Insights on Aerosol Lifetimes and Wet Scavenging Following the Fukushima Nuclear Accident

B. Croft¹, J. R. Pierce¹,², and R. V. Martin¹,³

¹Department of Physics and Atmospheric Science, Dalhousie University, Halifax, Canada
²Department of Atmospheric Science, Colorado State University, Fort Collins, USA
³Harvard-Smithsonian Center for Astrophysics, Cambridge, USA

Introduction:

- The Fukushima Dai-ichi nuclear power plant accident emitted large amounts of $^{137}$Cs, $^{131}$I, and $^{133}$Xe into the atmosphere after the March 10, 2011 earthquake.
- Examination of these radionuclide removal times is a useful constraint on aerosol lifetimes and wet scavenging in a global model.
- Simulation of $^{137}$Cs and $^{133}$Xe is implemented in the GEOS-Chem model and lifetimes of $^{137}$Cs/$^{133}$Xe following the Fukushima nuclear accident are examined.

Radionuclide Emissions:

- Total $^{133}$Xe Emitted: 15.3 EBq (Stohl et al., 2012)
- Largest release in history ~ 2x Chernobyl
- ~43% of Chernobyl emissions
- Total $^{137}$Cs Emitted: 36.6 PBq (Stohl et al., 2012)

Lifetime Definitions:

1) Decay-State Instantaneous Life (DSIL)
   \[ DSIL = \frac{-(t_i-t_i-1)}{\ln(C_i/C_{i-1})} \]
   - Decay-State: Pulse emissions with lifetime calculated after burden peaks
   - Steady-State: Emissions at equilibrium with removal over time considered

2) Decay-State Mean Life (DSML)
   \[ DSML = \frac{1}{Emissions} \sum (C_i-C_{i-1})/(t_i-t_{i-1}) \]

3) Decay State E-folding Time (DSET)
   \[ DSET = \frac{-(t_i-t_{i-1})}{\ln(C_i/C_{i-1})} \]

4) Steady-State Global Mean Life (SSML)
   \[ SSML = \frac{1}{Emissions} \sum (C_i/C_{i-1}) \]

Interpreting Lifetimes:

- $^{137}$Cs undergoes wet scavenging processes similar to soluble aerosols. The GEOS-Chem sulfate global mean lifetime (SSML) is ~6.8 days (standard simulation).
- The predominant sulfate production pathway in clouds likely contributes to the lower sulfate lifetime relative to $^{137}$Cs.

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