

Review of ^{222}Rn Emissions

Franz Conen

Radon-222 is emitted from all ice-free land surfaces. Ice cover inhibits its emission. Oceans, where its parent material, ^{226}Ra , is in solution emit about two orders of magnitude less ^{222}Rn than continents (Lambert et al., 1982). Negligible amounts are emitted in gas emanating from volcanoes (Lambert et al., 1979). There are no other sources of atmospheric ^{222}Rn .

Turekian et al. (1977) estimated ^{222}Rn flux from continents to be $1.2 \text{ atoms cm}^{-2}\text{s}^{-1}$. Lambert et al. (1982) derived an average ^{222}Rn flux of $0.71 \text{ atoms cm}^{-2}\text{s}^{-1}$ for the northern, and $0.72 \text{ atoms cm}^{-2}\text{s}^{-1}$ for the southern hemisphere. Conen and Robertson (2002) proposed an emissions distribution of $1 \text{ atom cm}^{-2}\text{s}^{-1}$ for 60°S to 30°N , declining linearly northwards to $0.2 \text{ atoms cm}^{-2}\text{s}^{-1}$ at 70°N . All these values are based on atmospheric ^{222}Rn concentration and ^{210}Pb deposition flux measurements. Based on directly measured ^{222}Rn soil flux and related parameters, Schery and Wasiolek (1998) modelled global ^{222}Rn flux on a 10×10 grid and estimated a global average of $1.6 (\pm 0.4) \text{ atoms cm}^{-2}\text{s}^{-1}$ with significant regional variations (map can be accessed on Stephen D. Schery's home page: <http://www.nmt.edu/~schery/>.)

In validating global circulation models (GCM), ^{222}Rn flux is generally assumed to be spatially uniform and $1 \text{ atom cm}^{-2}\text{s}^{-1}$ from ice-free land surfaces and zero from oceans. However, including emissions of $0.01 \text{ atoms cm}^{-2}\text{s}^{-1}$ from oceans between 60°S and 60°N improved predictions of measured ^{222}Rn concentrations by the GCM NIRE-CTM-96 at remote sites in the South Indian Ocean and Antarctic (Taguchi et al, 2002). For continental emissions Lee and Feichter (1995) concluded that a non-uniform distribution ($1 \text{ atom cm}^{-2}\text{s}^{-1}$ from 60°S to 60°N ; $0.005 \text{ atoms cm}^{-2}\text{s}^{-1}$ from 60°N to 70°N) would improve predictions of global transport and deposition of ^{210}Pb , a daughter product of ^{222}Rn . A similar assumption ($1 \text{ atom cm}^{-2}\text{s}^{-1}$ from 60°S to 60°N ; $0.5 \text{ atoms cm}^{-2}\text{s}^{-1}$ from 60°N to 70°N) was made in a comparison of scavenging and deposition processes in global models at the WCRP Cambridge Workshop 1995 (Rasch et al., 2000). Predictions by the GCM STOCHEM3 for ^{222}Rn concentrations in the surface layer based on a uniform ($1 \text{ atom cm}^{-2}\text{s}^{-1}$) and a northwards declining emissions distribution are currently compared to long-term ^{222}Rn concentrations measured at 17 ground based stations around the globe (L.B. Robertson, D.S. Stevenson & F. Conen; University of Edinburgh, in preparation). (Radon concentration data for 1991-1996 at Mauna Loa and Bermudas can be found at <http://www.eml.doe.gov/databases/radon/>).

In the long term, a reduction of the ice-covered land surface might result in very small increases in global ^{222}Rn emission. However, some of this increase would be offset by increasing sea levels and subsequent submersion of coastal areas.

Regionally, seasonal variations of $\pm 25\%$ (Schüler, 1996, cited in: Levin et al, 1999; Whittlestone et al., 1998) or of a factor of two (Schery & Wasiolek, 1998) have been reported, with largest emissions during summer and smallest emissions in winter.

Important factors affecting ^{222}Rn emission are ^{226}Ra content of the soil (Schery & Wasiolek), precipitation (Ferry et al., 2001), soil moisture (Nazaroff, 1992), water table depth (Conen & Robertson) and soil texture (Dörr & Münnich, 1990).

References

- Conen, F. & Robertson, L.B. 2001. Latitudinal distribution of Rn-222 flux from continents. *Tellus*, 54B, 127-133.
- Dörr, H. and Münnich, K.O. 1990. ^{222}Rn flux and soil air concentration profiles in West-Germany. Soil ^{222}Rn as a tracer for gas transport in the unsaturated soil zone. *Tellus*, 42B, 20-28.
- Ferry, C., Beneito, A., Richon, P. & Robe, M.-C. 2001. An automatic device for measuring the effect of meteorological factors on radon-222 flux from soils in the long term. *Radiation Protection Dosimetry*, 93, 271-274.
- Lambert, G., Polian, G., Sanak, J., Ardouin, B., Buisson, A., Jegou, A. & Le Roulley, J.C. 1982. Cycle du radon et de ses descendants: application à l'étude des échanges troposphère-stratosphère. *Annales de Géophysique*, 38, 497-531.
- Lambert, G., Buisson, A., Sanak, J. & Ardouin, B. 1979. Modification of the atmospheric polonium 210 to lead 210 ratio by volcanic emissions. *Journal of Geophysical Research*, 84, 6980-6986.
- Lee, H.N. and Feichter, J. 1995. An intercomparison of wet precipitation scavenging schemes and the emission rates of ^{222}Rn for the simulation of global transport and deposition of ^{210}Pb . *Journal of Geophysical Research*, 100, 23,252-23,270.
- Levin, I., Glatzel-Mattheier, H., Marik, T., Cuntz, M. and Schmidt, M. 1999. Verification of German methane emission inventories and their recent changes based on atmospheric observations. *Journal of Geophysical Research*, 104, 3447-3456.
- Nazaroff, 1992. Radon transport from soil to air. *Reviews of Geophysics*, 30, 137-160.
- Rasch, P.J., Feichter, J., Law, K., Mahowald, N., Penner, J., Benkovitz, C., Genthon, C., Giannakopoulos, C., Kasibhatla, P., Koch, D., Levy, H., Maki, T., Prather, M., Roberts, D.L., Roelofs, G.-J., Stevenson, D., Stockwell, Z., Taguchi, S., Kritz M., Chipperfield, M., Baldocchi, D., McMurry, P., Barrie, L., Balkanski, Y., Chatfield, R., Kjellström, E., Lawrence, M., Lee, H.N., Lelieveld, J., Noone, K.J., Seinfeld, J., Stenchikov, G., Schwartz, S., Walcek, C. and Williamson, D. 2000. A comparison of scavenging and deposition processes in global models: results from the WCRP Cambridge Workshop of 1995. *Tellus*, 52B, 1025-1056.
- Taguchi, S., Iida, T & Moriizumi, J. 2002. Evaluation of the atmospheric transport model NIRE-CTM-96 by using radon-222 concentrations. *Tellus*, 54B, 250-268.
- Turekian, K.K., Nozaki, Y. & Benninger, L.K. 1977. Geochemistry of atmospheric radon

and radon products. *Annual Review of Earth Planetary Sciences*, 5, 227-255.

Schery S.D. & Wasiolek M.A. 1998. Modelling radon flux from the earth's surface. In: *Radon and Thoron in the Human Environment, Proceedings of the 7th Tohwa University International Symposium*, (eds A. Katase & M. Shimo), pp. 207-217, World Scientific, Singapore.

Whittlestone, S., Zahorowski, W. and Schery, S.D. 1998. Radon flux variability with season and location in Tasmania, Australia. *Journal of Radioanalytical and Nuclear Chemistry*, 236, 213-217.

(last modified 02/28/05)