14.3 Lightning Emissions—Greenhouse Gases[a]

Observations have been made of increased levels of nitrogen oxides (NO_x), nitric oxide (NO), nitrogen dioxide (NO_2), and nitrous oxide (N_2O) in the atmosphere after the occurrence and in the proximity of lightning flashes.[1-3] Although lightning is thought to be one of the larger natural sources of NO_x, N_2O production by lightning is believed to be substantially less significant, particularly in comparison to anthropogenic sources.[4-5] Estimates for global production of N_2O from lightning range from 1.36 E-02 to 9.98 E-02 Tg.[6] Emission factors for this source are uncertain. Estimates of per-lightning-flash production of NO_x (emission factors) require calculations involving the length of the lightning stroke, the number of strokes per flash, the estimated energy discharge, and the amount of N_2O produced per joule, all of which are under discussion in the literature.

N_2O emissions from lightning are based on estimates of the molecules produced per joule for each lightning stroke 1.1 E+21 molecules/lightning stroke.[6]

Published estimates for the molecules/joule factors range from 4.3 E+12 to 4.0 E+16.[6] Although most researchers use a stroke length of 5 km, stroke length varies. Estimates of the electrical discharge are based on discharge per meter, so the variability of the lightning stroke adds to the emission estimate uncertainty. Other factors that are of significance, but that are not included in this emission factor, are estimates of the number of strokes in a lightning flash (not only are there multiple strokes, but the energy output varies, as does the length of the stroke), and indications that the production of N_2O depends on electrical discharge conditions, not just the amount of the discharge energy.[7] Estimates for the electrical discharge per lightning flash (as opposed to a lightning stroke) range from 1.0 E+08 joules/flash to 8.0 E+08 joules/flash.[5]

Because the first stroke in a lightning flash will release more energy than subsequent strokes, the energy per flash is estimated by assuming the subsequent strokes release one-quarter the amount of energy released by the first stroke. Hence the total flash energy is assumed to be 1.75 times that of the first return stroke.[5] The N_2O emission factor for each lightning flash is:

$$0.14 \text{ grams } N_2O\text{/flash}$$

The number of lightning flashes within a certain time period and area may be available through the East Coast lightning detection network,[8] satellite data, or from the lightning strike data archive from the National Lightning Detection Network (GDS) in Tucson, AZ. Several assumptions must be made in order to estimate the total number of lightning flashes from these sources.[9] It is assumed that not all of the lightning flashes are detected. The East Coast lightning detection network is estimated to record 0.7 of the lightning flashes that occur. Recorded lightning flashes can then be corrected by multiplying the recorded lightning flashes by an efficiency factor of 1.43. It is also assumed that lightning flashes recorded are cloud-to-ground (CG) lightning flashes. Intra-cloud (IC) flashes can be calculated from CG activity, but vary depending on latitude. It is assumed that about four IC flashes occur for every CG flash.

The equation to calculate the number of IC flashes from CG activity is:

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[a] This section uses only metric units because that is standard in this field.

$$\text{IC activity} = \text{CG activity}\left(\frac{10}{\left(1 + \frac{\ell}{30}\right)^2} - 1\right)$$

where:

ℓ = latitude of the study area in degrees

References For Section 14.3

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