Review: Global Sulfur Cycle

- Largest Reservoirs:
  - Rocks ($CaSO_4$, FeS_2)
  - Ocean Waters (as SO_4^{2-})
  - largest biogenic reservoir is the *terrestrial biosphere*
- Fluxes through
  - Denundation (weathering → river input to oceans)
  - Gaseous emissions (SO_2, DMS, COS, H_2S)
    - Ø largest biogenic emission is (oceanic) DMS
    - Ø largest geologic emissions are volcanic H_2S and SO_2
    - Ø largest anthropogenic emission is SO_2
  - Loss through sedimentation (→ geologic cycle)
- Most abundant atmospheric trace gas is COS (lifetime!)
  - important source of S to stratosphere (*Junge Layer*)
- Strong connection between gaseous S-Emissions and Climate through SO_4-CCN
  - (Oceanic) DMS-emissions feedback mechanism ("CLAW")

“Fixed” N (*Nr*) development

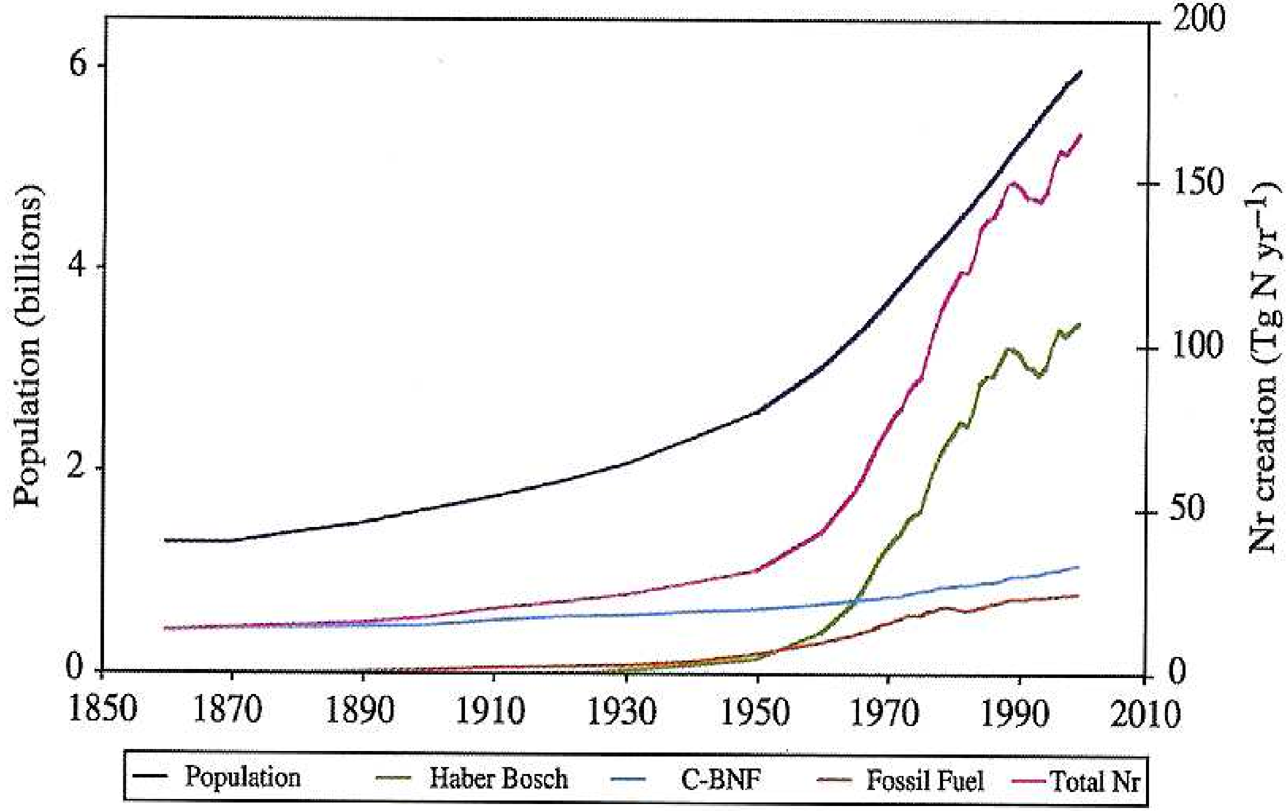


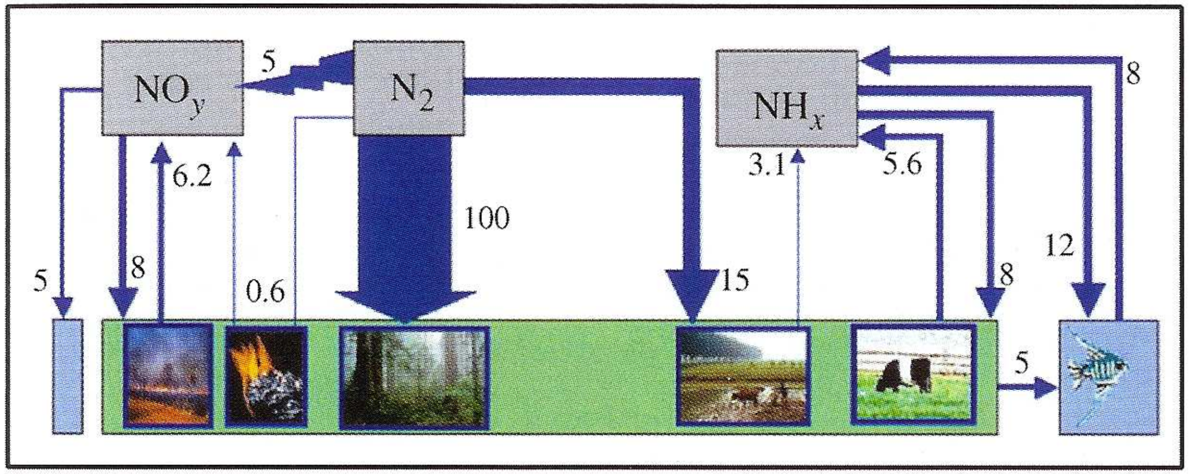
Figure 2 The (purple line) global population from 1860 to 2000 (left axis: population in billions; right axis: Nr creation in $Tg\,N\,yr^{-1}$) showing (green line) Nr creation via the Haber–Bosch process, including production of NH_3 for nonfertilizer purposes; (blue line) Nr creation from cultivation of legumes, rice and sugar cane; (brown line) Nr creation from fossil-fuel combustion; and (red line) the sum created by these three processes (source Galloway *et al.*, 2003b).

“Fixed” N (*Nr*) creation distribution

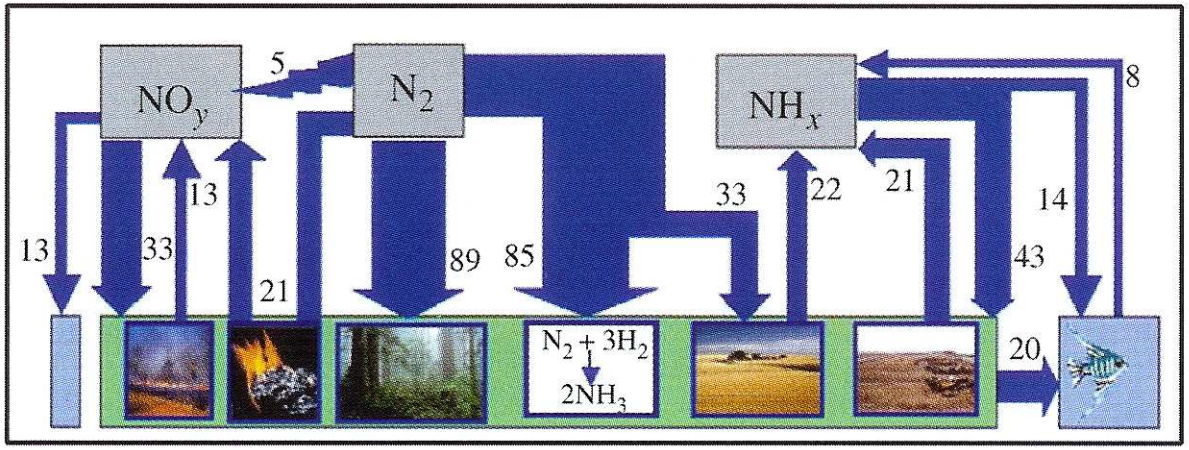
Table 7 Nr creation rates for various regions of the world in mid-1990s ($Tg\,N\,yr^{-1}$).

World regions	*Fertilizer production*	*Cultivation*	*Combustion*	*Net import/export*	*Total*
Africa	2.5	1.8	0.8	0.2	5.3
Asia	40.1	13.7	6.4	8.7	68.9
Europe + FSU	21.6	3.9	6.6	−5.6	26.5
Latin America	3.2	5.0	1.4	−0.2	9.4
North America	18.3	6.0	7.4	−3.3	28.4
Oceania	0.4	1.1	0.4	0.3	2.2
World	~86	~30	~23	0.1	~140

Source: Galloway and Cowling (2002).



(a)



(b)

Figure 3 Global nitrogen budgets for: (a) 1890 and (b) 1990, Tg N yr^{-1}. Emissions to the (left) NO_y box from (first from left) vegetation include agricultural and natural soil emissions and combustion of biofuel, biomass (savannah and forests), and agricultural waste and emissions from (second from left) coal reflect fossil-fuel combustion. Emissions to the (right) NH_x box from (third from right) agricultural fields include emissions from agricultural land and combustion of biofuel, biomass (savannah and forests), and agricultural waste, and emissions from (second from right) the cow and feedlot reflect emissions from animal waste. For more details, see text for “global N cycle: past and present” (source Galloway and Cowling, 2002).

The Global Nitrogen Cycle

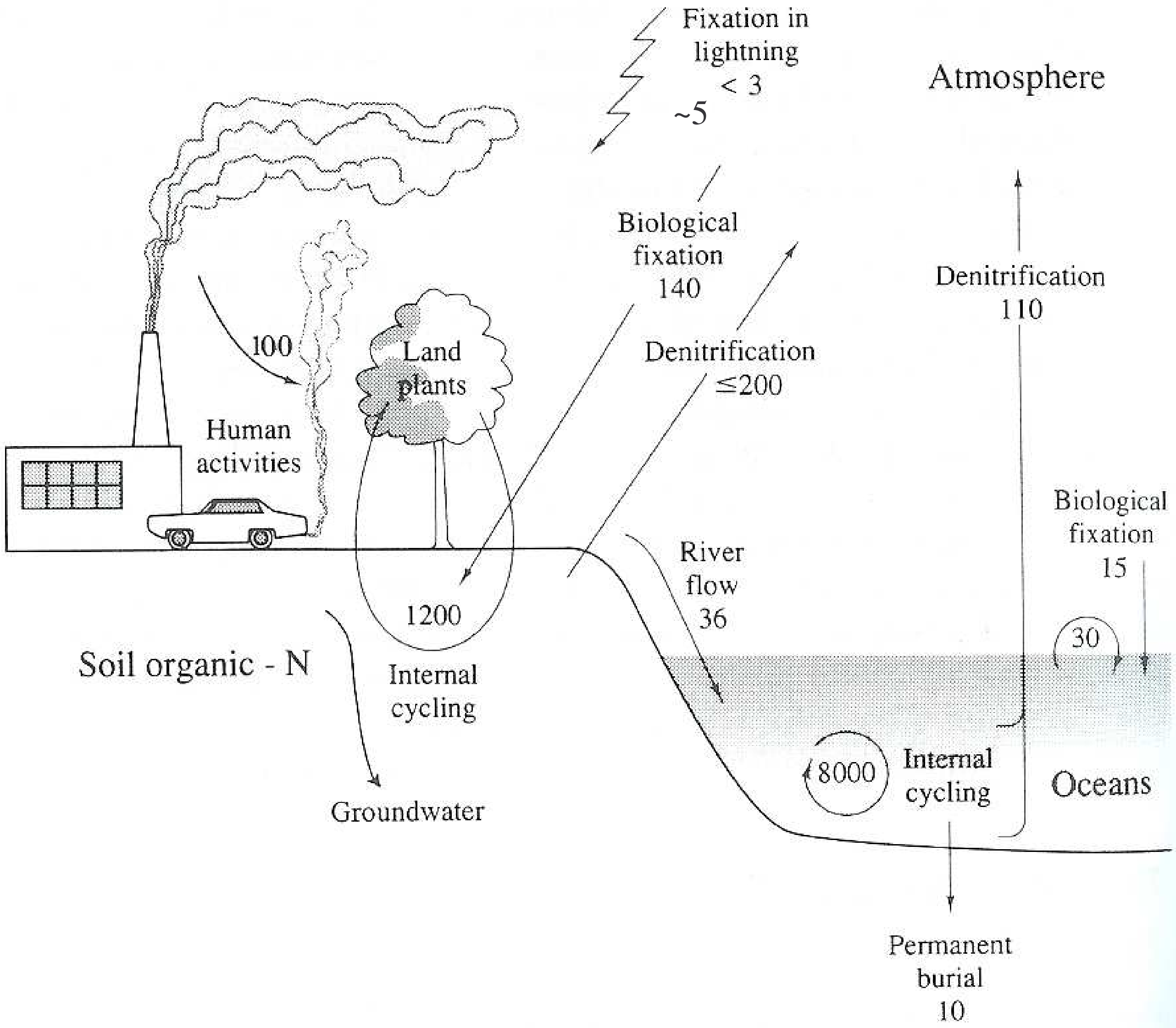


Figure 12.2 The global nitrogen cycle. Each flux is shown in units of 10^{12} g N/yr. Values are derived in the text.

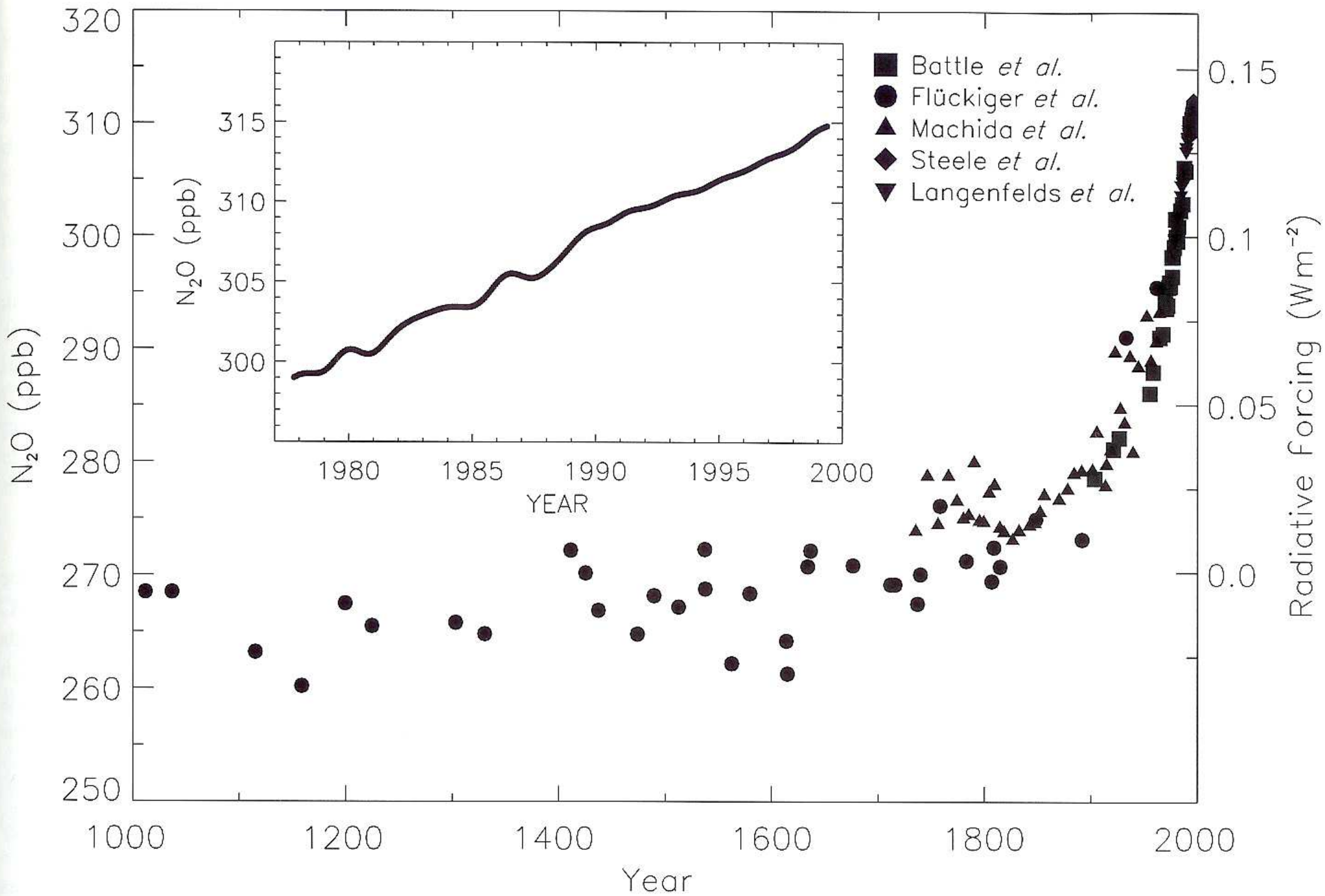


Figure 4.2: Change in N_2O abundance for the last 1,000 years as determined from ice cores, firn, and whole air samples. Data sets are from: Machida *et al.* (1995); Battle *et al.* (1996); Langenfelds *et al.* (1996); Steele *et al.* (1996); Flückiger *et al.* (1999). Radiative forcing, approximated by a linear scale, is plotted on the right axis. Deseasonalised global averages are plotted in the inset (Butler *et al.*, 1998b).

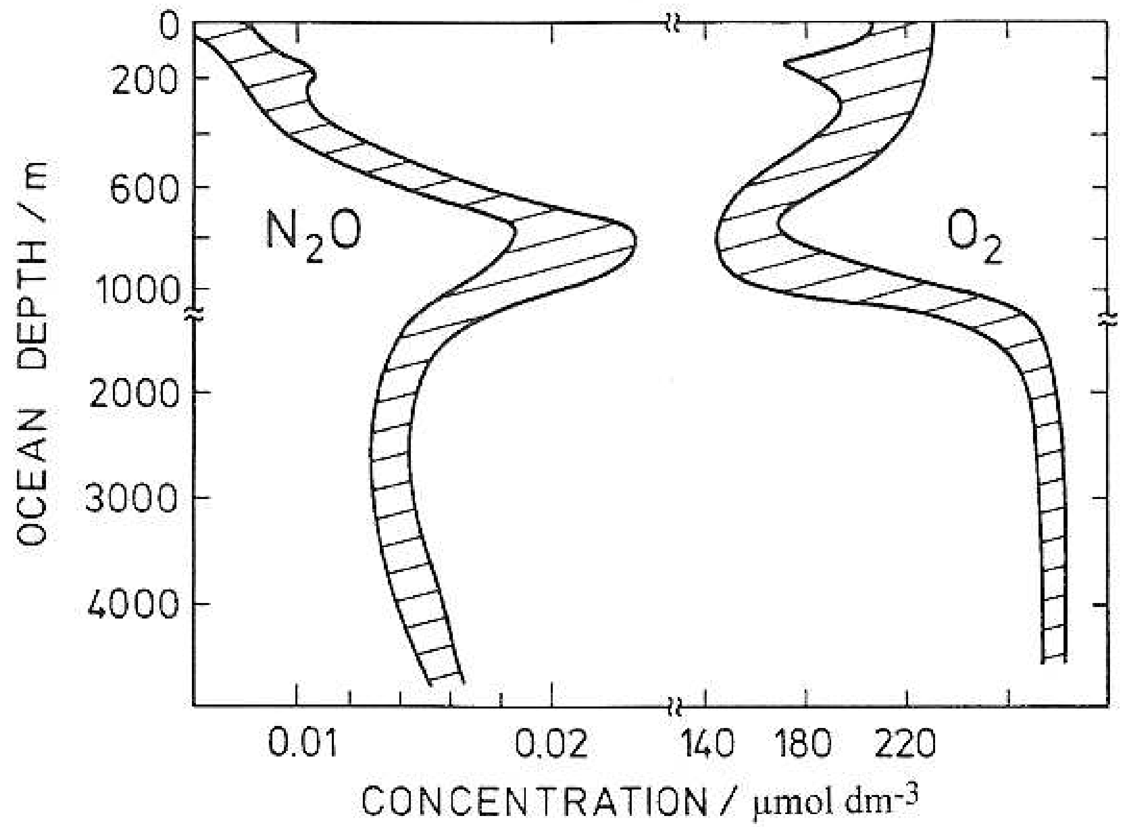


FIGURE 9.5 Vertical concentration profiles of N_2O and O_2 in the Atlantic Ocean (Gulf Stream area and Sargasso Sea) in 1971–1972, according to Yoshinari (1976).

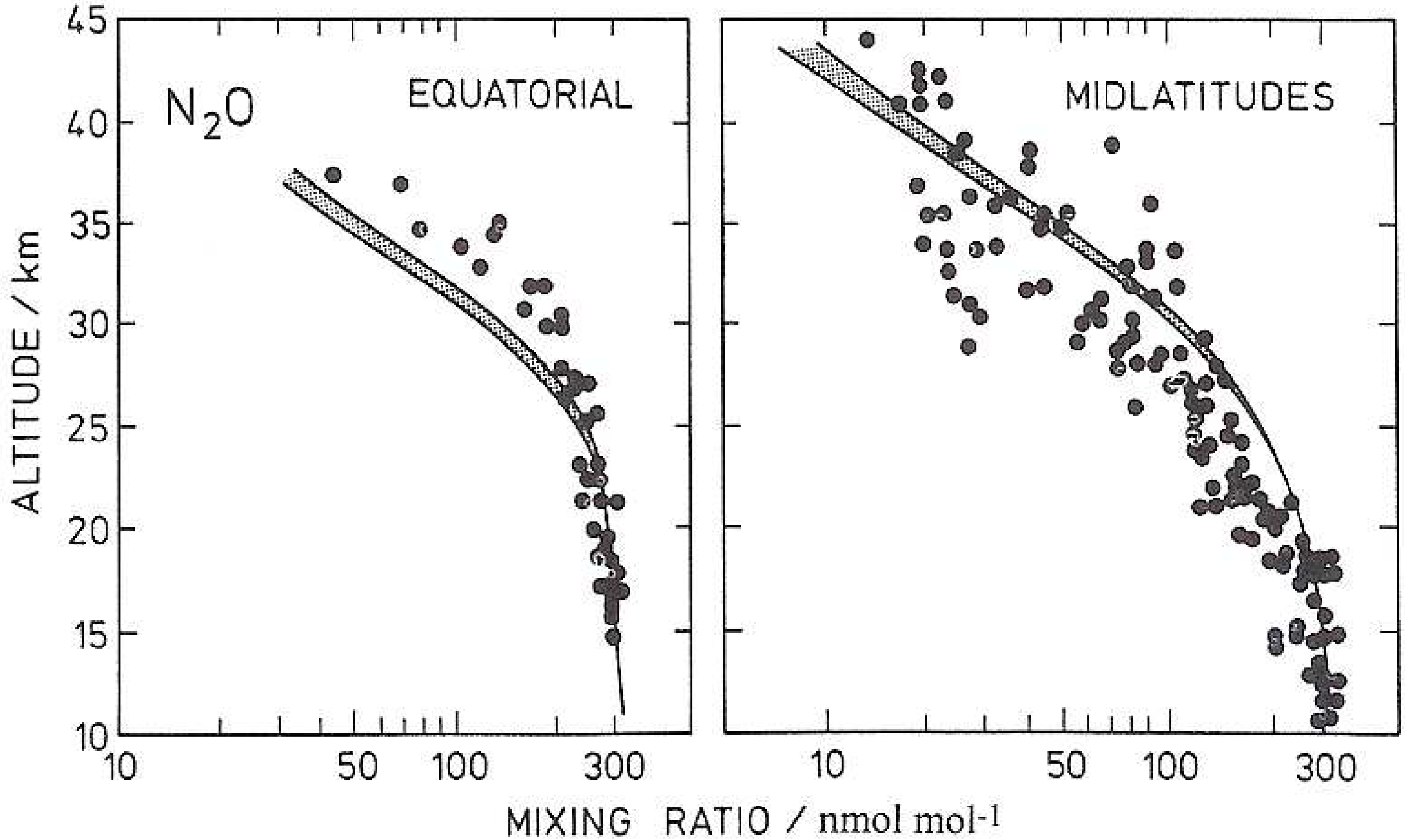
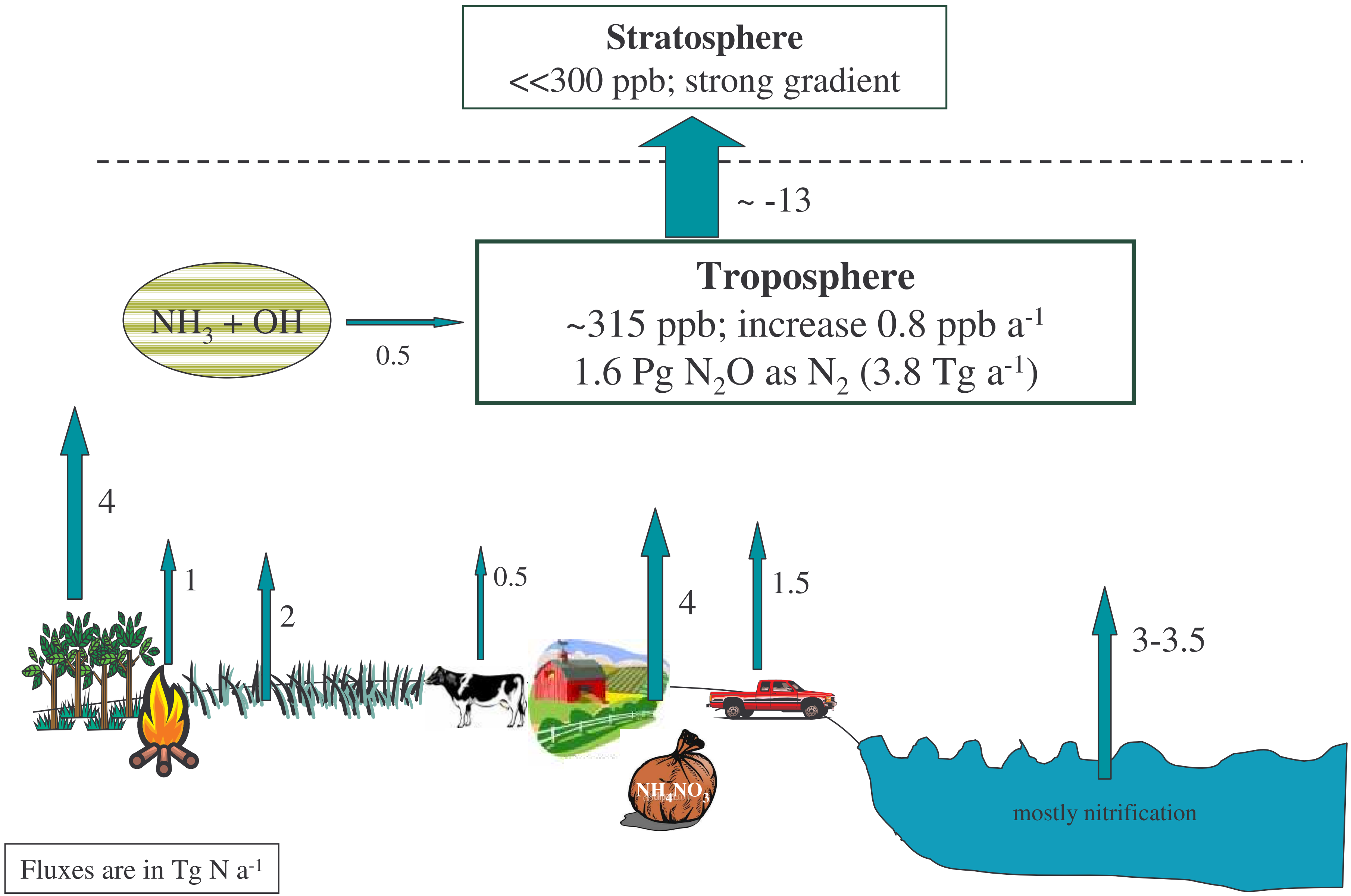


FIGURE 3.8 Vertical profiles of the N_2O mixing ratio at low and high latitudes. From measurements of Tyson *et al.* (1978a), Vedder *et al.* (1978, 1981), Fabian *et al.* (1979, 1981), Goldan *et al.* (1980, 1981). The solid lines are results of calculations by Gidel *et al.* (1983) based on a two-dimensional model.

The global cycle of atmospheric Nitrous Oxide, N_2O



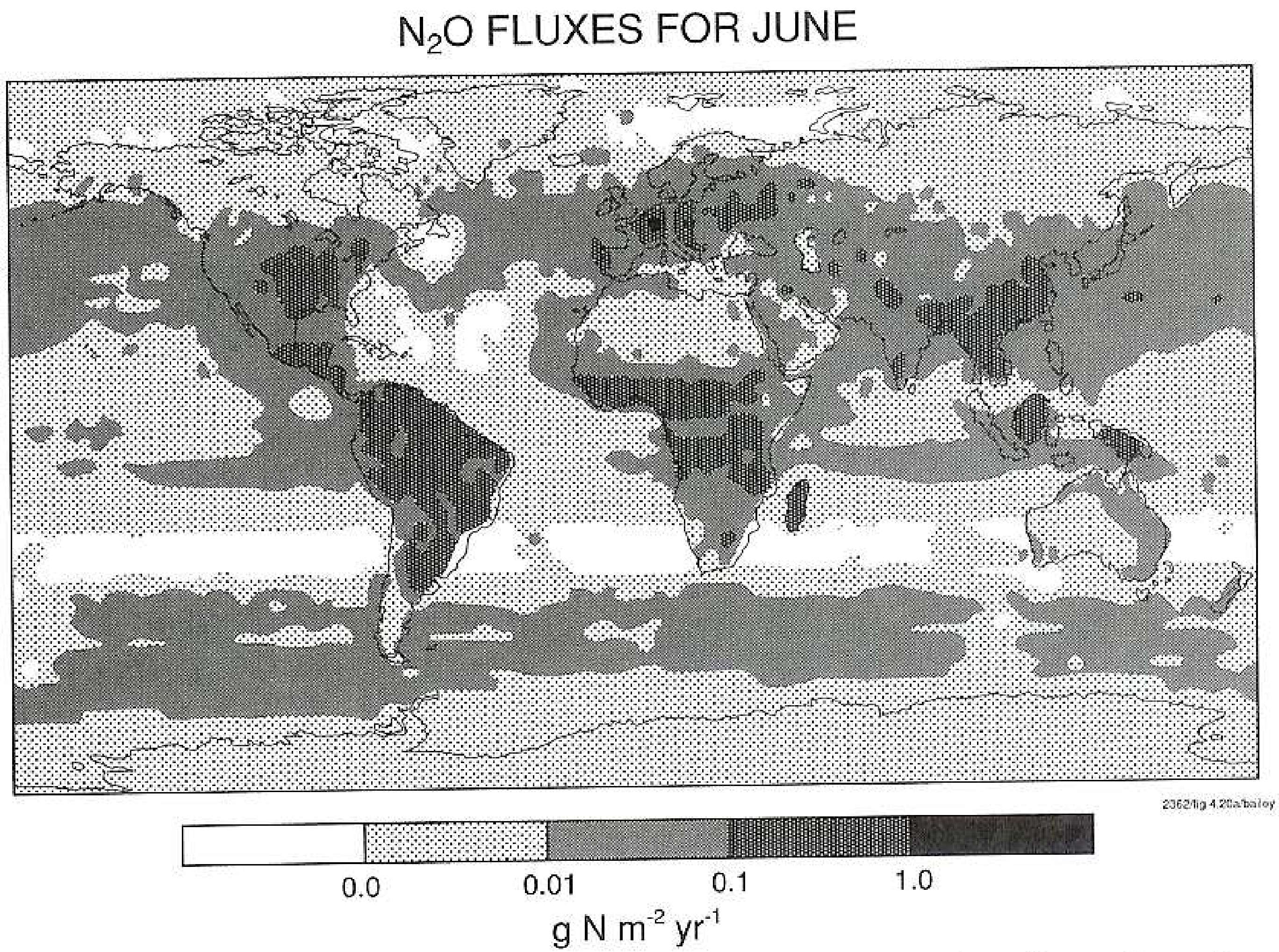


Figure 5.27. *Global distribution of N_2O emissions for June; based on data from Nevison (1994).*

Humans have doubled the "fixed" N inputs to earth

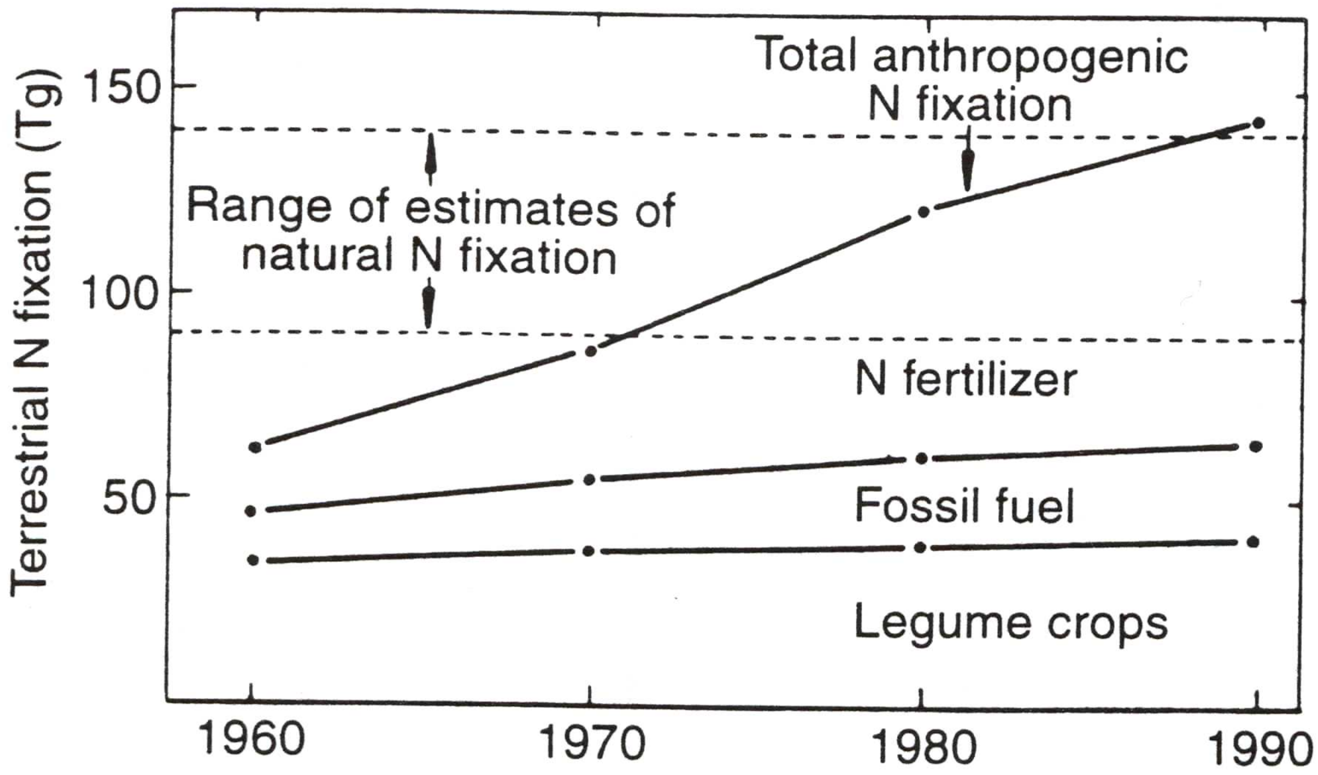


FIG. 1. Anthropogenic fixation of N in terrestrial ecosystems over time, in comparison with the range of estimates of natural biological N fixation on land. Modified from Galloway et al. (1995: Fig. 5).