DECADAL RISING OF OCEAN SURFACE CO_2 IN THE SOUTHERN INDIAN OCEAN (20°S-60°S).

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ABSTRACT
The decadal variability of air-sea CO_2 fluxes is poorly known in the southern hemisphere. To evaluate the changes or stability of these fluxes over several years, we compare seasonal observations obtained in 1991 and 2000 the Southern Indian Ocean. For summer and winter, we observed a significant increase of ocean fugacity (fCO_2) in subtropical waters (20°-35°S), about the same rate as in the atmosphere. In polar waters south of 40°S where meso-scale biological activity is high in summer, the rising of oceanic fCO_2 is only well detected when comparing austral winter data. The decadal evolution of fCO_2 observed in the cold waters certainly results from anthropogenic CO_2 emissions, but is also probably modulated by variations of primary production.

INTRODUCTION
Observing and understanding the long-term change of oceanic carbon dioxide in surface waters is crucial to better determine climatological air-sea CO_2 fluxes [*Takahashi et al*., 2002], their variability at interannual to decadal scales, and to understand how the fluxes will change in the futur under different environmental conditions, including anthropogenic CO_2 emissions and climate change. The continuous rising of sea surface CO_2 concentrations and CO_2 partial pressure, or fugacity (DIC and pCO_2 or fCO_2) has been relatively well documented in North Atlantic and Pacific oceans [e.g. *Feely et al*., 2002]. This is generally related to anthropogenic CO_2 but trends may also be attributed to natural variabilities such as evaporation anomalies [*Dore et al*., 2003] or changes in primary productivity. In the southern hemisphere, the long-term evolution of oceanic pCO_2 is not clearly detected because during austral summer, when most data are available, the decadal variations of biogeochemical properties are often masked by large spatio-temporal variabilities [*Inoue and Ishii*, 2005]. Therefore the detection of the decadal pCO_2 changes in cold polar waters requires an analysis over a very long period and, if possible, based on winter observations when the biological activity is low.

DATA SELECTION AND RESULTS
Seasonal observations of seasurface and atmospheric fCO_2 have been obtained in the Southern Indian Ocean in 1991 (MINERVE cruises) and 2000 (OISO cruises) using the same technic and data processing [*Metzl et al*., 1995]. Because spatial and monthly variabilities of fCO_2 could be large in this sector, we select observations obtained along the same tracks (Réunion-Kerguelen) and periods (January and August). Our analysis is based on the regional distribution of fCO_2 well reflected from fCO_2/SST seasonal relation-ships (Fig. 1), excepted in high latitudes during austral summer when meso-scale biological activity controls most of the fCO_2 variability [*Metzl et al.,* 1995]. During austral summer, in warm and temperate waters of the subtropical and sub-Antarctic zone (15-27°C) the fCO_2/SST relation is positive and nearly equal for 1991 and 2000, but shifted by more than 10 µatm. During austral winter, two relations are calculated for warm and cold waters. These relations are both negative and reflect the large and opposed seasonal fCO_2 variations in the subtropical and sub-Antarctic regions. As for summer, the winter relations are about the same and shifted towards higher fCO_2 in 2000 compared to 1991.

CONCLUSIONS

During almost a decade, the oceanic fCO_2 increased significantly in all sectors of the South Indian Ocean, in warm and cold waters. The increasing rate in the ocean is close to the one in the atmosphere. However, the analysis also suggests interesting regional characteristics. In the frontal zone (40°S-50°S) the decadal change of oceanic fCO_2 seems to be larger than in the air, implying a smaller oceanic carbon sink for recent years. This could be explained by a reduction of the biological pump. Interestingly these regional differences appear coherent with the distribution of anthropogenic CO_2 estimated from back-calculation methods. This study will be completed with historical (back to sixties) and more recent data (2002).

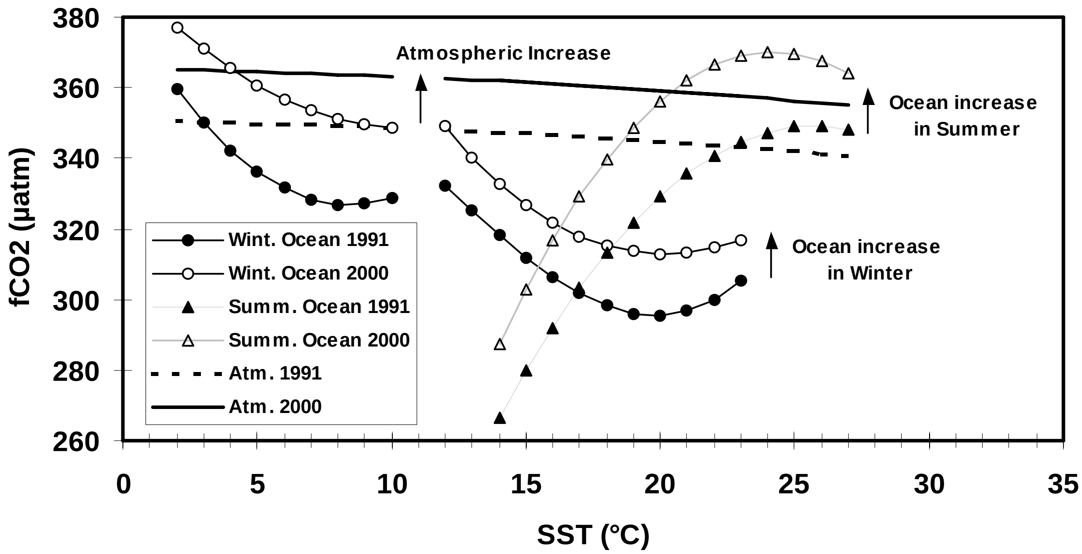

Fig. 1: The seasonal fCO_2/SST relation-ships derived from observations in 1991 (Minerve cruises) and 2000 (OISO cruises) in the south Indian Ocean. Arrows indicate the observed increase of atmospheric and oceanic fCO_2 for summer and winter.

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