Integration of marine food chain model POSEIDON into the Hydrological Dispersion Module of JRODOS

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POSEIDON in RODOS-HDM

PREPARE

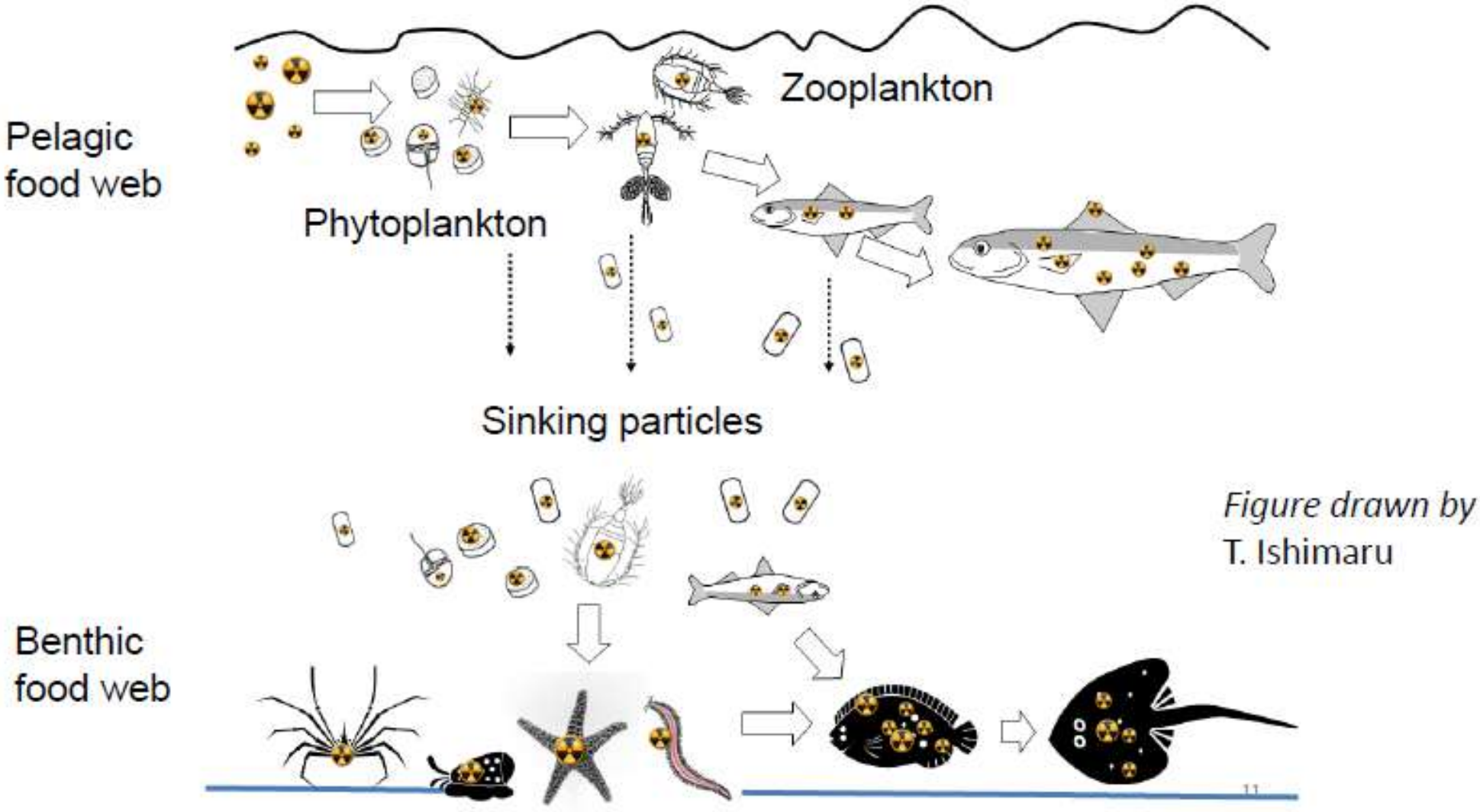
- RETRACE (source: deposition from ADM)
  - Model for calculation of radionuclide washout from watersheds
- RIVTOX (sources: direct release and washout from watersheds)
  - 1-dimensional model of radionuclide transport in river network
- COASTOX (sources: direct release, deposition from ADM and release with rivers water)
  - 2-dimensional model for simulation of short- or mid-term radionuclide transport in reservoirs, lakes, estuaries and coastal areas of seas
- THREETOX (sources: direct release, deposition from ADM and release with rivers water)
  - 3-dimensional model for simulation of short- or mid-term radionuclide transport in rivers, reservoirs, lakes, estuaries and coastal areas of seas
- **POSEIDON (sources: direct release, deposition from ADM and release with rivers water)**
  - **Compartment model for simulation of long-term radionuclide transfer in marine environment including marine biota**

Improvements of POSEIDON model

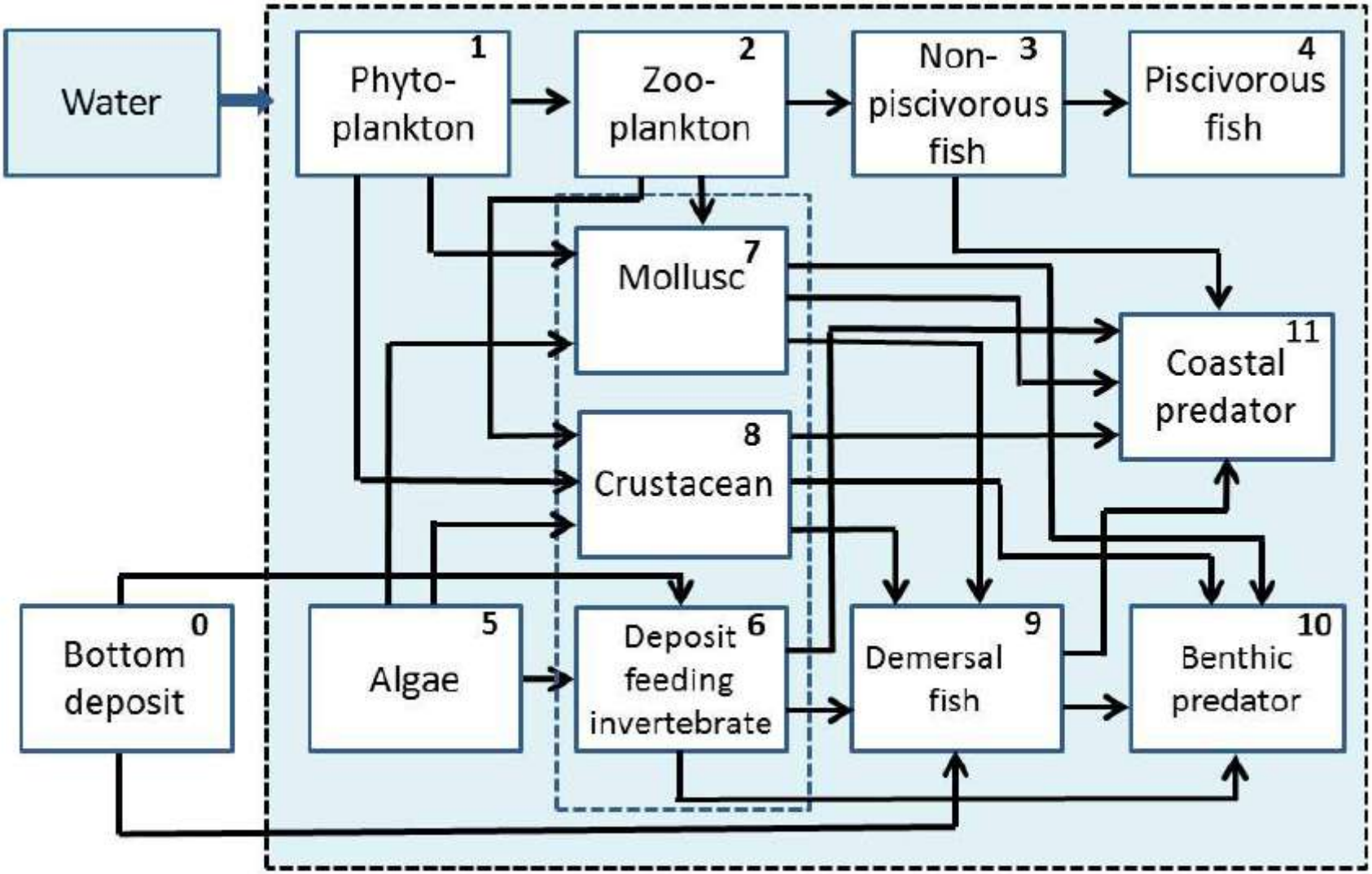
PREPARE

- Extension of the dynamical food web model
  - The marine food web model was extended by benthic organisms to describe the migration of radionuclides from contaminated bottom sediments to marine organisms through the food chain.
- Customization for the European seas
  - The new box systems for Mediterranean and Baltic seas were created. In both cases water fluxes between boxes were calculated based on averaging over 10 years of 3-dimensional currents from ocean reanalysis models.
- Integration in JRODOS
  - POSEIDON run under JRODOS using predicted radioactivity deposition from atmospheric dispersion model and release with rivers water under JRODOS interface and direct release from nuclear objects.

Radionuclide transfer in pelagic and benthic food webs



Food chains in POSEIDON model



Dynamical food chain model

- Equilibrium approach for phytoplankton

$$C_{phpl}(t) = C_w(t)\ CF_{phpl}$$

CF_{phyt} – concentration factor (depends on radionuclide)

- Simplified equation for macroalgae (uptake only from water)

$$\frac{dC_{(alg)}}{dt} = \left(CF_{alg} C_w(t) - C_{(alg)}\right) K_{0.5,alg}$$

- Complete dynamical equation for all other organisms

$$\underbrace{\frac{dC_{(pred)}}{dt}}_{\text{Accumulation}} = \underbrace{a\ K_{1,prey} C_{f,prey}}_{\text{Uptake from food}} + \underbrace{b\ K_w C_w(t)}_{\text{Uptake from water}} - \underbrace{K_{0.5,pred} C_{(pred)}}_{\text{Losses}}$$

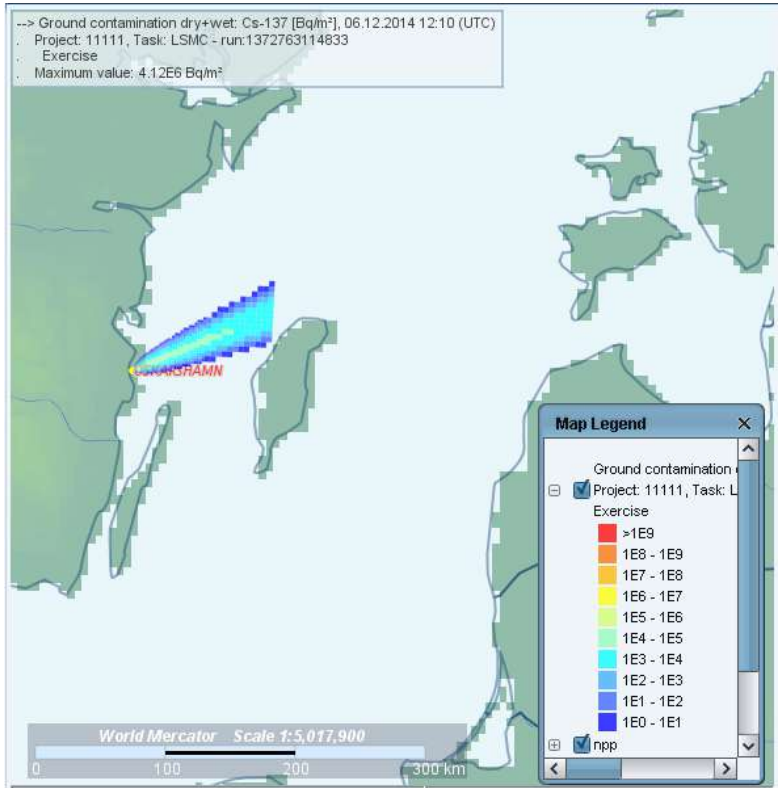
a, b – extraction coefficients,
K_1 – consumption rate of food

K_w – consumption rate of water
$K_{0.5}$ – biological half life

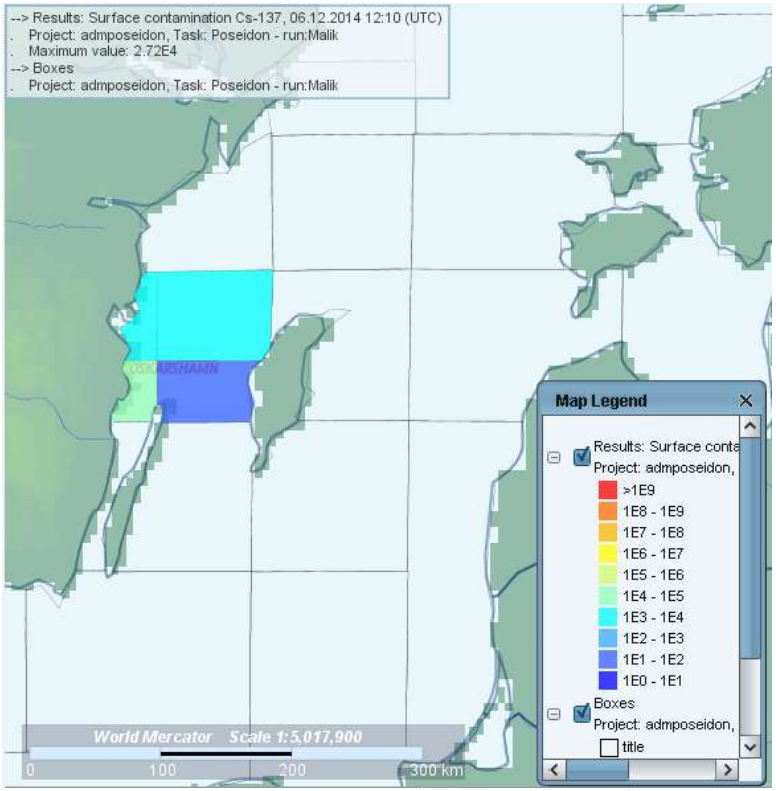
Convertation of ADM deposition into source term for POSEIDON model

PREPARE

- ADM deposition value is distributed between POSEIDON boxes
- For each box total deposition [Bq] is transformed to deposition flux [Bq/yr] taking into account duration of deposition



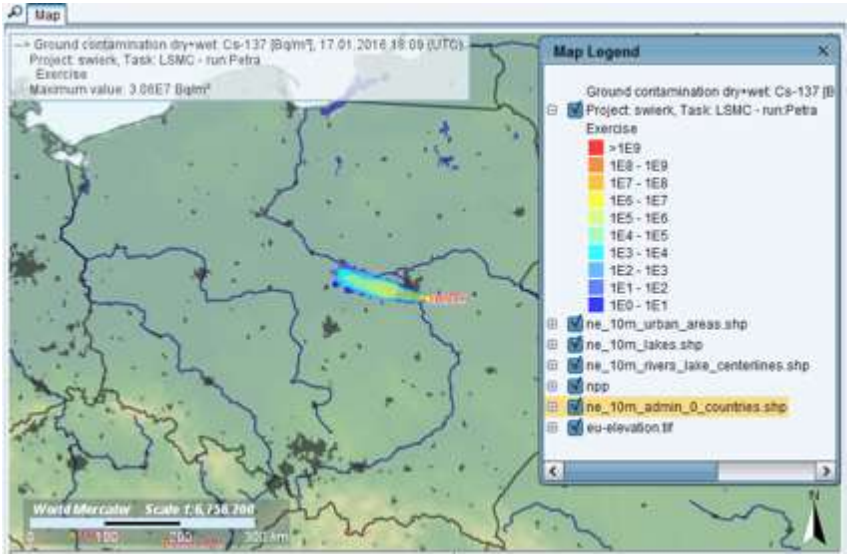
ADM simulation results



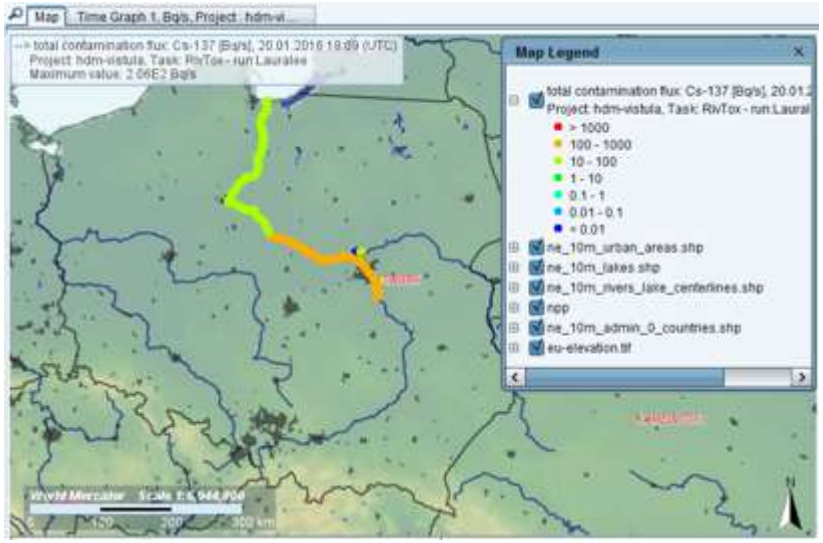
Surface deposition in POSEIDON model

RIVTOX-POSEIDON-R linkage

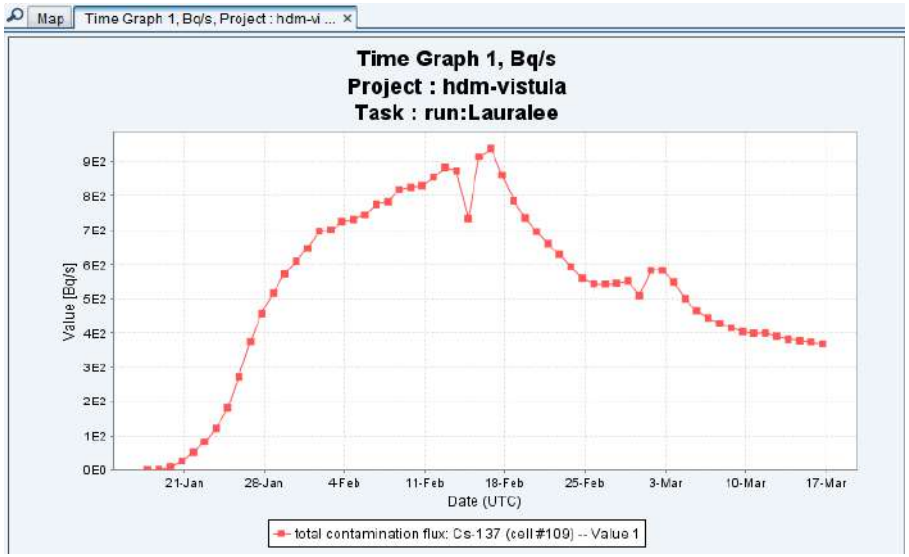
PREPARE



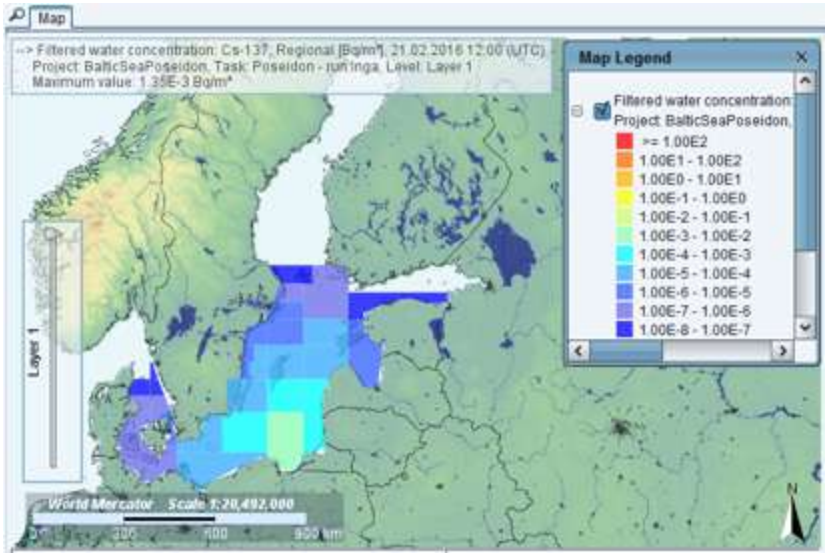
Deposition of Cs-137



Total flux of Cs-137 in Rivtox model after 8 days



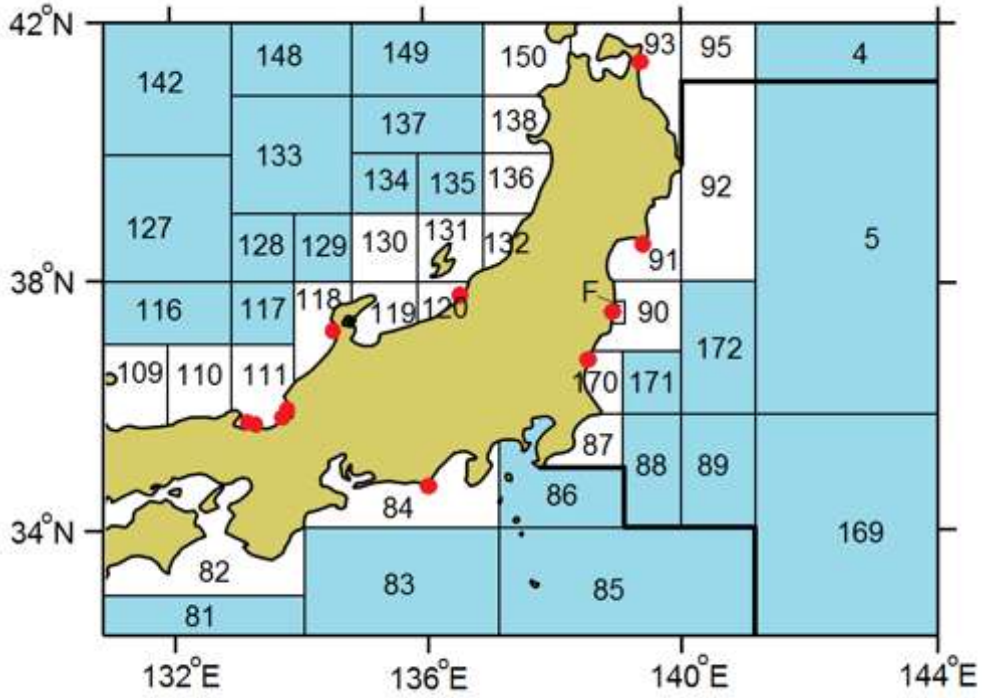
Total flux of Cs-137 in Rivtox model



Concentration of Cs-137 one month after release

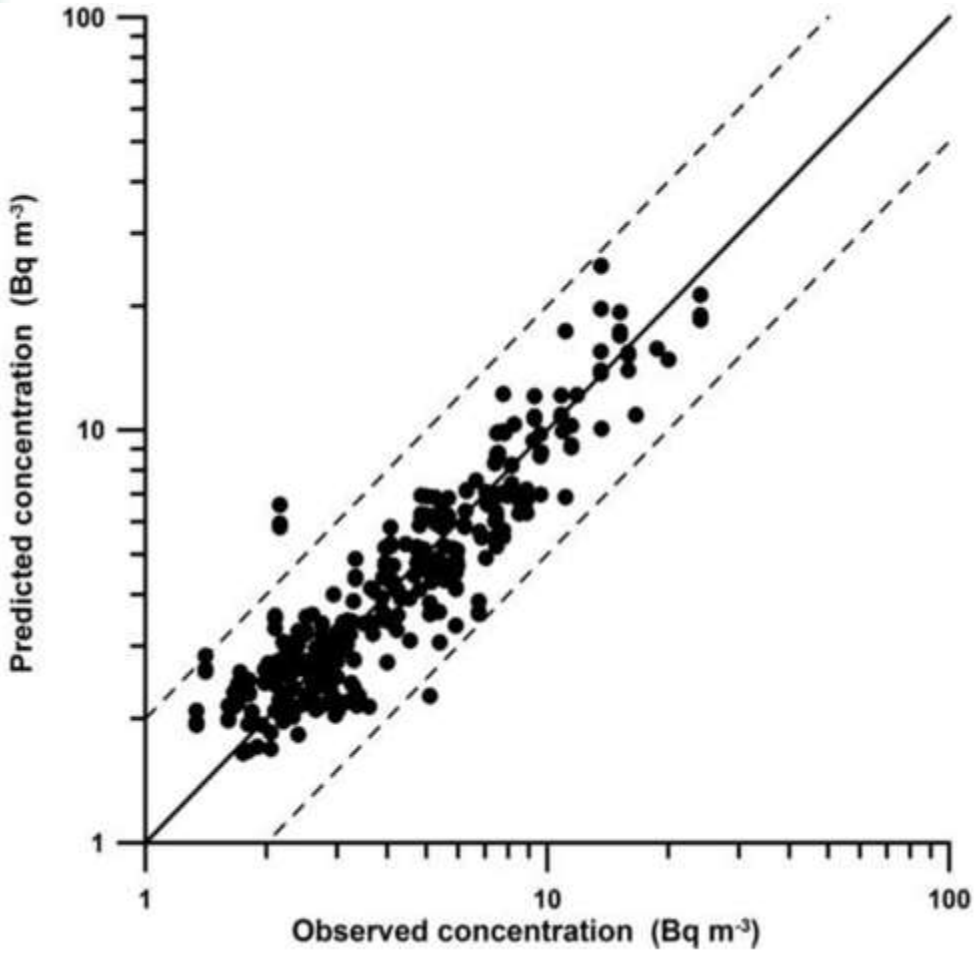
Application to the Fukushima accident:

Application to the Fukushima accident

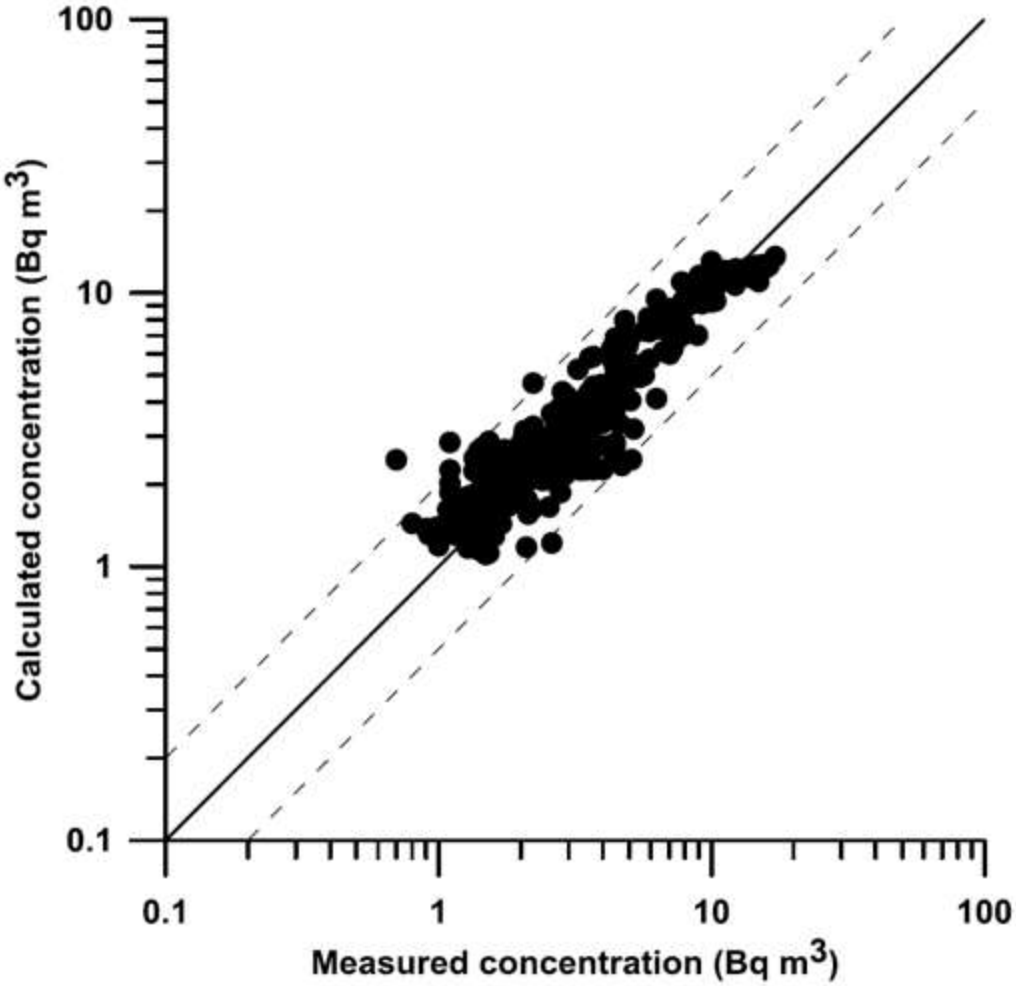


- Box system
  - 175 boxes for North-Western Pacific and adjacent seas
  - 3 water layers for deep boxes (blue color on the scheme)
  - Additional coastal box around FDNPP 15x30 km
- Sources of ^{137}Cs
  - Direct release (4.0E+15 Bq)
  - Atmosphere deposition (8.5E+15 Bq)
  - Continuous groundwater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

Correlation between observed and calculated activities in water

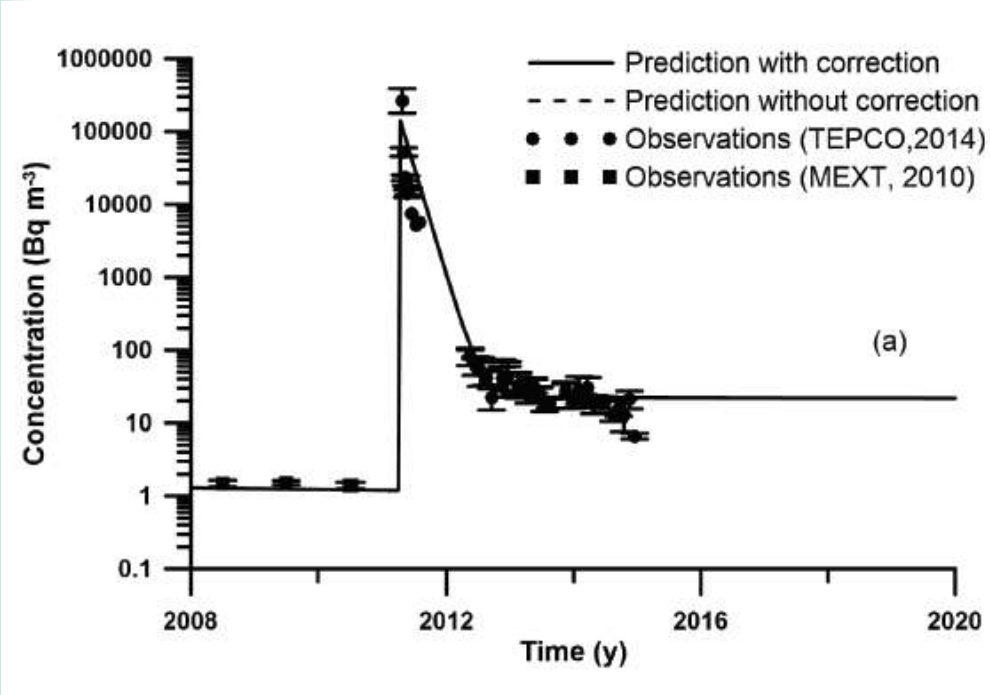


Cs-137

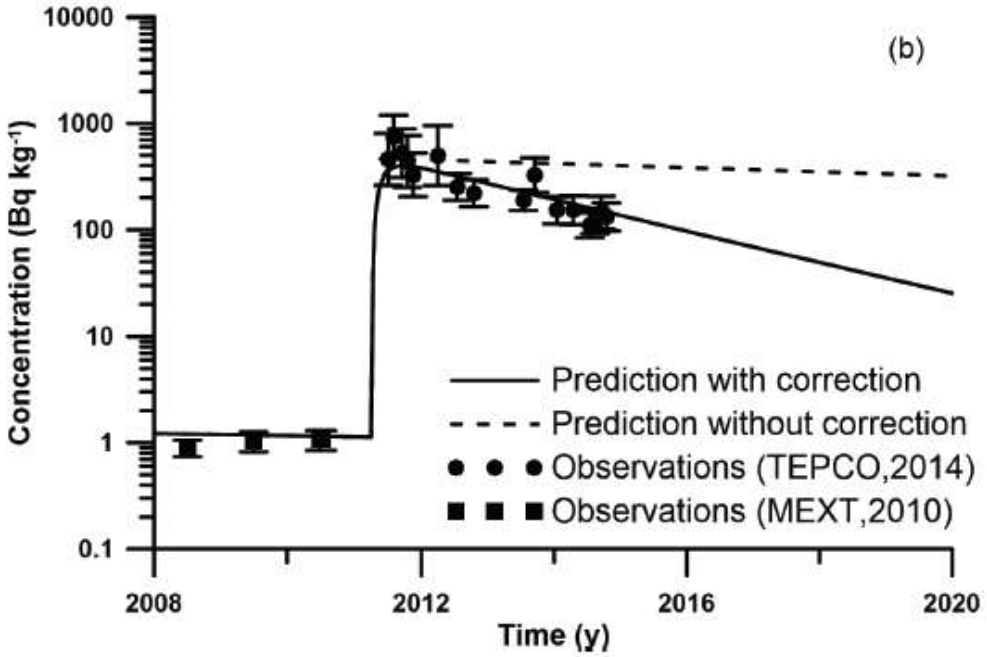


Sr-90

Comparison with measurements in coastal box

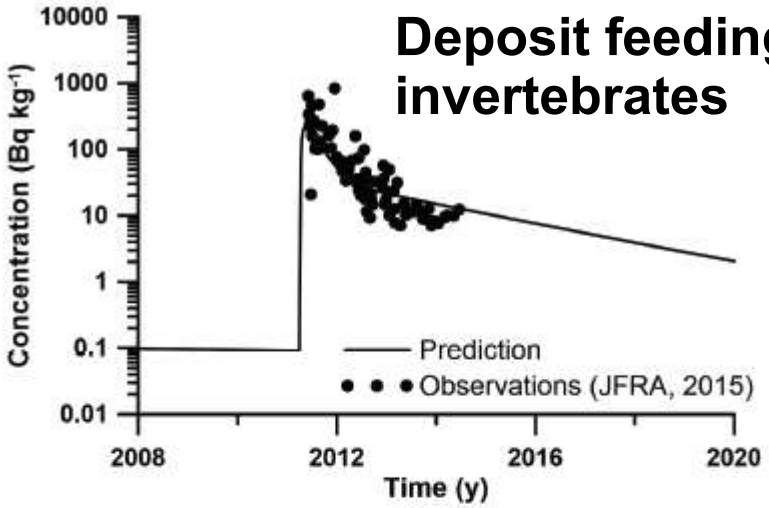


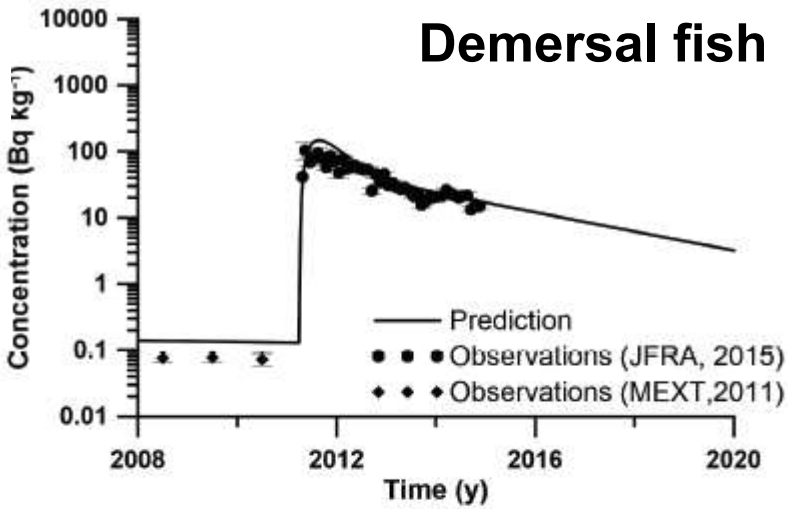
Cs-137 concentration in water

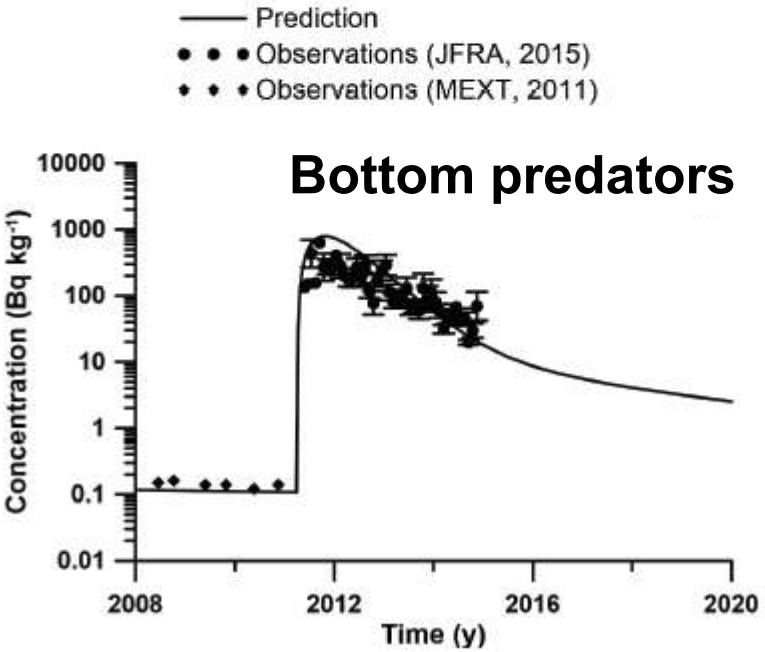


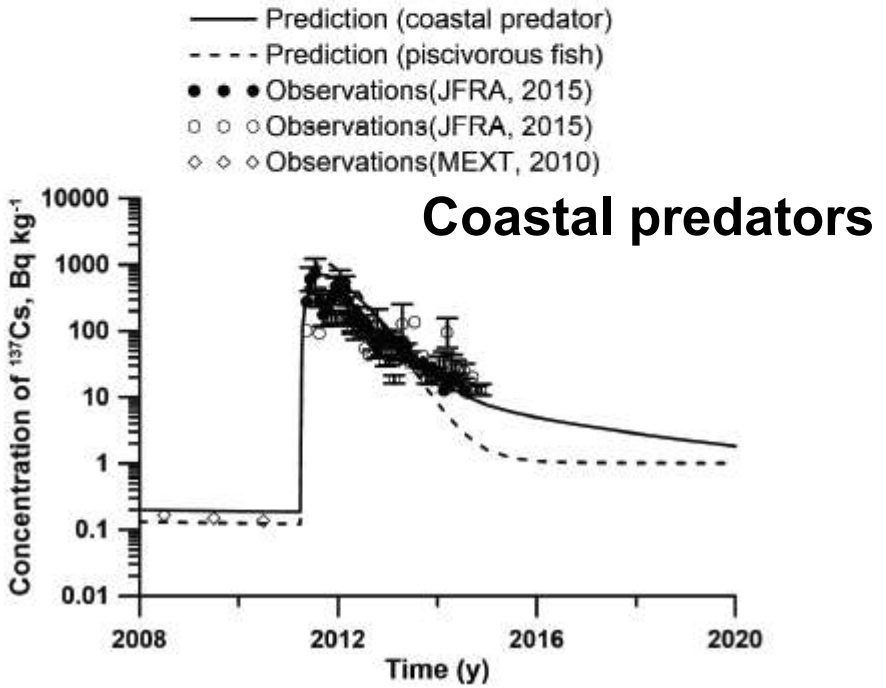
Cs-137 concentration in sediments

Comparison with measurements in coastal box



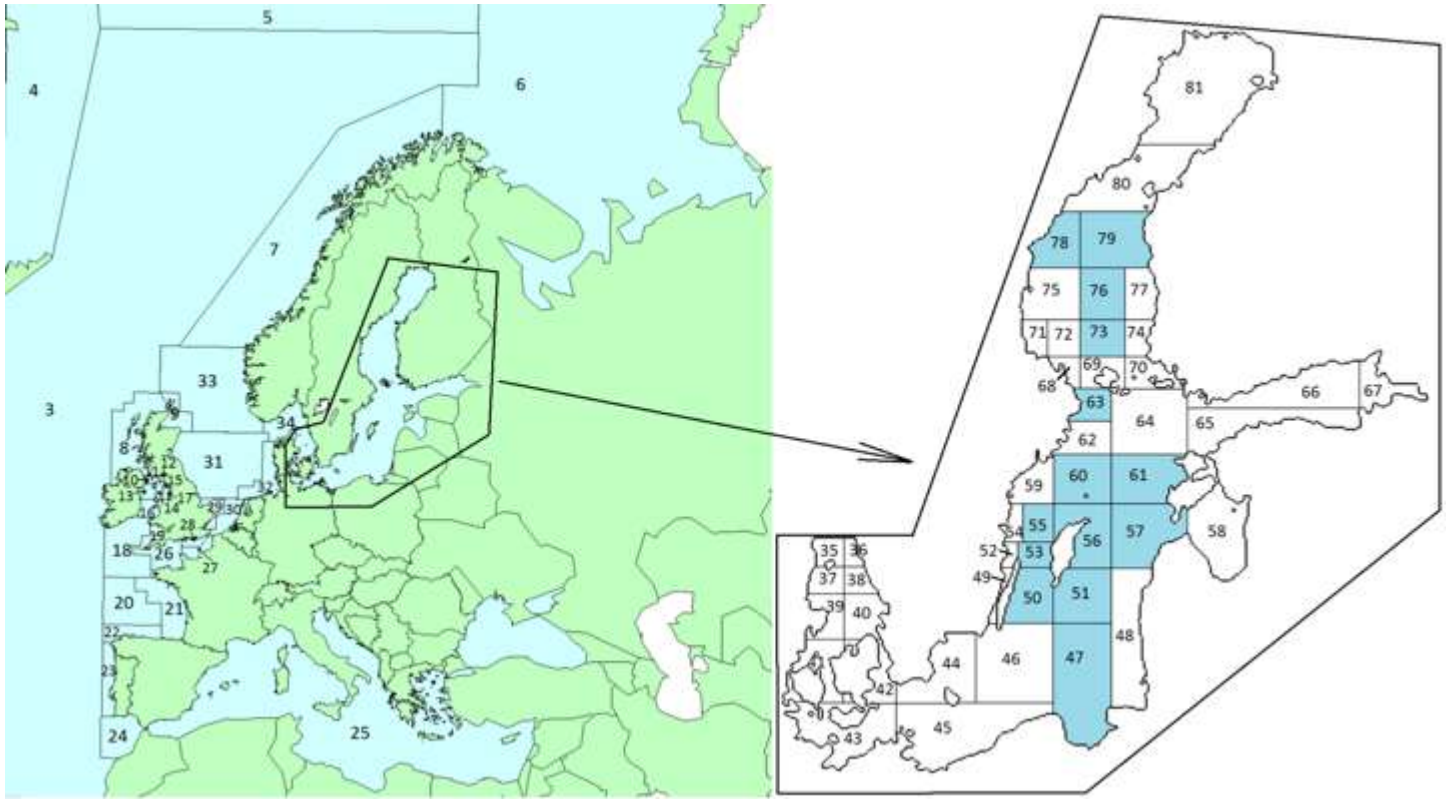






Application to the Chernobyl accident

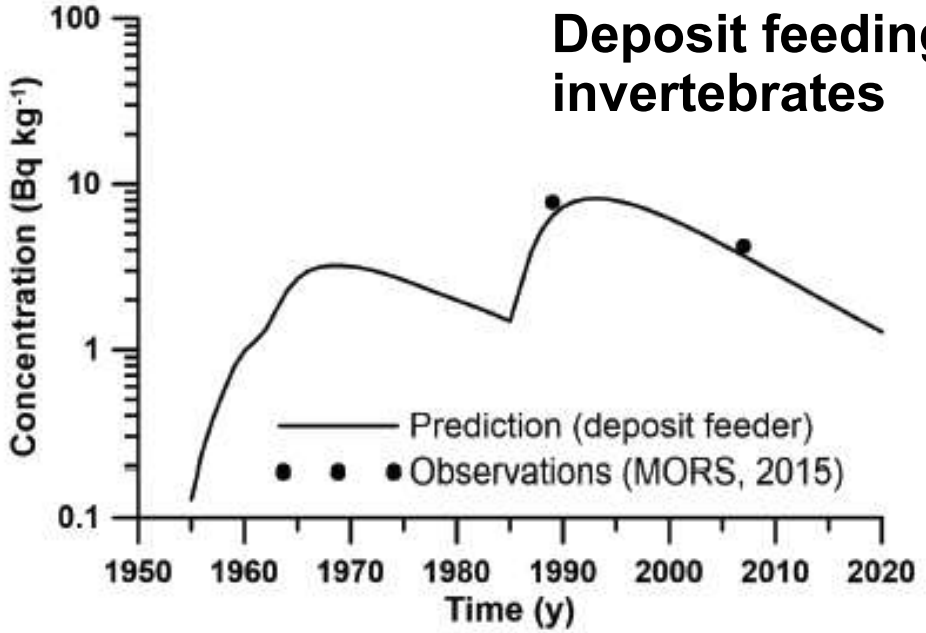
Box system for the Baltic Sea

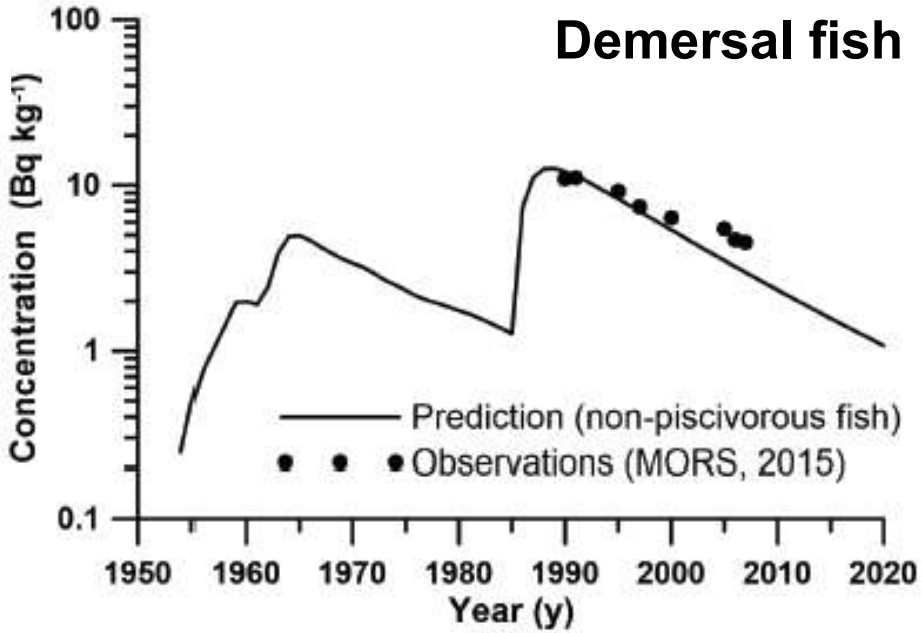


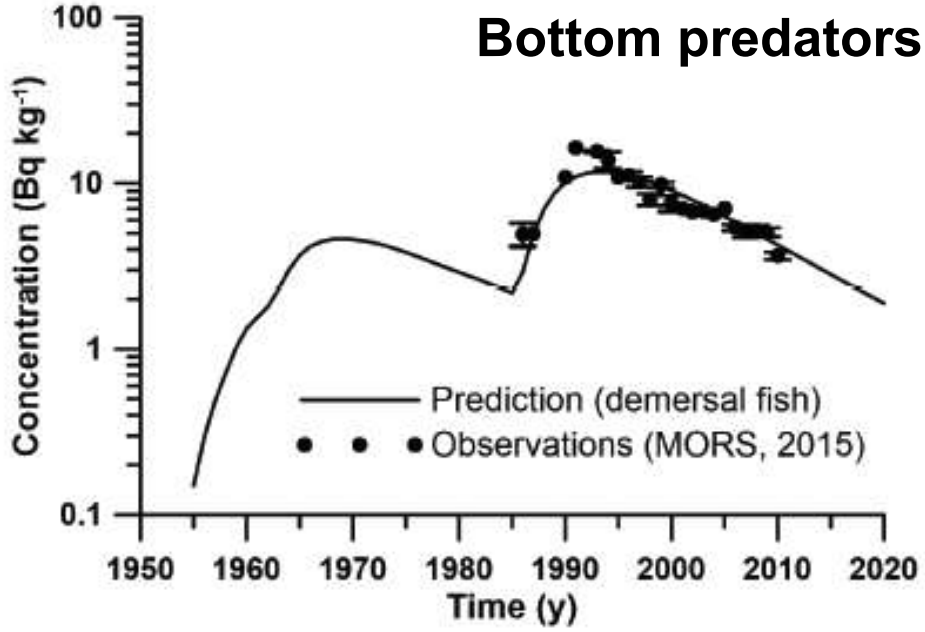
- 81 regional boxes + 16 river boxes
- A water column with a depth of more than 60m is divided into two layers (surface and bottom) to allow for activity stratification in the water column (blue colour on the scheme)

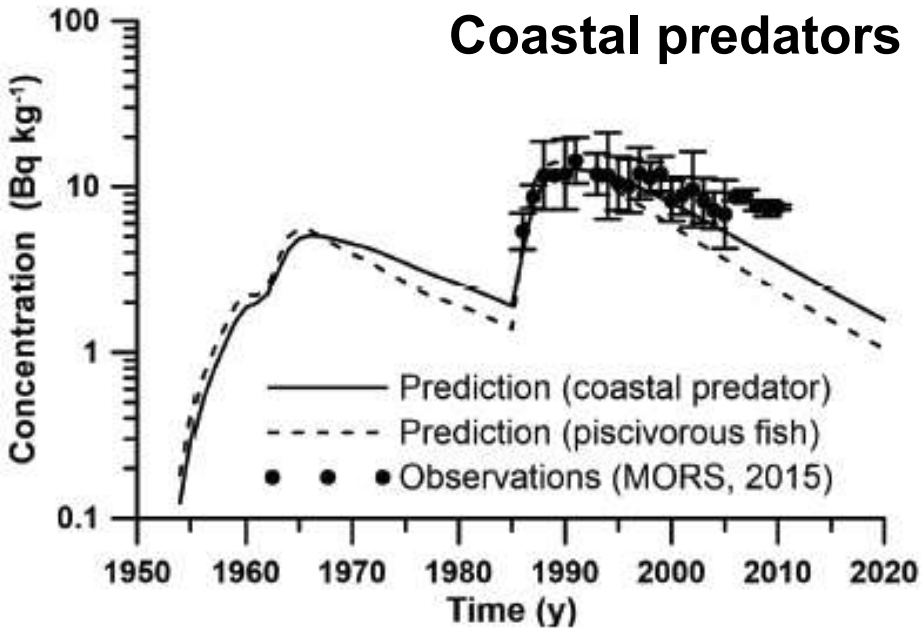
Comparison with measurements in box 45

PREPARE

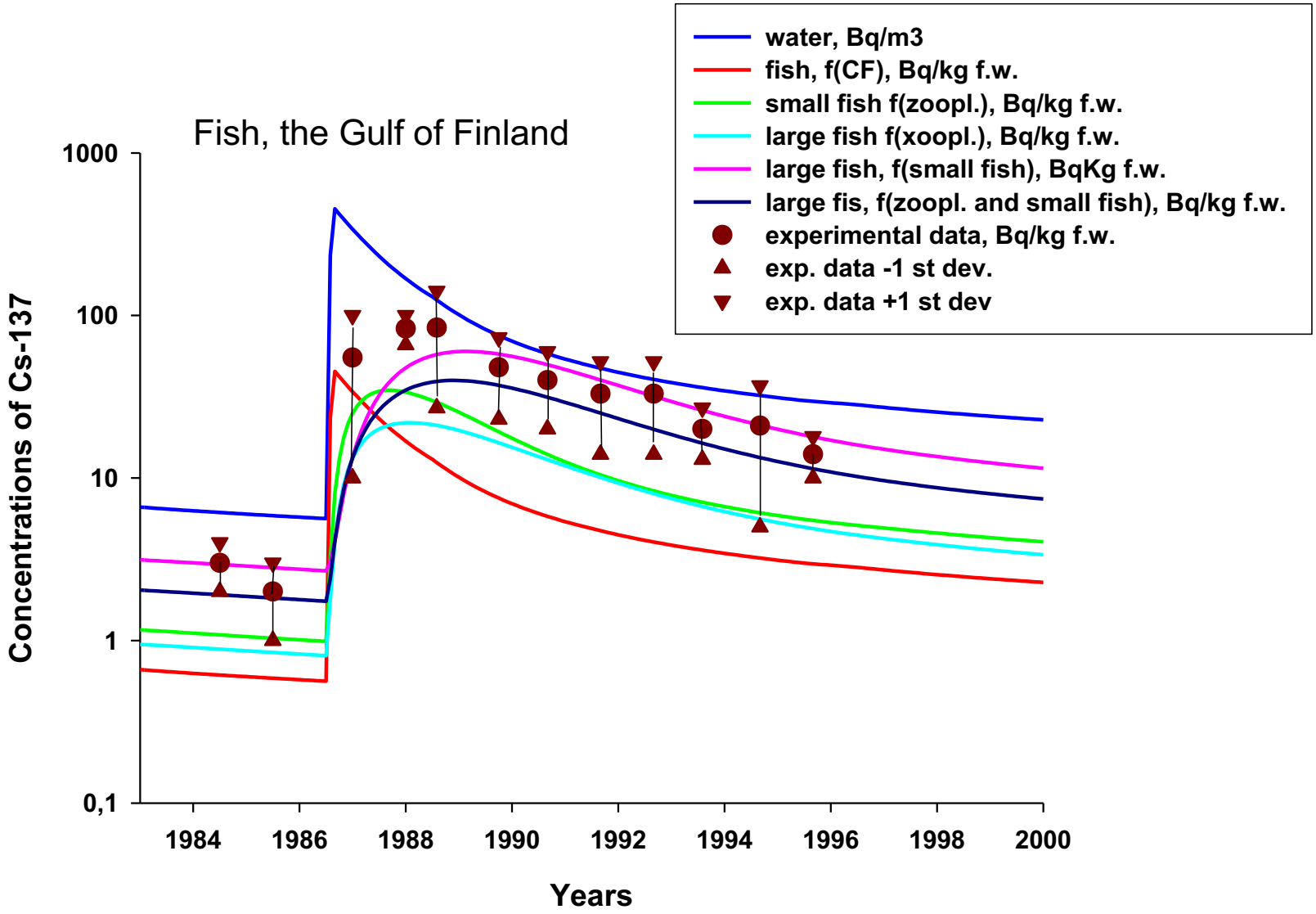




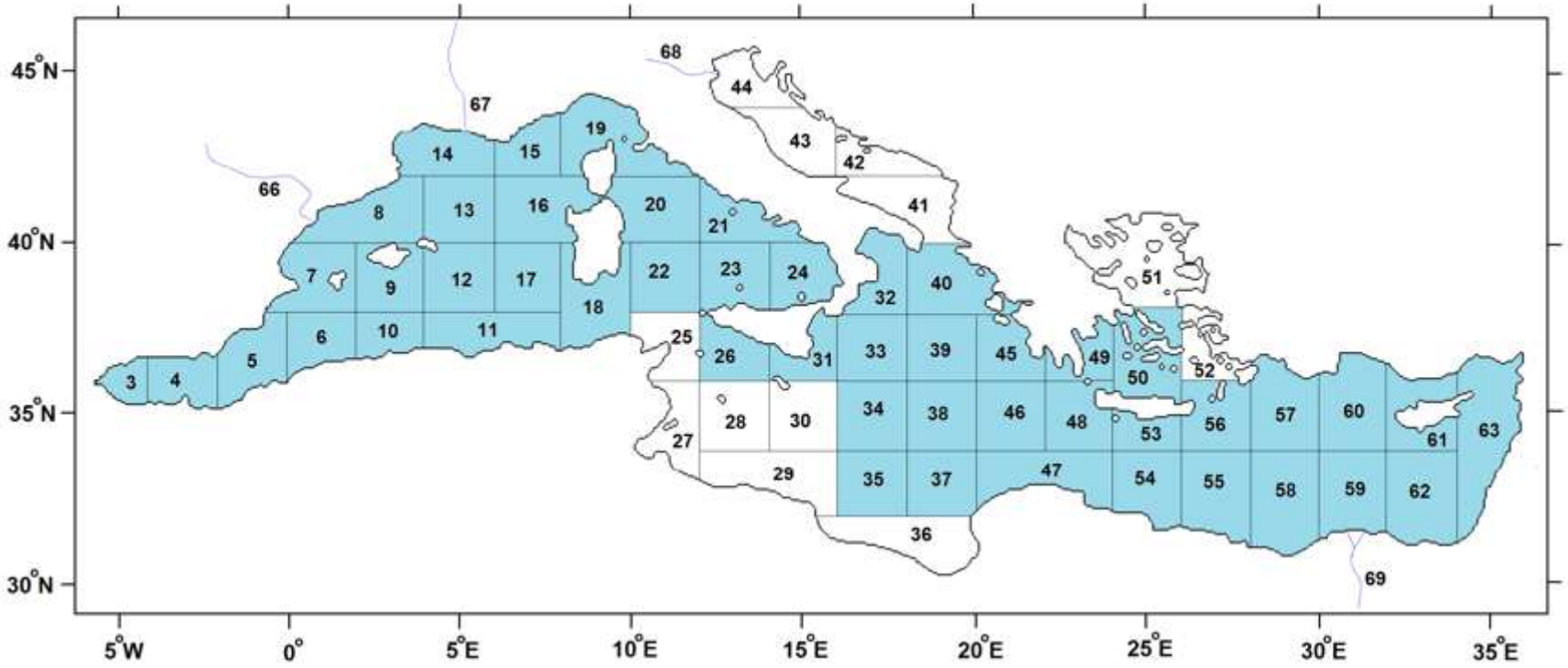




NRPA model: The Gulf of Finland



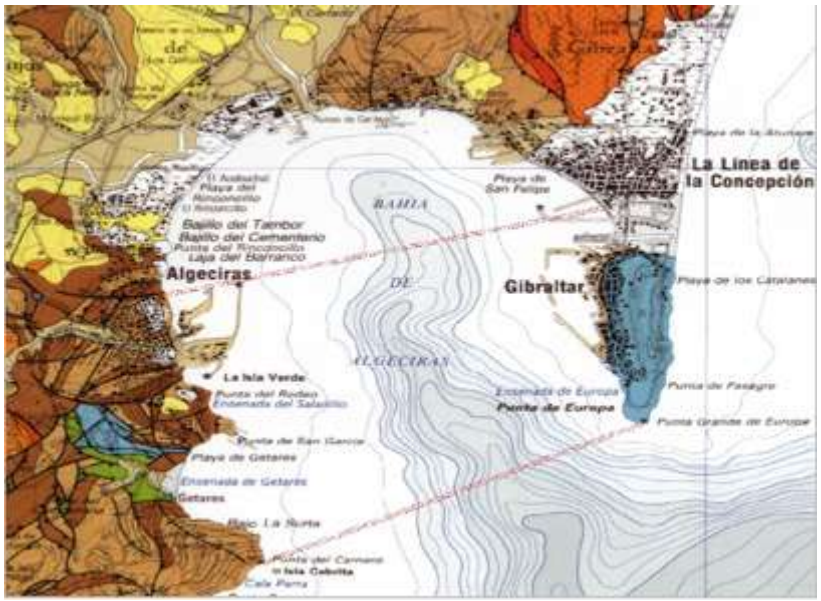
Box system for the Mediterranean Sea



- 61 regional boxes + 4 river boxes + 4 boundary boxes
- Deep boxes are divided into surface (0-100m), intermediary (100-500m) and bottom (>500m) layers (blue colour on the scheme)

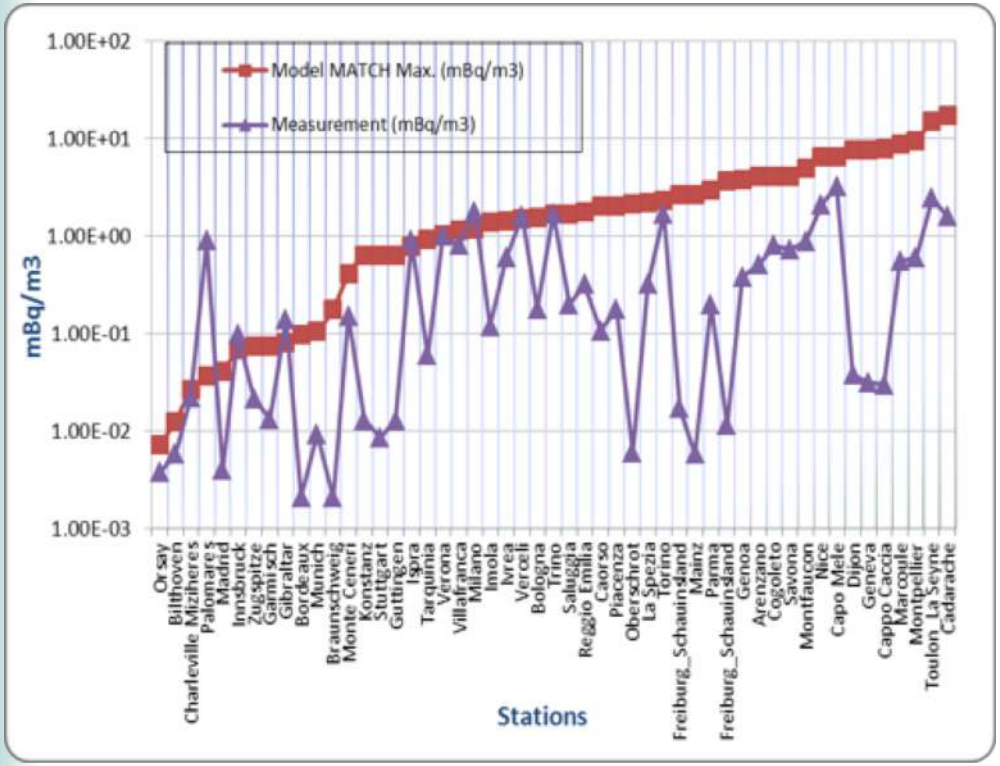
Acerinox incident (Spain)

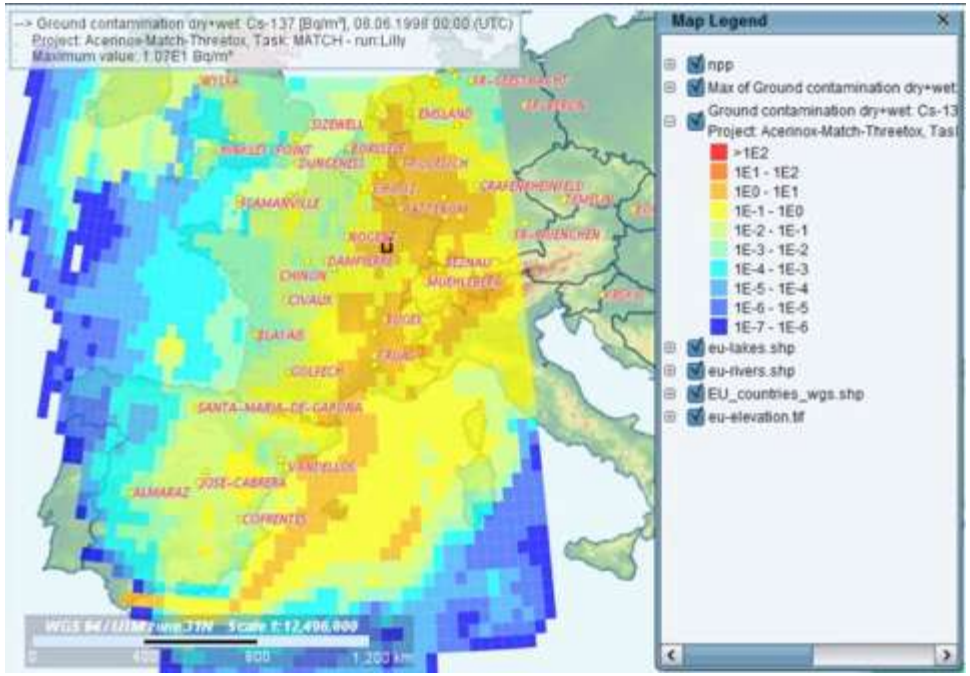
Algeciras Bay with ACERINOX plant location.



- On May 30, 1998, an orphan source of ^{137}Cs was accidentally melted in one of the furnaces of a stainless steel plant belonging to the enterprise Acerinox in the south of Spain
- 37 GBq of ^{137}Cs were released to the atmosphere
- The contamination was dispersed on the large distance, practically in all European countries

JRODOS application to the Acerinox incident



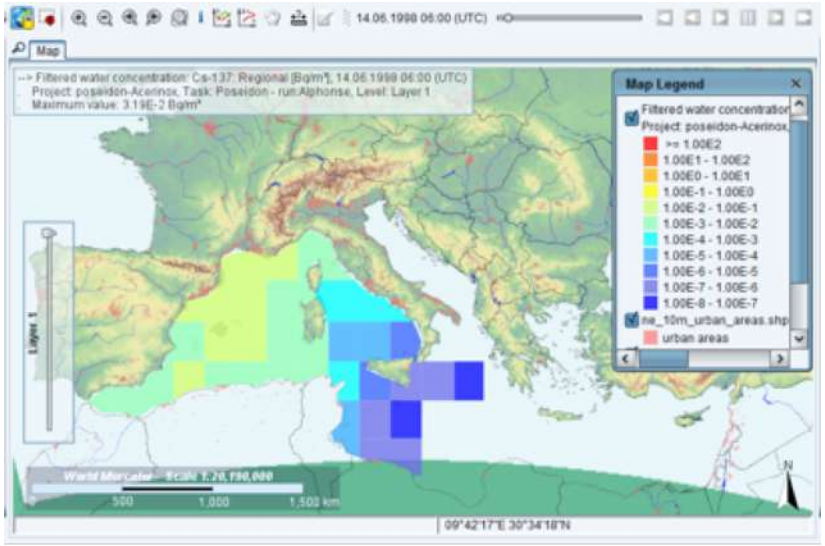


. Comparison of the maximum ^{137}Cs measured and modeled by MATCH

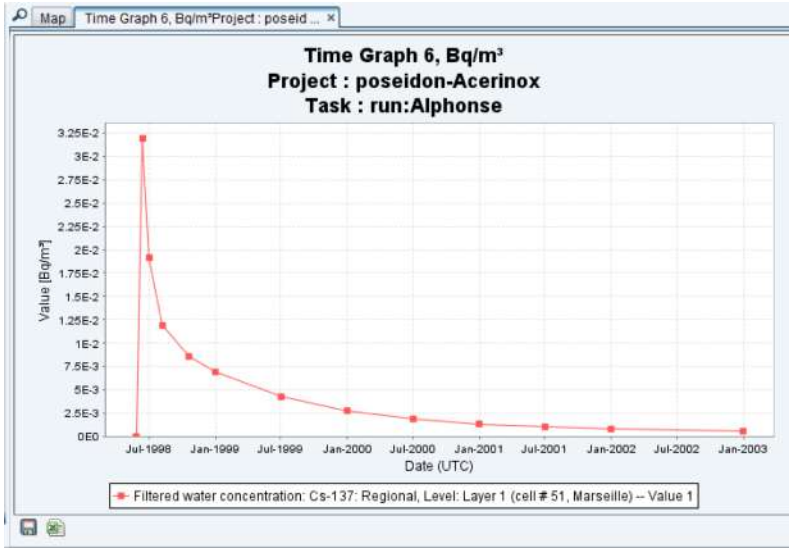
Atmospheric deposition simulated by MATCH model

Concentration of ^{137}Cs in the water

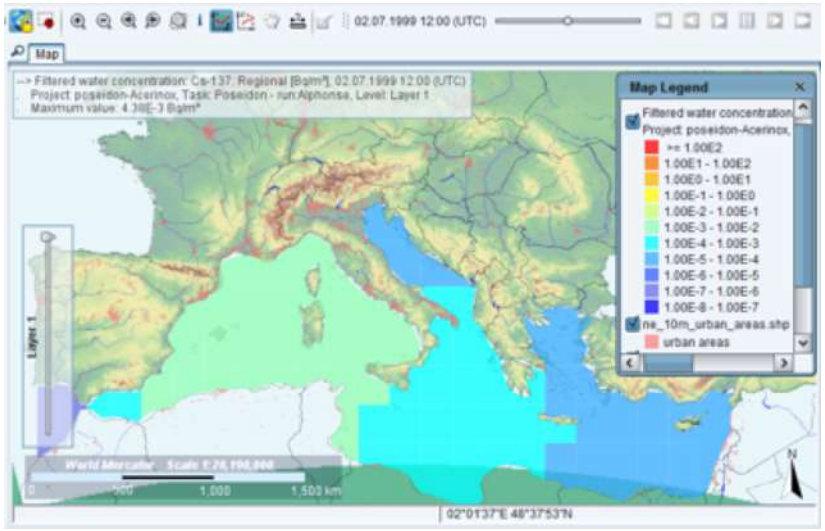
PREPARE



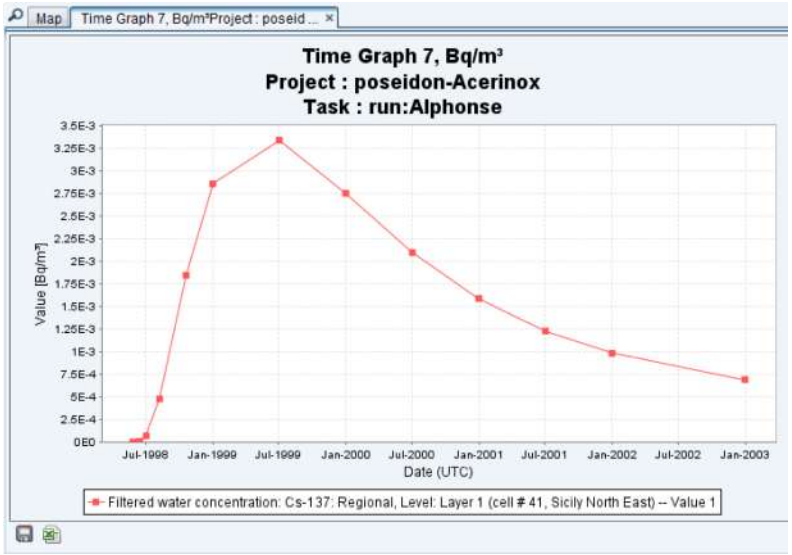
June 1998



Time series for box 14 (Marseille)

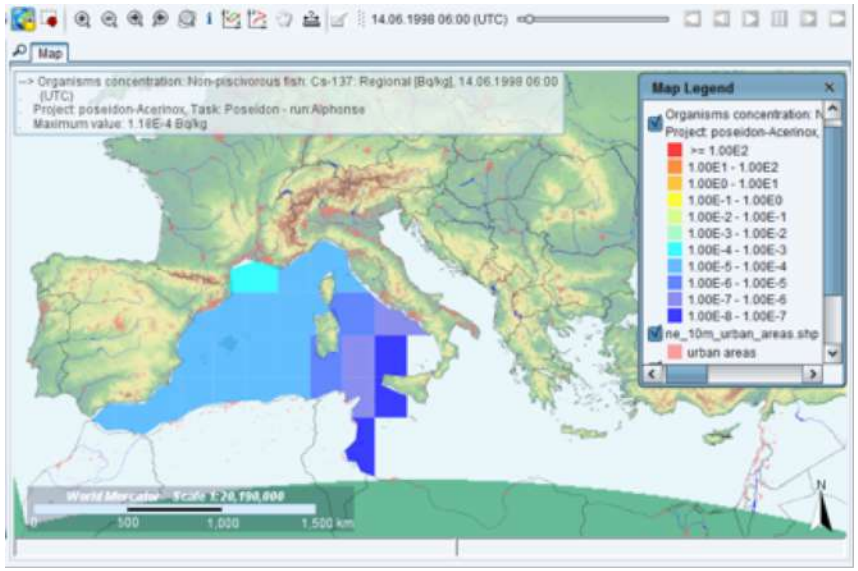


June 1999



Time series for box 24 (Sicily North)

Concentration of ^{137}Cs in non-piscivorous fish



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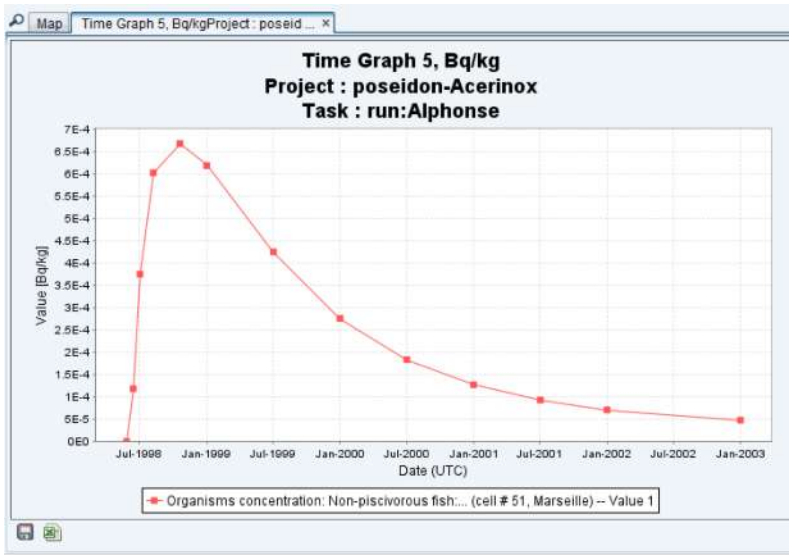
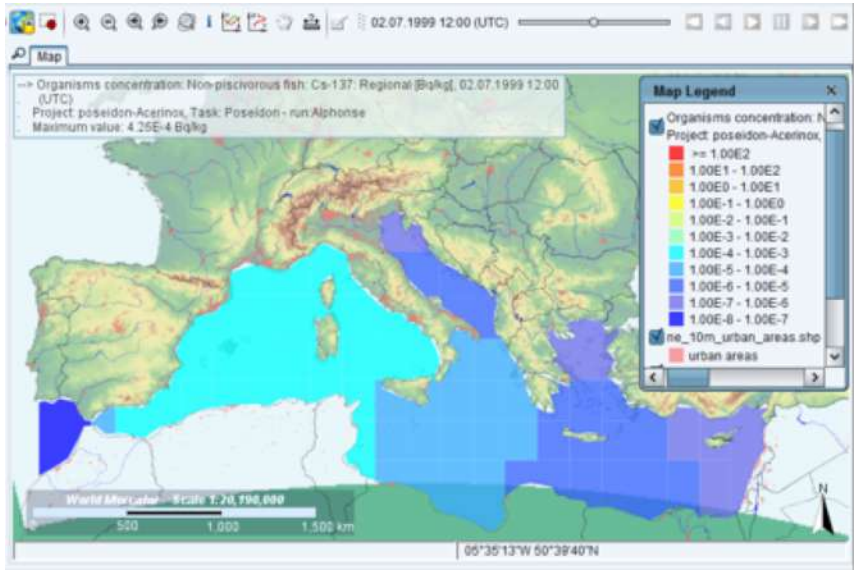
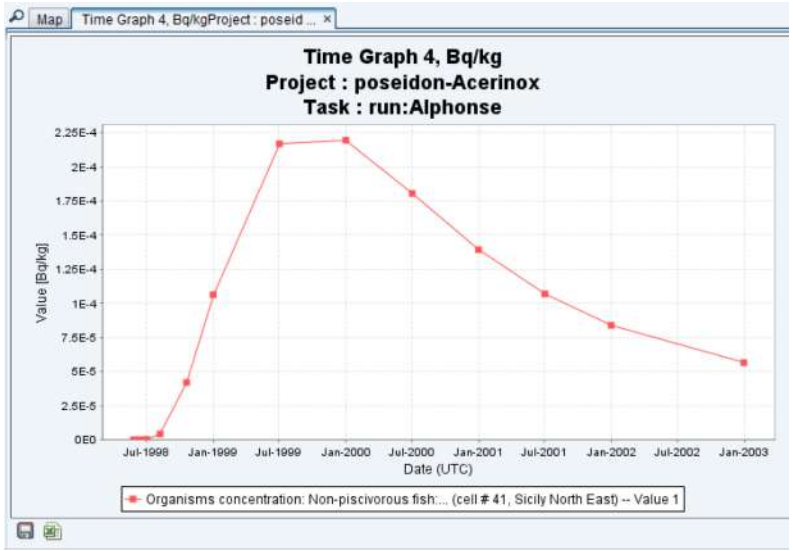


Time series for box 14 (Marseille)



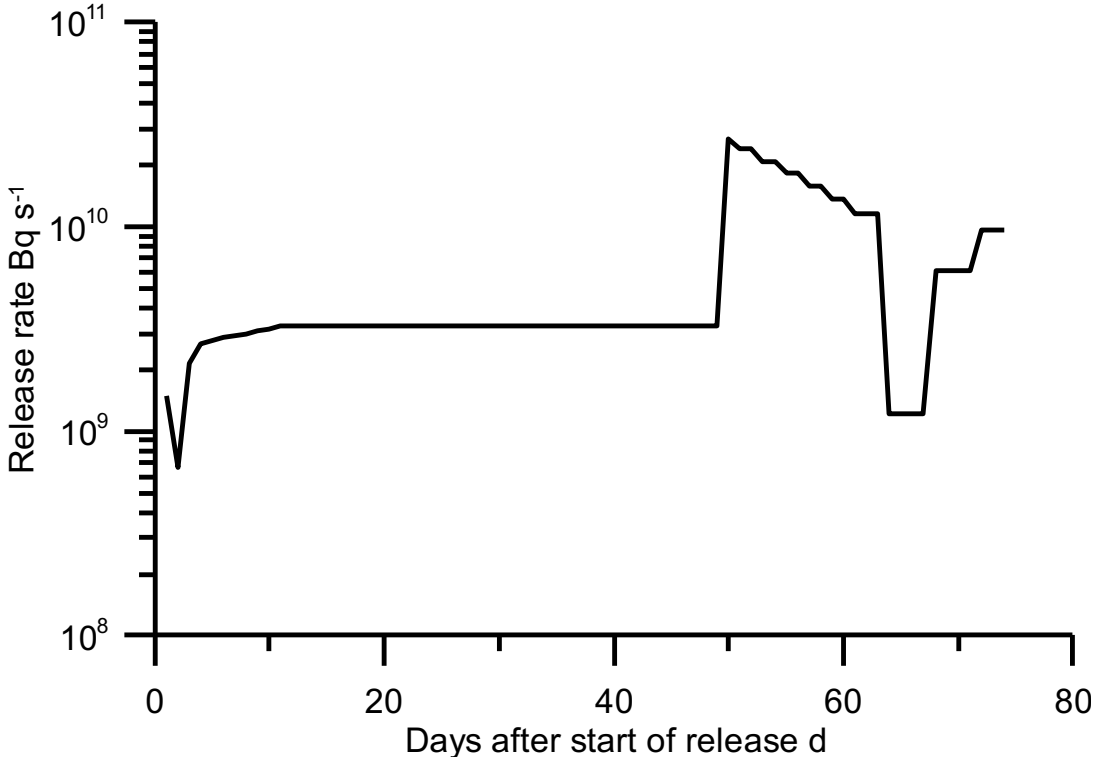
June 1999



Time series for box 24 (Sicily North)

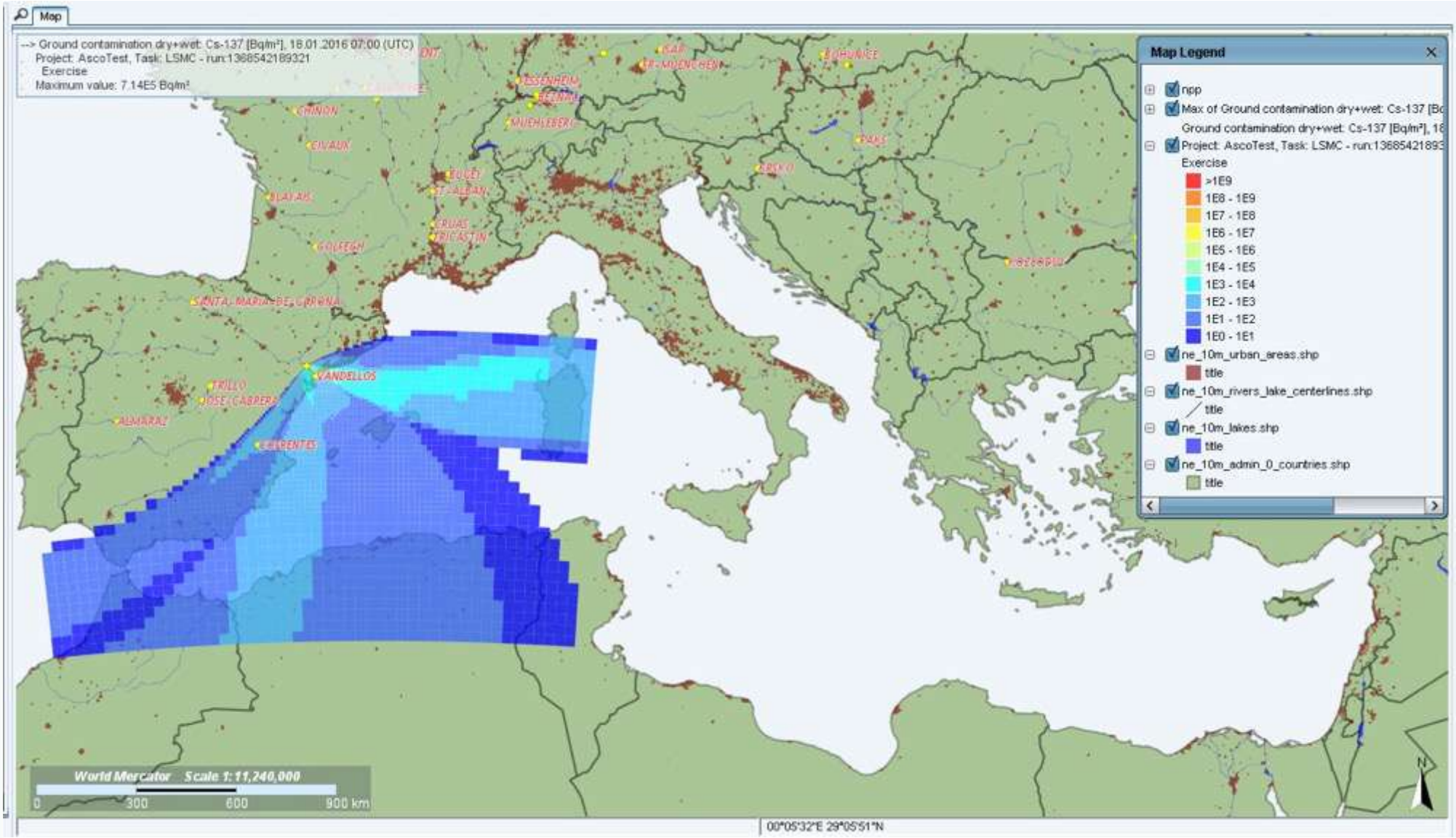
Stress test for Asco NPP (Spain)

Asco NPP.

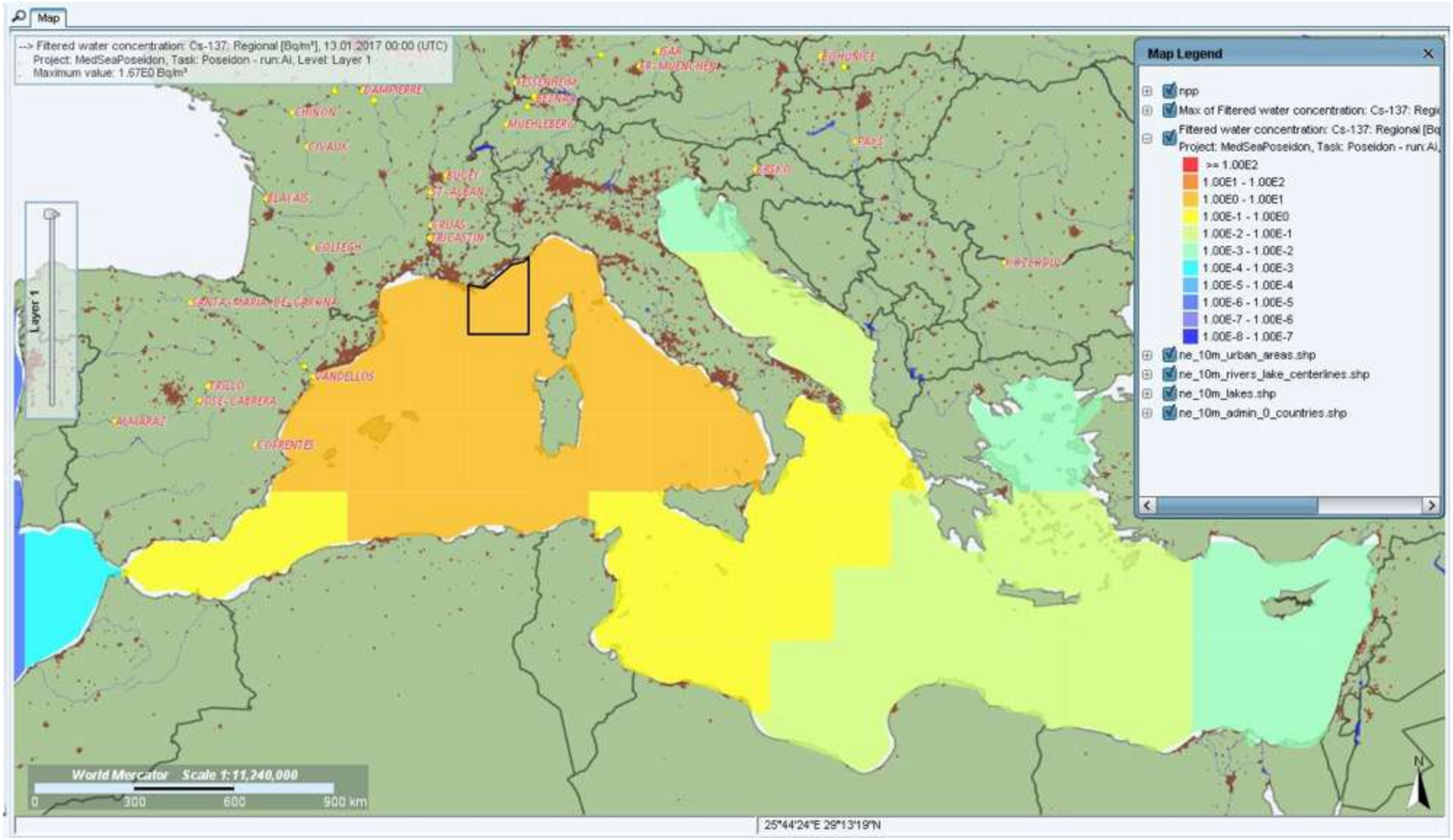


The intensity of source of ^{137}Cs in stress test

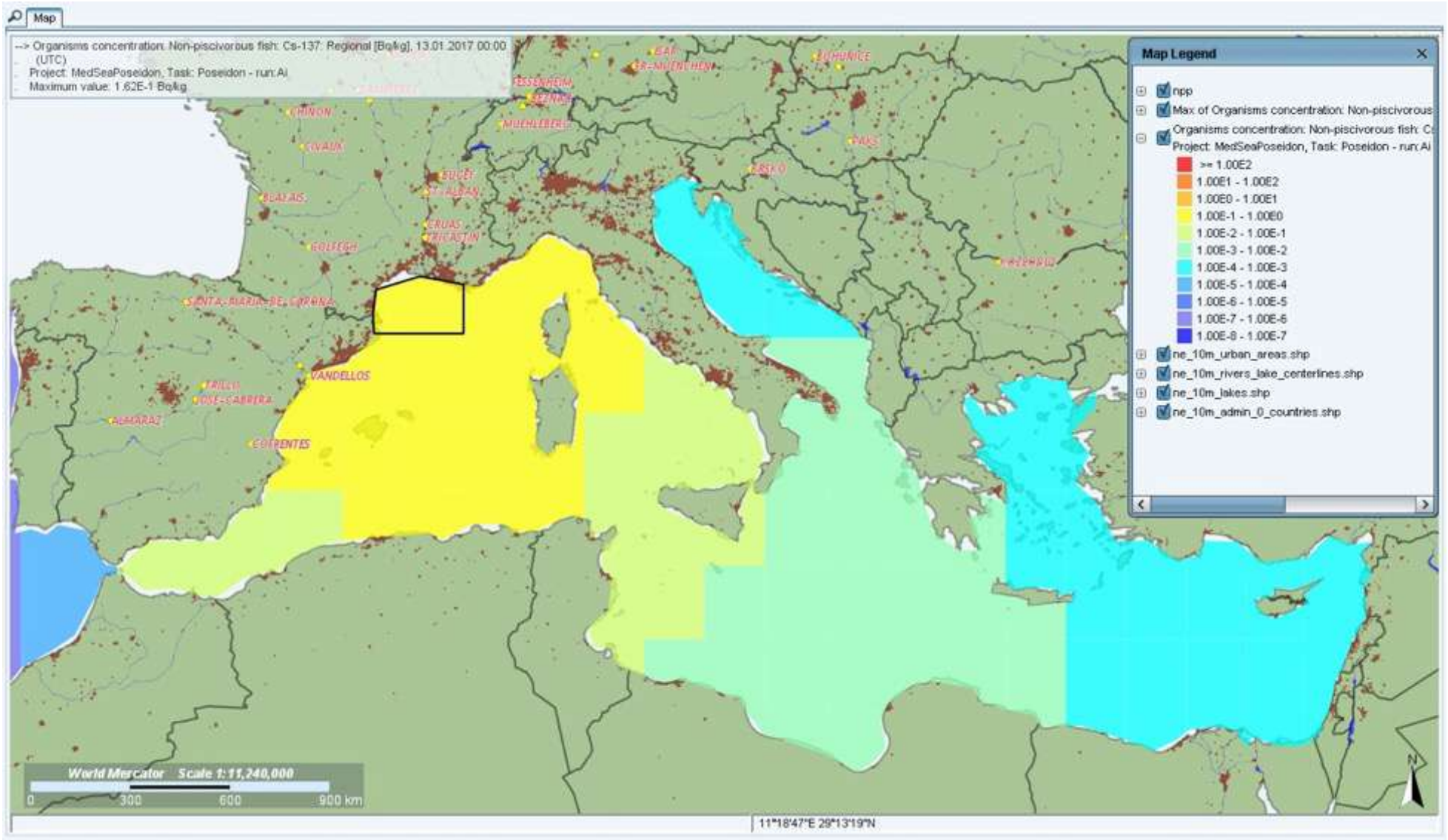
Results of deposition (wet + dry) for 18.01. 2016 07.00 (UTC)



Distribution of ^{137}Cs concentration in the water (surface boxes) for 13.01.2017



Distribution of concentration of ^{137}Cs in the non-piscivorous fish (surface boxes) for 13.01.2017



Conclusions

- The marine food chain model was extended by benthic organisms to describe the migration of radionuclides from contaminated bottom sediments to marine organisms through food chain.
- Application to Fukushima accident shows that model reproduces well concentration of ^{137}Cs in the water, bottom sediments and marine organisms.
- The new box systems for Mediterranean and Baltic seas were implemented. The water fluxes between boxes were calculated based on averaging over 10 years of 3-dimensional currents.
- POSEIDON run under JRODOS using predicted radioactivity deposition from atmospheric dispersion model and release with rivers water under JRODOS interface and direct release from nuclear objects.
- Application of POSEIDON model under JRODOS interface was realized for Acerinox incident and in the stress test for Asco NPP

Publications

- Bezhenar R., Heling R. , Ievdin Ye. , Iosjpe M. , Maderich V., de With G. , Willemsen S., Zheleznyak M. (2016) Integration of 3D model THREETOX in JRODOS-HDM, implementation studies and model validation on marine Fukushima scenarios. Radioprotection
- Vives i Batlle, J., Beresford, N.A., Beaugelin-Seiller, K., Bezhenar, R., Brown, J., Cheng, J.-J., Ćujić, M., Dragović, S., Duffa, C., Fiévet, B., Hosseini, A., Jung, K.T., Kamboj, S., Keum, D.-K., Kobayashi, T., Kryshev, A., LePoire, D., Maderich, V., Min, B.-I., Periáñez, R., Sazykina, T., Suh, K.-S., Yu, C., Wang, C., Heling, R. (2016) Inter-comparison of dynamic models for radionuclide transfer to marine biota in a Fukushima accident scenario. *Journal of Environmental Radioactivity* , **153**, 31-50.
- Periañez R., Brovchenko I.., Duffa C., Jung K.T., Kobayashi T., Lamego F., Maderich V., Min, B.-I., Nies H., Osvath I., Psaltaki M., Suh K. (2015) A new comparison of marine dispersion model performances for Fukushima releases in the frame of IAEA MODARIA program. *Journal of Environmental Radioactivity,* **150** 247-269

- Periañez R., Bezhenar R., Iosjpe M., Maderich V., Nies H., Osvath I., Outola I., de With G. (2015) A comparison of marine radionuclide dispersion models for the Baltic Sea in the frame of IAEA MODARIA program. *Journal of Environmental Radioactivity* **139**, 66-77. doi:10.1016/j.jenvrad.2014.09.013
- Maderich V., Jung K.T., Bezhenar R., de With G., Qiao F., Casacuberta N., Masque P., Y.H. Kim (2014) Dispersion and fate of ^{90}Sr in the Northwestern Pacific and adjacent seas: global fallout and the Fukushima Dai-ichi accident. *Science of the Total Environment,* **494-495**, 261–271.
- Maderich V., Bezhenar R., Heling R., de With G., Jung K.T., Myoung J.G., Cho Y.-K., Qiao F., Robertson L. (2014) Regional long-term model of radioactivity dispersion and fate in the Northwestern Pacific and adjacent seas: application to the Fukushima Dai-ichi accident. *Journal of Environmental Radioactivity,* **131**, 4-18

- Any questions?

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