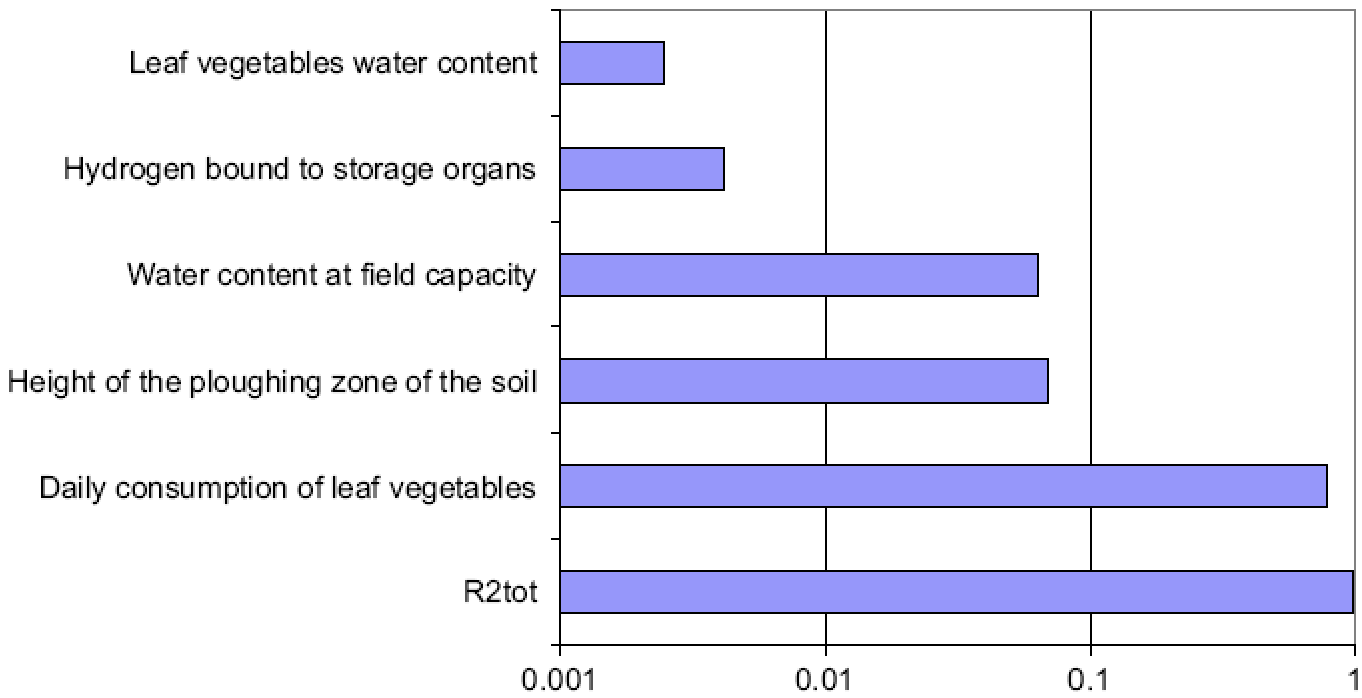
Sensitivity index : measures the "loss" of correlation when the parameter X_i is ignored in the regression analysis



→ Translocation of OBT to storage organs during linear growth stage is a sensitive process

Source : Ciffroy ,Siclet et al , 2006, *Journal of Environmental Radioactivity*

•Dose due to ingestion of leaf vegetables – sensitivity index



Most sensitive parameters are those influencing HTO dynamics in soil

Questions to be addressed

- Translocation of OBT to storage organs
  - EMRAS soybean scenario : OBT transfer to seed occurs even with exposure at very early stage of growth (before anthesis)
  - other limitations : TLI based on very few experimental data
  - Way forward
    - link OBT translocation to mass transfer to storage organs ?

$$OBT_{storage}(t) = \frac{\int_t storage\_organ\_growth\_rate(t).TFWT(t).OBHvegetative\_part(t)}{OBHstorage\_organ.\int_t storage\_organ\_growth\_rate(t).}$$

with storage organ growth rate in kg dry matter/day
OBH in vegetative part (water equivalent factor) L combustion water/kg dry matter
TFWT in vegetative part in Bq/L
OBH in storage organ (water equivalent factor) in L combustion water/kg dry matter

- Include OBT conversion to HTO in vegetative part to explain soybean scenario results (underestimation of HTO in plant freewater in the post exposure phase and underestimation of OBT transfer in storage organ with exposure before fruit formation)