The capabilities of STUK to assess radiological consequences of nuclear explosions

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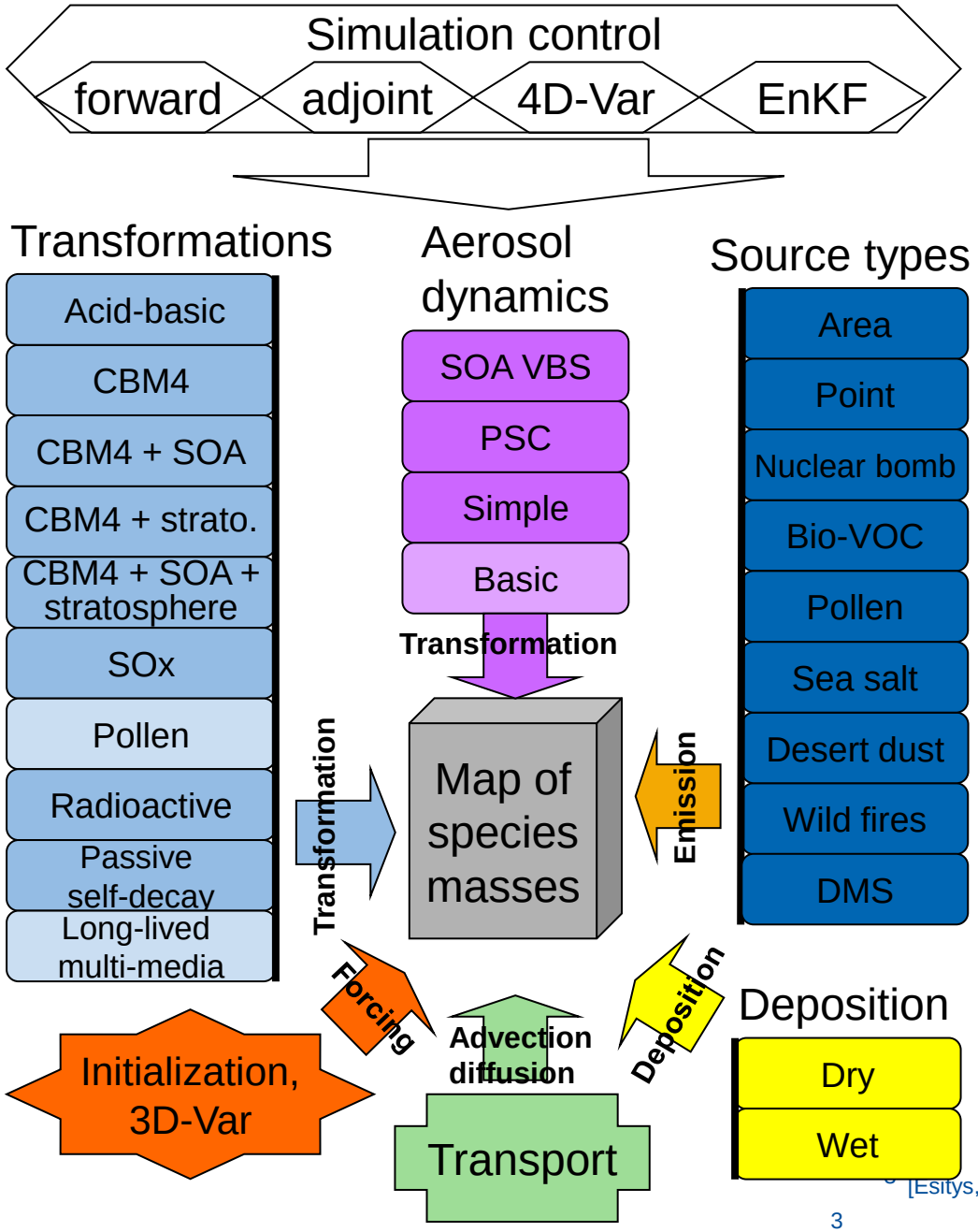
Outline

- Usage of long-range dispersion model SILAM in the case of nuclear explosions
- Coupling of SILAM nuclear bomb model with STUK's operation emergency management system TIUKU
- Other tools

SILAM dispersion model

- Dispersion model developed by Finnish Meteorological Institute (FMI)
- Modules
  - 10 chemical and physical transformation modules (8 open for operational use),
  - 9 source terms (all open),
  - 4 aerosol dynamics (3 open)
  - 3D-,4D- Var, EnKF, EnKS
- Domains: from global to beta-meso scale (~1km resolution)
- Meteo input:
  - ECMWF
  - HIRLAM, HARMONIE, AROME, HIRHAM, ECHAM, and any other who can write GRIB-1 or GRIB-2
  - WRF
  - ECHAM, NorESM, other GCM / RCM
- More information https://silam.fmi.fi/



The source term for nuclear detonations

- Initially source term for nuclear bomb was developed for ~20 years ago but the model remained unused for many years but recently it was recoded to be compatible with the newer SILAM versions (incluing Euler-type calcuations, better deposition etc.).
- Activity distribution of released nuclides:
  - Based on a fuel consisting of 94% of U^{235} and 6% of U^{238}
  - Currently 48 species, with the solid species distributed among multiple aerosol size bins
- Burst types:
  - Airburst (hat only)
  - Surface burst (stem and hat)
  - Underground detonation (base surge cloud, stem and hat)
- Parameters describing the vertical profile and the aerosol size distribution of the emission depend on the elevation and the yield of the detonation
- Fusion bombs are described by the estimated fission fraction
- Crude estimates for water surface and underwater detonations

Nuclear bomb source term nuclide composition

- STUK provided source term for SILAM nuclear bomb model based on literature study. Sample data of noble gases only described on the right.
  - Full nuclide list at https://github.com/fmidev/silam-model/blob/silam_v5_7pub/source/source_terms_bomb.silja.mod.f90
- Work was carried out under the project EUNADICS-AV [https://ec.europa.eu/inea/en/horizon-2020/projects/h2020-transport/aviation/eunadics-av]
- Other dispersion models involved: MATCH (SSM, SE) and FLEXPART (ZAMG, AU)

Radionuclide	Half-life	Source term activity (Bq·kt^{-1})	
		Uranium weapon	Plutonium weapon
Kr-85M	4.48 h	8.24E+16	3.71E+16
Kr-85	10.7 y	8.66E+09	2.81E+10
Kr-87	76.3 min	5.45E+17	2.29E+17
Kr-88	2.84 h	3.27E+17	1.27E+17
Xe-133M	2.19 d	2.15E+13	2.47E+14
Xe-133	5.245 d	3.10E+12	3.51E+13
Xe-135M	15.3 min	1.93E+17	9.26E+17
Xe-135	9.10 h	3.48E+15	1.88E+16
Xe-137	3.82 min	2.63E+19	2.45E+19
Xe-138	14.1 min	6.93E+18	5.60E+18

References

T. England and B. Rider. Fission product yields per 100 fissions for 235U, 238U and 239Pu pooled fast neutron fission decay. These data are based on the report LA-UR-94-3106 (1993) and can be found on the web.

S. Glasstone and P.J. Dolan. The effects of nuclear weapons. U.S. DoD and U.S. DoE, 1977.

T. Kraus and K. Foster. Analysis of fission and activation radionuclides produced by a uranium-fuelled nuclear detonation and identification of the top dose-producing radionuclides. Health Physics 107(2014)2, 150–163.

J. Lahtinen. Exchange of e-mails with Dr. Kraus in October 2017.

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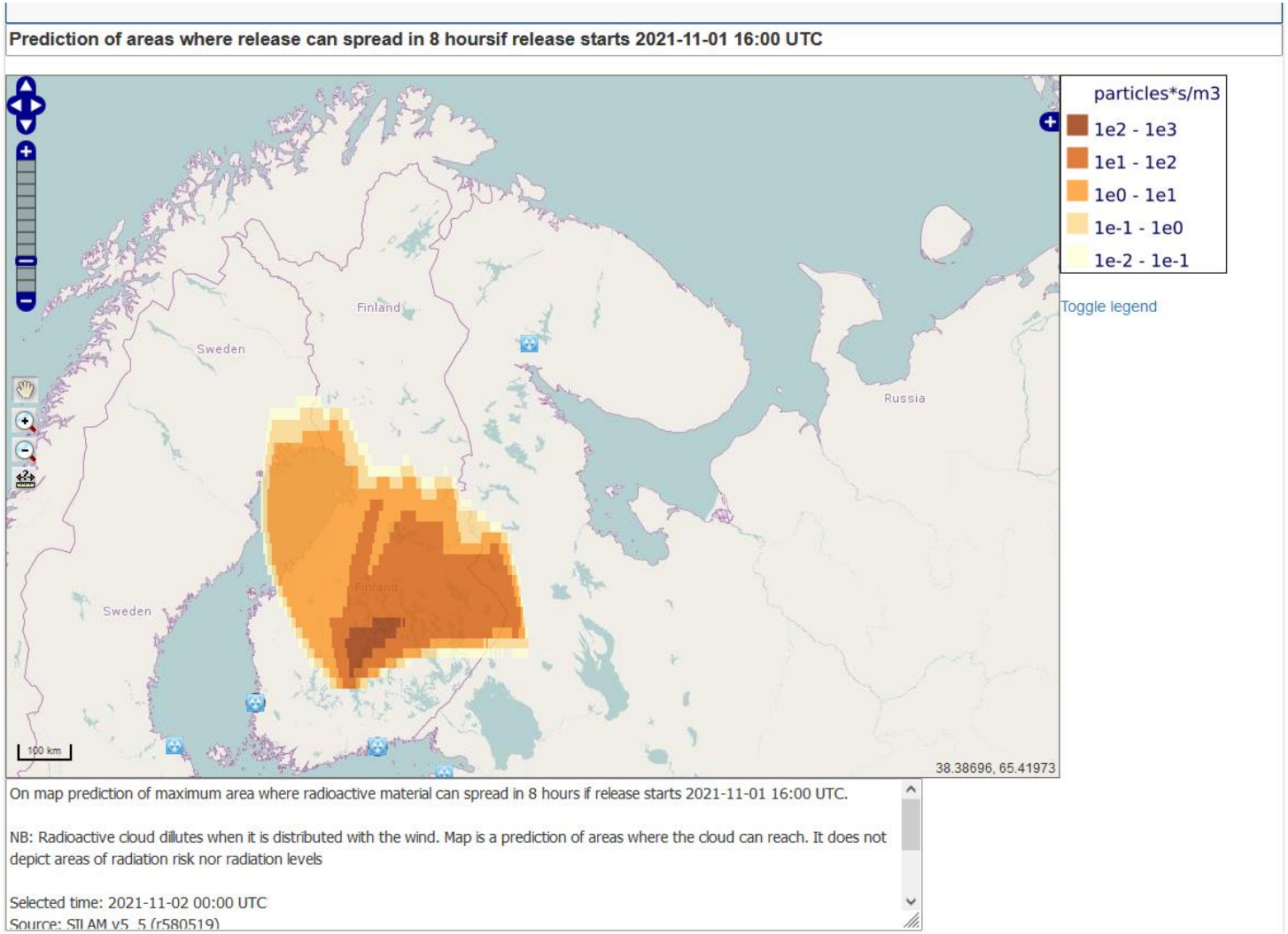
SILAM integration with emergency Management system TIUKU

- Usage of dispersion models, dose calculations, analyses and reporting are all done in TIUKU system.
- TIUKU system is a collaborative web application that provides a single user interface for all tools needed in analysing radiological emergency situations.
- Dispersion models usage in TIUKU system:
  - User fills a web form and submits it
  - Calculation request is made and sent to another server that contains the calculation software.
  - Result of the calculation request is either a result file or an error message (if something goes wrong).
  - After the results are received they are input in a database and can be viewed on a map, analysed further or reported.

SILAM Nuclear bomb model in TIUKU system

User input web form

- Location
- Start time and forecast length
- NWP model (MEPS Harmonie / ECMWF (global), HIRLAM)
- Dispersion type: Eulerian / Lagrangian
- Bomb type (Uranium / Plutonium / Passive)
- Yield (in kilotons)
- Spatial and temporal resolution
- Bomb height
- Include dose calculations or not
  - Height of dose calculation can be defined



Other tools

- HotSpot Gaussian dispersion modelling software
  - A wide range of input types (upper image)
- Gaussian dispersion model ALAMA (developed by Finnish Defence Forces)
  - ArcGIS code, rarely used anymore at STUK
- Non-computational methods
  - ”Cigar” type of manual drawing capability not anymore maintained by FMI (lower image).
  - Some ”thumb-rule” kind of data and tables available in literature.