

The ASGASEX program

W.A.Oost

Royal Netherlands Meteorological Institute (KNMI), De Bilt, the Netherlands.

Abstract

There is a difference of sometimes more than an order of magnitude in the transfer velocity of CO₂ at the sea surface if data based on concentration measurements are compared with direct flux measurements with the eddy correlation technique. To explain this discrepancy we performed the international VIERS-1 and ASGASEX (for Air Sea GAS EXchange) experiments at the research platform Meetpost Noordwijk off the Dutch coast.

The data indicate that the solution of the controversy may lie in the presence of an unexpected vertical concentration (fugacity) gradient of CO₂ in water. Acting on this result another experiment (ASGAMAGE) is planned for 1996 to confirm or refute this conclusion. On that occasion the fluxes of a number of other trace gases beside CO₂ will be measured with more methods and the CO₂ profile will be monitored over the full water column.

1. THE PROBLEM

The oceans play a crucial rôle in the carbon dioxide balance of the earth. Over 70% of the earth's surface is covered with water. The CO₂ transport (or CO₂ flux) between the oceans and the atmosphere is not well known. Two types of methods have been used to measure CO₂ fluxes: those based on chemical concentration measurements, and those using the eddy correlation technique. The chemical methods all need one or more assumptions that are possibly not always fulfilled and they require measurement times in excess of 24hrs. The eddy correlation method measures fluxes directly without such assumptions and within about half an hour, but suffers from a lack of accuracy, because the instruments used are functioning at the very limit of what's technically possible. The differences between the results of the two types of methods, however, are sometimes orders of magnitude, which is way outside the expected uncertainties [1].

2. METHOD AND RESULTS

The 1990 VIERS-1 experiment and the 1993 experiment of the Air Sea GAS EXchange (ASGASEX) project, both supported by NOP, were designed to establish the feasibility of CO₂ eddy correlation measurements from a relatively bulky platform and to explain the differences just mentioned by comparing the results of the two types of methods.

The VIERS-1 results showed that CO₂ eddy correlation flux measurements were possible at Meetpost Noordwijk (MPN), a research platform 9km off the Dutch coast.

ASGASEX'93 took place in September 1993 on the same platform. A large number

of environmental parameters, were measured to compare both types of methods.

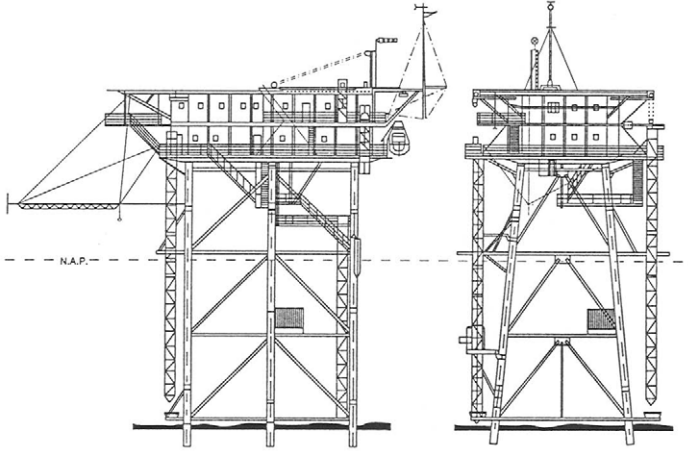


Fig. 1 Research platform Meetpost Noordwijk

The ASGASEX '93 CO_2 flux data, plotted as a function of $d\text{CO}_2$ (the difference between $p\text{CO}_2$, the concentration in the water, and the concentration in the air) showed no relationship at all. Plotted versus the wind speed, however, they showed a fairly systematic behavior, indicating trustworthy data. Looking more closely into the data we found a correlation of $p\text{CO}_2$ with the tide. $p\text{CO}_2$ had been measured using a pump, fixed to the platform. The depth from which the water was brought up therefore changed with the tide, so the correlation could indicate a vertical $p\text{CO}_2$ gradient at the level of the pump.

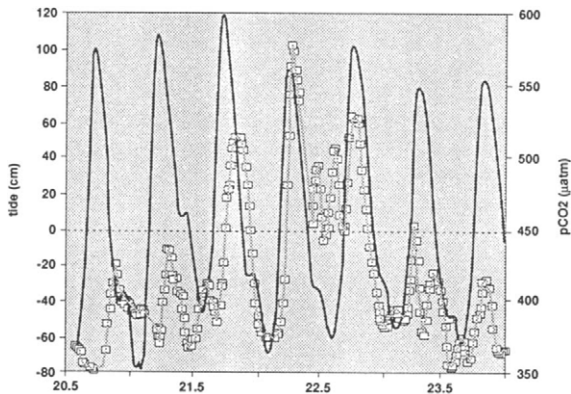


Fig.2 $p\text{CO}_2$ (see text) and the tide (heavy single line) versus time

Our measurements also indicated that the wind speed affects the CO_2 concentration in the water. This "wind effect" may be assumed to be absent at wind speed zero.

Extrapolating to that value we therefore find the "deep" concentration difference actually driving the CO_2 transport, in this case $272\mu\text{atm}$.

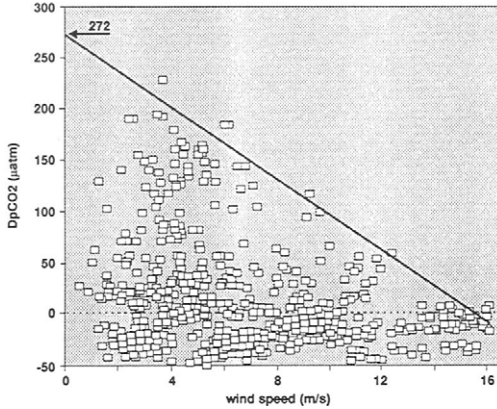


Fig.3 CO_2 concentration difference (sea-air) against wind speed.

With this value of the concentration difference we find a good correspondence with parametrisations for the CO_2 flux based on concentration measurements (here the one of Wanninkhof [2]). This in principle could solve the controversy mentioned in [1] and so pave the way for improved accuracy in the measurement of CO_2 transport over the oceans.

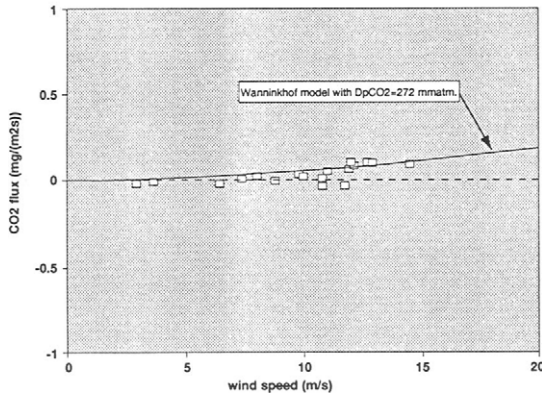


Fig.4 Measured flux values (open squares) compared with the results of the Wanninkhof parametrization.

If, as the ASGASEX'93 results suggest, the CO_2 concentration (fugacity) in water can vary with depth in the first few meters below the surface, the use of the CO_2 concentration close to the surface when comparing the flux methods - as has been done so far! - will lead to spurious values for the transport coefficients. This insight can explain the differences between the two types of methods and may lead to a greatly improved reliability and accuracy of CO_2 transport between sea and air.

3. FURTHER NEEDS

The ASGASEX '93 results require confirmation. The crucial data were obtained almost by accident and their interpretation is not unequivocal. More information is needed on the presence or absence of a CO₂ gradient.

To improve the accuracy of gas flux data over the sea we furthermore need better and generally applicable measurement methods. These methods must be tested and compared to assess their value. The eddy correlation method, as used presently, can measure the transport of only a single gas simultaneously and these measurements can so far only be done from a stable platform i.e. near the coast. However, due to the high quality of present-day motion sensing devices, it has become possible to allow with sufficient accuracy for the movements of e.g. a ship. Another new technique, the eddy accumulation method, holds promise of simultaneous and direct measurement of the fluxes of a number of gases. This would bring the direct measurement of gas fluxes on the high seas within reach.

4. THE FUTURE: ASGAMAGE

In 1996 there will be another experiment at Meetpost Noordwijk, called ASGAMAGE (MAGE, for Marine Aerosol and Gase Exchange, is a working group of the IGBP IGAC (International Global Atmospheric Chemistry) program. There will be two five week measurement periods (one starting in May, the other in October). Several eddy correlation systems for CO₂ fluxes will be functioning simultaneously and one or two eddy accumulation systems will also be present. One or two ships will make measurements in the MPN area to detect horizontal concentration gradients, one of them may be used for an attempt to perform eddy transport measurements from on board. Fluxes will be measured not only of CO₂, but also of DMS (with the eddy correlation technique!), CH₄ and N₂O.

5. REFERENCES

- 1 W.S.Broecker et al, J. Geophys.Res. 91, (1986), 10517-10527.
- 2 R.Wanninkhof, J.Geophys.Res., 97, (1992), 7373-7382.

Institutes (in alphabetical order) participating in ASGASEX/ASGAMAGE:

Bedford Institute of Oceanography (BIO)	Canada
Dalhousie University	Canada
Institute of Oceanographic Sciences (IOS)	UK
Risø National Laboratory	Denmark
Royal Netherlands Meteorological Institute (KNMI)	the Netherlands
Netherlands Institute for Sea Research (NIOZ)	the Netherlands
Southampton University	UK
TNO-Physics and Electronics Laboratory (TNO-FEL)	the Netherlands
University College Galway	Ireland