HelmholtzZentrum münchen
German Research Center for Environmental Health

Is the human sex odds at birth distorted in the vicinity of nuclear facilities (NF)?

A preliminary geo-spatial-temporal approach

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HELMHOLTZ ASSOCIATION

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Background / Motivation

- The Helmholtz Center Munich is a leading research centre in Europe in the field of environmental health
- Identification of environmental hazards: e.g. chemical toxins (endocrine disruptors), nano particles, particulate matter, ozone, ionizing radiation, non-ionizing radiation
- Identification of mechanisms of general health detriment for plants, animals, and humans, especially genetic effects
- Risk assessment – qualification and quantification of risks
- **The focus in this presentation is on ionizing radiation (IR) and possible radiation induced changes in the human sex odds at birth (SO) near Nuclear Facilities (NF)**

- **An influence of IR on the SO potentially indicates genetic damage**

Background / Motivation: Sex Odds (SO) vs. Sex Ratio (SR)

- Traditionally, the **SR** is the pertinent term for the number of newborn boys divided by the number of newborn girls

$$\mathbf{SR = boys/girls = m/f}$$

- However, considering the male probability

$$\mathbf{p_{male} = boys/(girls + boys) = m/(m+f)}$$

leads to considering the important and methodologically more appropriate sex odds

$$\mathbf{SO = p_{male}/(1- p_{male}) = boys/girls = SR}$$

- Comparing two **SO** leads to the obvious and natural measure **Sex Odds Ratio**

$$\mathbf{SOR = SO_{exposed}/SO_{nonexposed}}$$

- **The inconvenient term "sex ratio ratio" is avoided**

Background / Motivation: SO and IR

Genetic theory for the human sex odds at birth

Irradiated parents and offspring gender

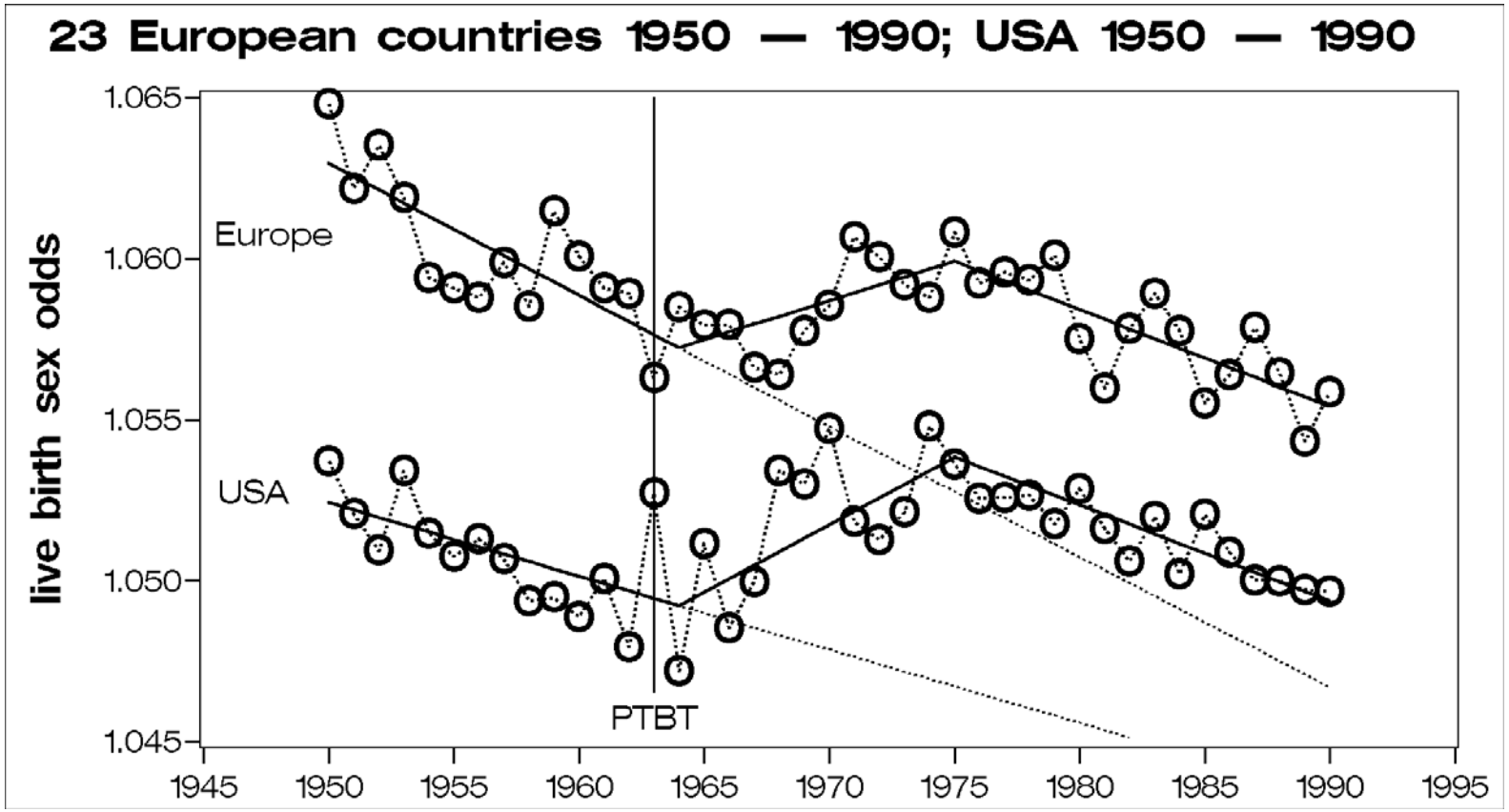
Fathers only	=>	sex odds ↑
Mothers only	=>	sex odds ↓
Both parents	=>	**???**

Schull WJ, Neel JV *(1958). Radiation and the sex ratio in man. Science 128: 343-348*

Dickinson HO et al. *(1996). The sex ratio of children in relation to paternal preconceptional radiation dose. J Epidemiol Community Health 50(6): 645–652*

Padmanabhan et al. *(2004) Heritable anomalies among the inhabitants of regions of normal and high background radiation in Kerala. Int J Health Serv 34 (3), 483-515*

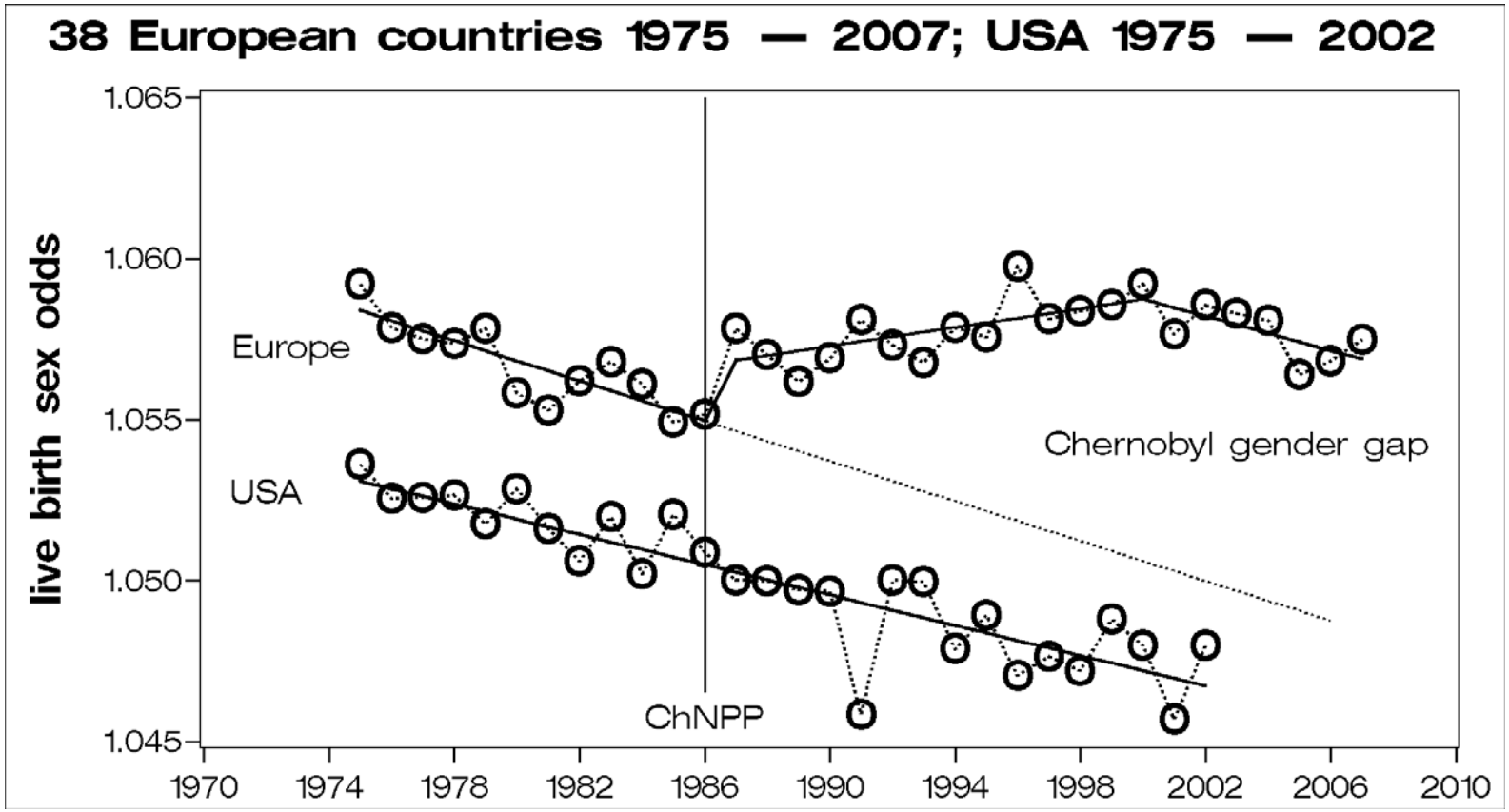
Background / Motivation: SO and Atmospheric Atomic Bomb Testing



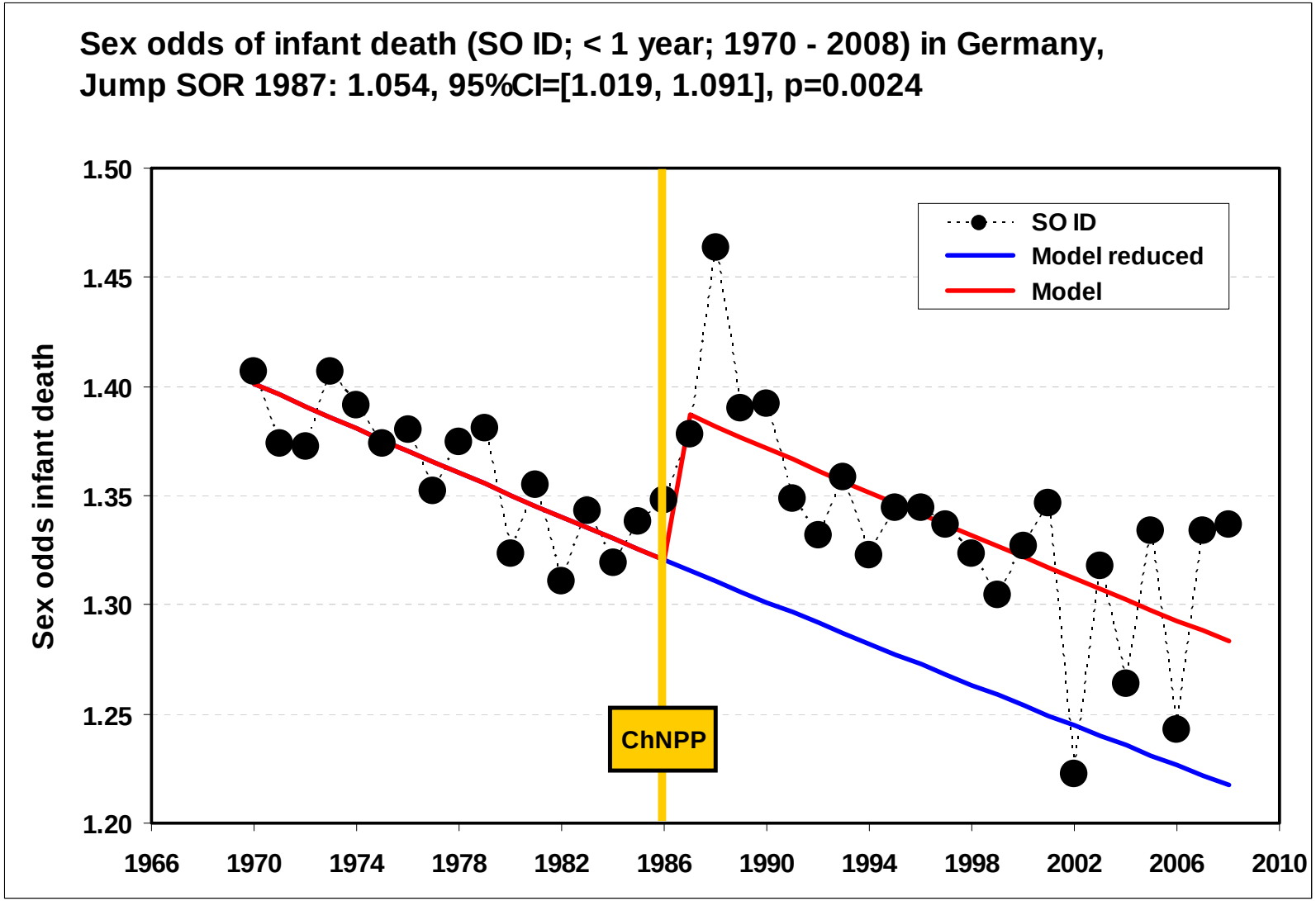
Trends of the live birth sex odds (male:female) in Europe and in the USA, 1950 to 1990 (Martuzzi et al. 2001; Mathews and Hamilton 2005), Synoptic reanalysis, submitted to ESPR, Environmental Science and Pollution Research

PTBT: Partial Test Ban Treaty

Background / Motivation: SO and Chernobyl in Europe and USA

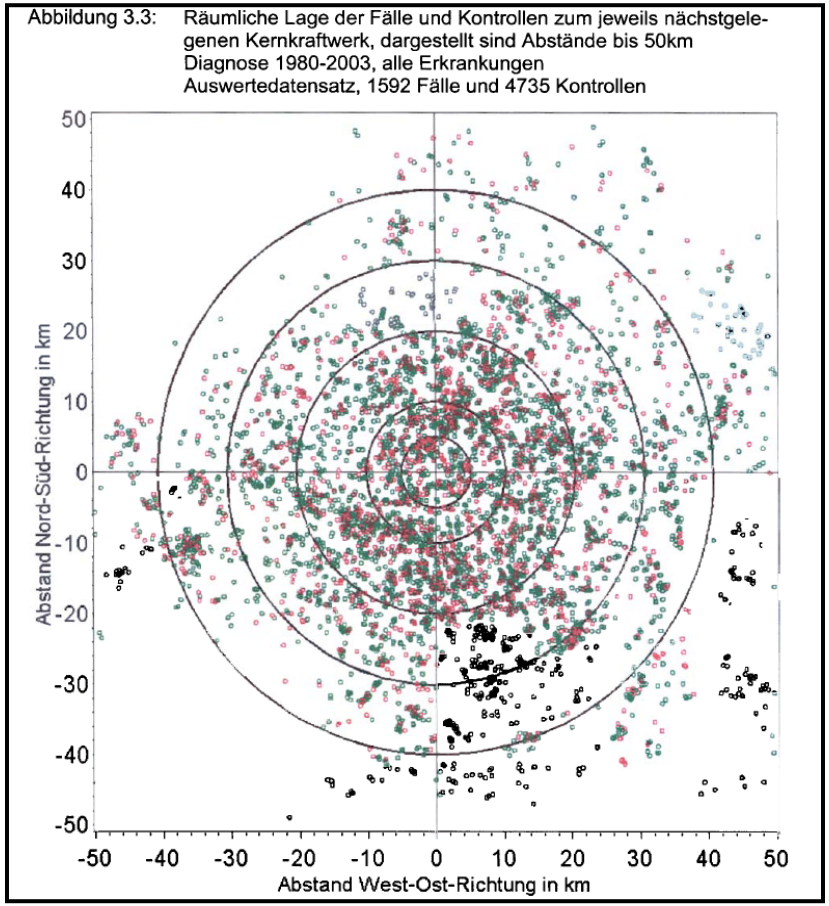


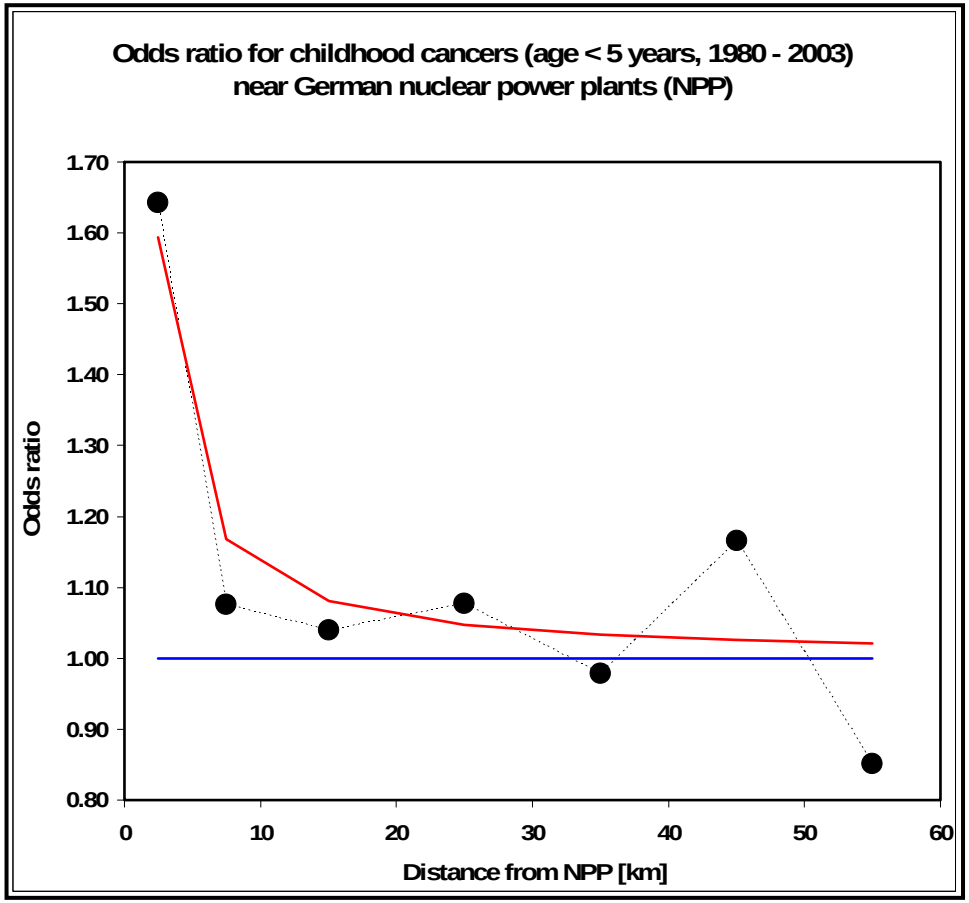
Background / Motivation: SO Trend of Infant Death in Germany



Background / Motivation: KiKK study

Childhood cancers are increased near nuclear power plants in Germany





Background / Motivation: Summary

- $SO_{Live\ Birth}$ disturbed after the atmospheric bomb testing world wide
- $SO_{Live\ Birth}$ disturbed after Chernobyl in Europe and not in the USA
- $SO_{Stillbirth}$ disturbed after Chernobyl in Europe (http://ije.oxfordjournals.org/content/29/3/596.full)
- $SO_{Infant\ Death\ <\ 1\ year}$ disturbed after Chernobyl in Germany
- Childhood cancers increased near German Nuclear Power Plants (NPP)
- **The question arises:** Is the SO also disturbed in the vicinity of NPP, or more generally, in the vicinity of NPP and Nuclear storage/processing Facilities (NF)?
- This question was first raised by the first author **Ralf Kusmierz** after he had perceived our Chernobyl–SO as well as the KiKK results. **Ralf Kusmierz** initiated this pilot study and he compiled and provided all the data including the uniform geographic coordinates for the municipalities and NF under study.

Data

Official annual gender and municipality specific live birth data for the study region

- **Belgium,**
- **Switzerland**
- **German states**
  - **Baden-Württemberg**
  - **Bavaria**
  - **Lower Saxony**
  - **North Rhine-Westphalia**
  - **Rhineland-Palatinate**

Official geographic coordinates of municipalities – at marked “central locations”

Official geographic coordinates of Nuclear Facilities (NF)

Operation time periods of those NF

Data: Municipalities and Live Births (LB)

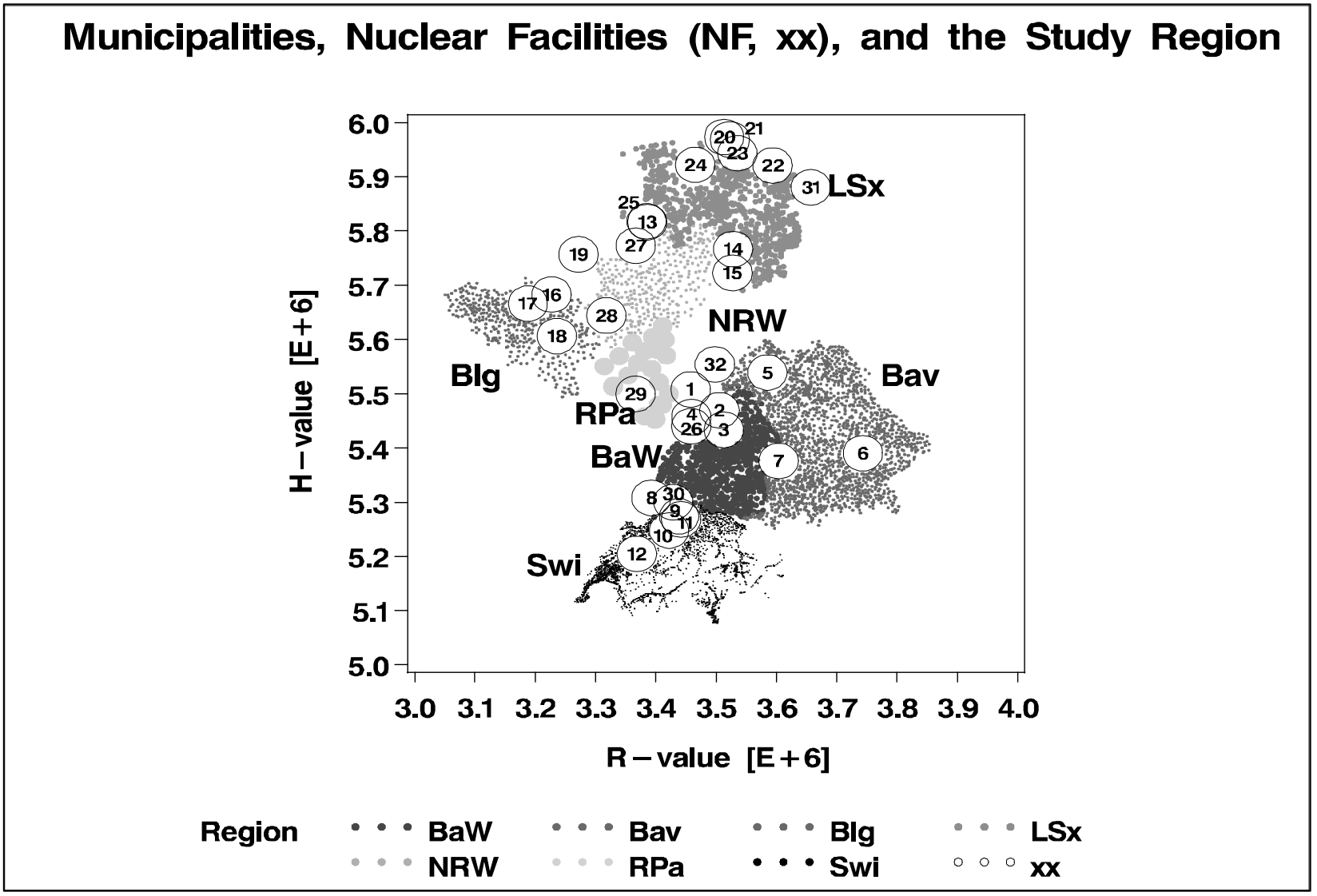
Region	Code of region	Municipalities
Baden-Württemberg	2	1 102
Bavaria	1	2 056
Belgium	5	589
Lower Saxonia	6	1 024
North Rhine-Westphalia	4	396
Rhineland-Palatinate (districts)	8	36
Switzerland	3	2 706
Combined		**7 909**

Region	Data available	Total births	Male births	Sex odds
Baden-Württemberg	1975 - 2008	3 498 211	1 795 839	1.0549
Bavaria	1972 - 2008	4 366 993	2 241 831	1.0549
Belgium	1989 - 2007	2 230 030	1 141 451	1.0486
Lower Saxonia	1971 - 2008	2 863 561	1 470 778	1.0560
North Rhine-Westphalia	1980 - 2008	5 033 665	2 584 664	1.0554
Rhineland-Palatinate	1970 - 2008	1 468 616	754 120	1.0555
Switzerland	1969 - 2008	3 182 400	1 633 929	1.0552
Combined		**22 643 476**	**11 622 612**	**1.0546**

Data: Nuclear Facilities by Type

NF	Type
Brunsbuettel	BWR
*Dodewa**	*BWR*
Gundremmingen	BWR
Karlsruhe	BWR
Kruemmel	BWR
Leibstadt	BWR
Lingen	BWR
Muehleberg	BWR
Wuergassen	BWR
Isar I und II	BWR/PWR
Philipsburg	BWR/PWR
Hanau/Kahl	NFE
Ahaus	NSS
Gorleben	NSS
Juelich	NSS
Beznau I und II	PWR
Biblis	PWR
*BR**	*PWR*
Brokdorf	PWR
*Doel**	*PWR*
Emsland	PWR
Fessenheim	PWR
Goesgen	PWR
Grafenreihnfeld	PWR
Grohnde	PWR
Neckarwestheim	PWR
Obrigheim	PWR
Stade	PWR
*Tihange**	*PWR*
Unterweser	PWR
Ellweiler	UM
Menzenschwand	UM

Data: Municipalities, Nuclear Facilities and the Study Region



Statistical Methods

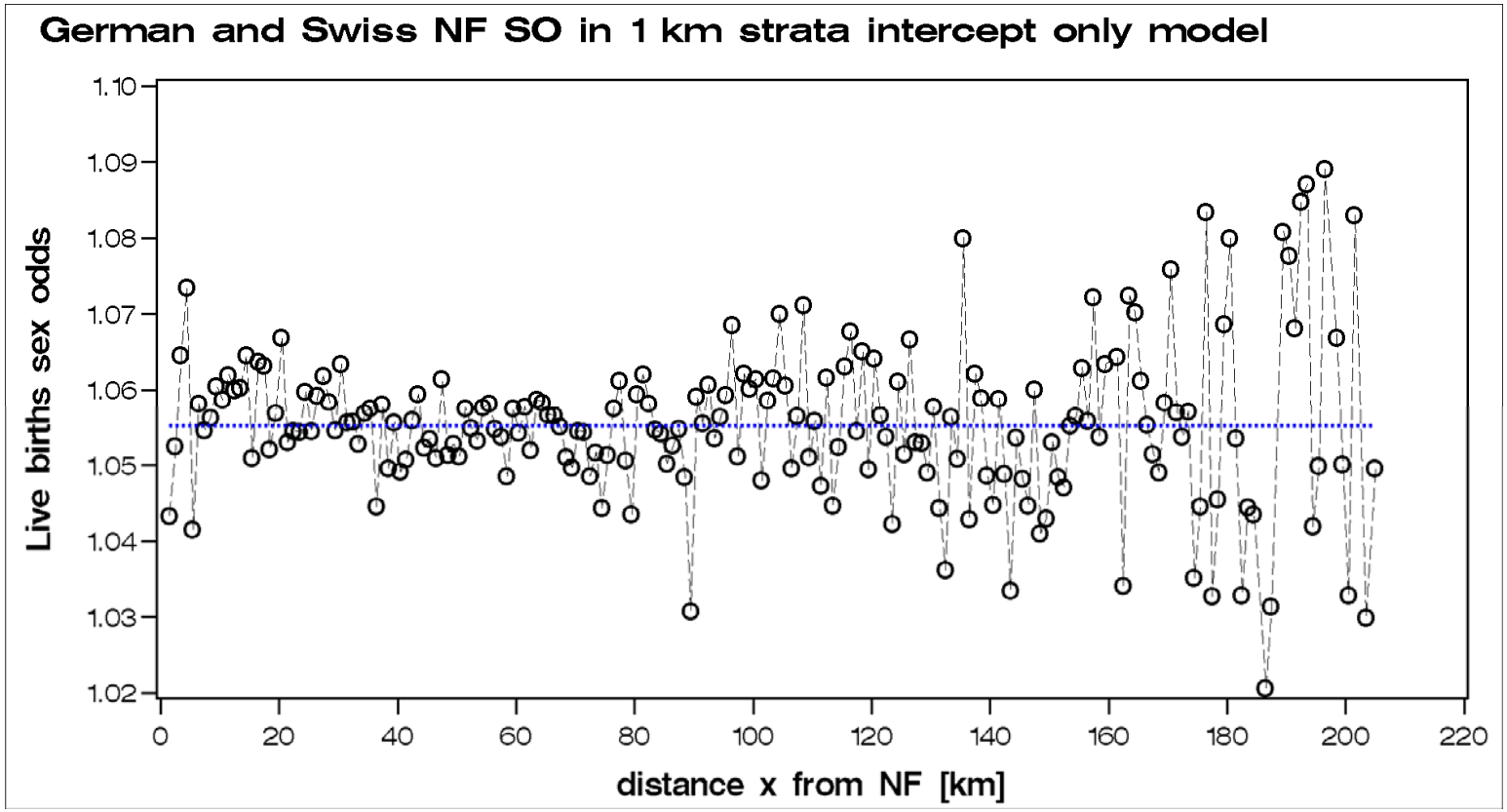
Logistic model

- LB: Live Birth, π_x Binomial probability parameter at distance x
- $Boys_x \sim Binomial(LB_x, \pi_x)$
- **Simple example:** Constant jump below 5 km distance

  d5(x) = 1 for x < 5 km; d5(x) = 0 for x ≥ 5 km (x = distance [km])

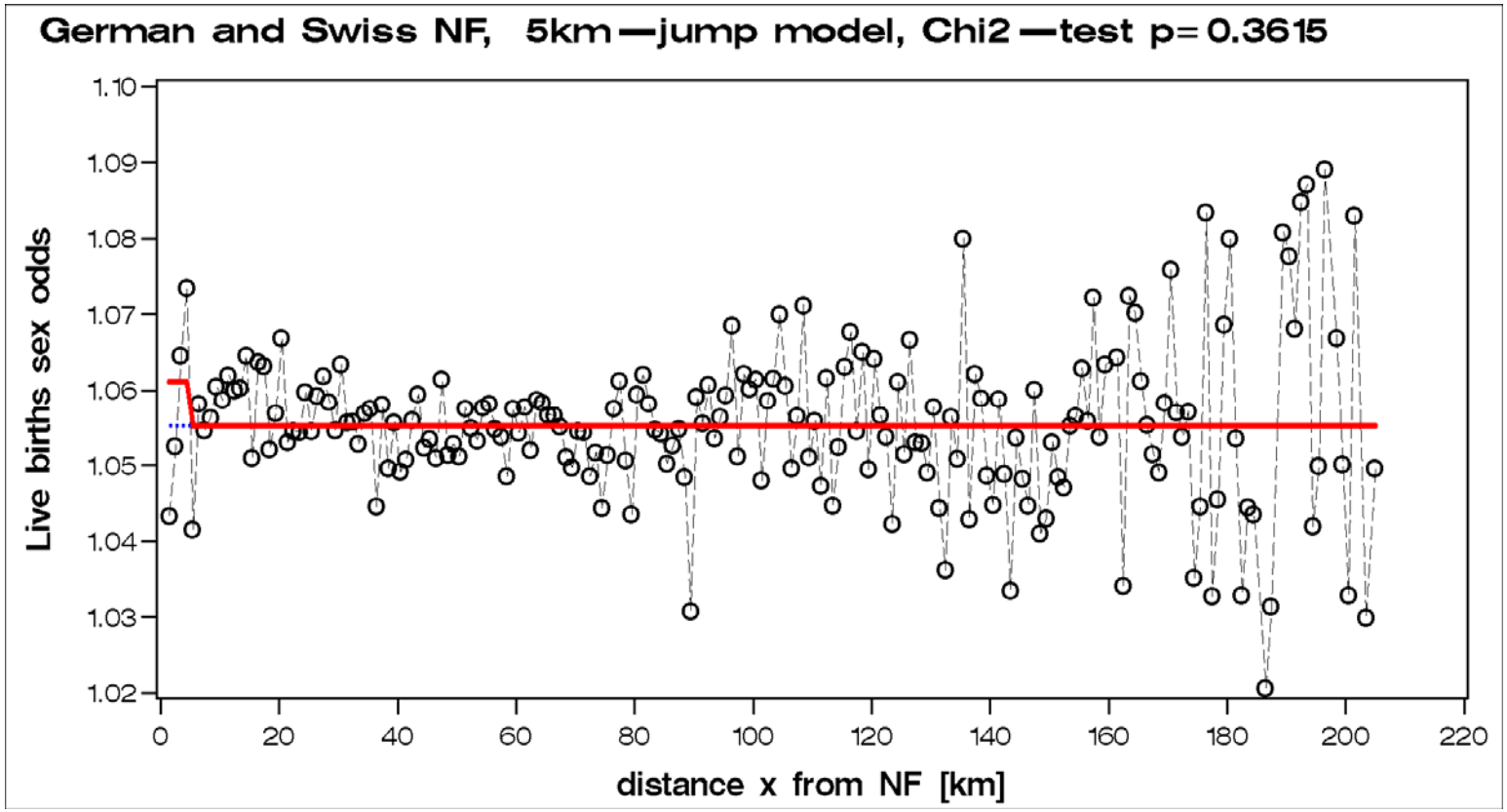
$$\log \text{ odds}\left(\pi_x\right) = \text{intercept} + \alpha * \text{d5(x)}$$

Results: Display of the LB SO in Aggregated 1 km Distance Categories

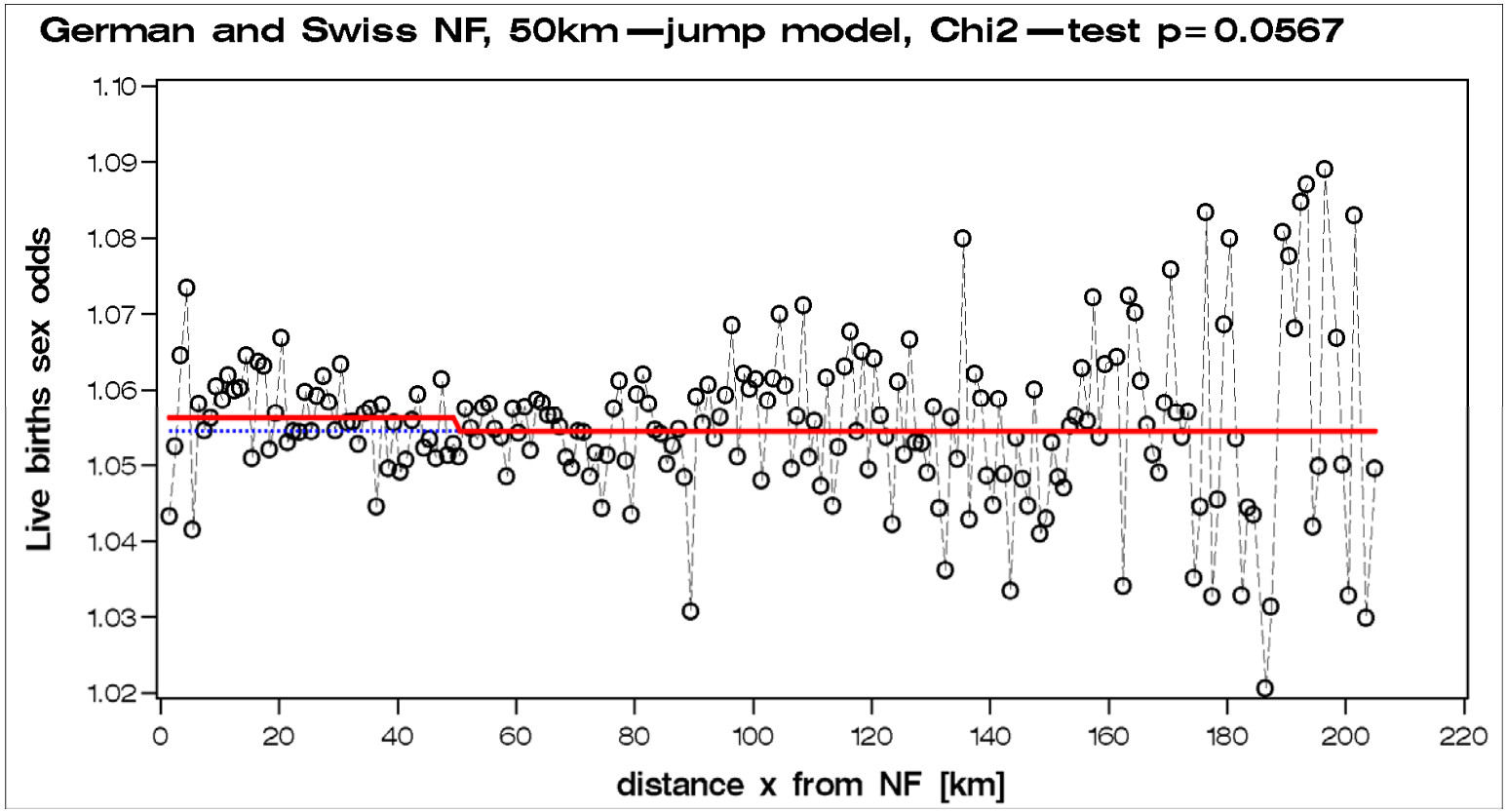


Question / Hypothesis: Is the SO in the vicinity of NF (say 0 < km < 20) different from the SO in the rest of the study region during the respective operation time periods of the NF?

Results: 5 km – Jump Model

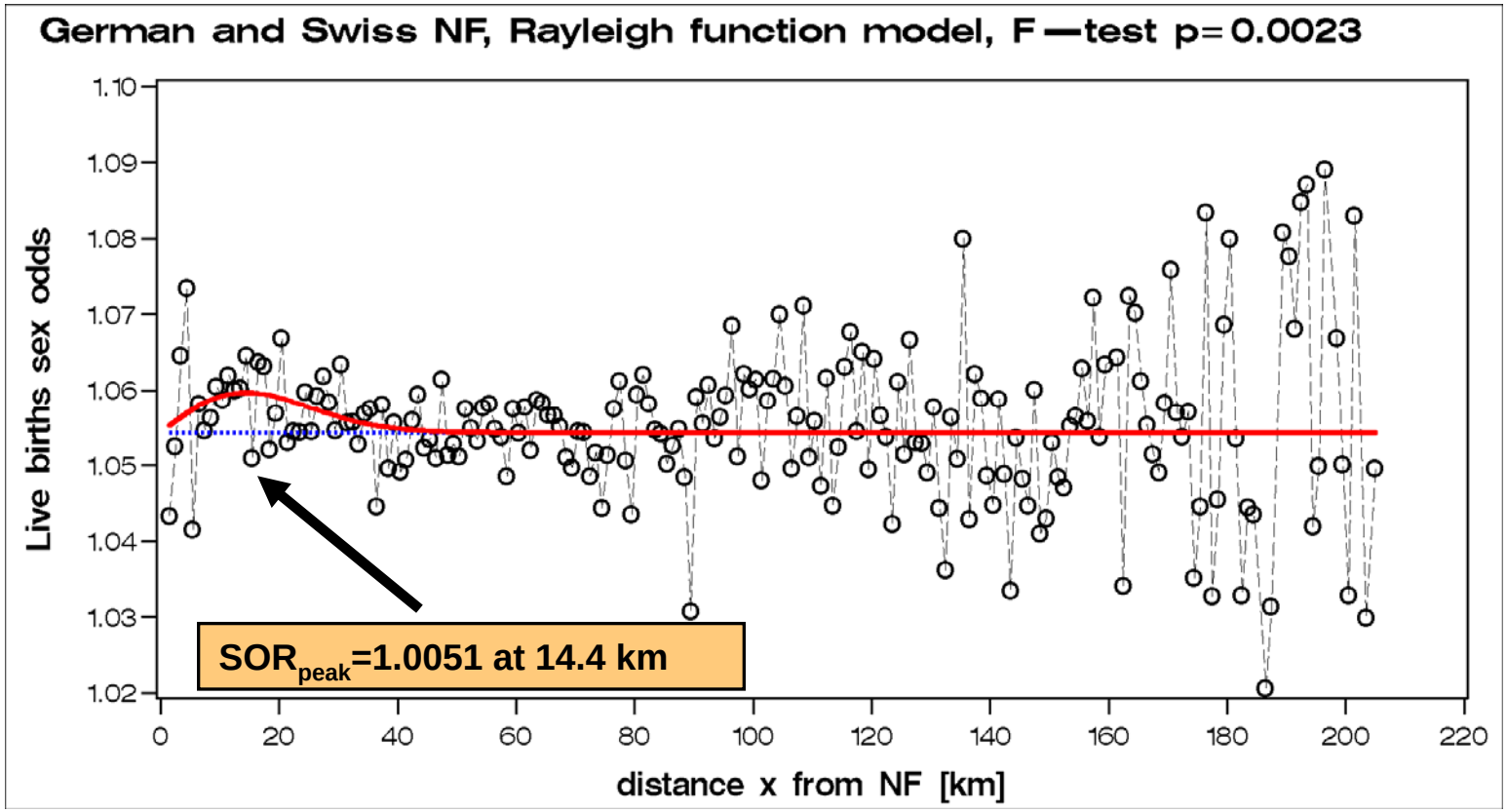


Results: 50 km – Jump Model



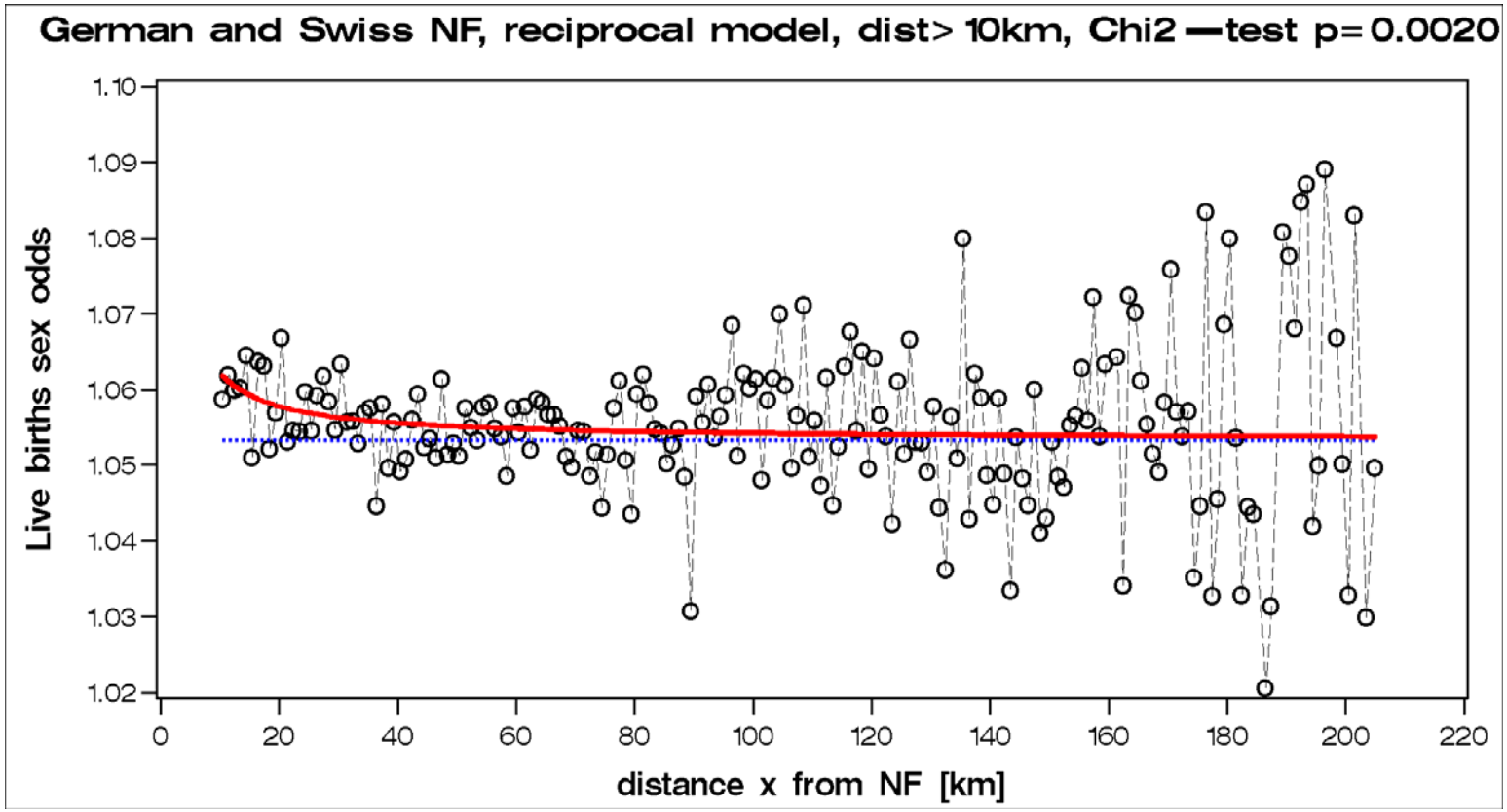
Fixed distances are arbitrary! Therefore, we utilized Rayleigh functions to avoid this.

Results: “Impartial” Rayleigh Function ln(SO) = a+b∗x∗Exp(- c∗x^2)



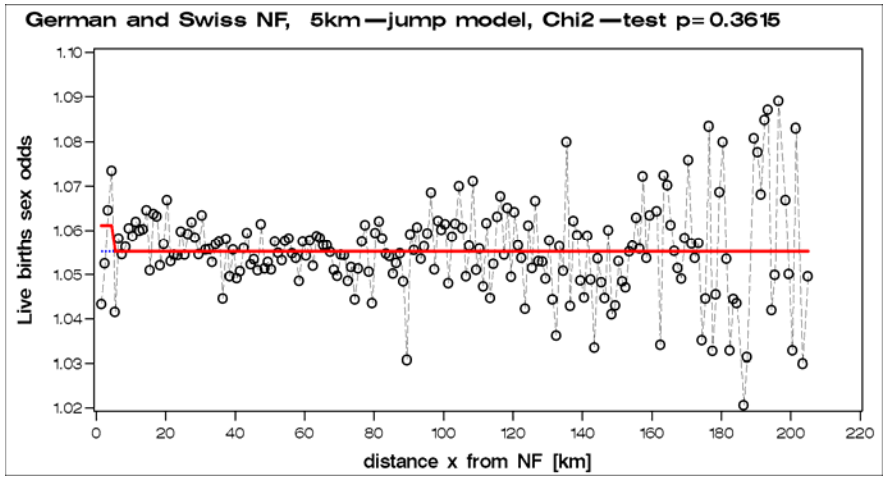
In probability theory and statistics, the Rayleigh distribution is a continuous probability distribution. As an example of how it arises, the wind speed will have a Rayleigh distribution if the components of the two-dimensional wind velocity vector are uncorrelated and normally distributed with equal variance. The distribution is named after Lord Rayleigh. (WIKIPEDIA)

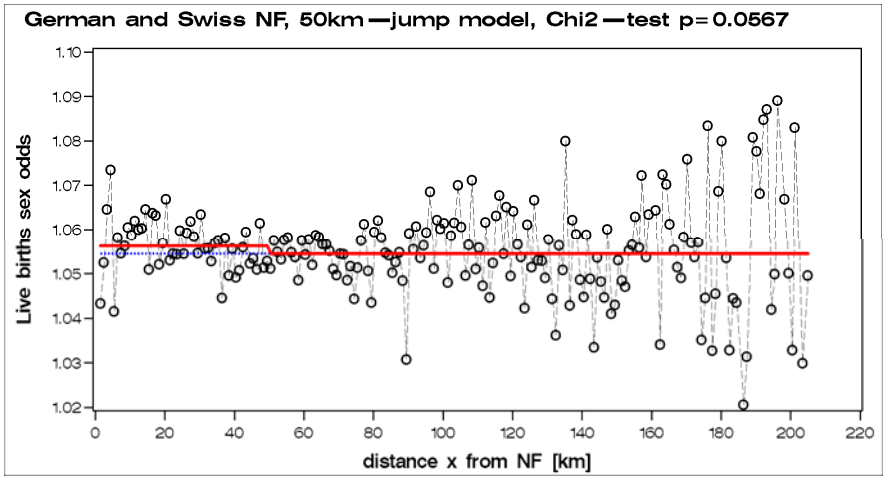
Results: Reciprocal Function Beyond 10 km, ln(SO) = a + b/x

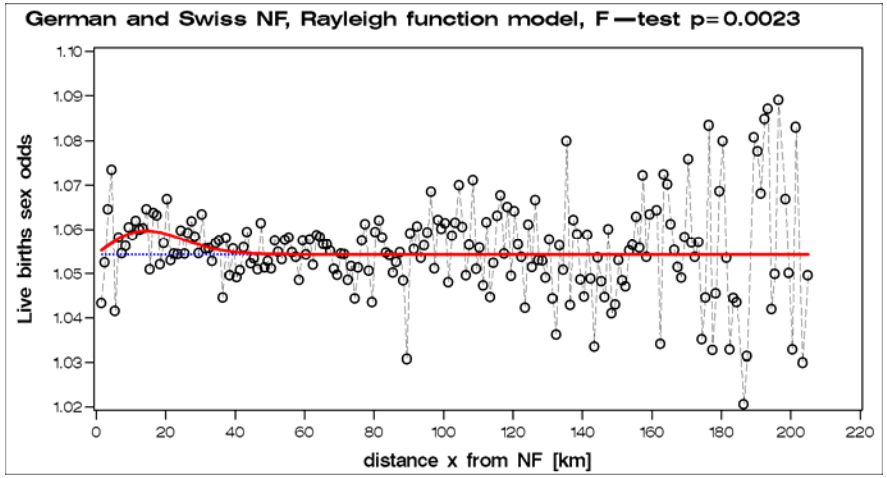


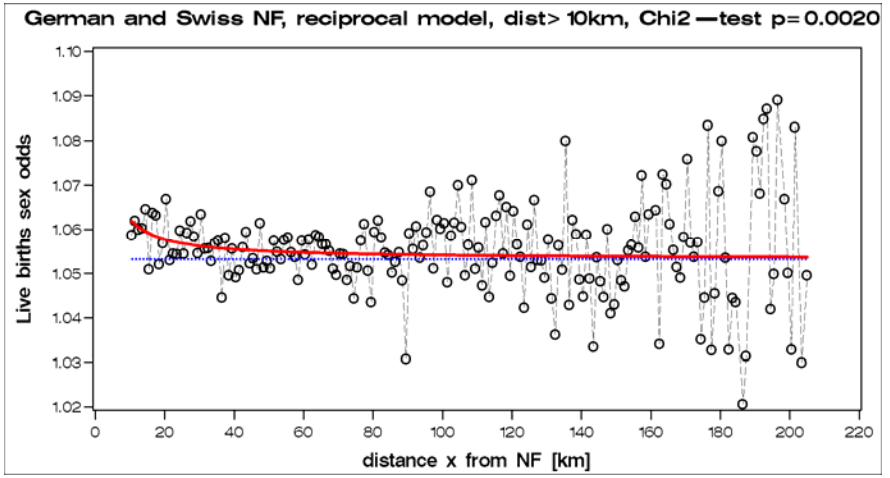
A reciprocal distance law (1/r) was applied in the KiKK study, but here it works only when data are restricted to distances greater than 10 km

Results: Overview on Alternative Models









Results: Single Site Specific Analyses

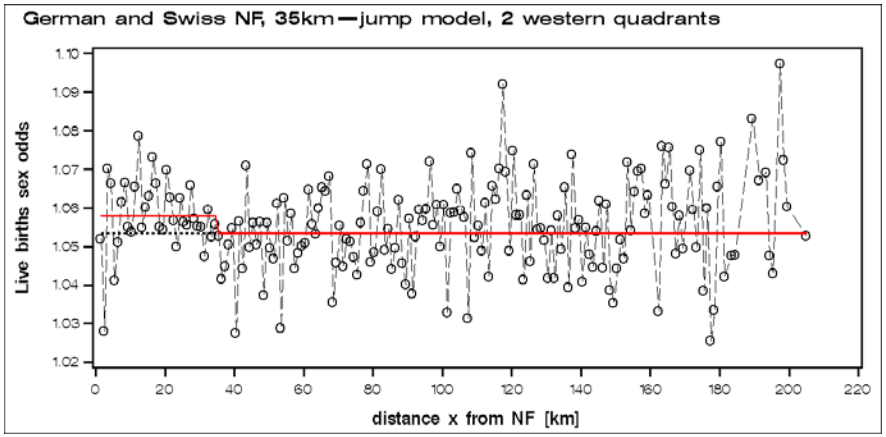
“Optimum” balance between effect and power between 30 and 40 km.

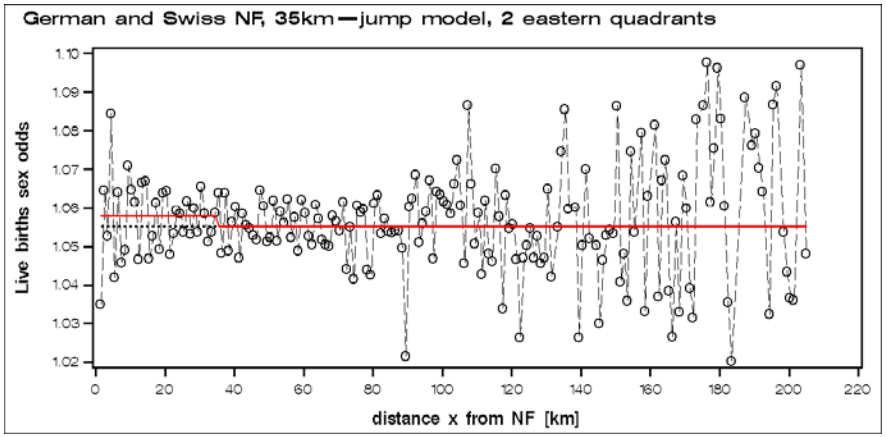
Therefore, we decided to consider 35 km circles around the NF during the respective operation time periods.

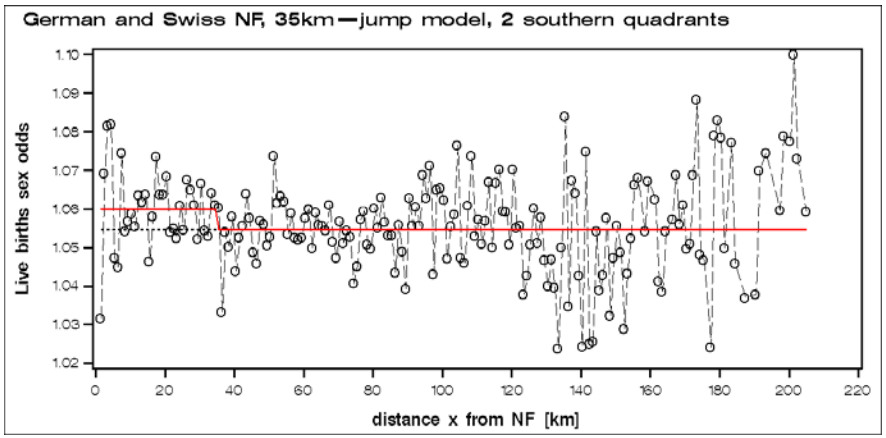
Results: NF and Results for 35 km Circles

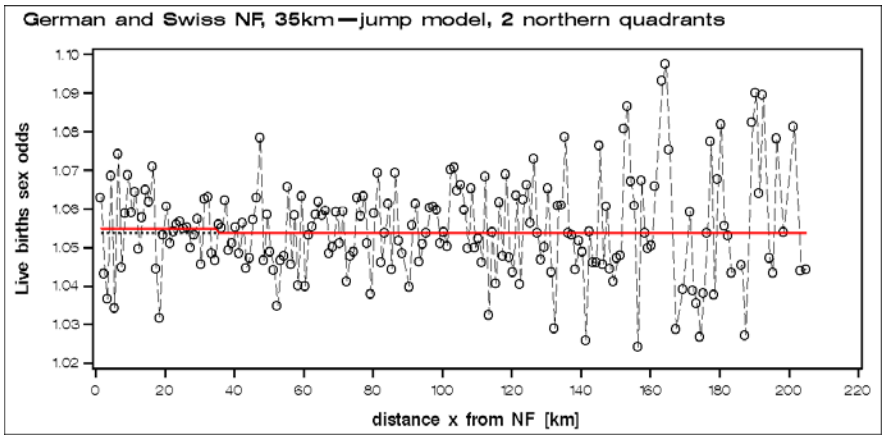
No. (s. Fig. 2)	NF	Type	In operation since/to	Live births < 35 km during NF operation, lagged for gestation		Sex odds ratio vs. last row of this Table	p-value (Chi^2)	hold one NF out p-value (Chi^2), compare to **
				male	female			
1	Biblis	PWR	1975 -	223 648	211 753	1.0017	0.5804	0.0007
2	Obrigheim	PWR	1969 - 2005	164 321	155 447	1.0026	0.4733	0.0010
3	Neckarwestheim	PWR	1976 -	380 463	360 212	1.0017	0.4640	0.0005
4	Philipsburg	BWR/PWR	1980 -	333 967	314 761	1.0063	0.0133	0.0019
5	Grafenreihnfeld	PWR	1981 -	95 714	90 722	1.0006	0.8957	0.0007
6	Isar I und II	BWR/PWR	1977 -	67 059	63 341	1.0041	0.4627	0.0011
7	Gundremmingen	BWR	1966 -	142 702	135 276	1.0005	0.8986	0.0006
8	Fessenheim	PWR	1977 -	99 148	93 694	1.0036	0.4290	0.0012
9	Beznau I und II	PWR	1969 -	337 335	317 880	1.0065	0.0106	0.0031
10	Goesgen	PWR	1979 -	220 979	208 604	1.0047	0.1308	0.0005
11	Leibstadt	BWR	1984 -	143 467	135 293	1.0057	0.1354	0.0008
12	Muehleberg	BWR	1971 -	218 795	207 560	0.9998	0.9387	0.0004
13	Emsland	PWR	1988 -	55 502	52 301	1.0065	0.2915	0.0011
14	Grohnde	PWR	1984 -	84 739	80 308	1.0008	0.8791	0.0009
15	Wuergassen	BWR	1972 - 1994	34 453	32 643	1.0010	0.8960	0.0010
16	BR*	PWR	1962 - 1987	5 332	5 288	0.9563	-	-
17	Doel*	PWR	1974 -	392 512	375 500	0.9914	-	-
18	Tihange*	PWR	1975 -	122 594	117 476	0.9897	-	-
19	Dodewa*	BWR	1968 - 1997	5 926	5 710	0.9843	-	-
20	Brunsbuettel	BWR	1977 -	21 085	20 003	0.9997	0.9779	0.0010
21	Brokdorf	PWR	1986 -	15 505	14 769	0.9957	0.7073	0.0009
22	Kruemmel	BWR	1984 -	35 882	33 745	1.0085	0.2662	0.0012
23	Stade	PWR	1975-2003	43 456	40 771	1.0109	0.1174	0.0021
24	Unterweser	PWR	1979 -	86 010	81 341	1.0029	0.5608	0.0010
25	Lingen	BWR	1968 - 1977	19 372	18 400	0.9985	0.8862	0.0007
26	Karlsruhe	BWR	1966 - 1991	149 269	140 584	1.0070	0.0624	0.0007
27	Ahaus	NSS	2000 -	26 427	24 866	1.0080	0.3701	0.0009
28	Juelich	NSS	2000 -	75 735	71 688	1.0020	0.7076	0.0008
29	Ellweiler	UM	1969 -	31 361	29 450	1.0100	0.2225	0.0013
30	Menzenschwand	UM	1969 -	132 037	124 574	1.0052	0.1892	0.0012
31	Gorleben	NSS	2000 -	1 753	1 573	1.0570	0.1108	0.0010
32	Hanau/Kahl	NFE	1969 -	54 772	51 343	1.0118	0.0577	0.0021
	< 35 km from NF			2 532 471	2 393 556	1.0035	** 0.0008	
	> 35 km from NF			7 948 690	7 538 729	1.0000	1.0000	

Results: Direction Specific Analyses



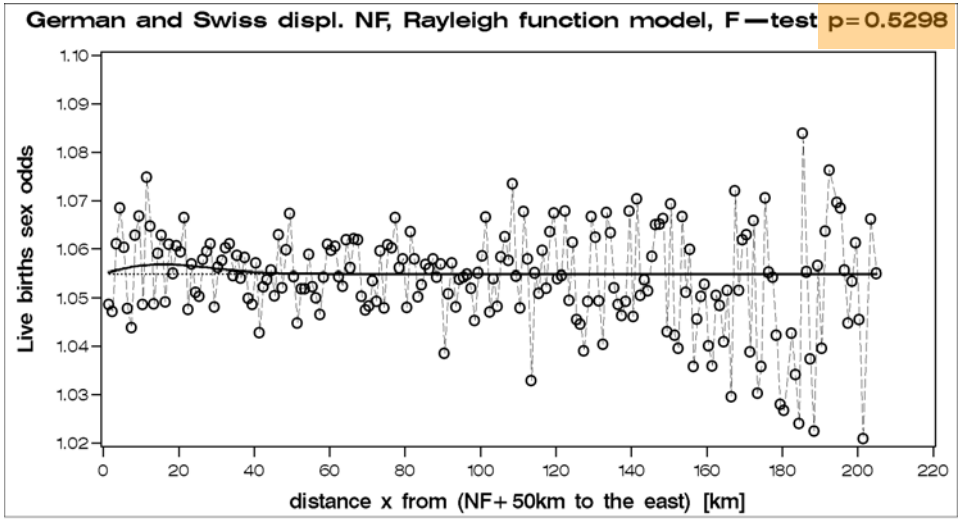


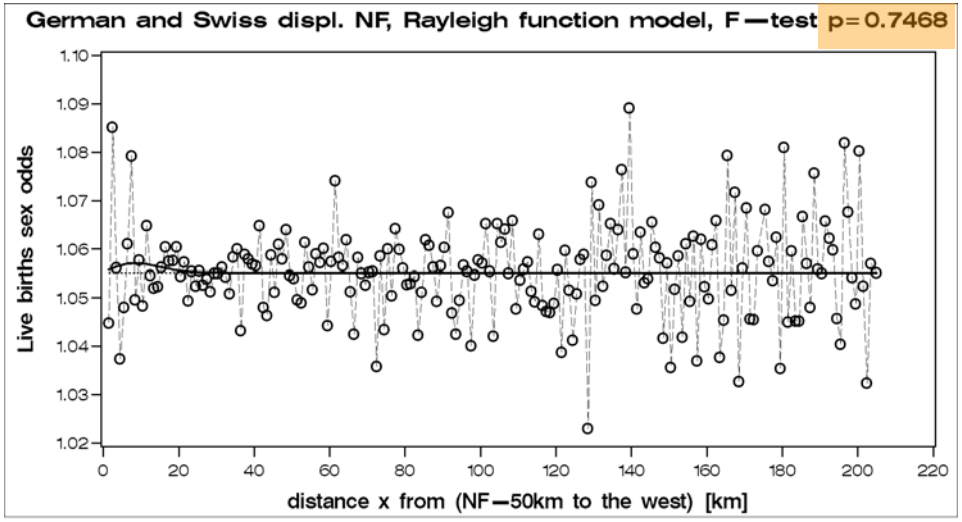




The effect seems to be more diluted in the northern and eastern directions and more concentrated in the southern and western directions. However, statistical power may become a concern when stratifying the data.

Results: Plausibility Analyses





The Rayleigh functions become insignificant when displacing all 28 NF 50 km to the east or 50 km to the west.

Summary

- **The human sex odds at birth (SO) is increased globally after the atmospheric atomic bomb testing and after Chernobyl in Europe**

- **Childhood cancers are increased near Nuclear Power Plants (NPP)**

- **The human sex odds at birth (SO) is increased near nuclear facilities (NF) in a way that could be associated with radioactive releases during routine operation of those facilities:**

  SOR_{peak} = 1.0051 at 14.4 km, 95%-CI = [10.9 km, 29.3 km]

Conclusions and Outlook: Improving Our Preliminary Pilot Study

- **Updating the data set:** Missing German states, time periods, NF
- **More specific/appropriate distance laws**
- **Monte Carlo simulations:** p-values, confidence limits
- **Direction specific distance laws:** North, East, South, West
- **Including possible confounding sites:** e.g. coal-burning power plants
- **Including possible confounding temporal trends:** e.g. before/after Chernobyl
- **Similar investigations from other countries are recommended**
- **Extensive corresponding analyses are needed to support or refute our findings**

Conclusions and Outlook: Environmental Health Data and Studies

- **Important data on underestimated environmental and health topics are partly available**
- **However, often there is no (optimum) utilization of the existing data bases**
- **Thus, greater input from mathematicians and statisticians is urgently needed to scrutinize those data**
- **To achieve this goal, the full spectrum of different data analysis approaches should be considered and applied appropriately**
- **Improved interdisciplinary skills are needed at all stages of environmental health research**

Thank you for your attention

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