A COMPARISON OF THE BARING HEAD AND MAUNA LOA ATMOSPHERIC CO_2 RECORDS

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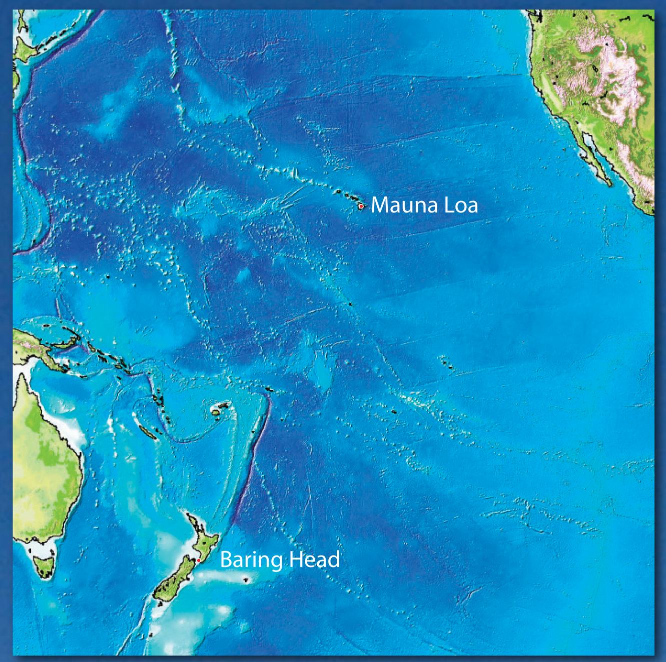

Introduction

The New Zealand atmospheric CO_2 record is the longest continuous measurement series in the Southern Hemisphere with its inception first at Makara (1970) followed by Baring Head (1972). Baring Head (41.4°S, 174.9°E), situated on a southern coastal cliff 85 m above sea-level, is a remote site located 12 km southeast of Wellington, New Zealand. Air masses arriving there from the South (onshore) are representative of a large part of the South West Pacific whereas northerlies are influenced mainly by local terrestrial biotic processes. The Southern Hemisphere, due to its large extent of ocean, plays an important role in processes relating to global climate and climate change.

By the early 1960s the Mauna Loa record clearly demonstrated both seasonal cycles and a secular trend in atmospheric CO_2 in the Northern Hemisphere. In 1969 Dave Keeling sent a team of 3 staff from Scripps Institution of Oceanography (SIO) to set up the first continuous site for atmospheric CO_2 in the Southern Hemisphere located at Makara, New Zealand (Lowe, 1974). The team was led by Arnold Bainbridge and joined by Dave Lowe, a New Zealander, in 1970. This site was moved to Baring Head towards the end of 1971 when it became clear that the record was influenced by the local vegetation..

Analysis method

The Baring Head and Mauna Loa CO_2 data are analysed using the STL procedure (Cleveland et al., 1990), a filtering procedure for decomposing seasonal time-series into trend, seasonal and remainder component series based on the loess (locally weighted regression) smoothers. The main features of STL are that it is robust to outliers in the data and it allows the seasonal component to evolve slowly over time in shape, amplitude and phase.

Baring Head CO_2 measurements in southerly air, which have not deviated by more than 0.2 ppm for 6 hours, are averaged within each calendar month to form a baseline monthly time-series representative of the oceanic air to the south of New Zealand (Lowe et al., 1979). The Mauna Loa CO_2 monthly series used in this analysis was acquired from the SIO CO_2 website. The same STL smoothing parameters were applied to both series to derive the trend and seasonal components used in this comparison.

Summary

The STL procedure is a useful tool in extracting information from a regular time-series. In analysing the Baring Head and Mauna Loa CO_2 measurement records we find the seasonal cycles do vary in amplitude with time. The steadily increasing gap between the trends changed since 2000 and has remained constant. Despite the different levels of CO_2 in the atmosphere in the two hemispheres and the larger source of emissions in the north, the growth rates and interannual variability are remarkably similar both in magnitude and in timing. This leads to further insights into the roles of the large scale processes of the CO_2 sources and sinks.

Reference

Cleveland, R.B.; Cleveland, W.S.; McRae, J.E.; Terpenning, I. (1990). STL: A Seasonal-Trend Decomposition Procedure Based on Loess. *Journal of Official Statistics Vol.6 No 1, 3-73*.

Lowe, D.C. (1974). Atmospheric carbon dioxide in the Southern Hemisphere. *J. Clean Air Soc. Aust. and N.Z. 8, 12-15*.

Lowe, D.C.; Guenther, P.R.; Keeling, C.D. (1979). The concentration of atmospheric carbon dioxide at Baring Head, New Zealand. *Tellus, 31, 58-67*.

Le Quere, C.; Rodenbeck, C.; Buitenhuis, E.T.; Conway, T.J.; Langenfelds, R.; Gomez, A.; Labuschagne, C.; Ramonet, M.; Nakazawa, T.; Metzl, N.; Gillett, N.; Heimann, M. (2007). Saturation of the Southern Ocean CO2 sink due to recent climate change. *Science 316(5832): 1735–1738*.

Acknowledgements

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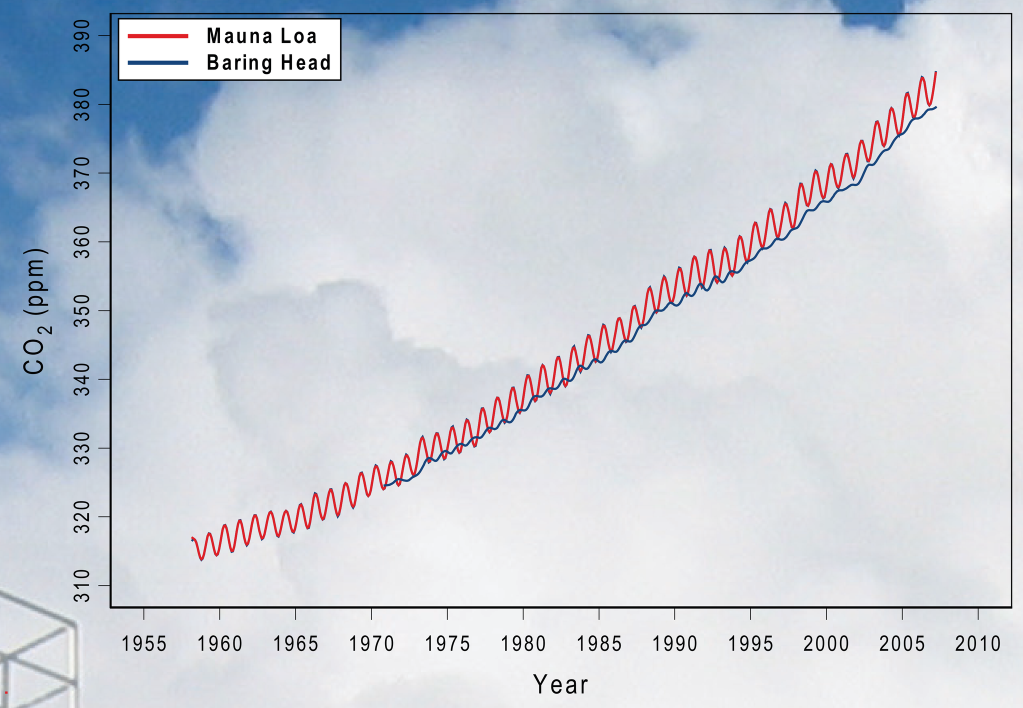


Fig 2. Increasing trends and seasonality of both the Baring Head and Mauna Loa records.

Trend and Seasonality at Mauna Loa and Baring Head

The Mauna Loa record exhibits a slightly higher trend than its southern counterpart due to the greater source contribution from fossil fuel emissions in the northern hemisphere. The larger seasonality in the north is a result of changes in photosynthesis and respiration of the vegetation of the greater land mass whereas seasonality in the southern hemisphere is primarily oceanic.

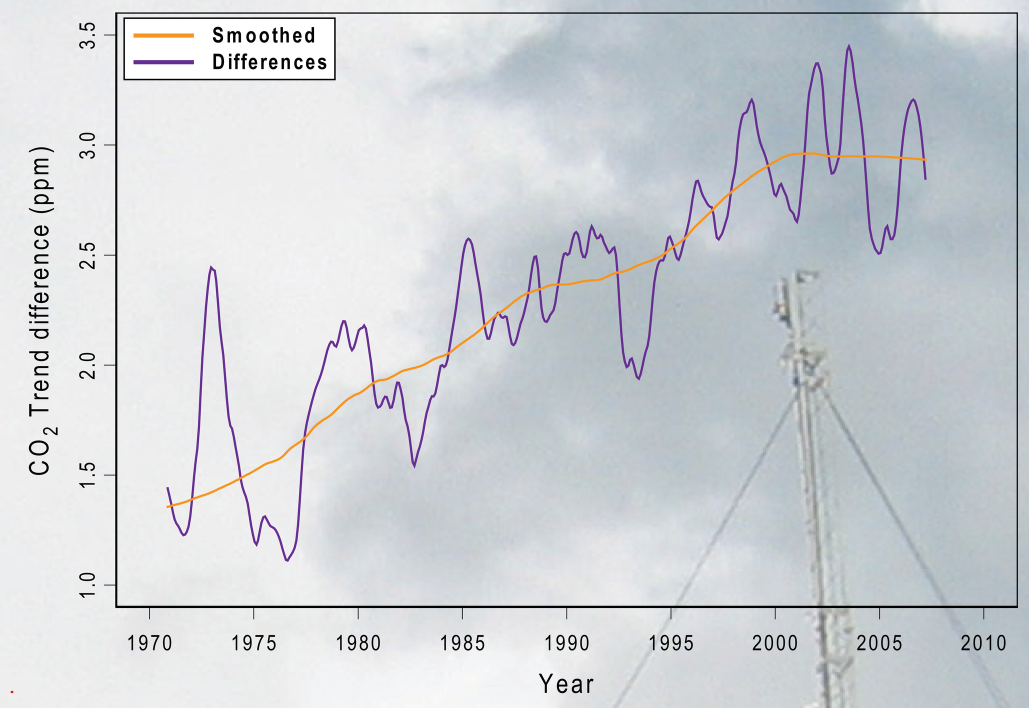


Fig 3. Difference in the trend at Mauna Loa to Baring Head where records match in time. Note that this does not take into account the altitude effect at Mauna Loa which would slightly under-estimate the difference.

Difference in the trends

As both trends increase over time due to mainly fossil fuel emissions, the smoothed difference shows a steadily increasing gap between the trends from 1.4 ppm in the early 1970s to around 2.9 ppm in 2000 where it remains constant. This could be an indication of a change in the sink processes such as a saturation of CO_2 absorption in the Southern Ocean (Le Quéré et al., 2007).

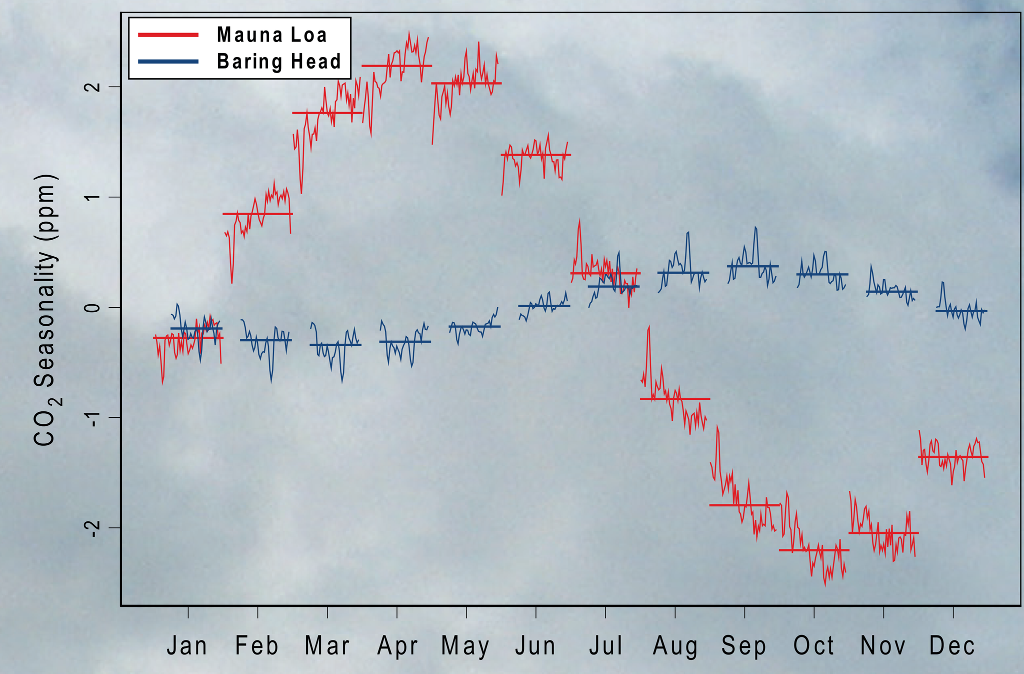


Fig 4. De-trended Mauna Loa and Baring Head CO_2 monthly series plotted by each month.

Seasonal cycles

This plot shows the larger peak to peak amplitude of the seasonal cycle in the northern hemisphere (~6 ppm) driven primarily by the seasonal changes in vegetation of the greater land mass. The larger variation and the trends in CO_2 measurements in the monthly sub-series at Mauna Loa reflect the larger variation in changes of vegetation from one year to the next and possible trends in these changes. The seasonality at Baring Head (~1.2 ppm) is not exactly 6 months out of phase with the northern hemisphere due to an influence of the northern hemisphere seasonality through the inter-hemispheric boundary.

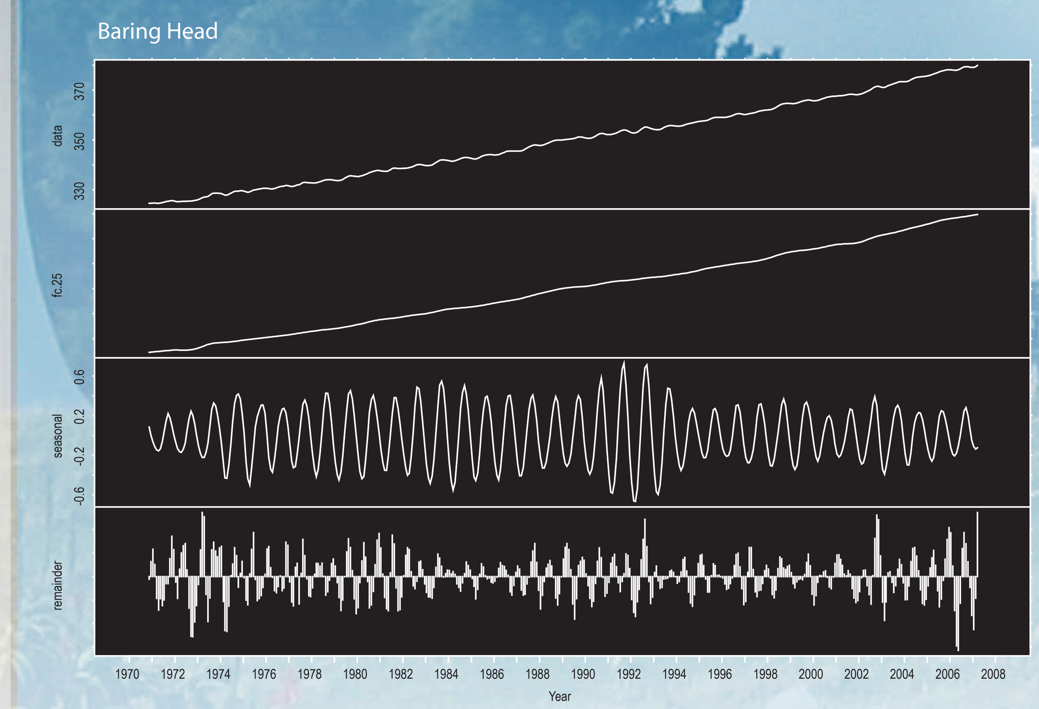
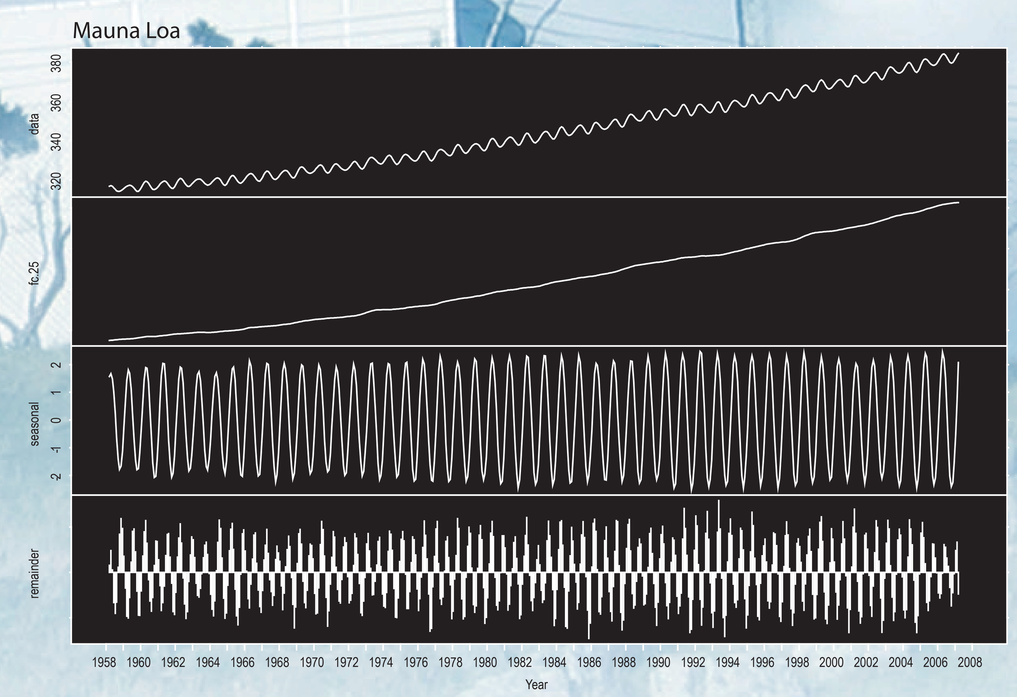


Fig 1. STL decomposition of the Baring Head (left) and Mauna Loa CO_2 (right) monthly time-series into trend, seasonal and remainder components using a 25-month smoother for the trend. A 25-month smoother allows structures larger in period than the annual cycle to be included in the trend component. The bars on the right of each plot represent scales of equal length. Note that the time domain and the measurement scales are different on these two plots.)



The STL plots show changes in amplitude of the seasonal cycle with time which is more pronounced at Baring Head when compared to the larger seasonal cycle of the Mauna Loa monthly time-series. For both sites the remainder series shows some structure in periods less than the annual cycle with larger variations occurring in the Mauna Loa series.

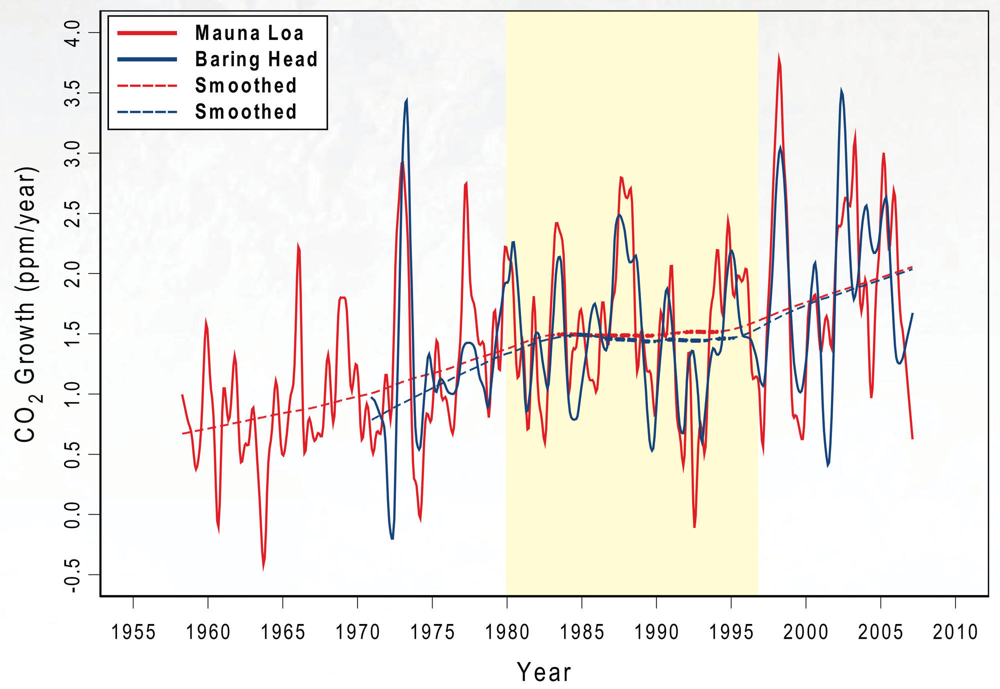


Fig 5. Growth rates in ppm/year at Mauna Loa and Baring Head.

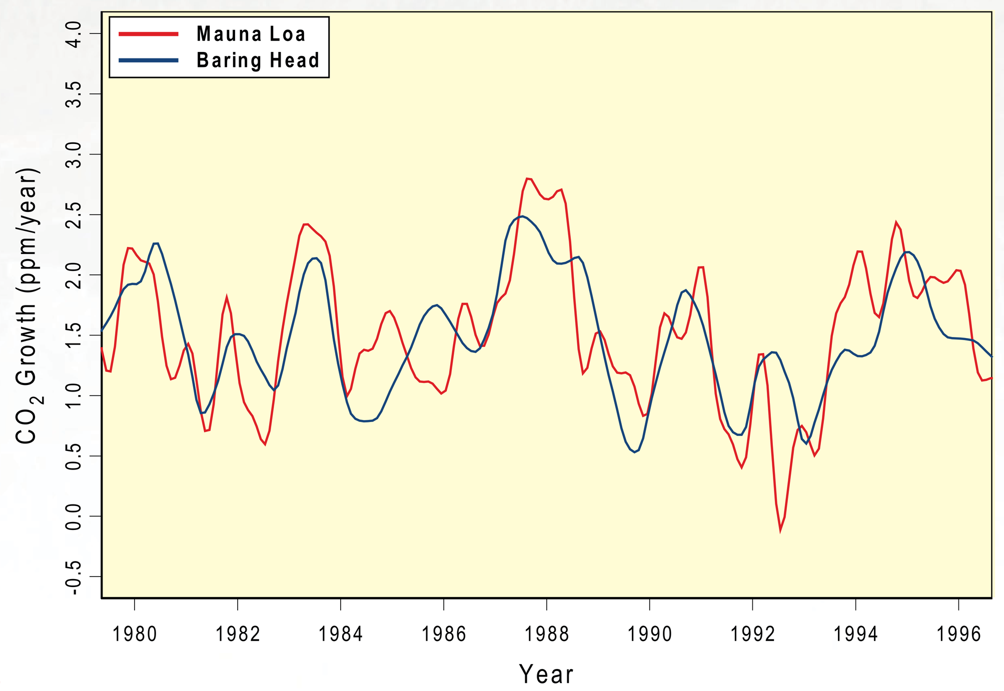


Fig 6. Growth rates in ppm/year for 1980 to 1996.

Growth rates

The growth rates (Fig 5) are determined by a first-order calculation of the gradient at each monthly value in the trends. Despite the different levels of CO_2 in the atmosphere in the different hemispheres and the larger source of emissions in the north, the growth rates are remarkably similar both in magnitude and in timing. The expanded plot (Fig 6) shows the growth rates between 1985 and 1996 and it is not obvious that the northern hemisphere leads the south as would be expected. When it does, it leads by a few months despite the inter-hemispheric atmospheric transport exchange time for CO_2 known to be around 18 months. During this period the smoothed plots show the growth rates levelling off at about 1.4 ppm/year. Since then the overall rates have started to increase to 2.0 ppm/year near the end of 2007.

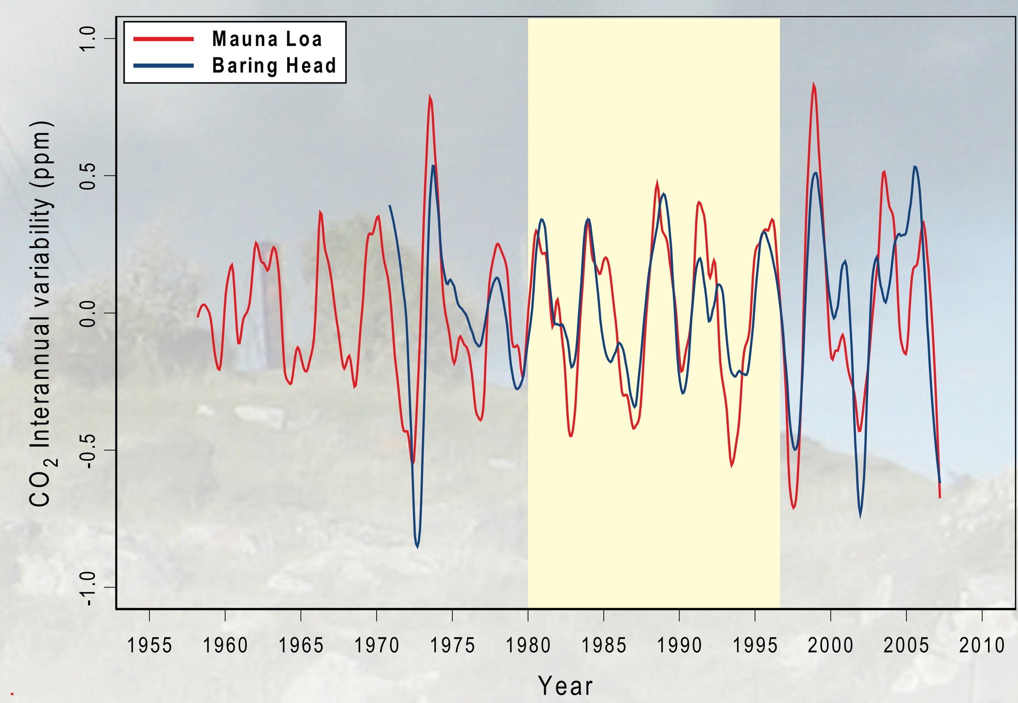


Fig 7. Interannual variability in the Mauna Loa and Baring Head CO_2 monthly series.

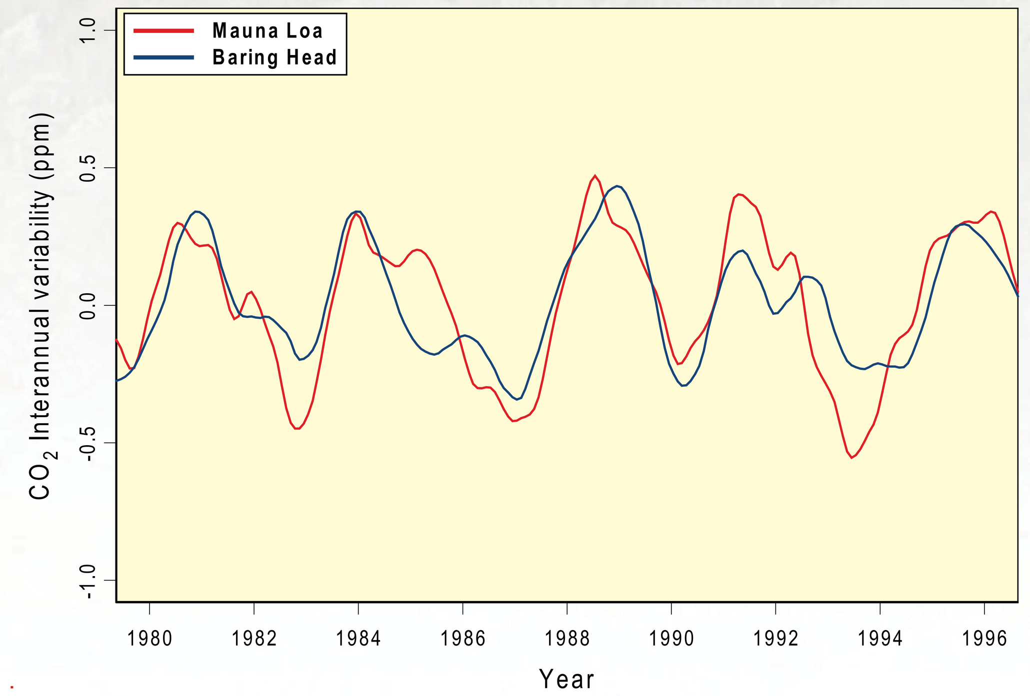


Fig 8. Interannual variabilityfor 1980 to 1996.

Interannual variability

The interannual variability was determined by looking at deviations from the overall mean trend line which was derived using the STL procedure with a 121 month smoothing parameter and subtracted from original monthly series. Once this smooth mean trend has been subtracted the STL procedure is reapplied and the resulting trend forms the monthly interannual variability series. Note that the interannual variability is of the same magnitude as the Baring Head seasonal cycle and significantly less than the Mauna Loa seasonal cycle.

As with the growth rates the magnitude and timing of the interannual variability for both sites is remarkably similar. An expanded view for the years 1980 to 1996 shows how similar the two series are. Given the different levels of CO_2 in the atmosphere and the different source and sink regimes in each hemisphere, may be related to a climate phenomenon affecting both hemispheres such as El Nino/La Nina events.