Zuwendungsempfänger:
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Vorhabenbezeichnung: **Ozeanische Aufnahme anthropogener Spurengase: Realistische Darstellung des Effekts mesoskaliger Prozesse in Zirkualtionsmodellen**

Laufzeit des Vorhabens: 1.9.2001 - 31.08.2005
Abschlussbericht

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1. Tasks, requisites, workflow

Summary/ Zusammenfassung

The model integrations to examine the effect of the oceanic mesoscale processes on the uptake and spreading of anthropogenic trace gases have been completed. It has been shown that the mesoscale variability plays an important role in the distribution of trace gases and in their meridional transports in the ocean. A detailed comparison of the model CO_2 and CFC fields with recent ship measurements indicates that such a highly-resolved model data set can be crucial for interpretations of the sparse geochemical measurements in the ocean.

Mit Hilfe einer Hierarchie ozeanischer Zirkulationsmodelle unterschiedlicher Auflösung wurde der Effekt mesoskaliger Prozesse auf die Aufnahme und Ausbreitung von Spurengasen untersucht. Es wurde gezeigt, dass die mesoskalige Variabilität eine wichtige Rolle bei der Verteilung von Spurengasen und ihrem Meridionaltransport spielt. Ein detaillierter Vergleich von CO_2 und CFC Modellfeldern mit neuen Schiffsbeobachtungen zeigte, dass ein hochauflösendes Modell entscheidend sein kann für die korrekte Interpretation räumlich und zeitlich schwach aufgelöster geochemischen Messungen im Ozean.

Scientific and technical status at the beginning of the project

At the beginning of the project a geochemical tracer model was already implemented in the FLAME-model. Therefore the project was performing well right from the beginning, focusing more on the integration of CFC and CO_2 in long-term and sensitivity experiments and its scientific analysis.

Collaboration

The project was closely accompanied by scientists from the chemical department at IFM-

GEOMAR, Profs. Wallace, Körtzinger, and Dr. Tanhua. There was a regular exchange with Dr. Völker, Alfred-Wegener-Institut Bremerhaven.

2 Scientific results, benefit

Scientific results

The major issue of this project was on the uptake of anthropogenic trace gases, its resolution dependence and representation in ocean models. It has been shown (Biastoch et al., 2006) that the horizontal distribution of CO_2 significantly depends on the representation of mesoscale eddies. Especially in the subpolar North Atlantic a fine-scale structure is most evident (Figure 1) which depends on the representation of small- and mesoscale processes determining the physics of the production of deepwater by convection processes.

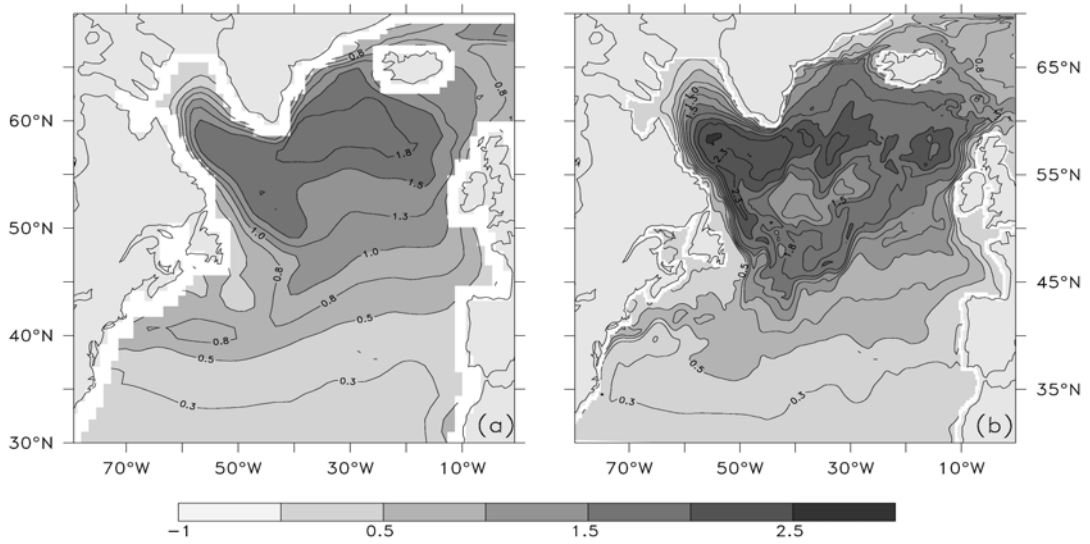

Figure 1. Mean 1990 atmosphere-ocean flux of CO_2 inventory (in mol m^{-2} $year^{-1}$) in the (a) 4/3° and in the (b) 1/3° model.

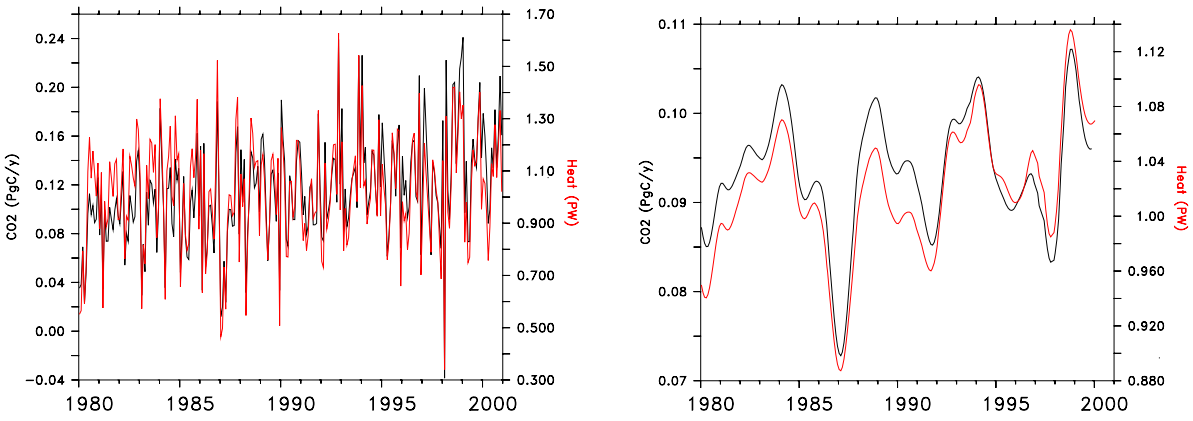

Figure 2. Transport of CO_2 (black) and heat (grey/red) across 25°N. (a) monthly data, (b) interannual variability.

After addressing the questions on the horizontal resolution, additional issues were raised: the temporal variability and the comparability of anthropogenic CO_2 and CFC. A good example is the

seasonal variability of the meridional CO_2 transport and its strong correlation with the meridional heat transport (Figure 2, left). This strong correlation also holds beyond seasonal variations on interannual time scales. The main driver here is the large-scale circulation, in particular the meridional overturning cell, the variability of which strongly depends on the variability of the wind fields. A series of experiments with different variability of the individual forcing components has shown that enhanced deepwater formation due to atmospheric heat fluxes leads to fluctuations in the gas uptake in the subpolar North Atlantic (Böning et al., 2003). But in integral quantities, as is the meridional heat or tracer transport, this is masked by the dominant wind fluctuations.

Another focus is the comparability of the two most important anthropogenic trace gases, CO_2 and CFC. Since anthropogenic CO_2 cannot, in contrast to CFC, directly be measured from a water sample but must be inferred from several quantities, several attempts have been made to relate both quantities (Körtzinger et al.,1998) and to get evidence for one quantity from the other. However, due to the different atmospheric history and different equilibration times at the surface (weeks for CFC, one year for CO_2), a relation should be taken with caution. Figure 3 shows the annually averaged fluxes of both quantities in the subpolar North Atlantic. CFC has a clear signal in the Labrador and Irminger Seas, those areas where wintertime convection occurs in the model. In contrast, CO_2 is prominent over the whole subpolar North Atlantic. Due to the longer equilibration time CO_2 in the upper ocean is never saturated during the relative short process of wintertime convection; a flux into the ocean persists over the whole year. In result, the uptake of CFC and CO_2 does follow different characteristics, although the physical mechanism of the gas uptake itself is the same.

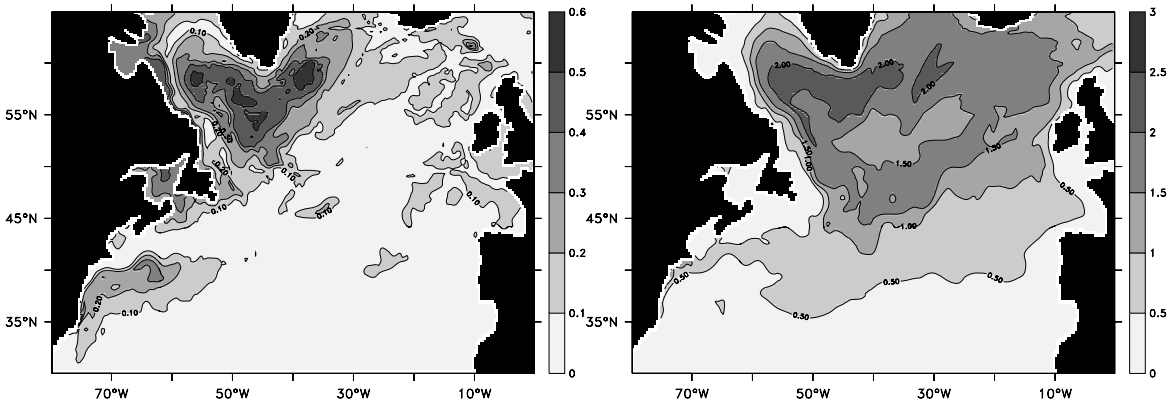

Figure 3. Mean 1990 atmosphere-ocean fluxes of (a) CFC-11 and (b) CO_2

The effect of different atmospheric history is visible further south where the deep water masses have been taken up and are away from surface contact for some twenty years. Figure 4 shows box averaged profiles of stations north of and within the export region from the subpolar to the subtropical regime, as well as further south completely in the subtropical regime. The profiles, 23-year differences (2001 -1978), do compare surprisingly well with observational analyses from recent ship data (Meteor M60) in comparison to historic (TTO) measurements (Tanhua et al., 2006). The northern and southern stations do give analogue pictures for both quantities, with a clear (no) increase within that 23-year period for the northern (southern) regime. The stations within the export of deep water, however, do show a much larger increase of CFC than of CO_2 in the (model) range of North Atlantic deep water. Due to the later and much stronger occurring atmospheric increase (and the shorter equilibration time) the increase of CFC is more prominent than CO_2 for which a steady contribution exists throughout the last decades.