IITA, Dpt. of Adaptive Systems

ENERGOPROJEKT PRAHA ®

Modelling of Random Activity Concentration Fields for Purposes of Estimation of Radiological Burden of Population

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From deterministic towards probabilistic formulation

DETERMINISTIC SCHEME:

MODEL : $\mathbf{Y} = \Re(\mathbf{X})$ - BOX, GAUSS (PLUME, PUFF), LAGR., EULER

INPUTS : $\mathbf{X} \equiv \{x_1^{best}, x_2^{best}, \ldots, x_N^{best}\}$ - vector of input parameters ADM, … (best estimate or worst case values)

OUTPUTS: $\mathbf{Y} \equiv \{y_1, y_2, \ldots, y_M\}$ - vector of endpoint values (TIC, DEPO, DOSE, ..)

PROBABILISTIC APPROACH:

$\mathbf{X} \equiv \{X_1^{rand}, X_2^{rand}, \ldots, X_N^{rand}\}$ → uncertainty propagation through $\Re$ → $\mathbf{Y} \equiv \{Y_1^{rand}, Y_2^{rand}, \ldots, Y_M^{rand}\}$

Causes of input uncertainties

- Imperfection in description of complex physical processes (parametrization errors)
- Stochastic effects in dispersion and deposition mechanisms
- Measurement errors
- Incomplete description of radioactivity release scenario
- Simplification in computational procedure (averaging …)

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Sampling-based method for uncertainty propagation analysis

$\mathbf{X} \equiv \{X_1^{rand}, X_2^{rand}, \dots, X_N^{rand}\}$;

X_i^{rand} ……. i-th input random parameter : - type of random distribution
- range of values
- correlation control

Monte Carlo analysis: Multiple evaluation of complex model $\Re$

➢ Randomly selected input vector realizations using stratified LHS :
(LHS tends to produce effectively more stable results than crude MC modelling)

$$\mathbf{x}^k \equiv \{x_1^k, x_2^k, \dots, x_N^k\} \; ; \; k=1,\dots,K \; ;$$

➢ Multiple model evaluation and generation of pairs:

$$\mathbf{y}^k = \Re\,(\,\mathbf{x}^k\,) \rightarrow \boxed{\{\,\mathbf{y}^k \,;\, \mathbf{x}^k\,\}_{k=1,\dots,K}} \; ; \quad K \sim 10^3 \; ;$$

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Statistical processing of M-C results

Statistical proces. of pairs $\{ Y^k ; x_1^k, x_2^k, \dots, x_N^k \}_{k=1, \dots, K}$

- ✓ **UNCERTAINTY ANALYSIS** of resulting endpoint values (estimation of sample statistics, CDF, CCDF, α-quantiles)
- ✓ **SENSITIVITY STUDIES** - determination of partial contribution of each input parameter fluctuation to overall endpoint variable uncertainty

MAIN ISSUE:

Probabilistic answers on assessment questions can be generated - in terms of $UF = 95^{th}/5^{th}$ percentiles, $RUC = 95^{th}/(\text{best estim.})$

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Probabilistic code HARP
Application 1: UA and SA

Gaussian plume model (straight-line or segmented version)

$$Y = \Re^{GPM,seg} (X_1^{rand}, X_2^{rand}, \dots, X_M^{rand} ; x_{M+1}^{best}, x_{M+2}^{best}, \dots, x_N^{best})$$

reduction: Y.... a) scalar spatial array of I131 deposition

b) scalar spatial array of effective dose for children

CDF and histograms are generated for M=12 (ADM) + M=16 (FCM)

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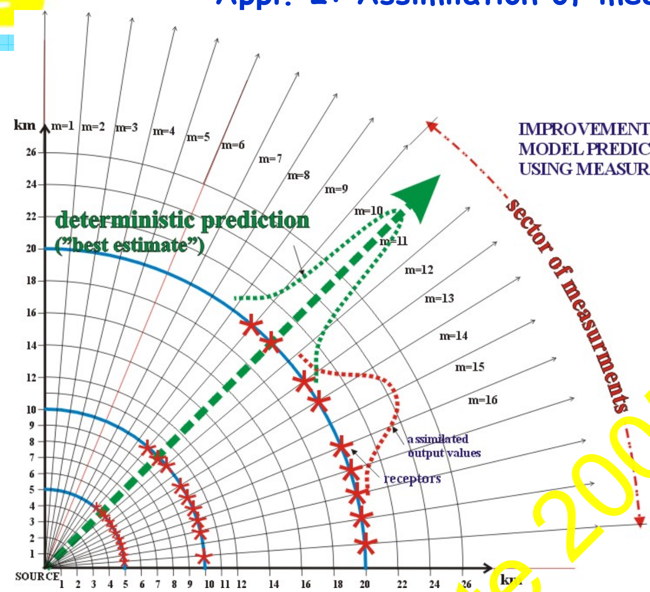
Probabilistic code HARP
Appl. 2: Assimilation of measurements



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Assimilation of model results with measurements on terrain

$\hat{\mathbf{y}}_r$, r=1, … , R - measurements at R points on terrain (so far simulated by model)

$\mathbf{y}_{rp}$, rp=1, … , R - subset of model prediction values (adjusted at points of terrain measurements)

Minimisation LS scheme :

$$FCN(M; C_1, C_2, \ldots, C_M) = \sum_{r=1}^{r=R} \left(y_{rp} - \hat{y}_r \right)^2$$

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Algorithms for one-time data assimilation (in space)

Minimisation algorithms : direct search (Nelder-Mead), Powell

Standard form of random param.: $X_i^{rand} = C_i^{rand} . X_i^{best}$; C ... dimensionless

Minimisation procedure searches for optimum set of $\{c_1^{opt}, c_2^{opt}, \ldots, c_M^{opt}\}$

Procedure of searching: multiple generation of realizations j tending to minimum of FCN ; for $j \to \infty$:

$$\{ c_1^j, c_2^j, \ldots, c_M^j \}^{j\to\infty} \Rightarrow \{ c_1^{opt}, c_2^{opt}, \ldots, c_M^{opt} \}$$

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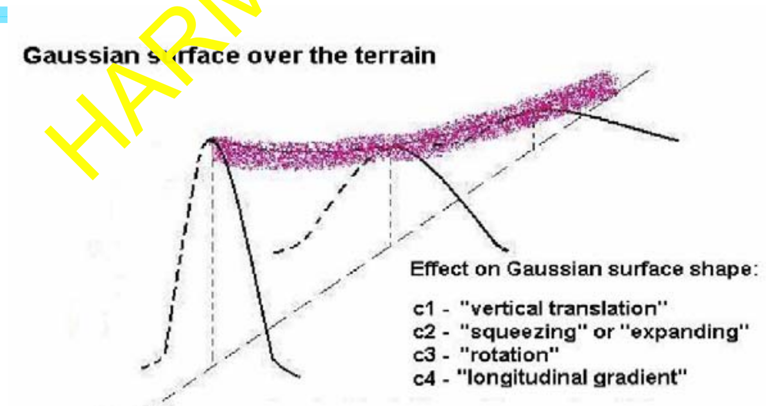
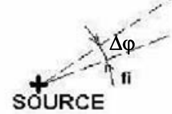
Fitting of Gaussian-shape surface using measurements





Release source strength (Bq/s): $A = c1 * A^{best}$

Horizontal dispersion (m) : $\sigma_Y = c2 * \sigma_Y^{best}$

Wind direction fluct. (rad) : $\Delta\varphi = c3 * 2\pi/80$

Dry deposition velocity (m/s) : $vg = C4 * vg^{best}$

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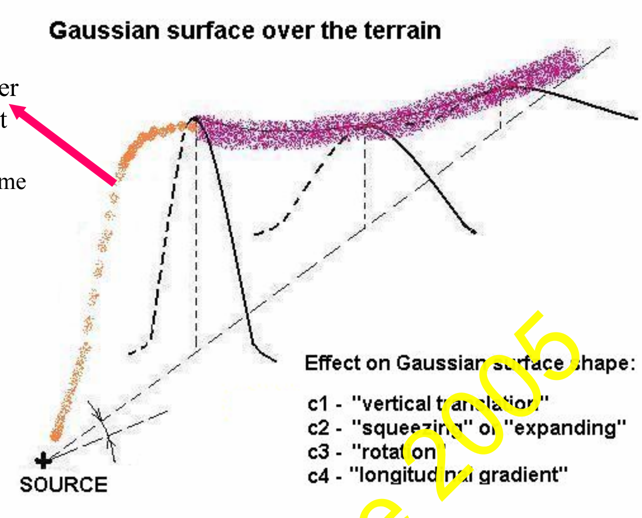
Fitting of more complicated Gaussian-shape

Frontal part – other random inputs must be added:

uncertainty in σ_z, plume rise, initial vertical momentum, effect of precipitation, …….



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