# Air-Sea Exchange of Reduced Nitrogen Gases

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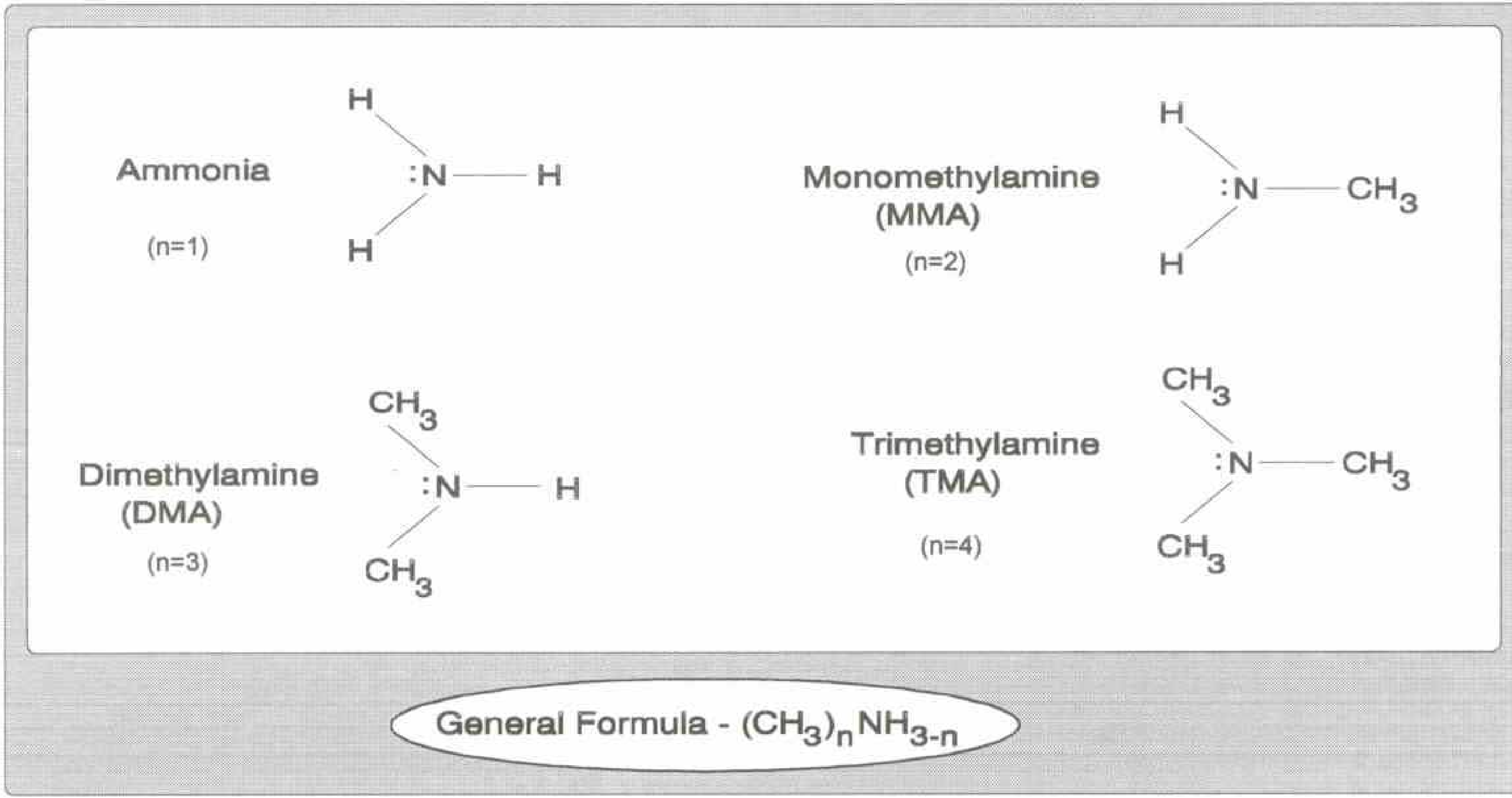
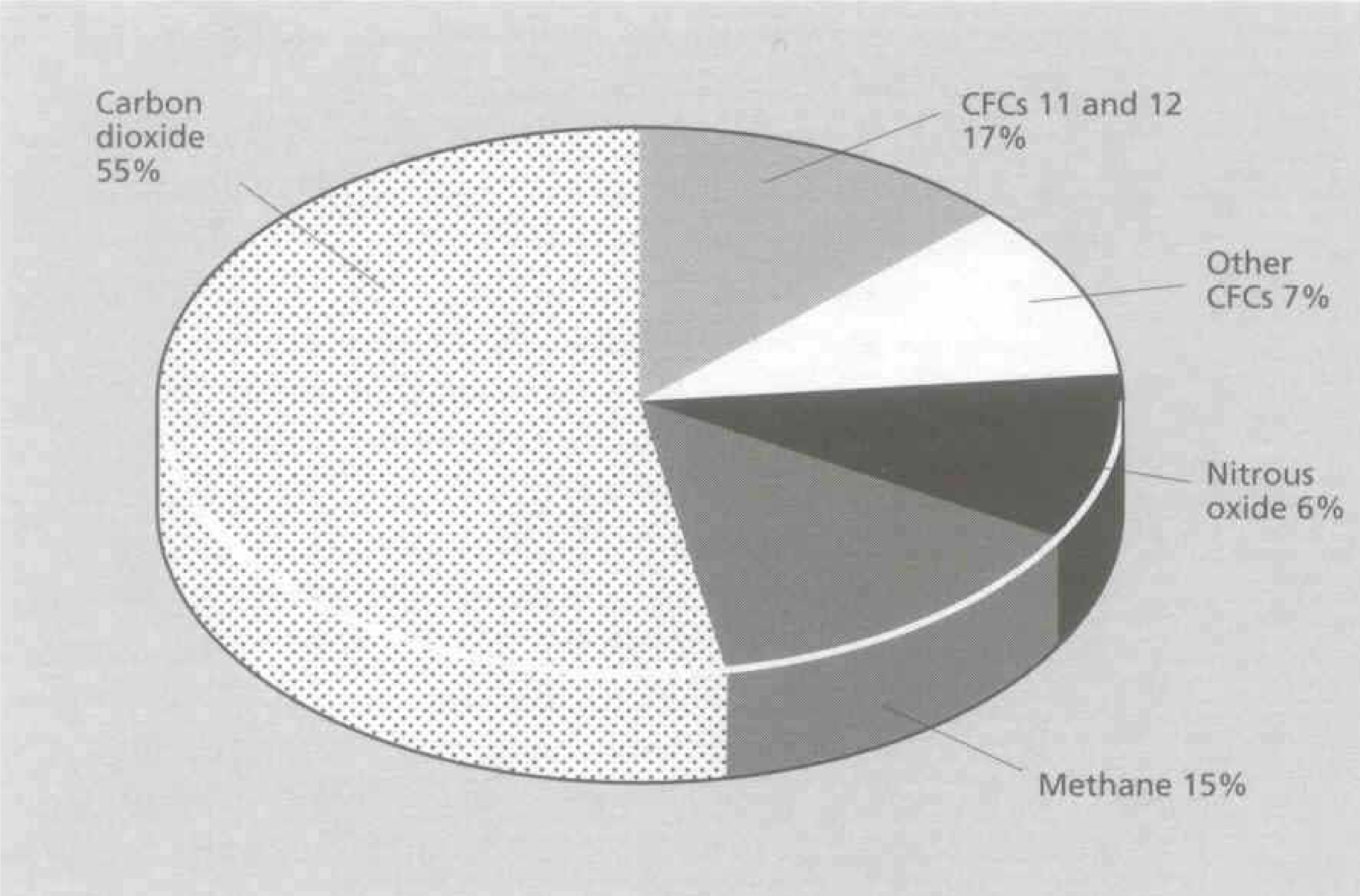
# What Gases and Why Are They Important?


Ammonia
(n=1)
Monomethylamine
(MMA)
(n=2)
Dimethylamine
(DMA)
(n=3)
Trimethylamine
(TMA)
(n=4)
General Formula - $(CH_3)_nNH_{3-n}$

# Importance of $NH_3$ and Methylamines:

- Atmospheric acidity
- Cloud processing
- Recycling of nitrogen
- Particle formation

# Nitrous oxide


Carbon dioxide 55%
CFCs 11 and 12 17%
Other CFCs 7%
Nitrous oxide 6%
Methane 15%

# GAS FLUX CALCULATION

$$F = K_T * \Delta C = K_T(C_a/H - C_w)$$

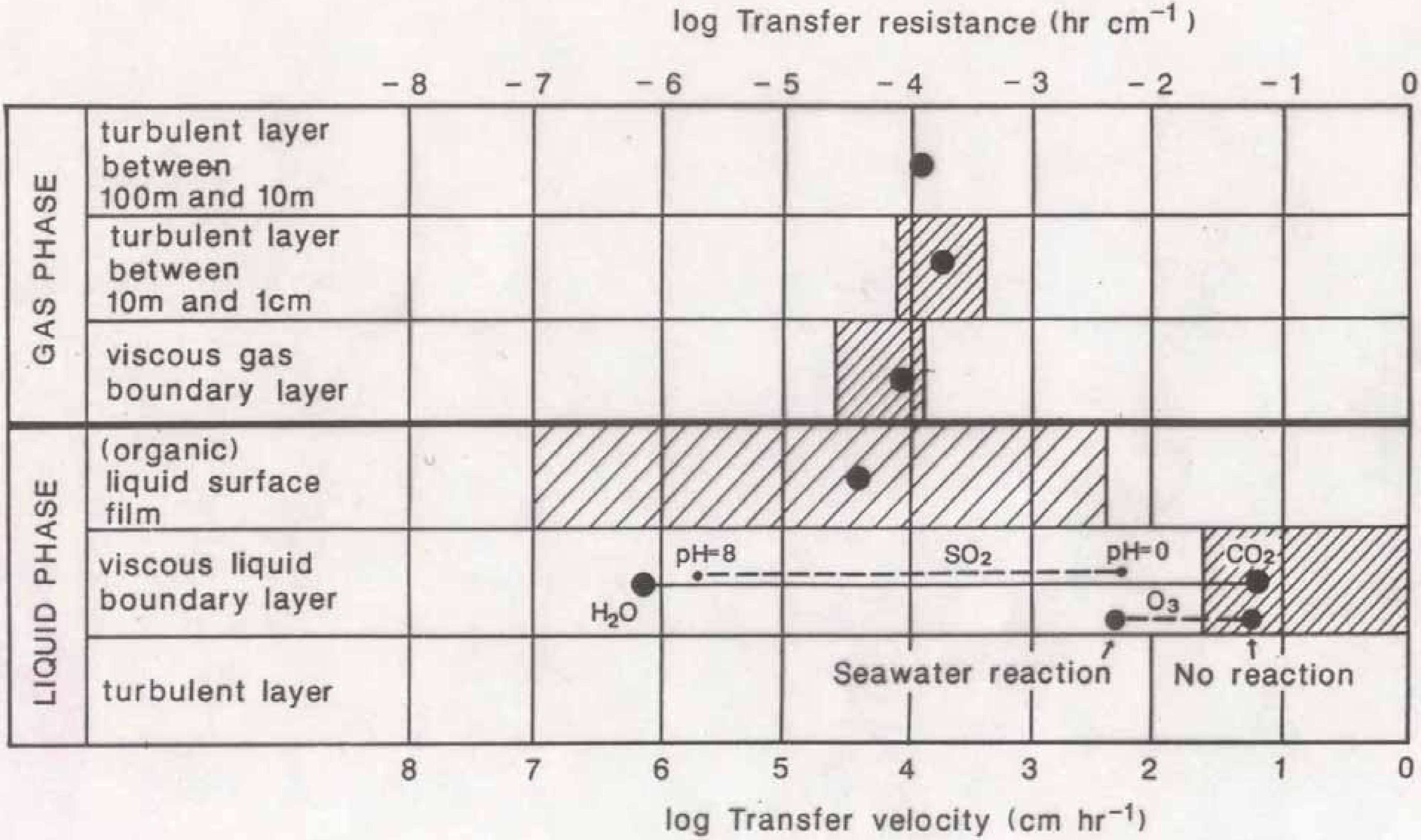
Where:

| | |
|---|---|
| $F$ | = Flux |
| $K_T$ | = Overall Transfer Velocity |
| $\Delta C$ | = Concentration Difference |
| | = $C_a/H - C_w$ |

Where:

| | |
|---|---|
| $C_a$ | = Concentration in Air |
| $C_w$ | = Concentration in Water |
| $H$ | = Henry's Law constant |
| | = $(C_a / C_w)$ at equilibrium |

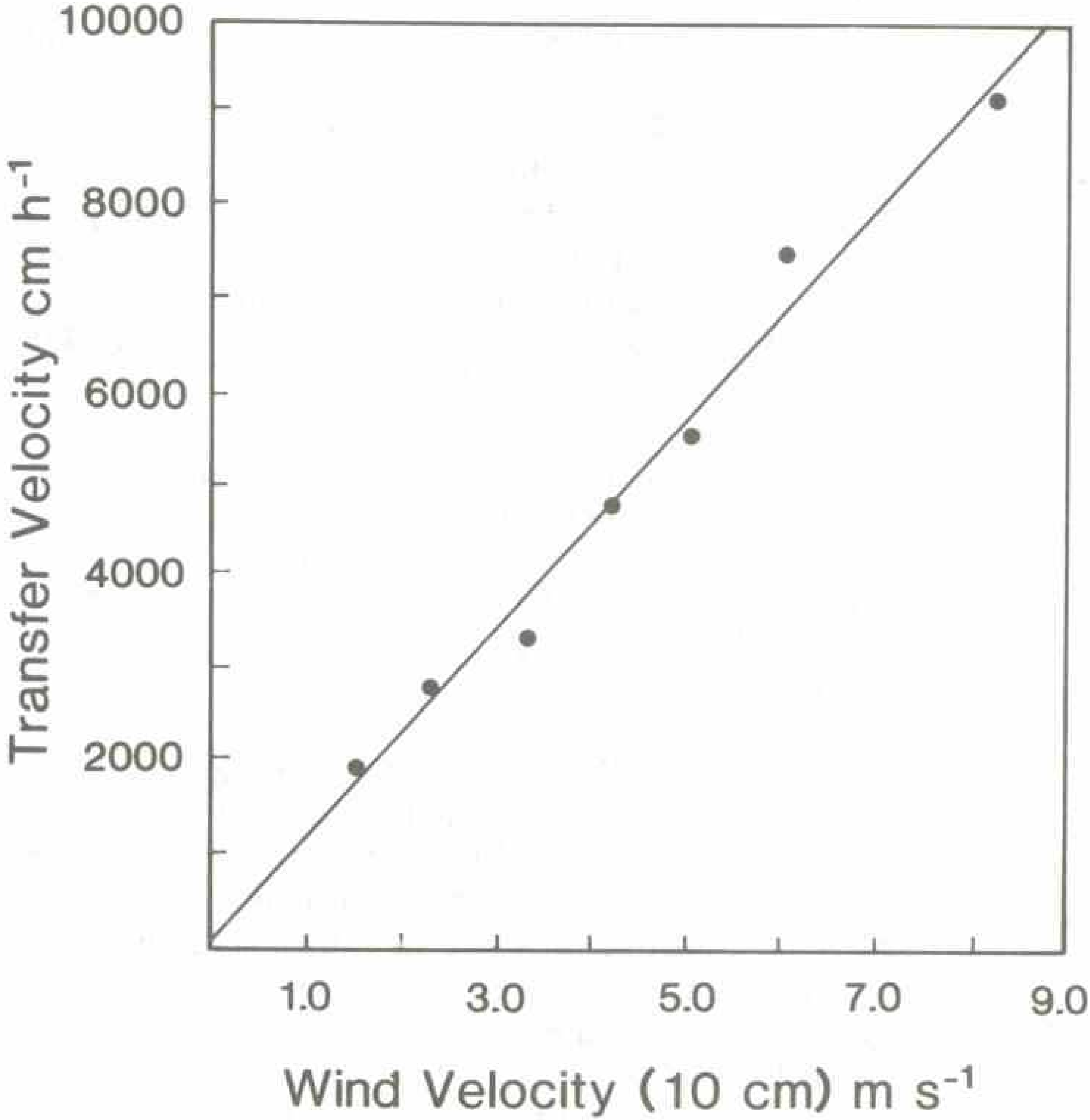
Liss & Slater 1974



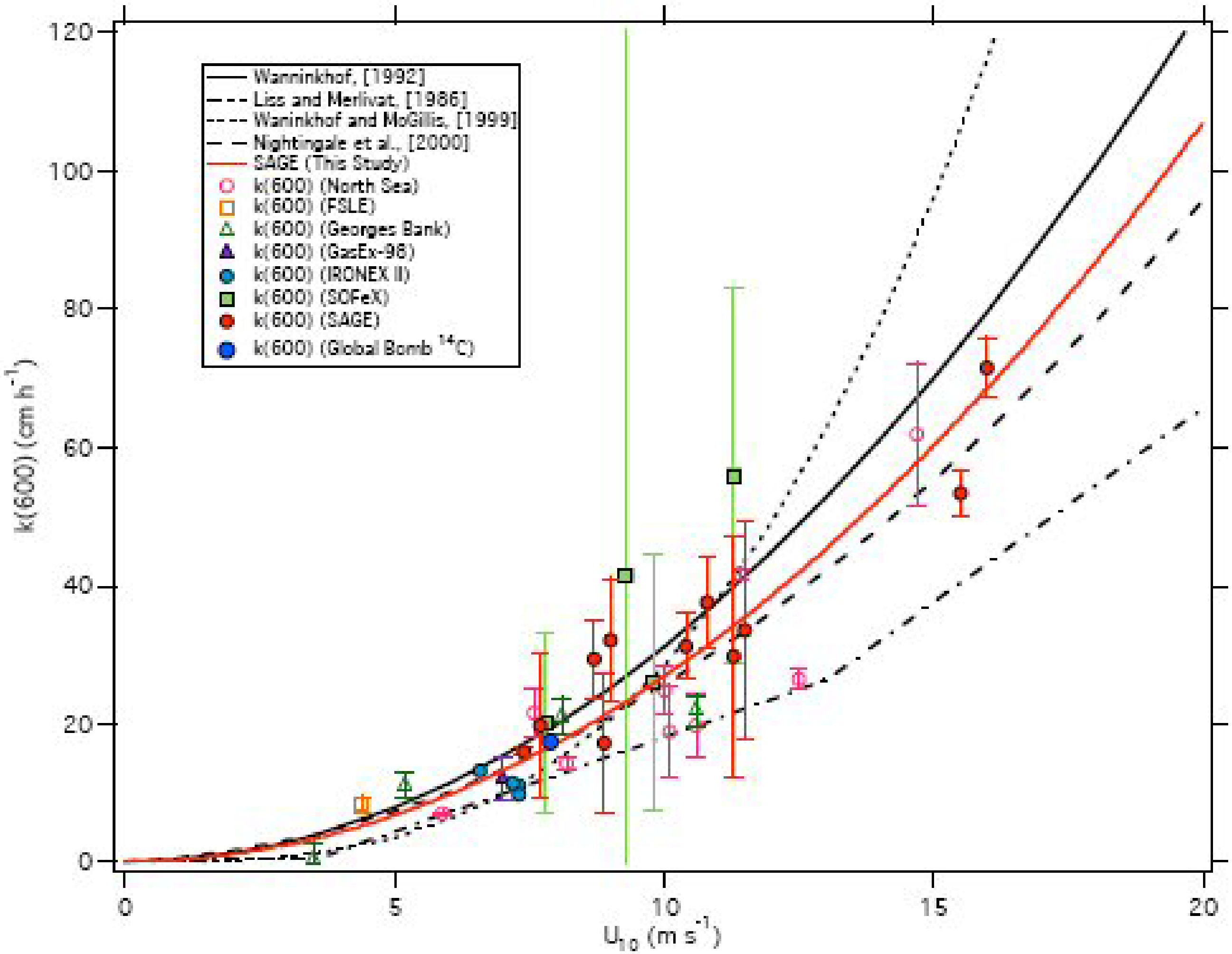

After K.O. Munnich

# Often One Resistance Controls:

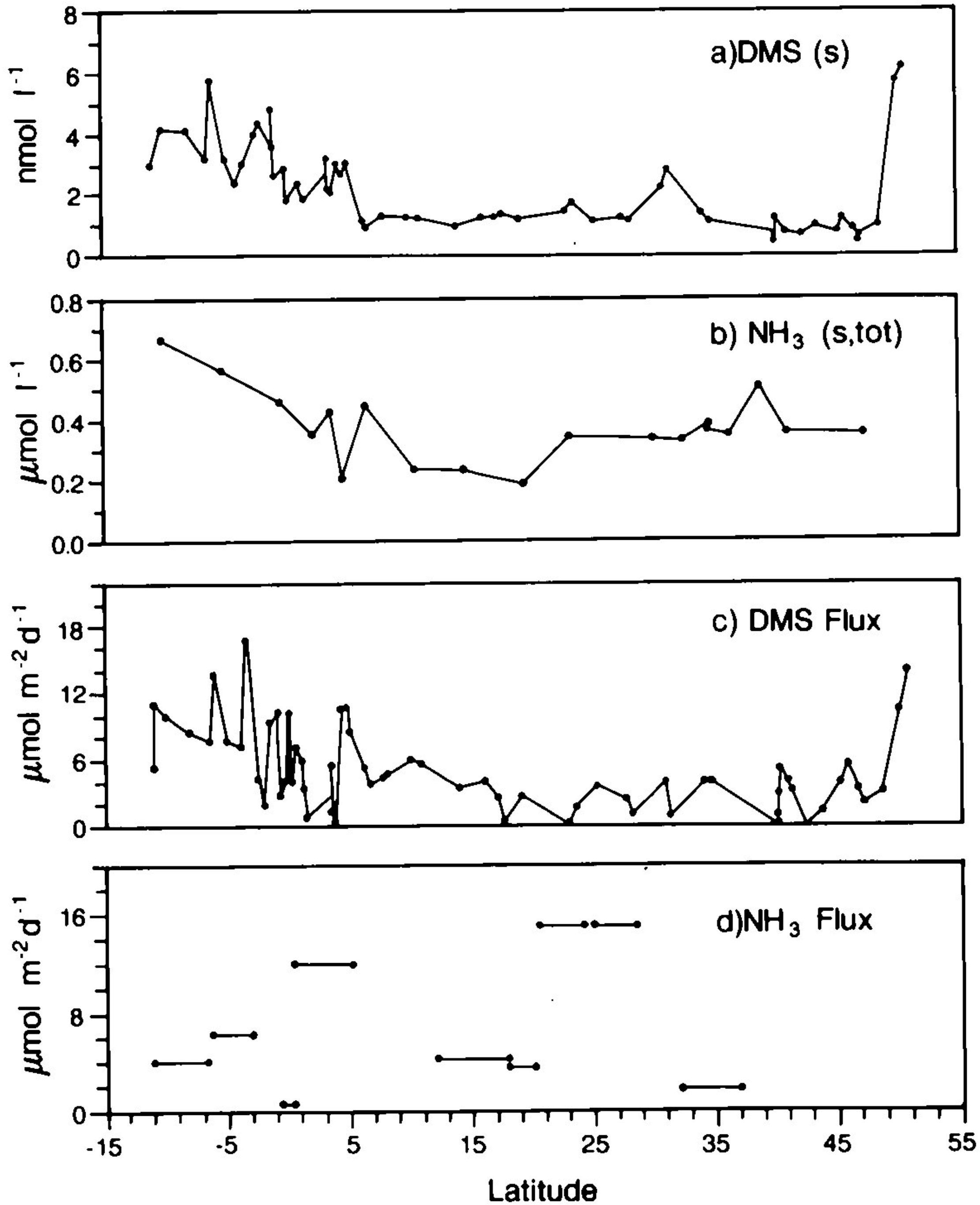
| $r_a >> r_w$ | $r_w >> r_a$ |
|---|---|
| $H_2O$ | $O_2$ |
| HCl | $N_2$ |
| $SO_2$ | Inert Gases |
| MSA<br>(methane sulphonic acid) | $CO_2$ |
| $SO_3$ | CO |
| $NH_3$ | $CH_4$ |
| $HNO_3$ | $N_2O$ |
| | $CH_3I$ etc. |
| | DMS<br>(dimethyl sulphide) |


10000
8000
6000
4000
2000
Transfer Velocity cm h-1
1.0
3.0
5.0
7.0
9.0
Wind Velocity (10 cm) m s-1

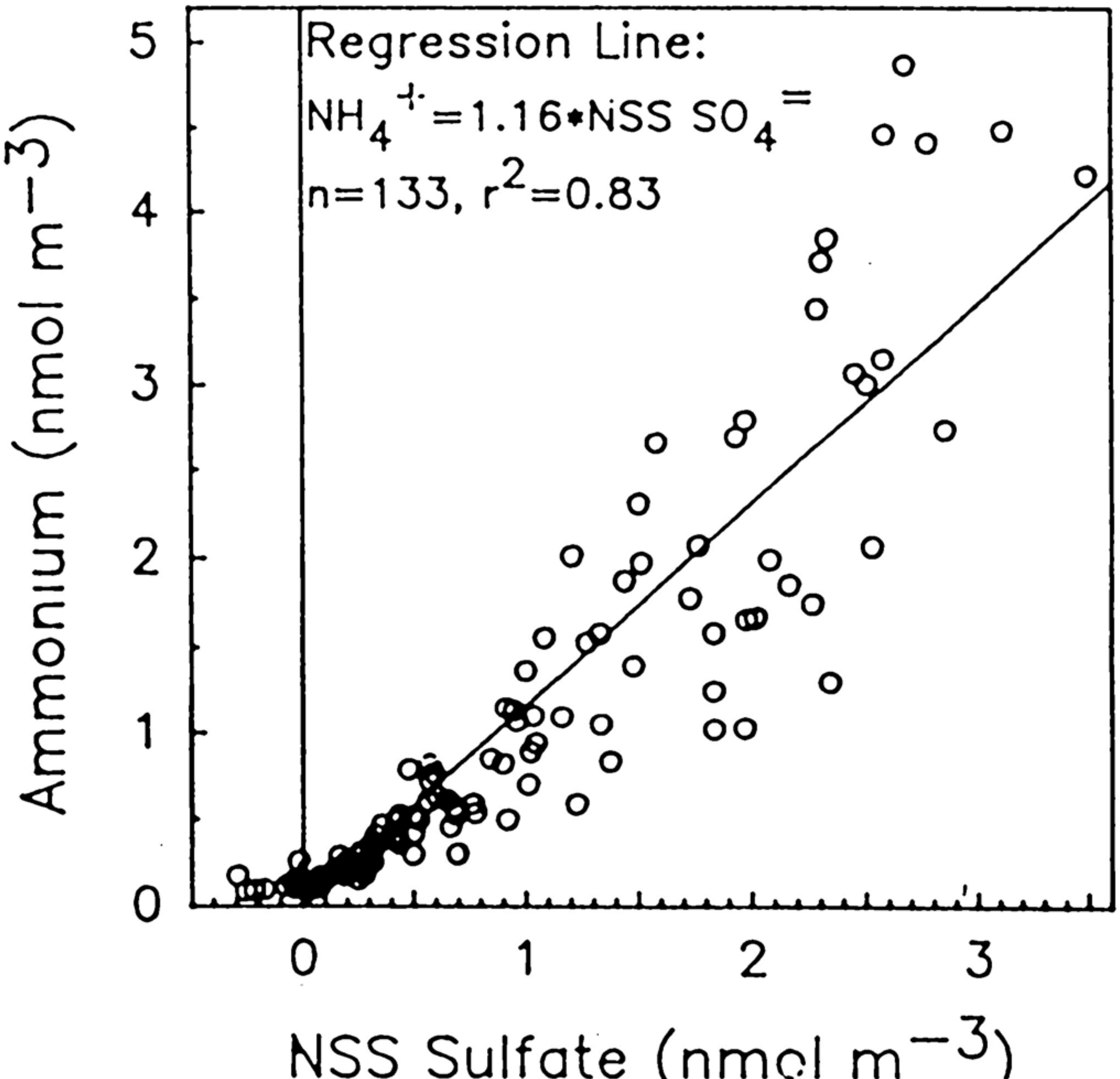
Liss 1973


Wanninkhof, [1992]
Liss and Merlivat, [1986]
Waninkhof and McGillis, [1999]
Nightingale et al., [2000]
SAGE (This Study)
k(600) (North Sea)
k(600) (FSLE)
k(600) (Georges Bank)
k(600) (GasEx-98)
k(600) (IRONEX II)
k(600) (SOFeX)
k(600) (SAGE)
k(600) (Global Bomb $^{14}$C)
k(600) (cm h$^{-1}$)
$U_{10}$ (m s$^{-1}$)
0
20
40
60
80
100
120
0
5
10
15
20

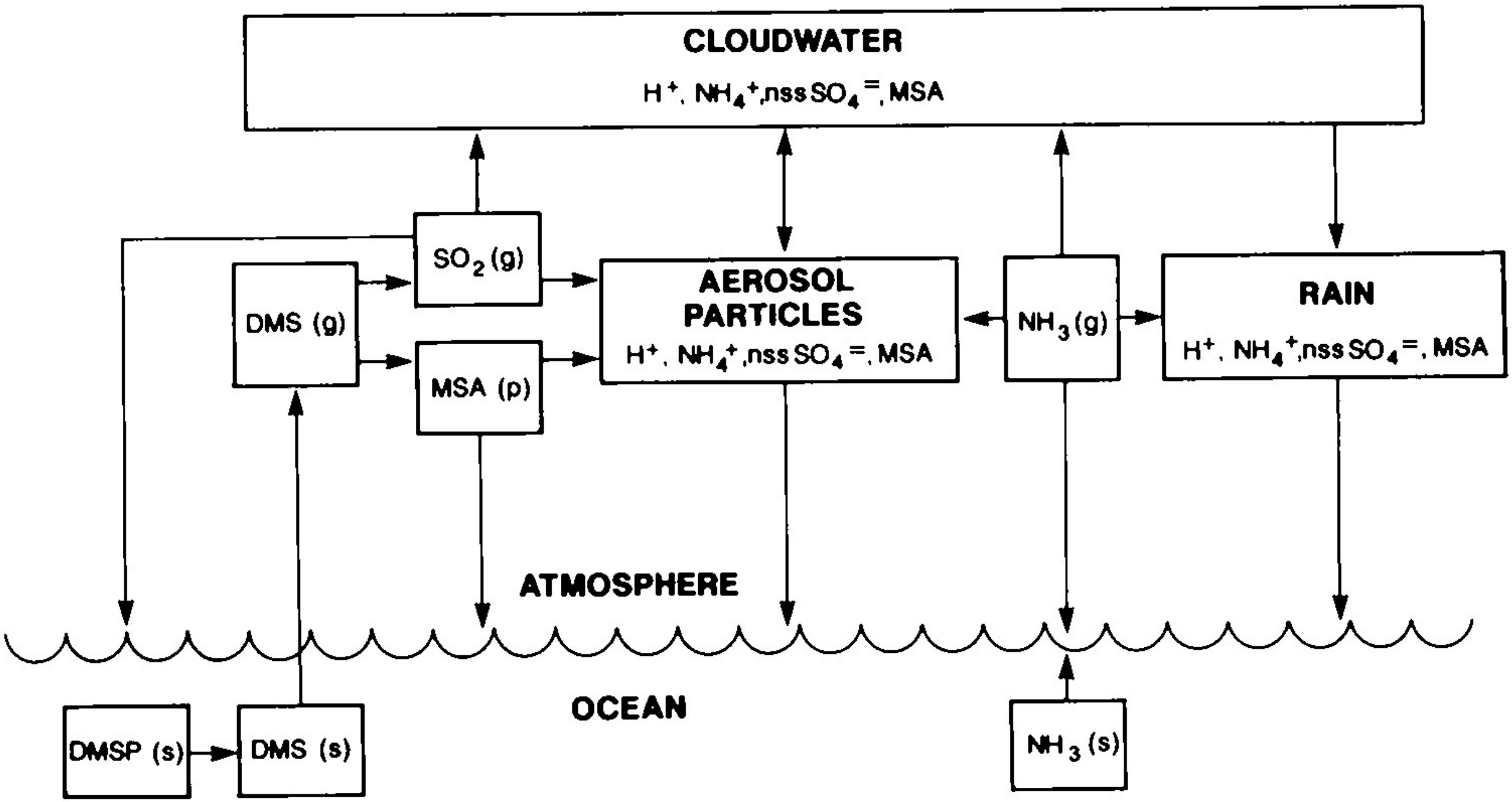
Ho *et al*. (2006)



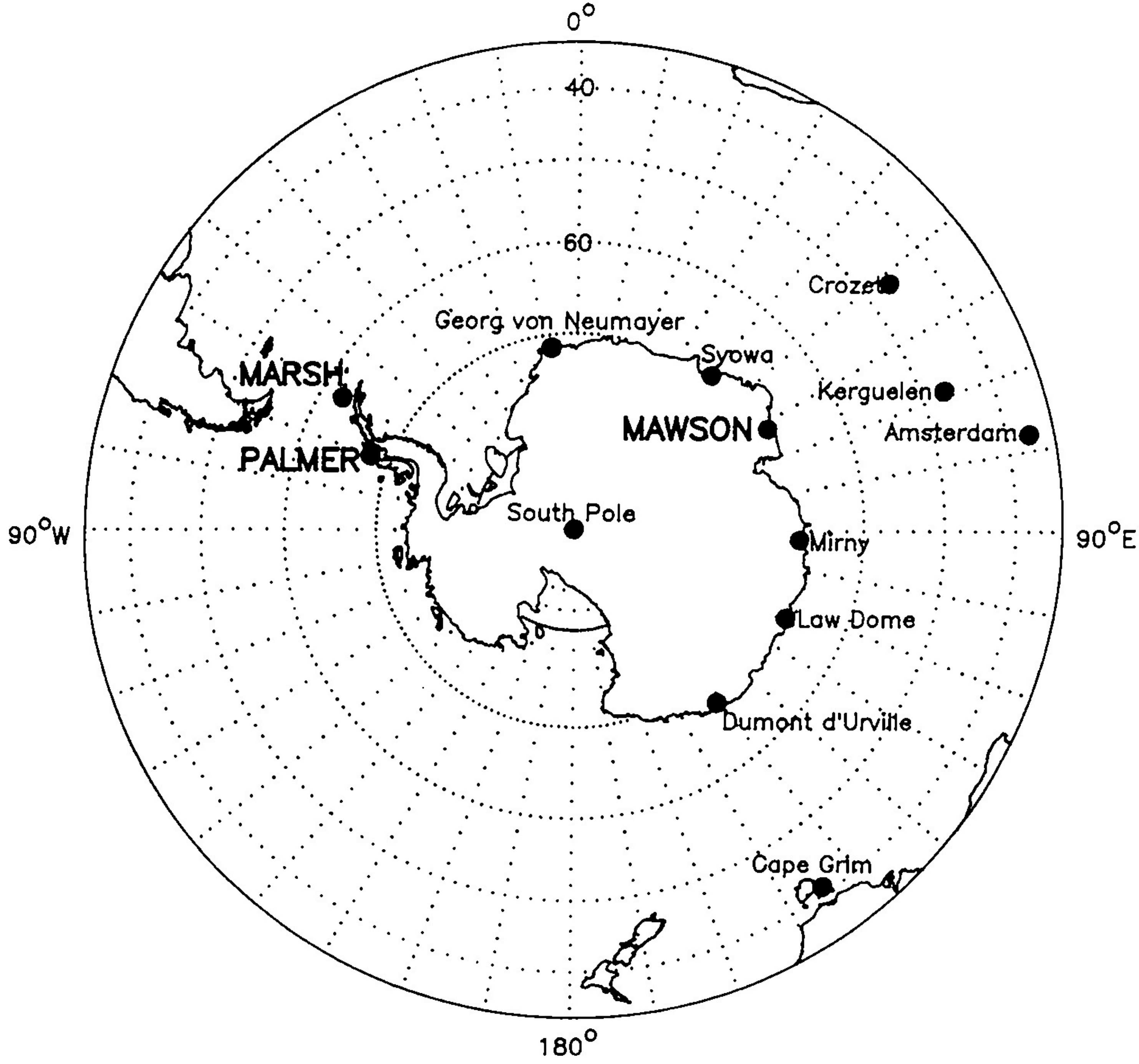

Quinn *et al*. 1990

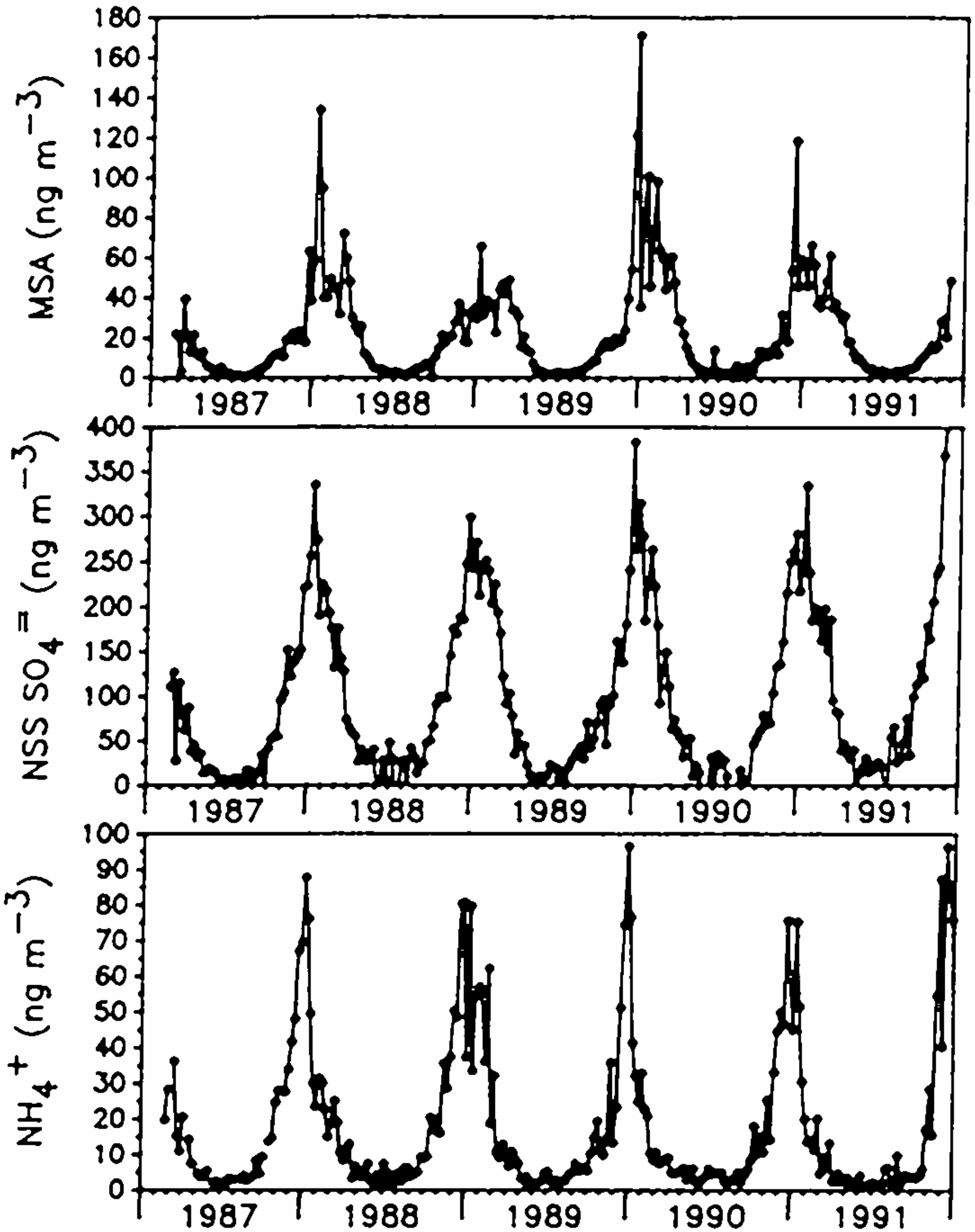



Quinn *et al*. 1990

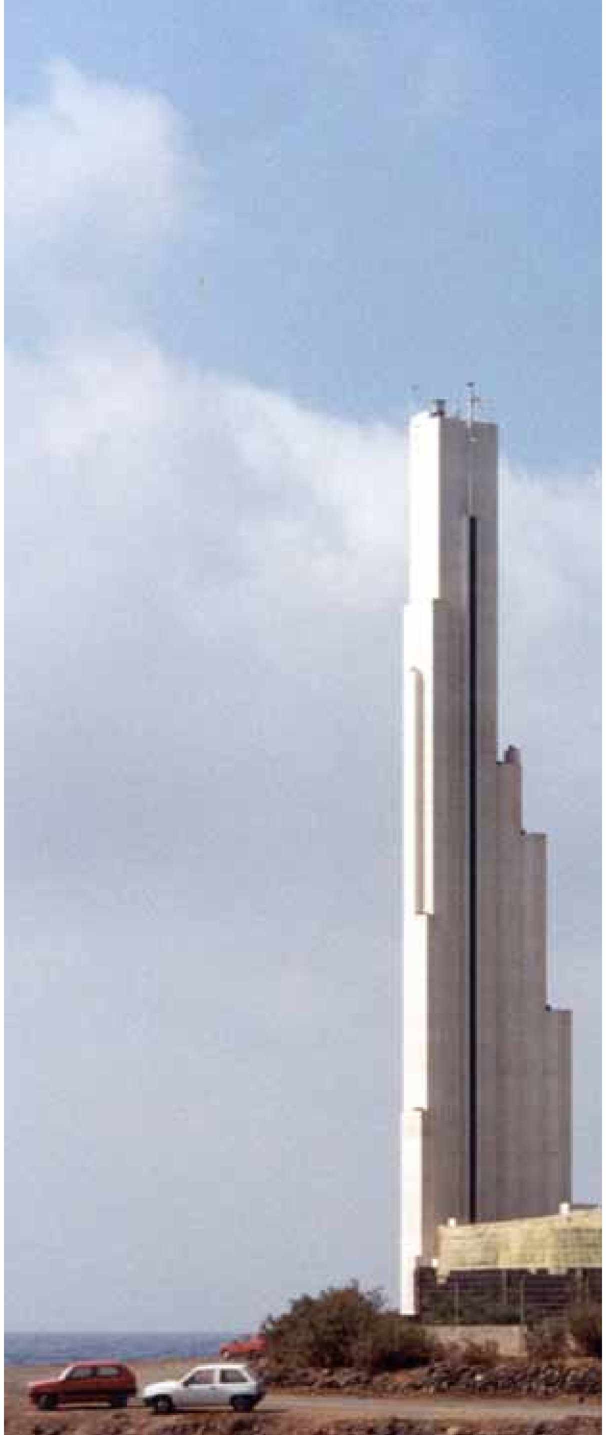


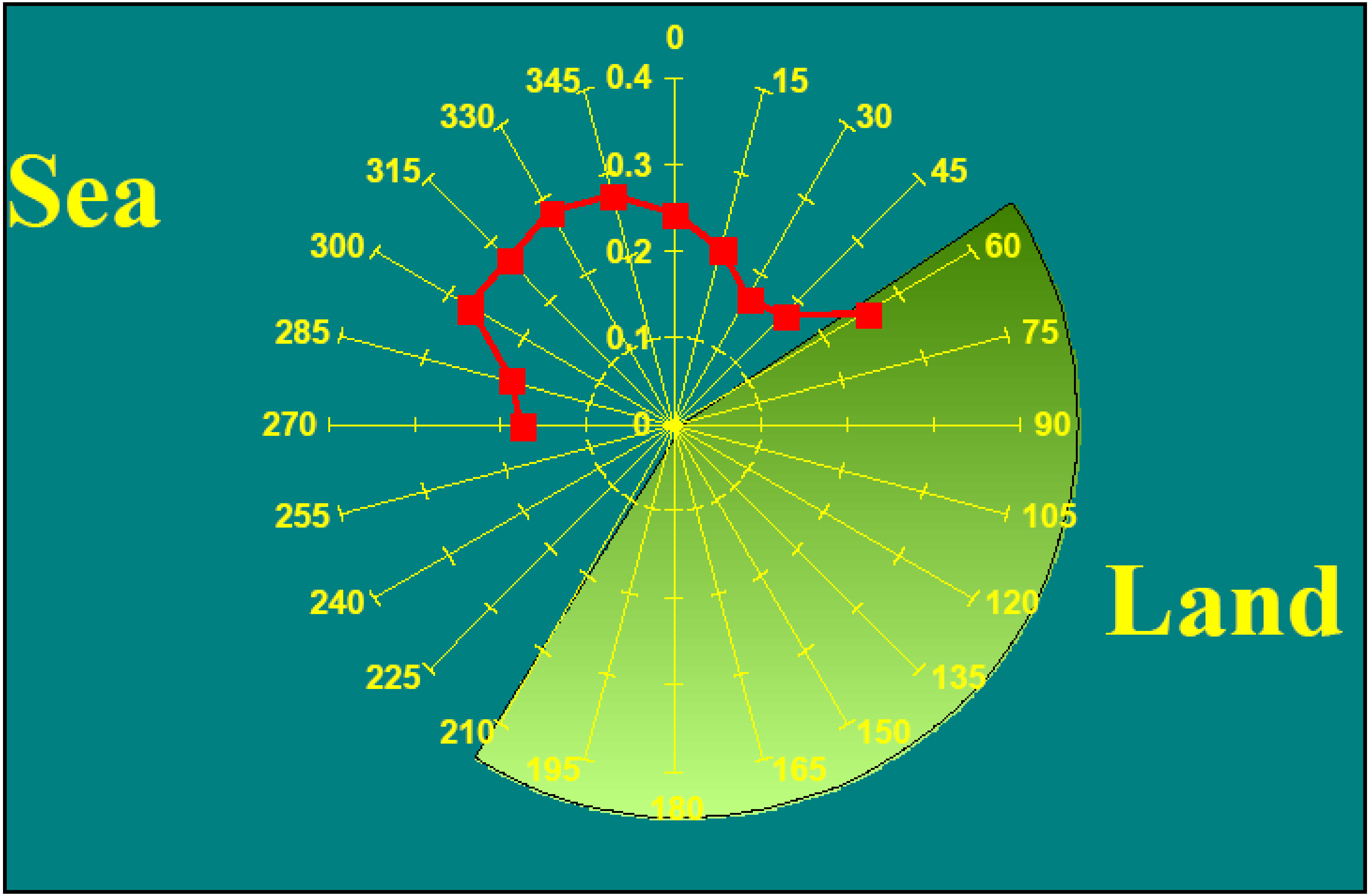

Quinn *et al*. 1990


0°
40
60
90°W
90°E
180°
Georg von Neumayer
Syowa
Crozet
Kerguelen
Amsterdam
MARSH
PALMER
MAWSON
South Pole
Mirny
Law Dome
Dumont d'Urville
Cape Grim

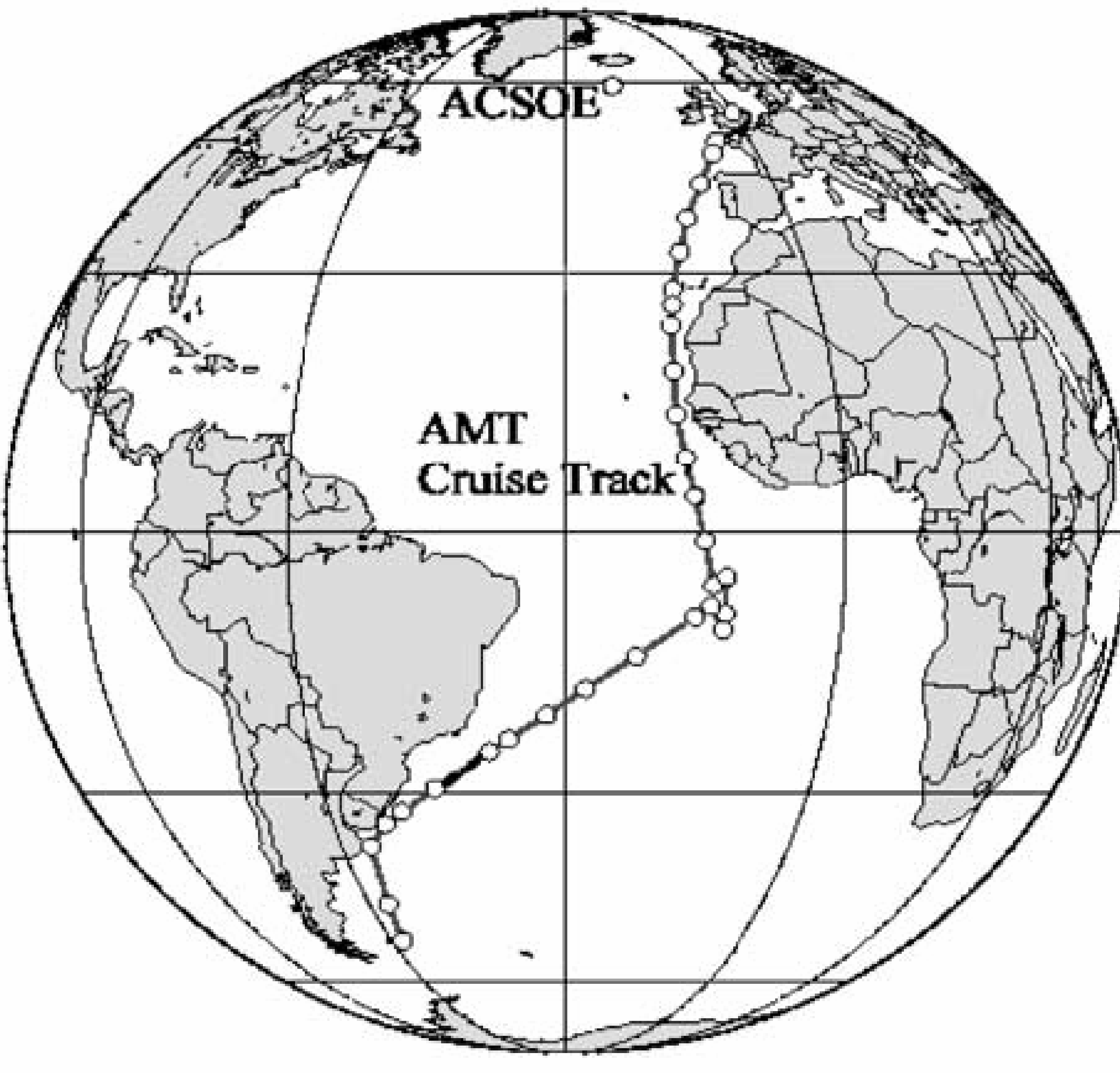


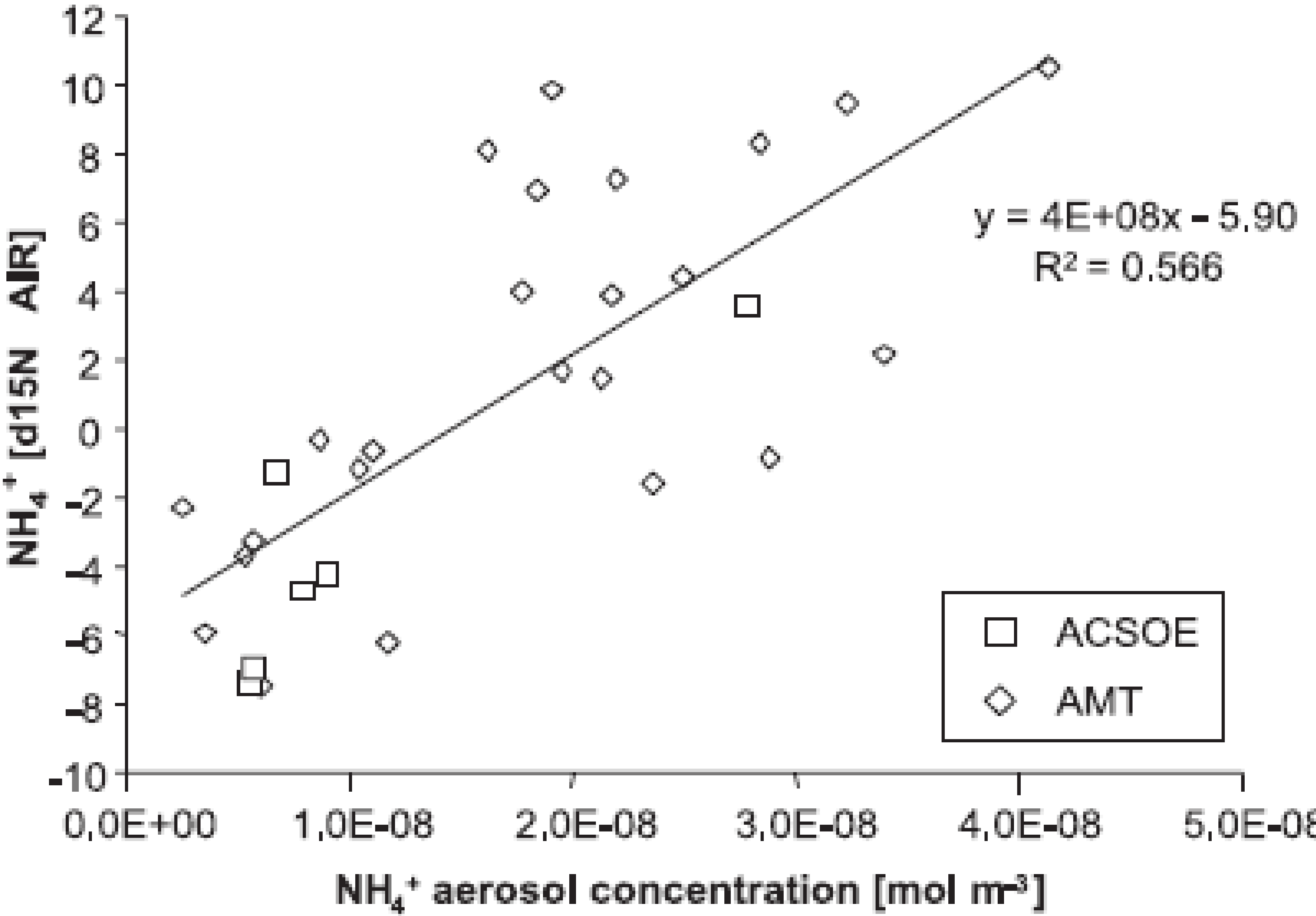

Savoie *et al*. 1993



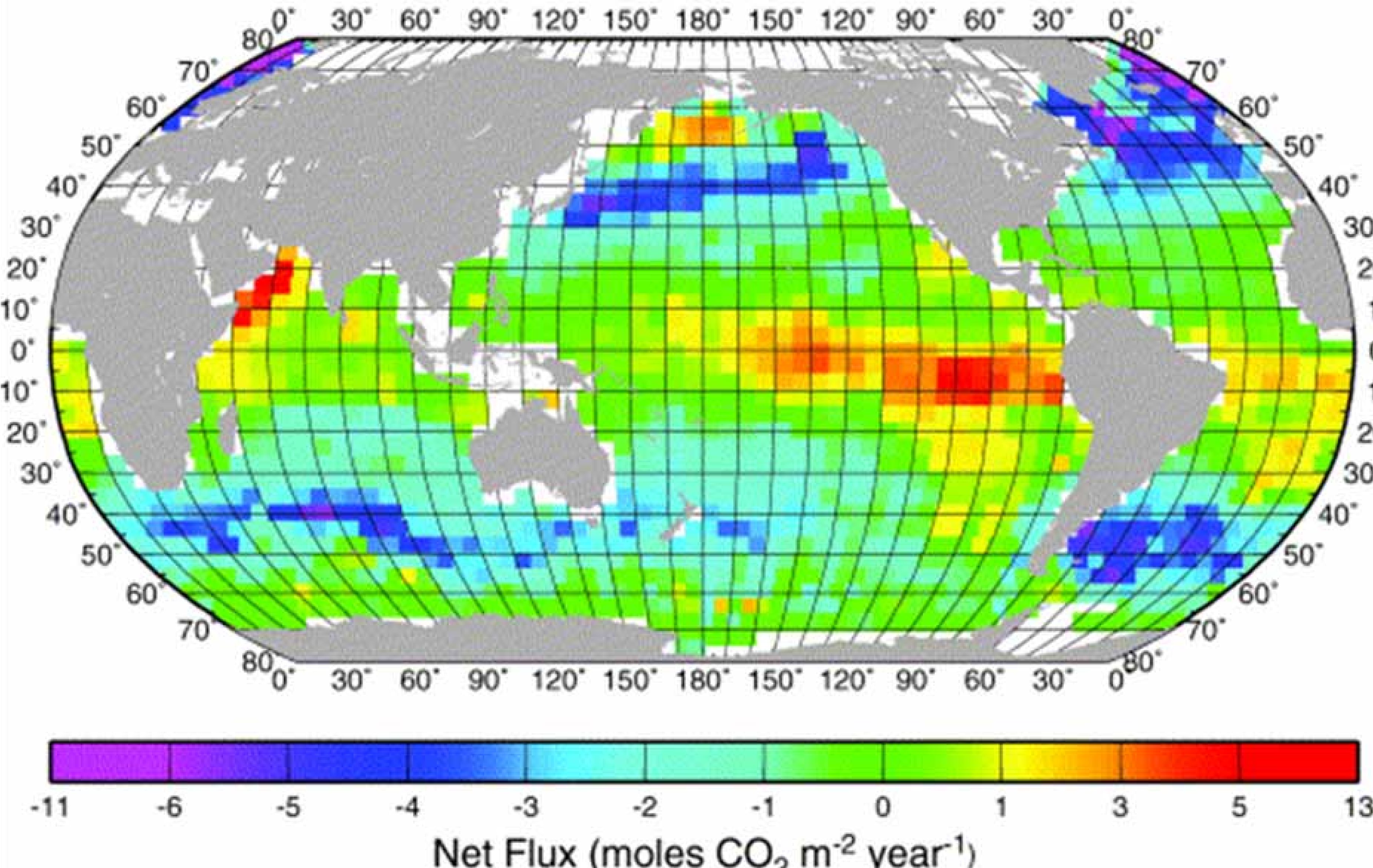



Millford & Sutton 2001


ACSOE
AMT
Cruise Track



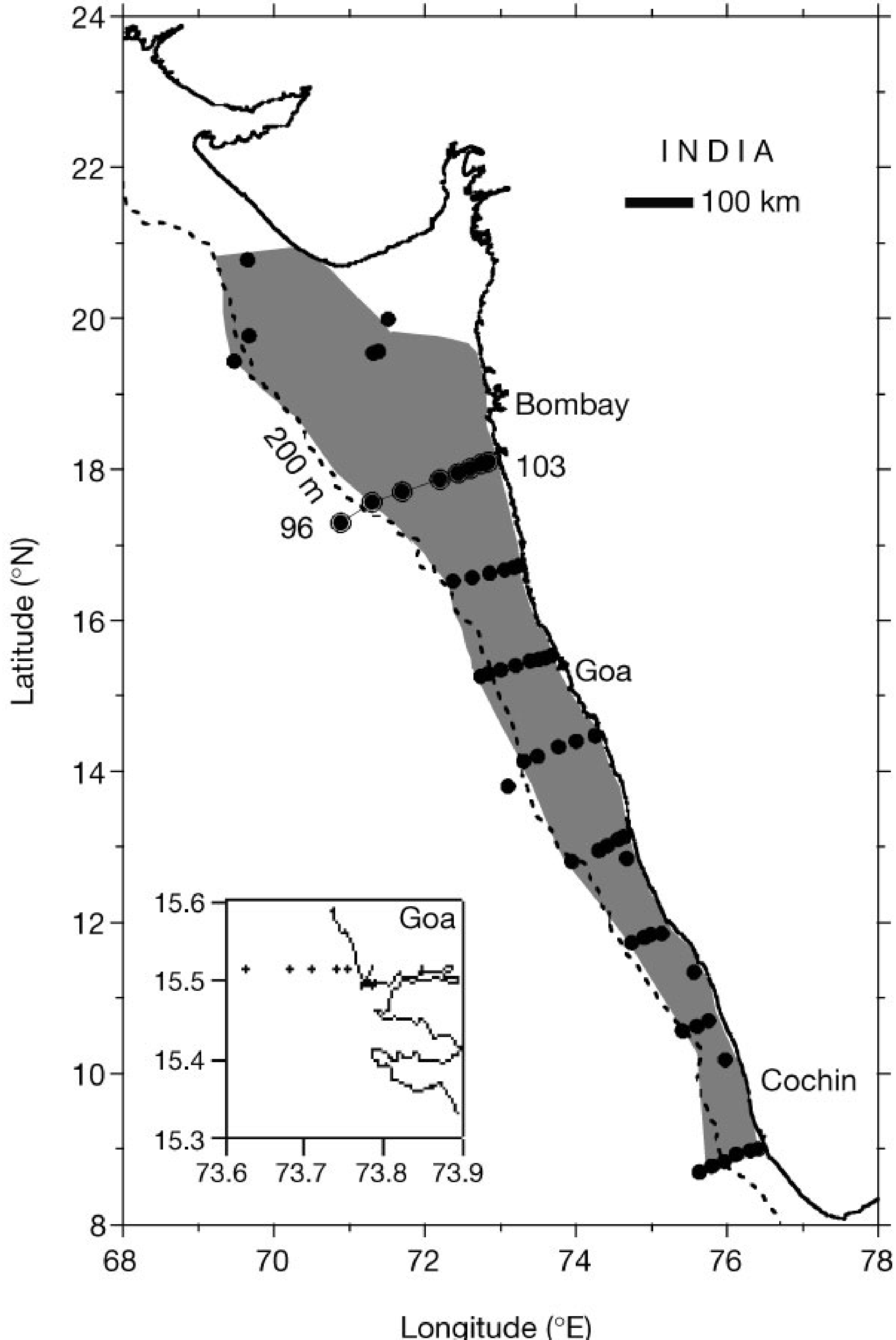

Jickells *et al*. 2003



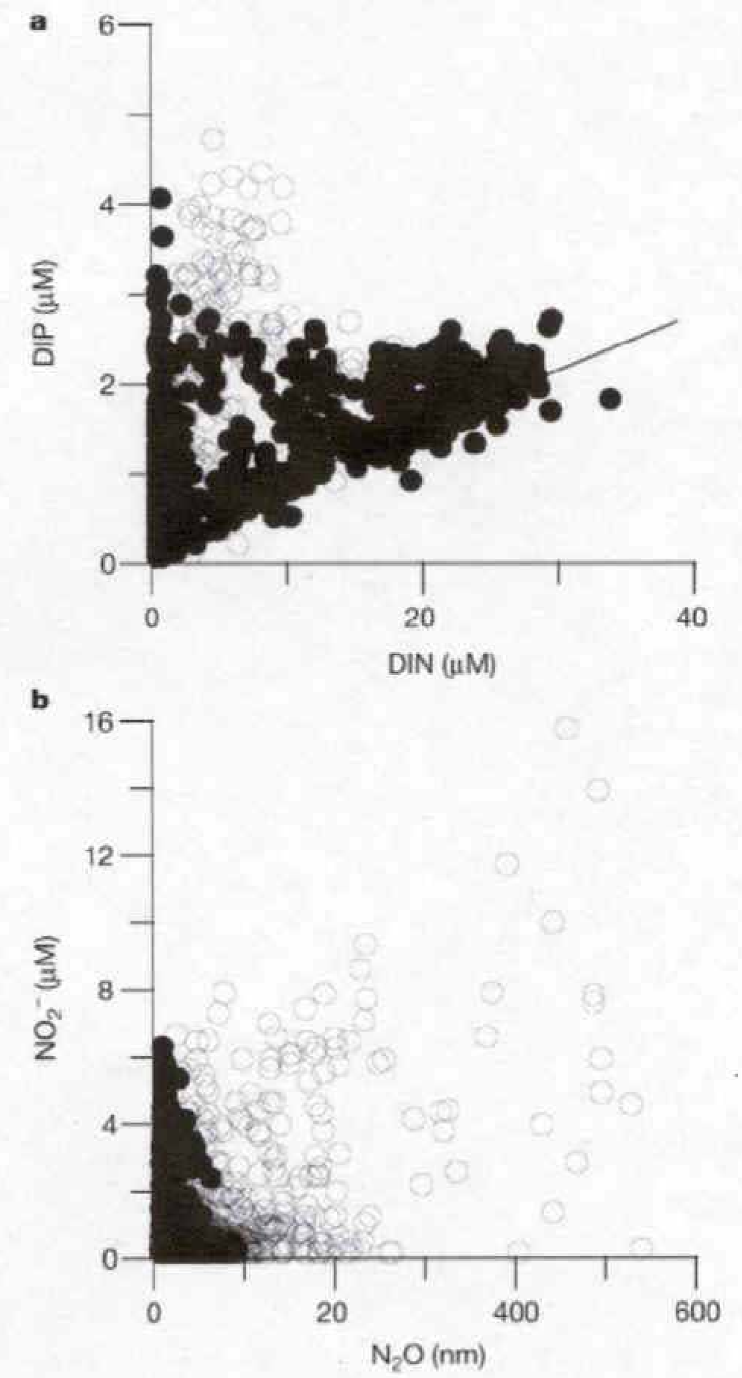

Global climatology of the annual net air-sea $CO_2$ flux based on interpolation of air-sea $pCO_2$ differences referenced to the year 1995 (Reprinted from Takahashi *et al.*, 2002, with permission from Elsevier Science)

| | $NH_3$ | MMA | DMA | TMA |
|---|---|---|---|---|
| CONDITIONS | Concentrations (nmol $m^{-3}$) | | | |
| Atmospheric Max. | 20 | 0.052 | 0.240 | 0.100 |
| Atmospheric Min. | 4 | 0.011 | 0.093 | 0.030 |
| Seawater max. | | | | |
| Ct | 1440000 | 38000 | 58000 | 25000 |
| Cl | 108759 | 125 | 140 | 557 |
| Seawater min. | | | | |
| Ct | 22000 | 0 | 1000 | 0 |
| Cl | 1662 | 0 | 3 | 0 |
| RESULTS | Flux (pmol$m^{-2}s^{-1}$) | | | |
| Atmospheric Max. | | | | |
| Seawater max. | -1511 | -0.86 | 0.31 | -5.44 |
| Seawater min. | 1462 | 0.33 | 1.26 | 0.46 |
| Atmospheric Min. | | | | |
| Seawater max. | -1649 | -1.12 | -0.47 | -5.76 |
| Seawater min. | 8.68 | 0.07 | 0.48 | 0.14 |
| Flux range | -1649 to 1462 | -1.12 to 0.33 | -0.47 to 1.26 | -5.76 to 0.46 |
| Van Neste *et al*. (1987) | -900 to 130 | -1.8 to -0.11 | 0.46 to 0.49 | -3.2 to -0.2 |

Gibb 1994

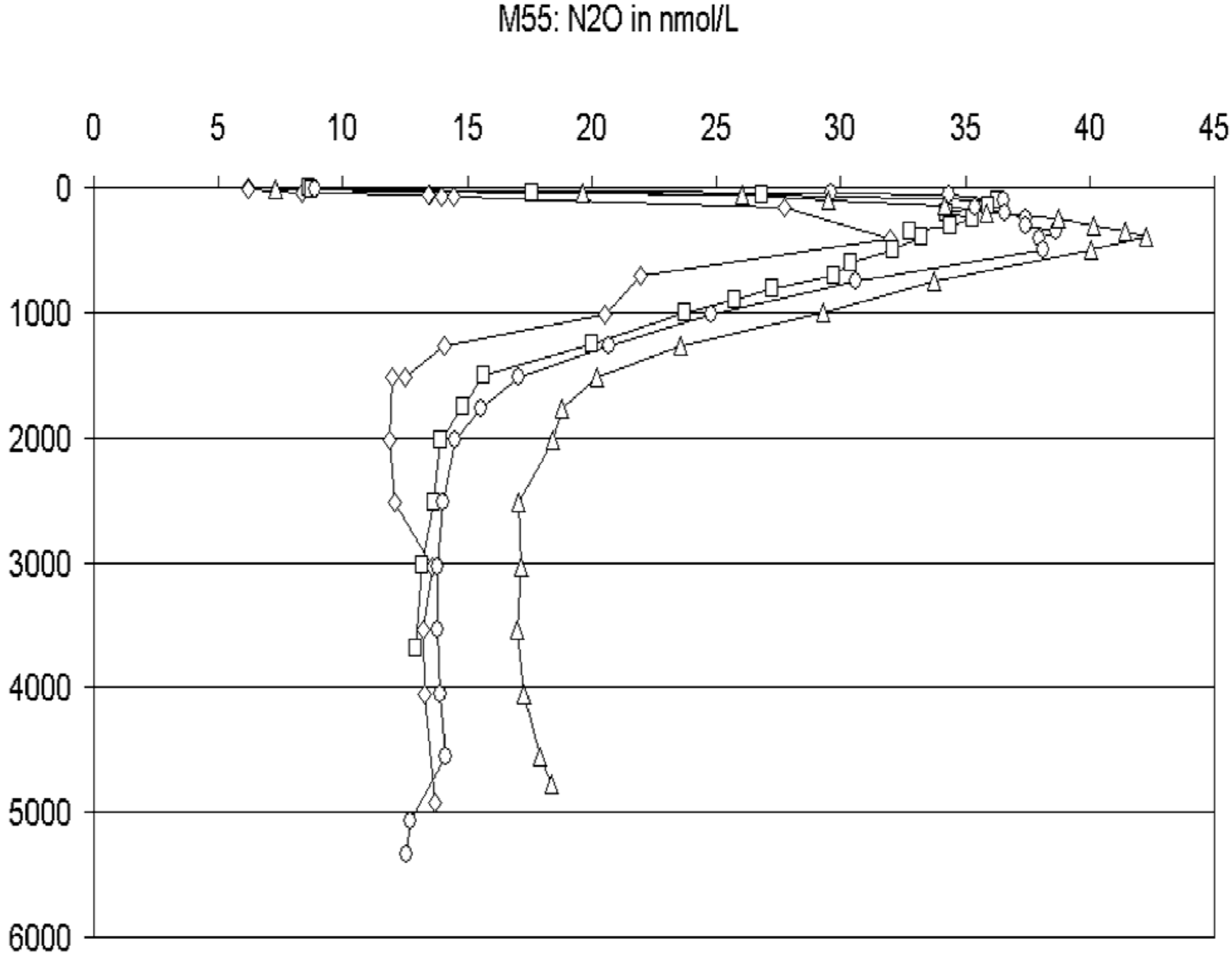


INDIA
100 km
Bombay
103
96
200 m
Goa
Cochin
Latitude (°N)
Longitude (°E)
24
22
20
18
16
14
12
10
8
68
70
72
74
76
78
Goa
15.6
15.5
15.4
15.3
73.6
73.7
73.8
73.9

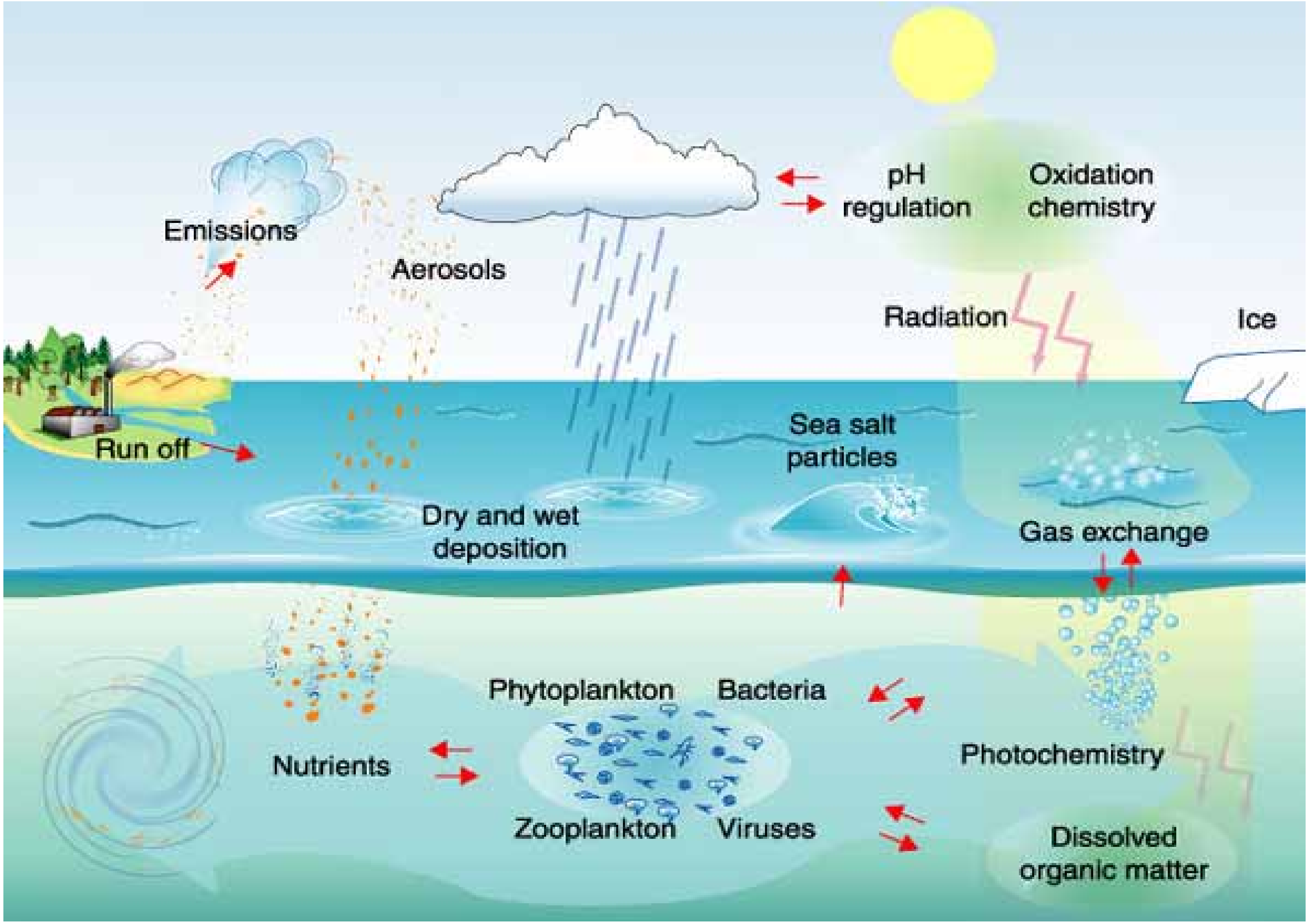



Naqvi *et al*. 2000

$N_2O$ in the water column at various sites in the equatorial Atlantic **(Walter, Bange and Wallace, 2003)**



# Surface Ocean- Lower Atmosphere Study Science



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