



# Remapping radon potential of SW England: Assessment of the differences between 2006 and 2014 Radon Potential maps.

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**Remapping radon potential of SW England:  
Assessment of the differences between 2006 and 2014 Radon Potential maps.**

## Outline of talk

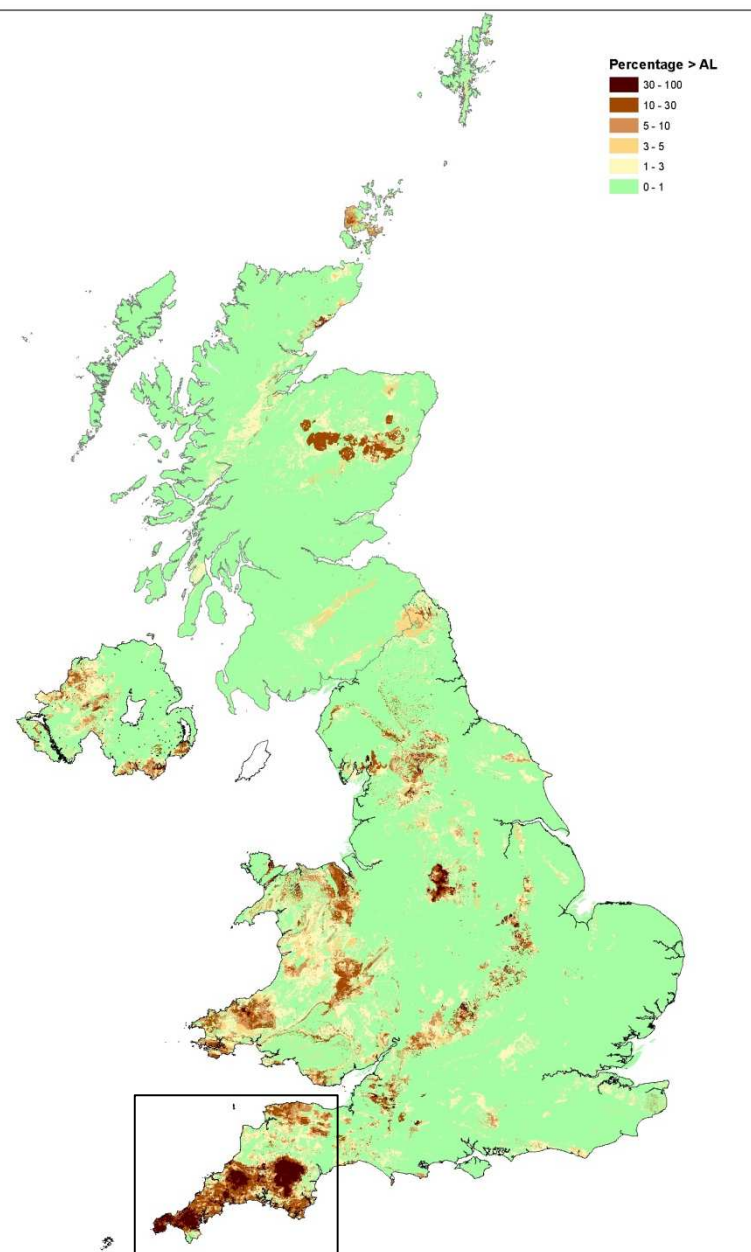
- 1. Radon Potential Mapping in the UK**
2. Differences between 2006 and 2014 in the SW England

# Radon Potential Mapping in the UK

in the UK, a radon potential map is **made** by  
**Public Health England (PHE)**  
and  
**British Geological Survey (BGS)**

... shows the  
spatial variation of the **probability** of  
dwellings **exceeding** the **Radon Action Level**  
(**200** Bq m<sup>-3</sup>)

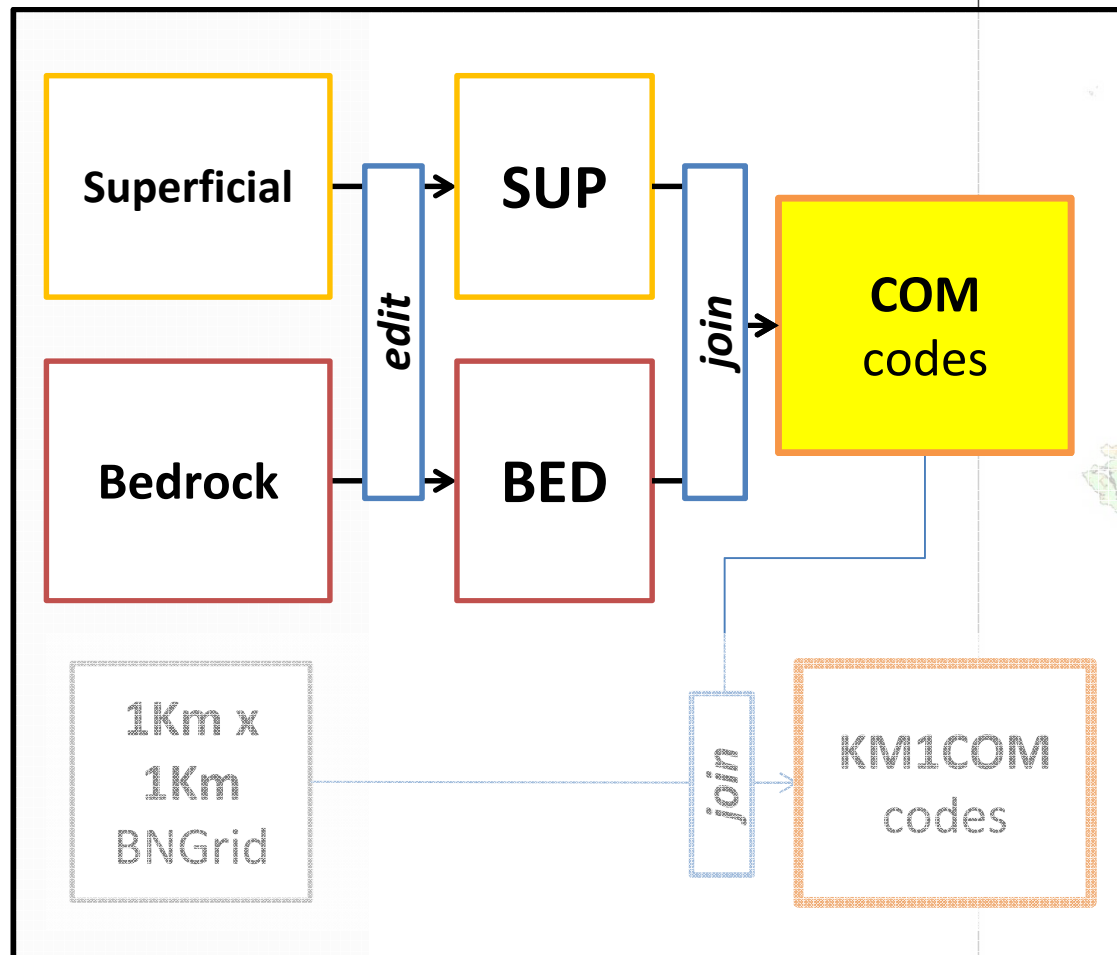
... based on  
**indoor radon** measurements (PHE)  
(~500,000 measurements until 2006; 1 m **accuracy** for location of  
houses via Ordnance Survey AddressPoint)  
and  
**geology (BGS)**  
(1:50,000 scale)



# Radon Potential Mapping in the UK

geology, 1:50,000 scale (BGS)

simplified geology classification systems, geological combinations

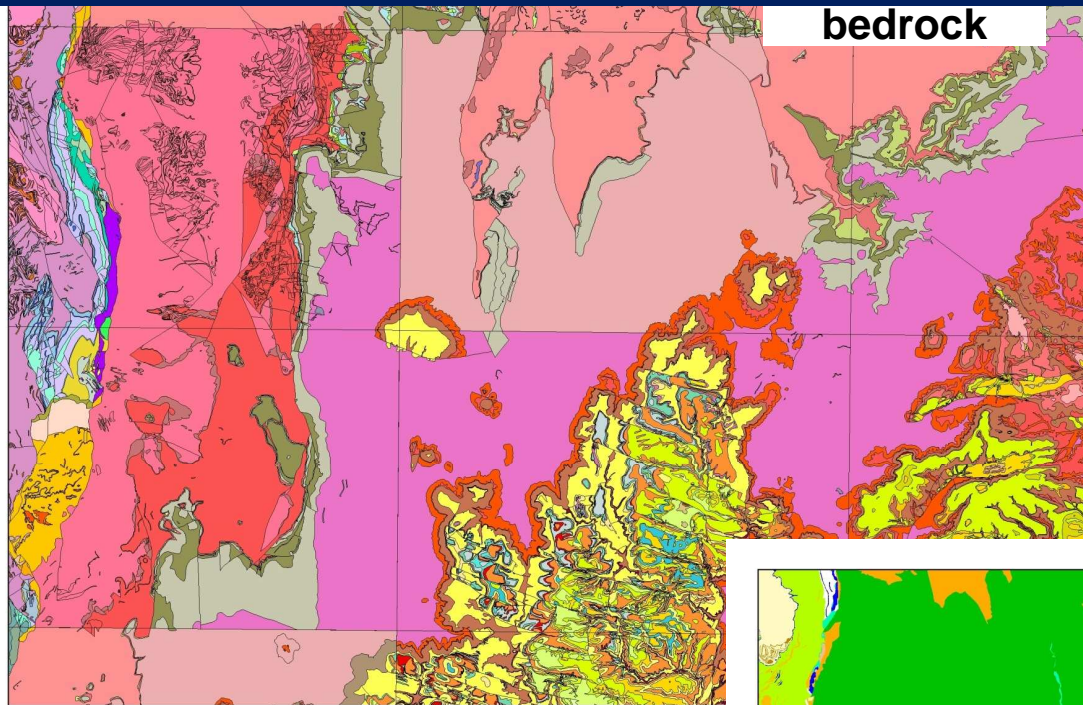


Percentage > AL  
30 - 100  
10 - 30  
5 - 10  
developed by  
Don Appleton  
(BGS)

- bedrock units: grouped in **BED** by
  - **AGE** and
  - **LITHOLOGY**, while
- superficial units: grouped in **SUP** by
  - **PERMEABILITY** or
  - **GENESIS**

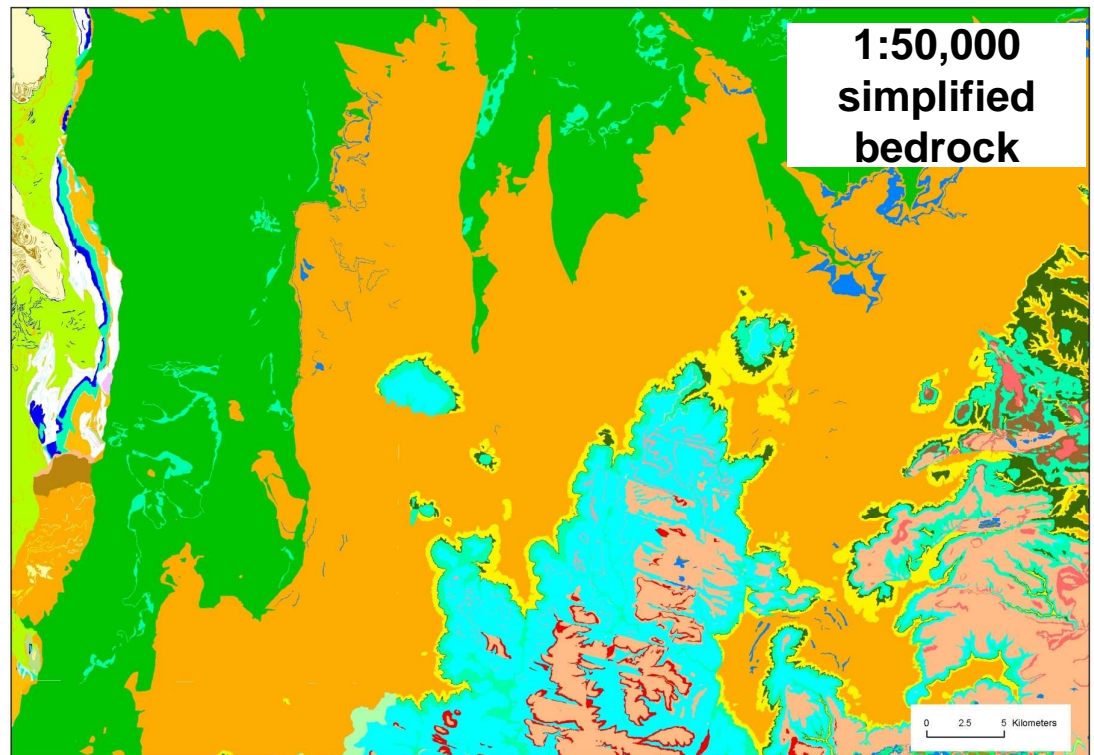


# Radon Potential Mapping in the UK



**Geology**  
1:50,000 scale (BGS)

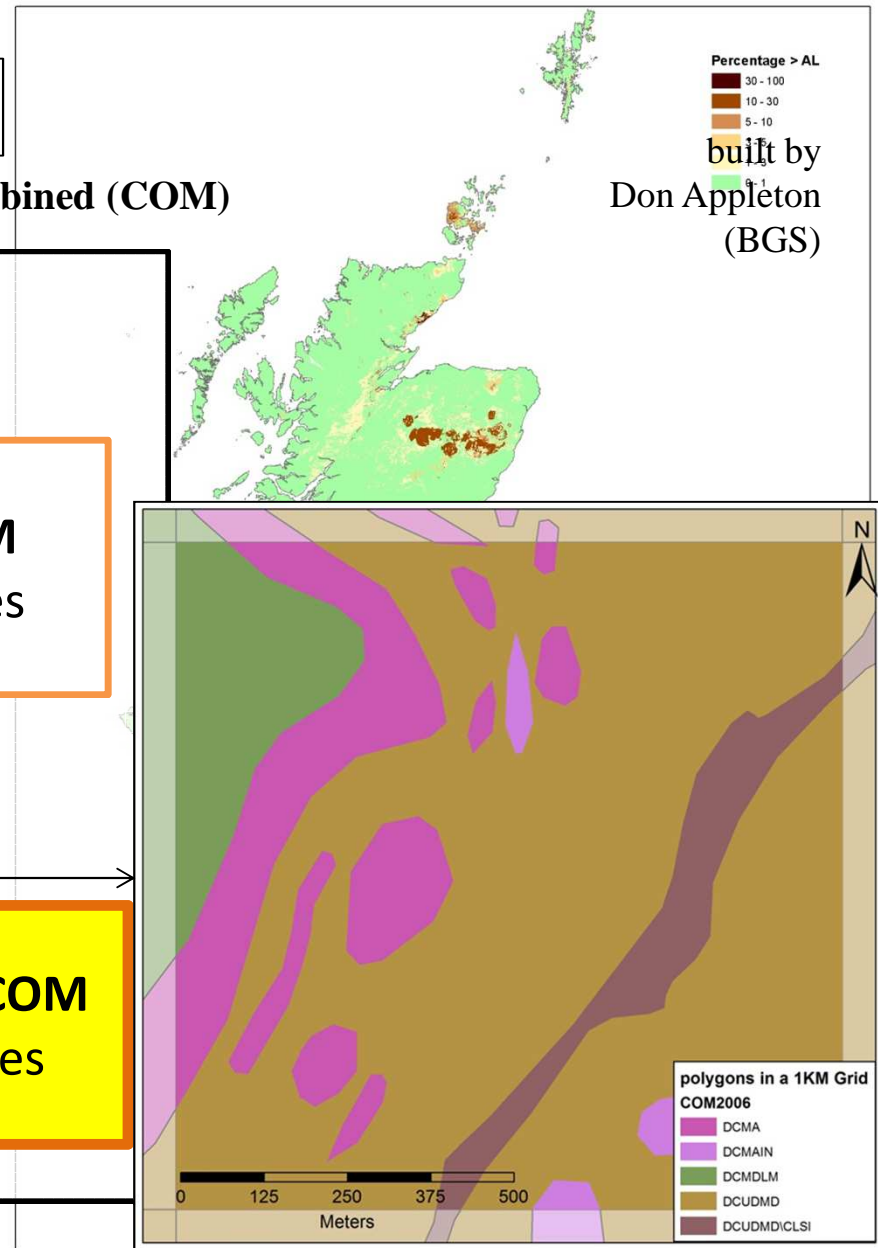
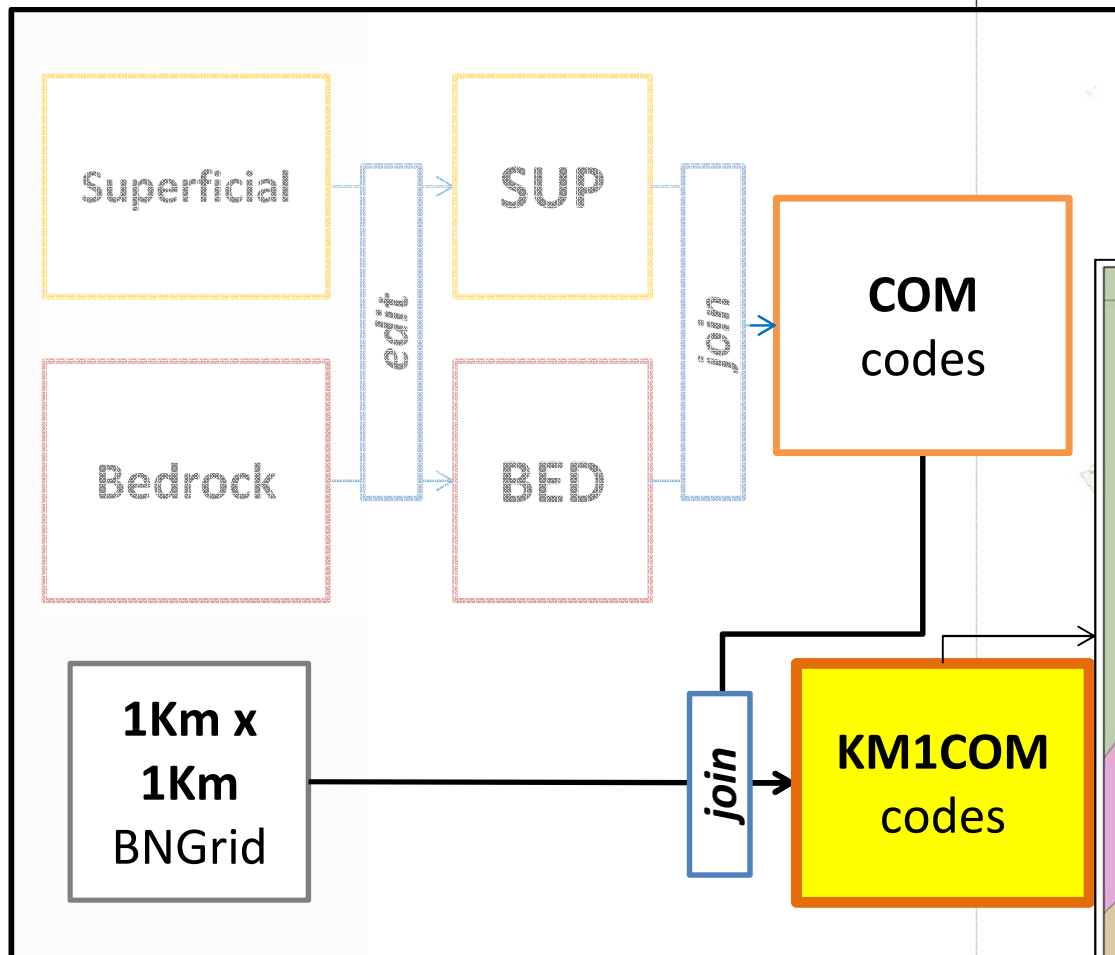
**Simplified 1:50,000  
bedrock geology (BED)**  
Seamless geological  
classification required for  
geological radon  
potential mapping



# Radon Potential Mapping in the UK

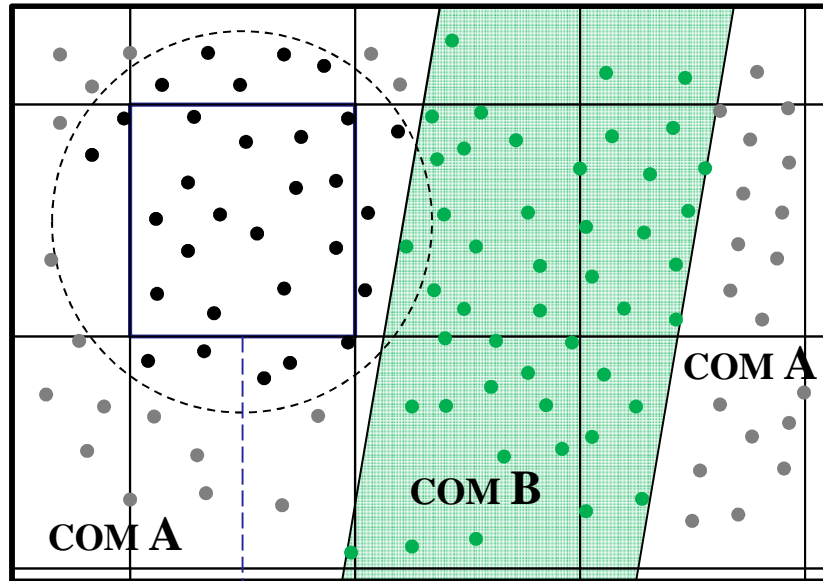
geology, 1:50,000 scale (BGS)

simplified geology classification systems: **BED**, **SUP**, combined (**COM**)



# Radon Potential Mapping in the UK

Computing the RnP in a **KM1COM** cell:



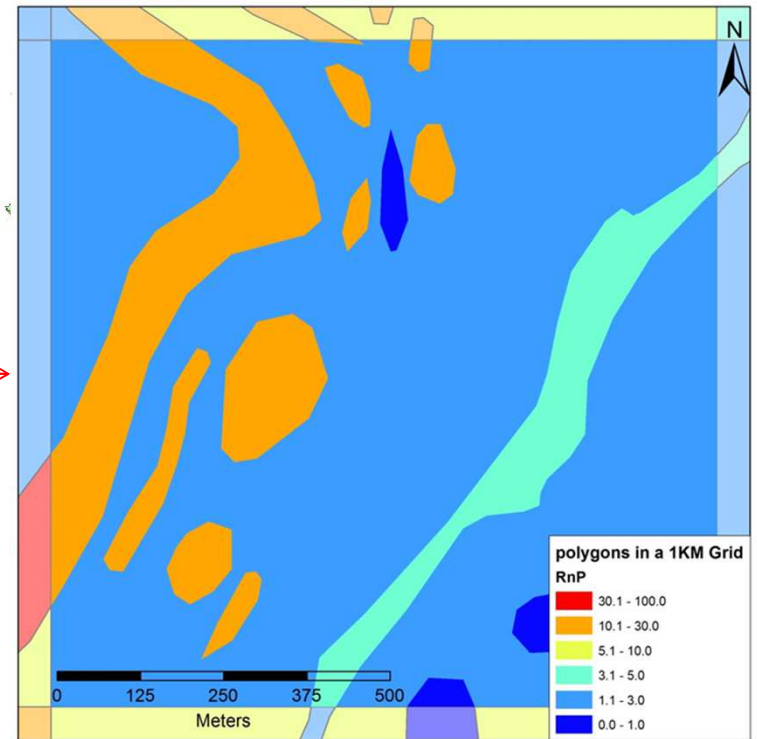
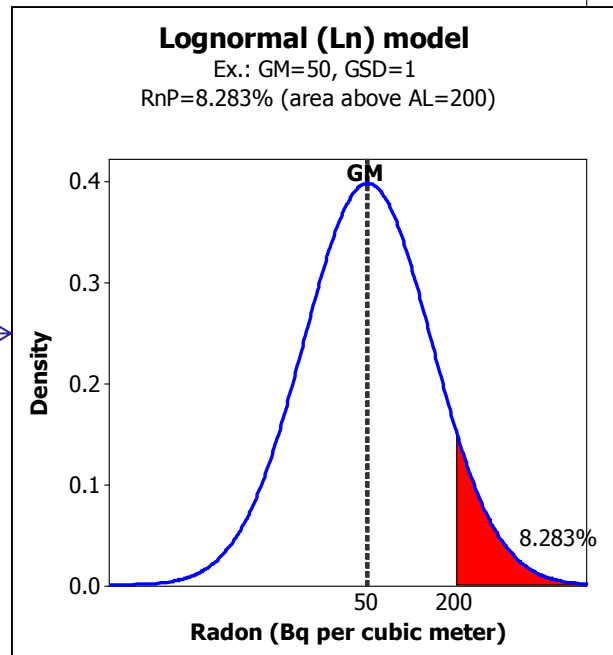
30 nearest  
(black dots)

probability that dwellings  
exceed the Radon Action Level  
(200 Bq m<sup>-3</sup>)

Rn measurements not taken into account:

- on other COM (green dots)
- out of the nearest 30 (grey dots)

GM  
±  
GSD





# Radon Potential Mapping in the SW England

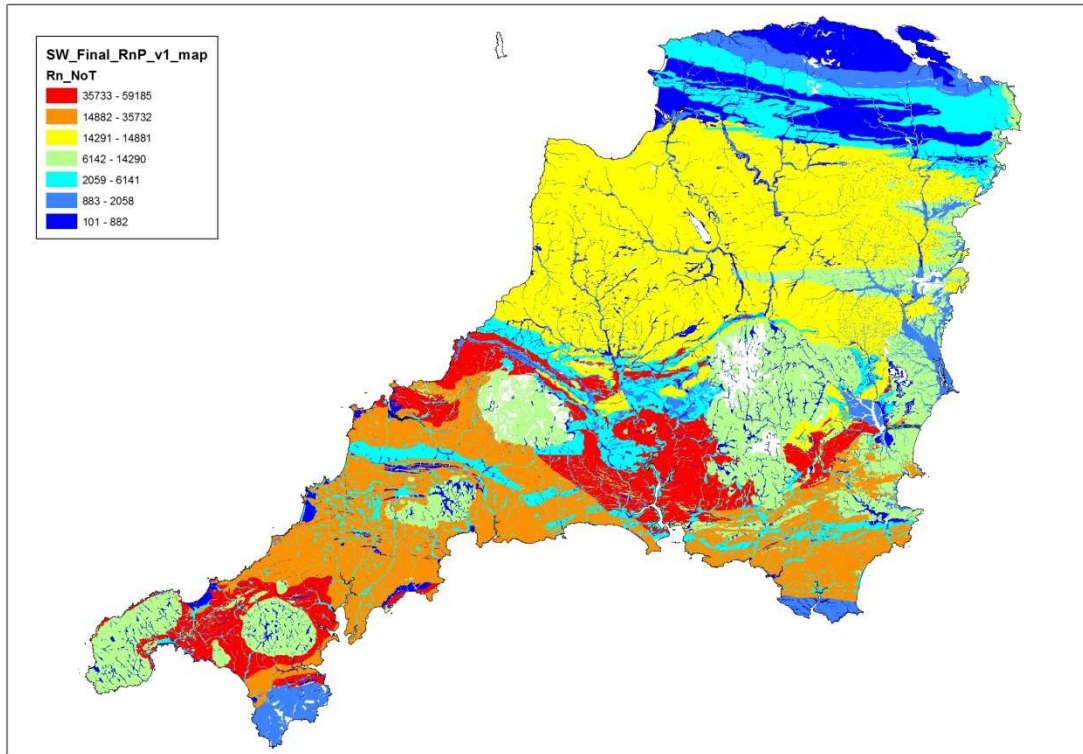
**Gridding Methods** used for estimating percentage of dwellings above AL for each KM1COM polygon (SW England)

**Lognormal** modelling applied in all radon mapping

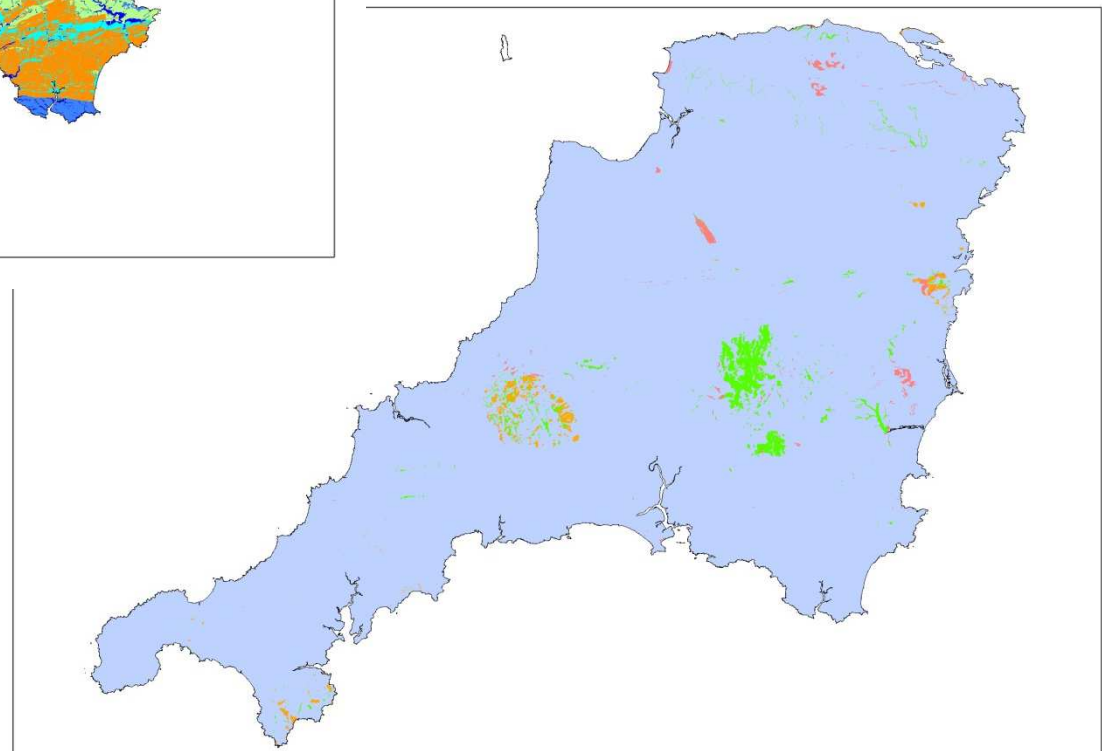
Method	No. of Rn measurements in each COM	Description of method used to estimate RnP ( $\% > 200 \text{ Bq m}^{-3}$ )
<b>Grid (G1a)</b> <b>Grid (G1b)</b>	>99	RnP based on <b>GM</b> and <b>GSD</b> of the <b>nearest 30</b> Rn measurements in the same COM ( <b>G1a</b> ) or <b>all</b> measurements <b>inside the same KM1COM</b> polygon(s) if its number of Rn measurements $> 30$ ( <b>G1b</b> ); Bayesian KM1COM GSD corrected for measurement uncertainty
<b>(M2)</b>	25 – 99	RnP based on GM of the nearest 10 measurements; GSD is average of study area COM GSD and KM1COM GSD both corrected for measurement uncertainty
<b>(M3)</b>	10 – 24	RnP based on GM of all data in the same COM group in SW England; GSD is average of UK national GSD (2.27) and study area COM GSD both corrected for measurement uncertainty
<b>(M4)</b>	3-9	RnP based on GM of all data in the same COM group in SW England and UK national GSD corrected for measurement uncertainty (2.27)
<b>(M5)</b>	0-2	Assessment of RnP based on analogy with similar geological combinations for which radon data are available

COM: geological combination; GM: geometric mean; GSD: geometric standard deviation

# Radon Potential Mapping in the SW England



No. of radon measurements for each COM2014 mapped using PHE gridding method



Main methods used for **2014 RnP** mapping:

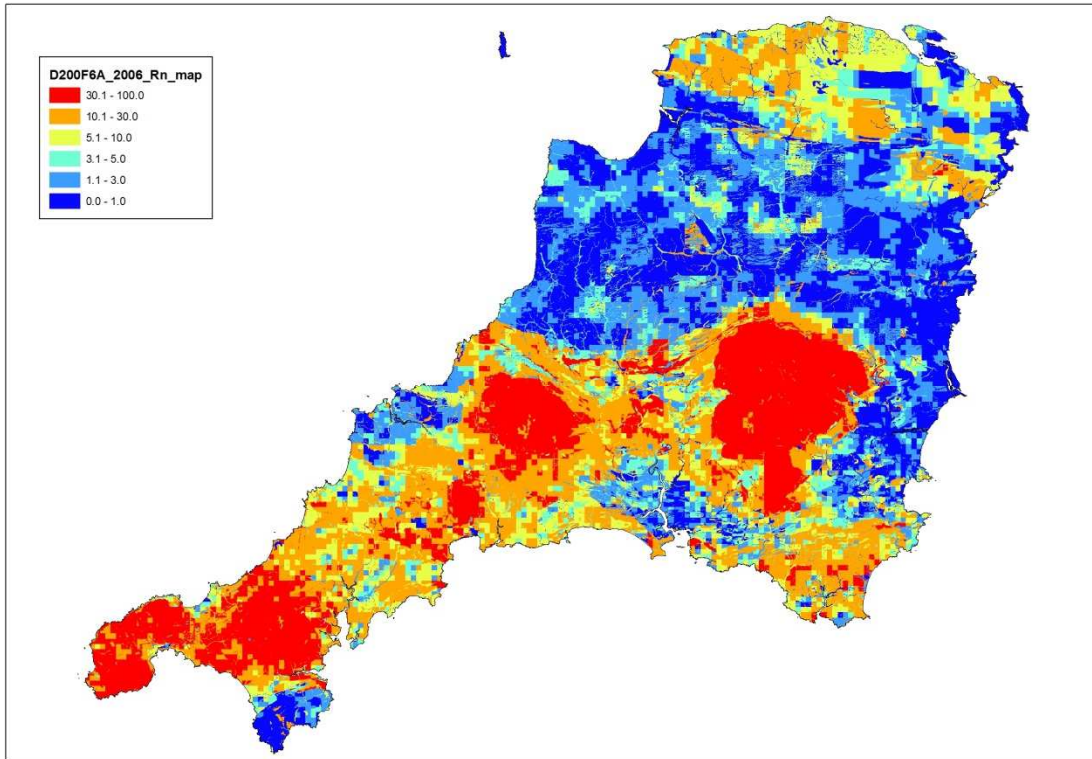
**Grid** (>99, 30 nearest): 97.5% A

**M2** (25-99, 10 nearest): 1.5% A

**M3 to M5** (24-0): 1% A

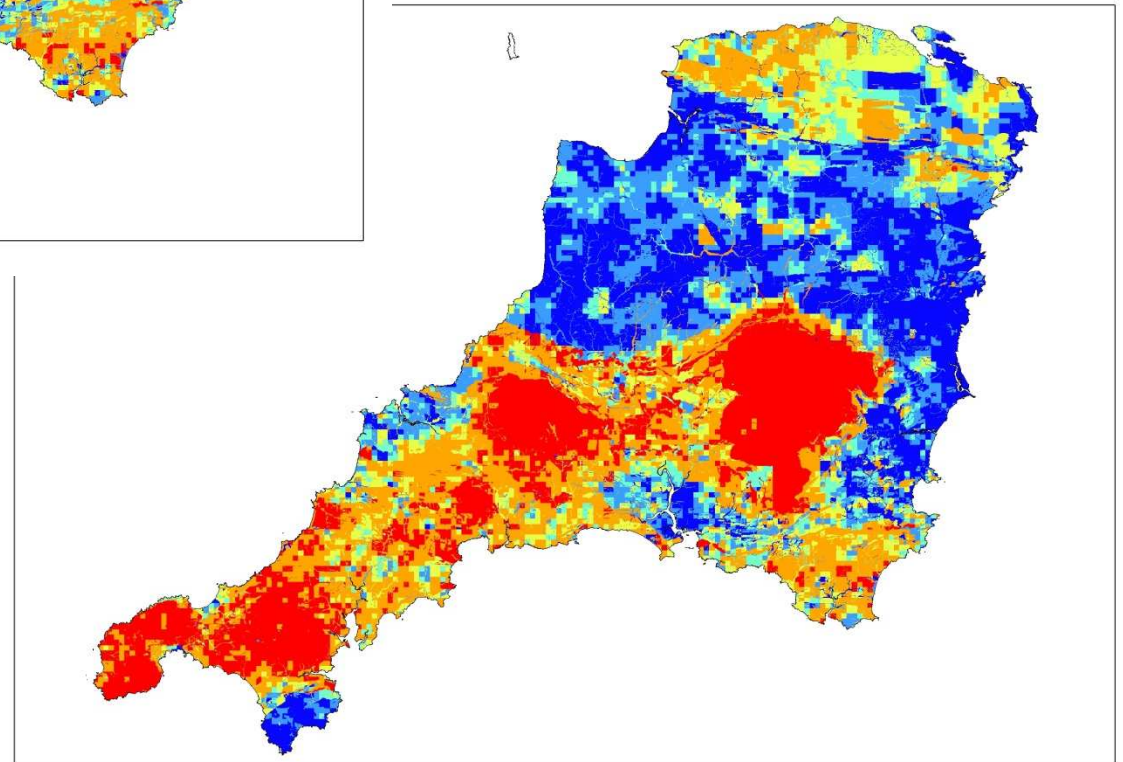


# Radon Potential Mapping in the SW England



RnP 2006

RnP 2014



How can we  
compare these two  
maps?

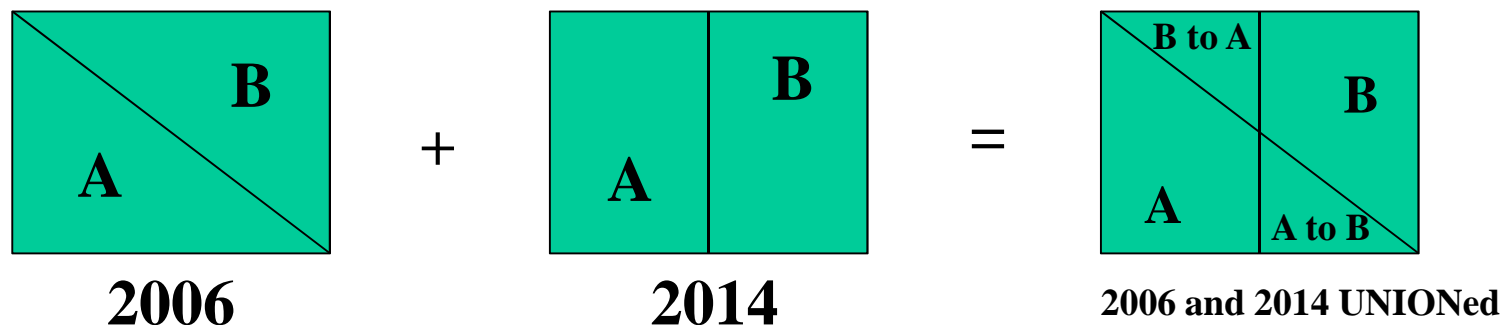
**Remapping radon potential of SW England:  
Assessment of the differences between 2006 and 2014 Radon Potential maps.**

## Outline of talk

1. Radon Potential Mapping in the UK
- 2. Differences between 2006 and 2014 in the SW England**

# How can we compare the two RnP maps

**after creating a file with both datasets:**  
(subdividing the original polygons if necessary)

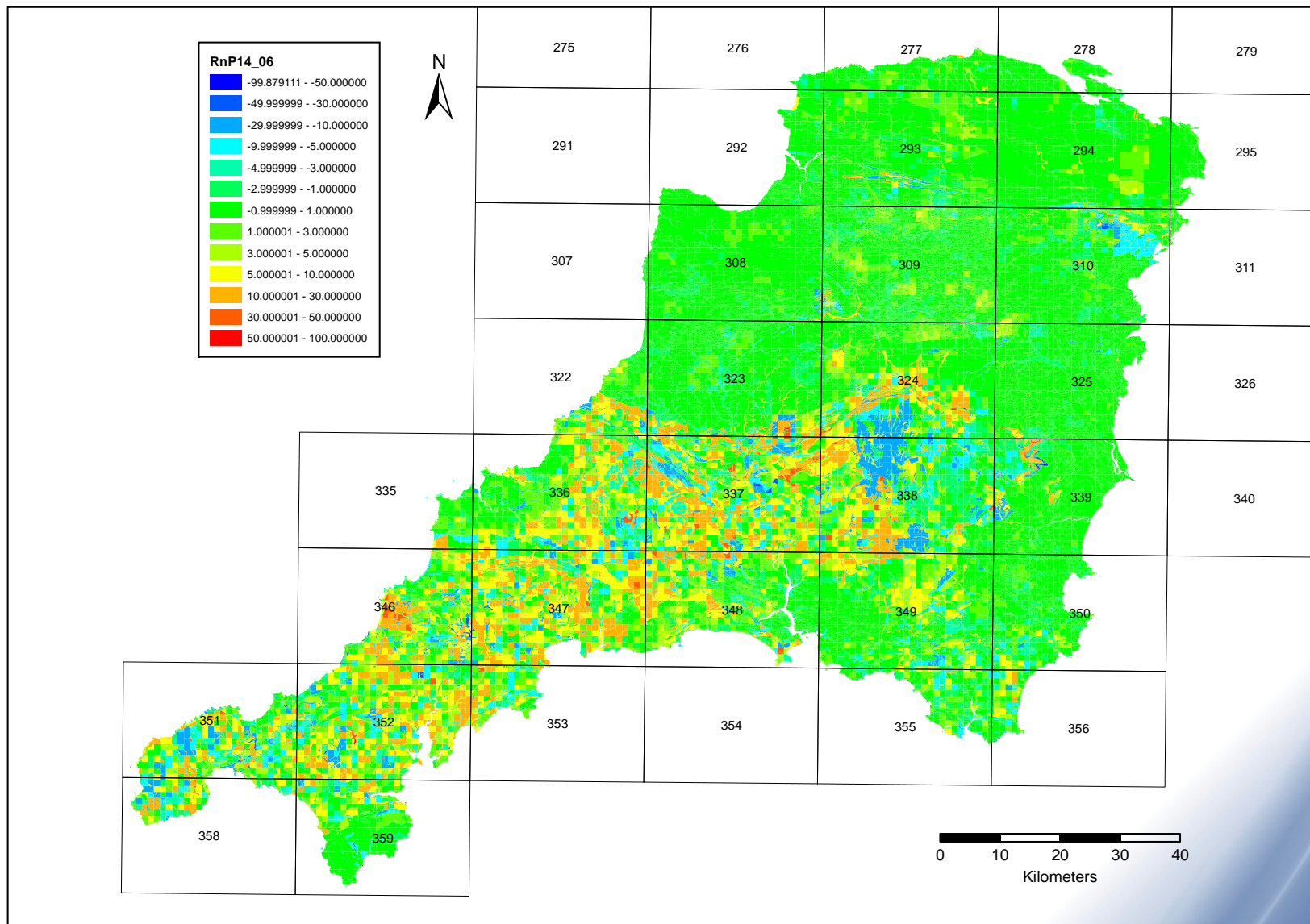


RnP2006 and RnP2014 were **UNIONed** (ArcGIS 10.1 tool), resulting a file with **123002** polygons (from 115345, 119898)

- reporting all the required original information from 2006 and 2014 such as the geological combinations (COMs), the KM1COMs and the radon statistics
- It remains possible to account with the **polygon size (area)** in the data analysis

# Observed Differences

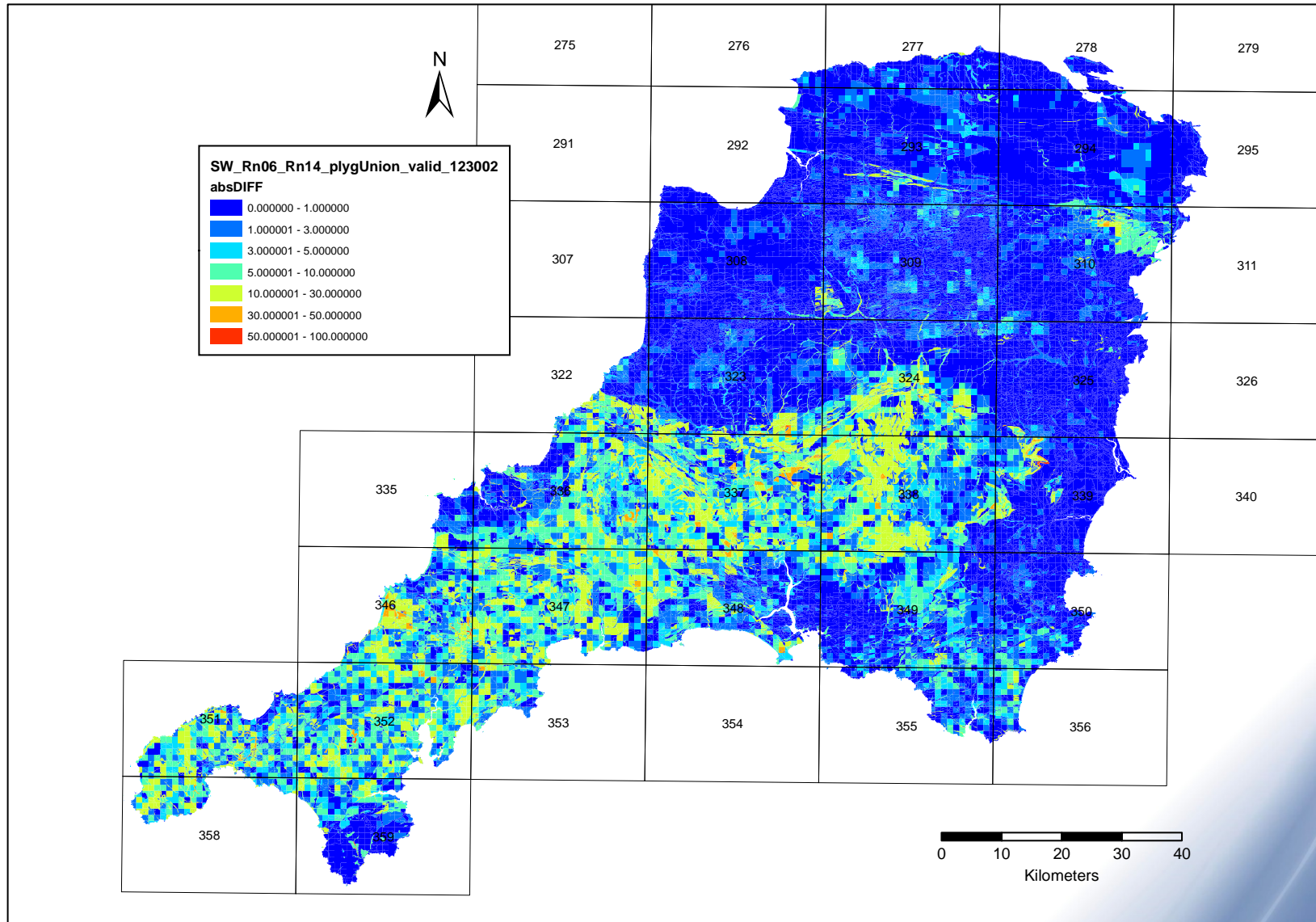
$$\text{DIFF} = \text{RnP14} - \text{RnP06}$$





# Observed Differences

Absolute Difference:  $|\mathbf{DIFF}| = \mathbf{abs}(\mathbf{RnP14} - \mathbf{RnP06})$



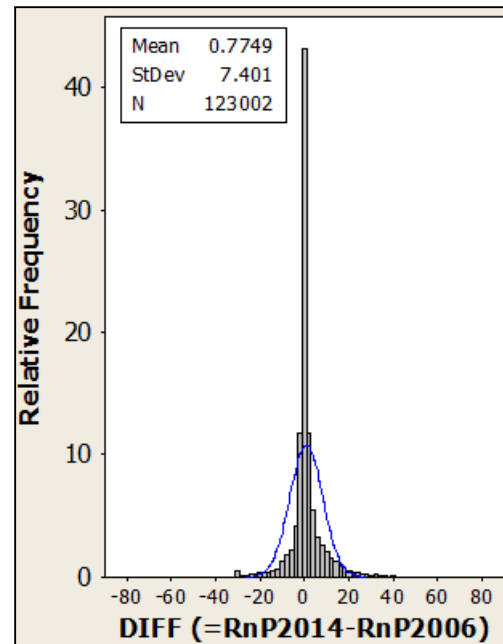
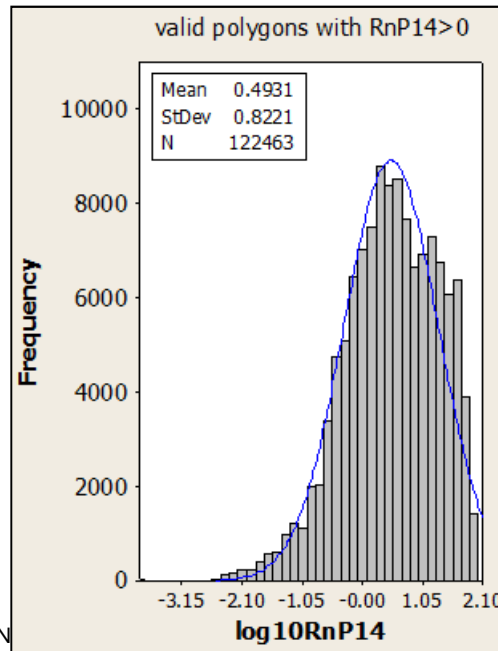
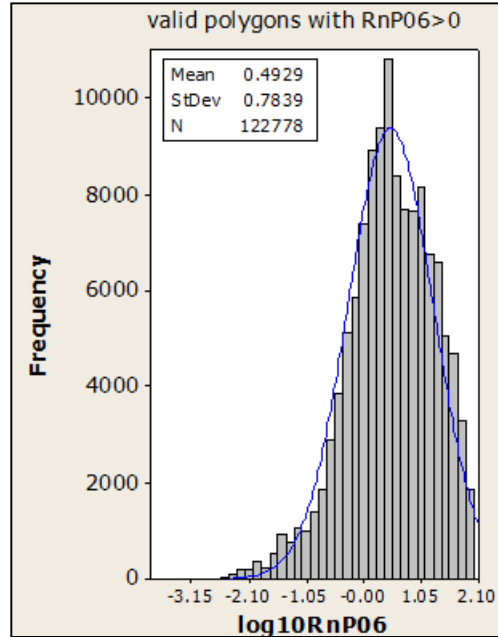


# Observed Differences

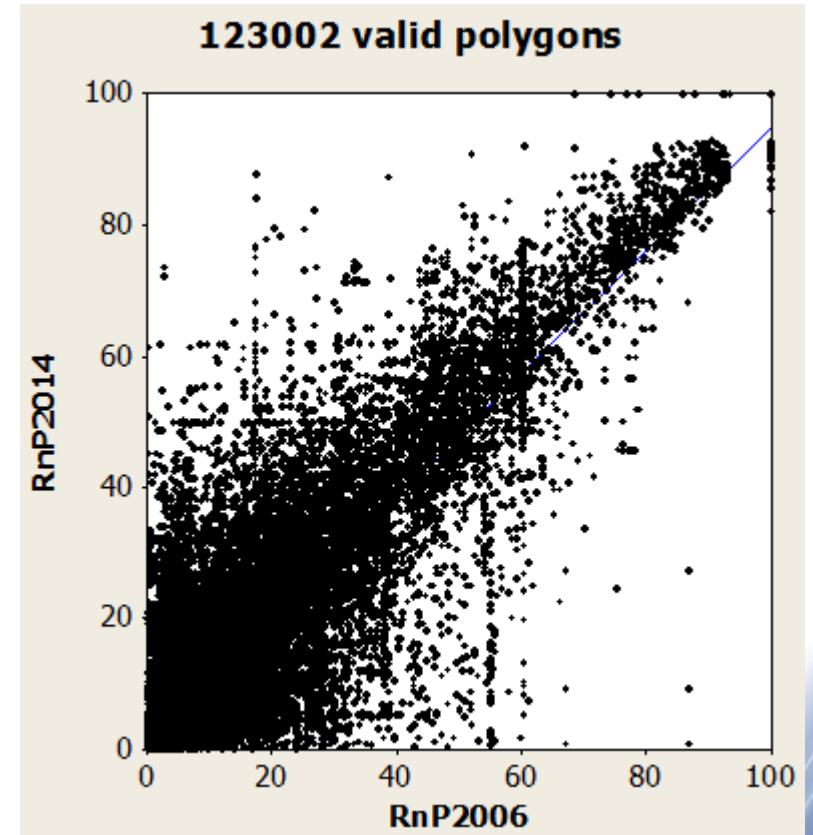
Some **basic statistics** of the Radon Potential maps of 2006 (RnP2006) and 2014 (RnP2014), and the difference (DIFF) and the absolute difference (|DIFF|) of 2014 relative to 2006.

Statistics	RnP2006	RnP2014	DIFF	DIFF	Area
Min	<b>0.001</b>	<b>0.001</b>	-86.04	0.00	
02p	0.03	0.03	-17.05	0.00	3.7
05p	0.12	0.10	-8.96	0.03	7.4
10p	0.32	0.26	-4.45	0.09	12.9
25p	1.02	0.87	-0.97	0.34	30.0
<b>Mdn</b>	<b>3.09</b>	<b>3.29</b>	<b>0.00</b>	<b>1.37</b>	<b>54.0</b>
75p	11.70	14.01	1.97	4.63	75.4
90p	31.21	35.94	8.09	11.31	90.7
<b>95p</b>	<b>48.80</b>	<b>49.80</b>	<b>13.39</b>	<b>17.11</b>	<b>95.5</b>
98p	64.80	66.28	20.08	25.31	97.9
Max	99.38	98.40	70.95	86.04	100.0
IQR	10.69	13.14	2.94	4.28	
Mean	10.42	11.19	0.77	3.97	
SD	16.40	17.01	7.40	6.30	
Skewness	2.48	2.21	0.18	2.92	
Kurtosis	6.38	4.87	9.50	11.24	

# Observed Differences



## linear regression



correlation coeff. (Pearson  $r$ ) = 0.902  
Coeff. of determination (R-squared) = 81.4%  
unexplained variation = 18.6%

# Understanding the Differences

## **Contributing factors**

to the unexplained variation budget (18.6):

(in a linear regression with raw RnP data)

## Differences a priori from 2006 to 2014 in SW England

### No of Rn measurements:

2006: 173,192

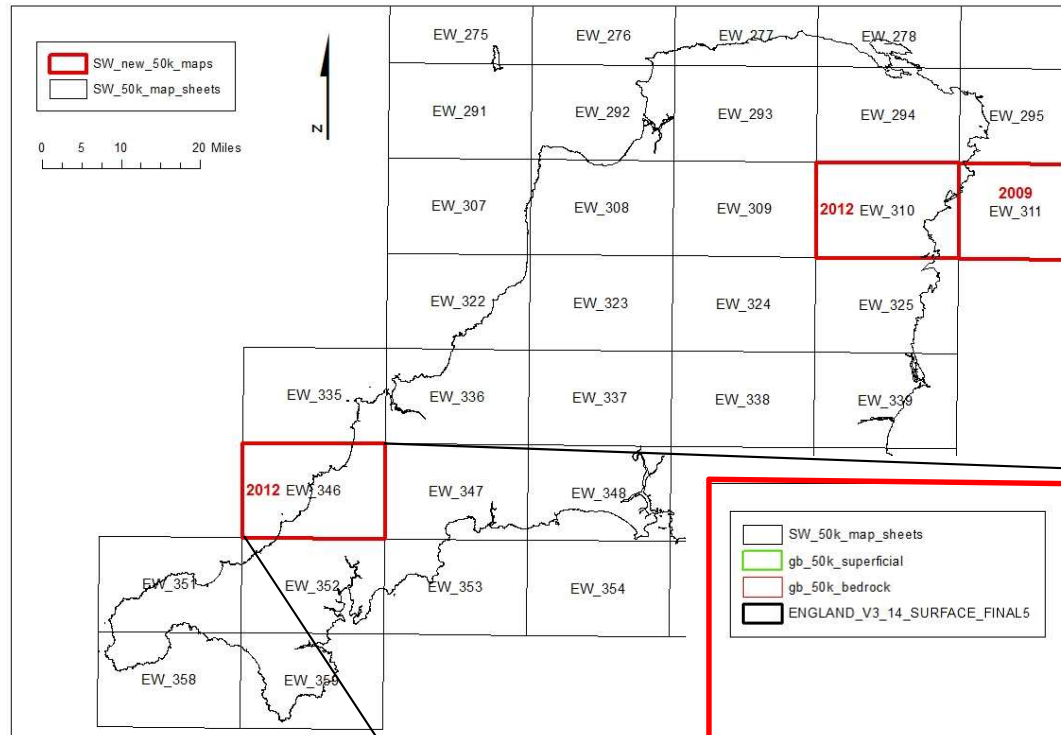
2014: 230,955

an increase of **57,763** (33%)

Method	2006				2014			
	N	N%	Area	Area%	N	N%	Area	Area%
Grid (G1a)	98003	85.0	9013167638	88.8	109341	91.2	9037930731	89.1
Grid (G1b)	4013	3.5	684268458	6.7	5511	4.6	853856542	8.4
<b>(G1a) + (G1b)</b>	<b>102016</b>	<b>88.4</b>	<b>9697436096</b>	<b>95.6</b>	<b>114852</b>	<b>95.8</b>	<b>9891787273</b>	<b>97.5</b>
(M2)	-	-	-	-	2011	1.7	151388632	1.5
(M3)	-	-	-	-	1395	1.2	57146850	0.6
(M4)	-	-	-	-	418	0.3	18066946	0.2
(M5)	-	-	-	-	1222	1.0	29758625	0.3
<b>(M2) to (M5)</b>	<b>13329</b>	<b>11.6</b>	<b>450102928</b>	<b>4.4</b>	<b>5046</b>	<b>4.2</b>	<b>256361052</b>	<b>2.5</b>
Total	115345	100	10147539025	100	119898	100	10148148325	100

No. (N) of polygons and corresponding area (Area) estimated by each mapping method

# Differences a priori from 2006 to 2014 in SW England

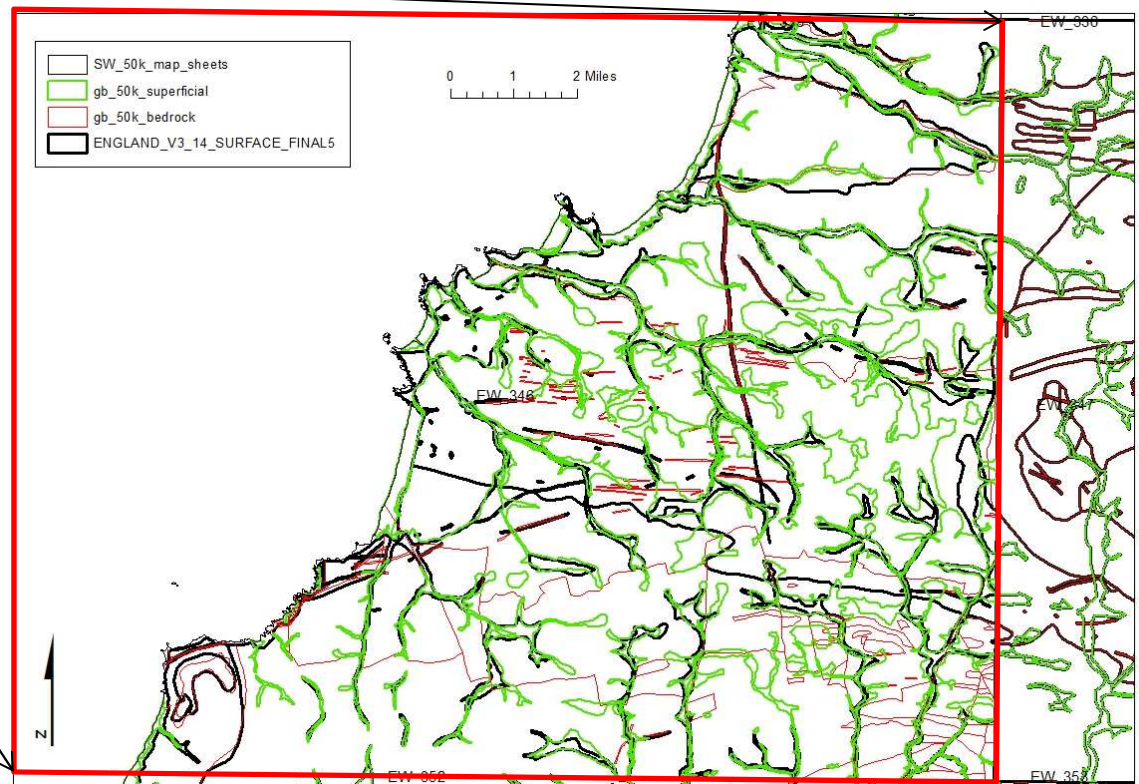


**≈50k**

**3 new 1:50 000 scale  
geological map sheets**

**10.7% of the polygons**

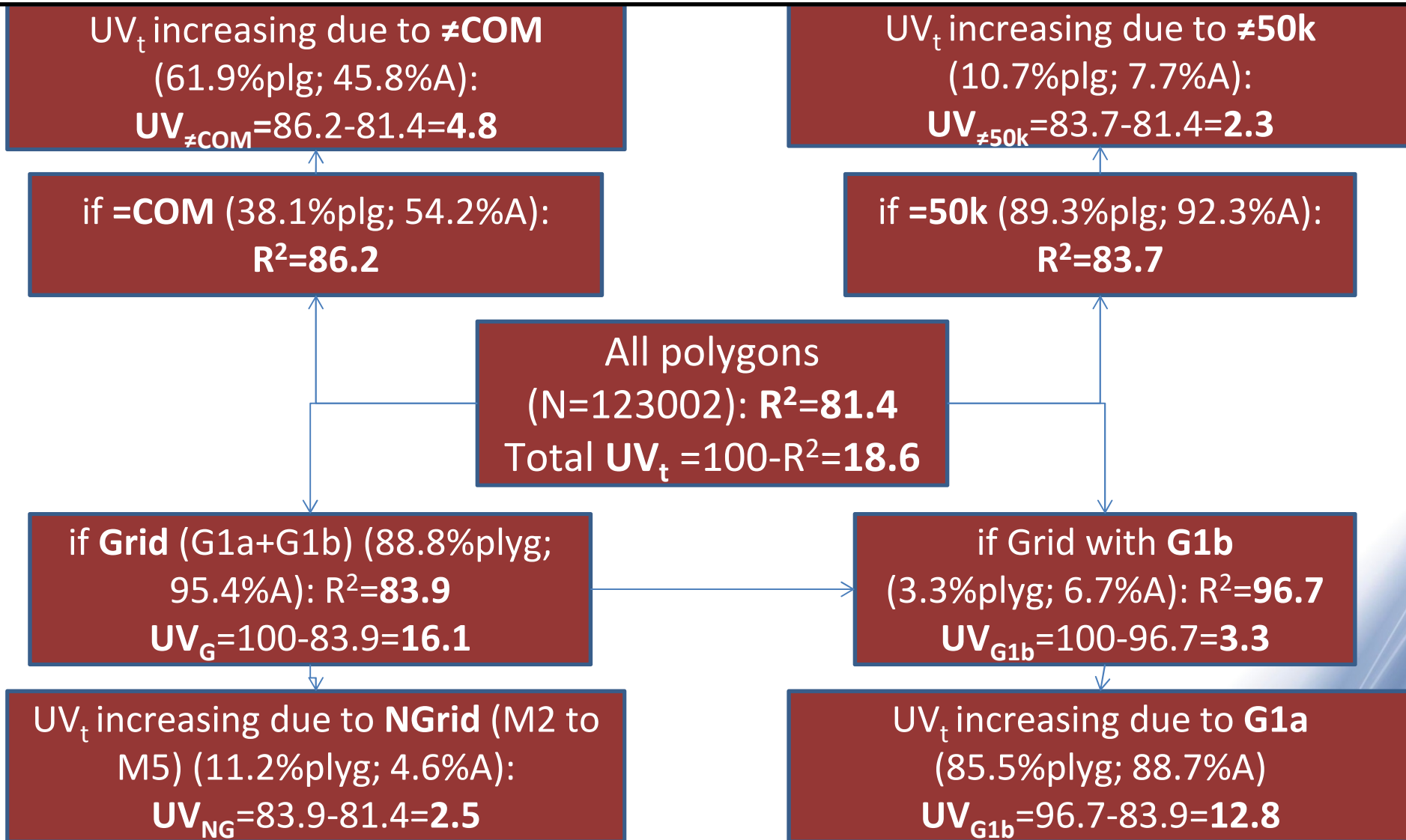
**7.7% of the total study area**







**Estimating the contribution of identified factors  
using  $R^2$  and  $UV$  ( $1 - R^2$ ) from **LINEAR REGRESSION** of **RnP14** with **RnP06**  
(LL=0.1, Area not taken into account) **1<sup>st</sup> attempt****



**Estimating the contribution of identified factors  
using  $R^2$  and  $UV$  ( $1 - R^2$ ) from **LINEAR REGRESSION** of **RnP14** with **RnP06**  
(LL=0.1, Area not taken into account) 2<sup>nd</sup> attempt**

**Total  $UV_t$  (N=123002):  $100 - R^2 = 100 - 81.4 = 18.6$**

Select polygons with RnP based on **Grid (G1a+G1b)** methods

if polygons were all **Grid (G1a+G1b)** (88.8%plg; 95.4%A):

$R_G^2 = 83.9$ ;  $UV_G = 100 - 83.9 = 16.1$

$UV_t$  increasing due to **M2 - M5**  
(11.2% plyg; 4.6%A)  
 $UV_{NG} = 83.9 - 81.4 = 2.5$

Select =COM

Select =50k

if **Grid** were =COM (34.8%plg; 52.7%A):  $R_{Gx=COM}^2 = 87.3$

$UV_{Gx=COM} = 100 - 87.3 = 12.7$

if **Grid** were =50k (78.8%plg; 87.7%A):  $R_{Gx=COM}^2 = 86.4$

$UV_{Gx=50k} = 100 - 86.4 = 13.6$

$UV_G$  increasing due to  $\neq$ COM (54.0%plyg; 42.7%A):

$UV_{Gx\neq COM} = 87.3 - 83.9 = 3.4$

$UV_G$  increasing due to  $\neq$ 50k (10.0%plyg; 7.6%A):

$UV_{Gx\neq 50k} = 86.4 - 83.9 = 2.5$

Select =COM + =50k

if **Grid (G1a+G1b)** plygs were =COM and =50k (32.8%plyg; 49.8%A):

$R_{Gx=COMx=50k}^2 = 88.1$   $UV_{Gx=COMx=50k} = 100 - 88.1 = 11.9$

$UV_G$  increasing due to  $\neq$ 50k (2.1% plyg; 2.9%A):

$UV_{Gx=COMx\neq 50k} = 88.1 - 87.3 = 0.8$

$UV_G$  increasing due to  $\neq$ COM (46.0%plyg; 37.9%A):

$UV_{Gx=COMx\neq 50k} = 88.1 - 86.4 = 1.7$

**G1b** (2.4%pl; 5.1%A):

$UV_{G1bx=COMx=50k} = 100 - 97.2 = 2.8$

**G1a**

$UV_{G1ax=COMx=50k} = 97.2 - 88.1 = 9.1$

in **Grid** plgs, estimate of the  $UV$  increasing due to  $\neq$ COM +  $\neq$ 50k

(56.0%plyg; 45.6%A):  $UV_{Gx(\neq COM + \neq 50k)} = 88.1 - 83.9 = 4.2$



**Estimating the contribution of identified factors  
using  $R^2$  and UV ( $1 - R^2$ ) from LINEAR REGRESSION of RnP14 with RnP06  
(LL=0.1, Area not taken into account) 1<sup>st</sup> and 2<sup>nd</sup> attempts**

( $R^2=$ ) 81.4% of the variance of RnP<sub>14</sub> is explained by the RnP<sub>06</sub>  
Unexplained Variance (N=123002):  $100 - R^2 = 100 - 81.4 = 18.6\%$

**(a) 11.9? (out of 18.6, 64.0%)** estimate of the **local to regional variability** due to the new Rn measurements:

**(a1) 2.8 to 3.3 (out of 18.6)** estimate of the **LOCAL (intra 1Km<sup>2</sup>) variability** due to the new Rn measurements;

**(a2) 8.6 to 9.1? (out of 18.6)** estimate of the **REGIONAL (intra COM) variability** due to the new Rn measurements.

**(b)** an estimated maximum increasing of **2.5 (out of 18.6, 13.4%)** is related to the **methods M2 to M5** used for NGrid polygons.

**(c) 4.2?(out of 18.6, 22.6%)** estimate of the **variability added to (a)** due to **changes in geology**.

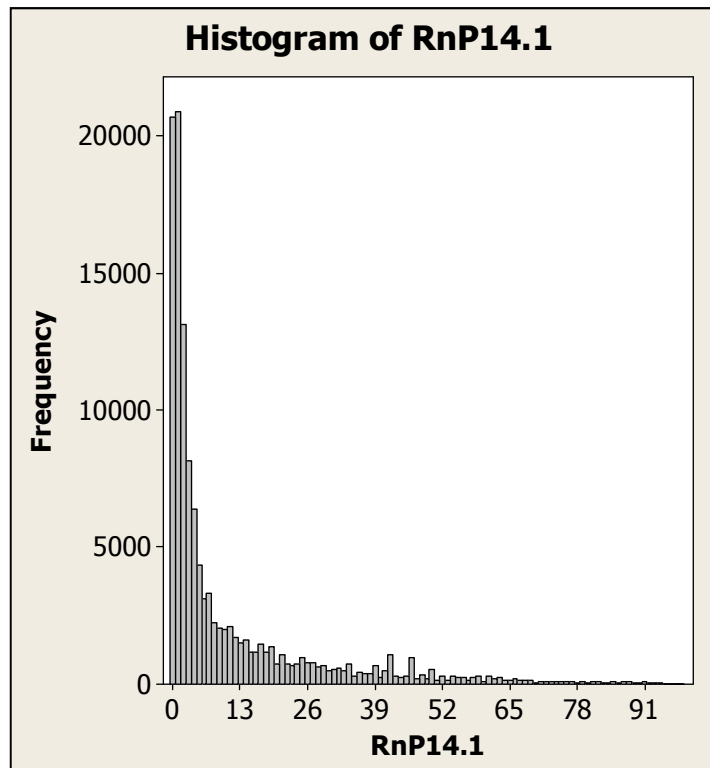
**(c1) 0.8 to 2.5 (2.3)** relates to the **3 new 1:50k geological maps**

**(c2) 1.7 to 3.4 (4.8)?** relates to **changes in grouping geology in the geologic combinations (COMs)**.

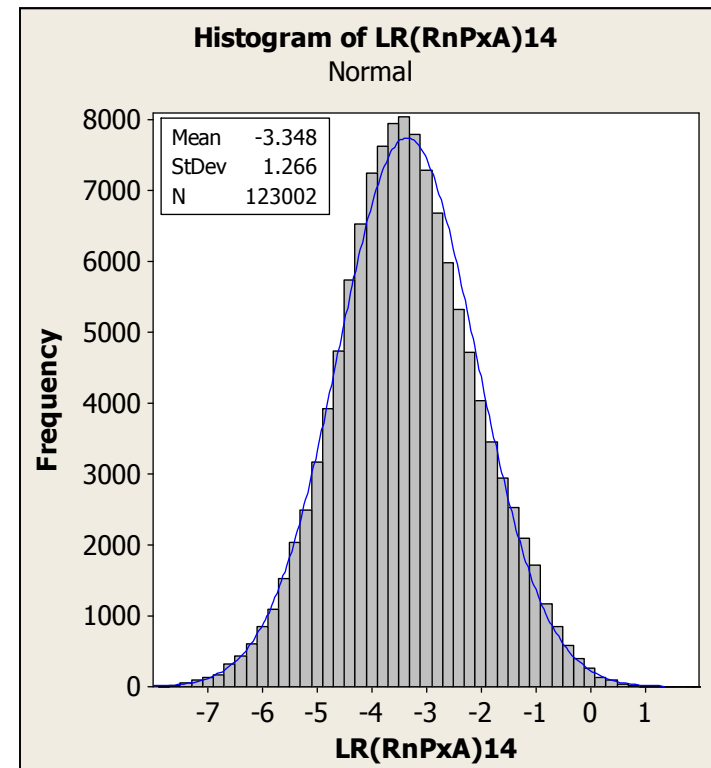
# Observed Differences

A second approach after a **LogRatio** transformation:

$$\text{Log}_{10} \frac{RnP14 * A}{100M - RnP14 * A}$$



Raw RnP data (0 to 100)  
**closed and not centred**



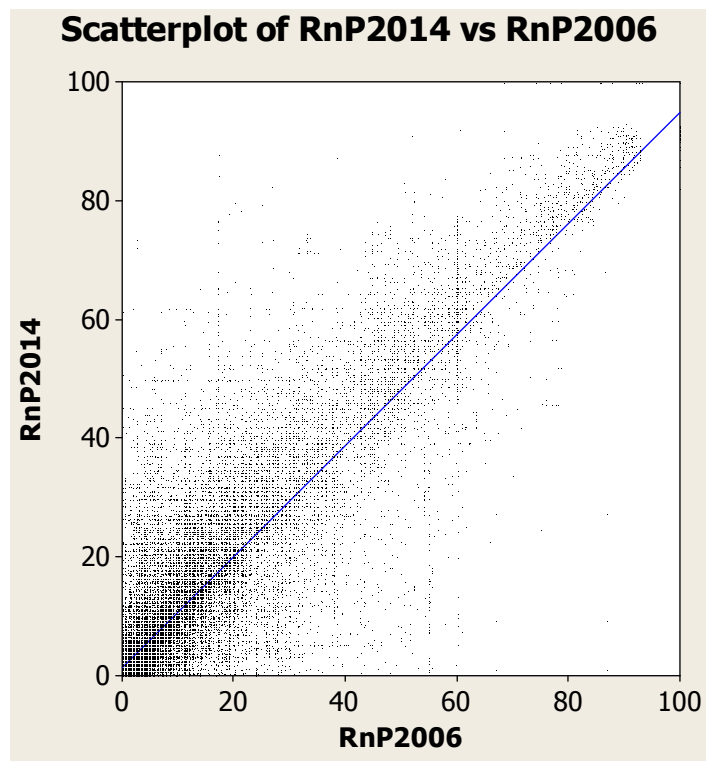
**open and centred!**



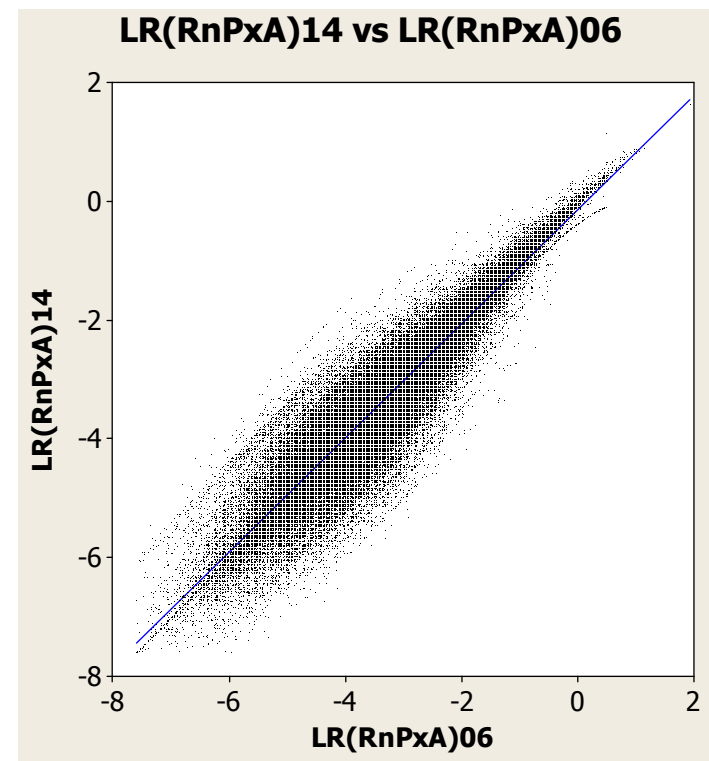
# Observed Differences

A second approach after a **LogRatio** transformation:

$$\text{Log}_{10} \frac{RnP14 * A}{100M - RnP14 * A}$$

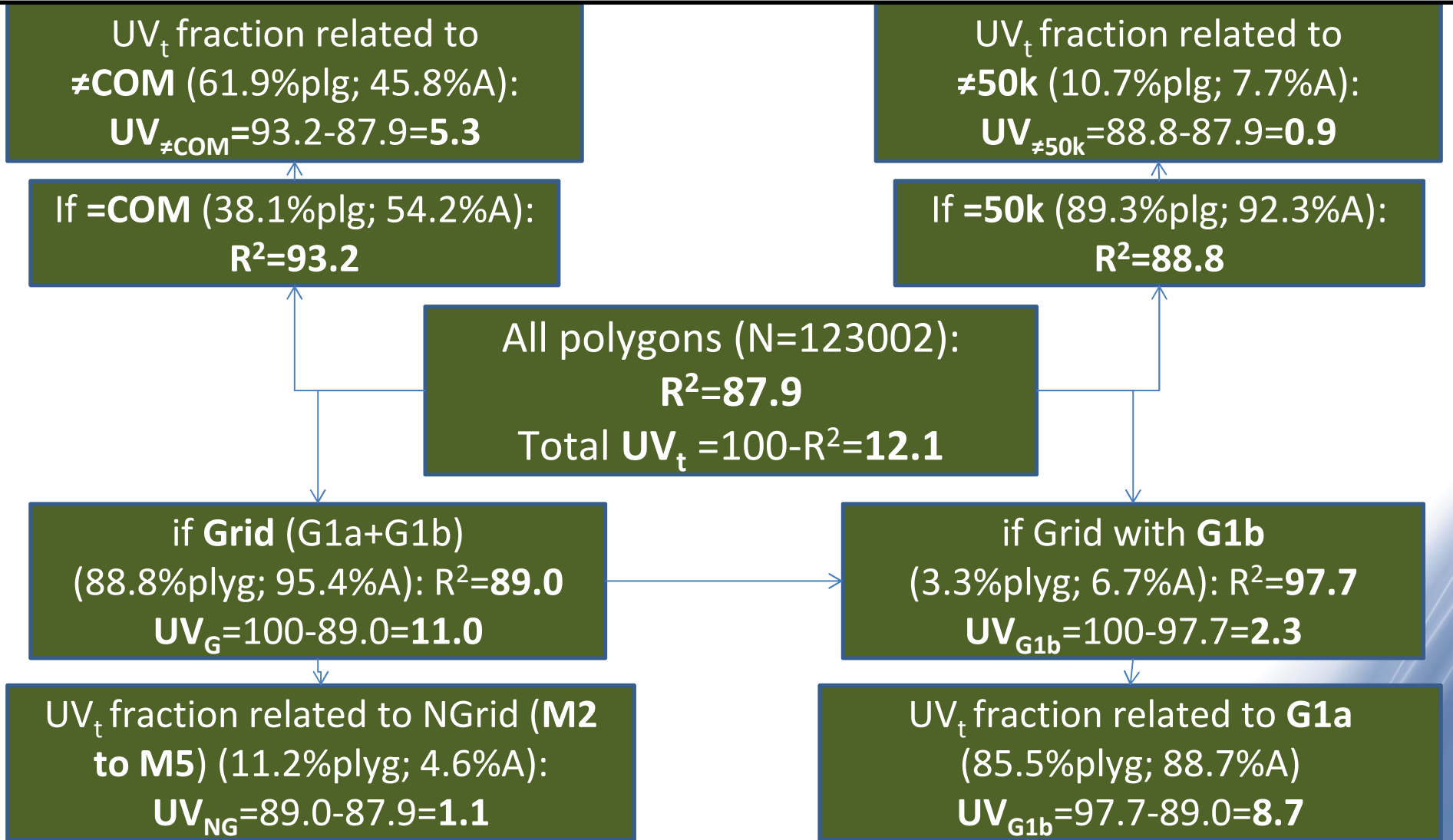


**raw RnP data (R2=81.4%)**



**LR(RnP\*A) (R2=87.9%)**

**Estimating the contribution of identified factors**  
**using  $R^2$  and UV (1-  $R^2$ ) from LINEAR REGRESSION of RnP14 with RnP06**  
**after a LogRatio transformation  $Log_{10} \frac{RnP*A}{100M-RnP*A}$  1<sup>st</sup> attempt :**



Estimating the contribution of identified factors  
 using  $R^2$  and  $UV$  ( $1 - R^2$ ) from **LINEAR REGRESSION** of **RnP14** with **RnP06**

after a LogRatio transformation  $Log_{10} \frac{RnP * A}{100M - RnP * A}$  2<sup>nd</sup> attempt :

**Total  $UV_t$  (N=123002):  $100 - R^2 = 100 - 87.9 = 12.1$**

Select polygons with RnP based on **Grid (G1a+G1b)** methods

if polygons were all **Grid (G1a+G1b)** (88.8%plyg; 95.4%A):

$R_G^2 = 89.0$ ;  $UV_G = 100 - 89.0 = 11.0$

Select =**COM**

Select =**50k**

if **Grid** plyg were =**COM** (34.8%  
plyg; 52.7%A):  $R_{Gx=COM}^2 = 94.8$

$UV_{Gx=COM} = 100 - 94.8 = 5.2$

$UV_G$  increasing due to  $\neq$ **COM**  
(54.0%plyg; 42.7%A):

$UV_{Gx \neq COM} = 94.8 - 89.0 = 5.8$

if **Grid** plyg were =**50k** (78.8%  
plyg; 87.7%A):  $R_{Gx=50k}^2 = 90.1$

$UV_{Gx=50k} = 100 - 90.1 = 9.9$

$UV_G$  increasing due to  $\neq$ **50k**  
(10.0%plyg; 7.6%A):

$UV_{Gx \neq 50k} = 90.1 - 89.0 = 1.1$

$UV_t$  increasing due  
to **M2 - M5**  
(11.2%plyg; 4.6%A)  
 $UV_{NG} = 89.0 - 87.9 = 1.1$

Select =**COM + =50k**

if **Grid (G1a+G1b)** plyg were =**COM and =50k** (32.8%plyg; 49.8%A):

$R_{Gx=COMx=50k}^2 = 95.3$   $UV_{Gx=COMx=50k} = 100 - 95.3 = 4.7$

$UV_G$  increasing related to  $\neq$ **50k**  
(2.1%plyg; 2.9%A):

$UV_{Gx=COMx \neq 50k} = 95.3 - 94.8 = 0.5$

$UV_G$  increasing related to  $\neq$ **COM**  
(46.0%plyg; 37.9%A):

$UV_{Gx=COMx \neq 50k} = 95.3 - 90.1 = 5.2$

**G1b** (2.4%pl;  
5.1%A):

$UV_{G1bx=COMx=50k} = 100 - 98.5 = 1.5$

**G1a**

$UV_{G1ax=COMx=50k} = 98.5 - 95.3 = 3.2$

in **Grid** plgs, estimate of the  $UV$  increasing due to  $\neq$ **COM + =50k**

(56.0%plyg; 45.6%A):  $UV_{Gx(\neq COM + =50k)} = 95.3 - 89.0 = 6.3$

Estimating the contribution of identified factors  
using  $R^2$  and UV ( $1 - R^2$ ) from **LINEAR REGRESSION** of **RnP14** with **RnP06**  
after a LogRatio transformation  $\text{Log}_{10} \frac{\text{RnP}^*A}{100M - \text{RnP}^*A}$  1<sup>st</sup> and 2<sup>nd</sup> attempts :

( $R^2=$ ) 87.9% of the variance of LR( $\text{RnP}_{14}^*A$ ) is explained by the LR( $\text{RnP}_{06}^*A$ )  
Unexplained Variance (N=123002):  $100 - R^2 = 100 - 87.9 = 12.1\%$

(a) **4.7** (out of 12.1, **38.8%**): estimate of the **local to regional variability** due to the new Rn measurements:

(a1) **1.5 to 2.3** (out of 12.1): estimate of the **LOCAL** (intra 1Km<sup>2</sup>) variability due to the new Rn measurements;

(a2) **2.4 to 3.2** (out of 12.1): estimate of the **REGIONAL** (intra COM) variability due to the new Rn measurements.

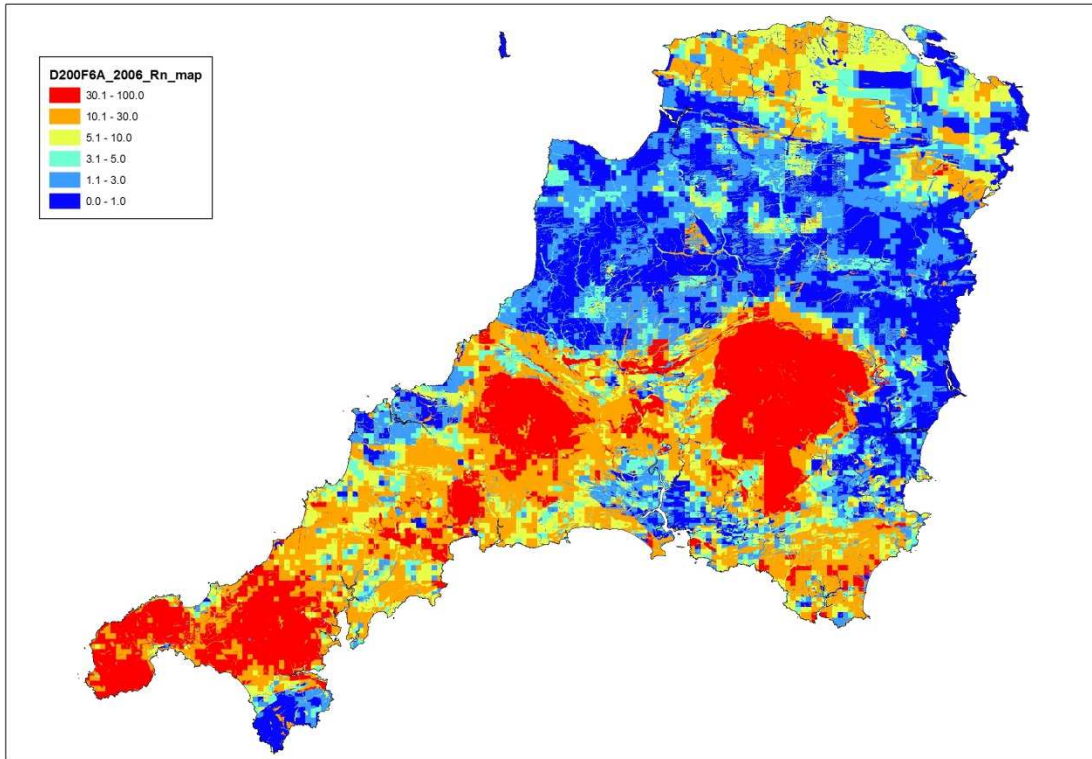
(b) an estimated maximum increasing of **1.1** (out of 12.1, **9.1%**) is related to the methods **M2 to M5** used for NGrid polygons.

(c) **6.3** (out of 12.1, **52.1%**): estimate of the variability added to (a) due to **changes in geology**.

(c1) **0.5 to 1.1** : relates to the 3 new **1:50k** geological maps

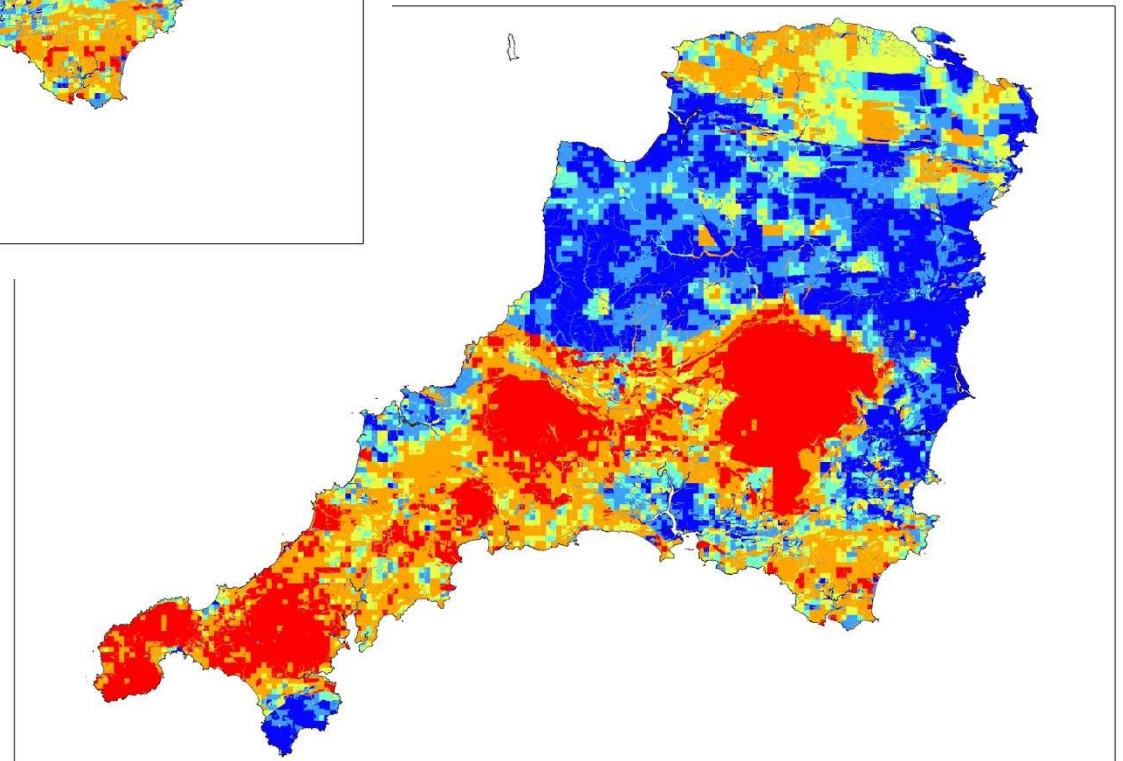
(c2) **5.2 to 5.8** : relates to the changes in the geological combinations (**COMs**).

# Radon Potential Mapping in the SW England



RnP 2006

RnP 2014



this may be not the end  
of the process...(??)

but is the  
**END of the TALK!** 😊