Atmospheric Transport of Radionuclides and Gravitational Settling

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Starting point of this investigation was the measurement of the ^{41}Ca bomb pulse in an ice core of the Fiescherhorn glacier in the Aletsch region in the Swiss Alps [1]. This pulse is with a maximum concentration of about $3 \cdot 10^6$ ^{41}Ca atoms/kg rather weak and is observed around 1954. For comparison, the ^{36}Cl bomb pulse observed in Greenland ice cores [2] has a maximun concentration of $7 \cdot 10^8$ atoms/kg in 1957. Bomb produced tracers are inputs sharp in time into atmosphere, hydrosphere, biosphere and lithosphere and are well suited for studies of transport and exchange processes. In order to explain the low amplitude and the early occurrence of the ^{41}Ca bomb pulse, a two-dimensional atmospheric box model was developed which is able to describe the atmospheric transport of all bomb produced radionuclides, fission products as e. g. ^{90}Sr and ^{137}Cs and activation products as e. g. ^{14}C, ^{36}Cl and ^{41}Ca which are gaseous or attached to aerosols, and of cosmogenic radionuclides as e. g. ^{10}Be and ^{36}Cl.

Two 2-dimensional box models were developed. The first one is divided horizontally into two hemisphere boxes and two local boxes for the input of radionuclides, and vertically into troposphere and lower and upper stratosphere. The second one is divided horizontally into 18 latitude belts and vertically into troposphere and 4 stratosphere layers and has seasonal dependent exchange rates. The late occurrence of the ^{36}Cl bomb pulse in comparison with the ones of ^{90}Sr and ^{137}Cs is explained by the fact that ^{36}Cl is gaseous in the stratosphere whereas ^{90}Sr and ^{137}Cs are attached to aerosols and subject to gravitational settling in the stratosphere in addition to diffusive and convectional transport. This sedimentation is described by the frictional force given by Stokes and Cunningham.

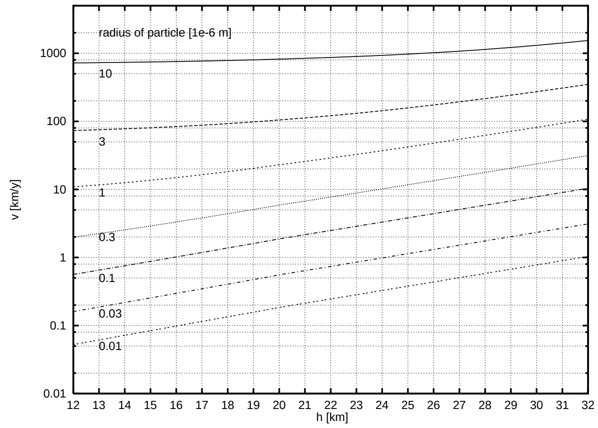

Fig. 1: Sedimentation velocities of aerosol particles in the stratosphere calculated with the frictional force of Stokes and Cunningham.

Fig. 1 shows sedimentation velocities v of small particles with radii between 0.01 and 10μm for different altitudes. For typical aerosols with radii around 0.3 μm v is in the range of several km/y.

Fig. 2 shows the ^{36}Cl bomb pulse calculated with the first model in comparison with measured data [2].

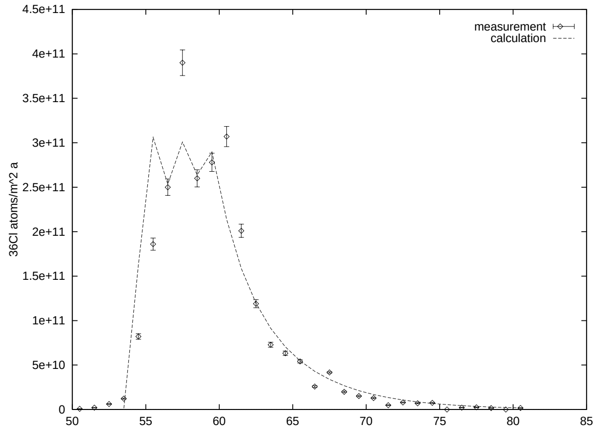

Fig. 2: Calculated ^{36}Cl bomb pulse in comparison with measured data [2]
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In this calculation, it was assumed that ^{36}Cl essentially is produced by the explosions on barges. In Fig. 3, the calculated ^{137}Cs bomb pulse is drawn together with measured concentrations in the Fiescherhorn glacier ice core [3]. It is seen that the model is well suited to describe the atmospheric transport of radionuclides which are gaseous or attached to aerosols in the stratosphere. The calculations with cosmogenic radionuclides are in progress.

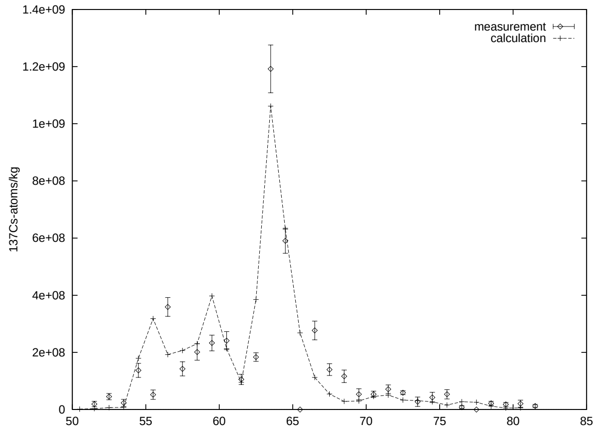

Fig. 3: Calculated ^{137}Cs bomb pulse in comparison with measured data [3]

References

[1] J. Beer et al., Jahresbericht 1994, p. 134
[2] H.-A. Synal et al., Nucl. Instr. and Meth. **B52** (1990) 483
[3] J. Beer, A. Albrecht, priv. comm. (1995)