Oxygen in the trapped air: identifying primary atmospheric signals and secondary bubble close-off fractionation

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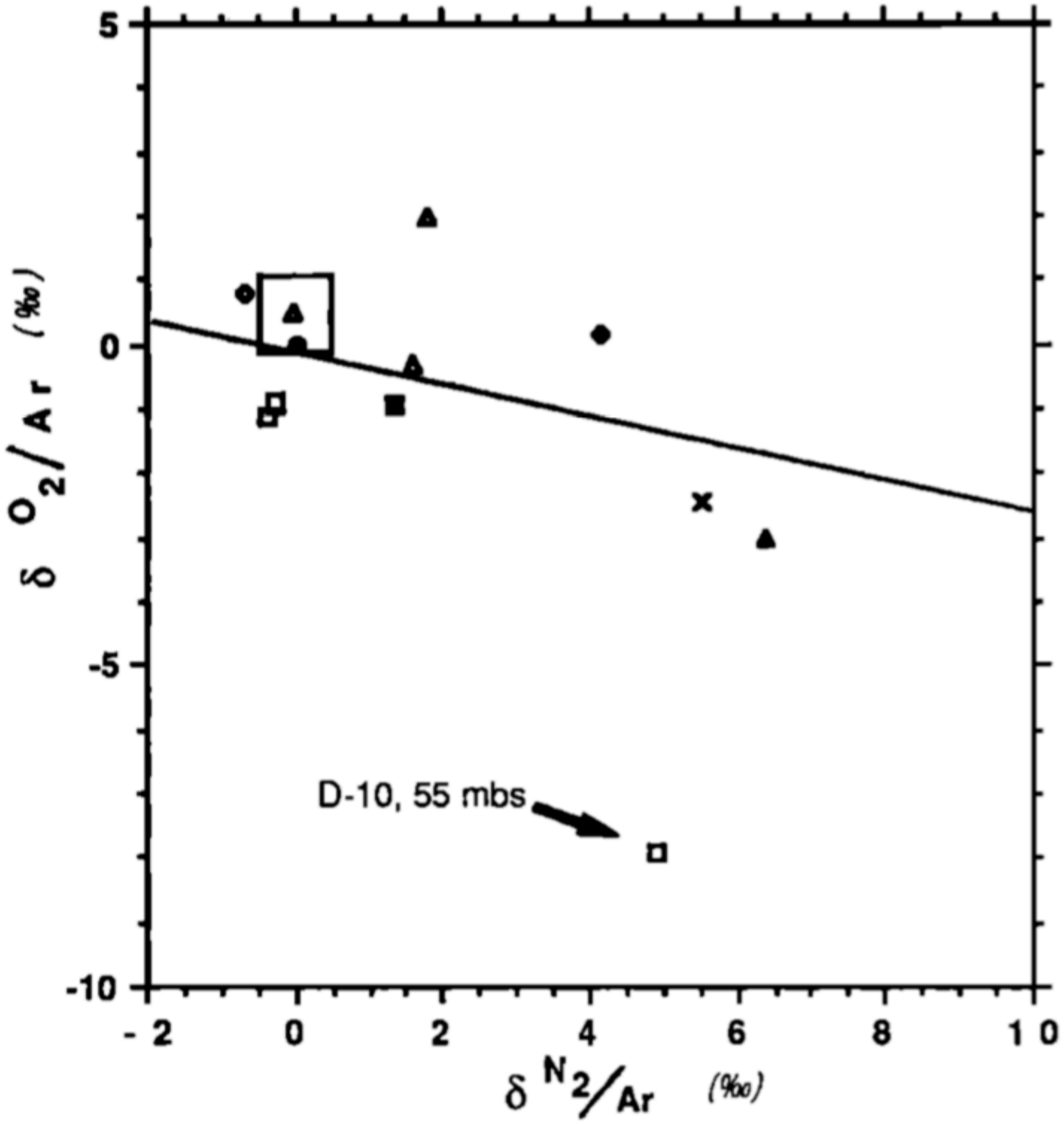
Ratios of O_2/N_2 in trapped gases in ice cores are different from the atmospheric value

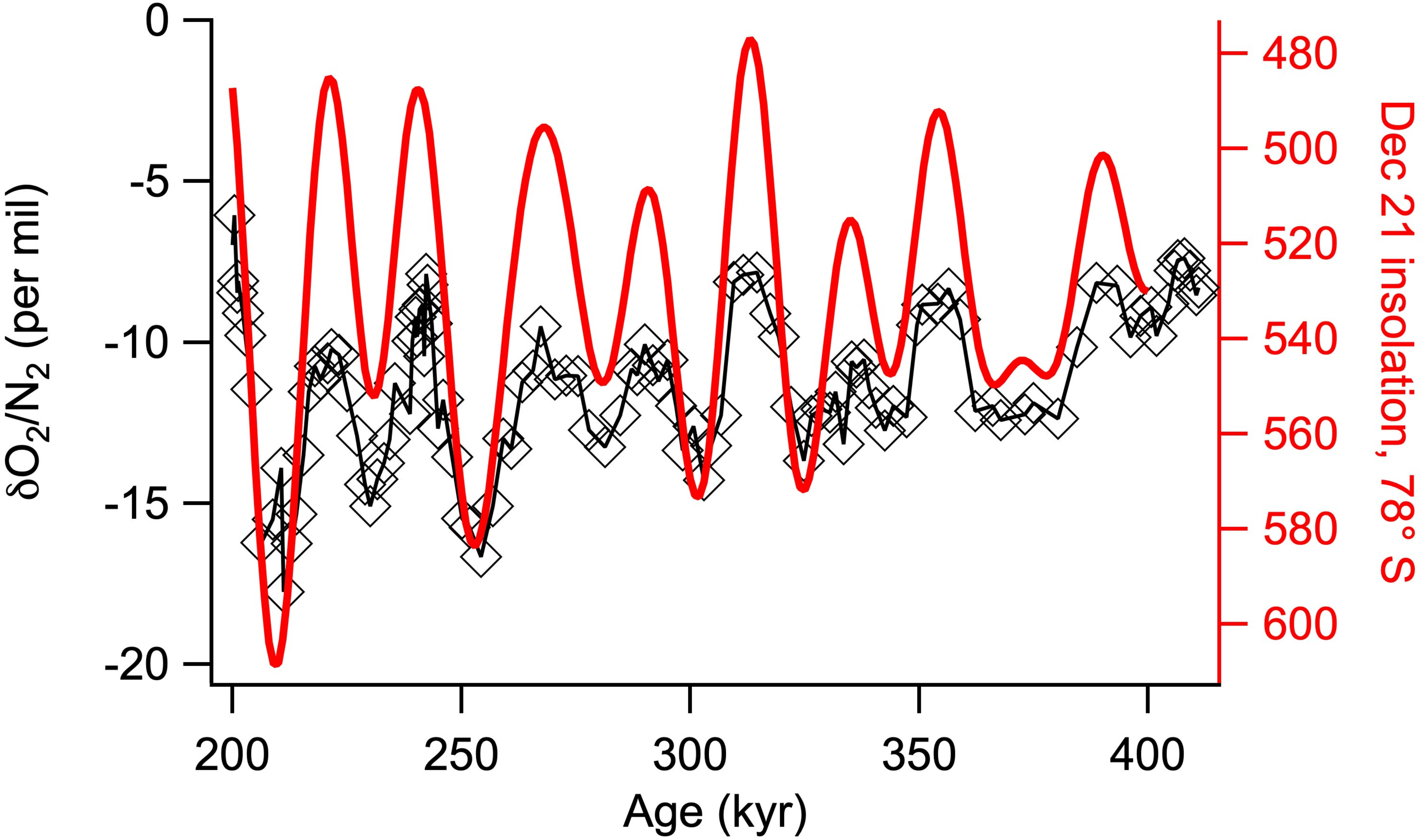


$$\delta = \left(\frac{R_{sample}}{R_{reference}} - 1\right) * 1000‰$$

$$\delta^{15}N = \left[\frac{\left(\frac{^{15}N}{^{14}N}\right)_{sample}}{\left(\frac{^{15}N}{^{14}N}\right)_{reference}} - 1\right] * 1000‰$$

Sowers et al, 1989

A strong insolation imprint is found in $\delta O_2/N_2$, presumably linked to bubble close-off



Modified from Suwa and Bender, 2008

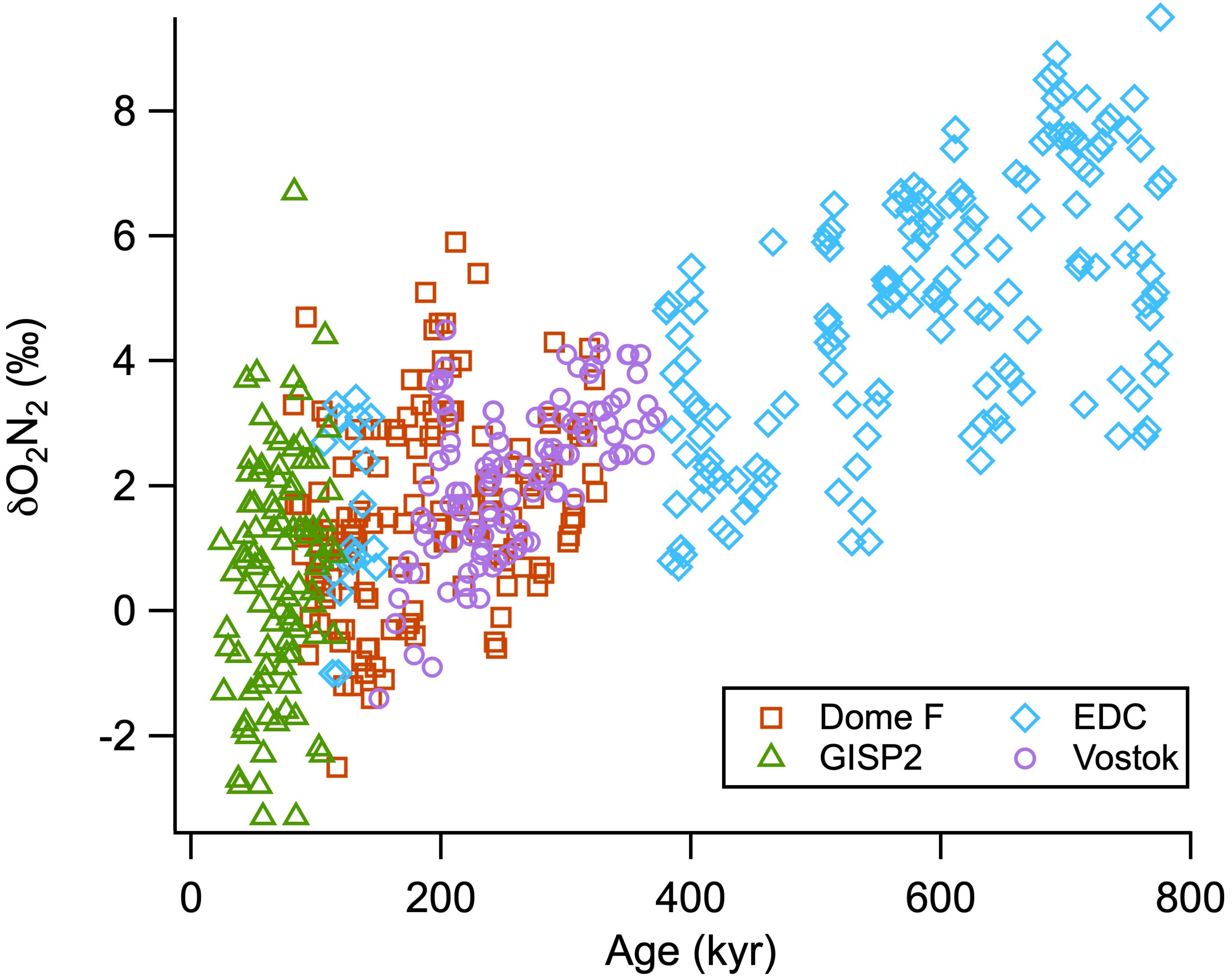
Two components in ice-core $\delta O_2/N_2$

"Random noise"

$$\delta O_2/N_{2,\,ice} = PO_2 + f_{insolation} + \varepsilon$$

"Primary" "Secondary"

After correcting for insolation, the primary signal in $\delta O_2/N_2$ (i.e. PO_2) can be retrieved



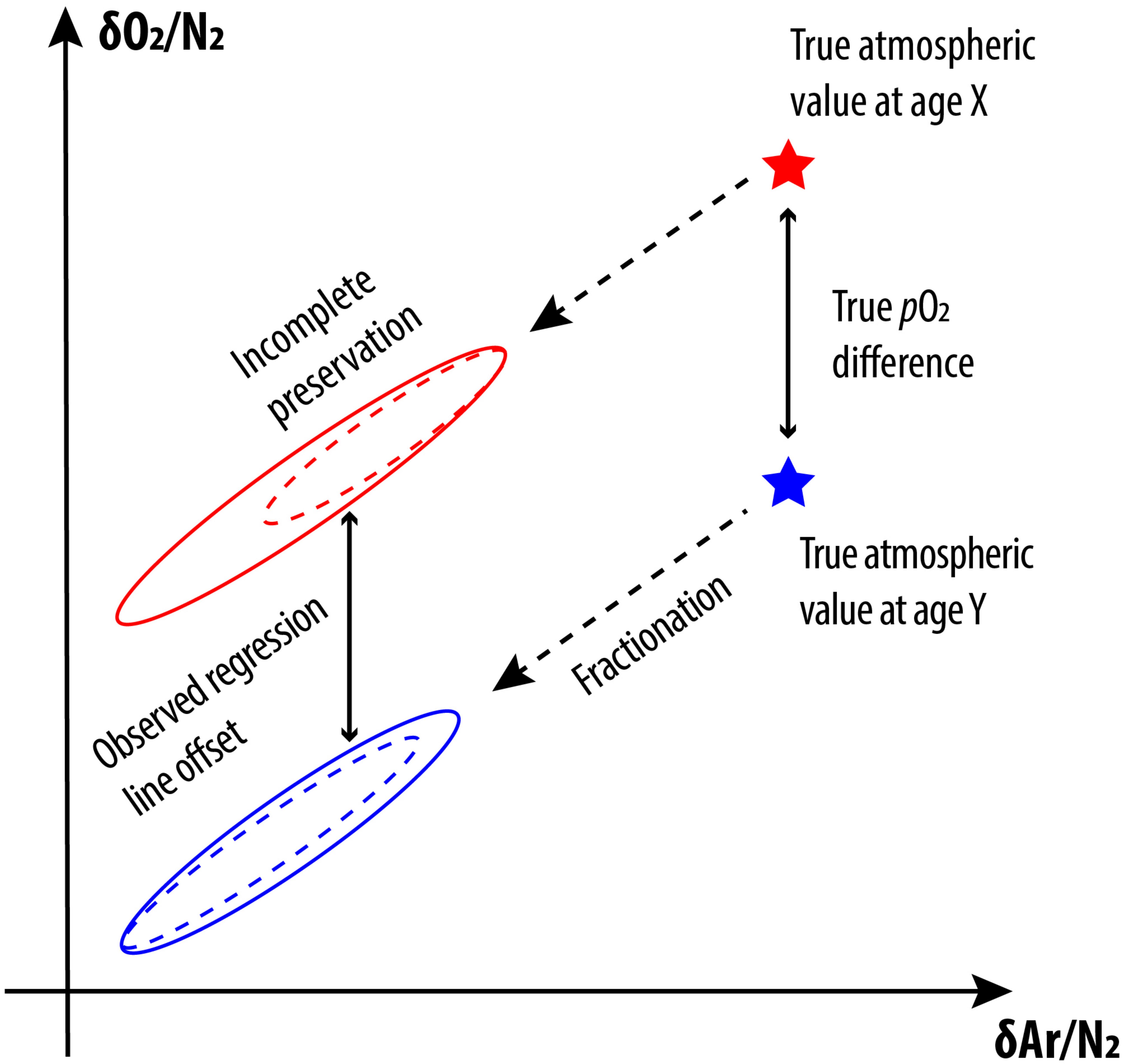
Rate of change:

-8.4±0.2 ‰/Myr (1σ; Stolper *et al* 2016)

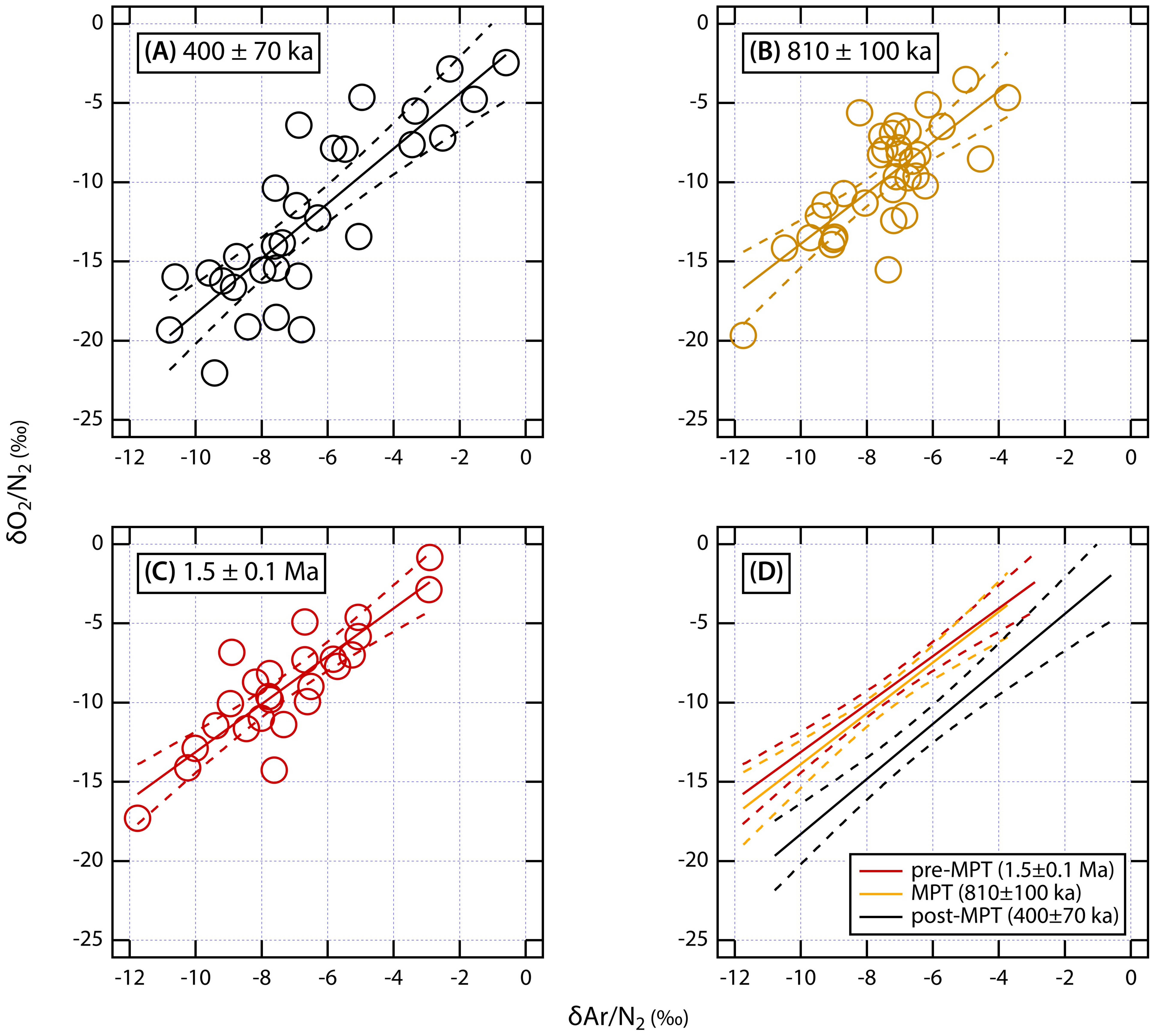
-7.0±0.6 ‰/Myr (1σ; Extier *et al* 2018)

Modified from Stolper et al, 2016

What if the precise chronology is unknown? $\delta Ar/N_2$ could be an insolation proxy



Million-year-old ice from Allan Hills provide snapshots of PO_2 in the Pleistocene



Key takeways:

The late-Pleistocene decline in $\delta O_2/N_2$ is observed in Allan Hills cores with a comparable rate of change.

Between 1.5 Ma and 950 ka, however, there is no statistically significant trend in blue ice $\delta O_2/N_2$.

Yan et al, 2021

Now let's return to the two components in ice-core $\delta O_2/N_2$

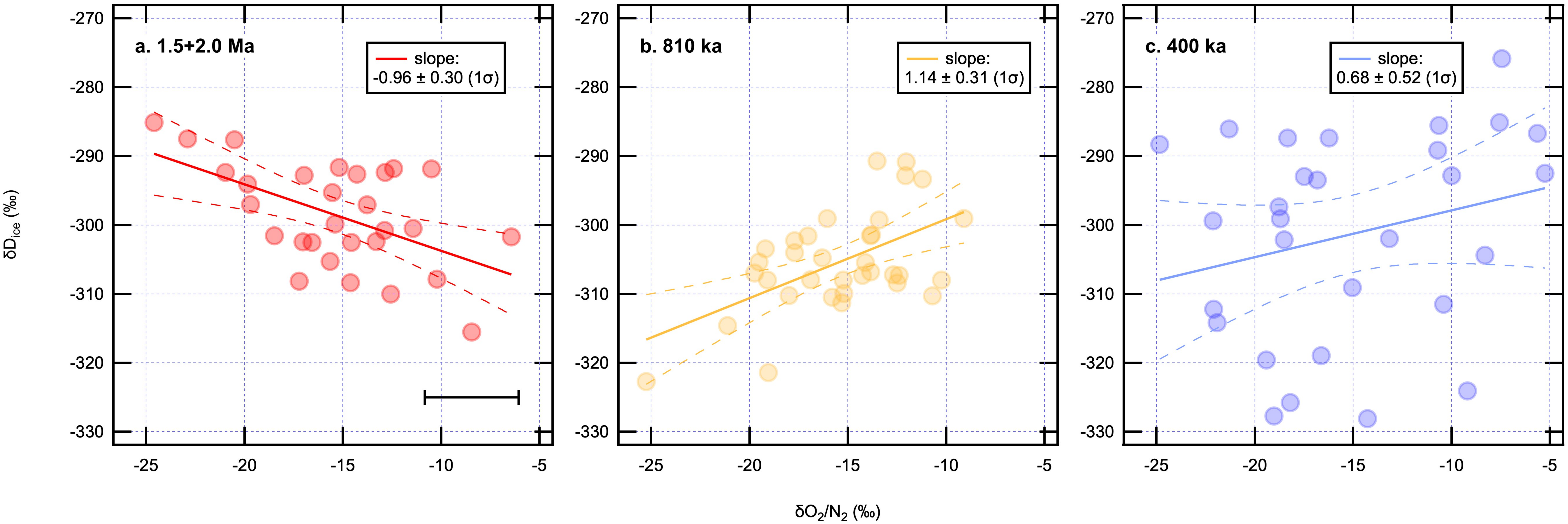
$$\delta O_2/N_{2,\,ice} = PO_2 + f_{insolation} + \varepsilon$$

"Secondary"

↓

Not many geologic archives record insolation!

$\delta O_2/N_2$ may be a proxy for local insolation at summer solstice



Implications:

Antarctic temperature (δD_{ice}) and summer insolation ($\delta O_2/N_2$) are positively correlated only in the Early Pleistocene, suggesting a **local** control on Antarctic climate.

Yan et al, in review