

Disease mapping

RIF: a tool for epidemiologists

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Rapid Inquiry Facility (RIF)

- Development: Small Area Health Statistics Unit (SAHSU)
- Free and integrated in ESRI® ArcGIS
- Aim: automated generation and representation of classical epidemiological and public health indicators based on routinely collected health and population data
- Altered and adapted for:
 - European countries: EUROHEIS (European Health and Environment Information System for Exposure and Disease Mapping and Risk Assessment)
 - US Centers for Disease Control and prevention(CDC) : EPHT (Environmental Public Health Tracking) Network

Rapid Inquiry Facility

- Two types of analysis
 - Risk analysis around putative hazardous sources
 - Disease mapping

Disease mapping via the RIF

4 characteristics to be defined:

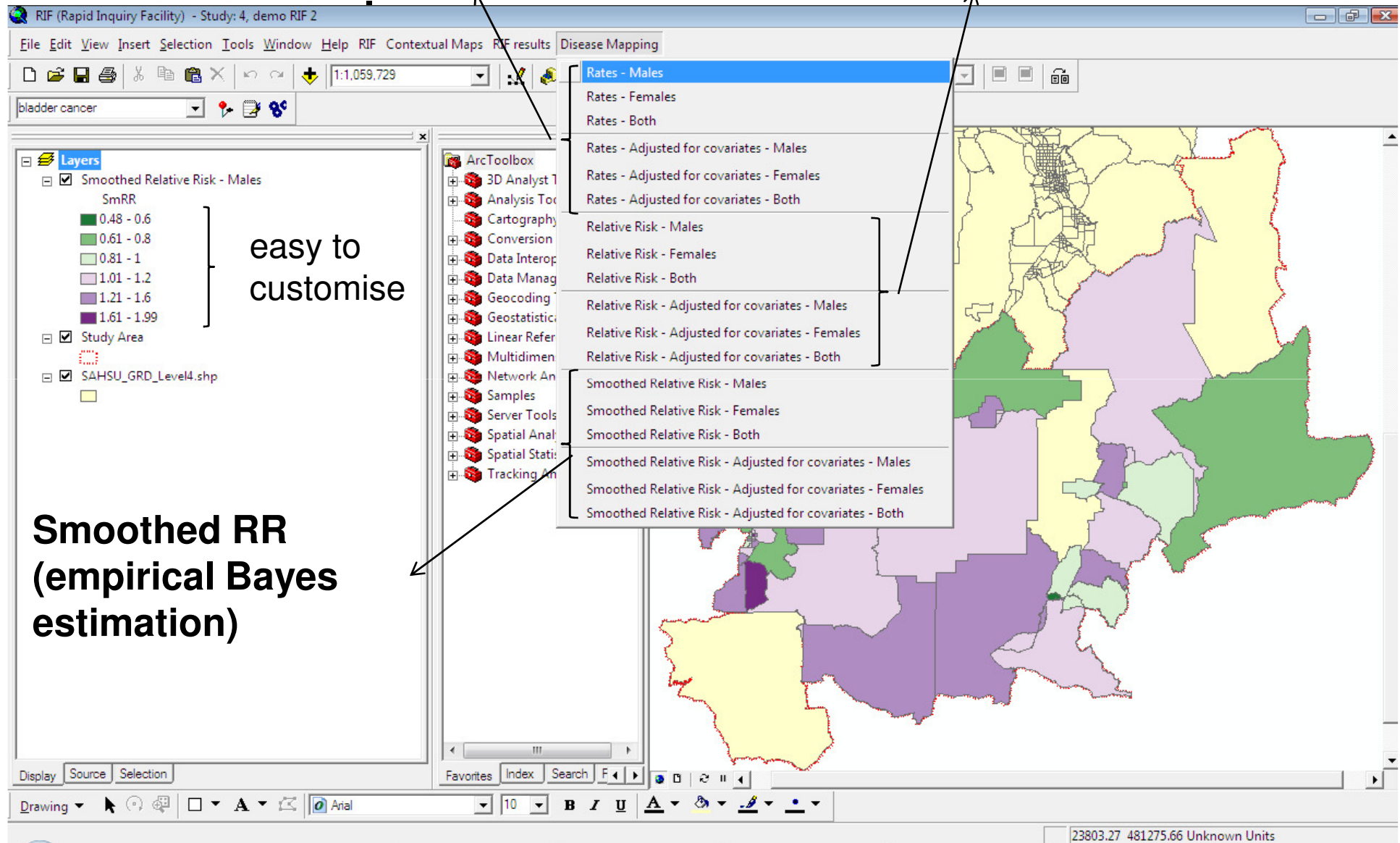
- Geographical level and reference area
 - Ward level, South East England
- Health outcomes
- Population
- Gender, age groups, adjustment covariates

Results presented as maps and/or tables

- Mortality/incidence rates
- SMR (Standardized Mortality Ratio)
- smoothed SMR (empirical Bayes estimation)

Mortality/Incidence rates per 100,000

SMR (Observed/expected)



Smoothed RR (empirical Bayes estimation)

Excel table: same results + 95% CI + expected numbers

Book1 - Microsoft Excel

Home Insert Page Layout Formulas Data Review View Developer Add-Ins

Clipboard Font Alignment Number Styles Cells Editing

B1 Males

1	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	AG	AH	AI
2	LEVEL4	LEVEL3	LEVEL	LEVEL	OBSERV	EXP_UNA1	RR_UNAD	RRL95UNA	RRU95UNA	SMRR_UNA	RATE_UNA	RATEL95UNA	RATEU95UNA	EXP_ADJ	RR_ADJ	RRL95ADJ	RRU95ADJ	SMRR_AD	RATE_AD	RATEL95A	RATEU95A							
3	01.014.017200.2	01.014.017200	01.014	01	8	10.2695406	0.77900271	0.336334422	1.534927472	0.89572639	27.58927555	11.54798279	54.98227065	10.0840368	0.79333308	0.34252156	1.56316367	0.90203362	28.4986079	12.0300121	56.59421275							
4	01.014.017200.3	01.014.017200	01.014	01	16	7.94249008	2.01448159	1.151402131	3.27139219	1.665677688	78.30699772	44.30973944	127.8175199	7.91265673	2.02207685	1.1557433	3.28372643	1.65262858	81.7475867	46.3440711	133.3060543							
5	01.014.017200.4	01.014.017200	01.014	01	16	10.3324977	1.54851232	0.885071574	2.51468723	1.40858104	62.48700335	35.28522197	102.1012096	12.3390441	1.29669688	0.7411431	2.1057547	1.23920346	60.7411474	34.704056	98.65920478							
6	01.014.017200.5	01.014.017200	01.014	01	4	7.24182495	0.55234686	0.150514547	1.414284392	0.791611766	20.0695428	5.423208114	51.48618234	7.2467417	0.55197221	0.15041243	1.41332483	0.78771124	21.9470443	5.90701812	56.35317598							
7	01.014.017200.7	01.014.017200	01.014	01	20	15.4064406	1.29815838	0.792980049	2.004875808	1.25550145	54.43027301	33.2594621	84.04710316	14.3737884	1.39142162	0.8499499	2.14891156	1.31414851	52.571907	32.0763929	81.24403323							
8	01.014.017300.1	01.014.017300	01.014	01	18	11.313025	1.59108639	0.942983866	2.514623642	1.44616691	67.22321321	38.26050303	108.4949205	13.186558	1.36502641	0.80900565	2.15734841	1.29042657	60.7913045	34.052761	98.89336427							
9	01.014.017300.2	01.014.017300	01.014	01	20	12.0854567	1.6548816	1.010884425	2.555739143	1.497389124	67.78647599	41.33708943	104.7877507	12.1967561	1.63978027	1.00165978	2.53247665	1.47714642	69.4515574	42.3453002	107.3717588							
10	01.014.017300.3	01.014.017300	01.014	01	10	7.042914	1.41986683	0.680826147	2.611135107	1.296536962	63.92241299	30.04974147	118.5221659	7.27412566	1.37473567	0.65918575	2.5281389	1.26109443	61.2858361	28.8472373	113.5739906							
11	01.014.017300.4	01.014.017300	01.014	01	14	7.18640329	1.94812334	1.065068662	3.268672666	1.605652892	71.29336796	37.7621023	121.4370348	6.38436624	2.19285665	1.19886606	3.6793002	1.69740913	70.2080261	37.4308537	119.2239994							
12	01.014.017300.5	01.014.017300	01.014	01	20	9.71945757	2.057728	1.25696315	3.17795125	1.735620602	81.96337538	49.62629961	127.2012118	10.0115935	1.99768398	1.22028526	3.08522314	1.68719942	82.1325424	49.7705262	127.4052692							
13	01.014.017300.6	01.014.017300	01.014	01	2	3.26699967	0.61218249	0.074074081	2.211509251	0.927795925	45.3360722	5.784173865	162.8893537	3.23394042	0.61844058	0.07483131	2.23411661	0.92287632	47.7623266	6.09372598	171.6067169							
14	01.014.017300.7	01.014.017300	01.014	01	12	6.26490572	1.91543186	0.989799412	3.345940214	1.560071356	82.8972688	42.45732847	145.3947244	6.34804381	1.89034434	0.97683554	3.3021165	1.53178124	83.5423389	42.7559245	146.5752491							
15	01.014.017500.1	01.014.017500	01.014	01	14	8.72572724	1.60445079	0.87717617	2.692039224	1.427551625	70.29247328	37.66700358	119.0815857	8.208224	1.70560647	0.93247943	2.861764	1.46915763	68.8044605	37.1513114	116.1395354							
16	01.014.017600.1	01.014.017600	01.014	01	14	14.7497896	0.94916808	0.518922655	1.592565085	0.995444222	40.29719797	21.94321866	67.74429277	14.9009119	0.93953982	0.51365984	1.57641359	0.98373887	42.5130408	23.0962008	71.54956955							
17	01.014.017600.2	01.014.017600	01.014	01	8	5.95595897	1.3431926	0.579923404	2.646593113	1.243356278	71.32453834	30.52032421	141.0040619	5.95140376	1.34422068	0.58036728	2.64861892	1.23173744	76.5673412	32.6325063	151.5928853							
18	01.014.017600.3	01.014.017600	01.014	01	4	8.34722907	0.47920094	0.130582256	1.226994002	0.726788916	17.81584449	4.527567569	46.31942809	8.01145439	0.49928512	0.1360552	1.27841956	0.74264533	19.3907457	4.97855226	50.0514825							
19	01.014.017600.4	01.014.017600	01.014	01	4	3.66511948	1.0913696	0.297398217	2.794451873	1.112737018	47.89508524	13.19456122	122.3283055	3.37288494	1.18592839	0.32316549	3.03656963	1.13733437	46.2057069	12.6885023	118.1081427							
20	01.014.017600.5	01.014.017600	01.014	01	4	10.7938097	0.37058278	0.100983807	0.948877207	0.615276189	15.5246319	4.234500518	39.74215771	10.7560185	0.37188482	0.10133961	0.95221108	0.61613352	16.6336575	4.52763372	42.60128635							
21	01.014.017700.1	01.014.017700	01.014	01	10	8.56050767	1.16815502	0.560130332	2.14823708	1.153045113	49.39793243	22.91247731	92.0901454	8.58227975	1.16519157	0.55870936	2.14278729	1.14272826	51.7362119	23.8205048	96.7338645							
22	01.014.017700.2	01.014.017700	01.014	01	22	23.8923683	0.92079612	0.577046185	1.394085323	0.957539058	40.25259598	25.06128891	61.16853288	24.8100284	0.8867382	0.55570271	1.34252164	0.92579159	34.119486	21.3475238	51.7044548							
23	01.014.017700.3	01.014.017700	01.014	01	18	8.39805159	2.1433543	1.270294649	3.387452398	1.75727823	94.9823799	56.33497902	150.054399	7.964488332	2.26003361	1.33944659	3.57185757	1.79635381	103.855278	61.5487352	164.1415242							
24	01.014.017700.4	01.014.017700	01.014	01	14	7.83542356	1.78675727	0.76845723	2.997923444	1.525412907	57.24569896	29.28429392	99.0602828	7.10262639	1.86411589	1.01913879	3.12772016	1.548886163	57.1309327	29.651643	98.22429224							
25	01.014.017700.5	01.014.017700	01.014	01	8	16.7637418	0.47722043	0.206039919	0.940303197	0.630189883	21.34267991	8.648271662	43.02035066	16.6666157	0.48000147	0.20724063	0.94578289	0.6324031	22.7240149	9.15188638	45.9005291							
26	01.014.017700.6	01.014.017700	01.014	01	22	21.9782997	1.00098735	0.627300572	1.515494847	1.025094645	42.36384454	26.54956007	64.13760917	23.1300104	0.95114527	0.59606545	1.44003394	0.98039382	40.2512048	25.2204352	60.94619358							
27	01.014.017700.7	01.014.017700	01.014	01	14	11.2346814	1.24614126	0.681823226	2.090847006	1.20897856	40.4053144	20.51126487	70.15551924	10.4966228	1.33376232	0.71381691	2.23786263	1.25706499	39.2058232	23.132434	54.80876549							
28	01.014.017700.8	01.014.017700	01.014	01	34	27.060643	1.25643726	0.870119753	1.755760202	1.23588585	54.84574172	37.87305689	76.78326969	31.0602471	1.0946468	0.7580751	1.52967231	1.09642328	48.170805	33.3589127	67.3154663							
29	01.014.017800.1	01.014.017800	01.014	01	24	15.028684	1.59694621	1.023176746	2.376122884	1.477213452	66.1930014	41.49718677	99.72982029	15.179479	1.58108193	1.01301237	2.35251816	1.4573788	65.5713943	41.0176847	98.91523509							
30	01.014.017800.2	01.014.017800	01.014	01	18	21.312813	0.84456238	0.500543968	1.334783914	0.899727131	36.46975866	17.88447481	57.88447343	19.107016	0.94652095	0.56097142	1.49592378	0.98172151	39.2048341	21.1425449	56.83940683							
31	01.014.017800.3	01.014.017800	01.014	01	36	33.8699694	1.06298847	0.744435275	1.471480513	1.071476684	43.91970886	30.74934496	60.81363418	31.6616864	1.13702093	0.79635682	1.57411072	1.13263849	43.5747787	30.511459	60.33569857							
32	01.014.017800.4	01.014.017800	01.014	01	24	24.2599043	0.98928667	0.333844214	1.471976126	1.013573392	36.83124779	23.55523753	54.8600198	25.5777739	0.93831865	0.6018602	1.39613401	0.96746992	35.5225023	22.7289456	52.89607624							
33	01.014.017800.5	01.014.017800	01.014	01	34	26.7380791	1.27159471	0.880616739	1.776944143	1.248386717	43.90707166	30.36217045	61.41412209	28.8409597	1.178758012	0.81640834	1.6473793	1.1648341	27.1322343	21.32343	54.80876549							
34	01.014.017900.1	01.014.017900	01.014	01	22	8.79760446	2.50068074	1.56713151	3.786030637	1.993693687	96.05604694	59.98107245	145.7255723	2.07104001	1.29788312	1.31355458	1.74784462	96.5868218	60.4450869	146.3482656								
35	01.014.017900.2	01.014.017900	01.014	01	52	34.5484077	1.50513449	1.124103905	1.97378127	1.456185938	66.09731435	48.86443587	87.29281234	30.7513202	1.69098431	1.26290513	2.21749829	1.60433159	64.7437771	47.9428628	85.40798277							
36	01.014.018000.1	01.014.018000	01.014	01	18	22.3829553	0.80418335	0.864759211	1.73967109	0.867460645	20.09411621	20.09411621	57.17358814	22.8694526	0.78707612	0												

Disease mapping issues

- Small areas and/or rare diseases
 - Low counts of observed cases/ small populations
 - Numerical instability of SMRs
 - Extreme risks associated to low populated areas
 - Small SE in highly populated areas: $SE(\log(SMR)) \propto E^{-1/2}$
 - Adjacent areas might show opposite risks
- Mapping the SMRs not allow to detect any spatial pattern

➡ Smoothing the SMRs via Bayesian hierarchical models

Smoothing using the RIF

- model BYM (Besag et al,1991)

$$O_i \sim \text{Poisson}(E_i \rho_i)$$

$$\text{Log}(\rho_i) = \alpha + U_i + V_i$$

- O_i, E_i : observed and expected number of cases in area i
 - ρ_i : unknown relative risk in area i
 - U : Spatially structured random effects \rightarrow local smoothing
 - V : Unstructured random effects \rightarrow global smoothing
-
- RIF runs externally the BYM model using WinBUGS or INLA

[..\..\RIF\example DiseaseMapping RIF\RIF v3.13 link to INLA.wmv](#)

RIF issues

- Limitations
 - Single model
 - Poisson model with BYM distribution for residual effects
 - Prior distribution on precision parameters: $\text{Gamma}(0.5, 0.0005)$
 - Fixed number of iterations for WinBUGS
 - No convergence diagnostics tool
- Advantages
 - Interface easy to use
 - Input files saved -> re-run modified models
 - Support (Linda Beale)

Improvements in process

Protocol developed for an atlas (South East England), in collaboration with Nicky Best

With WinBUGS and INLA

1. Parameters of interest
2. Sensitivity analyses
3. Convergence Monitoring for WinBUGS / accuracy of the approximation for INLA
4. Comparison of the results WinBUGS / INLA (?)
if the user wants to use both softwares

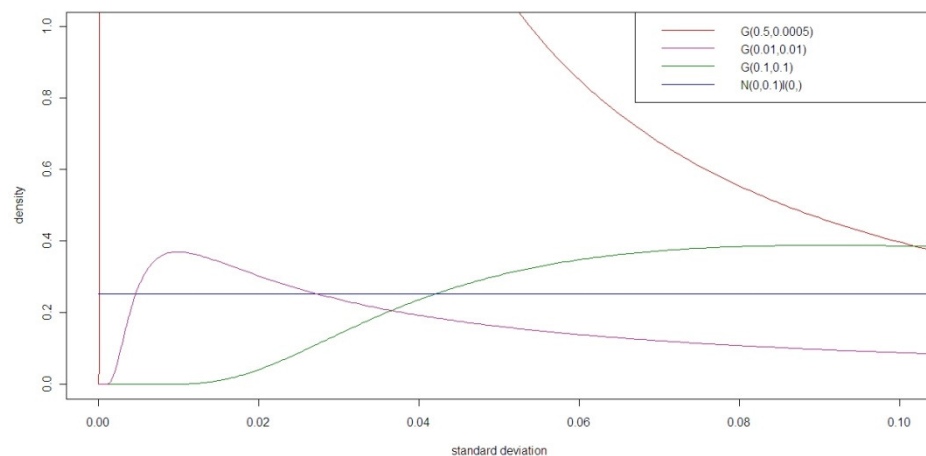
1. Parameters of interest

- Actual parameters
 - Smoothed SMR: overall risk + specific area risk ($\exp(\text{BYM})$)
 - Smoothed RR: specific area risk ($\exp(\text{BYM})$)
 - Posterior probabilities
- Added parameters: quantitative summaries of the spatial variability
 - **R.90.10**: ratio between the 90th and 10th percentile of the posterior distribution of the smoothed SMR/RRs
 - Indicator of the variability across the study region
 - **Spatial fraction**: relative contribution of spatial vs unstructured heterogeneity to the overall variability

2. Sensitivity analyses (default)

Priors for the precisions (N=4)

- Gamma distributions
- Truncated Normal distribution



Structure on the residuals (N=3)

- Heterogeneity only
- CAR model only
- BYM (heterogeneity + CAR)

Comparison of 12 models:

-DIC

-R.90.10

-posterior variance summaries

3. checking CV/accuracy of the approximation

- Visual checks
 - posterior densities of:
 - RR for 5 areas based on the expected numbers
(2.5, 25, 50, 75 and 97.5 percentile of the distribution of the expected numbers)
 - variance parameters
 - Autocorrelation (MCMC) of variance parameters

- Statistics

Pop-up windows
with warnings

WinBUGS	INLA
Gelman and Rubin diagnostics $R < 1.05$	Number of replicates > 2 expected number of parameters/size of data
Monte Carlo error $< 5\%$ of sd	Symmetric Kullback-Leibler divergence (SKLD) between the Gaussian and the Laplace approximation

Suggestions and comments are
welcome!