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CEA, CNRS, UVSQ

## RadioClimFire

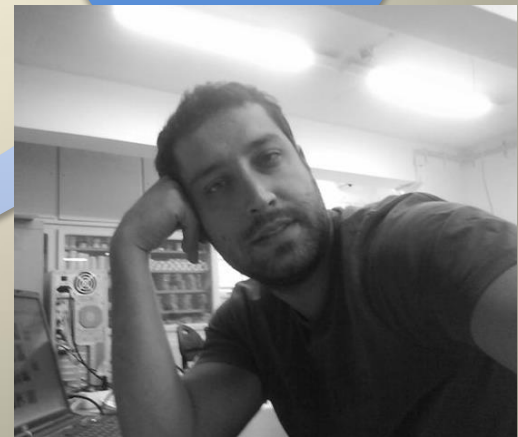
Radioactivity, climate,  
fire and human  
health:

A second Chernobyl  
catastrophe about to  
happen?

Anders  
Pape  
Møller



Nikolaos  
Evangelou



CLIMAT  
ENVIRONNEMENT  
SOCIÉTÉ

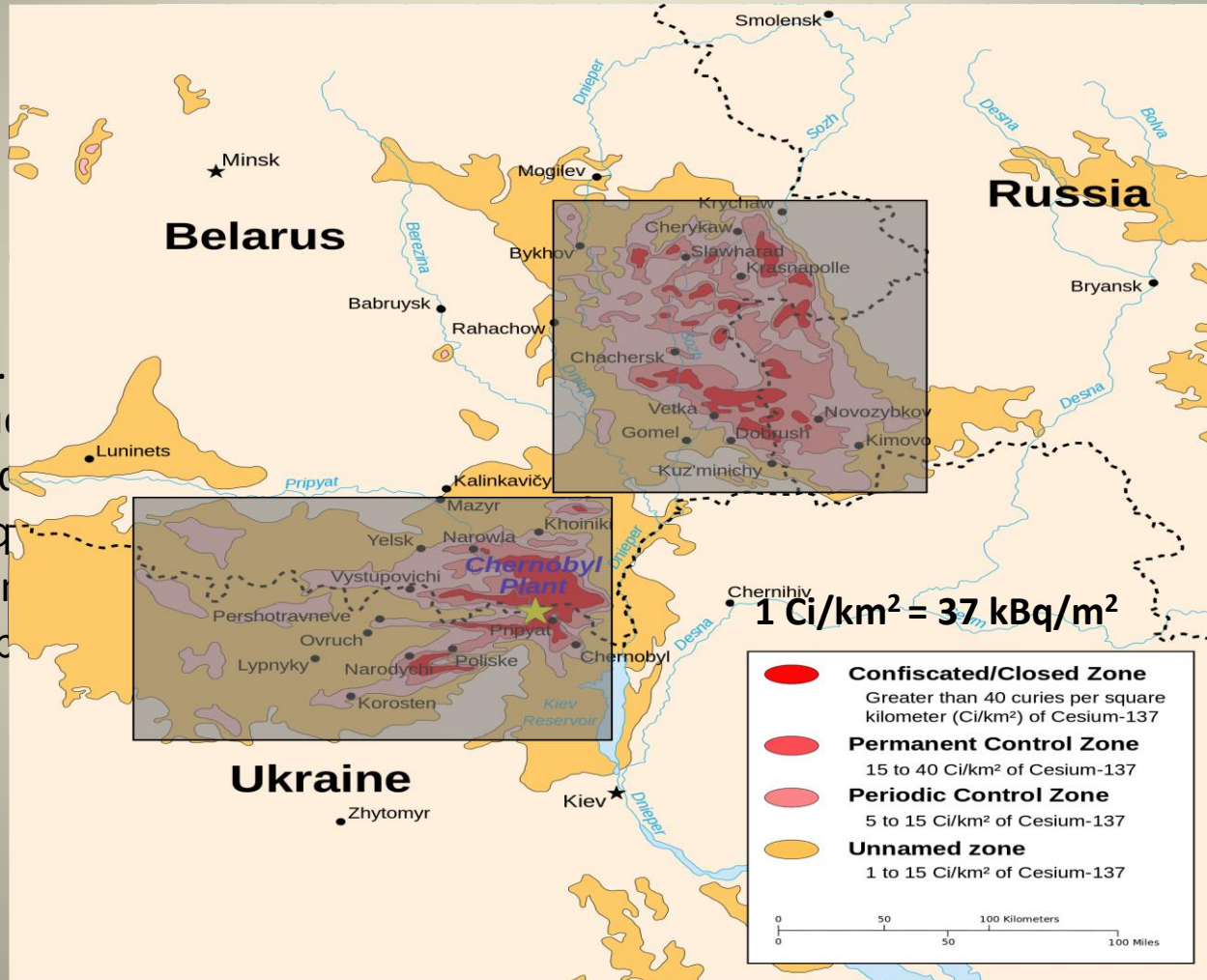


Groupement d'Intérêt Scientifique

Ecologie Systématique  
et Evolution  
CNRS, P11, ENGREF

# Chernobyl accident – Impact in Europe

- $\approx 85 \text{ PBq}$  ( $10^{15}$ ) released among fission products.
- Total radionuclide release:  $\approx 10 \text{ EBq}$
- 80 % ( $\approx 8 \text{ EBq}$ ) of volatile compounds (e.g.  $^{131}\text{I}$  and noble gases)



# Land cover change in Chernobyl



CEZ: 2600 km<sup>2</sup>

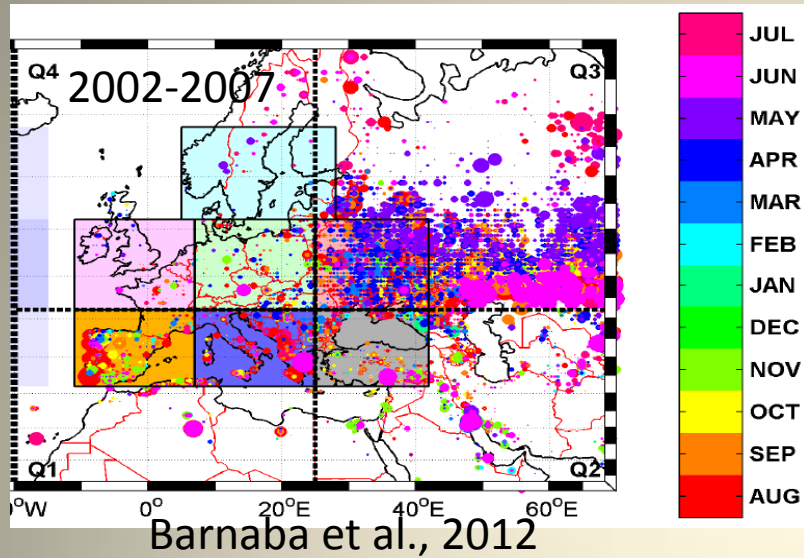
75% boreal forest (pine trees)

25% agricultural land & shrubs

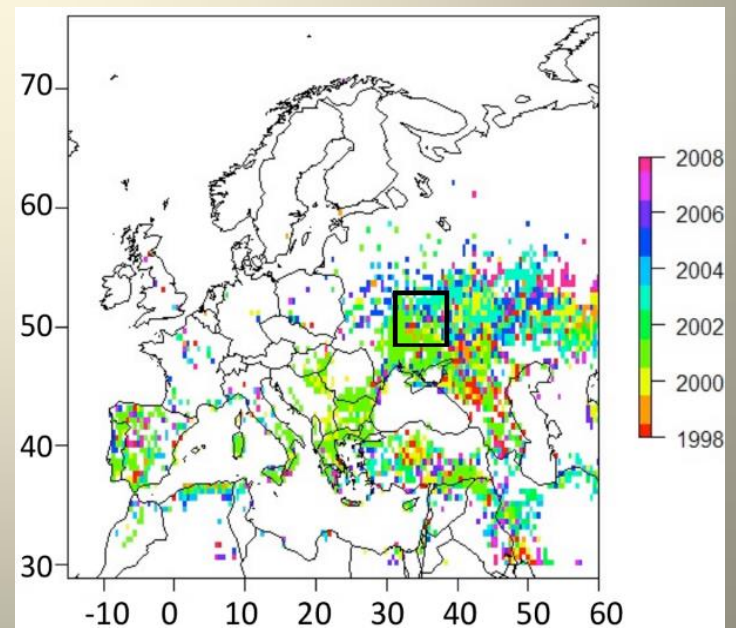
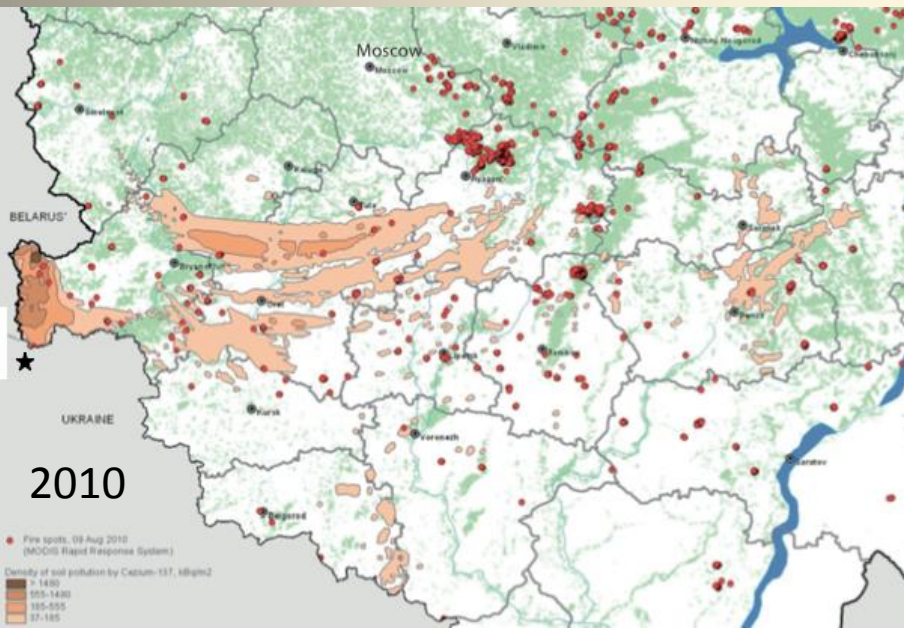
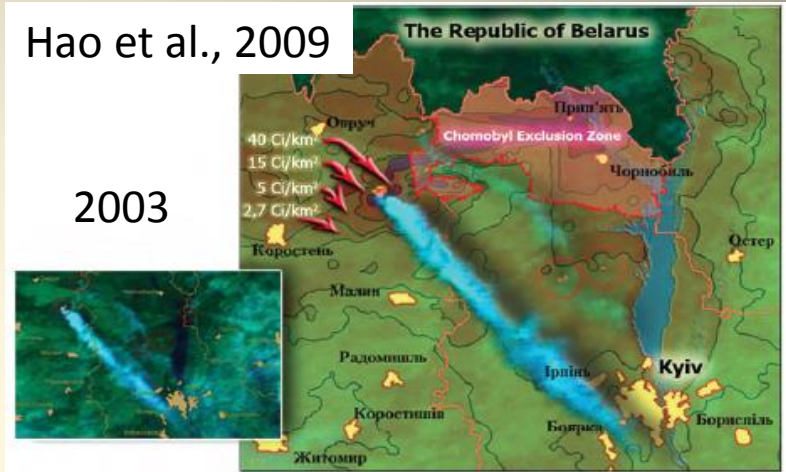
Lack of any forest management



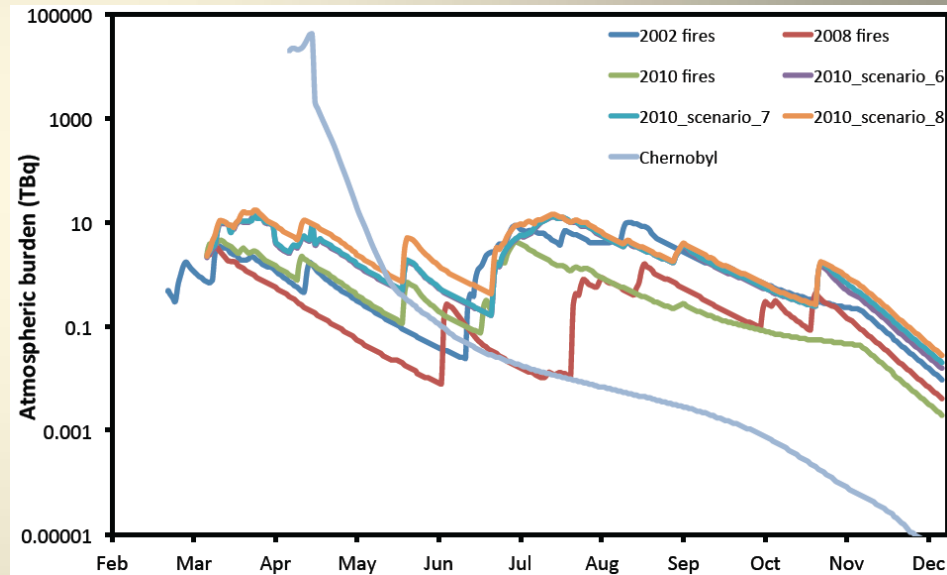
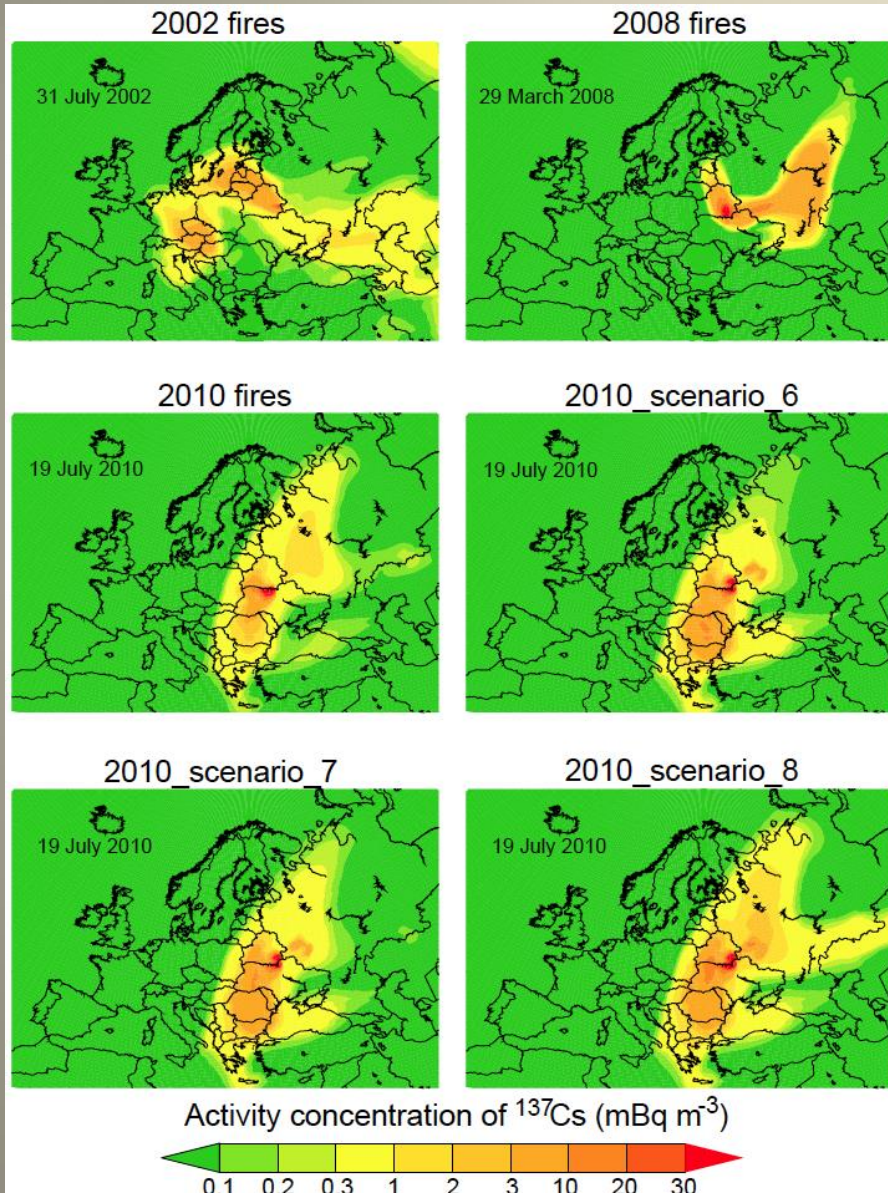
# Fire history by satellites



Hao et al., 2009



# Real fire events (2002, 2008, 2010)



Scenarios

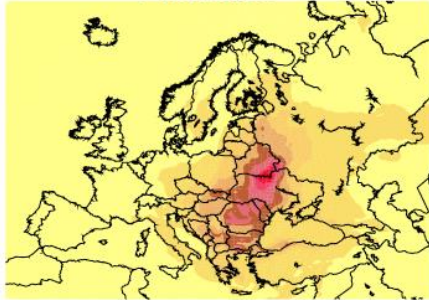
lev6: 2.9 km

lev7: 4.3 km

lev8: 6.0 km

# “New” deposition

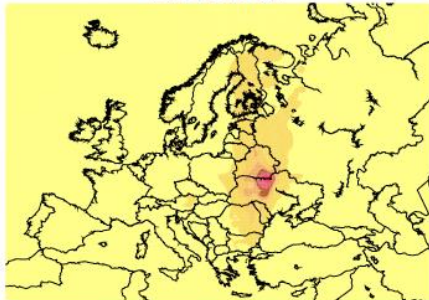
2002 fires



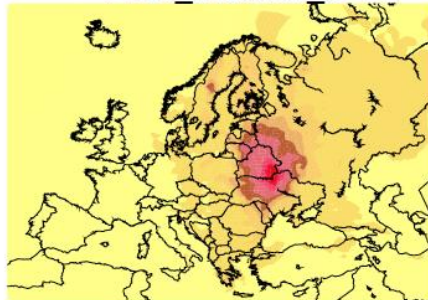
2008 fires



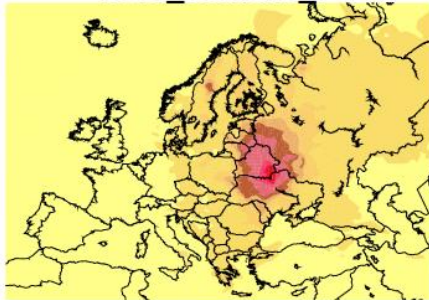
2010 fires



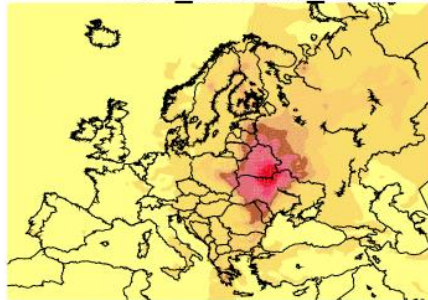
2010\_scenario 6



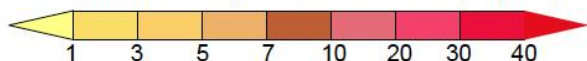
2010\_scenario 7



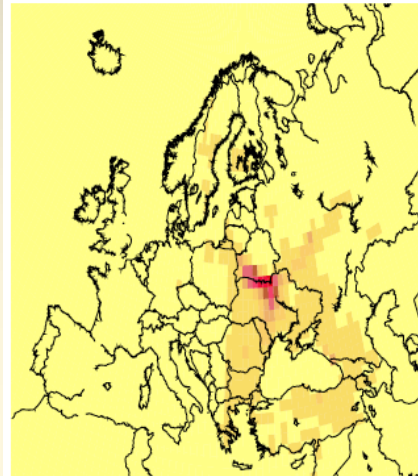
2010\_scenario 8



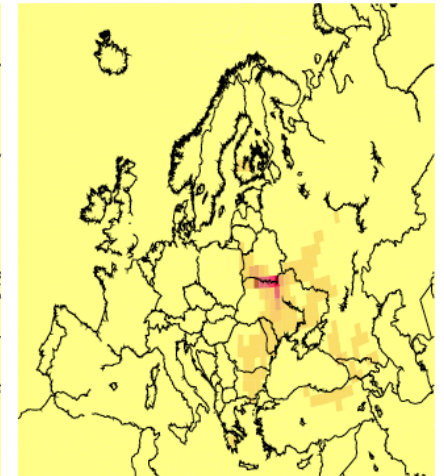
Cumulative deposition of  $^{137}\text{Cs}$  ( $\text{Bq m}^{-2}$ )



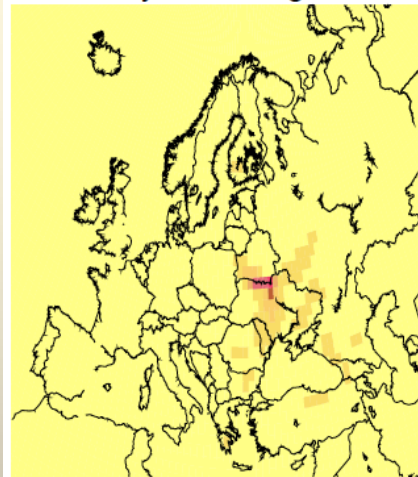
Chernobyl-remaining in 2002



Chernobyl-remaining in 2008

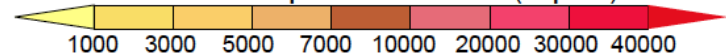


Chernobyl-remaining in 2010



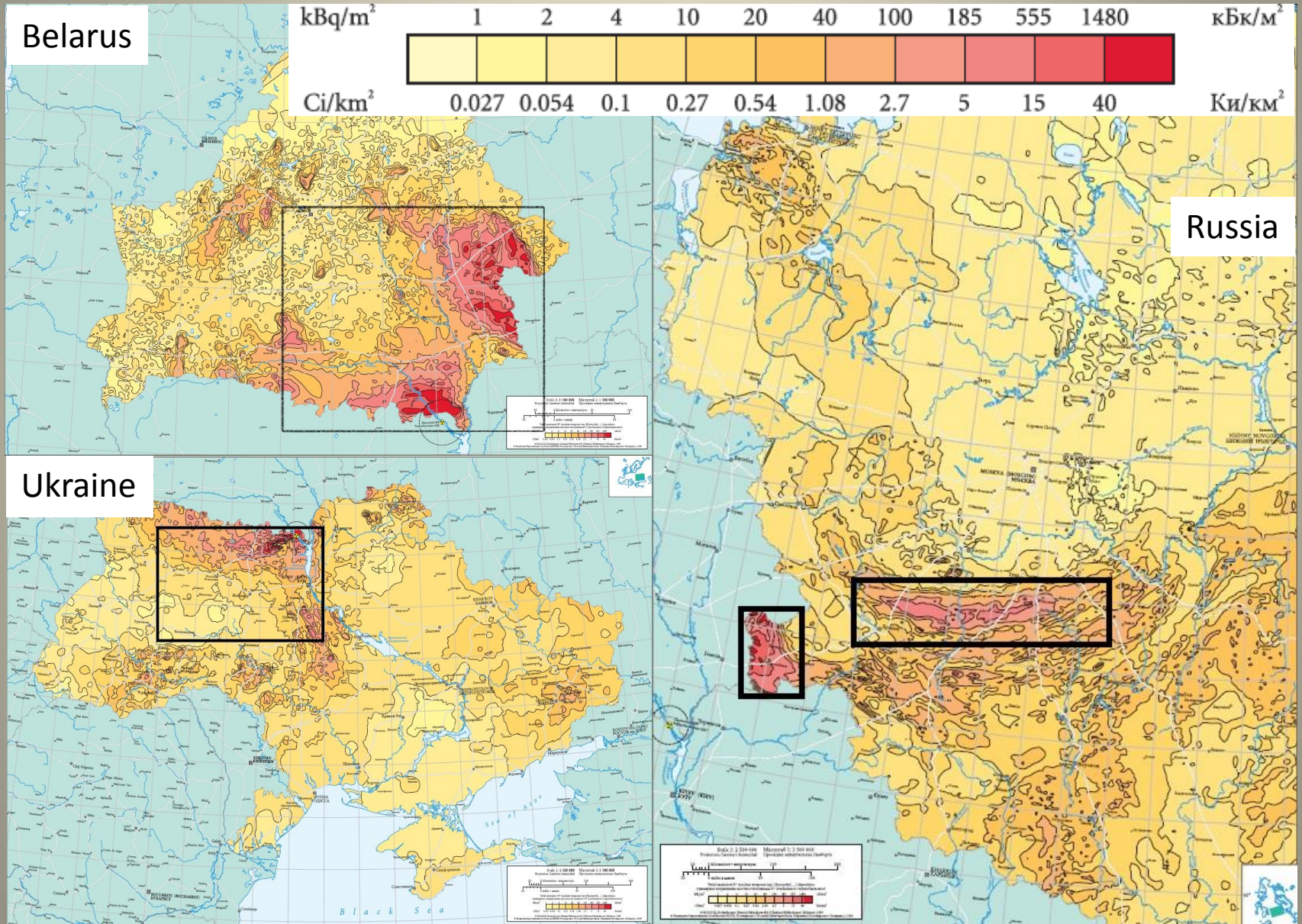
Corrected with an effective half-life of 10 years for the soil.

Cumulative deposition of  $^{137}\text{Cs}$  ( $\text{Bq m}^{-2}$ )



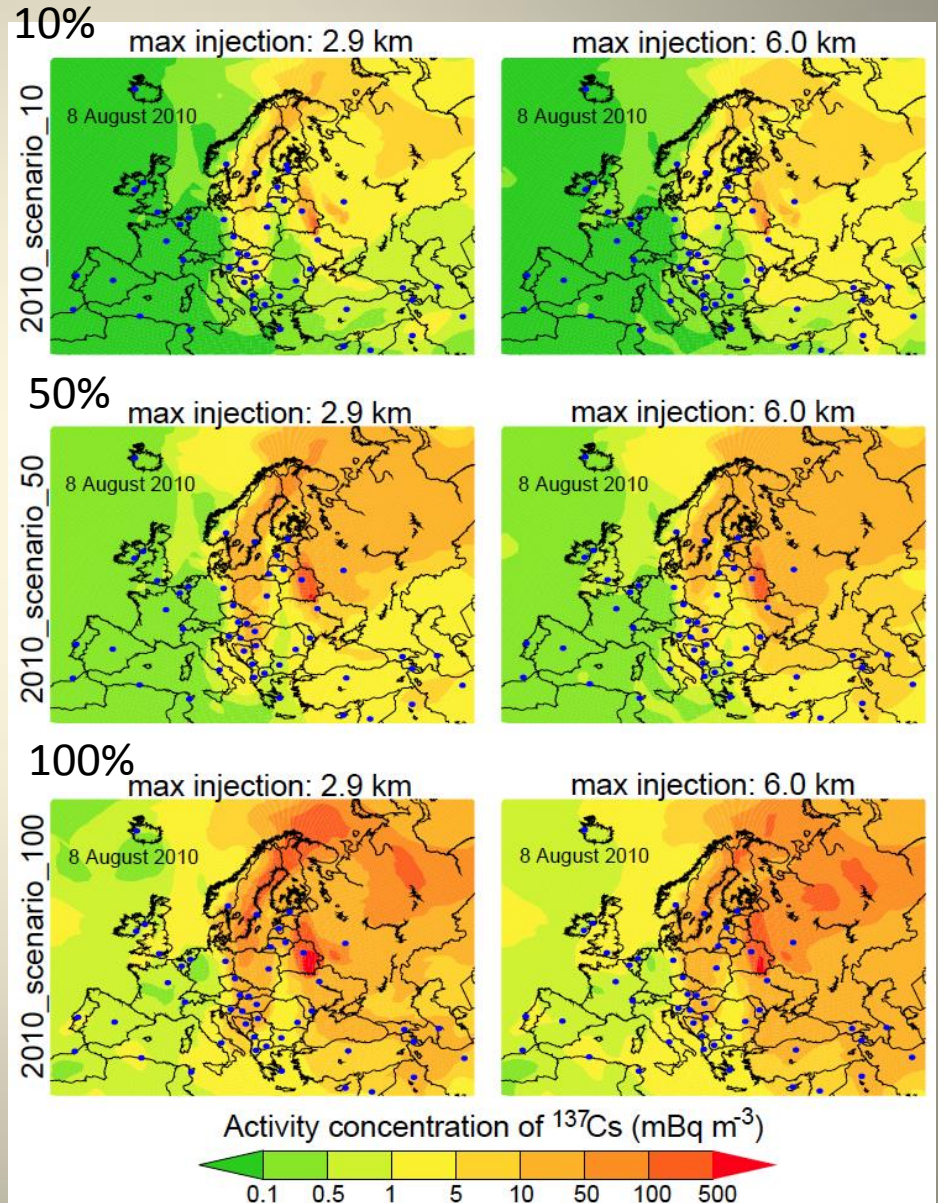
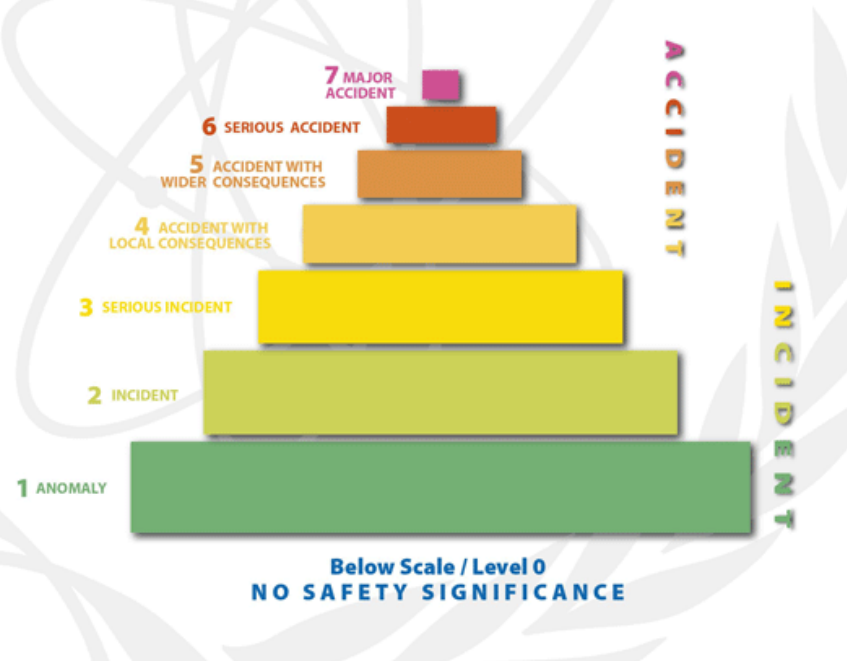
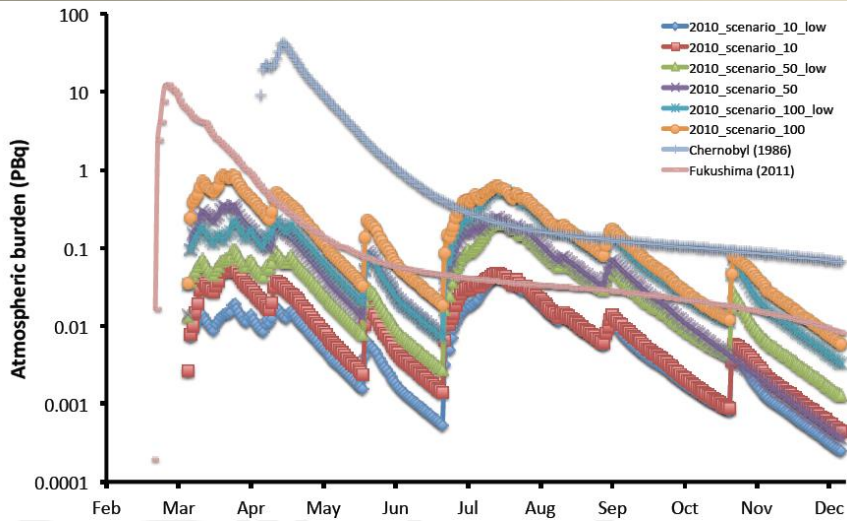
**Wildfire scenarios in the area!!!!**

# Ukraine, Belarus PLUS Russia

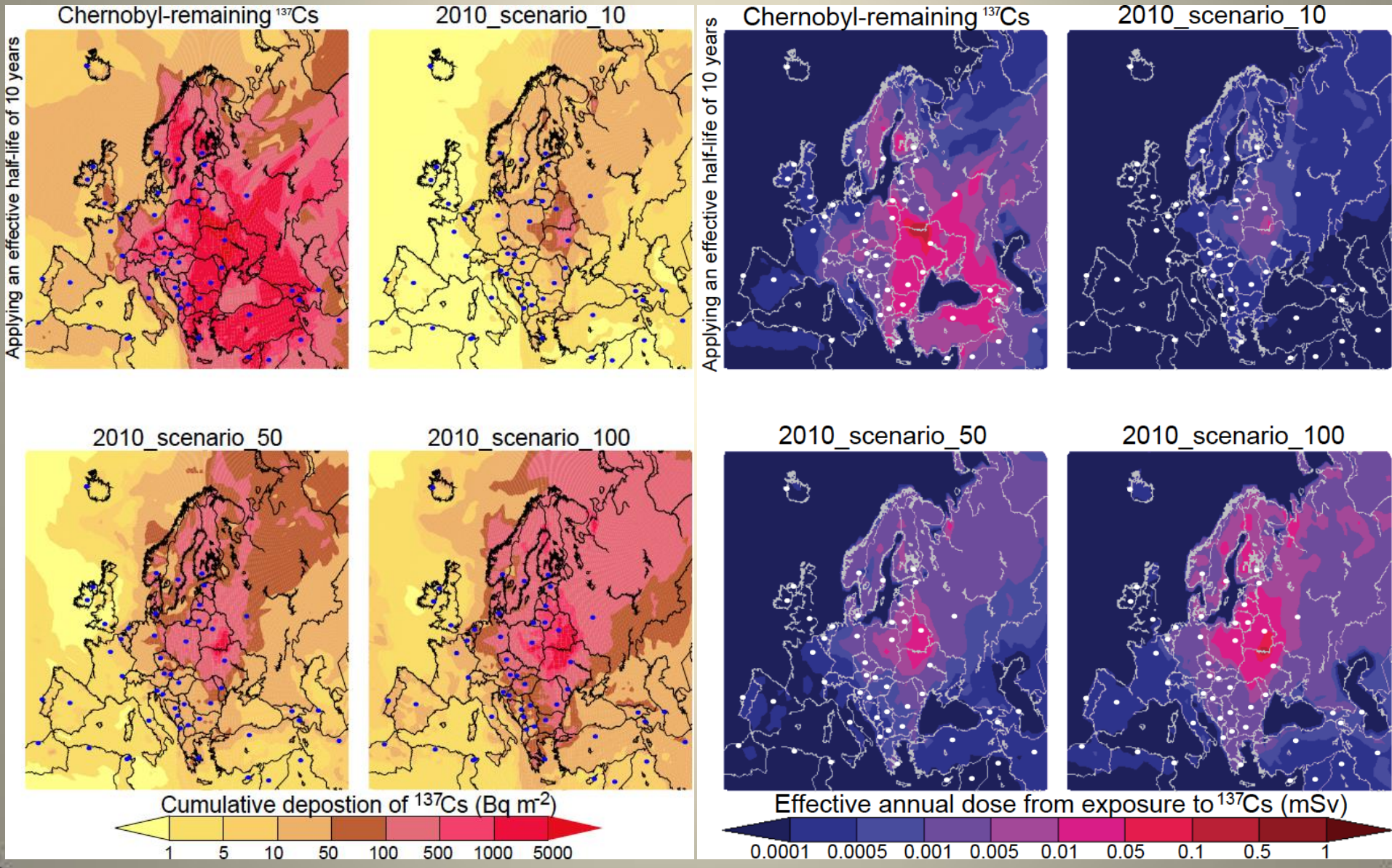




# New Chernobyl????

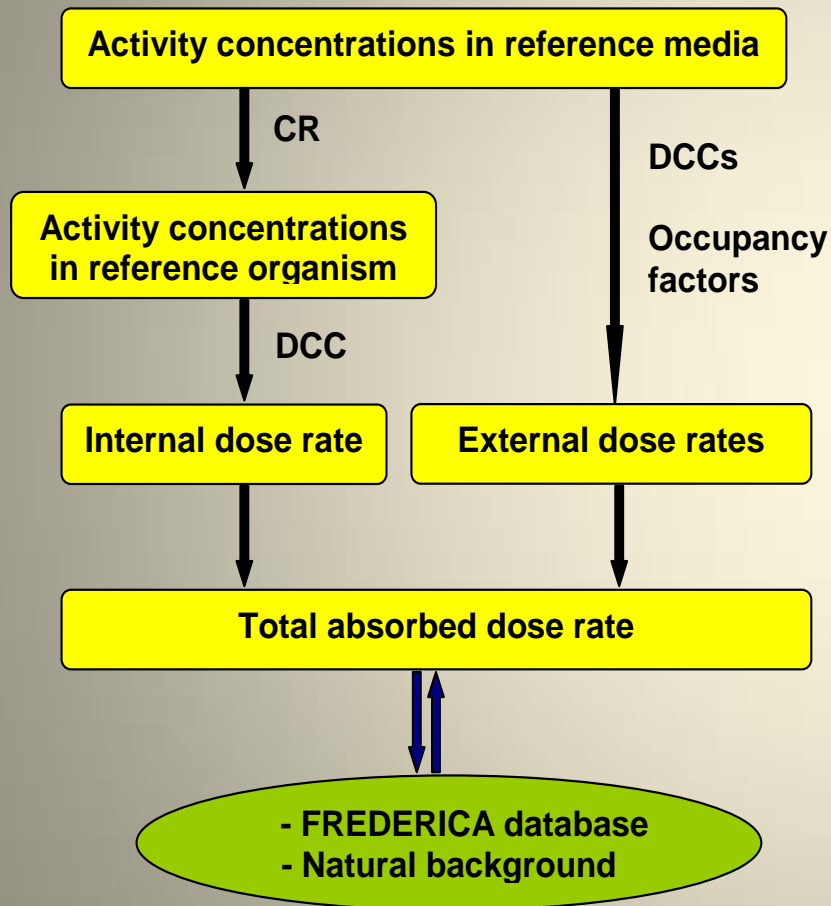


# “New” deposition and “new” dosimetry



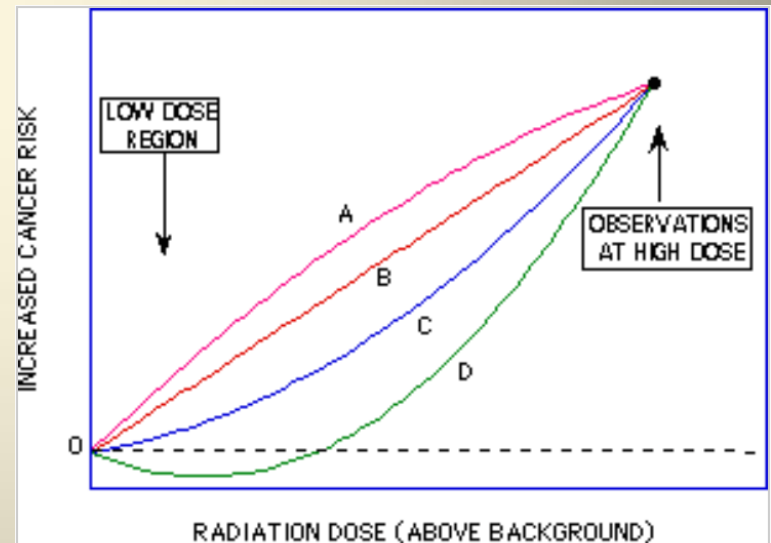
# Health assessment (animals-humans)

## ERICA Tool



## LNT-hypothesis

- Damage is directly proportional (“linear”) to the dose of radiation
- Radiation is harmful without threshold
- The sum of several small exposures has the same effect as one larger exposure
- Even small doses of radiations can be dangerous, and they add up linearly
- There is no lower bound, no tiny amount of radiation that is considered harmless



Alternative assumptions for the extrapolation of the cancer risk vs. radiation dose to low-dose levels, given a known risk at a high dose:  
**(A)** supra-linearity, **(B)** linear  
**(C)** linear-quadratic, **(D)** hormesis

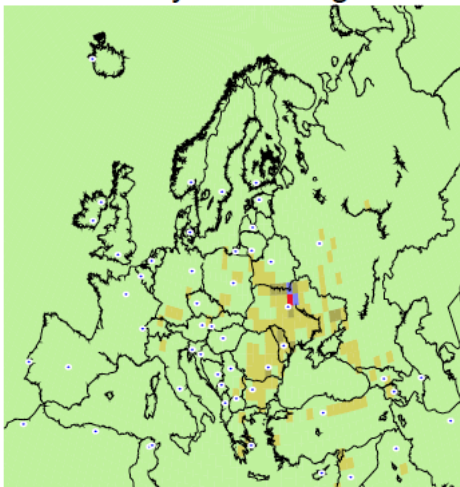
Info: [www.ERICA-project.org](http://www.ERICA-project.org)

Other models: RESRAD Biota

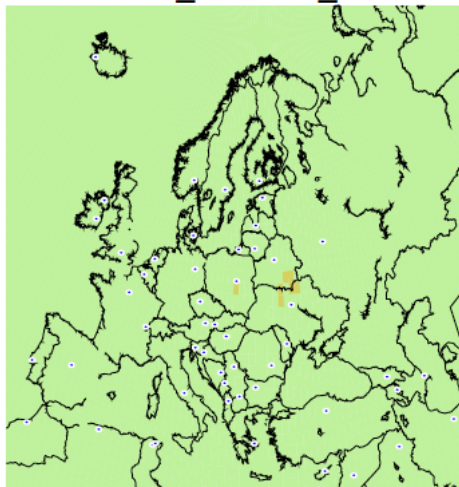
# Impact on animals and population

Applying an effective half-life of 10 years

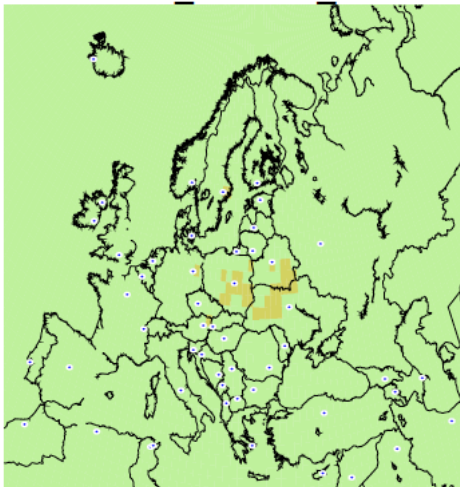
Chernobyl-remaining  $^{137}\text{Cs}$



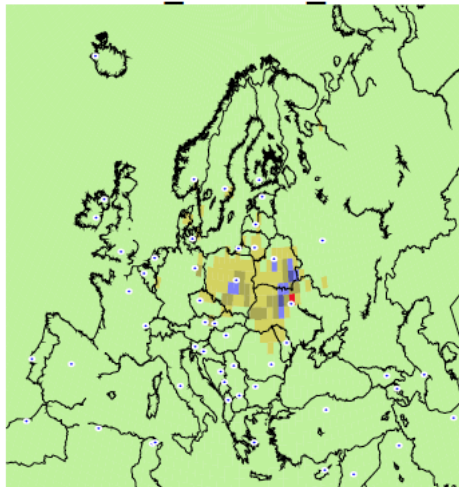
2010\_scenario\_10



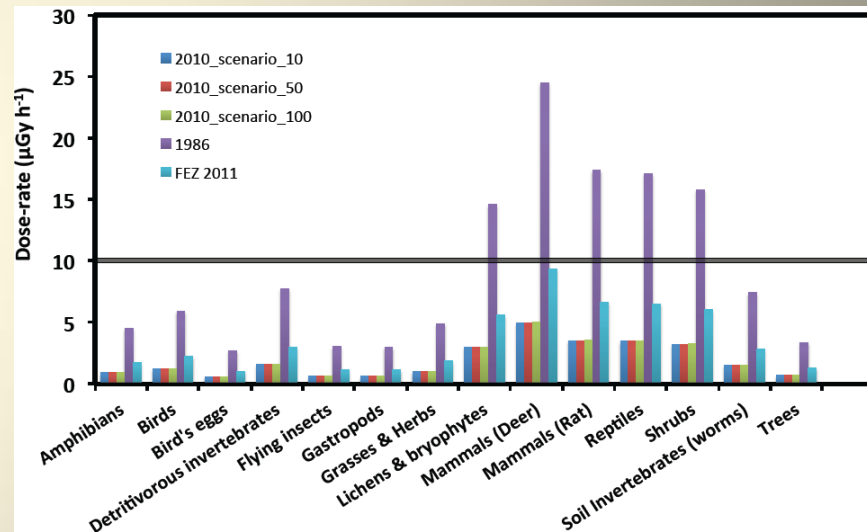
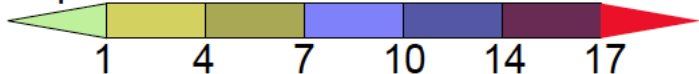
2010\_scenario\_50



2010\_scenario\_100



Expected number of cancer mortalities



# Publications

- Kristiansen, N.I., Stohl, A., Christoudias, T., Kunkel, D., Croft, B., Pierce, J., Martin, R., Bergman, T., Kokkola, H., Lee Y., Shindell, D., Pitari, G., Zhang, H., Zhao, S., Søvde, A., Wang, H., Zhang, K., Liu, X., **Evangelou, N.**, Balanski, Y., Tsigaridis, K., Bauer, S., Klein, H., Leadbetter, S., Olivie, D.J.L., Schulz, M. (2014), "Evaluation of observed and modelled aerosol lifetimes using radioactive tracers of opportunity and an ensemble of 19 global models", Atmospheric Chemistry and Physics, **in preparation**.
- **Evangelou, N.**, Balkanski, Y., Cozic, A., Hao, W.M., Mouillot, F., Thonicke, K., Paugam, R., Zibtsev, S., Mousseau, T.A., Wang, R., Poulter, B., Petkov, A., Yue, C., Cadule, P., Koffi, B., Kaiser, J. W., Møller, A.P. (2014), "Fire evolution in the radioactively contaminated forests of Ukraine and Belarus: future risks for the European population and the environment", Ecological Monographs, **accepted**.
- **Evangelou, N.**, Balkanski, Y., Cozic, A., Møller, A.P. (2014). "How "lucky" we are that the Fukushima nuclear accident occurred in early spring. Predictions on the contamination levels from various fission products released from the accident and updates on the risk assessment for solid and thyroid cancers", The Science of the Total Environment, doi: 10.1016/j.scitotenv.2014.08.102.
- **Evangelou, N.**, Balkanski, Y., Cozic, A., Hao, W.M., Møller, A.P. (2014). "Wildfires in Chernobyl-contaminated forests and risks to the population and the environment: A new nuclear disaster about to happen?", Environment International, doi:10.1016/j.envint.2014.08.012.
- **Evangelou, N.**, Balkanski, Y., Cozic, A., Møller, A.P. (2014), "Global and local health risk assessment after the Fukushima Nuclear Power Plant accident as seen from Chernobyl: A modeling study for radiocaesium ( $^{134}\text{Cs}$  &  $^{137}\text{Cs}$ )", Environment International, 64, 17–27.
- **Evangelou, N.**, Balkanski, Y., Cozic, A., Møller, A. P. (2013), "Simulations of the transport and deposition of  $^{137}\text{Cs}$  over Europe after the Chernobyl NPP accident: influence of varying emission-altitude and model horizontal and vertical resolution", Atmospheric Chemistry and Physics, 13, 7183–7198.
- **Evangelou, N.**, Balkanski, Y., Cozic, A., Møller, A.P. (2013), "Global transport and deposition of  $^{137}\text{Cs}$  following the Fukushima NPP accident in Japan. Emphasis in Europe and Asia using high-resolution model-versions and radiological impact assessment to the population and the environment using interactive tools", Environmental Science and Technology, 47, 5803 –5812.

THANK YOU VERY MUCH  
FOR YOUR ATTENTION!!!