Predicting dispersion of radioactive materials in the atmosphere with SILAM

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Outlook

- Silam model
- Nuclear bomb source (new)
- Dose assessment module
- Forward simulation: Fukushima
- Probabilities: Ensemble simulation of a volcano
- Inverse simulations: RU-106 case
- Summary
SILAM v.5.5

- **Modules**
  - 9 chemical and physical transformation modules (7 open for operational use),
  - 8 source terms (all open),
  - 4 aerosol dynamics (1 open)
  - 3D-,4D- Var, EnKF
- **Domains:** from global to beta-meso scale (~1km resolution)
- **Meteo input:**
  - ECMWF
  - HIRLAM, AROME, HIRHAM, ECHAM, and any other who can write GRIB-1 or GRIB-2
  - WRF
  - ECHAM, NorESM, other GCM / RCM
Operational AC/AQ-modelling at FMI

Global: 50 km, troposphere + stratosphere

All forecasts:
4 days with 1hr step,
SILAM v.5.5
http://silam.fmi.fi

Asia: 12 km, troposphere

Northern Europe:
2.5km, troposphere

Europe:
10 km, troposphere
boundaries: C-IFS
hindcast: 3D-Var
Nuclear bomb source

- Input: location, time, blast height, and yield
- 56 nuclides with activities per kiloton yield (STUK)
- Mushroom height and size function of yield
- Based on MATCH, SNAP, HYSPLIT and KDFOC3 models
- Simulates
  - cloud shape,
  - activity-height distribution,
  - activity-particle size distribution
  - activities of different nuclides
  - In-air/underground blasts
Dose assessment module

• Post-processor of SILAM output
  - Concentrations/depositions to dose
  - Conversion activity (Becquerels) to effective dose (Sieverts)

• Effective dose represents the health risk for people

• The four paths of dose
  - Cloudshine (SILAM database)
  - Groundshine (SILAM database)
  - Inhalation (STUK publications)
  - Ingestion (RODOS publications)

• Output is a NetCDF file with map of effective dose for different age groups.
Fukushima

- One of the biggest NPP worldwide
- Six reactors
  - Four buildings damaged
- Broken power supply
- Failed backup cooling systems
- Radiation levels many times above the limits
SILAM forecasting for Fukushima case

• Active since the first day of the accident
• Two scales
  - Hemispheric, 1 degree resolution, forecasting up to 6 days forwards
  - Regional, 15km resolution, up to 48 hours
• Results were:
  - protected Web site – for the Finnish authorities
SILAM forecasting for Fukushima case
High-resolution test case: Loviisa

- Coastal area
- Hypothetical case to study breeze effects
- 500m resolution, dedicated Harmonie run
- Several injection heights
Model ensemble: measure of uncertainty

EnKF, ensemble, 80 members, concentrations at roughly FL250.
Red: ash concentration of 0.2 mg/m³ exceeded by ≥ 50 % ensemble members.
Orange: ash concentration of 0.2 mg/m³ exceeded by ≥ 2 % ensemble members
Fake eruption, Eyjafjallajökull source relocated to Etna
Summary:

- End-September, beginning of October 2017 Ru106 was detected in air
- No one compelled to take responsibility
- Few indirect evidences for “Mayak” plant
- No other reasonable hypothesis around

- ~400 observations (incl. <BDL) publicly available from IRSN2018 report
- Averaging times of 1 day to 1 month.
- The dispersion problem solved “to the end”
Source area of an observation (4D field)
- SA brings evidence for every point in time and space
- Non-zero: “should release happened at particular instant-point it must be YY TBq”
- Zero (or “< XXX mBq/m3”): no release more than YY TBq could happen here

The evidences are contradictory
Challenge: Make a conclusion

Can we derive something from individual source areas?

Constrain for hourly release from the observation Volgograd
2017-09-26 – 2017-10-01, 19 mBq/m3
Scores for release time & location

score, 75–175m 23:00, 050CT2017
Summary

- Silam is a tool to model all kinds of atmospheric dispersion
- Driven with ECMWF, Harmonie, WRF etc…
- Scales from global to sub-kilometer
- Dose assessment module as a postprocessor
- Regular sources, bomb source
- Forward and inverse trajectories
- Forward and inverse Eulerian/Lagrangian
- Ensemble modelling and probabilistic forecasting is another modern development, potentially altering the means of information support of emergency response