Transport and scavenging of radionuclides in deep convection

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- What processes explain the evolution of the concentration?
- How does convection influence the particle distribution in the atmosphere?

**Goal**

- Provide diagnostics for atmospheric processes parameterized assessment
Transport of tracer

$$(\partial_t q)_{\text{large scale}} + (\partial_t q)_{\text{conv}} + (\partial_t q)_{\text{PBL}} + (\partial_t q)_{\text{deposition}} = S$$
Transport of tracer

\[ (\partial_t q)_{\text{large scale}} + (\partial_t q)_{\text{conv}} + (\partial_t q)_{\text{PBL}} + (\partial_t q)_{\text{deposition}} = S \]

Deep convection

Deposition terms

Wet scavenging, dry scavenging, radioactive decay

- Radionuclide $^7$Be → neutral tracer
- Half-life 53 days
- Source mainly in upper tropo lower strato

Emanuel mass-flux scheme
Parameterization of convective scavenging

Convective saturated updraft

Introduction of tracer into the cloud
Parameterization of convective scavenging

Convective saturated updraft

- Mixing
- Entrainment
- Introduction of tracer into the cloud
Parameterization of convective scavenging

Convective saturated updraft

Introduction of tracer into the cloud
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Convective saturated updraft

- Precipitation of condensate
- Detrainment
- Mixing
- Entrainment
- Introduction of tracer into the cloud
Parameterization of convective scavenging

Unsaturated downdraft

Source of precipitations

precipitations

evaporation

impaction

unsaturated air

entrainment
detrainment
Parameterization of convective scavenging

Unsaturated downdraft

Resolving these budget equations

\[
\begin{align*}
- \frac{\partial (\mathcal{P} q_p)}{\partial z} + S_p q_C + \rho \sigma_d ( -E q_p + \mathcal{I} q_d ) &= 0 \\
- \frac{\partial (M_d q_d)}{\partial z} + e \tilde{q} - d q_d + \rho \sigma_d ( E q_p - \mathcal{I} q_d ) &= 0
\end{align*}
\]

Impaction term \( \mathcal{I} = \frac{3\mathcal{P}}{4\rho_1 \sigma_d r} \)
Experimental simulation: TOGA with $^7\text{Be}$
Experimental simulation: TOGA with $^7\text{Be}$
Experimental simulation: TOGA with $^7$Be

- Precipitation
- Entrainment into the cloud
- Entrainment into the unsaturated downdraft
Experimental simulation: TOGA with $^7$Be

Integral of concentration in the atmosphere
Black: no convective scavenging, red, with convective scavenging

Difference between the 2 curves  precipitation
TOGA with $^7$Be and datas

- Convective scavenging increases levels of concentration at the surface
- Magnitude closer to the datas

Surface concentrations
Black: CTBTO datas, blue: without convective scavenging, purple: with convective scavenging
Summary and outlook

- Process-based convective scavenging
- Tool for validation of convective scheme parameterization
- Help to understand processes in convection
- Comparison with CRM
- Model-data comparison methodology (GCM)
- Paleoclimatology ($^{10}$Be)
Wet scavenging

\[ \frac{dN(D_p)}{dt} = -\Lambda(D_p, t)N(D_p, t) \]

with

\[ \Lambda(D_p, t) = \int_0^\infty \frac{\pi}{4} D^2 E(D_p, D) V_t(D) N(D) dD \]

- particle size
- aerosol number concentration
- drop size
- collision efficiency
- terminal velocity of rain drop