MULTI-SCALE MULTIMEDIA MODELING
OF TOXIC IMPACT ON AQUATIC BIODIVERSITY

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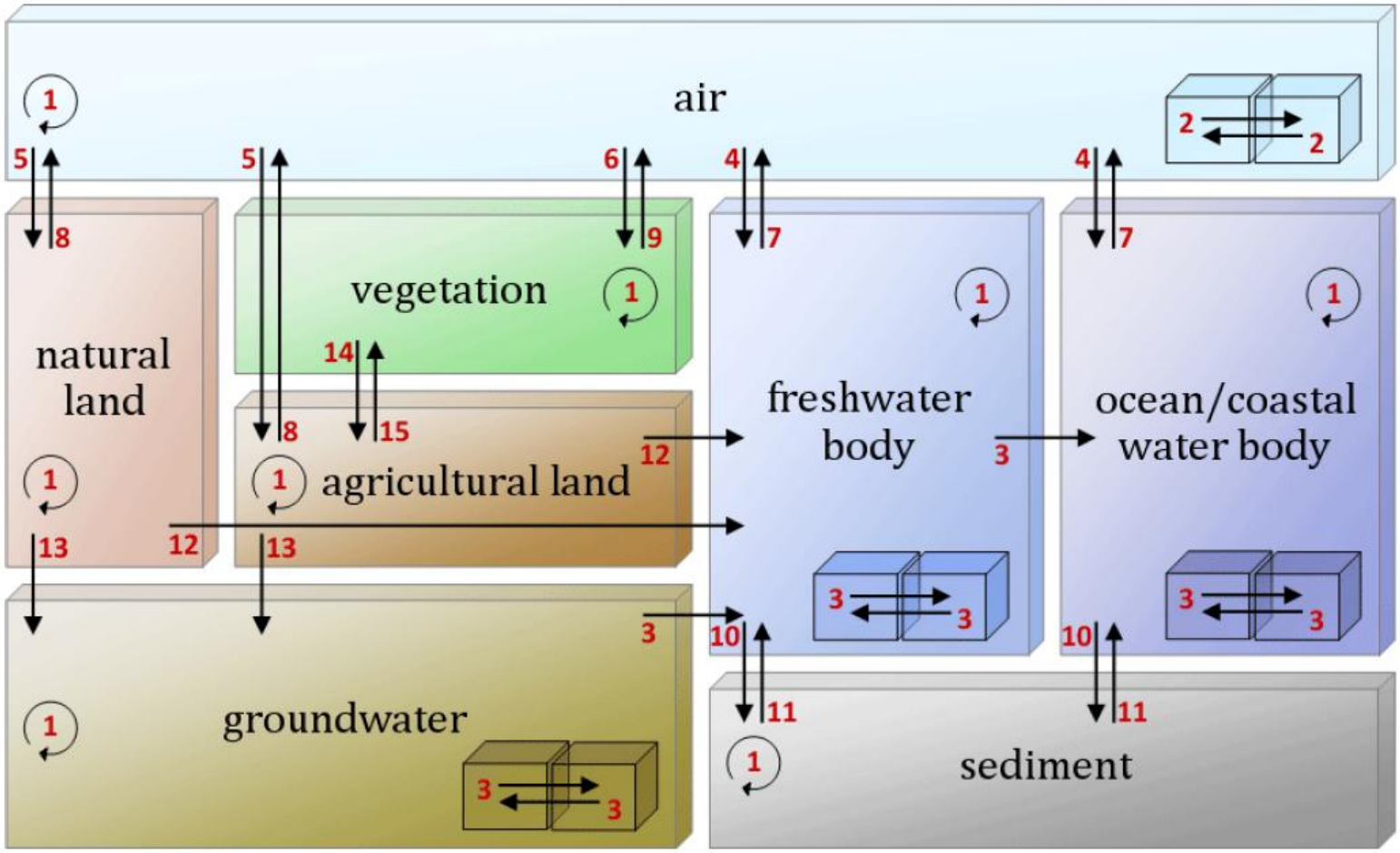
Overview

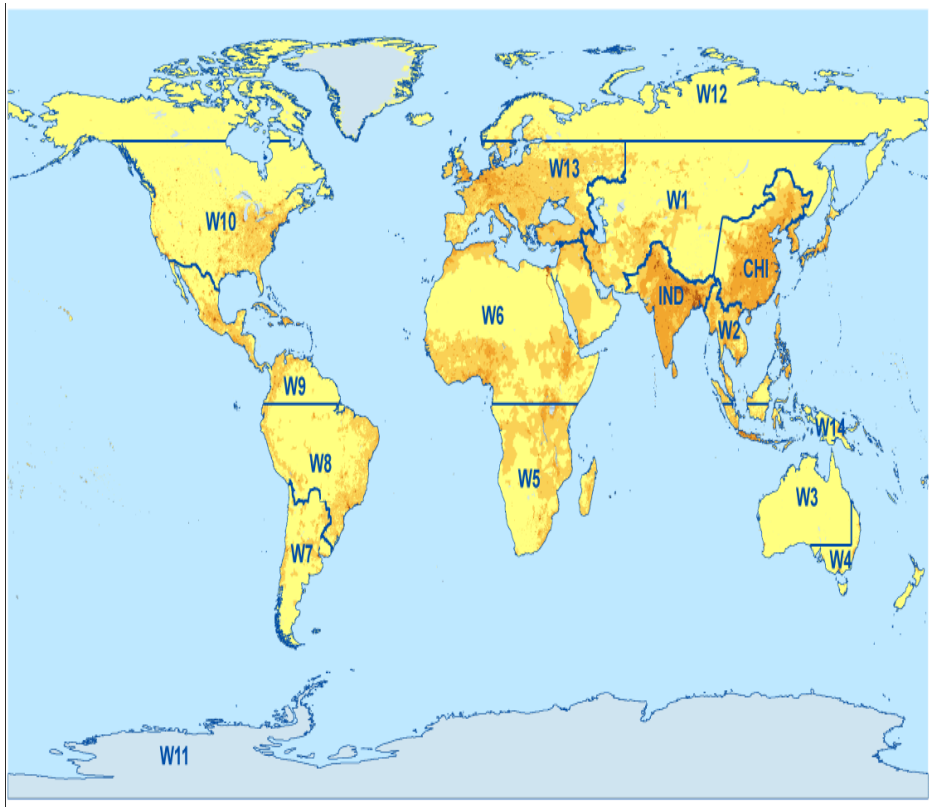
- Spatial multimedia (box-) models.
- Simple study: illustration of an **artifact** that biases the computation of the **impact on biodiversity** in spatial box models.
- Grid refinement method implemented in *Pangea*, a multi-scale multimedia model => **potential for refinement**.

"Box" type multimedia models
assumption: homogeneity

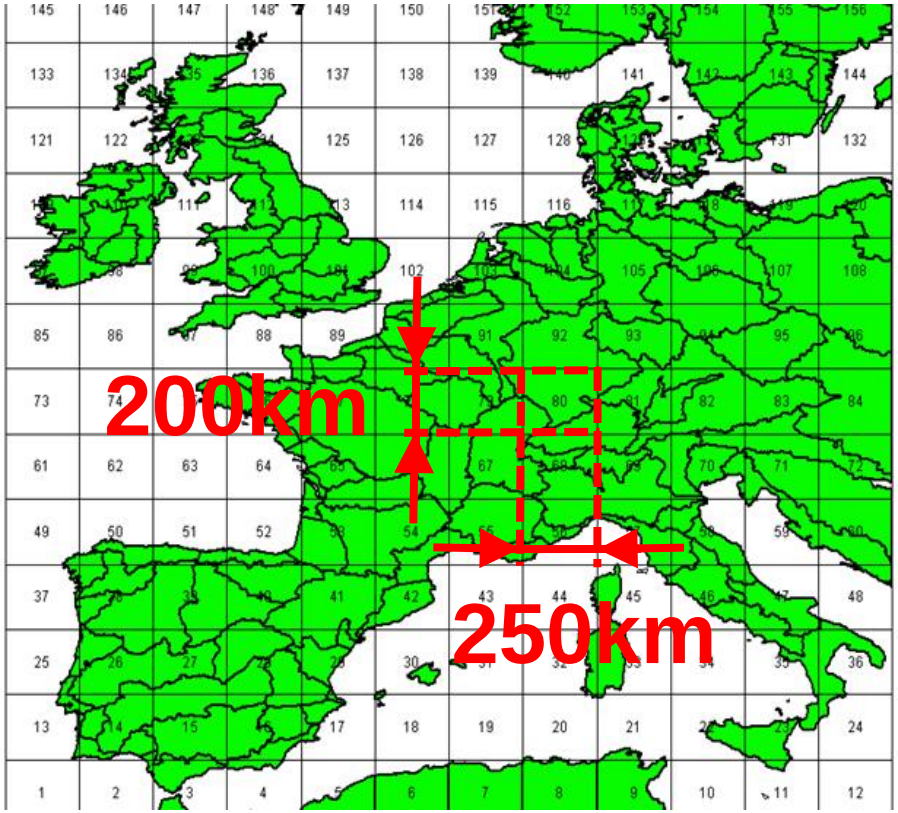


$d\mathbf{m}/dt = \mathbf{K}\mathbf{m} + \mathbf{s}, \quad \mathbf{K} = \mathbf{f}$(intra- and inter-media processes)

Spatial "Box" type multimedia models

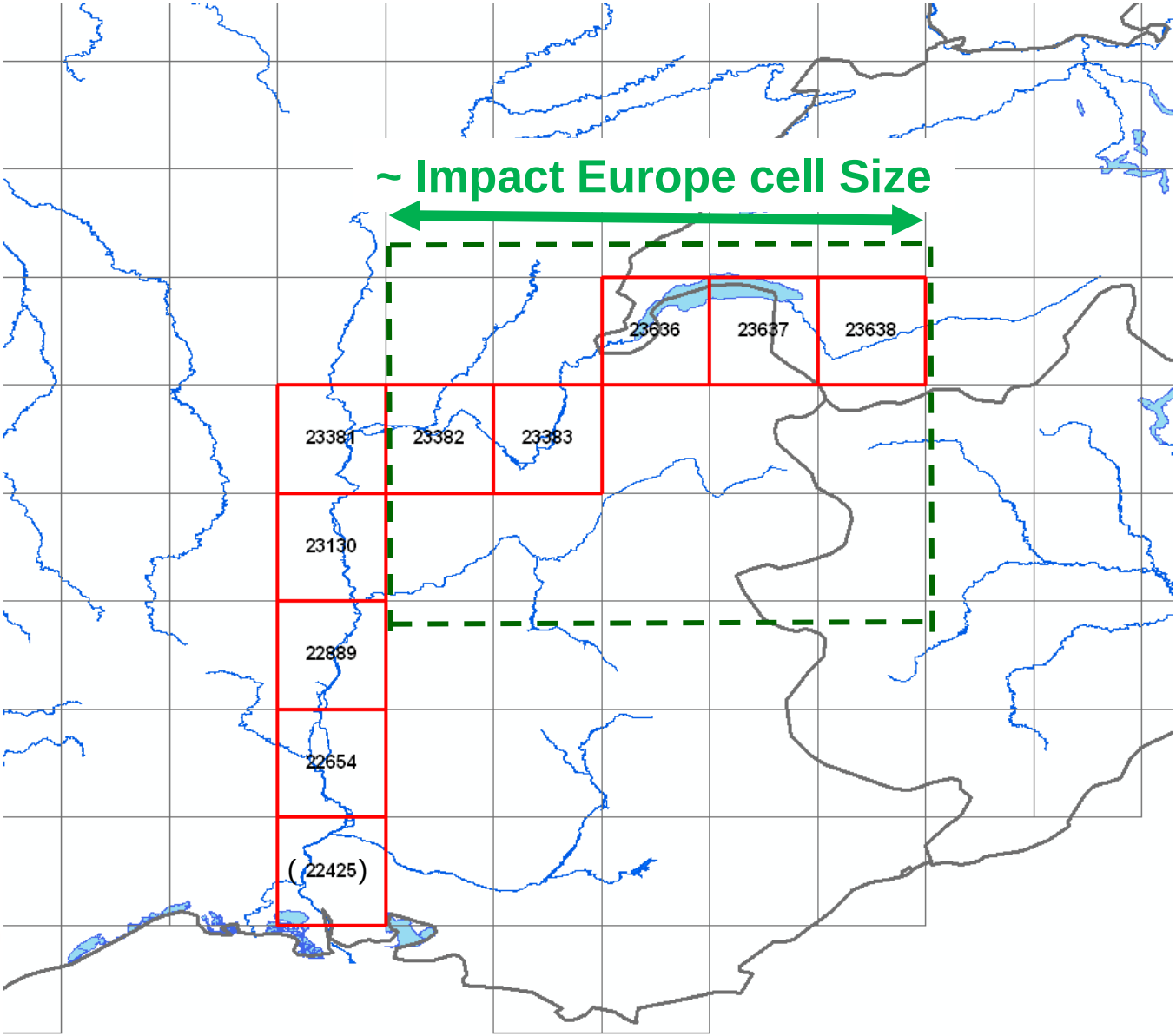


Impact World

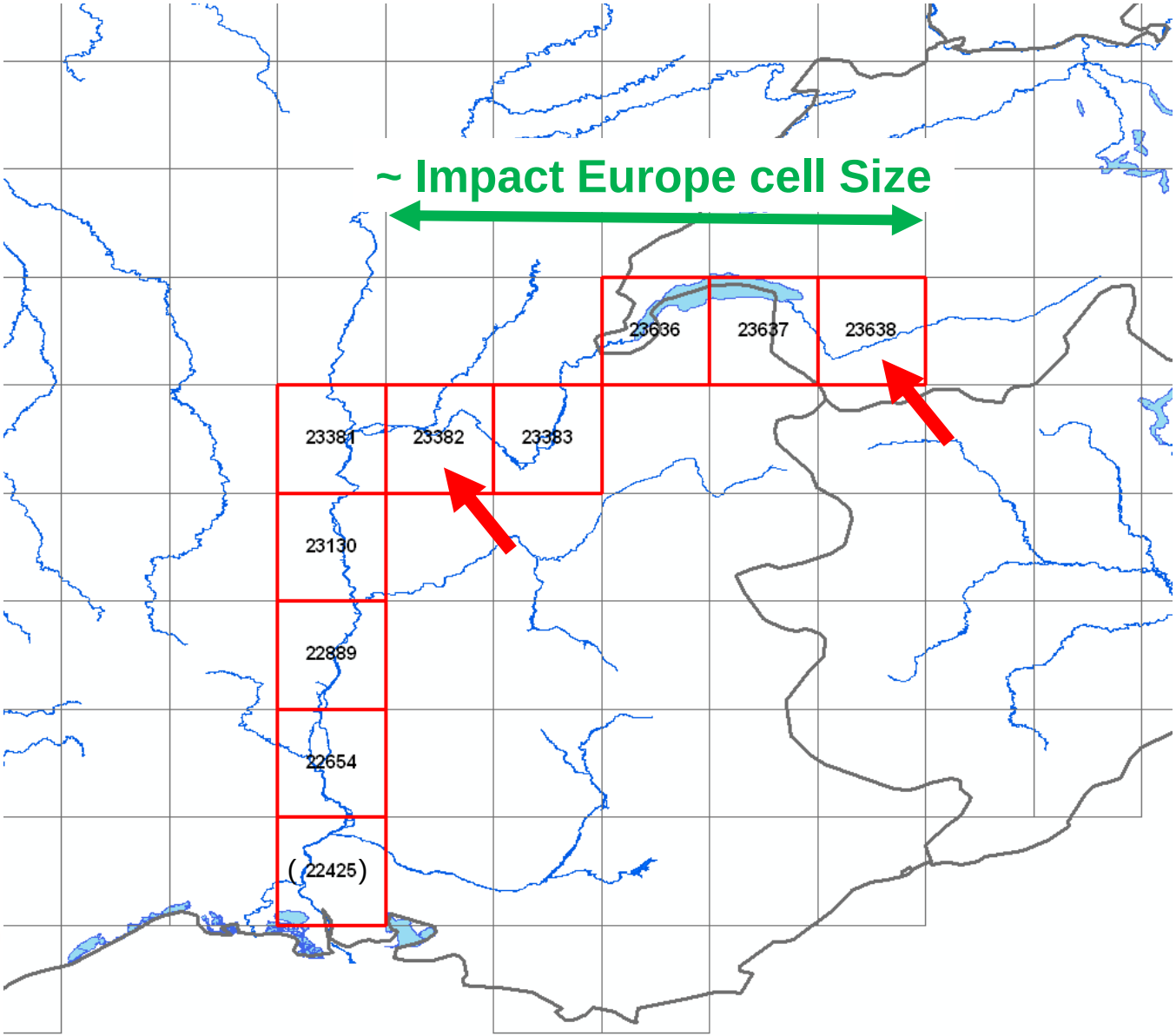


Impact 2002 Europe

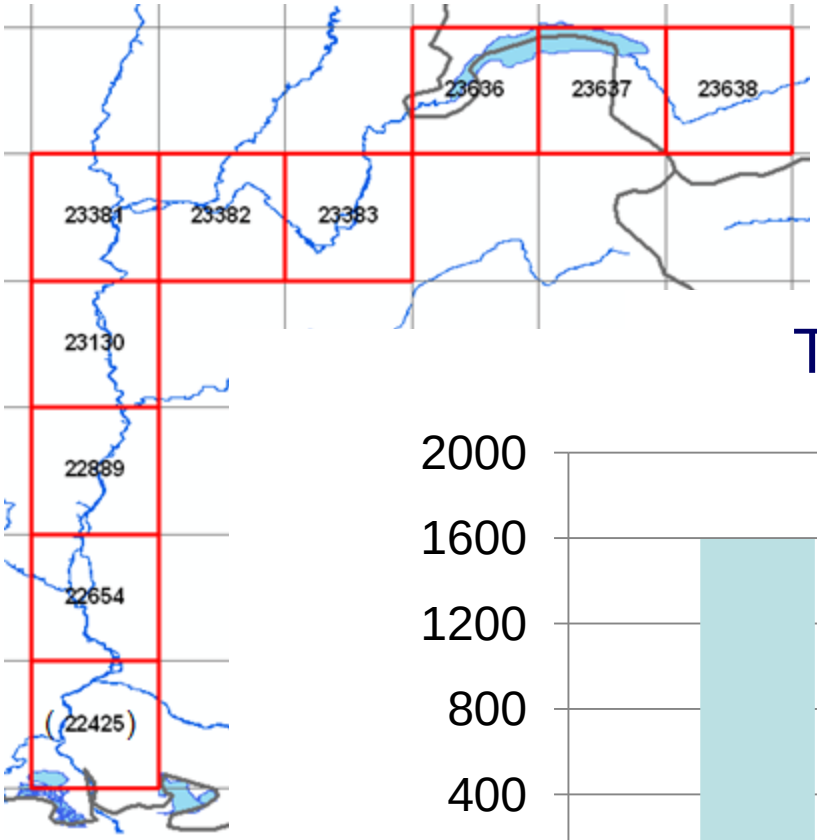
Rhône river, gridded at 0.5°x0.5°

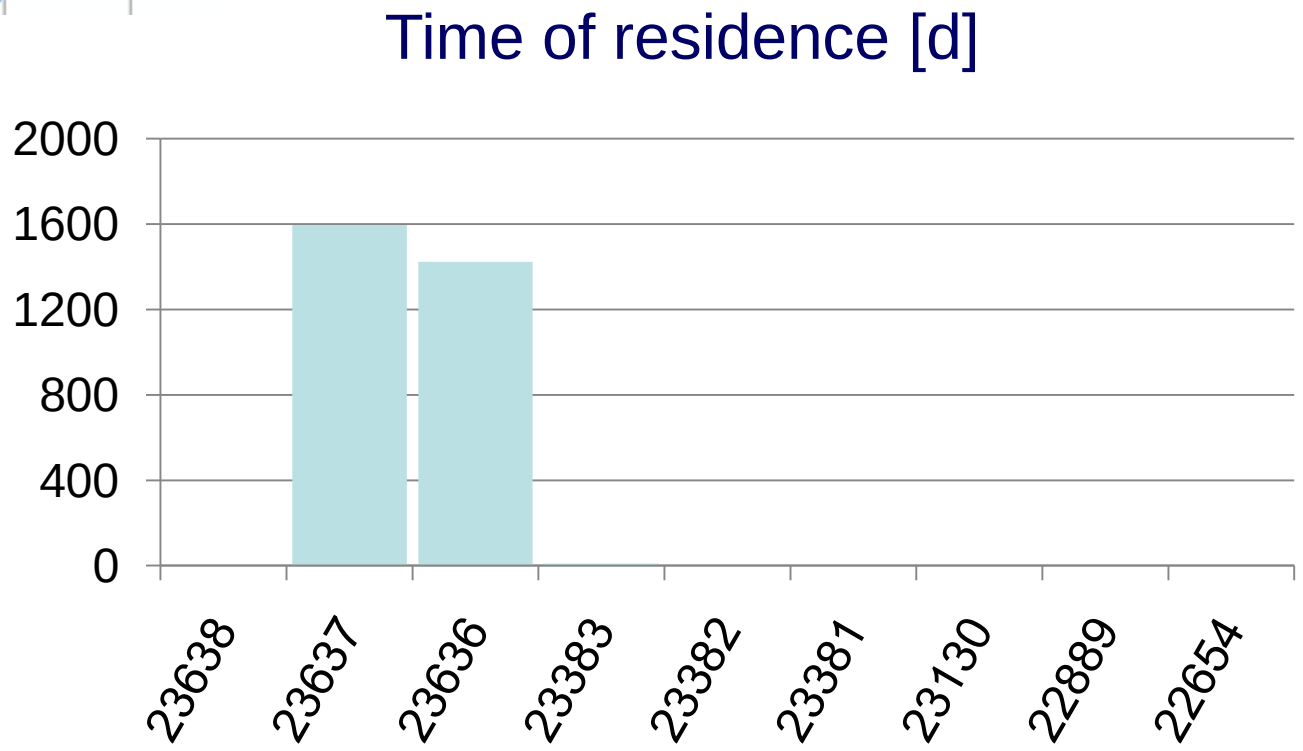


Rhône river, gridded at 0.5°x0.5°



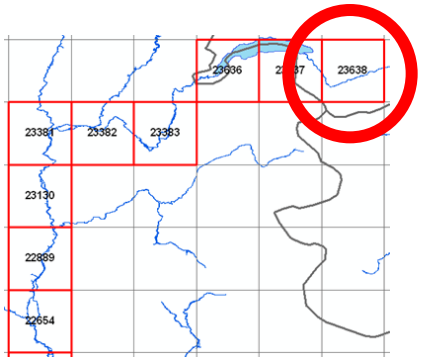
Residence time of water in the cells

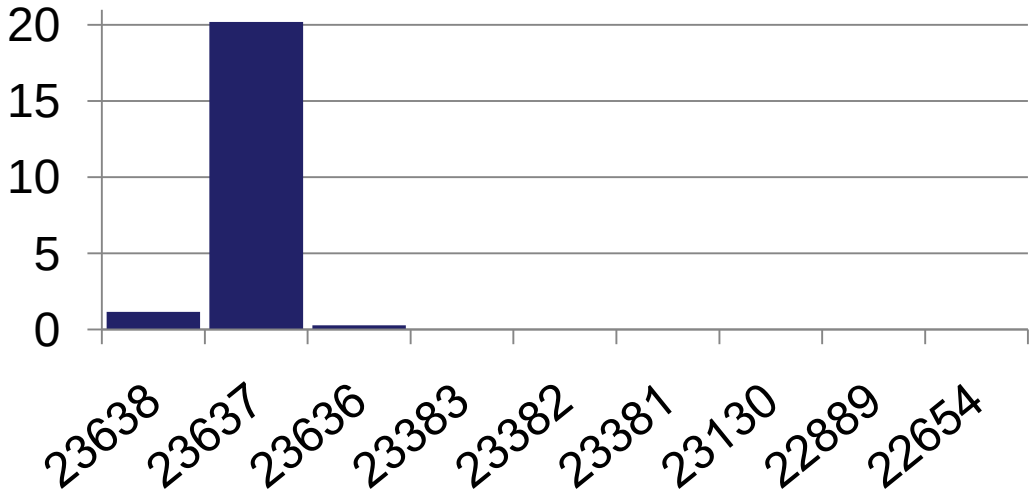




Mass [kg] Triethylene glycol at steady-state..

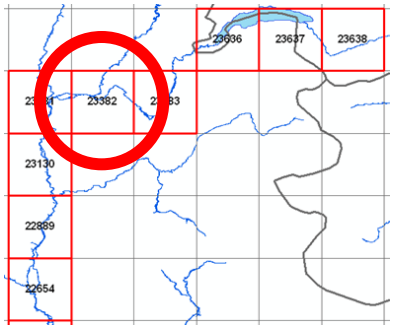
..for a 1kg/day direct emission into water, in cell 23638

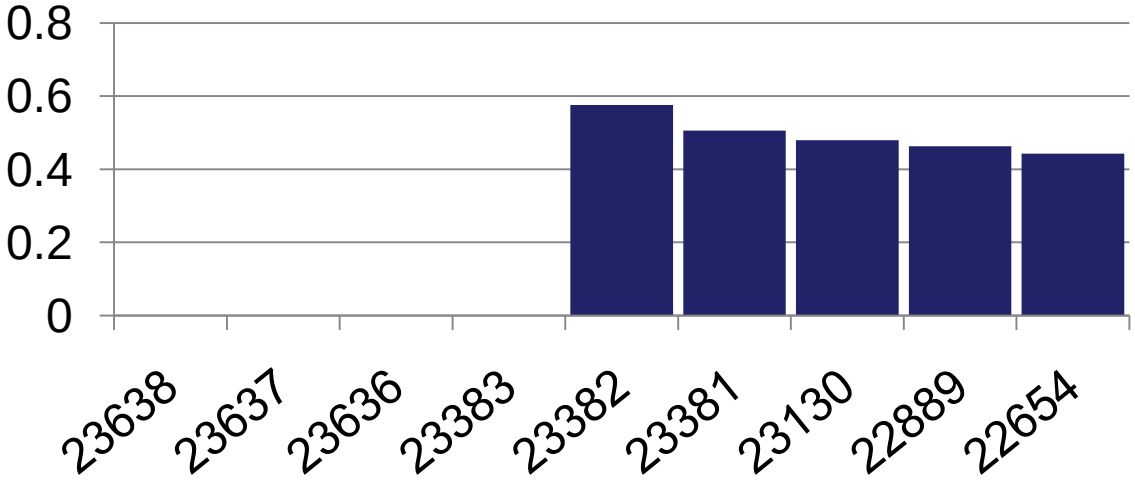




SUM
≈ 22kg

..for a 1kg/day direct emission into water, in cell 23382





SUM
≈ 2.5kg

Total mass [kg] at steady-state..

	Triethylene glycol	Acephate	Penta-chlorophenol	Toluene	2,3,7,8-TCDD
$T_{1/2}$ water	15	38	180	15	180

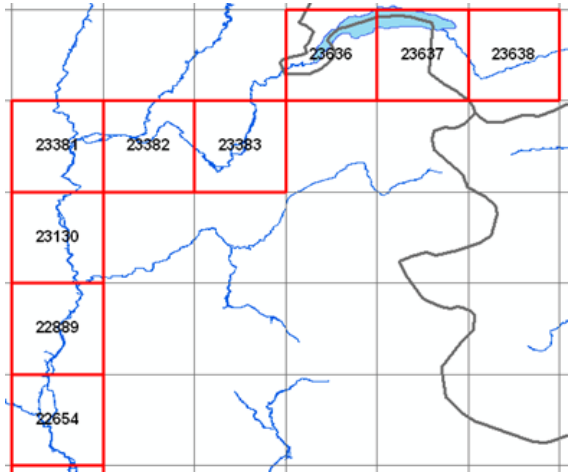
~ x10

	Triethylene glycol	Acephate	Penta-chlorophenol	Toluene	2,3,7,8-TCDD
Sum [kg] upstr.	22	55	254	22	254
Sum[kg] downstr.	2.5	3.2	3.8	2.5	3.8

~ x10

~ x1

x10 - x100



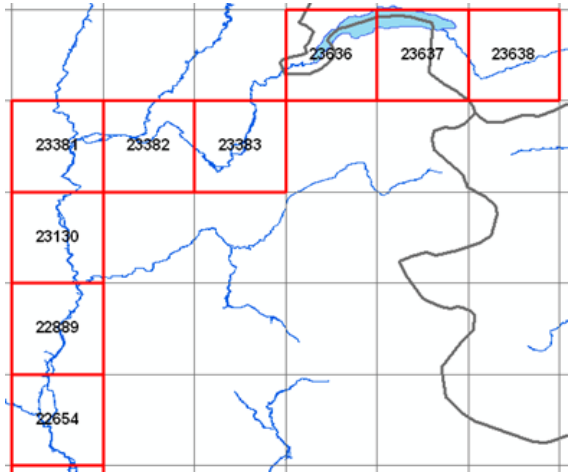
Total Characterization Factors (CF)

Total CF = total mass * EF / emission, with EF = 0.5/HC_{50}

	Triethylene glycol	Acephate	Penta-chlorophenol	Toluene	2,3,7,8-TCDD
Sum CF upstr.	4.5 E-1	8.8 E2	3.8 E5	3.0 E2	**1.4 E9**
Sum CF downstr.	5.2 E-2	5.2 E1	5.7 E3	3.5 E1	**2.1 E7**

≠ x10

x10 - x100



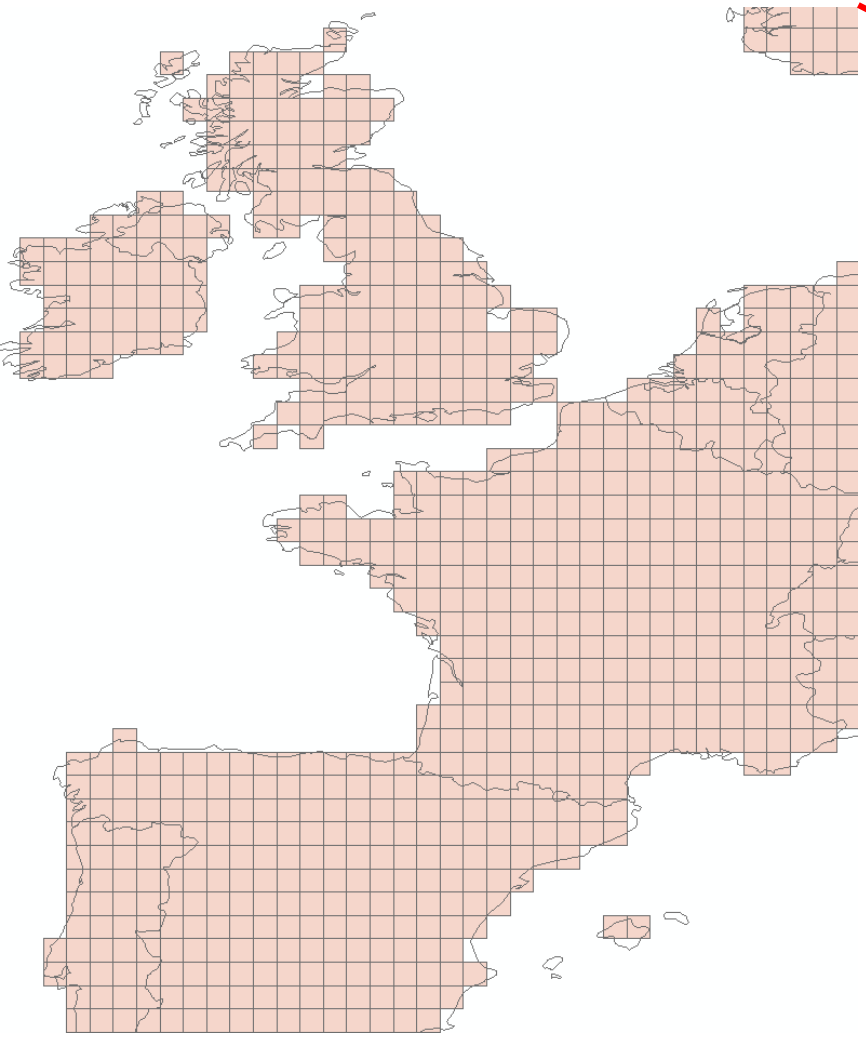
Were do we stand?

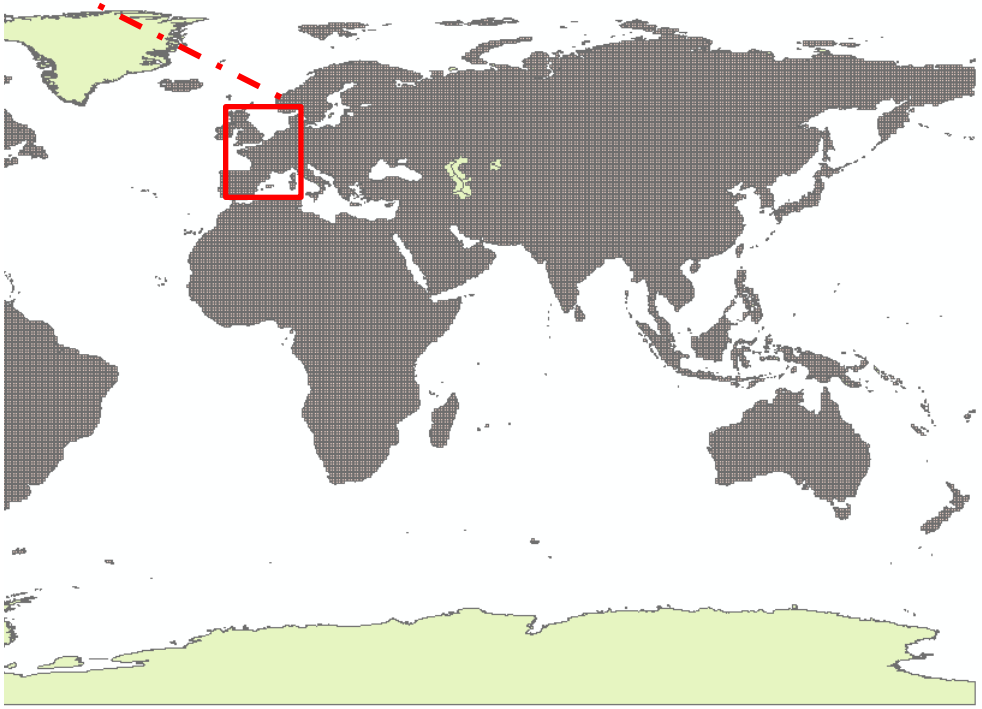
- We have seen an **artifact due to lack of spatial resolution**.
- Several authors already demonstrated the importance of an accurate characterization of pollutants **entry points** into the environmental media.
- Jolliet et al., 2011: when estimating the **impact on aquatic biodiversity of pollutants emitted in the air**, their physical-chemical properties **related to media other than water lead to more variability** in the results **than parameters related to the water itself**.

Conclusion: for estimating the impact on biodiversity related to pollutants that have **a multimedia fate**, we have to be able to **spatialize all the media that are involved**.

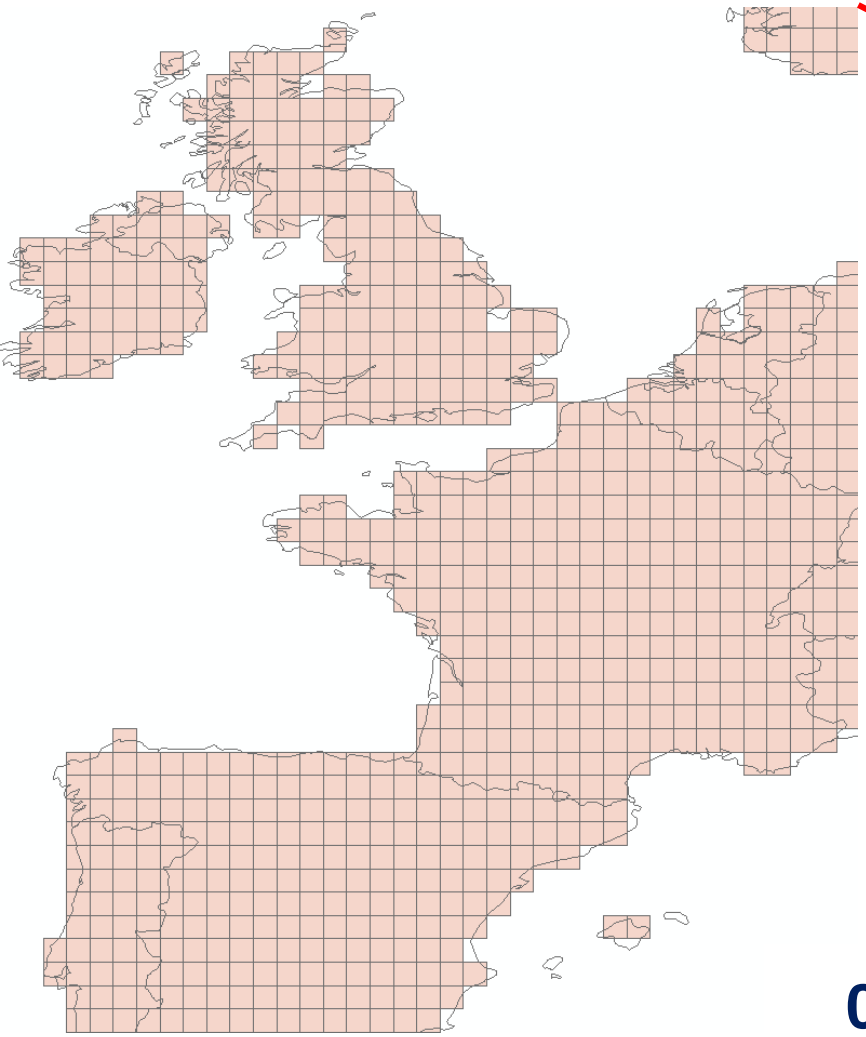
⇒ **Create grids covering these media, that attenuate artifacts, adapt to data availability, and lead to a computationally affordable problem.**

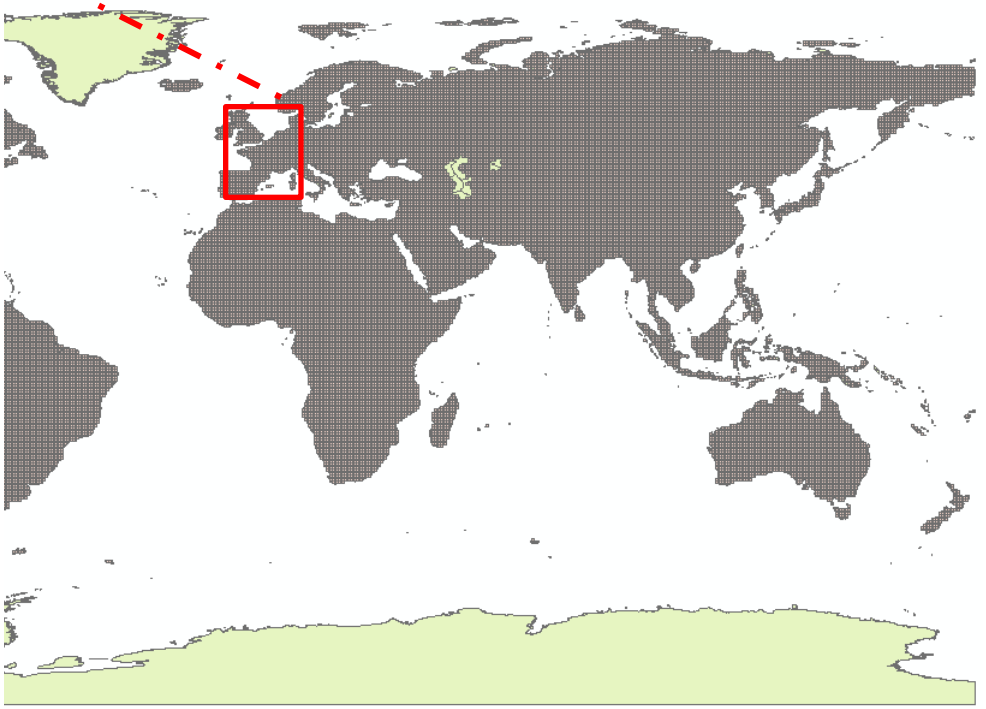
How to spatialize?





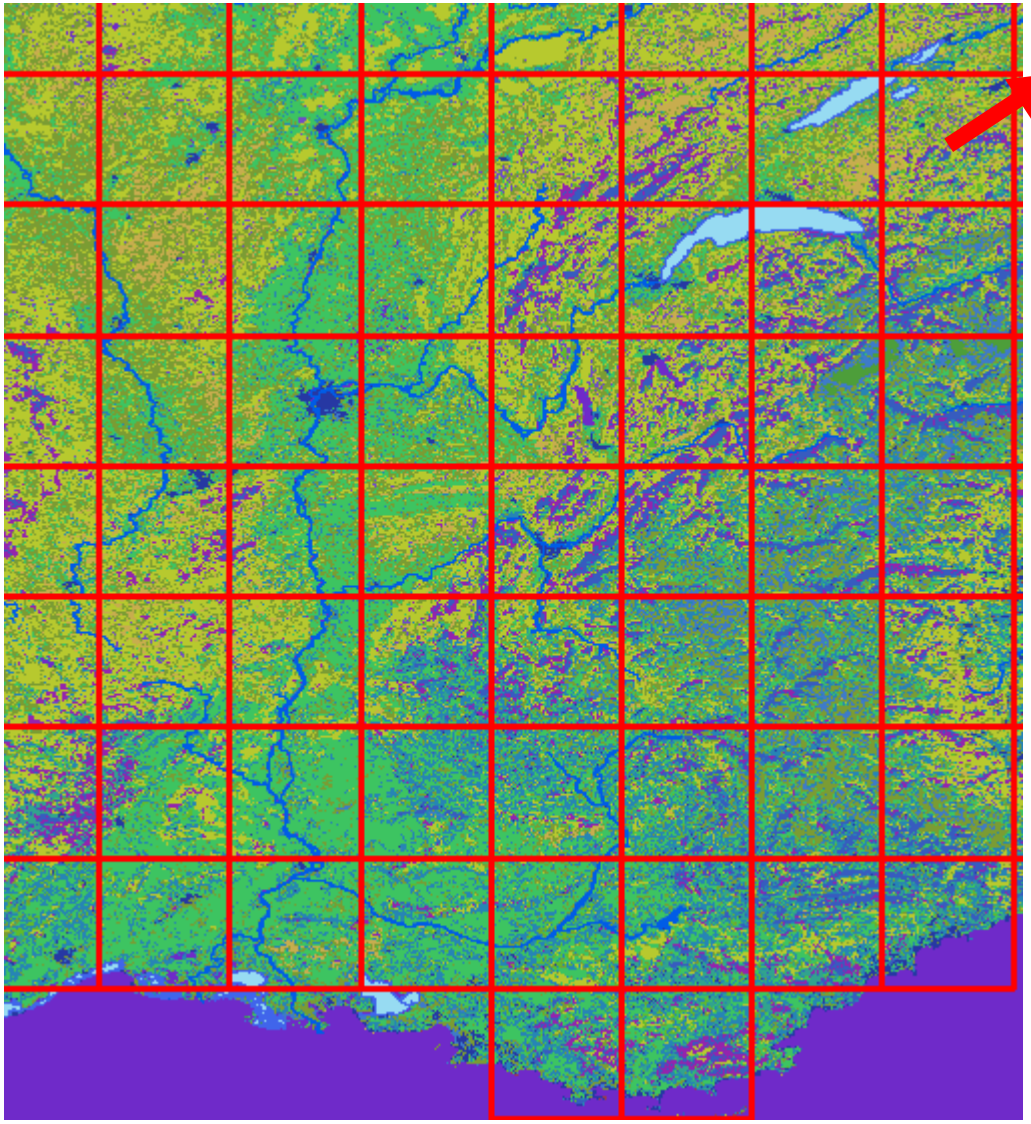
How to spatialize?





0.5°x0.5° => 60’000 cells global

Terrestrial cells composition



1 terrestrial cell =>
22 internal compartments
based on Globcover cat.

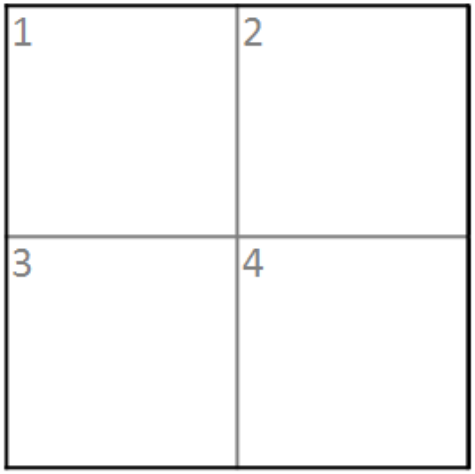
60’000 cells => **more than 1 million compartments**

.. **without** even including **atmospheric** and **ocean grids.**

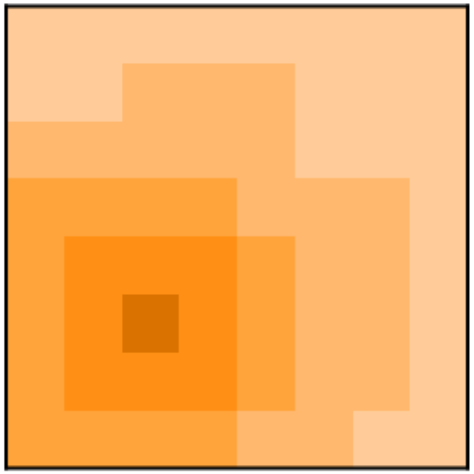
Multi-scale grids are mandatory!

The Potential for Refinement

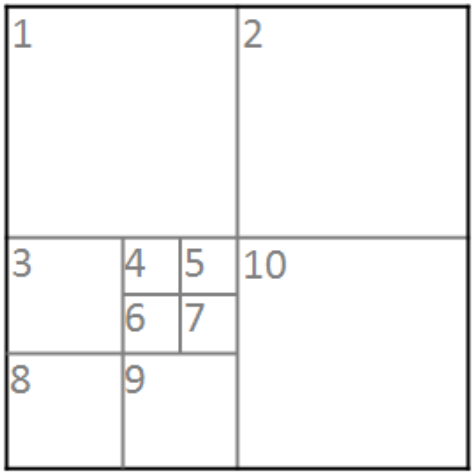
Background grid
(static)



Potential for refinement



Multiscale grid
(iterative refinement)

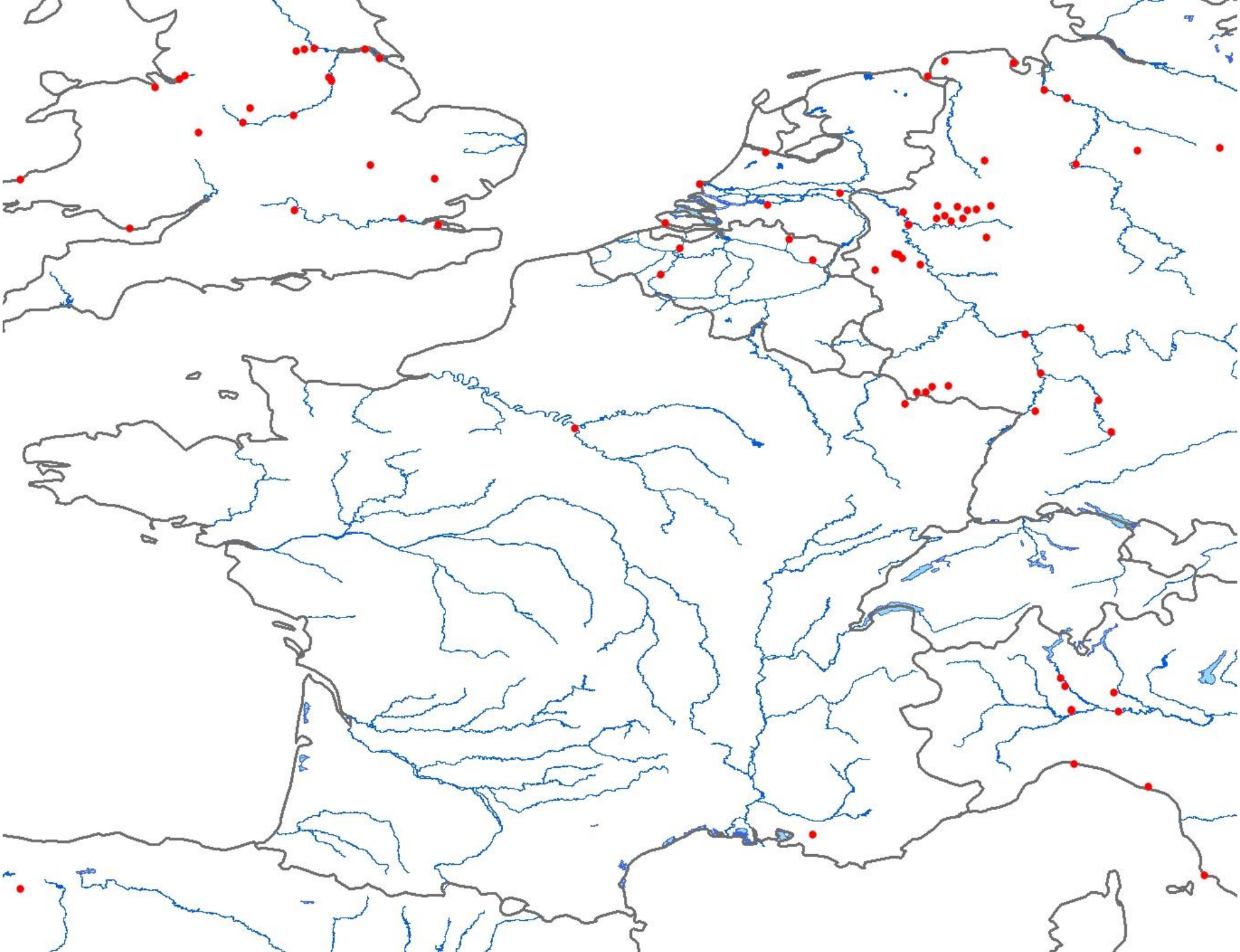


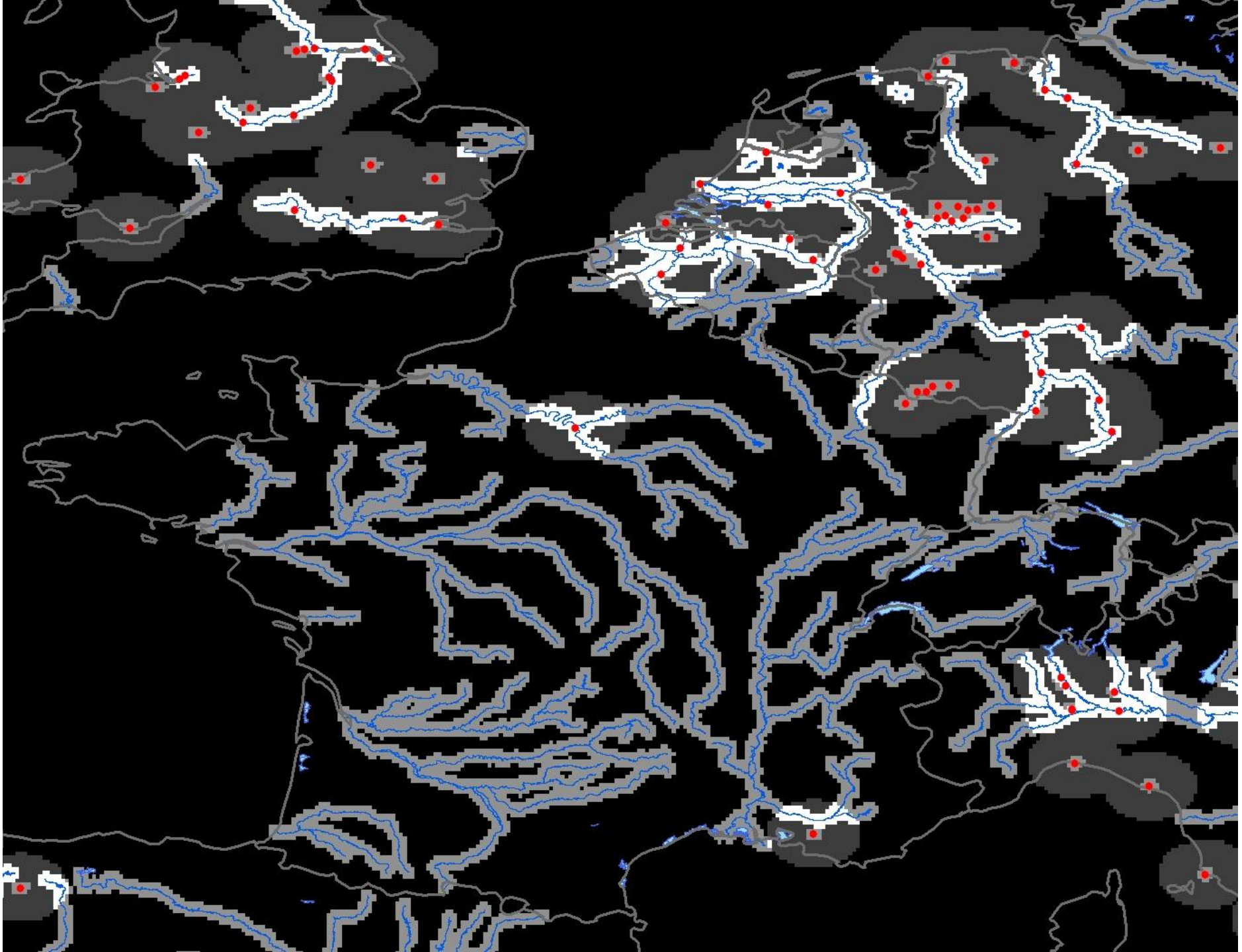
$$f = \prod_{D_i \in \Delta} D_i^{\text{normalized}} \;;\; \text{or} \quad f = c + \prod_{i=1}^{n} (a_i + b_i \cdot D_i^{\text{normalized}}) \;;\; \text{or any} \quad f(\{D_i\})$$

$D_i^{\text{normalized}}$: spatial dataset (raster) #i. Each raster pixel indicates a local weight for refinement (0=no to 1=max)

a_i, b_i : scalars associated with D_i, that allow offset + rescale

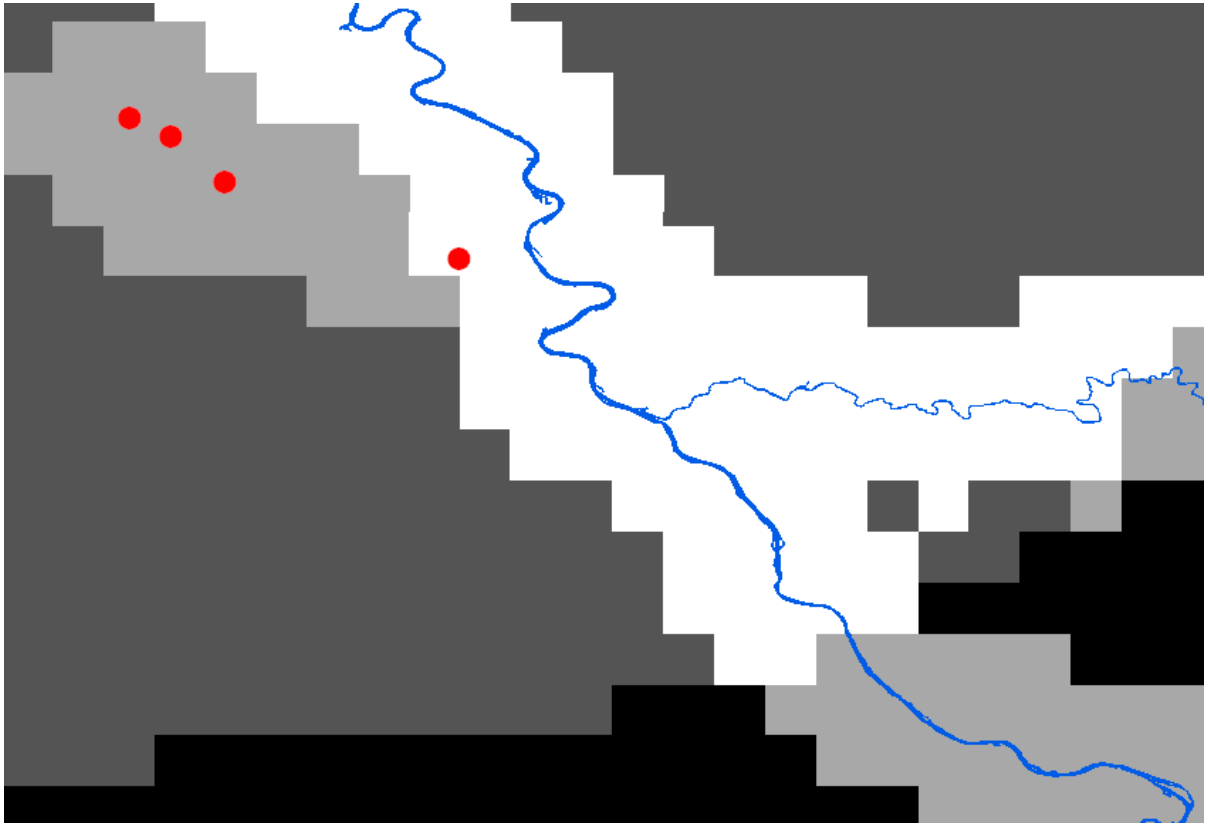
c : scalar, offset

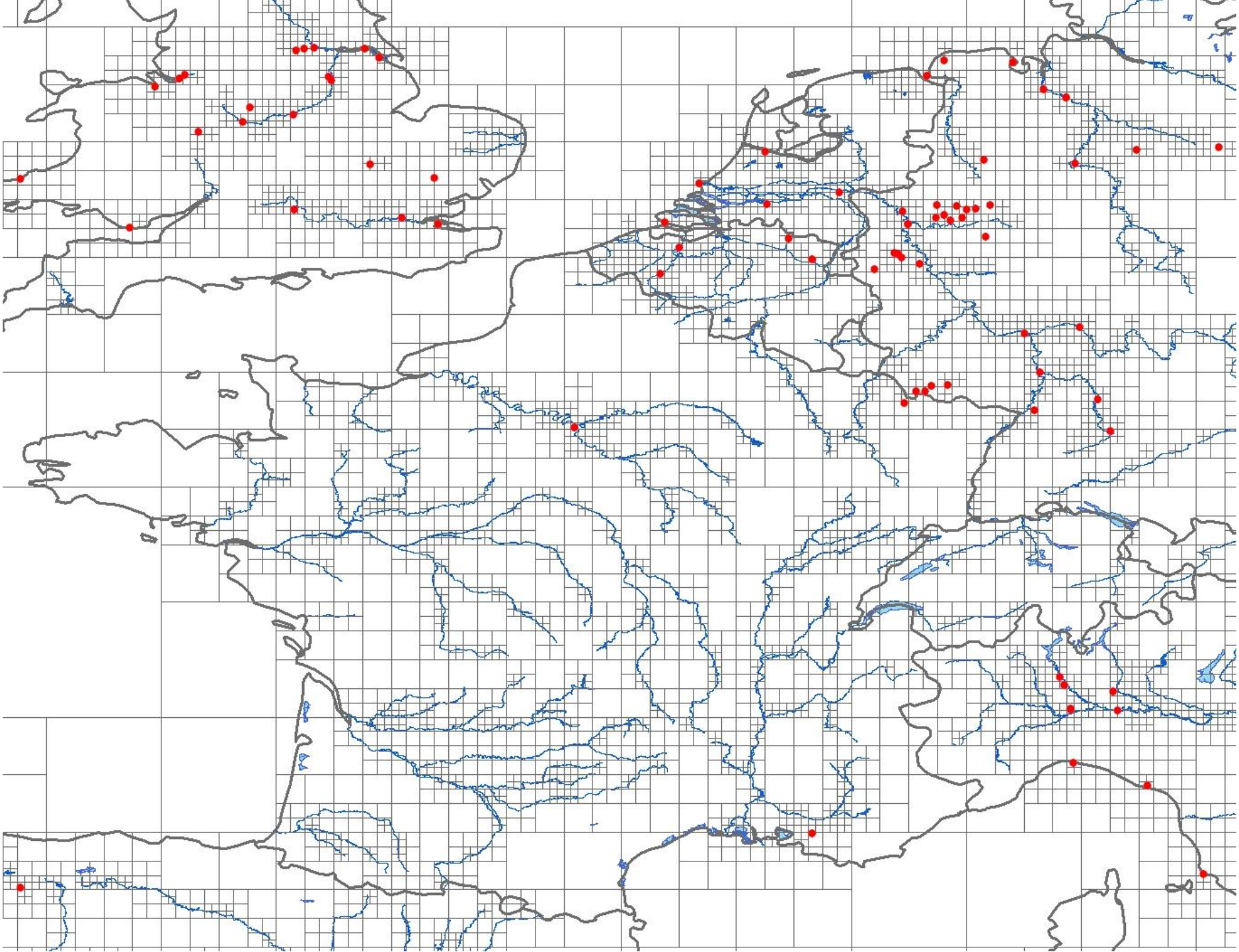




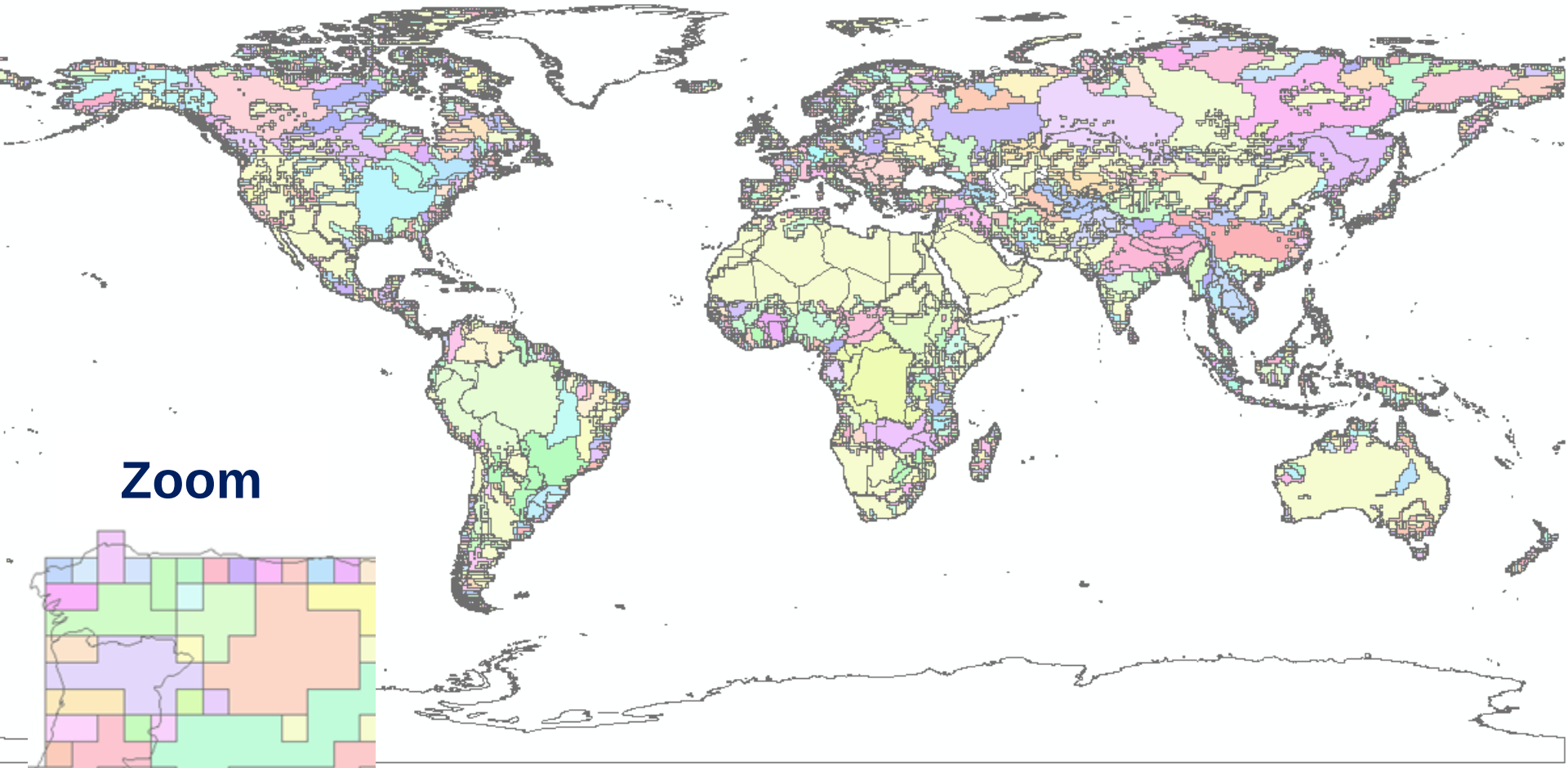
White=1: most influencial

Black=0 no influence





Clustering of the terrestrial grid



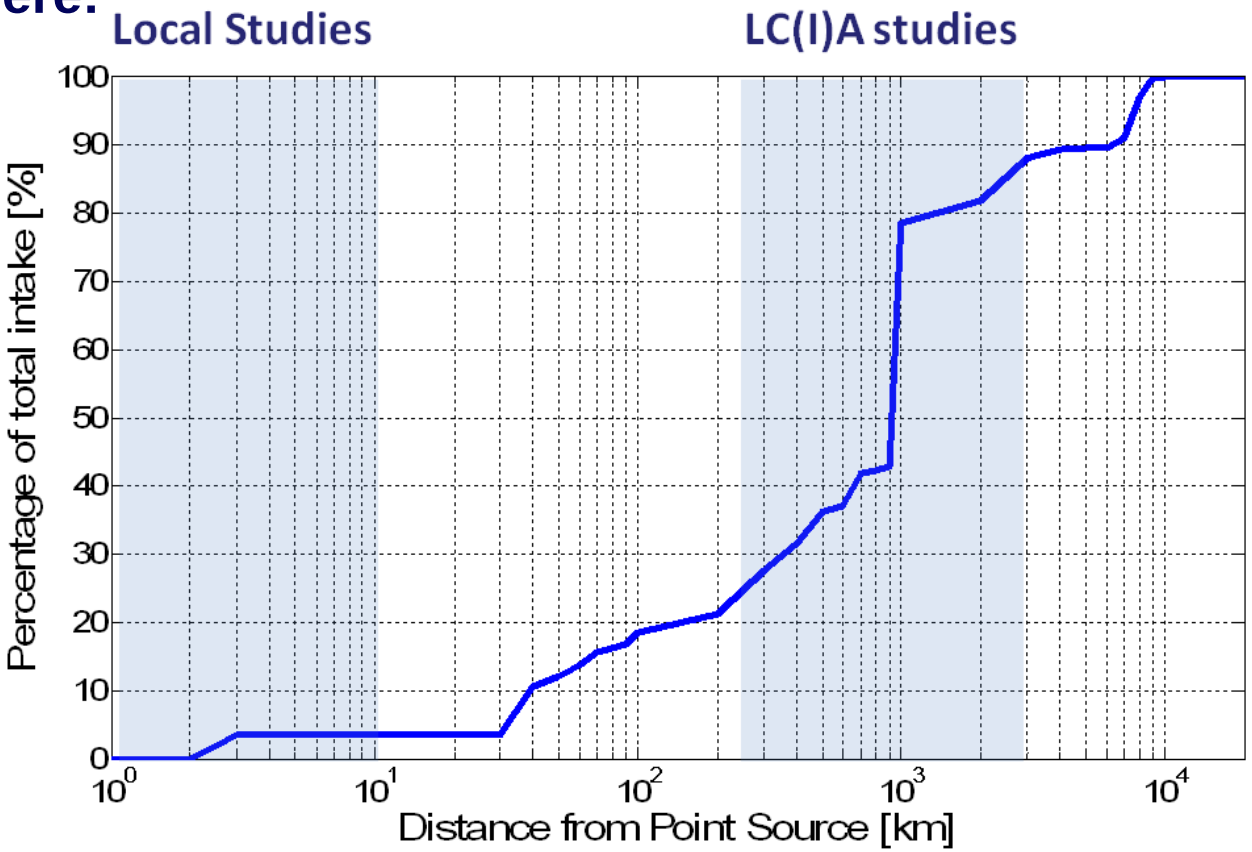
Zoom

Conclusion

- Need to **attenuate artifacts** due to large cells grids **in all the media**.
- Fine spatialization is **needed at relevant places**, but **not possible everywhere** (at global scale).
- Multi-scale approach **solves the technical aspect**.
- Rescaling can be **adpated to data availability**.
- Multi-scale engine able to **project datasets** into relevant grids, **build a K matrix** and **solve the system**.
- Can be **quickly adapted** to specific studies AND allows to perform **sensitivity studies** towards grid variations!

Next step(s)

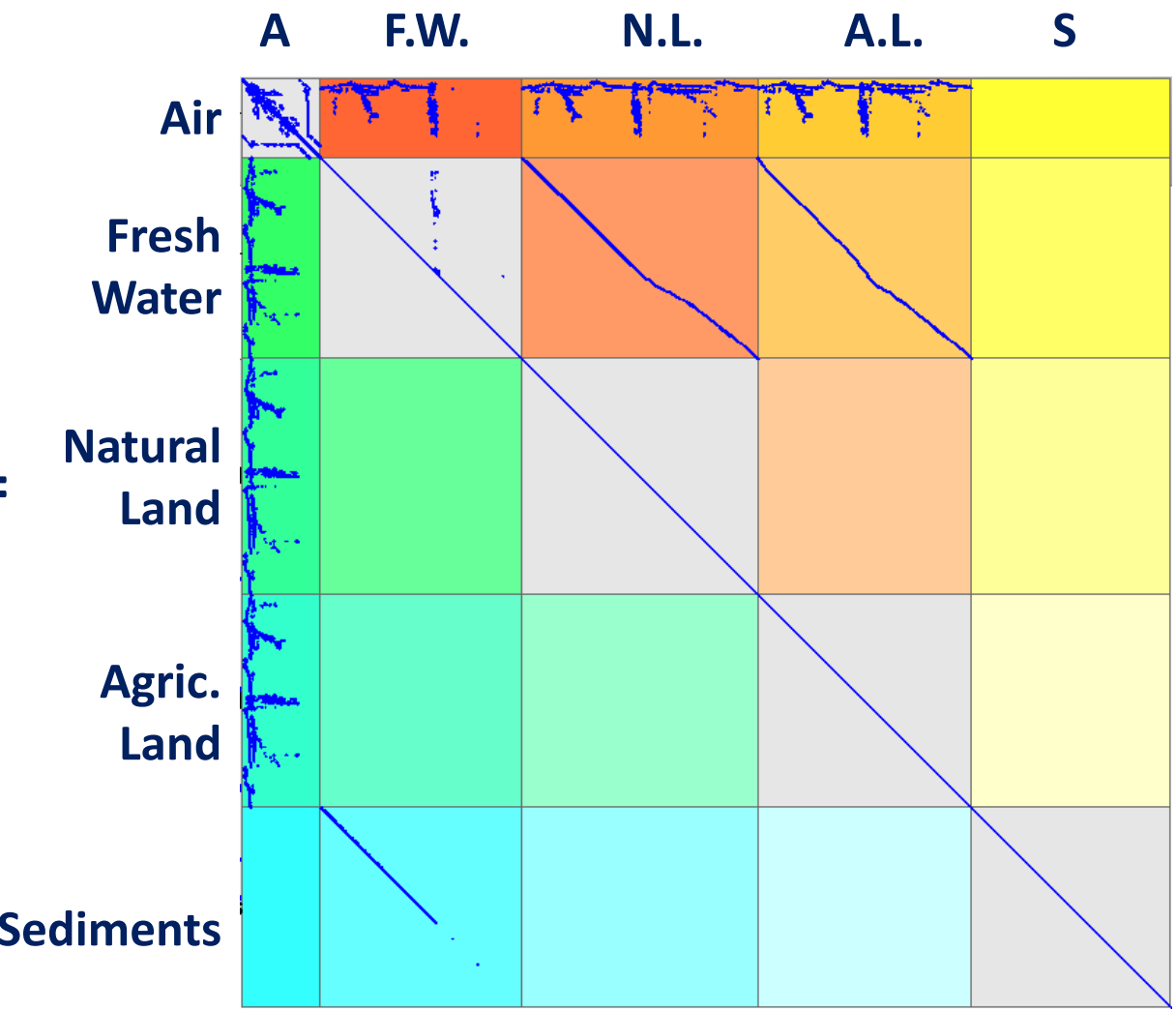
For the impact on human health of an emission into the atmosphere:



What happens with impact on aquatic biodiversity?

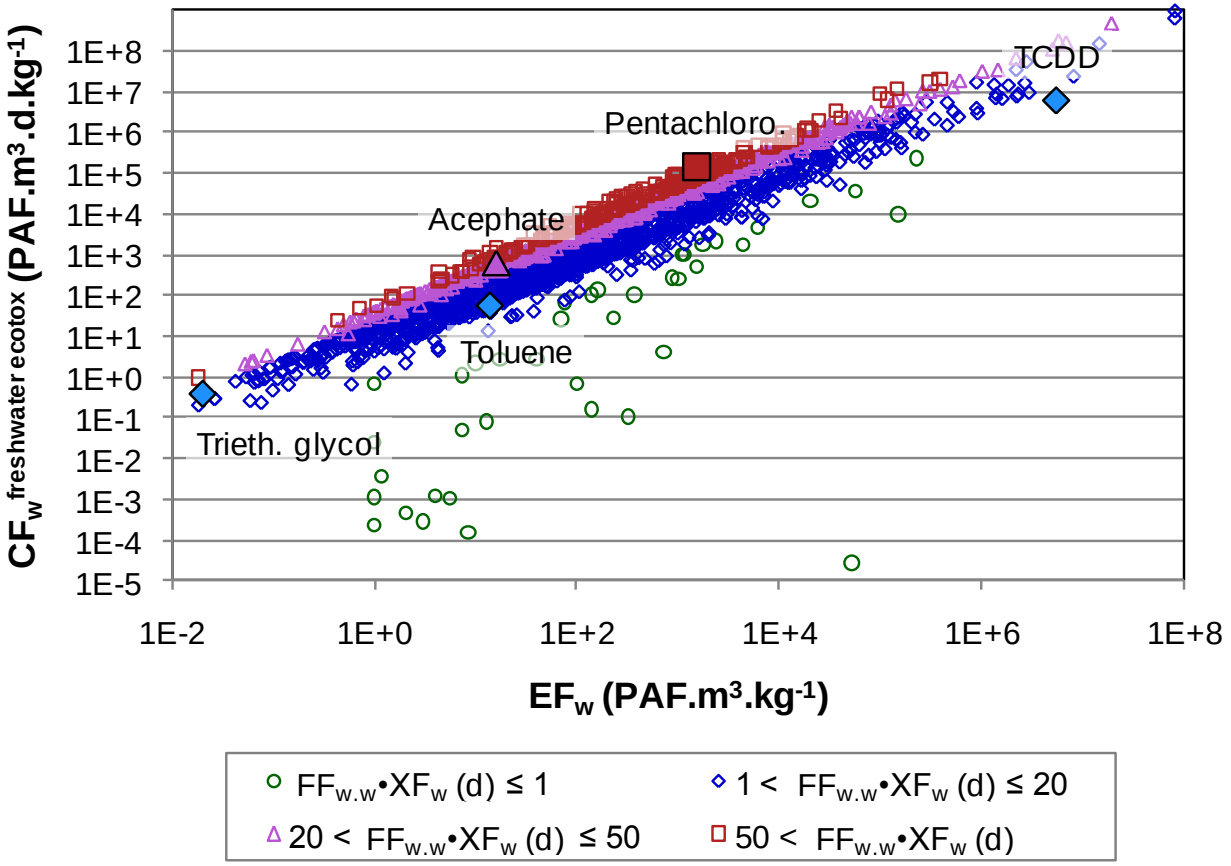
Thank you!

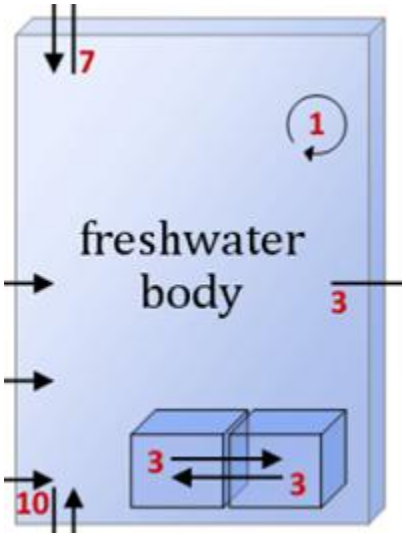
$K_{multi\text{-}scale}$ structure =



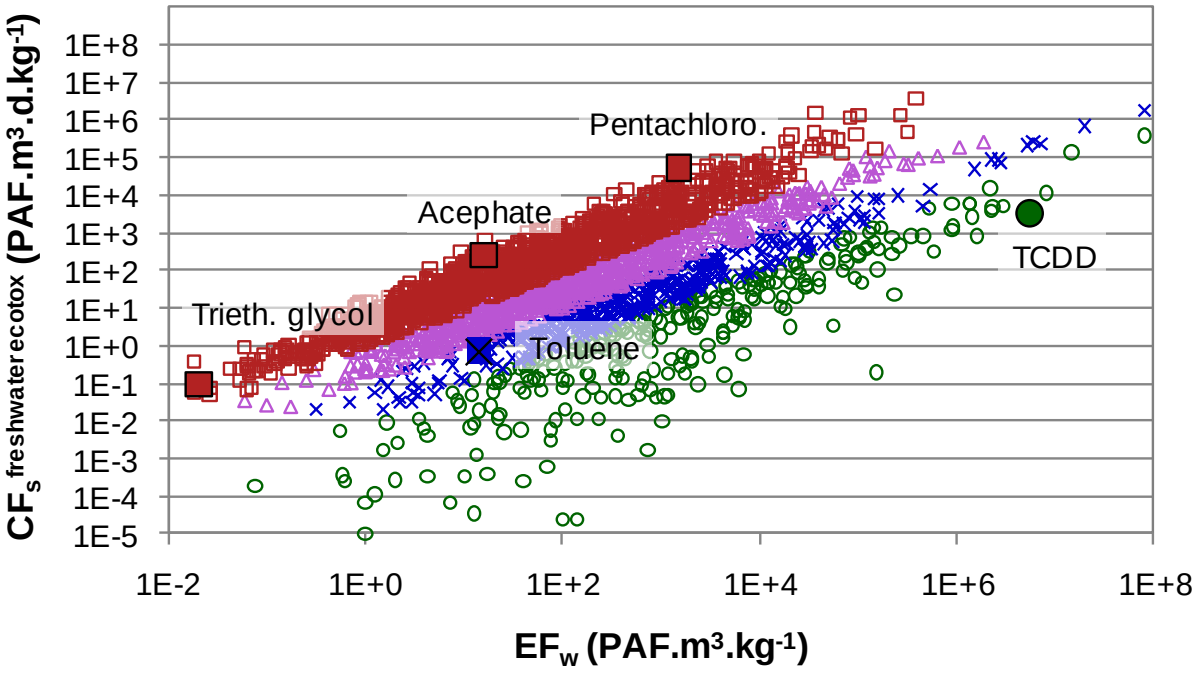
38521x38521, nnz = 137981

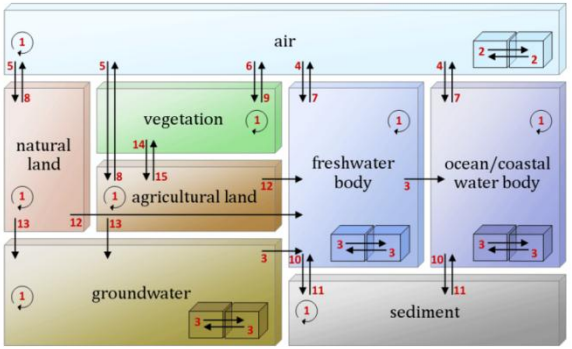
CF_{water} variability for direct em. to water





CF_{water} variability for em. to air





Artificial Dilution

Example:

over-estimation of impacts