Integrating tritium functionalities into JRODOS

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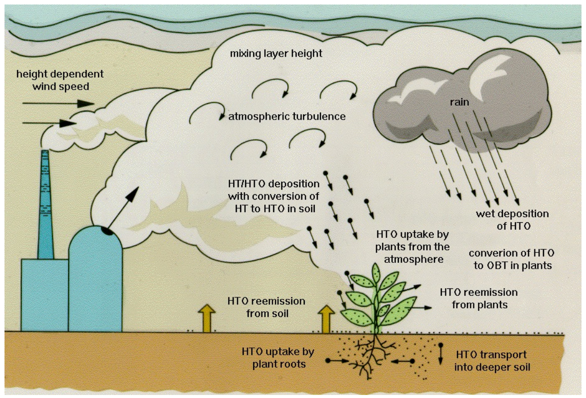

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Layout of presentation

- Introduction
- Processes to be considered in modelling of tritium behaviour in the environment
- Current assessment modelling
- Integrating of tritium functionalities into JRODOS
- Status and outlook

Acknowledgement

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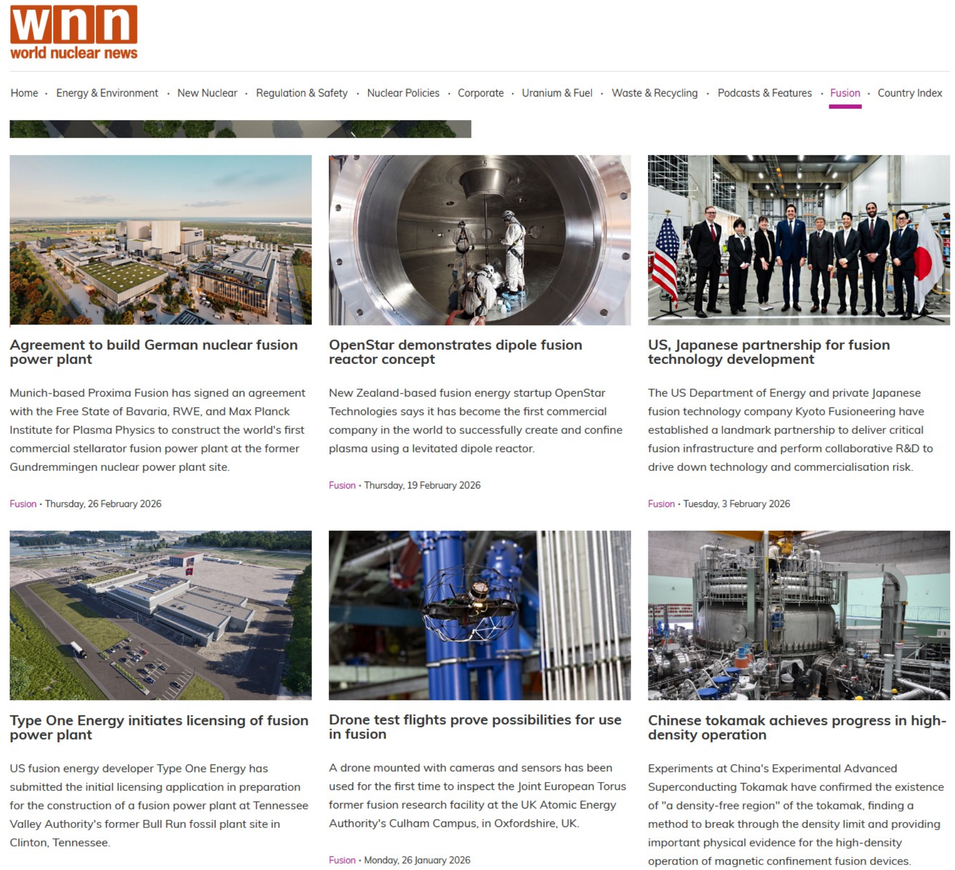
Need for assessing consequences from tritium releases into the environment

- All over the world, research is devoted to develop fusion reactors – outside the ITER community
- German Startup claims to develop a Stellarator power plant within 10 years
- Challenges for authorities
  - How to license the plant?
  - Is the knowledge about design based accidents or beyond design based accidents sufficient?
    - Is MELCOR or ASTEC capable to simulate possible transients?
  - How to assess doses to the population – is there a simulation model that has been validated and available for authorities?
  - Do we know the behaviour of possible materials and are they considered in all relevant models?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Agreement to build German nuclear fusion power plant

Munich-based Proxima Fusion has signed an agreement with the Free State of Bavaria, RWE, and Max Planck Institute for Plasma Physics to construct the world's first commercial stellarator fusion power plant at the former Gundremmingen nuclear power plant site.

Fusion · Thursday, 26 February 2026

OpenStar demonstrates dipole fusion reactor concept

New Zealand-based fusion energy startup OpenStar Technologies says it has become the first commercial company in the world to successfully create and confine plasma using a levitated dipole reactor.

Fusion · Thursday, 19 February 2026

US, Japanese partnership for fusion technology development

The US Department of Energy and private Japanese fusion technology company Kyoto Fusioneering have established a landmark partnership to deliver critical fusion infrastructure and perform collaborative R&D to drive down technology and commercialisation risk.

Fusion · Tuesday, 3 February 2026

Type One Energy initiates licensing of fusion power plant

US fusion energy developer Type One Energy has submitted the initial licensing application in preparation for the construction of a fusion power plant at Tennessee Valley Authority's former Bull Run fossil plant site in Clinton, Tennessee.

Drone test flights prove possibilities for use in fusion

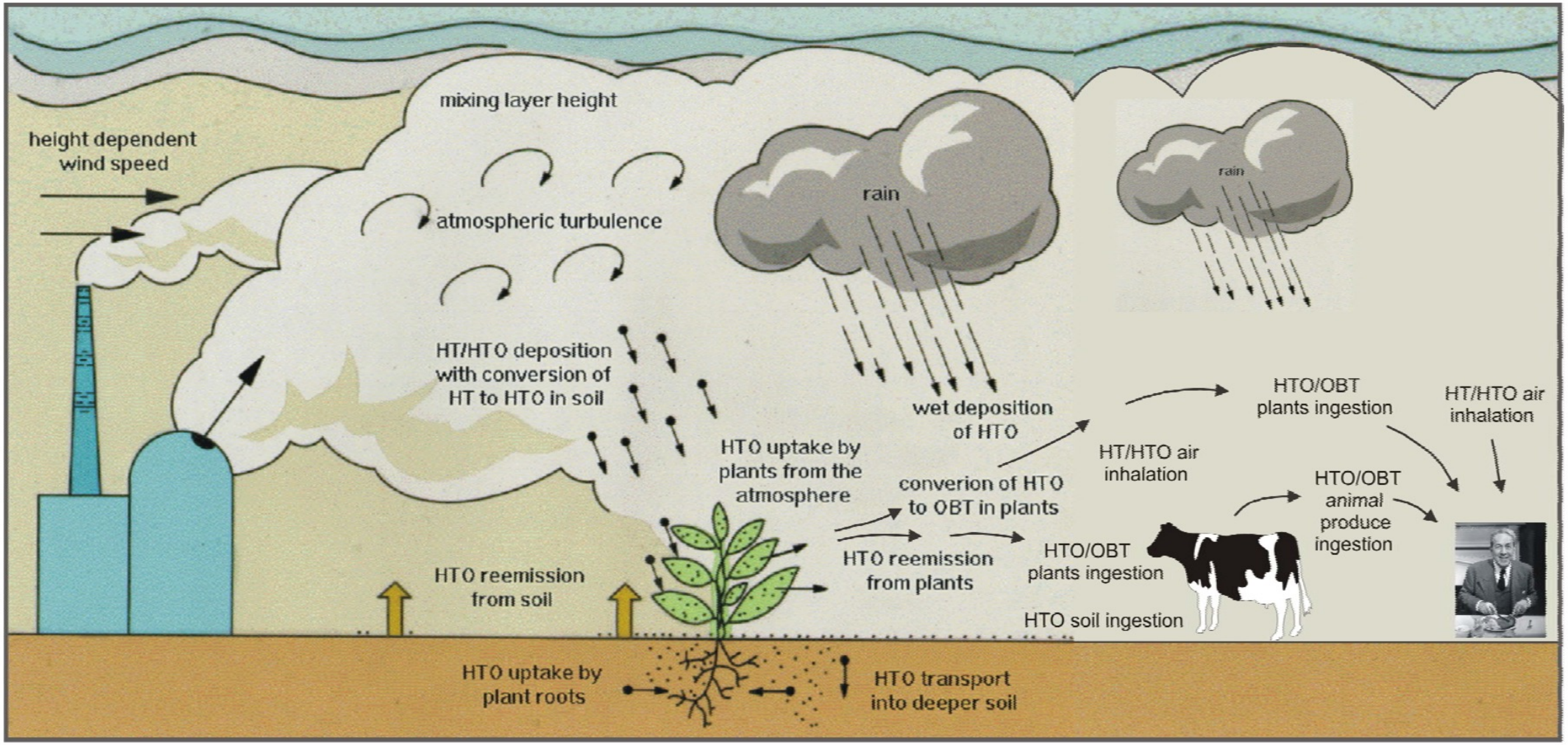
A drone mounted with cameras and sensors has been used for the first time to inspect the Joint European Torus former fusion research facility at the UK Atomic Energy Authority's Culham Campus, in Oxfordshire, UK.

Fusion · Monday, 26 January 2026

Chinese tokamak achieves progress in high-density operation

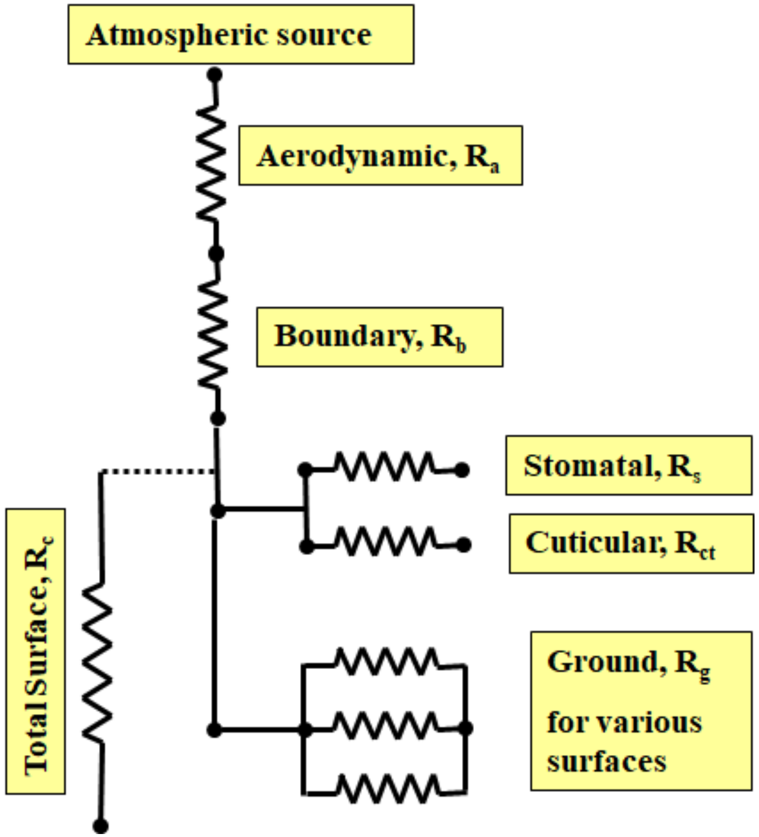
Experiments at China's Experimental Advanced Superconducting Tokamak have confirmed the existence of "a density-free region" of the tokamak, finding a method to break through the density limit and providing important physical evidence for the high-density operation of magnetic confinement fusion devices.

Processes to be considered in a tritium model

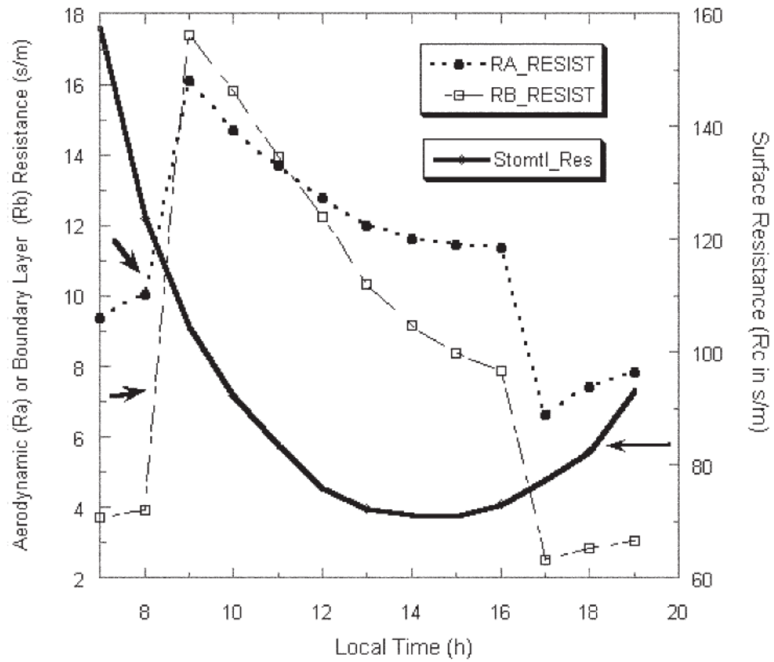


W. Raskob et al.

Why is tritium different from other radionuclides?
Dynamic behaviour – special resistances



Sample time history of simulated aerodynamic (Ra), boundary layer (Rb), a (Rc) resistances using a photosynthesis-based biophysical model. Effects of changes and the dominance of the canopy resistance term is clearly seen

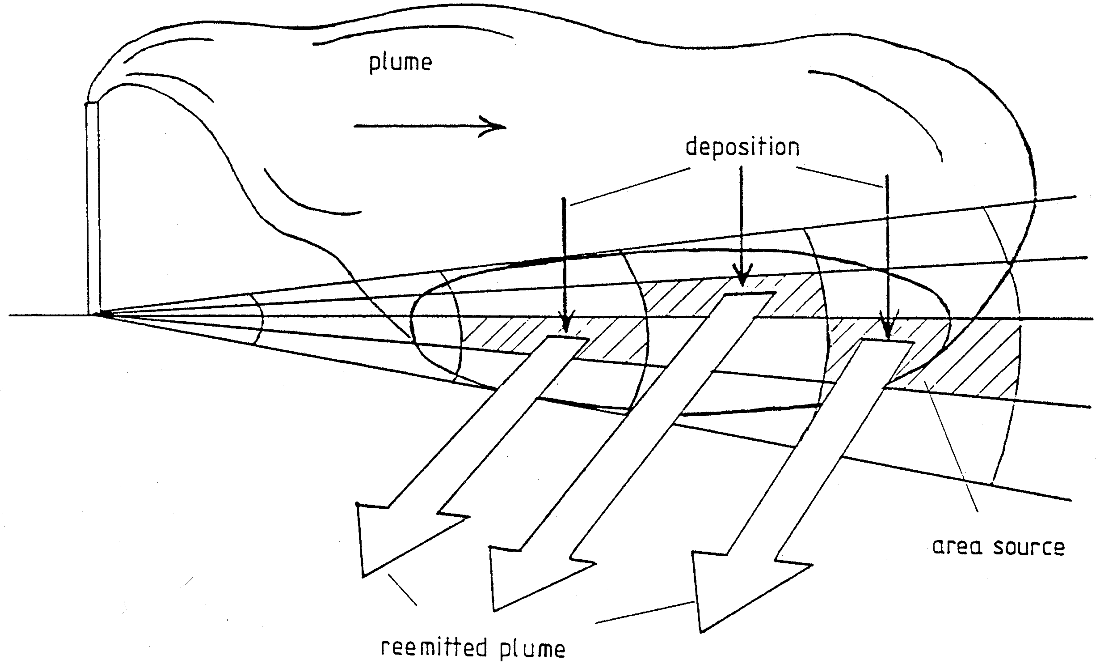


Why is tritium different from other radionuclides?
Behaviour as water

- Tritiated water vapour (HTO) and tritiated gas (HT) once deposited to soil (HT is converted in soil to HTO via micro-organisms) or to crops, behaves like water
  - This requires modelling of water movement in soil based on precipitation and evaporation of water vapour from soil
  - Uptake by crops is based on the water uptake via the root system which is triggered from transpiration of crops
  - Transpiration and evaporation has to be modelled based on the environmental conditions, in particular solar radiation
  - Water stress conditions have to modelled also as this affects the root uptake and evapotranspiration

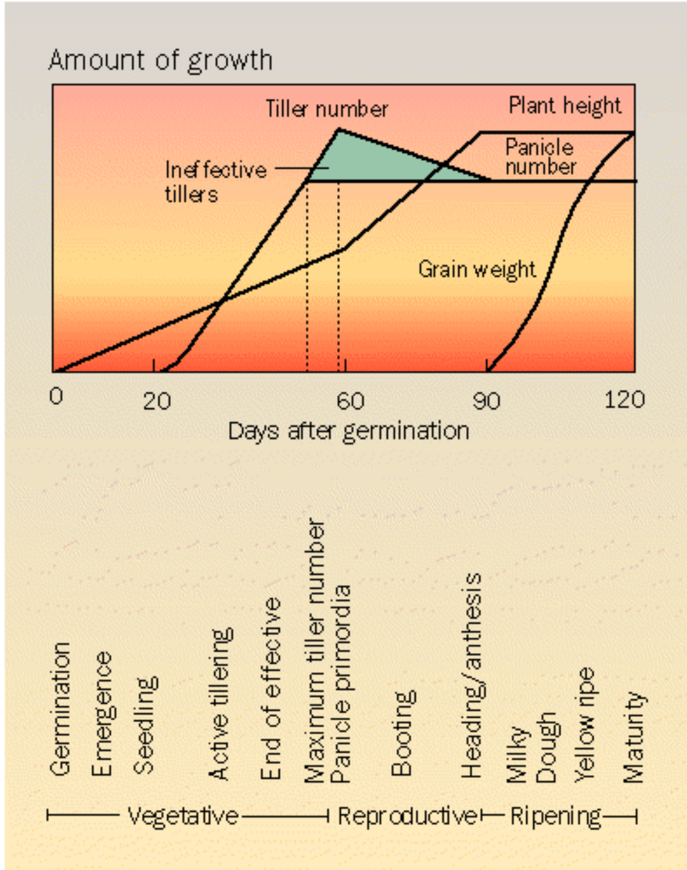
Why is tritium different from other radionuclides?
Reemission

- HTO will be re-emitted from soil and crops – once deposited
- Re-emission is strongly time dependent and requires consideration of environmental conditions such as solar radiation and precipitation
- Re-emission requires the simulation of many area sources
- Re-emission is mostly important for HT releases as dose conversion factor of HT is low



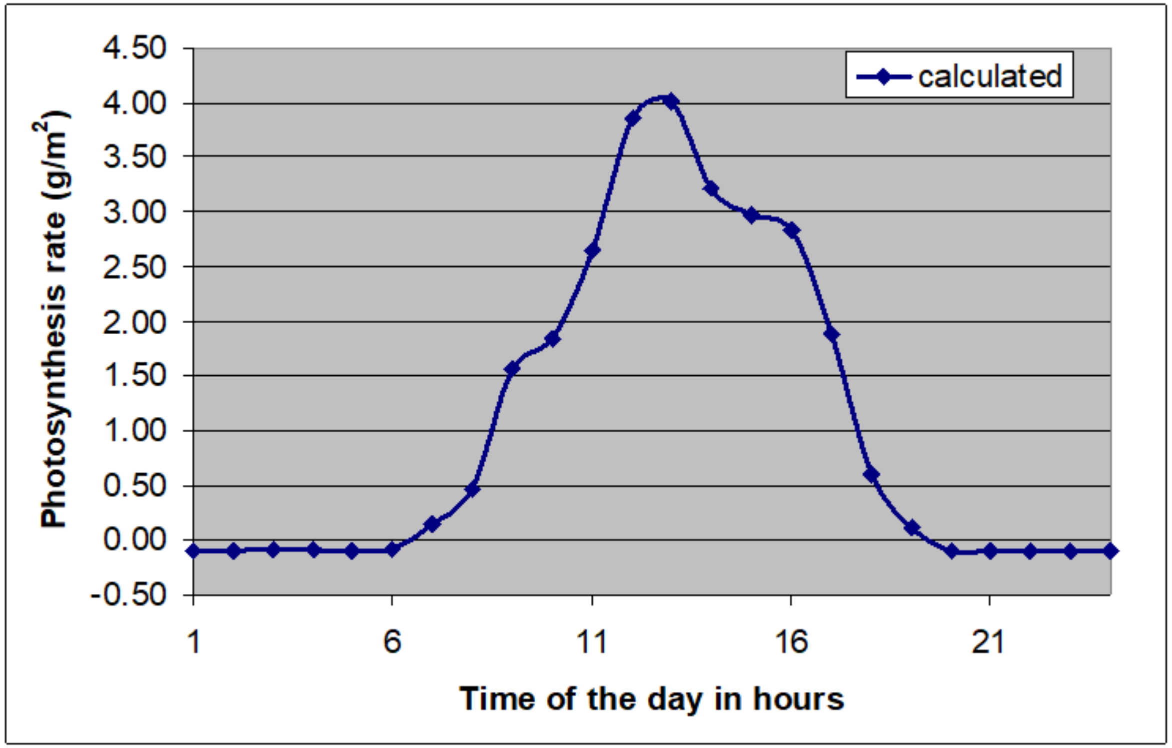
Why is tritium different from other radionuclides?
Transfer into organic matter

- Concentration in crops are typically modelled in a simple way
  - Concentration in crop = concentration in source X transfer factor
- For tritium, formation of organic matter (OBT) is important as it dominated the dose from food products
- Curves like on the right picture are used to determine the uptake for traditional radionuclides in seeds



Why is tritium different from other radionuclides?
Transfer into organic matter

- For tritium models – e.g. UFOTRI, the build-up of organic matter is calculated based on the photosynthesis rate
- Highly dependent on time of the day, solar radiation and other conditions such as water availability and humidity



Assessment for ITER and DEMO

- KIT has and is performing dose assessments for ITER and DEMO
- Probabilistic unit releases for Cadarache, one year of meteorological data, 144 representative cases with probability of occurrence
  - The maximum exposed individual at various distances is selected and typically the 95% percentile is used for the dose value
- Source term consists of tritium and activation products
  - UFOTRI for tritium
  - COSYMA for activation products
- Both dose results have to be combined before doses are estimated – weather sequences with high doses are different for tritium and activation products due to different deposition characteristics

Existing tritium models

Environmental tritium model	Affiliation	Atmospheric dispersion model	Tritium forms	Buoyancy	Dry deposition	Ref.
UFOTRI	KIT Germany	Gaussian	Gaseous HTO/ HT	No	Neglect gravitational deposition	Galeriu et al. (1995)
ETMOD	AECL Canada	Gaussian	Gaseous HTO/ HT	No	Neglect gravitational deposition	Russell and Ogram (1992)
CERES	CEA France	Gaussian	Gaseous HTO/ HT	No	Consistent deposition velocity (3 mm/s HTO and 0.3 mm/s HT)	Monfort et al. (2011)
DCART	LLNL USA	Gaussian	Gaseous HTO/ HT	No	Neglect dry deposition	Peterson (2004)
SOLVEG-II	JAEA Japan	Diffusion equation	Gaseous HTO	No	Neglect gravitational deposition	Yamazawa (2001)
ATDC	KAIST Korea	Gaussian	Gaseous HTO	No	Neglect gravitational deposition	Rho and Lee (1998)
TERM	CHU UK	Gaussian	Gaseous HTO/ HT	No	Neglect gravitational deposition	Jeffers and Parker (2014)
DISPT	IFIN-HH Romania	Gaussian	–	No	Soil concentration as $0.1C_{air}$	Galeriu and Melintescu (2015)
TAS	CAS China	Gaussian	Gaseous HTO/ HT	No	Neglect gravitational deposition	Nie et al. (2015)

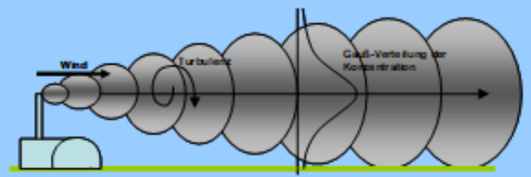
From: Deyi Chen et al., in Chemosphere 2022, https://doi.org/10.1016/j.chemosphere.2022.137231

- To benchmark/improve the Assessment code MACCS (used in US and worldwide for licensing), comparison was performed between MACCS, ETMOD and UFOTRI (Sandia report 2023)
- Conclusion: a simple approach is possible for releases of HTO, but not for HT, also ingestion dose cannot be modelled so far

JRODOS EMERGENCY chain models

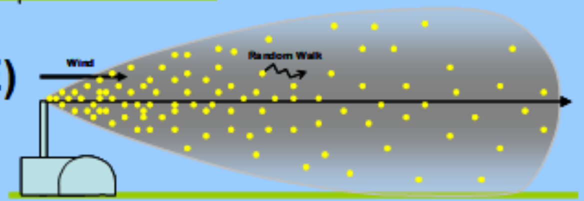
Released activity (Measurement / User)	Meteorological data (Measured / Prognostic / User)	Further data (from JRodos Data bases)

LSMC: Atmospheric dispersion and deposition, local scale (up to several 100 km)



Rimpuff (DEN)

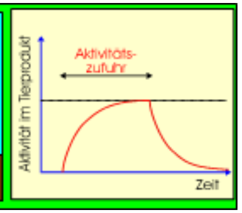
Dipcot (GRE)
Lasat (GER)



- **Why not integrating UFOTRI as additional model?**
- **The dispersion model of UFOTRI is not state of the art!**

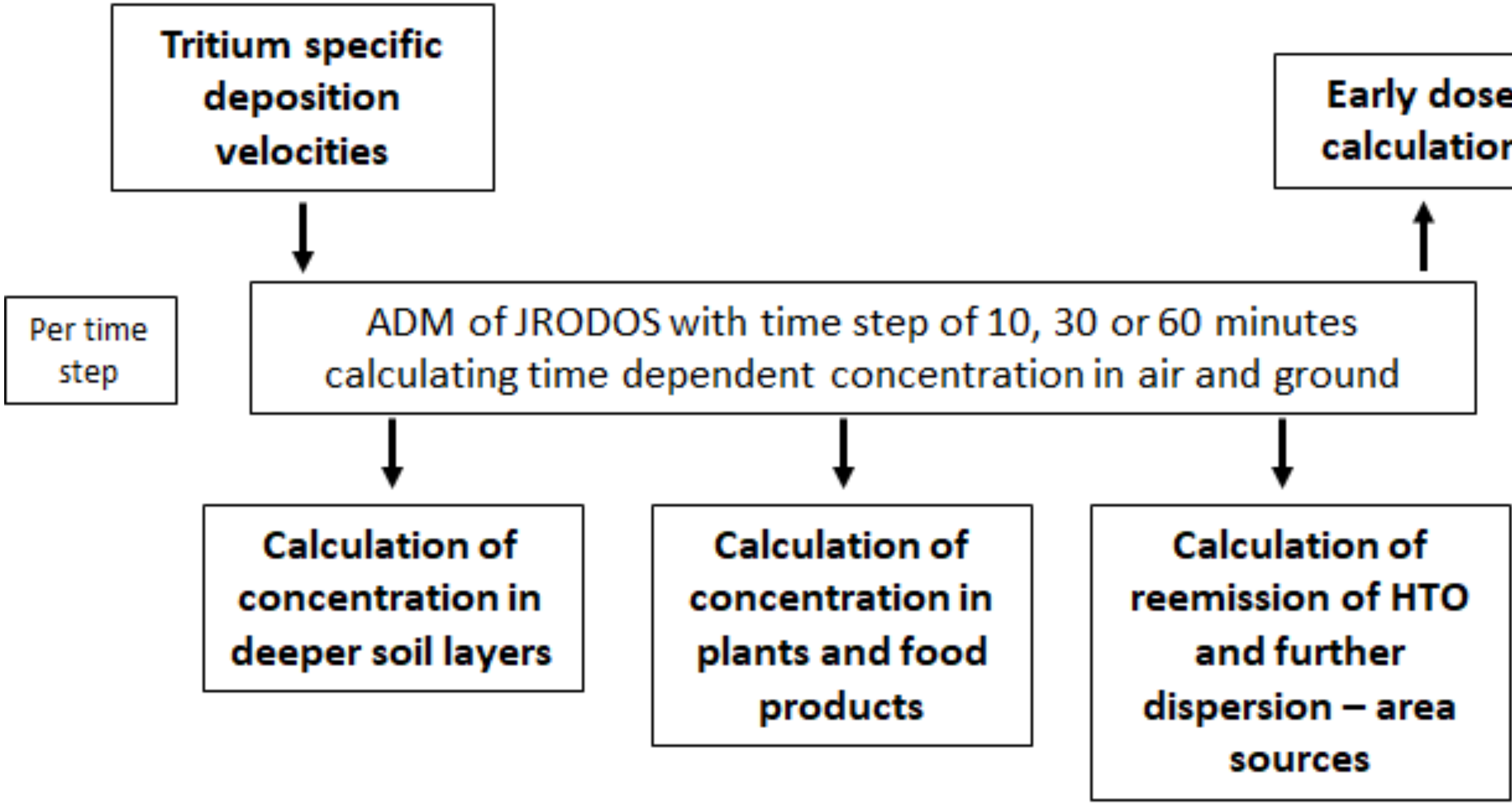
Dose rate calculation,
Early countermeasure simulation,
Health effects and costs

Food chain and dose model, terrestrial FDMT (GER)



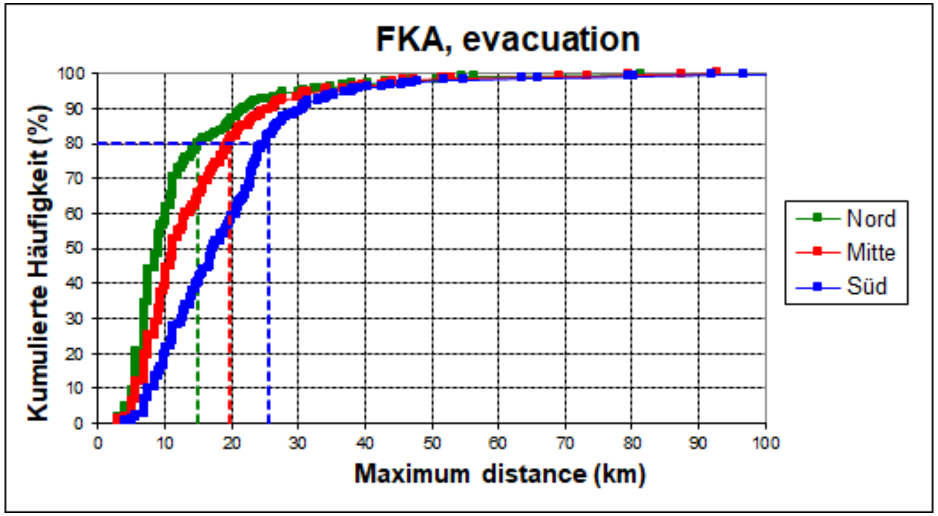
KIT ITES

How to integrate



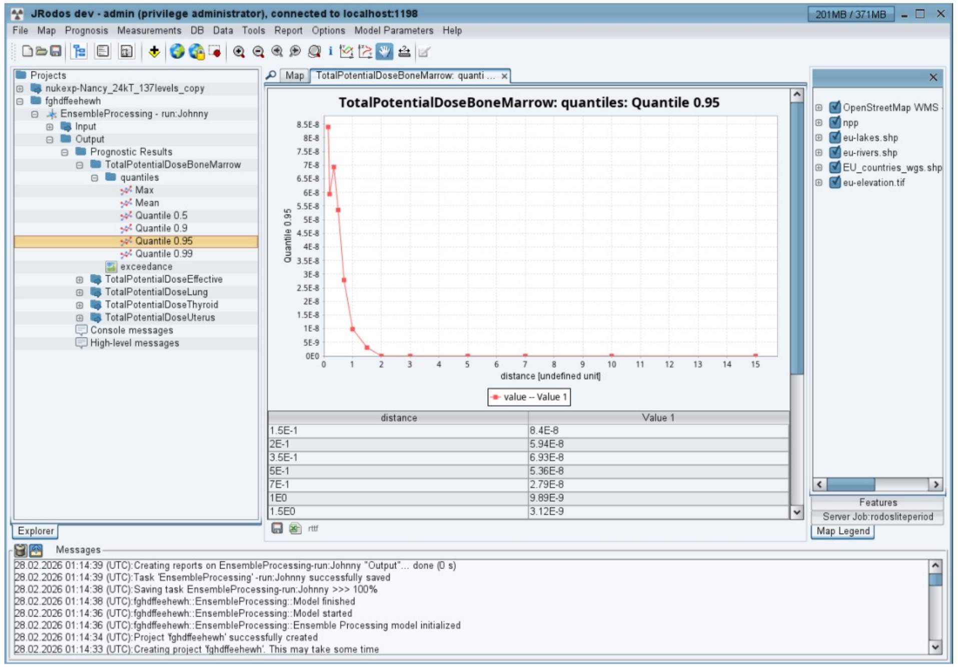
JRODOS will contain probabilistic functions

- When tritium is part of JRODOS, we can follow the methodology applied by Germany (JRODOS) and Sweden (ARGOS) that performed assessments for new planning zones for countermeasures following Fukushima accident
- In Germany, calculations were performed for 365 days, 3 sites and 3 source terms
- 80% percentile for maximum distance from NPP was taken as representative distance for the planning zone



Status

- Tritium as nuclide is integrated in JRODOS
- Basic deposition processes integrated
- Simulation of tritium and activation products possible with statistical approach (1 release per day or more often)
- Statistical evaluation possible



Future steps in the integration

- Movement of water in soil
- Evapotranspiration of water
- Reemission process modelling with advanced dispersion models – so far straight-line Gaussian approach
- Comparison if the current approach in the food and dose module terrestrial (FDMT) can be expanded to deal with HTO and OBT
- Additional foodstuffs – so far UFOTRI considers only five food products, FDMT more than 20

Open research work

- During a workshop in Aiken, South Carolina, in 1990, the most important processes which have to be considered in an assessment model for accidental tritium releases were defined
- Research needs and modelling needs are
  - Deposition
  - Synthesis of organic material
  - Transport though the foodchain, in particular animals

Process	Importance	Status of modelling	Experimental data need
Atmospheric dispersion	H	H	
Atmospheric conversion HT to HTO	L	-	
Wet deposition	M / H	L*	
Condensation / dew	L / M	L	
Dry deposition HTO			
Plants	H	M / H	x
Soil	H	M*	x
Free water surface	L	-	
Dry deposition HT			
Plants	L	-	
Soil	H	M	
Free water surface	L	-	
Re-emission			
Soil surface	M / H	M / H	x
Root / plant uptake	H	M / H	
Synthesis of T into organics			
Plant	H	L / M*	x
Soil	L	-	
Transport through food chain	H	M*	x
Absorption of tritium from			
air in humans HT	L	M	
HTO	H	H	
Translation of exposure to dose	H	M / H*	

C. E. Murphy Jr., editor, Workshop on Tritium Safety and Environmental Effects, October 15-17, 1990, Aiken, South Carolina, Westinghouse Savannah River Company, WSRC-TR-91-351, 1990

Summary and conclusion

- There is a need to improve assessment models as fusion power is emerging – besides ITER
- Tritium behaves differently in the environment and this is the main reason why it is not part of existing decision support systems
- As the atmospheric transport and dispersion model of UFOTRI is outdated a simple integration of UFOTRI is not a good idea – tritium processes are highly linked to the dispersion model
- Integration into JRODOS is ongoing – however delayed compared the plan we had
- However, there are still functionalities that might require new research