REPORT ON REVISIONS TO
5TH EDITION AP-42
Section 14.3
Lightning

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14.3 Lightning

Section 14.3 of the AP-42 addresses nitrous oxide (N_2O) emissions from lightning flashes. Since the troposphere consists of approximately 78% N_2 and 21% O_2, a significant amount of nitrogen oxides can be produced as a result of the heating and/or shock wave from a lightning channel.[1] However, the production of N_2O by lightning is relatively small compared to other biological and anthropogenic sources.

One method of determining the production of N_2O from lightning is to multiply the amount of N_2O produced per lightning flash by the number of flashes. The following factors are considered in the N_2O emission factor:

- Number of molecules of N_2O produced per lightning stroke;
- Total flash energy in relation to the first return stroke; and
- Number of lightning strokes in a lightning flash.

Together, these factors can be combined to create an emission factor that can be applied to an estimate of the number of lightning flashes to yield an estimate of the amount of N_2O generated from lightning flashes.

Hill and co-workers modeled the air chemistry of the region surrounding a lightning flash to estimate N_2O concentrations.[2] The mechanism they investigated was N_2O production from the corona discharge of lightning as opposed to the luminous central channel of lightning. They modeled an N_2O concentration increase from 330 parts per billion by volume (ppbv) under ambient conditions to 390 ppbv in the region of the lightning channel. This information was used to develop an estimate of 1.1×10^{21} molecules of N_2O produced per lightning stroke.[2]

Assuming an average stroke length of 5 km and mean energy dissipation per unit length per stroke of 1.5×10^4 J/meter,[3] Hill and co-workers also developed an estimate of N_2O

production efficiency of $1.5x10^{13}$ molecules per joule for comparison to estimates developed by other researchers. The N_2O production efficiency value of $1.5x10^{13}$ molecules per joule is in the range of other published estimates, which range from $4.3x10^{12}$ to $4.0x10^{16}$ molecules per joule.[4]

To derive the emission rate per flash, as opposed to the emission rate per stroke, the energy of a single stroke, the number of strokes per flash, and the distribution of energy among the first and subsequent strokes must be considered. Borucki and Chameides (1984) developed some assumptions about an average lightning flash based on a number of studies and reviews of the literature.[5] A lightning flash is the total discharge of energy, and consists of one or more closely-spaced strokes in time that use the same discharge channel. Optical methods of estimating the total energy dissipated by a lightning stroke are based on measurements of the optical flux, and on a conversion to the total energy, with the use of a laboratory-measured value of the optical efficiency. The optical efficiency is the fraction of the energy that appears in a specified optical region. Because optical flux measurements can be made at long distances from the lightning channel, hundreds of measurements have been made from ground-based platforms, and thousands have been made from satellite platforms.[6]

The first stroke in a flash generally dissipates the largest amount of energy, with subsequent strokes dissipating approximately 75% less energy than the first stroke.[5] This estimate provides a factor of 1.75 to scale up the estimate of emissions from the first lightning stroke to an estimate of the entire lightning flash.

The number of strokes in a lightning flash varies, depending on latitude. Values range from 1.9 strokes for cloud to ground flashes up to 6 strokes for intracloud flashes. The global average is estimated to be 4 strokes per flash.[5] Therefore, given the number of N_2O molecules generated per stroke and the number of strokes per flash, the amount of N_2O (in grams) generated per flash of lightning can be estimated as:

$$\frac{[(1.1 \times 10^{21} \text{ molecules } N_2O/\text{stroke}) \times (1.75 \text{ strokes/flash}) \times (44 \text{ g/mole } N_2O)]}{(6.02 \times 10^{23} \text{ molecules } N_2O/\text{mole})}$$

$$= \quad 0.14 \text{ grams } N_2O/\text{lightning flash}$$

Observed lightning flash activity data are available from several sources, including the East Coast lightning detection network,[7] satellite data, or from the lightning strike data archive from the national Lightning Detection Network (GDS) in Tuscon, AZ. Strokes can be characterized as being either cloud to ground or intracloud strokes. Most flashes are of the intracloud type. Estimates of the number of lightning flashes based on satellite systems data may slightly underestimate the number of cloud to ground flashes, because much of the light is reflected by the cloud base.[5]

References

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