Application of Regional Environmental Code HARP in the Field of Off-site Consequence Assessment

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Presentation Outline

- Description of HARP (HAzardous Radioactivity Propagation) system
- Computationally intensive applications:
  - Application related to PSA Level 3
  - Application for assessment of long-term releases due to normal operation
  - Application in MC data assimilation method in early phase of a reactor accident
    - What is DA?
    - Application in early phase of radiation accident

Environmental Code HARP

HARP HAzardous Radioactivity Propagation

- Estimation of consequences of accidental aerial releases of radioactivity
- Atmospheric propagation of radionuclides (up to 132 nuclides) - dispersion modeling
  - Segmented Gaussian plume model (hybrid puff-plume model)
  - Temporal and spatial variations in meteorological conditions, source term, influence of terrain, land-use etc.
- Interactive input subsystems for easy definition of release scenarios
- Averted doses due to countermeasures
- Propagation of radionuclides through the food chain
  - dynamic food chain model dependent on Julian date of radioactive fallout
  - interactive input subsystem INGMODEL (variations of phenology, consumption baskets, feeding rates, etc.)
- The code was successfully validated against COSYMA and RODOS

Evaluated Radiological Quantities

HARP
HAzardous Radioactivity Propagation

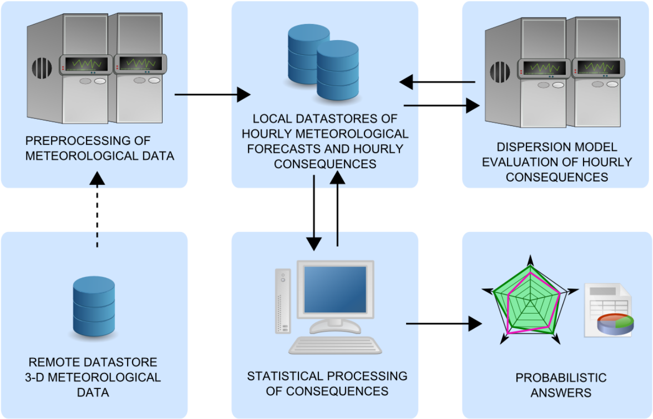
- All quantities are evaluated on a polar grid up to 100km from the source
- Dose evaluation for the different exposure pathways:
  - External irradiation:
    - Cloud shine, ground shine
  - Internal irradiation:
    - Inhalation, inhalation due to resuspension
    - Contamination of foodstuffs, ingestion
  - Total committed doses:
    - 24 hours; 7, 30, 90 days; 1, 5, 50 years
    - 6 age groups
    - different body parts and whole body (effective) dose

- Radiological quantities serve as inputs to health effect models

Probabilistic analysis

HARP
HAzardous Radioactivity Propagation

- The deterministic core is inserted into probabilistic framework allowing for effective sampling of different inputs to the model and thus simulate propagation of uncertainties through the model.
- Generally, an arbitrary atmospheric dispersion model can be used.



Computationally Intensive Applications

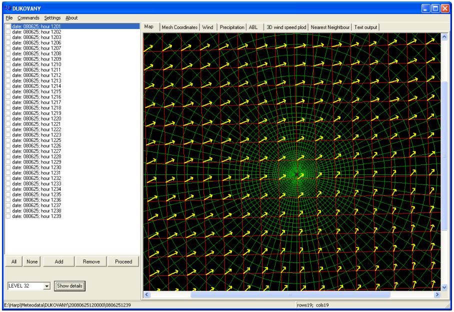
HARP
HAzardous Radioactivity Propagation

Repetitive evaluation of deterministic dispersion model using different source terms and meteorological conditions, Monte Carlo (MC) methods.

- Weather variability assessment, a special case of PSA Levels 3.
- Simulation of consequences of long-term discharges of radionuclides into the atmosphere due to normal routine operation of a NPP.
- Data assimilation in the early phase of a radiation accident - estimation of the true scale and consequences in case of a reactor accident using dose measurements from a radiation monitoring network.

Weather Variability Assessment

- Evaluation of population doses and land contamination probabilities based on repetitive evaluation of atmospheric dispersion model using different source term(s) and hourly meteorological sequences given by HIRLAM numerical weather prediction model.
- We analyze influence of variability of meteorological conditions for a given source term(s).
- We use hourly 3-D meteorological HIRLAM forecasts instead of annual meteorological statistics $\Longrightarrow$ better treatment of seasonal and diurnal changes, e.g., calm conditions.



Weather Variability Assessment

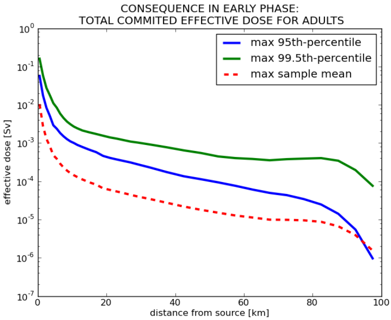
- The methodology is demonstrated using two-year (2008-2009) hourly meteorological sequence, i.e., 24 * 365 * 2 = 17520 releases for a given source term configuration.
- The hypothetical release is assumed from NPP Temelin, release height H=45m, no thermal power
- Source term was chosen as follows:

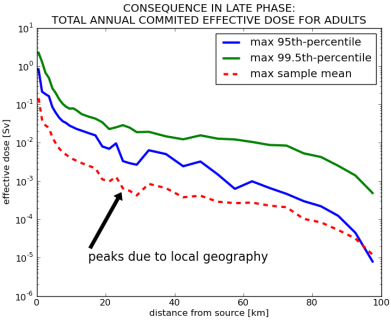
Isotope	Chosen release target	Physical-chemical form
Sr-90	5E+12 Bq	aerosol form
I-131	1E+16 Bq	prevalent elemental form
Cs-137	3E+13 Bq	aerosol form
Xe-133	7.7E+17 Bq	noble gas

- Using empirical distributions of target quantities, we can evaluate different statistics

Weather Variability Assessment

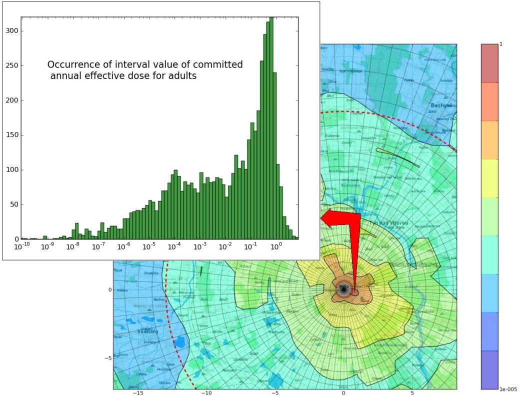
Doses from the early and the late phase:





Sample mean and *p*th percentiles consequences (probabilities of exceeding no more than 100-*p* percent). Angular maximums (from 80 sectors) at each radial distance.

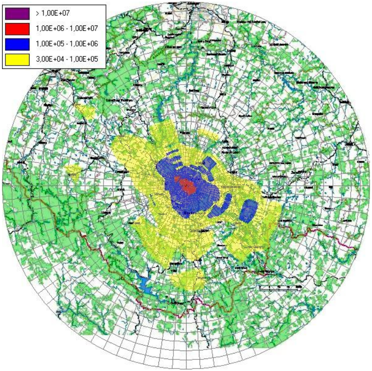
Weather Variability Assessment



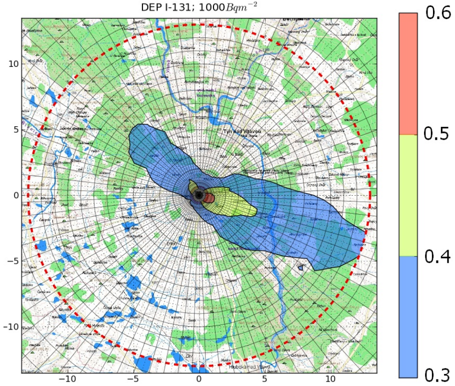
Background: 2-D visualization of sample mean of annual committed effective dose for adults. Foreground: Histogram representing empirical distribution of committed doses using hourly meteorological forecasts.

Weather Variability Assessment

Deposition:



2-D representation of I-131 deposition sample mean $(\mathrm{Bq/m^2})$

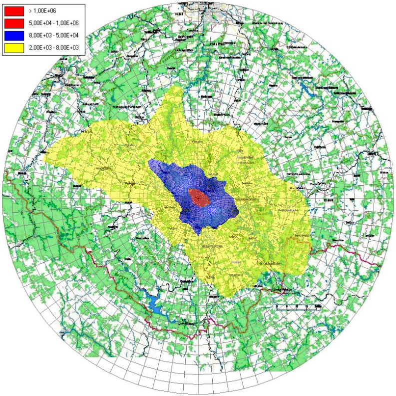


2-D representation of complementary CDF - probability of exceeding deposition limit 1E3 $\mathrm{Bq/m^2}$

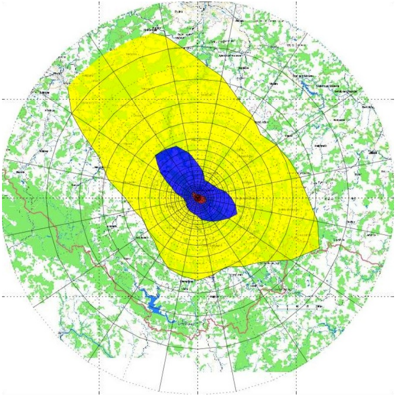
Assessment of Long-Term Discharges into Atmosphere

- Source terms of hourly releases are set according to reported releases from NPP due to normal operation, e.g. Tritium, C-14.

Near ground time integrated activity concentration in air of H-3, year 2008



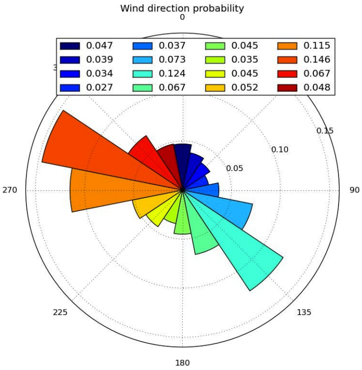
Code HARP: 17520 hourly releases using hourly 3-D HIRLAM meteorological forecasts



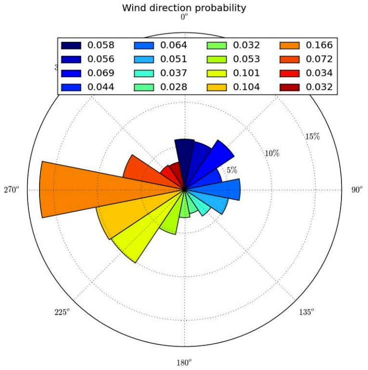
Code NORMAL: Annual meteorological statistics in 16 directions, flat terrain

Application of HARP to MC Data Assimilation

- The difference between forecasted and measured meteorological data together with other uncertainties implies that the assessment in case of a reactor accident based only on a dispersion model could be wrong



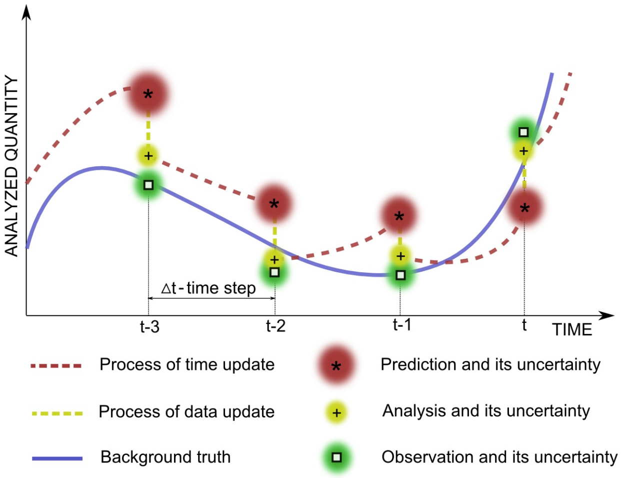
Annual statistics produced using forecasted data



Annual statistics produced using measured data

Data Assimilation (DA) - Basic Concepts

- DA refers to a group of mathematical methods for estimation of a state of a dynamic system by the means of combining multiple sources of information, typically observational data with a numerical model of the system under investigation

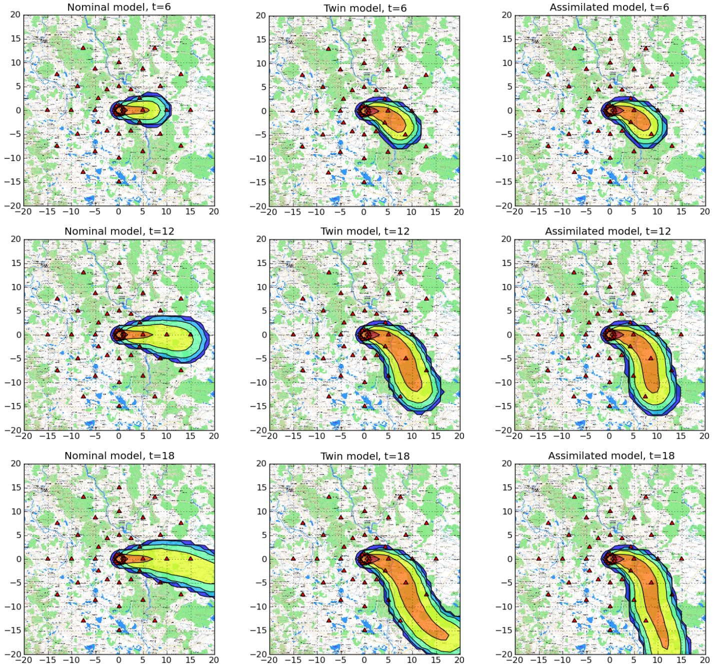


On-line Data Assimilation in Early Phase

- We assimilate time integrated gamma dose rate measurements from a radiation monitoring network with activity concentration in air given by a parameterized dispersion model
- DA is our case consists in tuning of selected model inputs to be in accordance with the measurements
- The methodology is based on Bayesian filtering - sequential Monte Carlo methods
- The main goals are:
  1. Estimation of the true scale of the accident and prediction of its consequences $\Longrightarrow$ improvement of reliability of the decision support through the different phases of the accident
  2. Testing of different configurations of radiation monitoring network - assessment of information brought by different topologies of receptors

Data Assimilation in Case of Accidental Release

- We estimate selected inputs of a given parametrized dispersion model using available measurements - the set of estimated parameters is selected using sensitivity studies performed with dispersion models.
- Tuning of model inputs in a way the the model results is in correspondence with the measurements.
- The most important parameters are:
  - **Magnitude of release,**
  - **Wind speed, wind direction,**
  - Atmospheric stability category (horizontal and vertical dispersion),
  - Magnitude of dry and wet deposition, . . .
- We propagate simultaneously multiple dispersion models and use the theory of Bayesian estimation to produce posterior statistics of estimated parameters.
- To validate the methodology we use *twin experiments.*


Nominal model, t=6
Twin model, t=6
Assimilated model, t=6
Nominal model, t=12
Twin model, t=12
Assimilated model, t=12
Nominal model, t=18
Twin model, t=18
Assimilated model, t=18

Thank you!

http://havarrp.utia.cas.cz/harp/

http://havarrp.utia.cas.cz/normal/

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