**TIES 2009** 



# HARP - A Software Tool for Fast Assessment of Radiation Accident Consequences and their Variability



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### Introduction

System HARP is designed for fast assessment of radiological consequences of accidental releases of radionuclides into the living environment. Transport of toxic agens is studied from initial atmospheric propagation up to 100 kilometeres from the source of pollution. Dis-

persion, deposition and successive radioactivity transport toward human body is modeled. Deterministic estimation of consequences is superseded by **probabilistic** approach. The product is intended for its utilization e.g. for staff training and students' education.



The HARP system in its probabilistic version offers 3 implicit groups of input data and model parameters. The first group consists of 14 random members and stands for ADM model. Subsequent group for FCM

model offers 16 random items and group for dosimetric model DOS has 9 random members. The groups were assembled on basis of extensive literature review and expert judgments.

# **Conversational mode of result visualization**

The main principal quantities of concentrations in air, time integrals of near-ground activity concentration, specific deposition on terrain and its time integrals are calculated in the early stage of accident by means of segmented Gaussian plume algorithm. Implemented numerical difference scheme enables to simulate approximately formation of important parent-daughter pairs. Just after the time consuming early-stage analysis is completed, the main task is waiting and the autonomous visualization subsystem is started. Both tasks are cooperating on-line and wide range of various graphical results can be demonstrated **conversationally**, on basis of **user demands**.

be compared conversationally, too. The product HARP is fully localized for both Czech NPP Dukovany and Temelin. The results are displayed on the proper map backgrounds provided by company PJSOFT.



Interactive regime offers wide range of input data and model parameters alternative options thus enabling fast examination of their variability and uncertainty on

random fluctuations of resulting outputs. The final goal of progression is integration of assimilation subsystem ([5],[4]) for improving the model predictions.

# Interactive input subsystems

Prospective user has interactive access into "hot" input definitions of a given release scenario. Alternative options are offered for important input data or model parameters that helps to estimate uncertainty propagation through the model and to judge roughly the effects arising from imperfect parametrization of complex physical reality.

Entering ADM interactively Atmospheric dispersion and deposition model (ADM) is based on segmented Gaussian plume approach [4] which can approximately account for release dynamics and short term meteorological forecast. Parameters of 6 subgroups (Scenario, Plume depletion, Nearstanding objects, Segments of release, Meteorology) can be unrolled onwards. After filling up, the complete definitions are archived under selected run-id and can be recalled, possibly modified and re-run with fast response.

### Ingestion control panel

Parameters of dynamic food chain model (FCM) [3] for estimation of internal irradiation due to consumption of contaminated foodstaffs are split into 8 subgroups, can be unrolled onwards and then archived, e.g.:

JE Temelín
e <u>M</u> aps <u>V</u> isualization <u>G</u> raphs <u>T</u> ools <u>C</u> ountermeasures <u>D</u> ata assimilation <u>H</u> elp
✓ Implicit outputs of the code HAVAR-RP
Basic control values (early phase) Irradiation from late phase Doses for early phase
Basic control values (early phase)
• TIC - Time integrals of near-ground activity in air
OEP - Nuclides deposition in time tB after release start
<ul> <li>TID - Time integrals (0 to tB) of nuclides deposition</li> </ul>
tB: Duration of early phase of accident from the start of release

#### Basic control values (early phase) Irradiation from late phase Doses for early phase

#### Irradiation in late phase

(usually tB = 24 hours)

 Long-term external irradiation from deposition (incl. early phase) Internal irradiation from inhalation due to long term resuspension Internal irradiation from ingestion • Total committed doses (from early phase and late phase)

#### Basic control values (early phase) Irradiation from late phase Doses for early phase

#### Doses in early phase

External irradiation from the cloud External irradiation from deposition (0 to tB) Internal irradiation from inhalation (early phase) • Total committed doses (cloud + deposition + inhalation)

The main goal of the architecture lies in establishing of user friendly environment with fast response time

Picture below: Spatial distribution of  $^{137}\mathrm{Cs}$  activity deposition on terrain  $[Bq \cdot m^{-2}]$ . Deterministic "best estimate" (left) is compared with probabilistic calculation of sample mean (right – 5000 samples). Retrospective meteorological forecast sequence "CASE2" from June 28, 2002 with release start at 00 UTM was used (scenario from joint Czech-Austrian workshop STEP II b). The "red bull" eye in deposited activity is caused by local atmospheric precipitation, which occurred between hours 5 to 6 after the release start (random rain intensity has uniform distribution  $U[0; 6mm \cdot h^{-1}]$  ). Significance of probabilistic assessment approach is evident. It enables generate more informative probabilistic answers on assessment questions





Basisc parameters Plume depletion Near-standing buildings Release segments and nuclide group Meteorological forecast

Nuclid		^	Source term LD									
1134			Source term ST	2 from RODOS. or	nly nuclia	les with contri	bution to eff. dose	>1%.				_
I134A			Source term des	cription	-							
11350			April 21, 2009,	5 segments of rele	ase, dist	persion SCK/C	EN smooth terrain	1				-
1135	<ul> <li>Image: A set of the set of the</li></ul>		1									
1135A			No. of release s	egments	5	•	Read source ter	m from arc	hive	Save source te	erm to archive	e
XE131M			Release segme	nts								
XE133M						1	2	3		4	5	
XE133			Release du	uration (hou	ırs)	1.0000	1.0000	1	.0000	2.0000	1.00	00
XE135M			Initial t	hermal power (I	<vv)< td=""><td>0.0</td><td>0.0</td><td></td><td>0.0</td><td>0.0</td><td></td><td>0.</td></vv)<>	0.0	0.0		0.0	0.0		0.
XE135			linitial v	vertical speed (n	n/s)	0.0	0.0		0.0	0.0		0.1
XE137				Release height	(m)	99.0	99.0		99.0	99.0	9	9.1
XE138												_
CS134	<ul> <li>Image: A set of the set of the</li></ul>		Nuclid	1		2	3		4		5	1
CS136			TE132	1.80E+13		1.30E+18	4.50E	+16	9.00	E+16	4.50E+16	
CS137	~		1131	1.41E+14		1.98E+18	1.13E	+17	2.27	E+17	1.13E+17	
CS138			1133	2.88E+14		4.02E+18	2.30E	+17	4.60	E+17	2.30E+17	
BA139			1135	2.70E+14		3.78E+18	2.16E	+17	4.32	E+17	2.16E+17	
BA140	~	~	CS134	2.10E+12		2.36E+17	1.31E	+15	2.63	E+15	1.31E+15	
			C8137	1.32E+12		1.48E+17	8.23E	+14	1.65	E+15	8.23E+14	
	-84	- 1	BA140	1.09E+13		3 28E+17	1.37E	+15	2.73	E+15	1.37E+15	

a top									
Phenolog	au	Con	sumption bask	ets	Feedina	rates of cattle	) Feedir	na rates - others	
Basic charac	cteristic	Radio	activity transpo	ort in soil	Long-time d	leposition / resuspensi	on Le	eafy / root transport	
Heading									
1st heading li	ine			E F	Results for counte	ermeasure module			
Summer fallo	out, consumpti	on basket: fam	ners	_		_			
2nd beading l	line				yes	<u> </u>			
31.8.2008: f	fix + migration:	RODOS, phe	enology: lowlan	d					
	-								
Time charact	teristics					Date format			
Date of radio	pactive fallout		End of cor	ntaminated intak	e	💿 Julian day	s		
182.00			365 days	after fallout	•	C Calendar	days		
L									
- Integration tim	ne for arounds	hine and resus	spension				A		
(resuspension	n for more that	n 1 year)					and of ourrent u		
Time of integ	gration		Time of int	egration is in:		day	365 days after f	allout	
50.00			vear	-		month	5 years after fall	out	
			1,00			year	50 years after fa	llout	_
Basic charac Phenolog	cteristic 19 onsumption (1	Radio	oactivity transp nsumption bas	port in soil kets	Long-tim Feedir	e deposition / resuspong rates of cattle	ension     Fi	Leafy / root trans eeding rates - other:	s
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Basic charac Phenolog Average year co DTkonz - delay Implicit valu	onsumption ( from harvest	Radiu Con kg(litr)/rok) for to consumptic Consum. basł	oactivity transp nsumption bas 6 age catego oni (d) ket: local	port in soil kets ies;	Long-tim Feedir Cons Cons Austr	e deposition / resuspr ng rates of cattle sum. basket: local sum. basket: farmers sum. basket: global rian consum: typical	ension     Fi	Leafy / root trans eeding rates - other:	s
Basic charac Phenolog Average year co DTkonz - delay Implicit valu foods	onsumption (I from harvest ues	Radiu Con kg(litr)/rok) for to consumptio Consum. bask	oactivity transp nsumption bas 6 age catego oni (d) ket: local	port in soil kets ies; 2 2-7	Long-tim Feedir Cons Cons Cons Austr	e deposition / resuspr ng rates of cattle sum. basket: local sum. basket: farmers sum. basket: global rian consum: typical 12-17	ension     Fi	Leafy / root trans eeding rates - other DTkonz	s
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### LHS sampling tool

Sheep milk

1.00 🗸

0.06

Generation of random samples from uncertainty groups of ADM, FCM and DOS models are constructed using Latin Hypercube Sampling algorithms. Distributions of random characteristics are selected according to expert judgment and elicitation procedures. Speand saving of computational resources. Identical principle "on demand" is embodied for assessment of some countermeasure actions introduced on protection of population. Some alternative ingestion scenarios can

# Data assimilation (DA): From model to reality

Detailed predictions of pollution infiltration into the living environment and propagation of uncertainties through the model is inevitable prerequisite for application of advanced statistical methods for assimilation of observations incoming from terrain with model results. The techniques are based on **optimal blend**ing of all information resources including prior physical knowledge given by model, observations incoming from terrain, past experience, expert judgment and intuition. In broader sense, assimilation techniques cover various methods from pure interpolation methods (none or poor informative model available) over empirical methods of successive corrections up to statistically constant methods of optimal interpolation (OI), that can handle model and measurement errors. Advanced DA techniques account for time evolution of forecast and model error covariance structure.

Real scenario of radioactivity dissemination represents complex problem, which requires a good degree of understanding and ad hoc developments. We have tested several DA techniques and applied them in the late stage of radiation accident (prediction of long term evolution of  $^{137}Cs$  deposition on terrain [2]). The first results are achieved for early phase based on particle filter methodology [1].



Examples of model inputs to DA process: (a) Visualization of a section of model error covariance structure in a dimension (covariance of certain point of polar network with the rest of points); (b) Modeled values of estimated quantity



ariations according to hourly	y meteorological forecas	t 🔻	METEOSEKVENCE - Melk_Case	2.wea	
eteoseq	4				
rel. start of step	wind direction	wind speed	Pasquil stability class (A -	precipitation intensity	Hmix
0.00	234.00	1.31	F	0.03	76.00
1.00	250.00	1.48	F	0.03	109.00
2.00	267.00	1.65	F	0.03	143.00
3.00	283.00	1.82	F Straight-line propagation (cor	nstant meteorology) 0.03	176.00
4.00	300.00	1.99	F Variations according to hourly	y meteorological forecast 0.03	210.00
5.00	316.00	2.16	D	0.03	243.00
6.00	333.00	2.33	D	0.07	277.00
7.00	325.00	2.31	с	0.07	440.00
8.00	317.00	2.28	с	0.07	604.00
9.00	309.00	2.25	с	0.07	768.00
10.00	301.00	2.23	B	0.07	931.00
11.00	293.00	2.20	B	0.07	1095.00
12.00	285.00	2.18	B	0.07	1259.00
13.00	284.00	2.42	В	0.07	1156.00
14.00	280.00	2.66	с	0.07	1054.00
					>

1micrometer     > 1micrometer											
deposition (m/s) for various physical- chemical forms - dependency on landuse ms (and aerosol size)											
	water surface grass agricultural forest urban areas										
percecte < 1 micrometer	0.00070	0.00150	0.00200	0.00750	0.00050						
aerosois - i micrometer				0.00050	0.0000						
aerosols > 1 micrometer	0.00080	0.00250	0.00300	0.00850	0.00080						
aerosols > 1 micrometer elemental iodines	0.00080	0.00250 0.01500	0.00300	0.00850	0.00500						
aerosols > 1 micrometer elemental iodines rganically bounded iodines	0.00080 0.00100 0.00050	0.00250 0.01500 0.00015	0.00300	0.00850	0.00080						

cial solution for assignment of random variable range is demonstrated on the following panels:

			LHS generator of the HARP s	ystem	
# of vectors	5000	Model uncertainties for Particle	Filter assimilation method applica	tion	
Random fluctuations of model par	ameters				
Scale factor: release intensity - 1.	nom. value	1	0.05-quantile 1	truncation	3,5-sigma 💌
, .	distribution	truncated lognormal	0.95-quantile 100	# of values	11
Scale factor: horizontal atm. dispe	nom. value ersion	1	0.05-quantile 1	truncation	2,5-sigma 💌
,	distribution	truncated lognormal	0.95-quantile 4	# of values	11
Scale factor: dry depo velocity-el	nom. value em l	1	left bound 2	truncation	3-sigma 💌
	distribution	Iogunitorm	right bound  518	# of values	3 3.5-sigma
Fluctuation of wind direction - 1. ho	distribution	uniform 💌	right bound 5	# of values	11
	nom. value	1	left bound -5	truncation	3,5-sigma 💌
Fluctuation of wind direction - 2. hour	distribution	uniform 💌	right bound 5	# of values	11
Wind around fluet during 1, hour	nom. value	1	left bound -1	truncation	1-sigma 💌
wind speed lide, during 1, nour	distribution	uniform 💌	right bound 1	# of values	1
Wind speed fluct during 2 hour	nom. value	1	left bound -1	truncation	1-sigma 💌
	distribution	uniform 💌	right bound	# of values	1
Wind speed fluct. during 3. hour	nom. value	1	left bound -1	truncation	3,5-sigma 💌
1	distribution	uniform 💌	right bound	# of ∨alues	1
Scale factor: release intensity - 2.	nom. value hour	1	0.05-quantile  1	truncation	3,5-sigma ▼
	distribution	truncated lognormal	left.bound 0.5	Standard Standard Quantiles	input input - relative - 0,05 a 0,95 - abs.
ADM11:kor. na výšku směš, vrstv	y distribution	truncated lognormal uniform discrete uniform loguniform triangle	right bound 1.5	Quantiles Quantiles Quantiles	- 0,10 a 0,90 - abs. - 0,05 a 0,95 - rel. - 0,10 a 0,90 - rel.
(	Correlation settings		Save the panel	P	eset
	)		Log data and a	0	

Prediction of <sup>131</sup>I contamination on terrain juster after three hours from release start. Red squares are real positions of the Czech Radiation Monitoring Network measurement stations. Objective: improvement of model predictions in early phase on basis of incoming measurements.

#### Acknowledgment

This work is part of the grant project GAČR No. 102/07/1596 funded by Grant Agency of the Czech Republic and the research center DAR. A lot of useful knowledge has been also acquired during RODOS customization procedure for the Czech territory.

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