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by

Cynthia S. Atherton

Introduction

Acetone (CH_3COCH_3) may be an important source of reactive odd hydrogen (HO_x) in the upper troposphere and lower stratosphere. This source of odd hydrogen may affect the concentration of a number of species, including ozone, nitrogen oxides, methane, and others. Traditionally, acetone has been considered a by-product of the photochemical oxidation of other species, and has not entered models as a primary emission. However, recent work (Singh et al., 1994) estimates a global source term of 40 - 60 Tg acetone/year. Of this, 25% is directly emitted during biomass burning, and 20% is directly emitted by evergreens and other plants. Only 3% is due to anthropogenic/industrial emissions. The bulk of the remainder, 51% of the acetone source, is a secondary product from the oxidation of propane, isobutane, and isobutene. Also, while Singh et al. (1994) speculate that the oxidation of α -pinene (a biogenic emission) may also contribute ~ 6 Tg/year, this term is highly uncertain. Thus, the two largest primary sources of acetone are biogenic emissions and biomass burning, with industrial/anthropogenic emissions very small in comparison.

Below a global acetone emission inventory is derived for use in global, three-dimensional models.

A. Biogenic emissions (primary source of acetone)

Acetone is emitted directly by plants. In a study of 22 different plant species representative of northern hemisphere forests, Isidorov et al. (1985) found that all 22 species emitted acetone. Evergreens appear to be the largest contributor. Monthly acetone sources were created by scaling the monthly IGAC/GEIA isoprene emissions (Guenther et al., 1994) such that acetone emissions totaled 10 Tg/year (Kanakidou, private communication, 1997; Singh, private communication, 1997). Table 1 lists the monthly biogenic emissions of acetone. The biogenic source of acetone is shown in Figures 1 and 2 for January and July, respectively.

Table 1. Monthly primary biogenic emissions of acetone

Month	Acetone source, kg
January	7.3(8)
February	6.9(8)
March	7.9(8)
April	7.6(8)
May	8.5(8)
June	8.5(8)
July	9.7(8)
August	9.8(8)
September	8.3(8)
October	7.9(8)
November	7.2(8)
December	7.3(8)
TOTAL ANNUAL SOURCE	9.7(9)

B. Biomass burning emissions (primary source of acetone)

Singh et al. (1994) showed that the concentrations of acetone, CO, C₂H₂ and other species are elevated in biomass fire plumes. Singh et al. (1994) measured an average excess emission ratio of ($\Delta\text{acetone}/\Delta\text{CO}$, volume basis) equal to 0.025 (range: 0.02 - 0.03). The ratio of 0.025 should be considered an upper limit because it was measured in the plume, which may have experienced secondary propane oxidation to form acetone.

Biomass burning emissions of acetone were developed based on the amount of combusted biomass as tabulated by Liousse et al. (1996) for tropical regions and by Dignon and Penner (1991) for regions with latitudes greater than 25°. Combined, these regions yield a total biomass burning source of 461 Tg CO/yr (Atherton, 1995). Assuming an excess emission ratio of 0.025 ($\Delta\text{acetone}/\Delta\text{CO}$, volume basis) yields a total source term of 24 Tg acetone/year, with the monthly variations shown in Table 2. The biomass burning source of acetone is shown in Figures 3 and 4 for January and July, respectively.

C. Secondary emissions of acetone

Acetone is an important secondary byproduct of the oxidation of propane and other NMHCs. Acetone is produced from propane via the reaction mechanism below (Singh et al., 1994):

Table 2. Monthly biomass burning emissions of acetone, kg

Month	Tropical Forest	Savanna	Agricultural fires - developed countries	Agricultural fires - developing countries	Fuelwood and charcoal - developed countries	Fuelwood and charcoal - developing countries	Boreal forests	Non-tr woodl.
Jan	8.4(8)	7.6(8)	-----	3.9(7)	1.2(8)	2.2(8)	1.7(7)	4.6(6)
Feb	8.7(8)	6.9(8)	-----	9.4(7)	1.2(8)	2.2(8)	1.5(7)	4.1(6)
Mar	7.2(8)	4.9(8)	-----	2.7(8)	1.2(8)	2.1(8)	1.7(7)	4.6(6)
Apr	3.6(8)	1.4(8)	4.5(7)	2.8(8)	-----	2.1(8)	1.6(7)	4.4(6)
May	4.1(8)	7.7(8)	2.2(7)	2.3(8)	-----	2.5(8)	1.7(7)	4.6(6)
June	6.0(8)	1.6(9)	-----	3.9(7)	-----	2.3(8)	1.6(7)	4.4(6)
July	7.4(8)	1.9(9)	-----	9.0(7)	-----	2.3(8)	1.7(7)	4.6(6)
Aug	8.0(8)	1.9(9)	-----	9.4(7)	-----	2.3(8)	1.7(7)	4.6(6)
Sept	5.7(8)	1.2(9)	2.2(7)	9.7(7)	-----	2.3(8)	1.6(7)	4.4(6)
Oct	2.8(8)	2.9(8)	8.9(7)	2.1(8)	1.2(8)	2.3(8)	1.7(7)	4.6(6)
Nov	3.9(8)	3.5(8)	4.5(7)	2.3(8)	1.2(8)	1.8(8)	1.6(7)	4.4(6)
Dec	5.9(8)	5.9(8)		2.3(8)	1.3(8)	2.1(8)	1.7(7)	4.6(6)
Total	7.2(9)	1.1(10)	2.2(8)	1.9(9)	7.3(8)	2.4(9)	2.0(8)	5.4(7)

For this work, a 12 Tg/year source of propane was specified for industrial emissions, based on the distribution of Piccot et al. (1992) (Atherton, 1994). The biomass burning source was 4.8 Tg C₃H₈/year based on the work of Liousse et al. (1996) and Atherton (1995). Summed, these two propane sources yield 16.8 Tg C₃H₈/year. If it is assumed that 80% of propane (carbon based) is converted to acetone (Singh and Hanst, 1981), the oxidation of propane will yield 17.7 Tg acetone/year. Because biomass burning sources of propane vary monthly, the resulting formation of acetone from the oxidation of propane also varies monthly.

Table 3. Secondary production of acetone assuming 80% conversion (carbon basis) of primary propane emissions

Month	Biomass burning C ₃ H ₈ source (primary), kg C ₃ H ₈	Industrial C ₃ H ₈ source (primary), kg C ₃ H ₈	Biomass burning C ₃ H ₈ converted to CH ₃ COCH ₃ , kg CH ₃ COCH ₃	Industrial C ₃ H ₈ converted to CH ₃ COCH ₃ , kg CH ₃ COCH ₃	Total CH ₃ COCH ₃ formed from oxidation of C ₃ H ₈ , kg CH ₃ COCH ₃
Jan	4.8(8)	1.0(9)	5.1(8)	1.1(9)	1.6(9)
Feb	4.9(8)	9.1(8)	5.2(8)	9.6(8)	1.5(9)
Mar	4.2(8)	1.0(9)	4.4(8)	1.1(9)	1.5(9)
Apr	2.1(8)	9.8(8)	2.2(8)	1.0(9)	1.2(9)
May	3.0(8)	1.0(9)	3.2(8)	1.1(9)	1.4(9)
June	4.6(8)	9.8(8)	4.9(8)	1.0(9)	1.5(9)
July	5.7(8)	1.0(9)	6.0(8)	1.1(9)	1.7(9)
Aug	5.9(8)	1.0(9)	6.2(8)	1.1(9)	1.7(9)
Sept	4.1(8)	9.8(8)	4.3(8)	1.0(9)	1.4(9)
Oct	2.0(8)	1.0(9)	2.1(8)	1.1(9)	1.3(9)
Nov	2.5(8)	9.8(8)	2.6(8)	1.0(9)	1.3(9)
Dec	3.7(8)	1.0(9)	3.9(8)	1.1(9)	1.5(9)
Total	4.8(9)	1.2(10)	5.0(9)	1.3(10)	1.8(10)

D. Total acetone source

Together, the primary sources of acetone from biogenic emissions and biomass burning are 34 Tg acetone/year. The secondary source due to the oxidation of propane is 18 Tg acetone/year. Thus, combined the total primary and secondary source of propane is 52 Tg/year.

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Figure 1

Figure 2

Figure 3

July Biomass Burning source of acetone

Figure 4

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