Soil uranium, soil gas radon and indoor radon empirical relationships in the UK and other European countries

Don Appleton (BGS) and Jon Miles (HPA)

EUROPEAN GEOGENIC RADON POTENTIAL MAP

- Wide range of numerical (quantitative) data types: indoor radon, soil gas radon, U in soil (measured and estimated from airborne or ground gamma spectrometry), U in rock; U in sediment.
- European radon potential classification based on combining layers of available input variables requires an understanding of the empirical relationships between indoor radon (main hazard to human health) and other numerical data types.
- European radon potential classification will also have to deal with categorical (qualitative) data (e.g. rock type and structural features, such as faults) but this is outside scope of this presentation.

DATA

- Estimated U in <2mm topsoil derived from estimated U (eU) from airborne gamma spectrometry [*Estimated <2mm soil U = 1.7216 * HiRES eU mg/kg)*]
- U in topsoil (5-20 cm depth) soil geochemical samples (<2mm fraction); potentially better correlation with airborne gamma spectrometry data than subsurface (20-50 cm soil U data)
- Radon concentrations in soil gas
- Radon concentrations in homes

Data grouped by geological unit and sub-area (usually 1-km or 5-km grid square)

REGRESSION ANALYSIS

- Spatially and geologically grouped data should be approximately normally distributed to give most robust central estimate for *least squares linear regression analysis*

- Anderson-Darling normality tests indicate regression modelling should be based on:

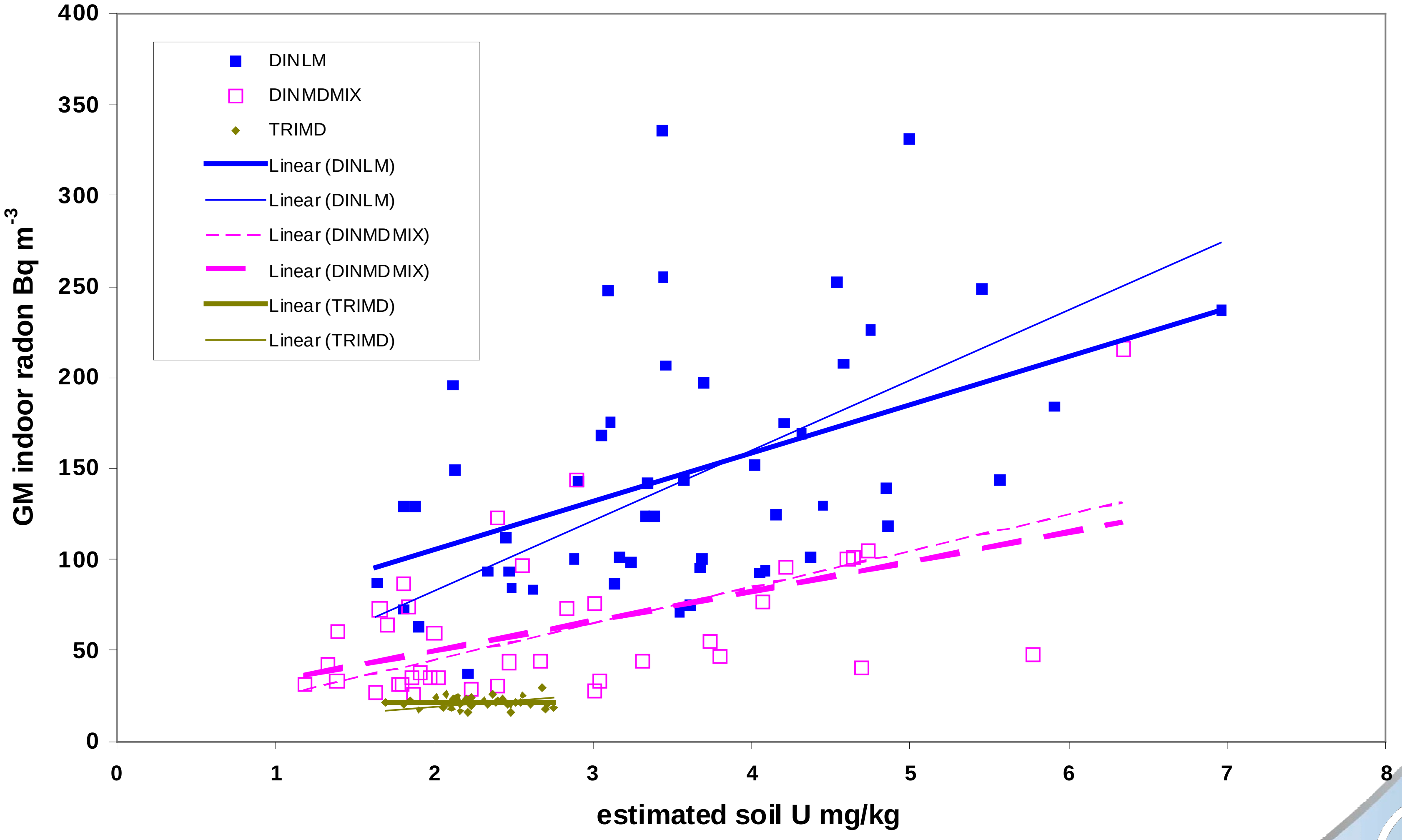
  1. Arithmetic means of airborne eU and soil U data
  2. Geometric means of lognormally distributed soil gas and indoor radon data

- LS regression analysis results have limitations related to uncertainties of x and y axis data AND outliers

MODELS BASED ON AIRBORNE GAMMA SPECTROMETRY DATA

Estimated U in <2mm topsoil derived from estimated U (eU) from HiRES airborne gamma spectrometry [*Estimated <2mm soil U = 1.7216 * HiRES eU mg/kg)*]

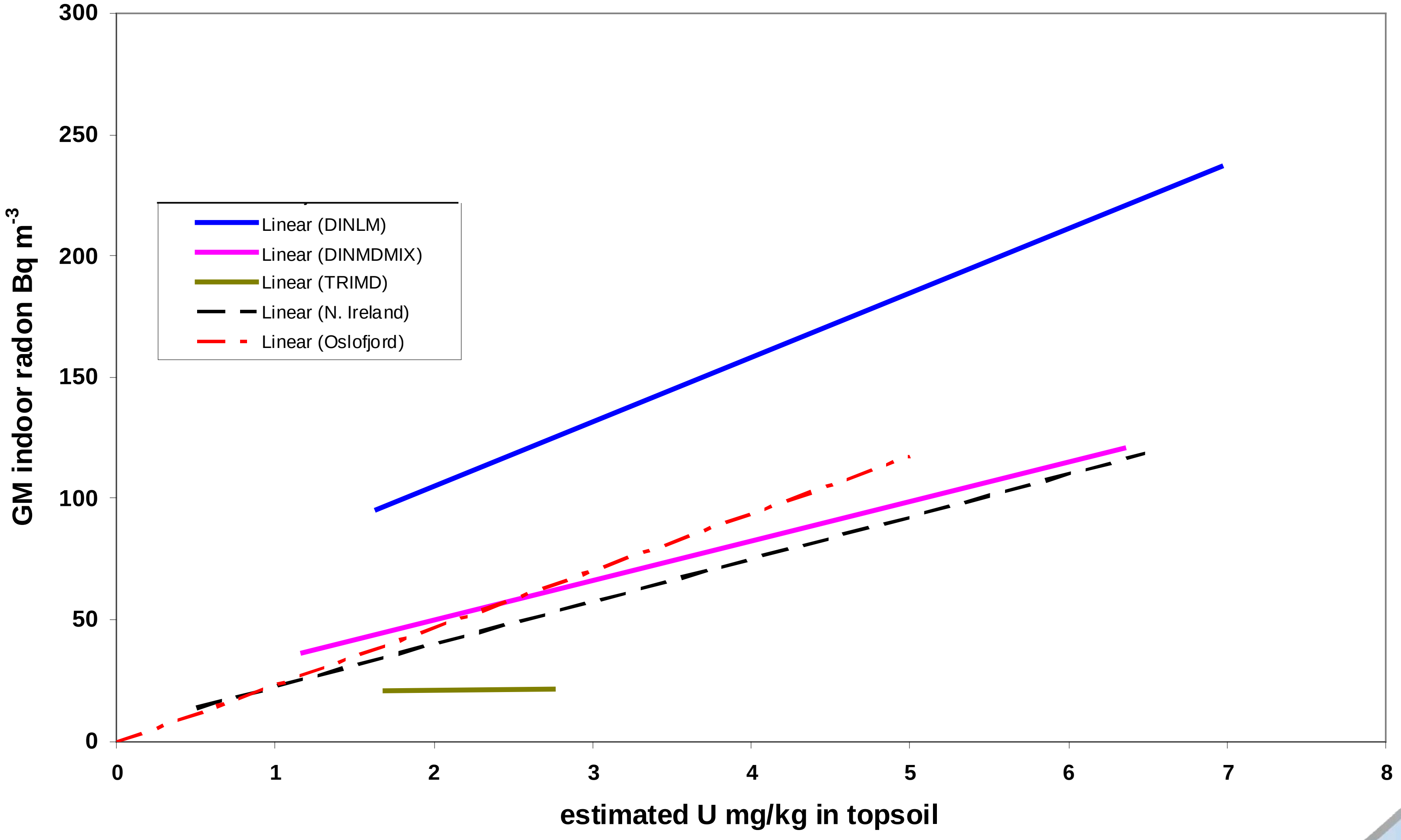
Figure 1: Least squares regression models between estimated soil U (derived from HiRES eU) and GM indoor radon (data grouped by 1-km grid square and geology; thin lines have intercepts set to 5 Bq m^{-3}))



INTERCEPTS

- High positive intercepts on y axis of least squares (LS) linear regression models probably due to uncertainties of indoor radon, soil gas radon and soil U data
- UNSCEAR (1993) estimated world mean outdoor radon (10 Bq m^{-3}) and indoor contribution from building materials (6 Bq m^{-3})
- UNSCEAR intercept of 16 Bq m^{-3} inappropriate for UK where a value of 5 Bq m^{-3} is the best estimate for combined indoor contribution from outdoor radon and UK building materials
- LS regression models for UK data therefore forced to intercept y-axis at 5 Bq m^{-3} (thin regression lines in previous slide)

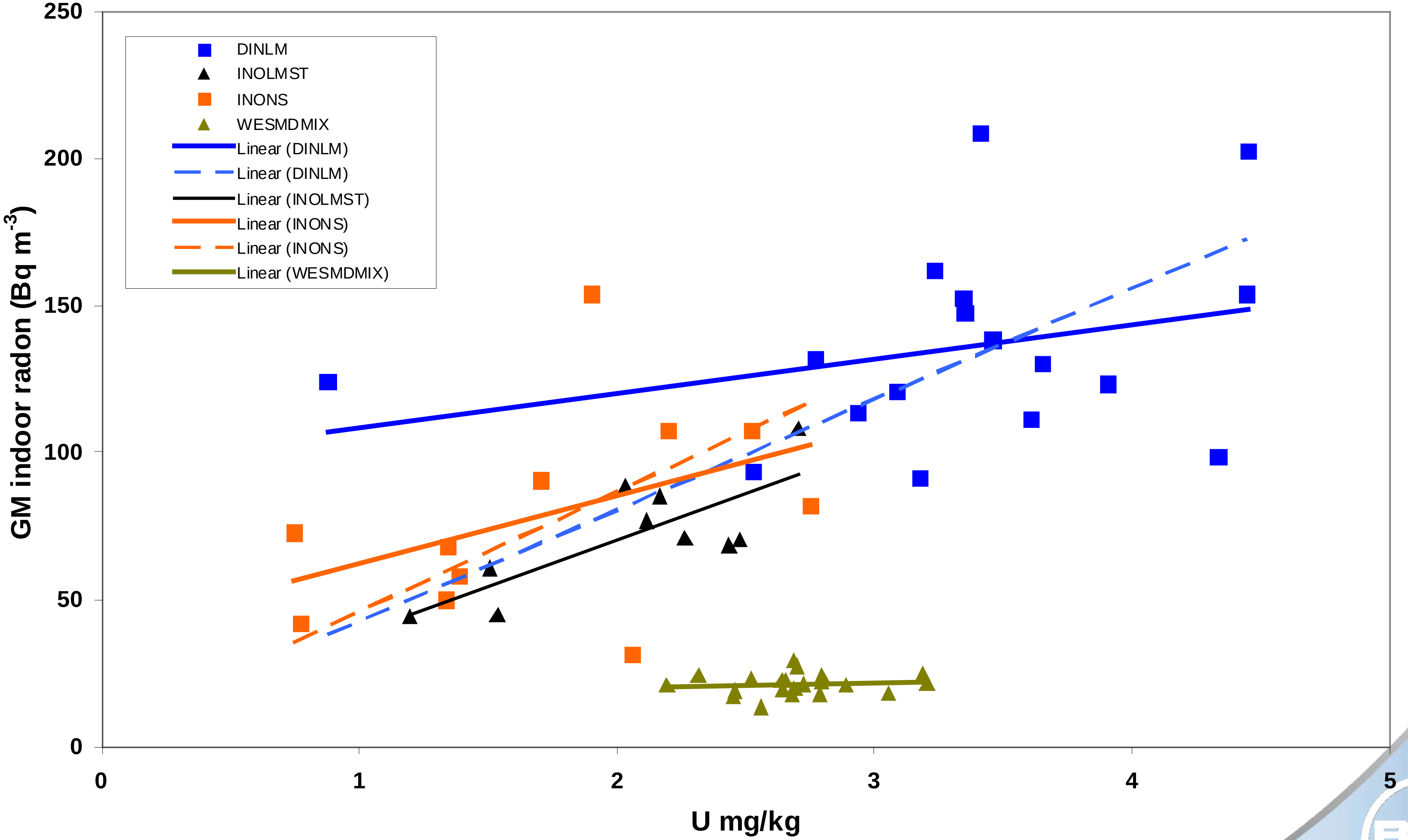
Figure 2: Least squares regression models between estimated soil U (derived from HiRES eU) and GM indoor radon (data grouped by 1-km grid square and geology) compared with data for Oslofjord region and N. Ireland



MODELS BASED ON SOIL CHEMISTRY DATA

U (mg/kg) in <2mm fraction of topsoil determined by XRF

Figure 3: Least squares regression models between U in <2mm fraction of topsoils and GM indoor radon (data grouped by 5-km grid square and geology; dashed lines have intercepts set to 5 Bq m^{-3})



MODELS BASED ON SOIL GAS RADON DATA

Geometric mean of soil gas radon concentrations (Bq/L) grouped by geology and grid square

Figure 4: GM soil gas radon vs. GM indoor radon (data grouped by 1-km or 5-km grid square and geology)

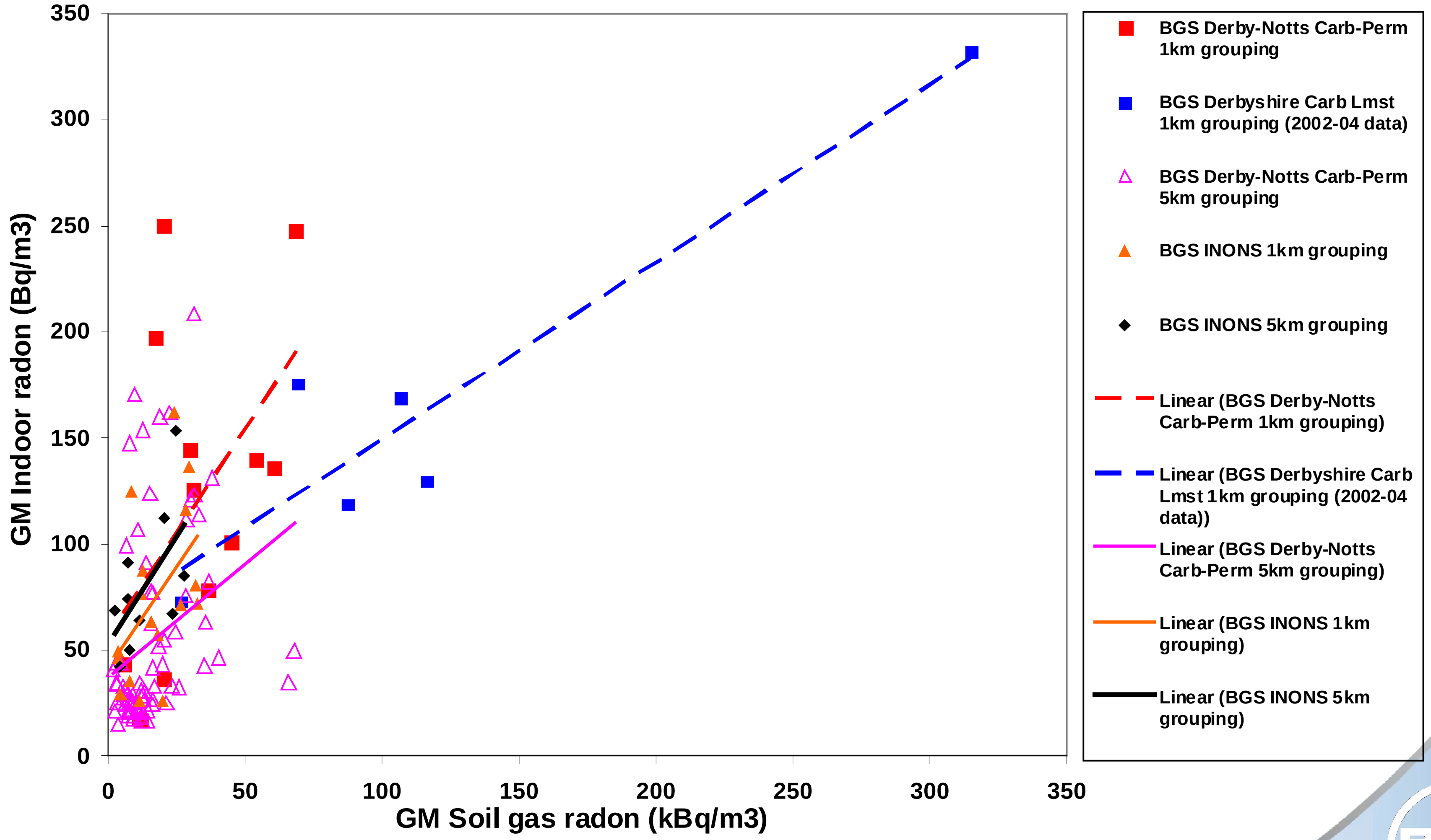


Figure 5: GM soil gas radon vs. GM indoor radon (data grouped by 1-km or 5-km grid square and geology; intercepts set at 5 Bq m^{-3})

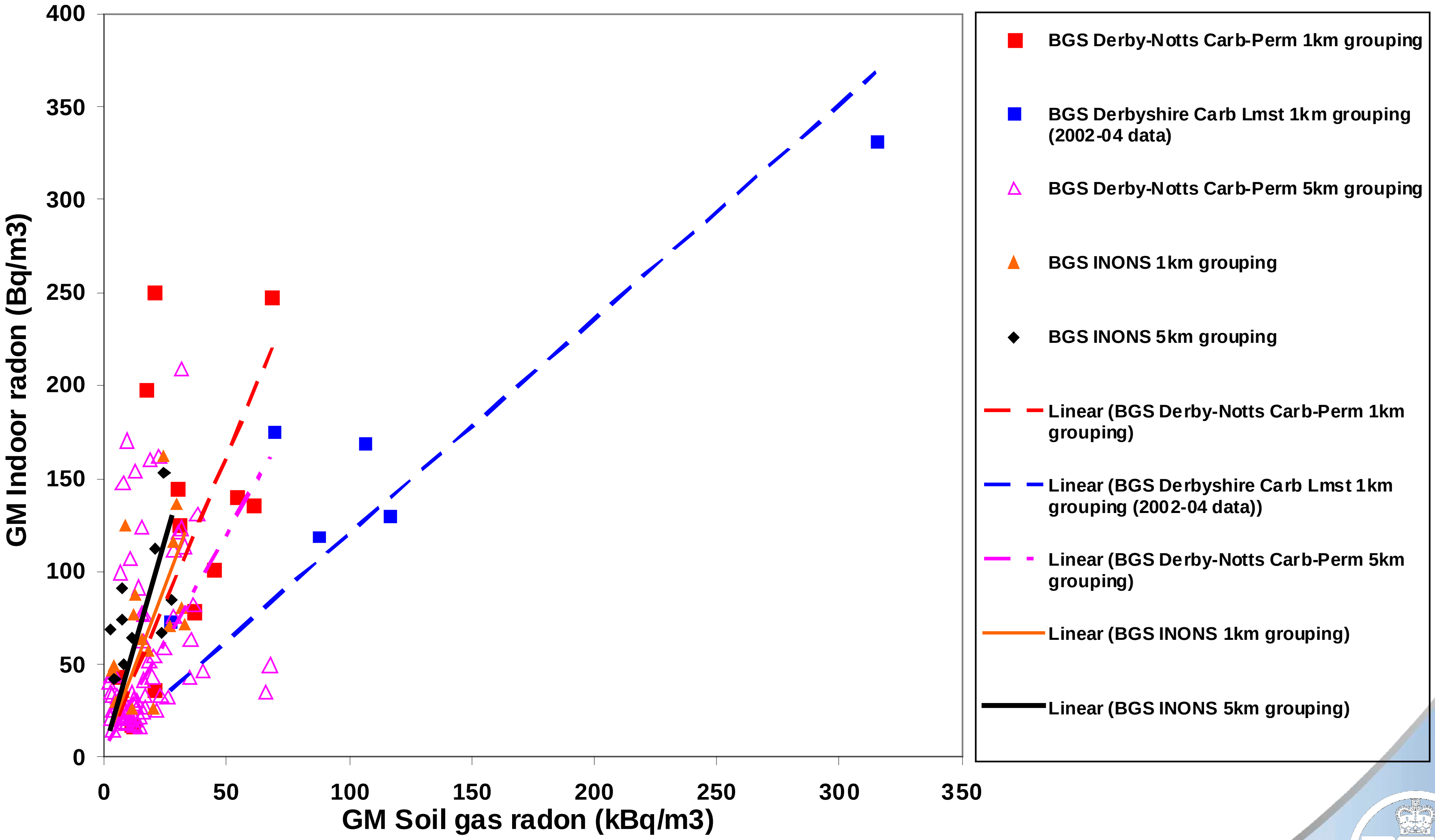


Figure 5a: Least squares regression models between GM and AM indoor radon (data grouped by 5-km grid square and geology)

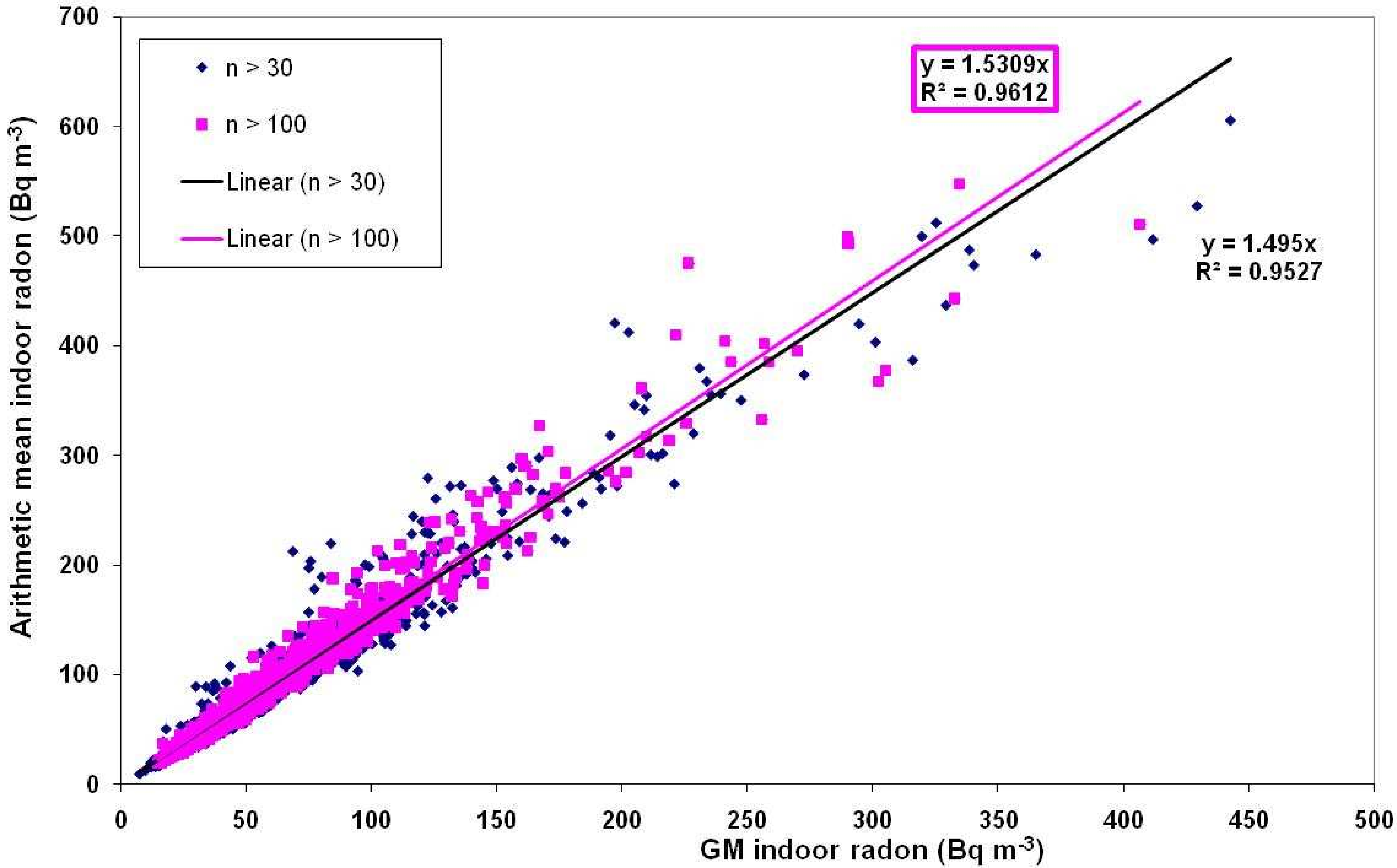
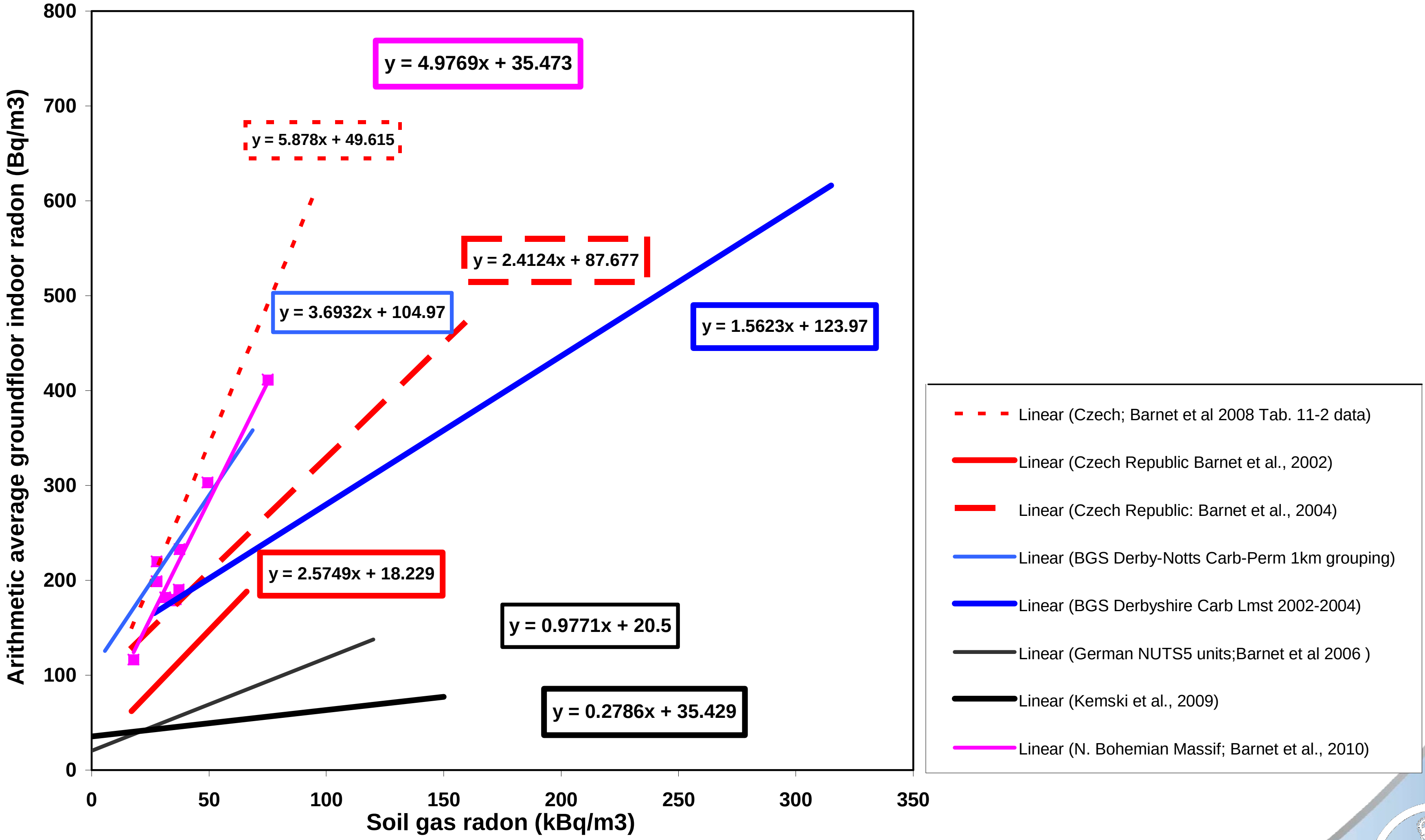


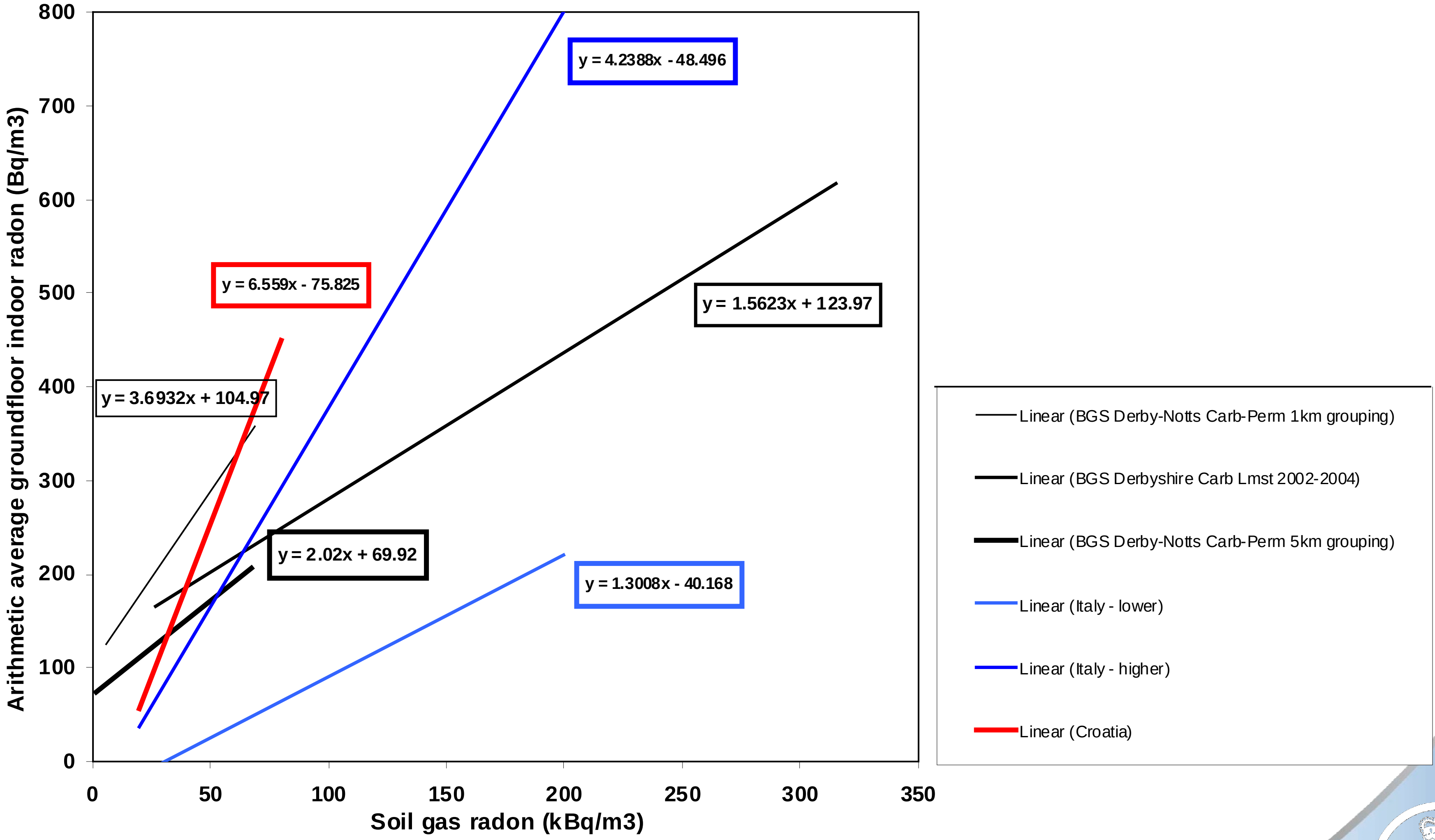
Figure 6: Soil gas radon vs. estimated arithmetic mean indoor radon linear regression models for England, Czech Republic and Germany



Indoor radon: soil gas radon ratios

- UK (GM) models similar to arithmetic mean SG Czech data
- Both significantly higher than German models based Maximum SG data
- Different house national and regional characteristics will also impact on IR/SG ratios
- Older buildings with ‘leaky’ floors are likely to have higher IR/SG ratios
- Příbram (Czech Rep) has higher IR/SG ratio than average; lower ratios for magmatic rocks, medium ratios for metamorphic, highest ratios for sedimentary rocks.

Figure 7: Soil gas radon vs. estimated arithmetic mean indoor radon linear regression models for England, Italy and Croatia



CONCLUSIONS

- ASSUMPTIONS: linear relationship between surrogates for source of radon (e.g. eU or U) and radon in homes
- DATA DISTRIBUTIONS : eU and soil U normally distributed (therefore use AM for modelling); soil gas and indoor radon log-normally distributed (use GM)
- MEASUREMENT UNCERTAINTIES: impact on slopes and intercepts of LS regression models; slopes generally steeper for fixed intercepts (5 Bq m^{-3} in UK)
- PERMEABILITY OF THE GROUND: Radon concentrations in houses generated from specific U or soil gas radon concentrations generally increase with the permeability of the ground
- GEOGENIC RADON MAP OF EUROPE: further research required to generate robust empirical relationships for the wide range of numerical input data types (and also for categorical data types).