INTERPRETATIONS OF SOUTHERN OCEAN CARBON CYCLE PROCESSES FROM ATMOSPHERIC MEASUREMENTS OF CO_2 AND O_2 AT BARING HEAD, NEW ZEALAND

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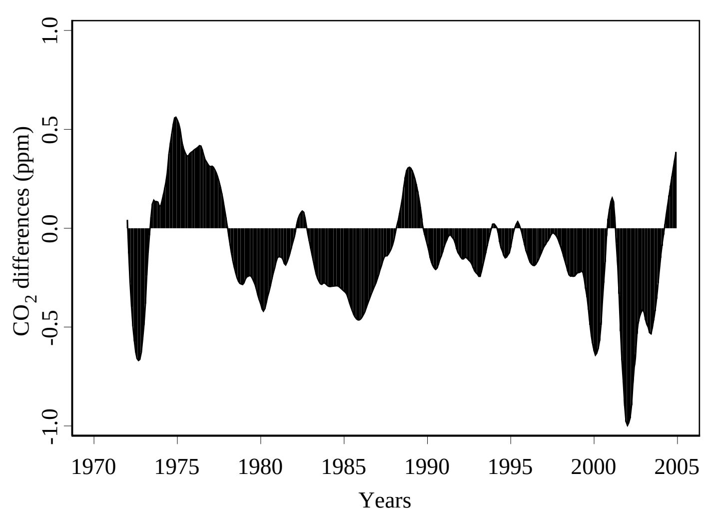
ABSTRACT
We present a 30+ year record of continuous atmospheric CO_2 concentrations and a 5 year record of continuous O_2 concentrations from Baring Head, New Zealand. When compared to South Pole data, the CO_2 concentrations indicate a persistent, but variable net carbon sink in the Southern Ocean since the late 1970s. The amplitude of the seasonal cycle of O_2 concentrations (expressed as "APO", Atmospheric Potential Oxygen) shows large inter-annual variability, suggesting high variability in annual air-sea O_2 fluxes, and thus also potentially suggesting high variability in year to year marine productivity in the Southern Ocean.

INTRODUCTION
The longest continuous records for atmospheric carbon dioxide (CO_2) [*Lowe et al.*, 1979] in the Southern Hemisphere and for atmospheric oxygen (O_2) [*Manning*, 2001] in the world were started in 1970 and 1999 respectively, in Wellington, New Zealand. The station, operated by NIWA, is situated at Baring Head (41.41°S 174.87°E) where it receives wind from the ocean to the south approximately 30% of the time. Back trajectories in these southerly conditions indicate no contact with land for five days or more. For this reason the data represent well mixed air masses derived from the Southern Ocean region. This region plays a significant role in the global ocean carbon cycle. Because of high spatial variability and a sparse measurement network, large uncertainties exist, to the extent that it is unclear if the region is a net sink or source for atmospheric CO_2. Due to the complex interplay between ventilation of CO_2-enriched waters, absorption of CO_2 by cold waters, zones of high marine productivity, high wind speeds, and changes in ocean stratification, we can expect relatively high variability in carbon sink/source characteristics on timescales of days to decades.

RESULTS
On inter-annual and decadal timescales, we examine some of these features by comparing the atmospheric CO_2 records of Baring Head with that from the South Pole, operated by Scripps Institution of Oceanography. Due to comprehensive reference gas inter-comparisons between Scripps and NIWA for over 30 years, we are able to interpret the relatively small signals with more confidence than would otherwise be the case. Differences between the two CO_2 records are shown in the figure as Baring Head concentrations minus South Pole concentrations. Periods of negative differences, as seen for almost all of the



1980s and 1990s suggest that the Southern Ocean is taking up CO_2, and acting as a net carbon sink. Significant inter-annual variability is observed in the Baring Head – South Pole difference, suggesting that there is significant inter-annual variability in the size of the Southern Ocean carbon sink. For the first ~25 years of the record, we found a relationship between this difference and the Southern Oscillation Index (SOI). However, during strong El Niño conditions this does not hold. In addition, since about 2000, no relationship is observed. Thus, it appears that the Southern Ocean carbon sink is partly influenced by El Nino southern oscillation conditions, but that other competing factors, for example variability in mixed layer depth and marine productivity may also be important.

We also examine Southern Ocean processes on shorter timescales (days to seasons) by examining our more recent record of Atmospheric Potential Oxygen (APO). Derived by combining atmospheric observations of CO_2 and O_2, APO is an approximately conservative tracer with respect to land biotic photosynthesis and respiration, and thus changes in APO reflect predominantly oceanic processes and a small influence from fossil fuel emissions [*Stephens et al.*,1998]. On short timescales, APO provides information about oceanic O_2 fluxes, and on longer timescales provides information about the ocean carbon sink. Our APO data from Baring Head have an average seasonal amplitude of about 70 per meg. We observe year to year variability in this seasonal cycle sometimes greater than 30%. This implies high seasonal variability in air-sea O_2 fluxes in the Southern Ocean. Possible causes of this are variability in marine productivity, changes in mixed layer depth and ventilation, or ocean temperature. These parameters in turn may be varying due to changes in wind speed, nutrient supply, light availability, or ocean circulation changes.

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