Karlsruhe Institute of Technology

JRODOS Hydrological Model Chain (HDM)

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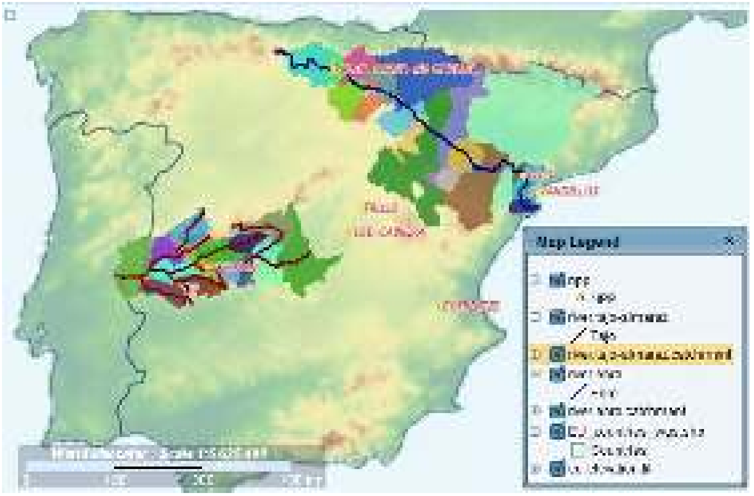
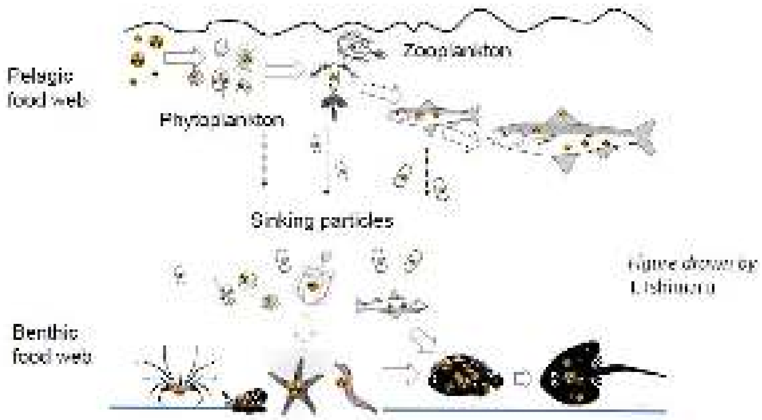
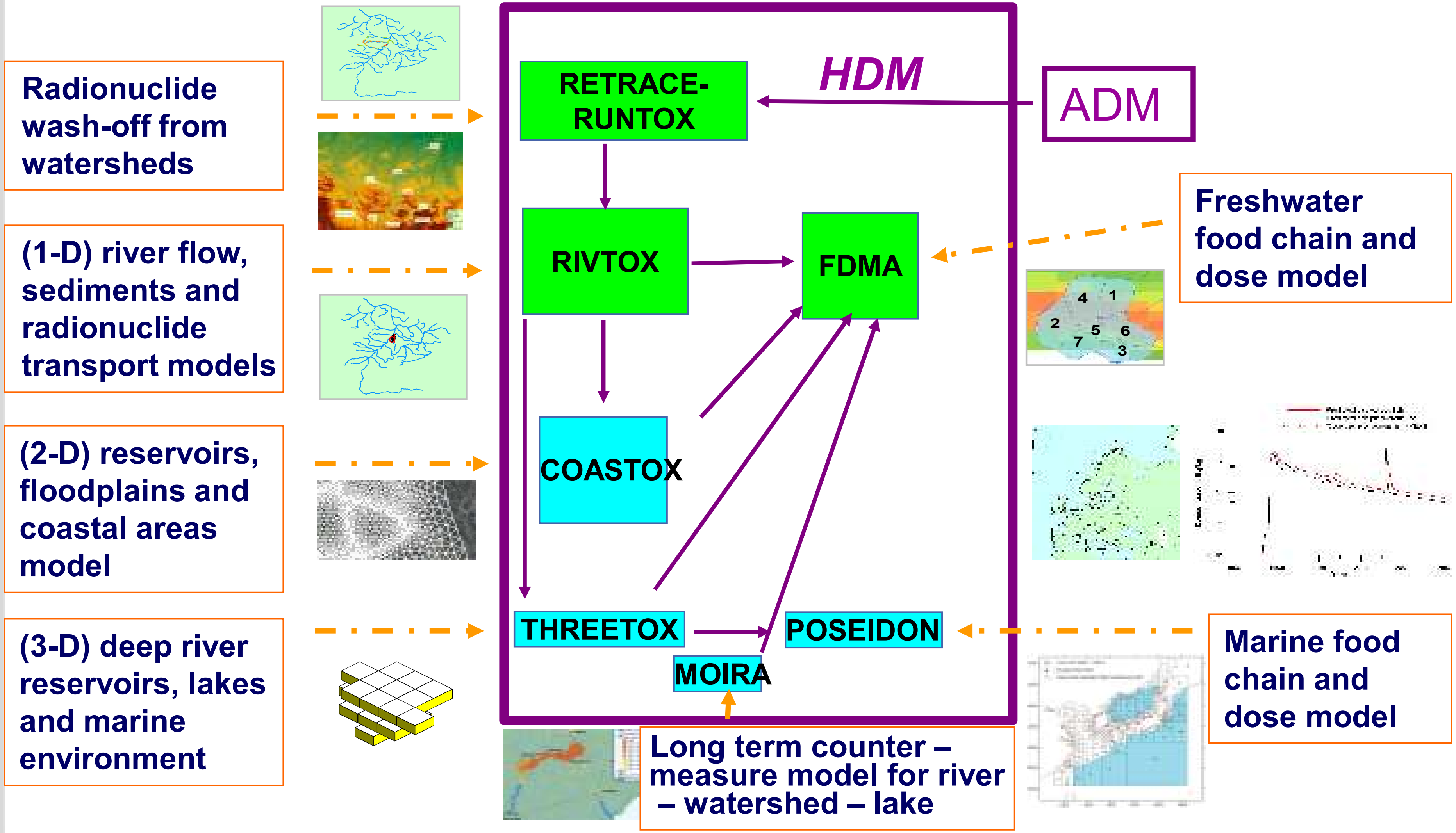




Short history

- Following the Chernobyl accident, the RODOS project started beginning of the 1990th
- The Hydrological Model Chain (HDM) became an integral part from the mid 90th onwards, key developers are the team of UCEWP in Kiev
- Within several European Frameworks, the HDM was expanded and improved
  - EURANOS project with first marine model and aquatic foodchain, several model improvements
  - PREPARE project with a complete revision of the computational models, integration of MOIRA (late phase) into Jrodos and improved marine model
- Ongoing activities
  - Test and application of the HDM in Japan
  - Test in the frame of the IAEA MODARIA II project

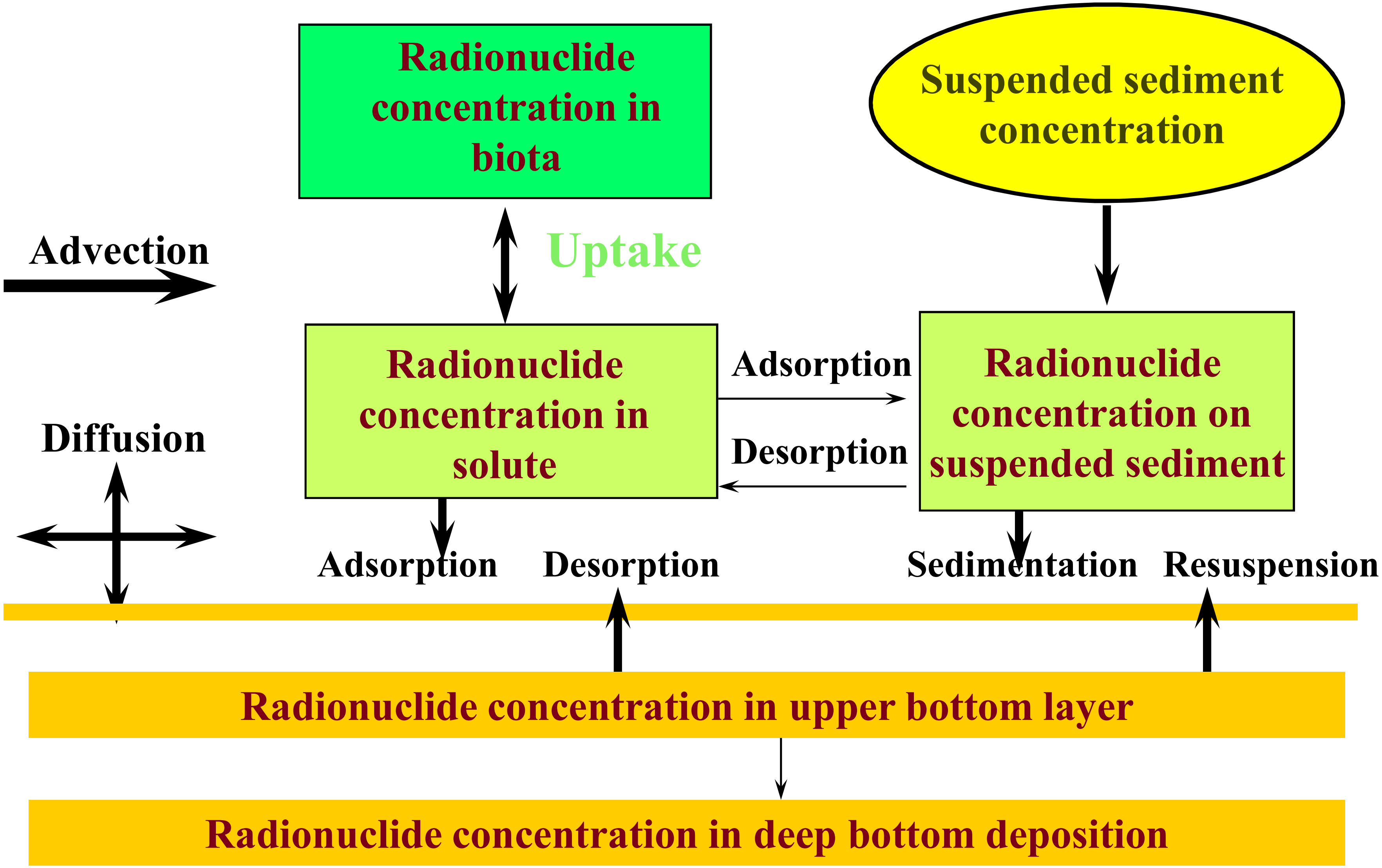
Hydrological models in JRodos



1-D model RIVTOX

- RIVTOX describes the river flow, suspended sediment transport, radionuclide transport in solute and transport of radionuclides adsorbed by suspended sediments
- The river hydraulic module is based on the numerical solution of the full version of the Saint Venant equation (RIVTOX-SN) – before, a numerical solution of the diffusive wave approximation of the Saint Venant equation was used
- Inputs
  - River nodes
  - River cross sections
  - Water depth
  - Characteristics of river bottom/sediments
  - Boundary conditions such as time dependent discharge rates

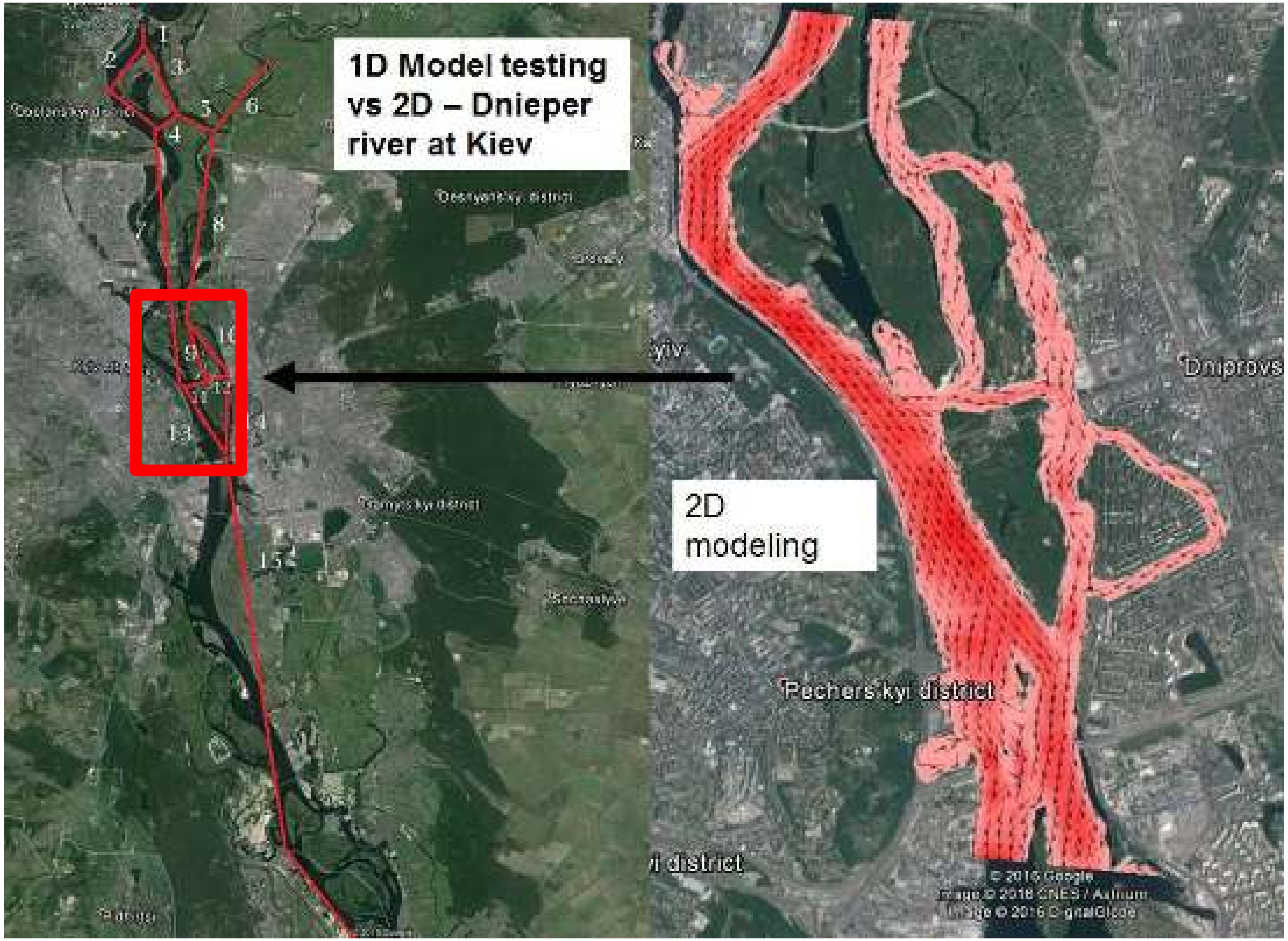
Processes considered



2-D COASTOX

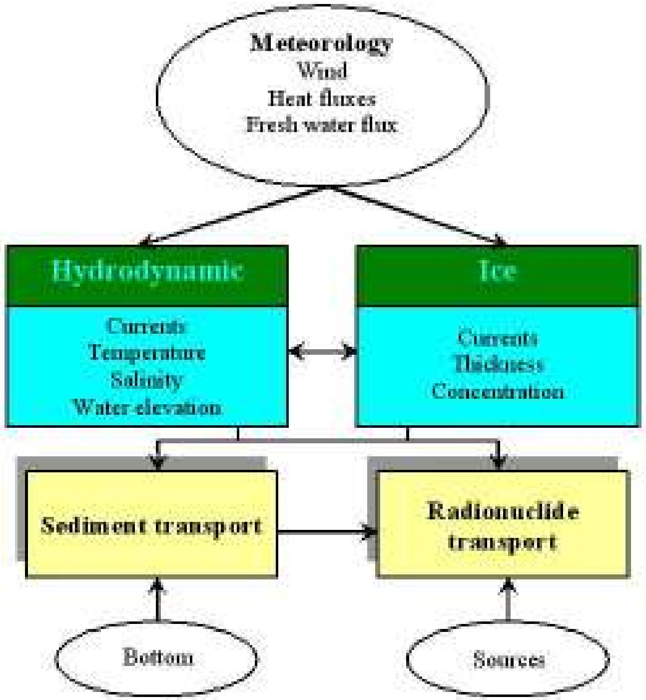
- COASTOX describes the water transport with a two–dimensional (depth averaged) model of open flow hydrodynamics
- It contains sub-models describing the transport of suspended sediments and radionuclide in shallow water bodies
- It can be applied for river floodplains, shallow reservoirs and coastal areas

Comparison 1-D and 2-D approximation

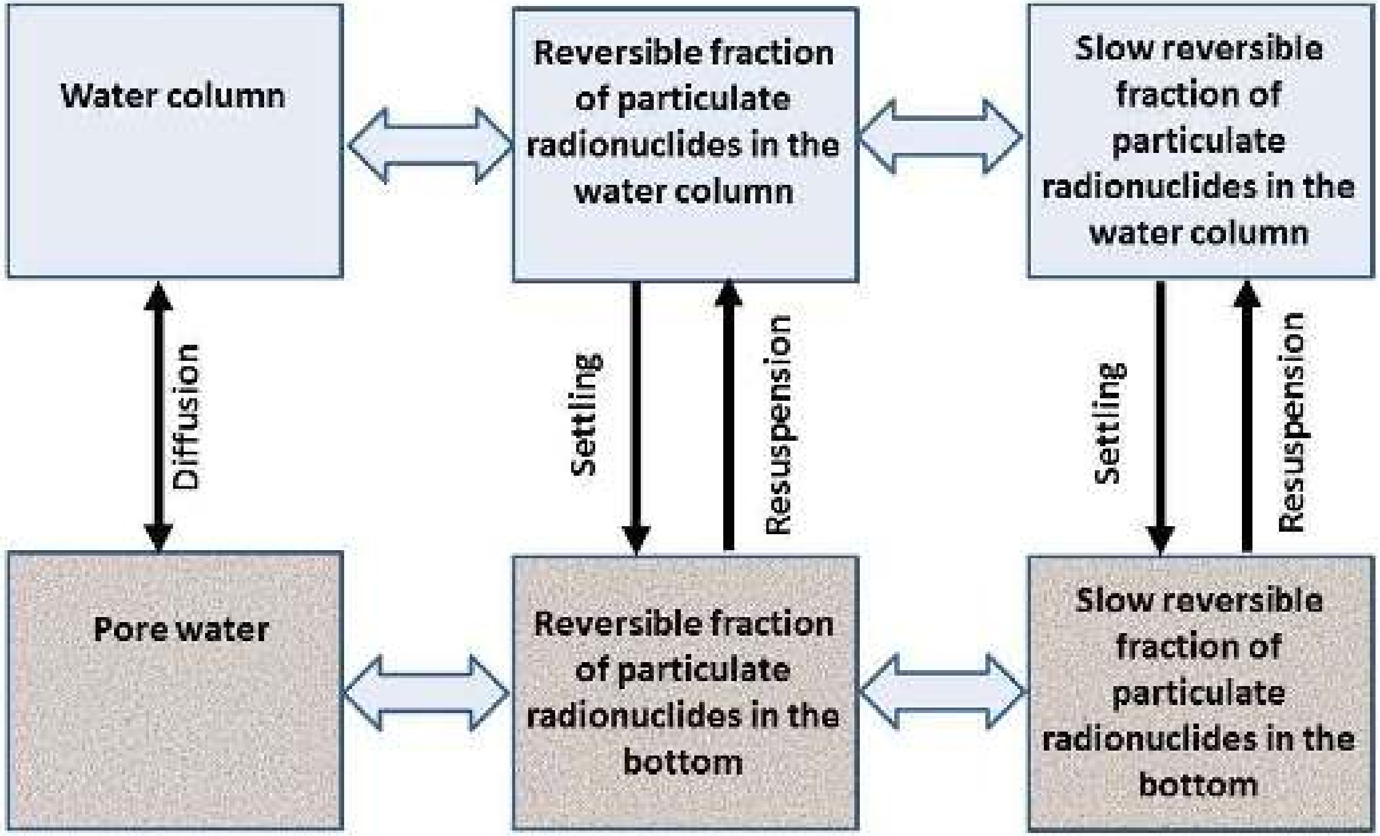


3-D THREETOX

- THREETOX can be used for 3-D simulation of the dispersion of radionuclides and other contaminants in deep lakes, estuaries and coastal areas
- THREETOX includes sub-models for hydrodynamics, ice dynamics-thermodynamics as well as sediment and radionuclide transport
- Prognostic variables of the hydrodynamics sub-model are the three components of the velocity field, temperature, salinity, surface level elevation, kinetic energy of turbulence and dissipation rate
- The ice sub-model predicts the ice drift, thickness and ice concentration
- Driving forces are upper boundary conditions from atmospheric flow models and ocean models (MyOcean) in case of coastal areas

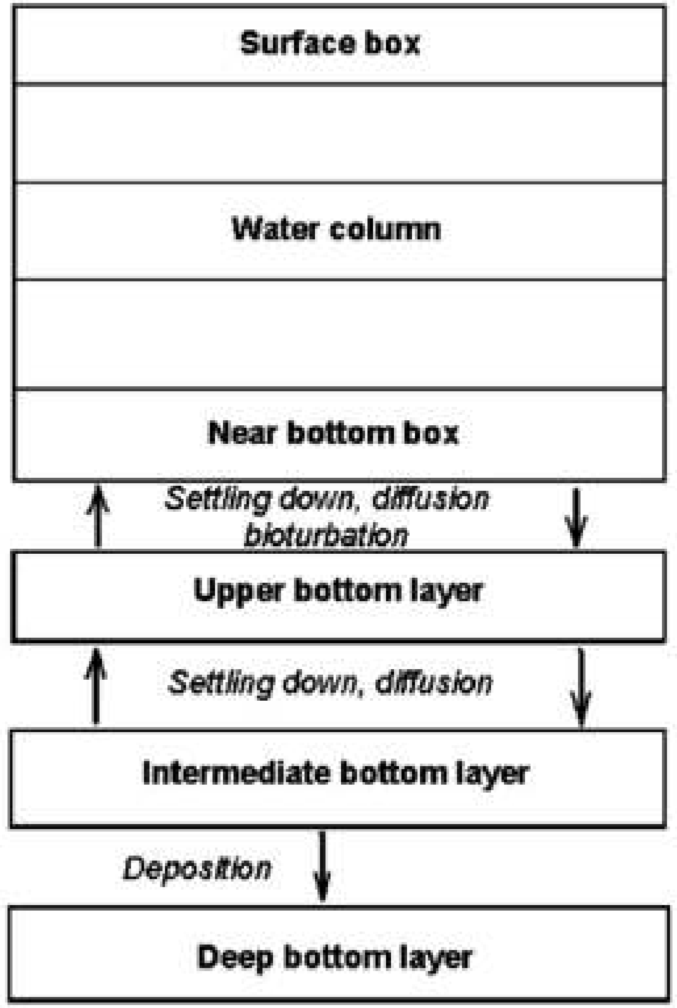


Radionuclide transfer in water/sediments

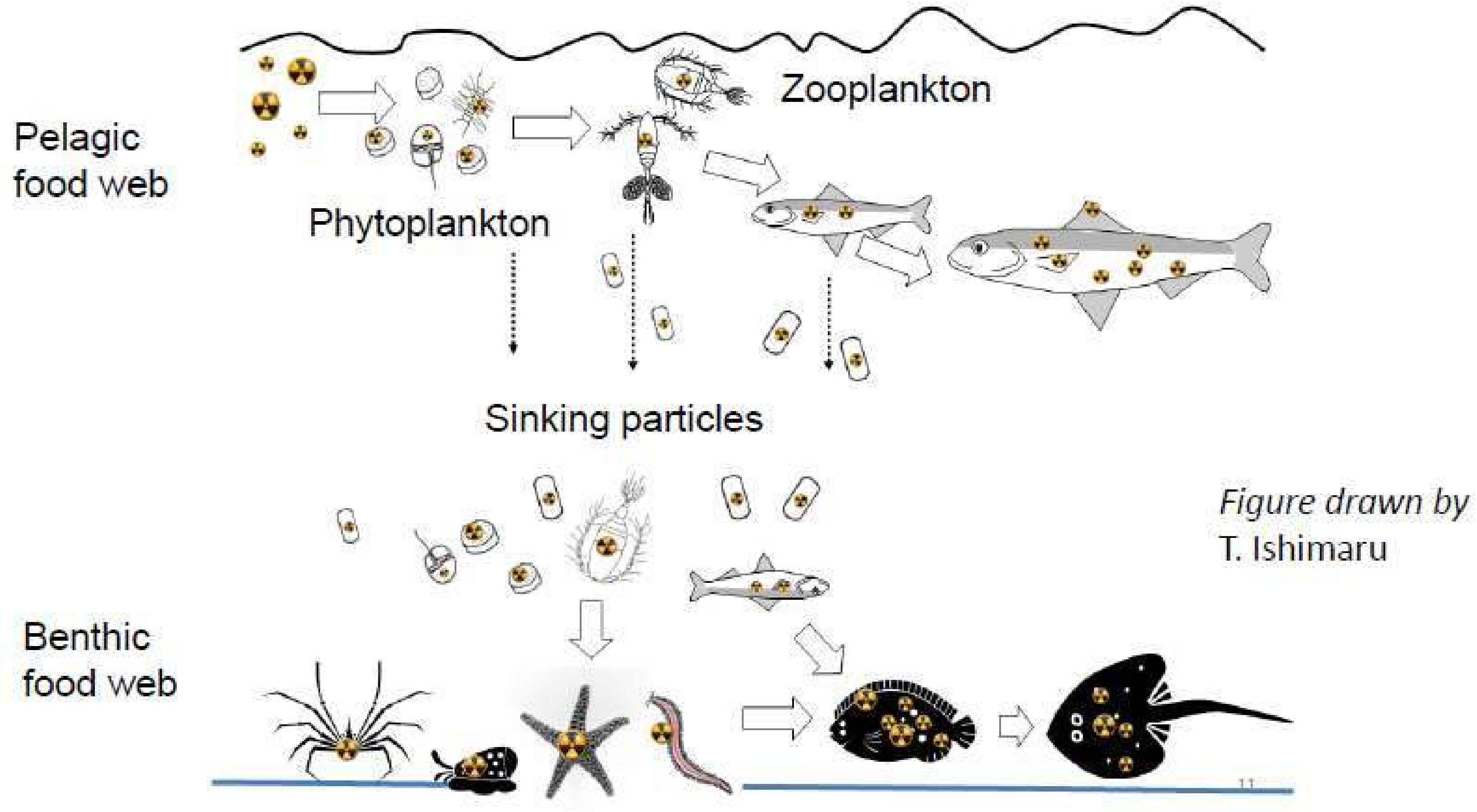


Box model POSEIDON

- POSEIDON is a box model that was developed to assess releases into the European seas
- The dispersion of radionuclides takes place via neighbouring boxes and across the vertical water column
  - horizontal and vertical water exchanges between boxes
  - adsorption on suspended sediments
  - depletion of activity in suspended materials in equilibrium with the water phase activity
  - exchange of radionuclides between water column and bottom through molecular diffusion and bioturbation phenomena



Improved food web model



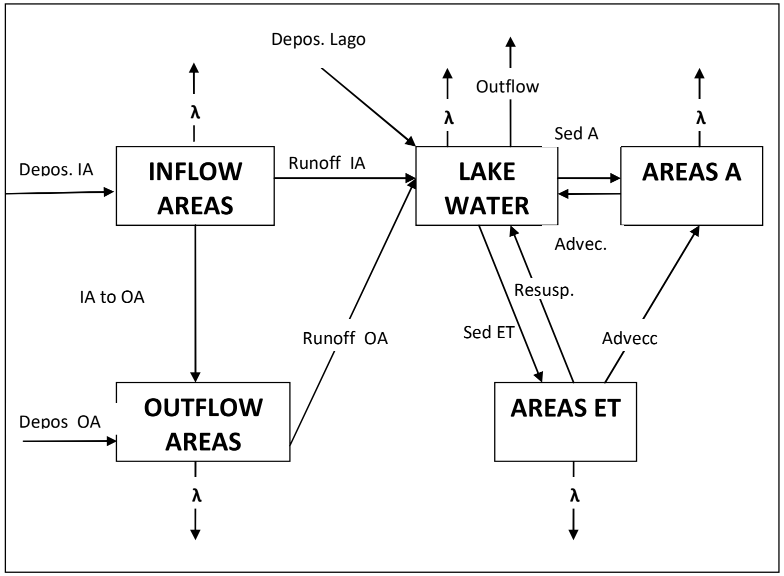
Foodchain and Dose Module Aquatic FDMA

- FDMA (Food and Dose Modules Aquatic) is the model for simulating the transfer of radioactive material in the food chain following contamination of water (used for drinking, animal feeding and irrigation of crops), and for the assessment of doses via some relevant aquatic pathways (internal exposure via ingestion of drinking water, agricultural products, and fish) to the population
- The calculation engine was taken over from the terrestrial foodchain and dose module FDMT
- The endpoints of FDMA are essentially the time dependent activity concentrations in a variety of feed and foodstuffs, and the resulting radiation exposure for the population via the exposure pathways ingestion of contaminated foodstuffs, drinking water and consumption of contaminated fish
- Contamination of fish is an input value!

MOIRA basics

- MOIRA was a Decision Support System (DSS) developed in the 90's during Euratom FP4 (MOIRA, COMETES) and FP5 (EVANET-HYDRA). Implemented and applied to different scenarios in Spain, France, Italy, Chernobyl affected areas, etc. More than 20 users. Significant feedback from end-users during FP6 EURANOS project and NERIS-TP (PENTA).
- The purpose of MOIRA is to help characterizing the radiological situation and selecting adequate management strategies for different aquatic ecosystems contaminated by radionuclides.
- MOIRA is not aimed at the emergency, but rather at management strategies for the long-term. It complements JRODOS-HDM. Some users suggested integrating them.
- Based on validated models for predicting the dynamic behaviour of **^{137}Cs and ^{90}Sr** in **lakes, rivers and catchment areas** and well as the effect of selected countermeasures to reduce the contamination levels.
  - To analyse complex rivers systems and catchments it is limited to the definition of <u>20 river branches and reaches</u>
  - The models have been validated against historical data from several lakes and rivers

MOIRA Lake model



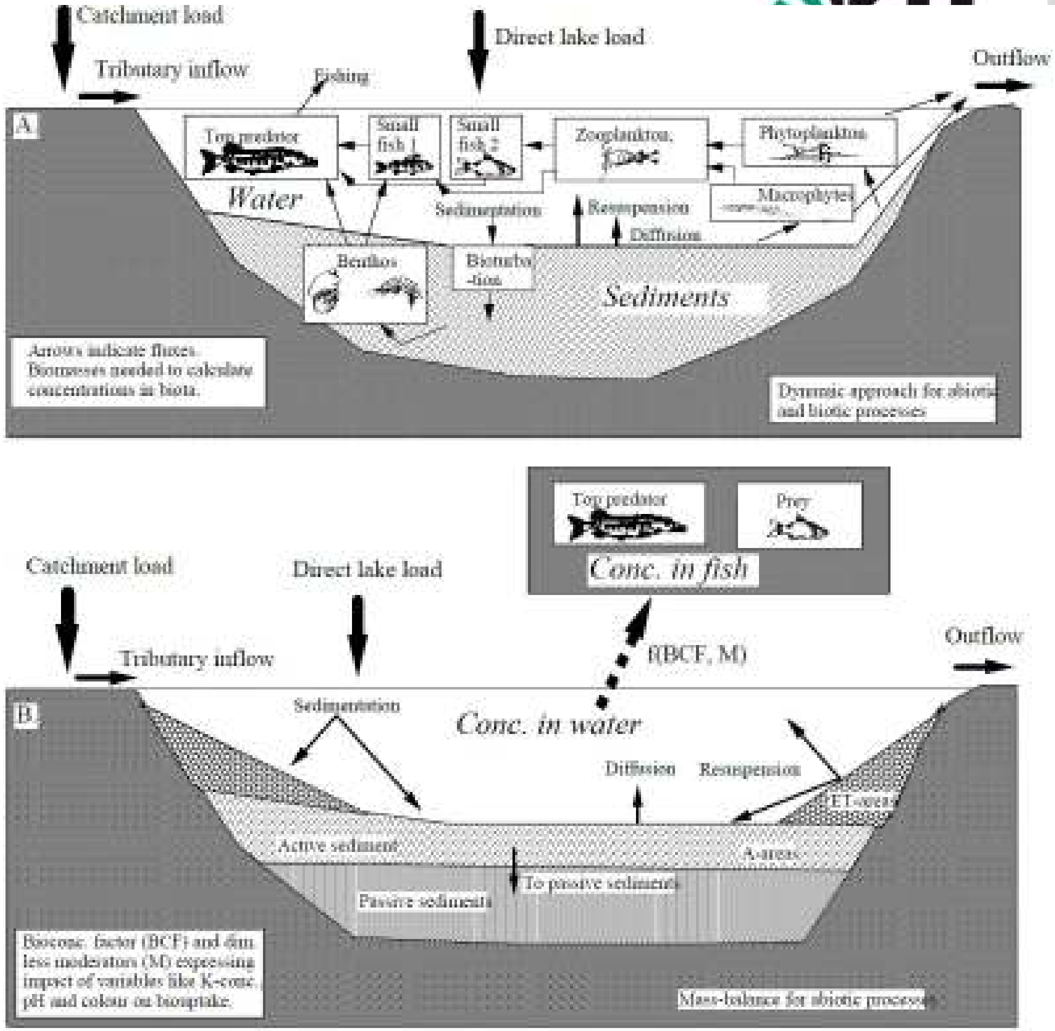
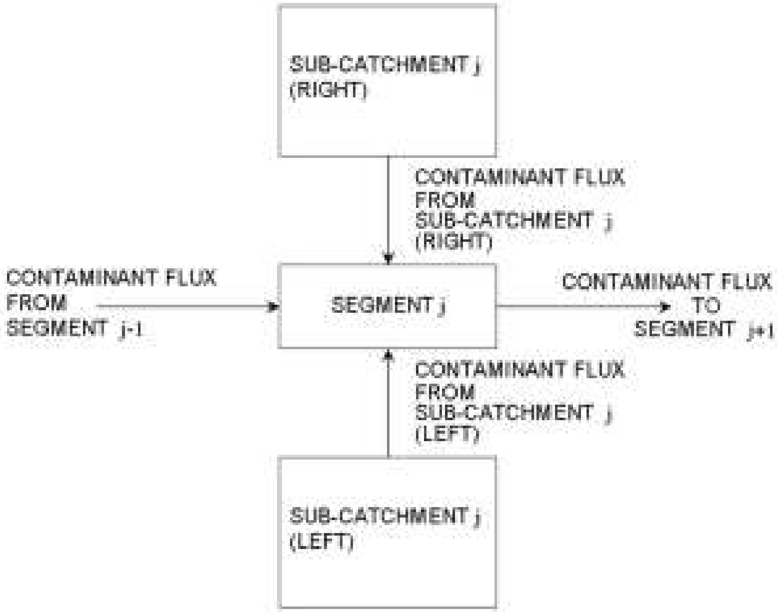


Figure 1: General view of the lake model (Håkanson, 1999).

MOIRA River model



(Monte, 2001)

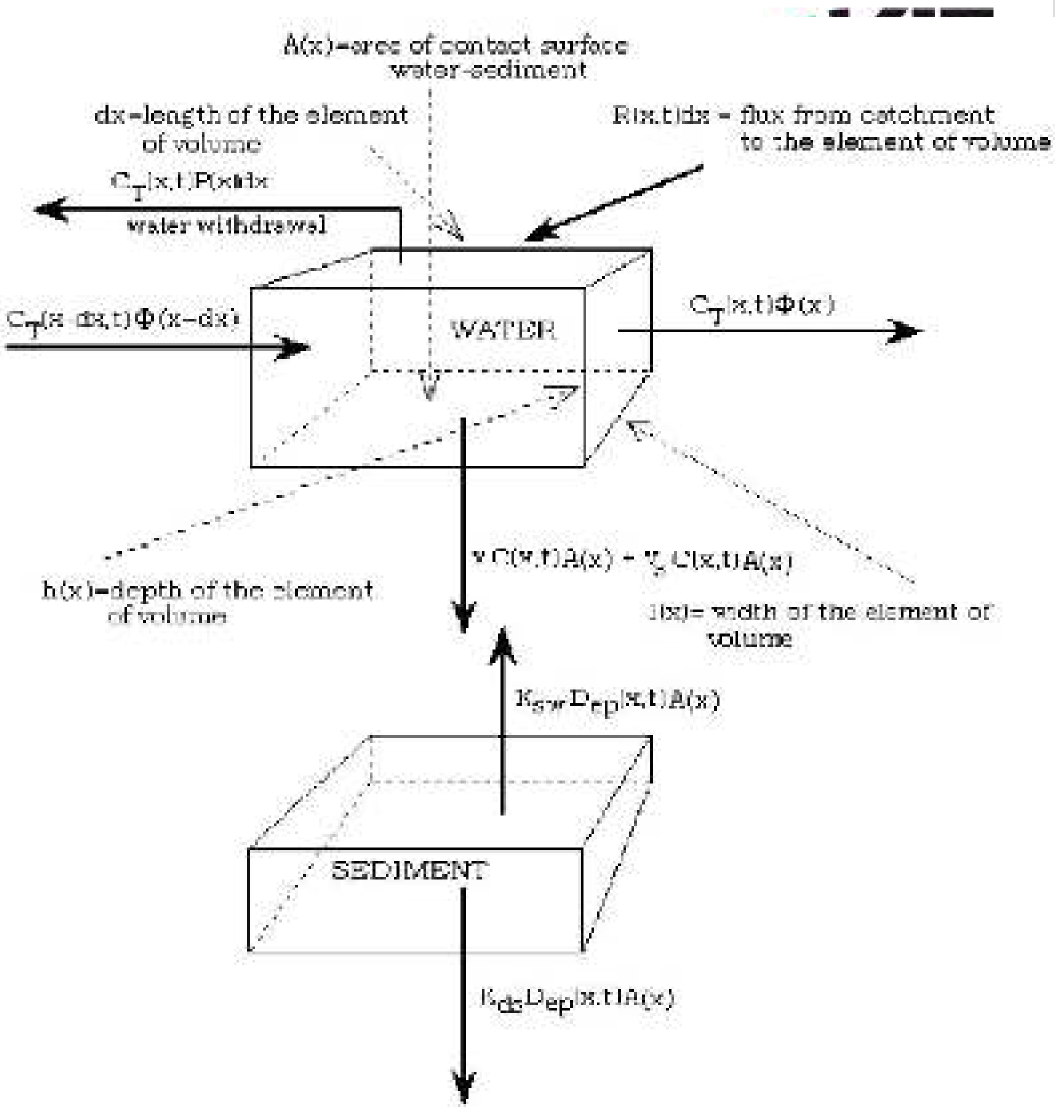


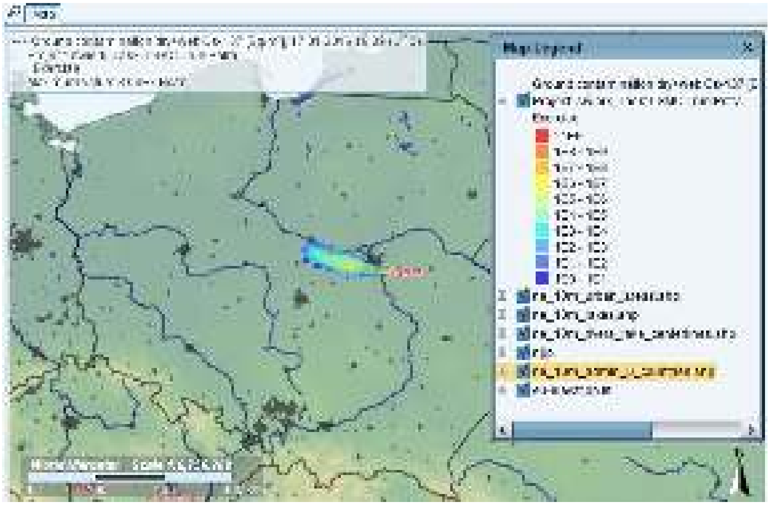
Figure 6. Radionuclide migration fluxes within an elementary segment.

Countermeasures available for simulation in the MOIRA-JRodos modules

Application of chemical agents (in Lakes) (Time dependent)	Application of physical measures (Time dependent)	Application of social restrictions (in FDMA) (in user defined periods)
• Potash treatment • Direct liming • Wetland liming • Fertilisation	• Removal of sediments (Lakes and Rivers) • Removal of snow and ice (Lakes) • Water flow diversion between segments (Rivers)	• Bans on fish consumption • Bans on water ingestion • Bans on irrigation  

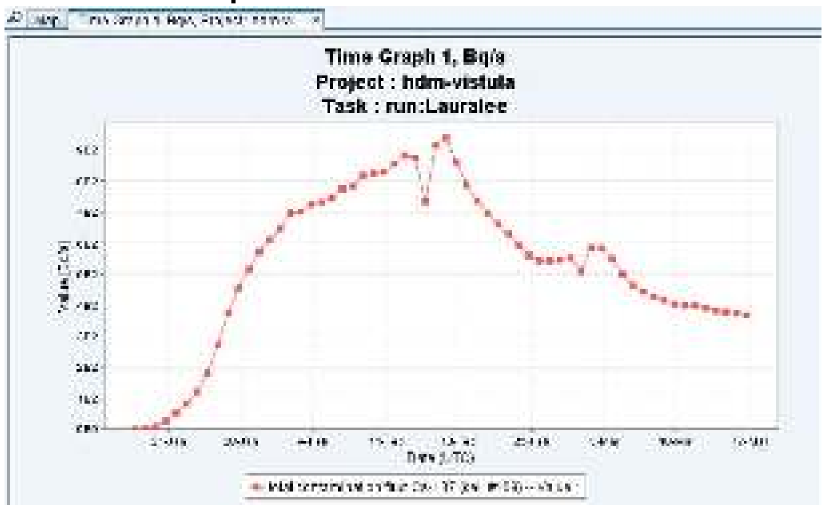
Applications

RIVTOX-THREETOX linkage

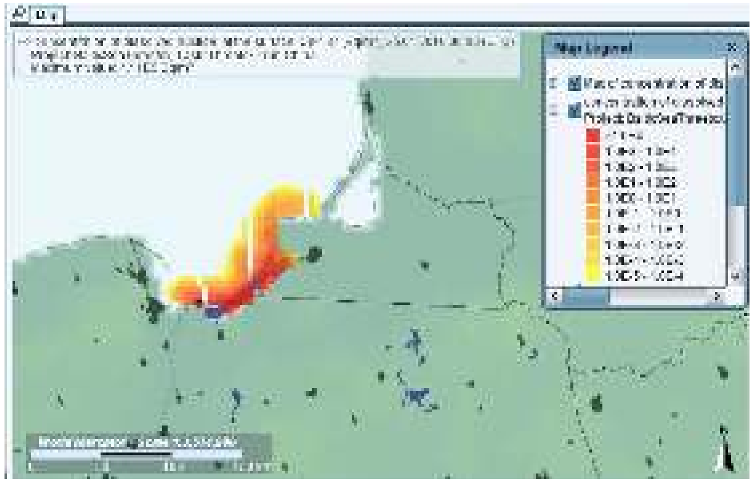


Deposition of Cs-137

Cs-137 in Rivtox model after 8 days

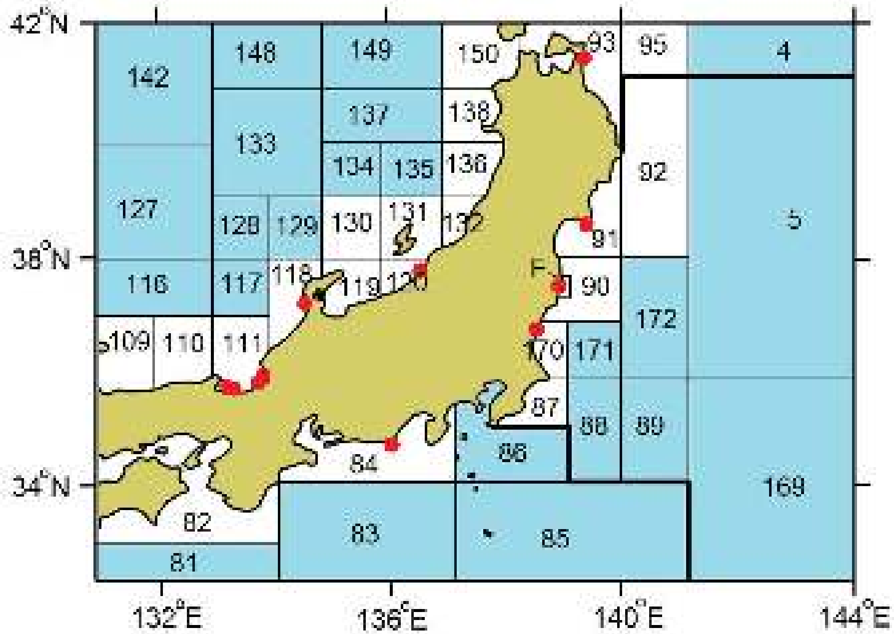


Total flux of Cs-137 in Rivtox model



Concentration of Cs-137 after one month

Application to the Fukushima accident



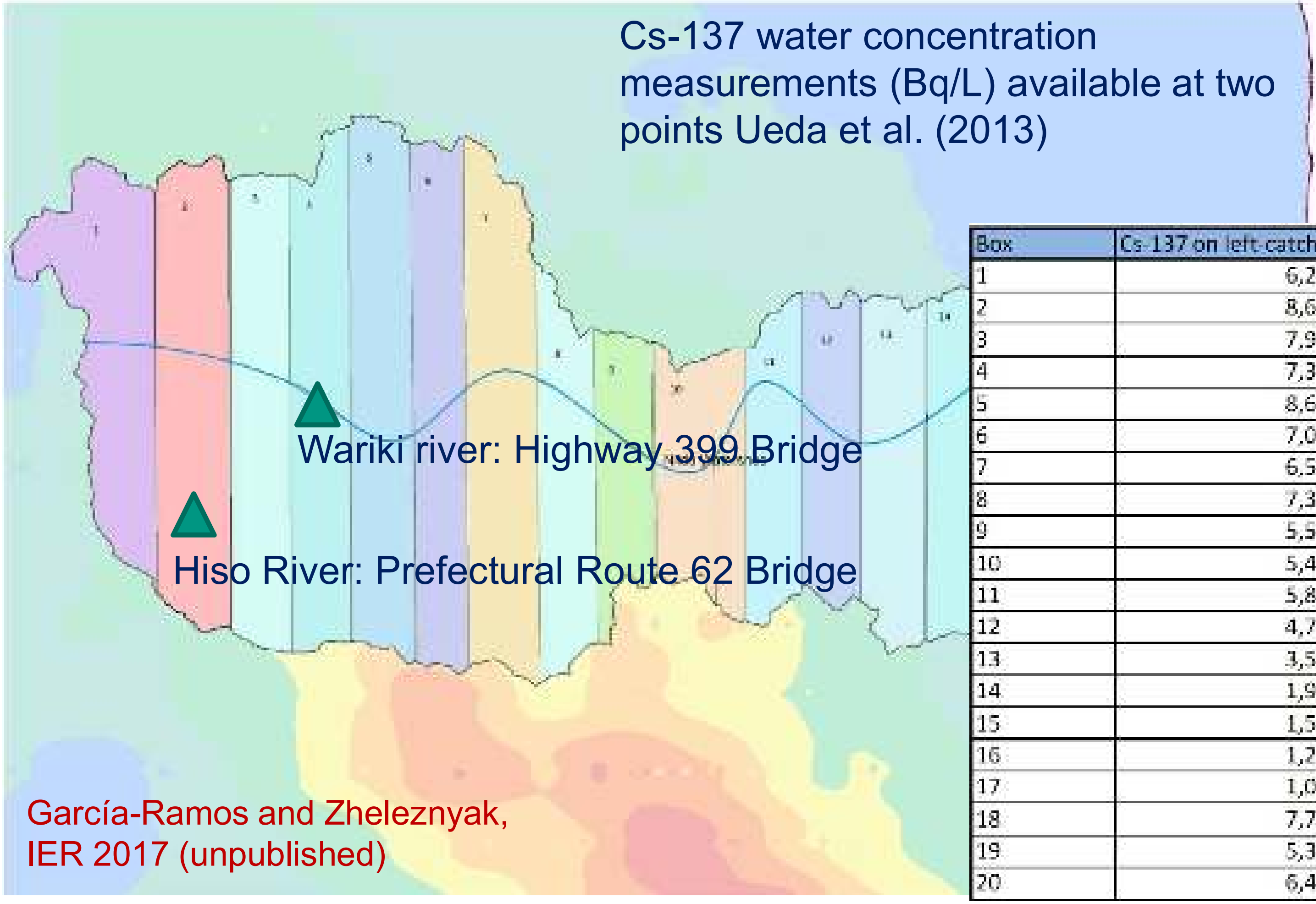
- Box system
  - 175 boxes for North-Western Pacific
  - 3 water layers for deep boxes (blue color on the scheme)
  - Additional coastal box around FDNPP 15x30 km
- Sources of ^{137}Cs
  - Direct release (4.0E+15 Bq)
  - Atmosphere deposition (8.5E+15 Bq)
  - Continuous groundwater leakage (3.5E+12 Bq/yr)

MOIRA application in Japan

Niida river basin

Catchment area: 265 km^2,
Initial Cs-137 deposition (3rd Airborne survey by MEXT)): 703 kBq/m^2
High Cs-137 deposition (up to 1000~3000 kBq m^{-2}) Upstream area
Approximately 40 thousand people

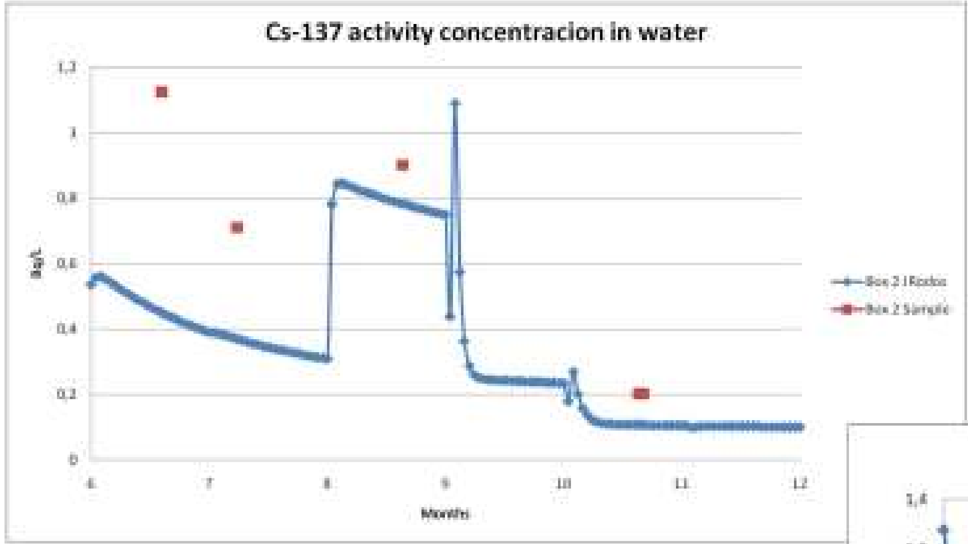
Representation of catchment by 20 boxes

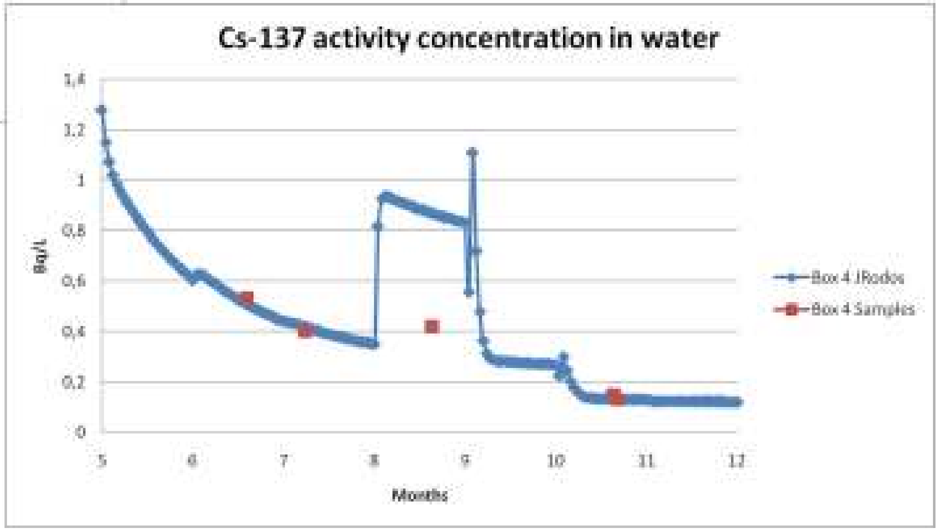


Fallout data in each box (Bq/m²)

Box	Cs-137 on left catchment	Cs-137 on right catchment
1	6,22E+05	6,74E+05
2	8,63E+05	7,01E+05
3	7,95E+05	6,82E+05
4	7,39E+05	1,31E+06
5	8,66E+05	2,00E+06
6	7,09E+05	1,60E+06
7	6,59E+05	1,25E+06
8	7,37E+05	1,19E+06
9	5,55E+05	1,25E+06
10	5,47E+05	1,13E+06
11	5,86E+05	7,53E+05
12	4,72E+05	6,92E+05
13	3,50E+05	6,76E+05
14	1,95E+05	2,99E+05
15	1,59E+05	1,74E+05
16	1,27E+05	1,29E+05
17	1,08E+05	7,74E+04
18	7,75E+04	7,98E+04
19	5,34E+04	5,06E+04
20	6,48E+04	4,34E+04

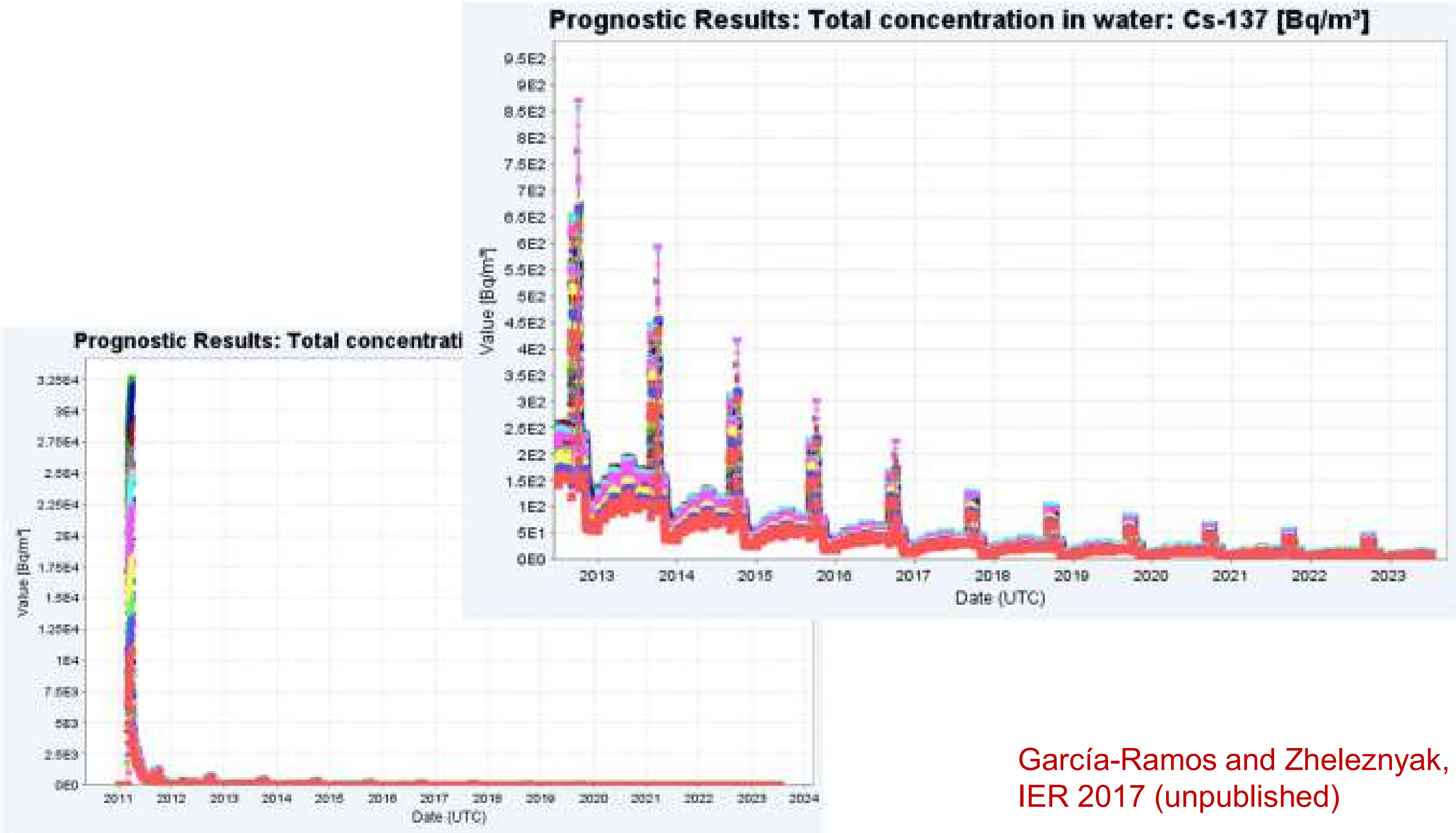
Calibration with measured data (short-term. 15 months)





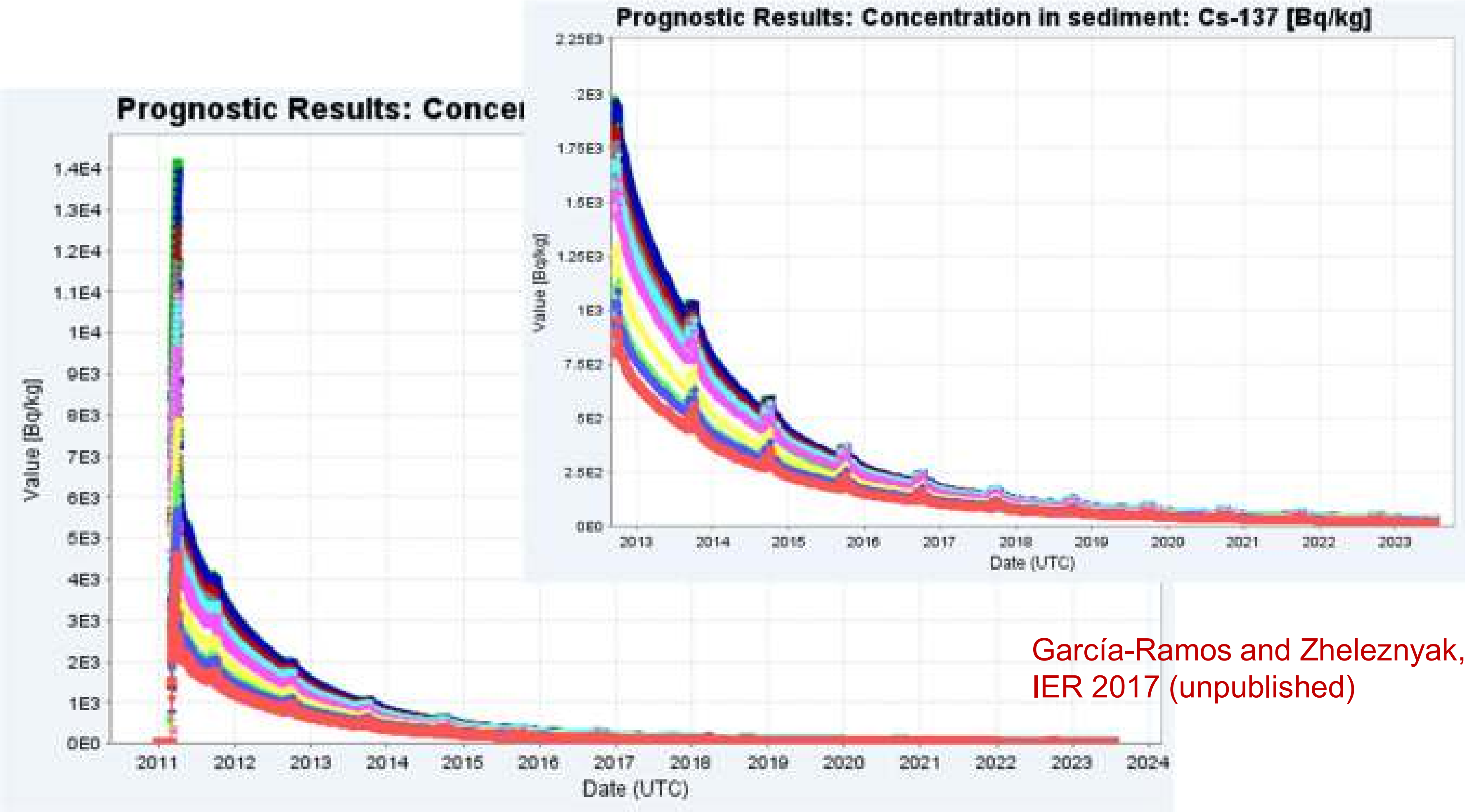
García-Ramos and Zheleznyak, IER 2017 (unpublished)

Long-term case. Cs-137 concentration in water in all boxes



García-Ramos and Zheleznyak, IER 2017 (unpublished)

Long-term case. Cs-137 concentration in sediments in all boxes



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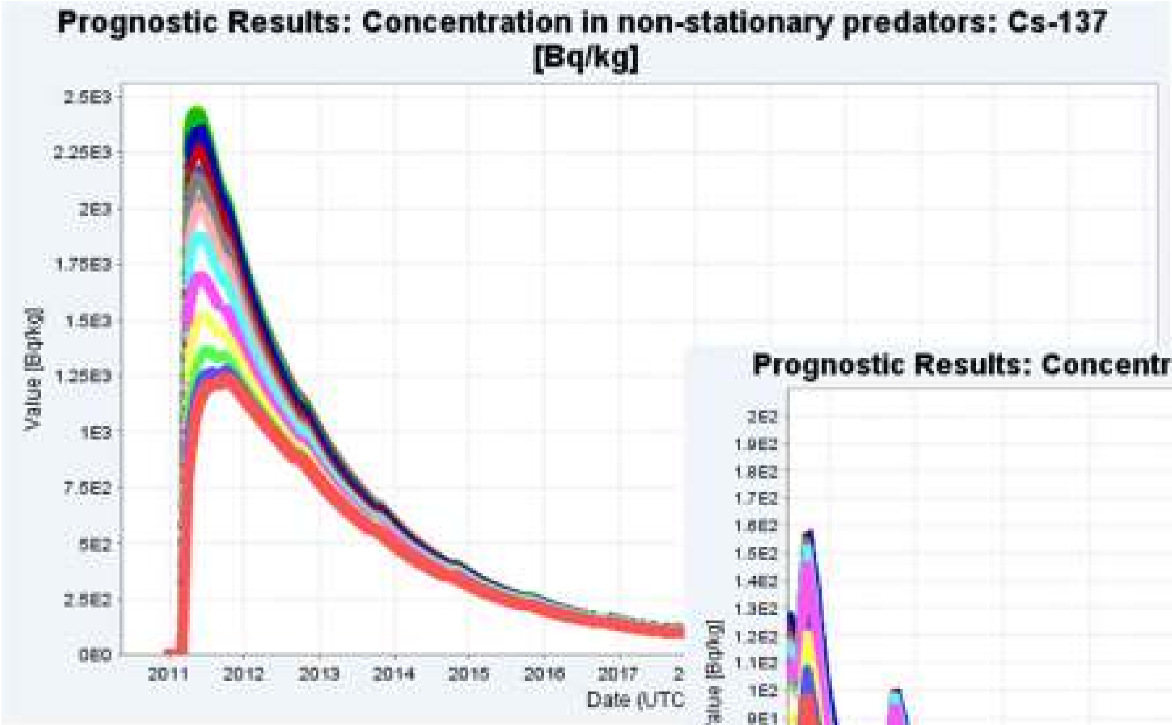
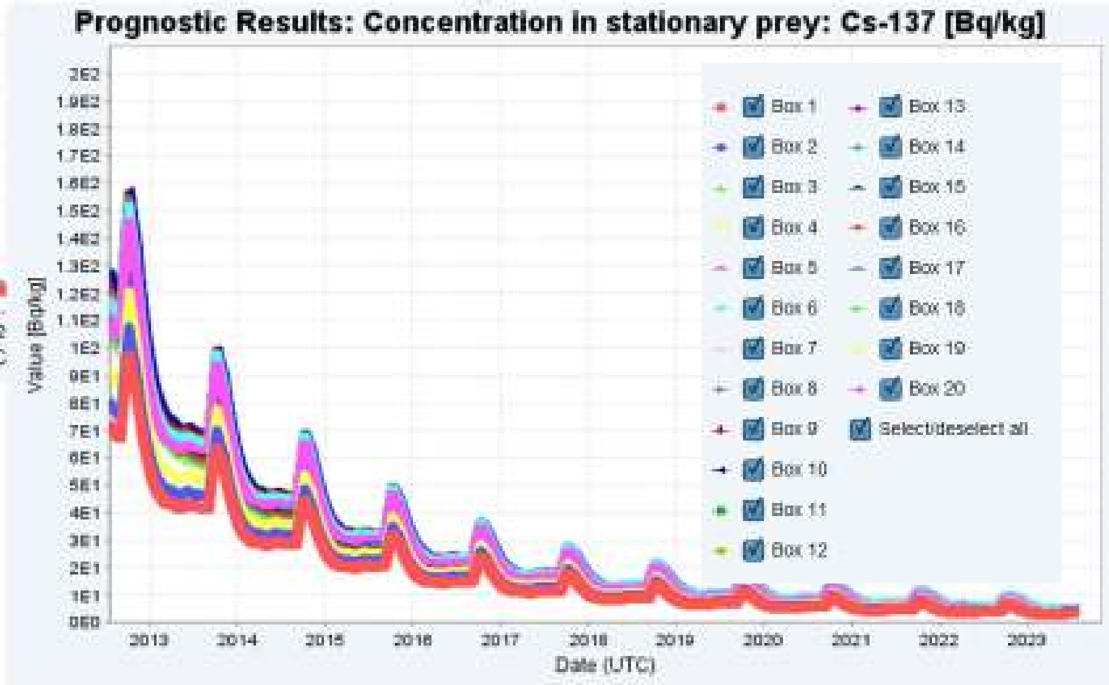
Cs-137 concentration in prey and predatory fish in all boxes





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Thank you very much for your attention

Questions?