Variations in pyrogenic and biogenic CH_4 sources over the last 2 millennia

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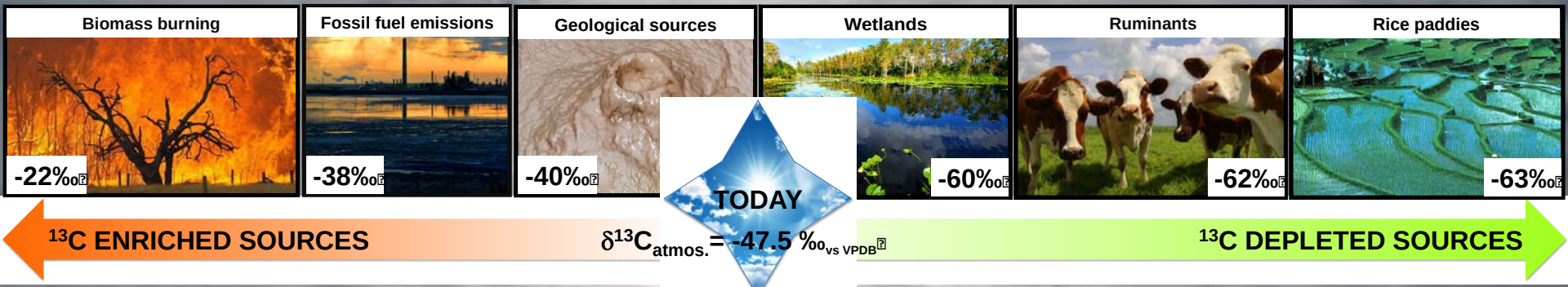
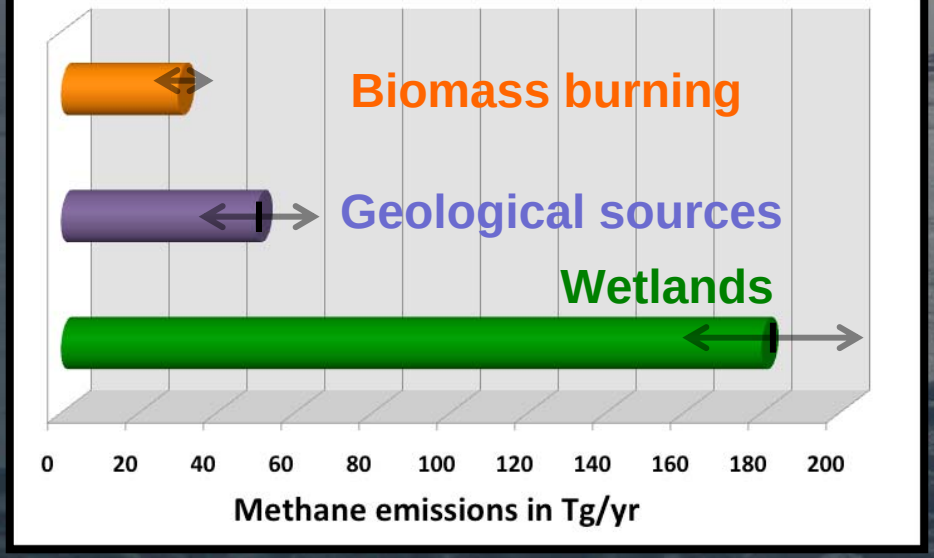
Acknowledgements to the NEEM SC & the gas consortium for providing samples!

Major CH_4 sources

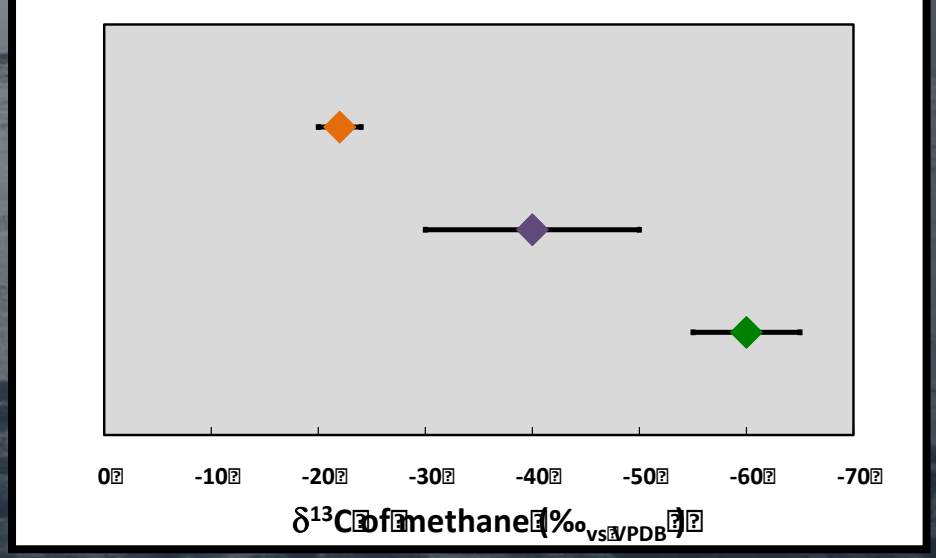


NATURAL SOURCES & UNCERTAINTIES

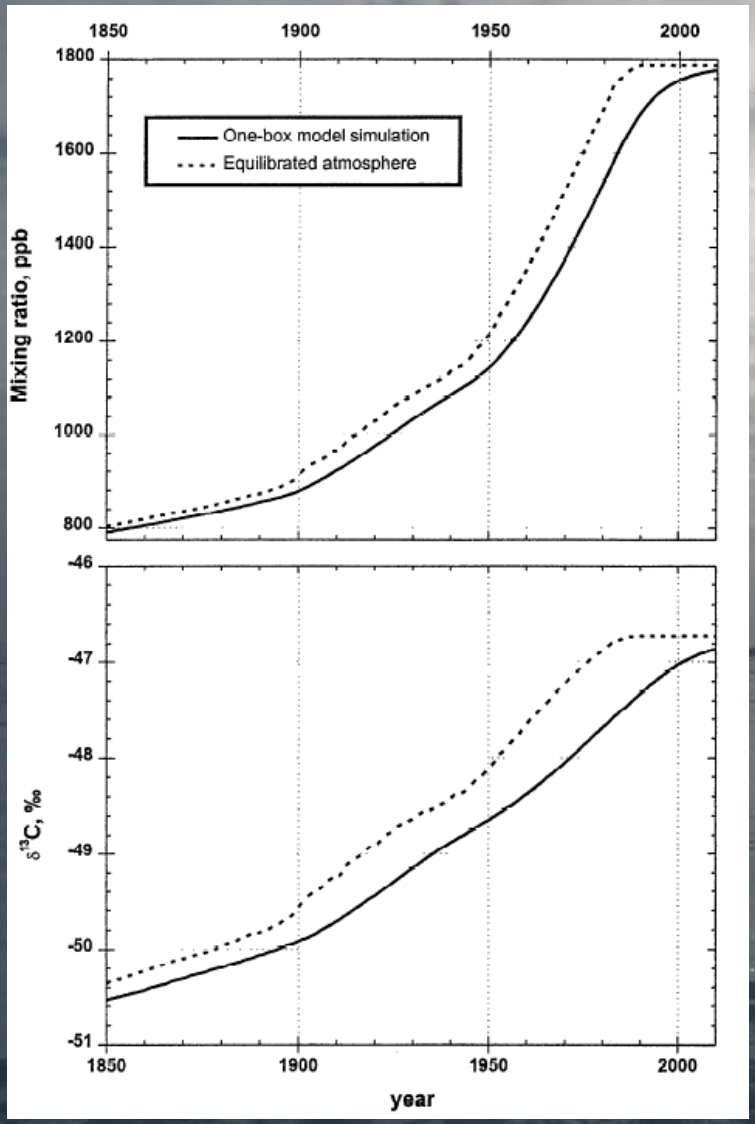
CH_4 source strength



Source isotope signatures



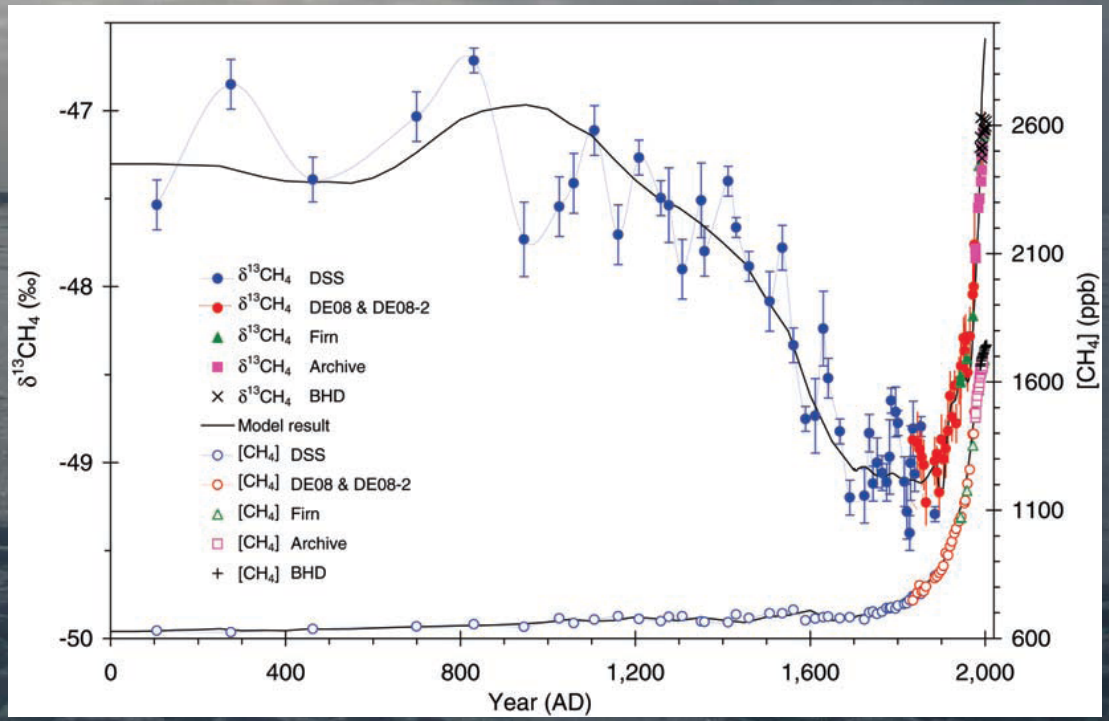
Methane isotopic composition – model and measurements



Lassey et al., 2000

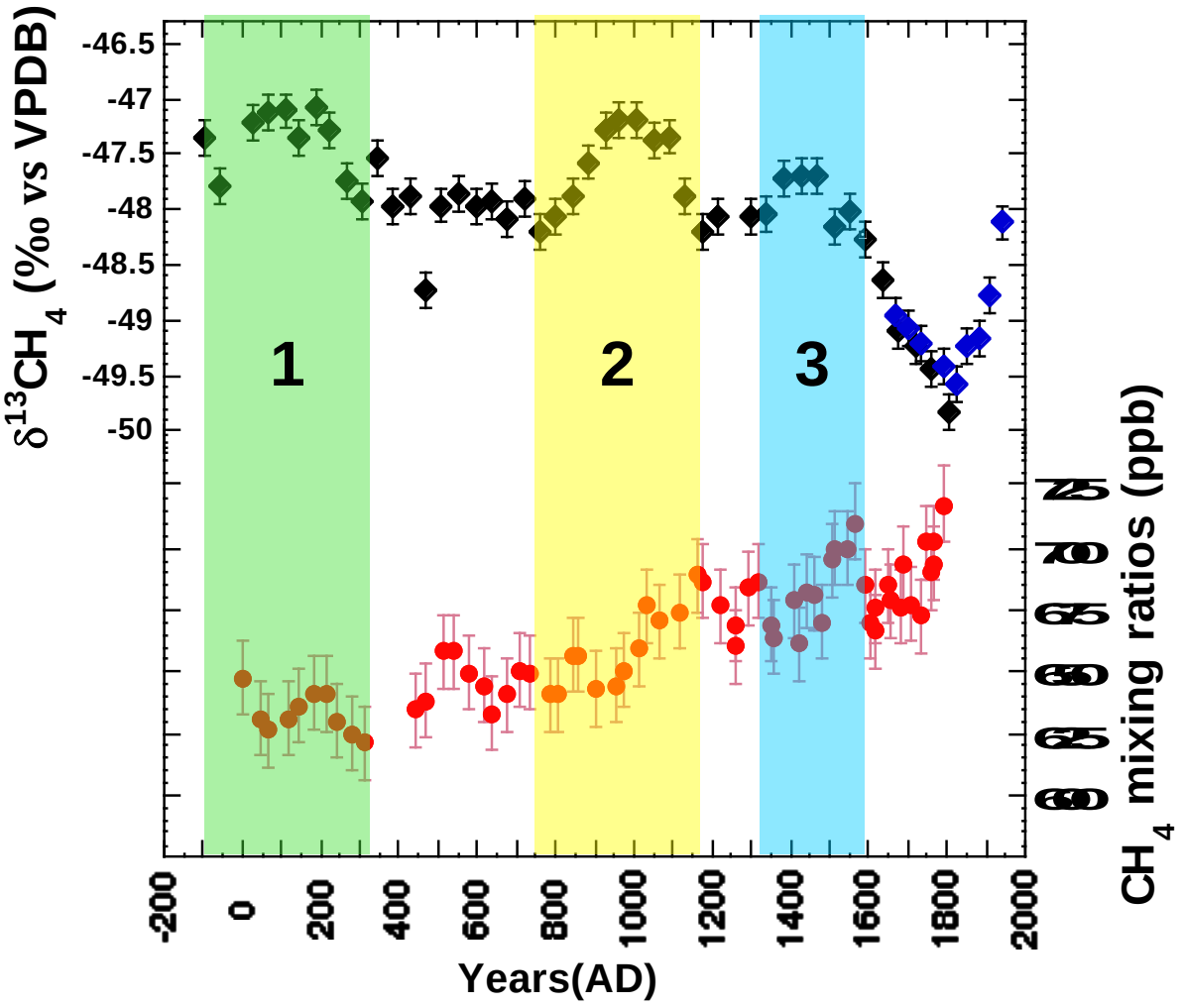
Unexpected Changes to the Global Methane Budget over the Past 2000 Years

D. F. Ferretti,[1,2*] J. B. Miller,[3] J. W. C. White,[1] D. M. Etheridge,[4] K. R. Lassey,[2] D. C. Lowe,[2] C. M. MacFarling Meure,[4] M. F. Dreier,[1] C. M. Trudinger,[4] T. D. van Ommen,[5] R. L. Langenfelds[4]



Centennial-scale variability

3 excursions in $\delta^{13}CH_4$ not represented clearly in the CH_4 mixing ratio records!



2-box model

INPUT

OUTPUT

SOURCES

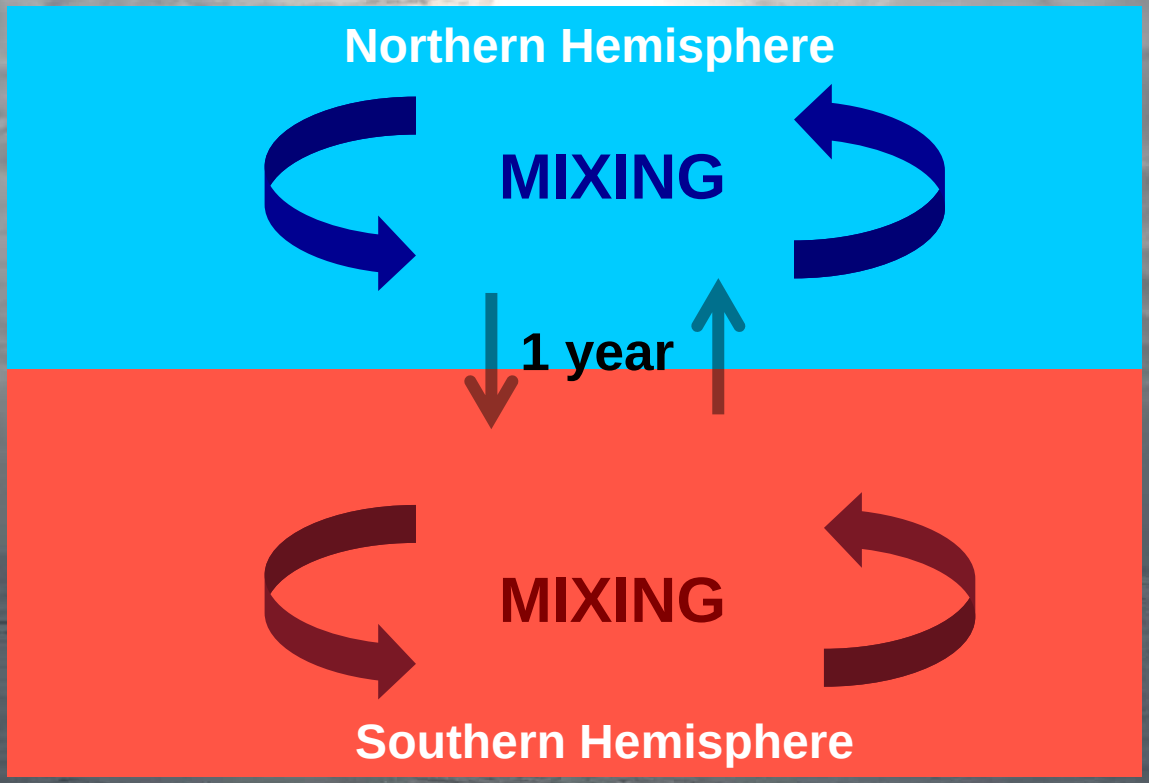
Strength(Tg/yr)

Isotope signatures

SINKS

Lifetime ($1/\tau$)

Fractionation factor (α)



Atmospheric Scenarios

NH CH_4

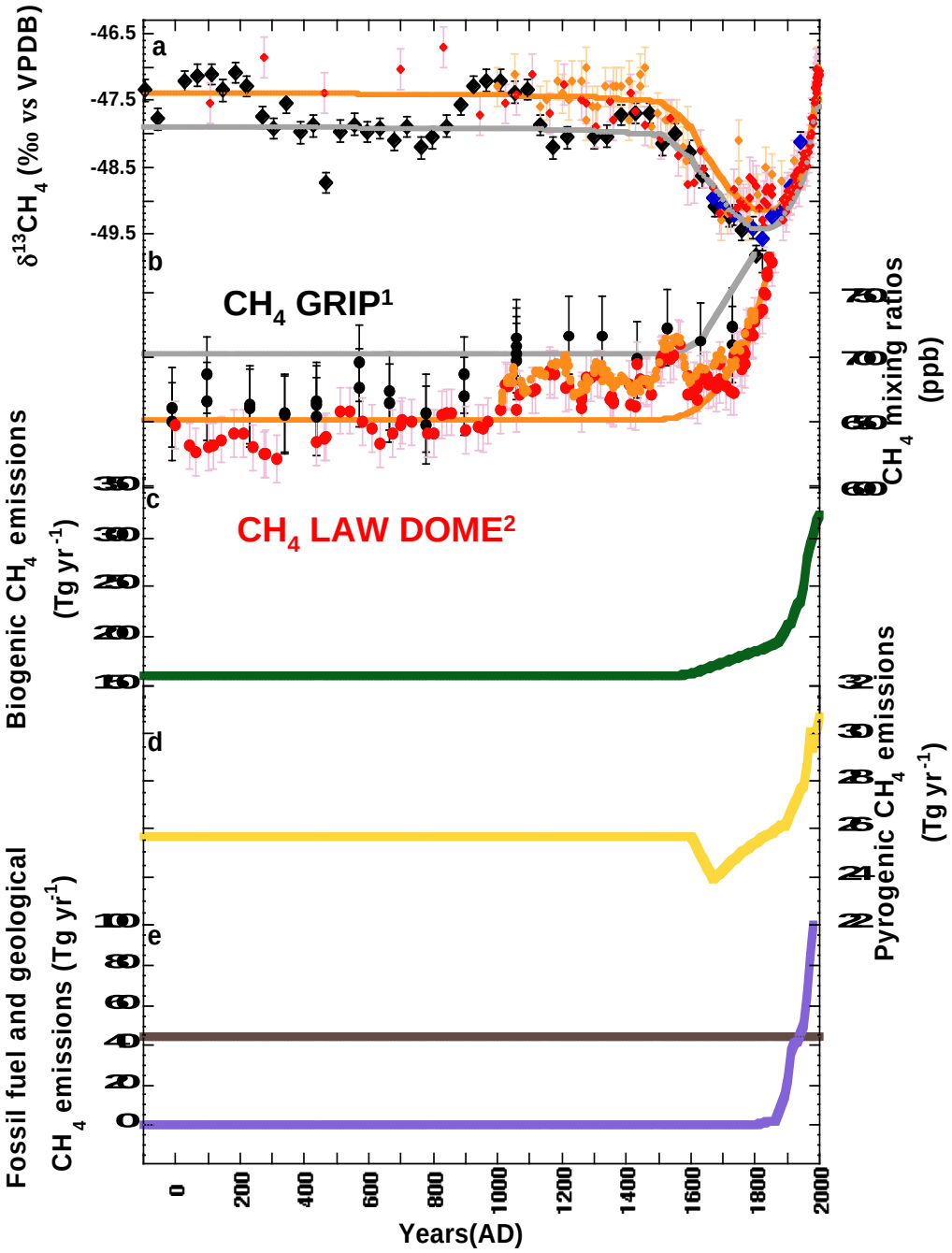
NH $\delta^{13}C$

SH CH_4

SH $\delta^{13}C$

Goal: detect which sources are the most likely to cause the observed changes!

Base scenario



Biogenic (-60‰)
Agriculture, Natural
(Wetlands,Termites,Oceans,Wild animals)

Pyrogenic(-22‰)
Biomass burning and biofuel

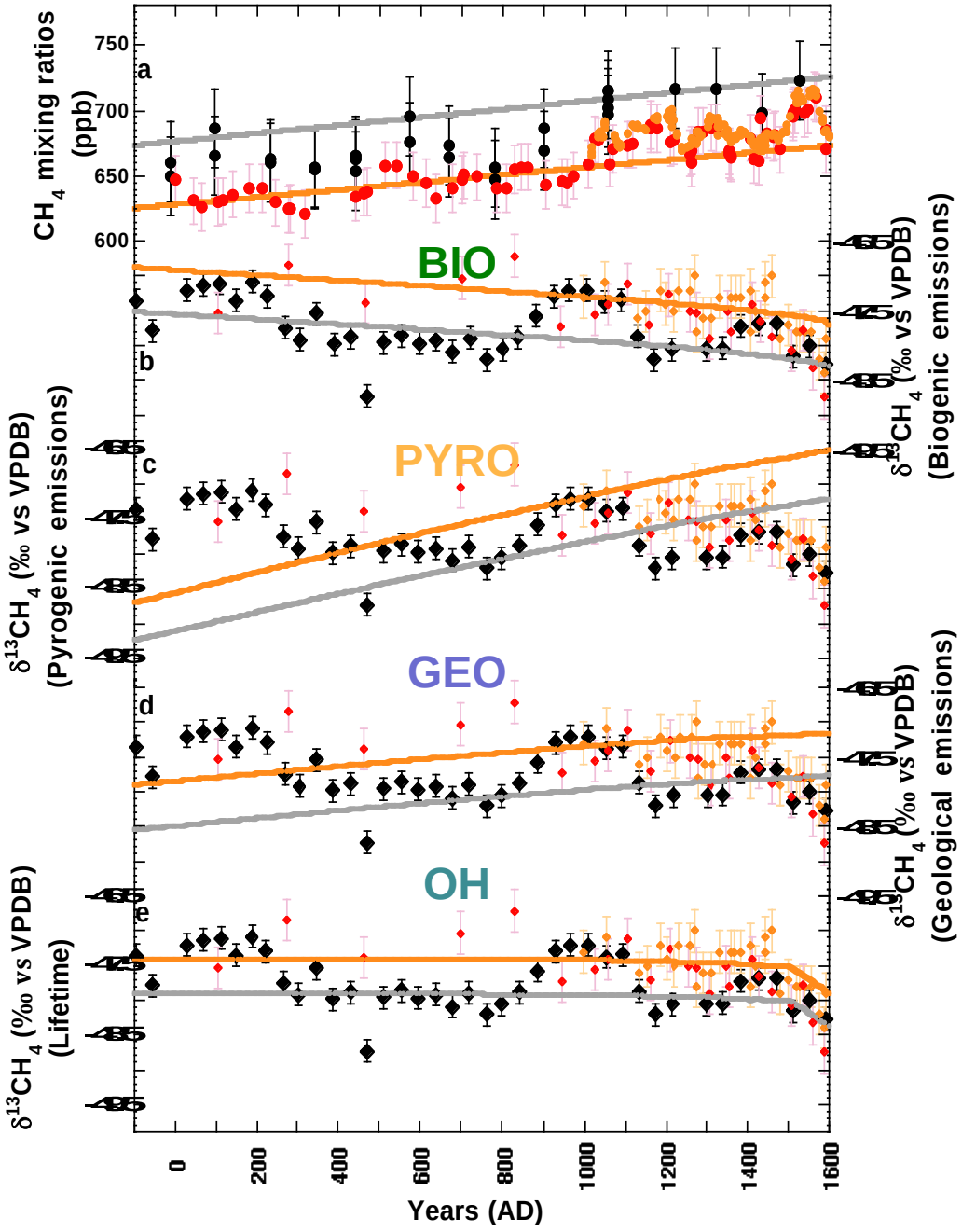
Geological (-40‰)
Mud volcanoes, macro and micro seepages

Fossil Fuel (-38‰)
Fossil Fuel consumption, production and industrial production

[1] Chappellaz et al., 1997 & Blunier et al., 1995.
[2] MacFarling Meure et al.,2006.

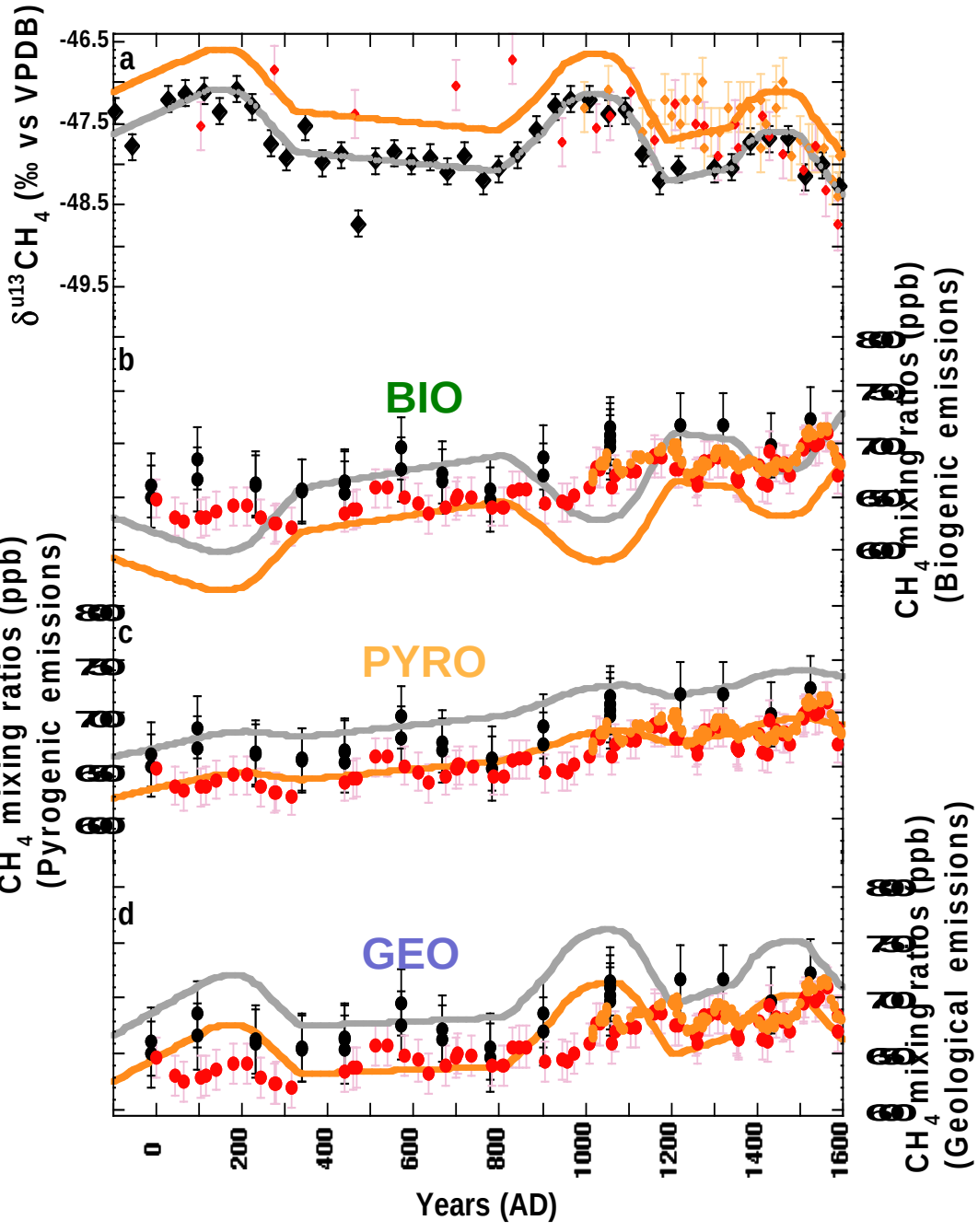
Single-source scenarios

1) Long-term CH_4 trend



=> A rise in biogenic sources can explain both CH_4 and $\delta^{13}C$ records!

CHANGES in SOURCES

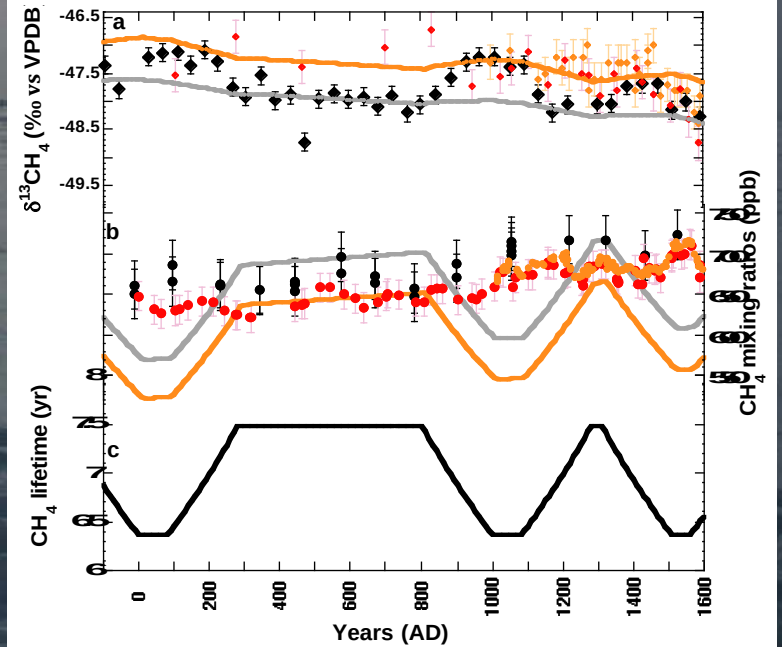


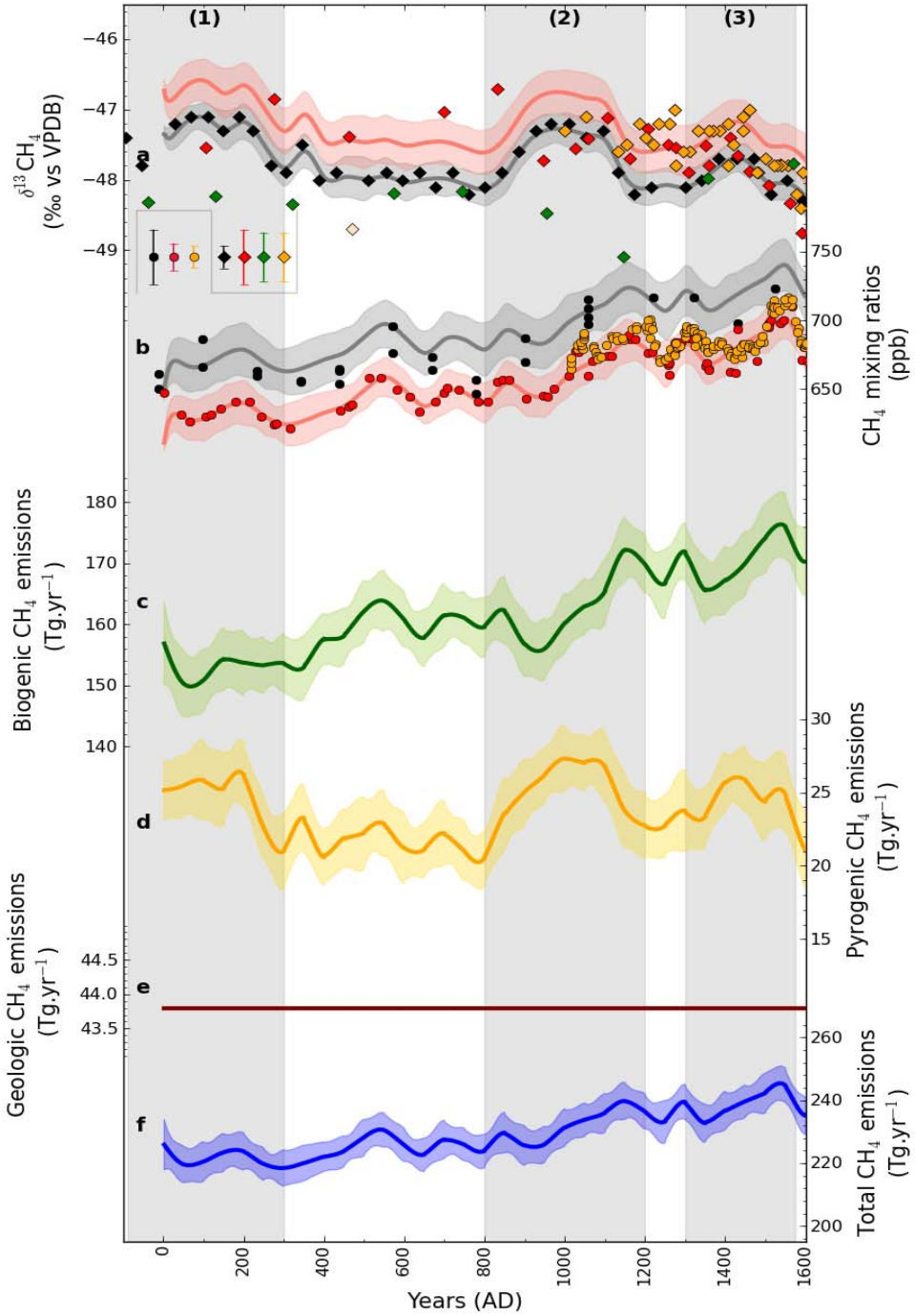
Single-source scenarios

2) Centennial scale isotope variability

=> Pyrogenic sources require smallest CH_4 changes

CHANGES in CH_4 lifetime



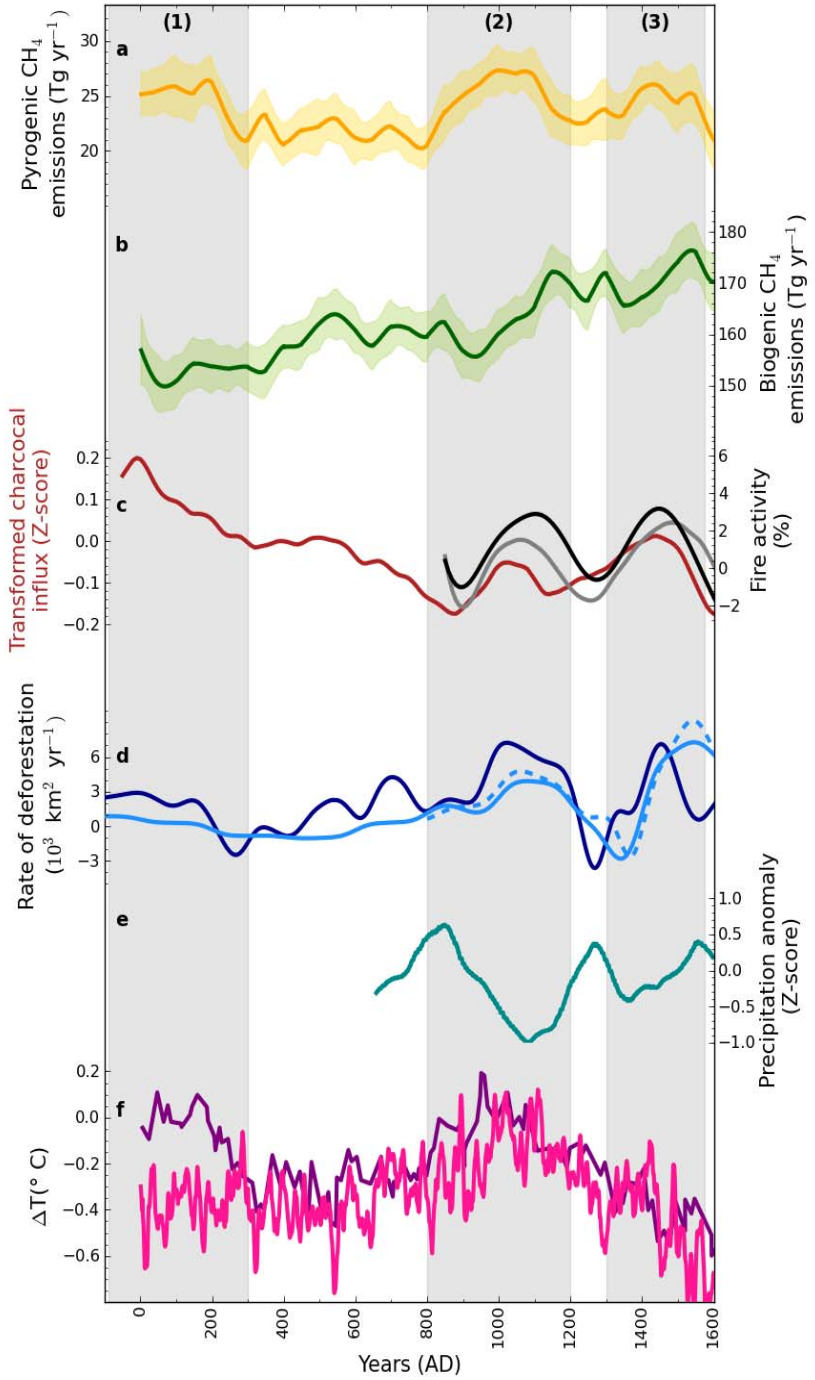


Mathematical source reconstruction

=> long-term increase of biogenic sources

=> Centennial-scale variations in pyrogenic and biogenic sources

Comparison to indicators of natural and anthropogenic variability



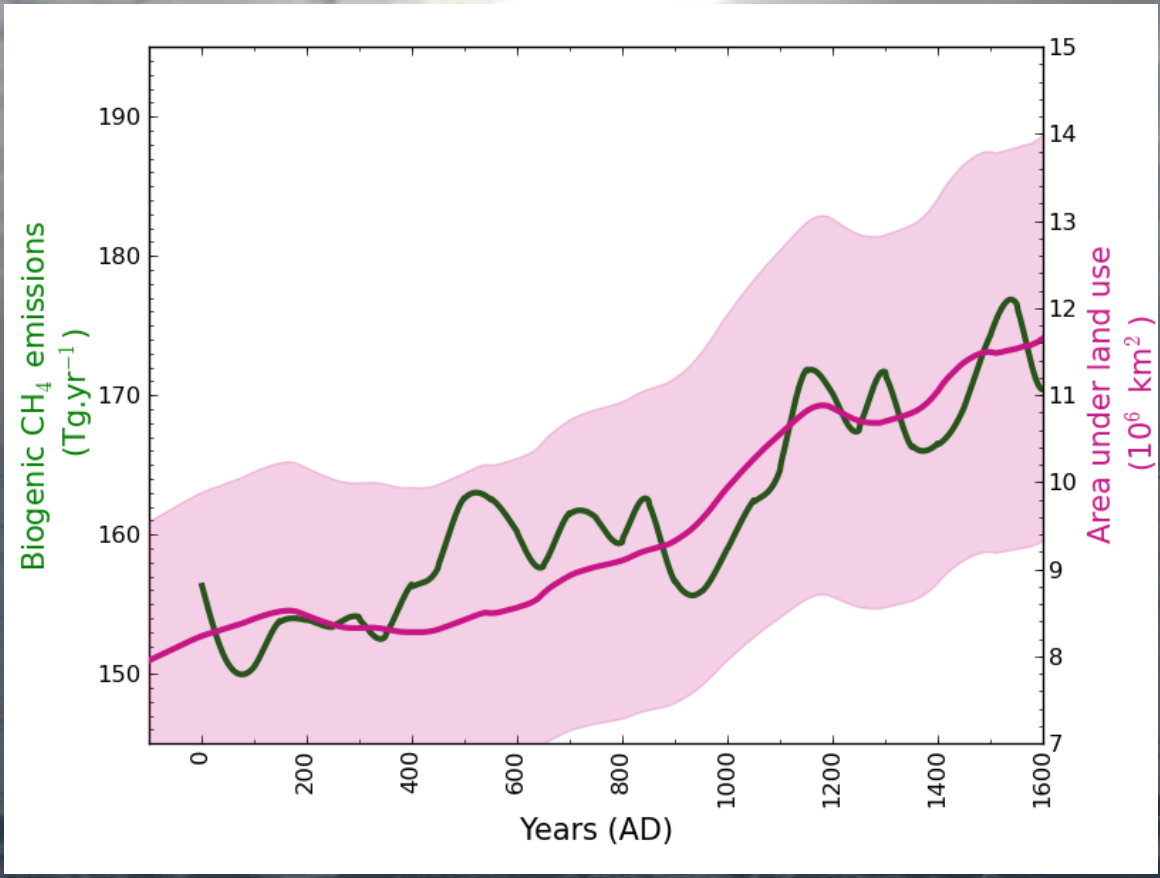
Correlation with the NH Charcoal Index (Marlon et al., 2008)

Rate of land use change shows fast land clearing during $\delta^{13}C$ excursions (Kaplan et al., 2010)

Precipitation anomalies during $\delta^{13}C$ excursions! (Helama et al., 2009)

Varying correlations with NH (NEXT) temperature reconstructions
Moberg et al., 2005, Ljungquist et al., 2011

Biogenic emissions and area under human land use



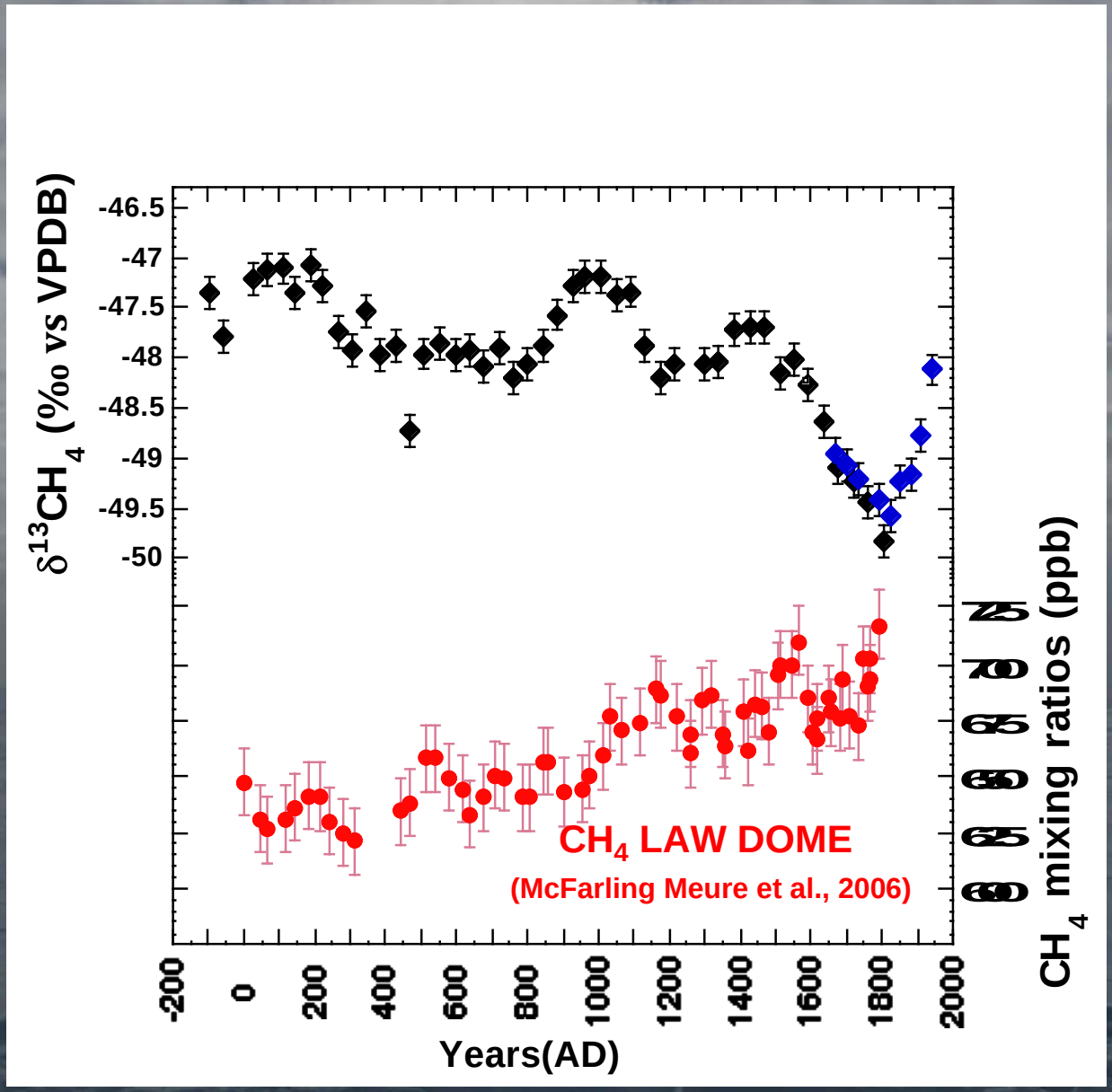
Conclusions

- Pronounced centennial-scale $\delta^{13}C(CH_4)$ variability in pre-industrial period
- Highly likely caused by changes in pyrogenic sources
- Correlation with NH charcoal index and anthropogenic land use rate of change
- Long term CH_4 rise due to biogenic sources, and correlates well with land use data
- Both natural variability and anthropogenic activities may have influenced the CH_4 budget in the pre-industrial period

Outline

- Introduction: CH_4 and its isotopic composition
- The NEEM (and EUROCORE) $^{13}CH_4$ ($\delta^{13}C$) record
- Box modeling (single source scenarios)
- Box modeling (source reconstruction)
- Comparison to historical climate and land use records
- Conclusions

The NEEM and EUROCORE dataset



Comparison to other records