Climate change drivers modify N2O fluxes via changes in microbial populations in a grassland experiment

Amélie Cantarel, Juliette Bloor, Thomas Pommier, Nadine Guillaumaud, Jean-François J.-F. Soussana

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Climate change and N_2O fluxes

- Current climate models predict (IPCC 2001, 2007)
  - ↑ global air temperatures
  - Changes in regional patterns of rainfall
  - ↑ atmospheric greenhouse gases concentrations (as carbon dioxide, CO_2)

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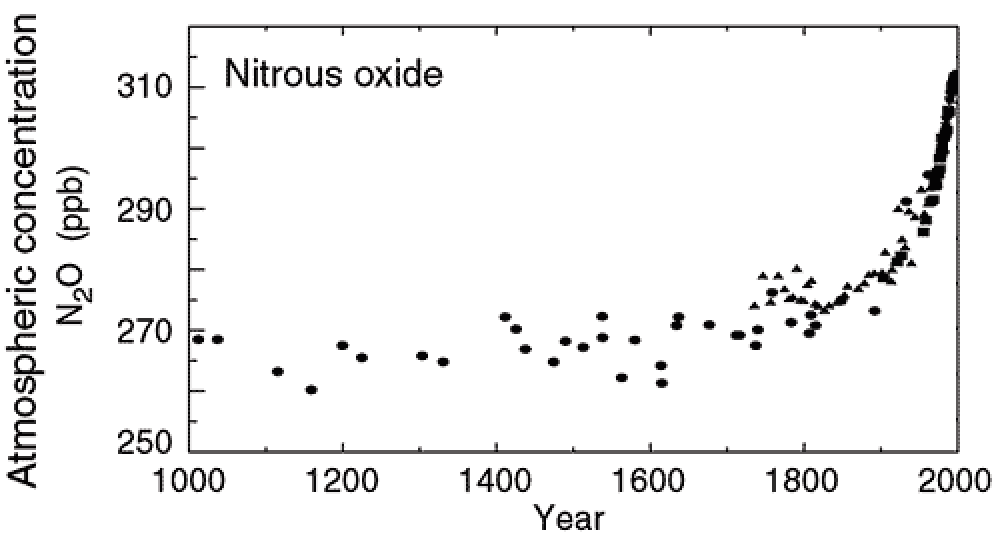
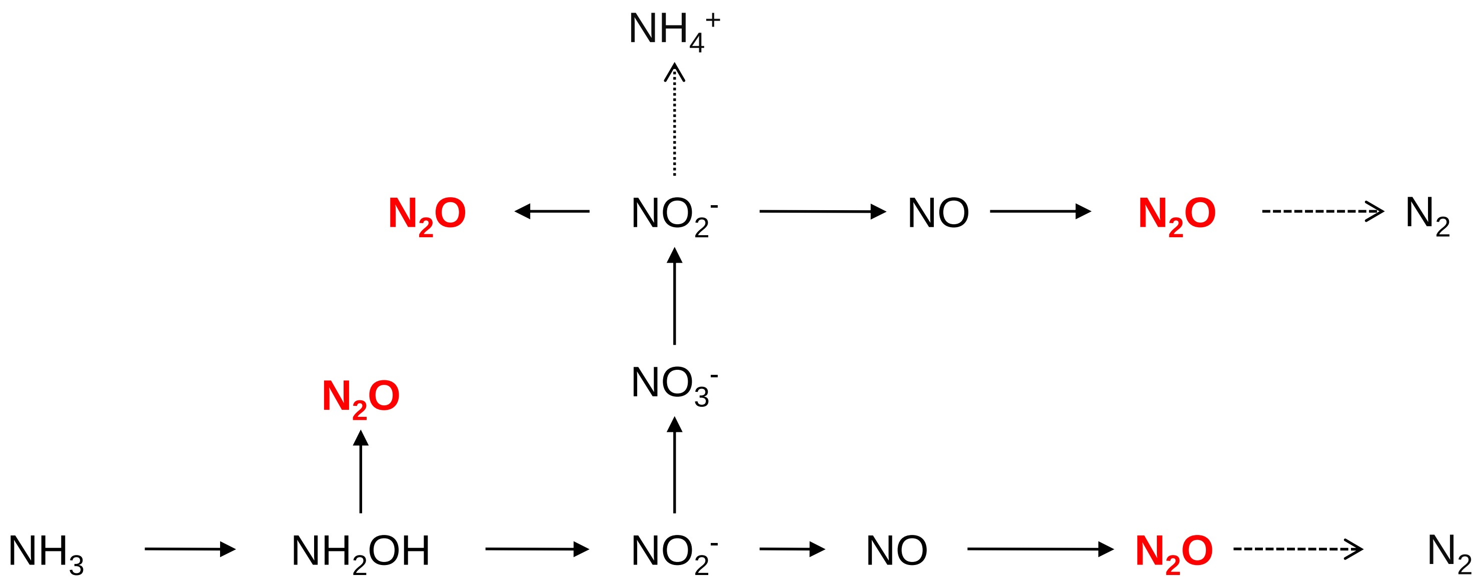
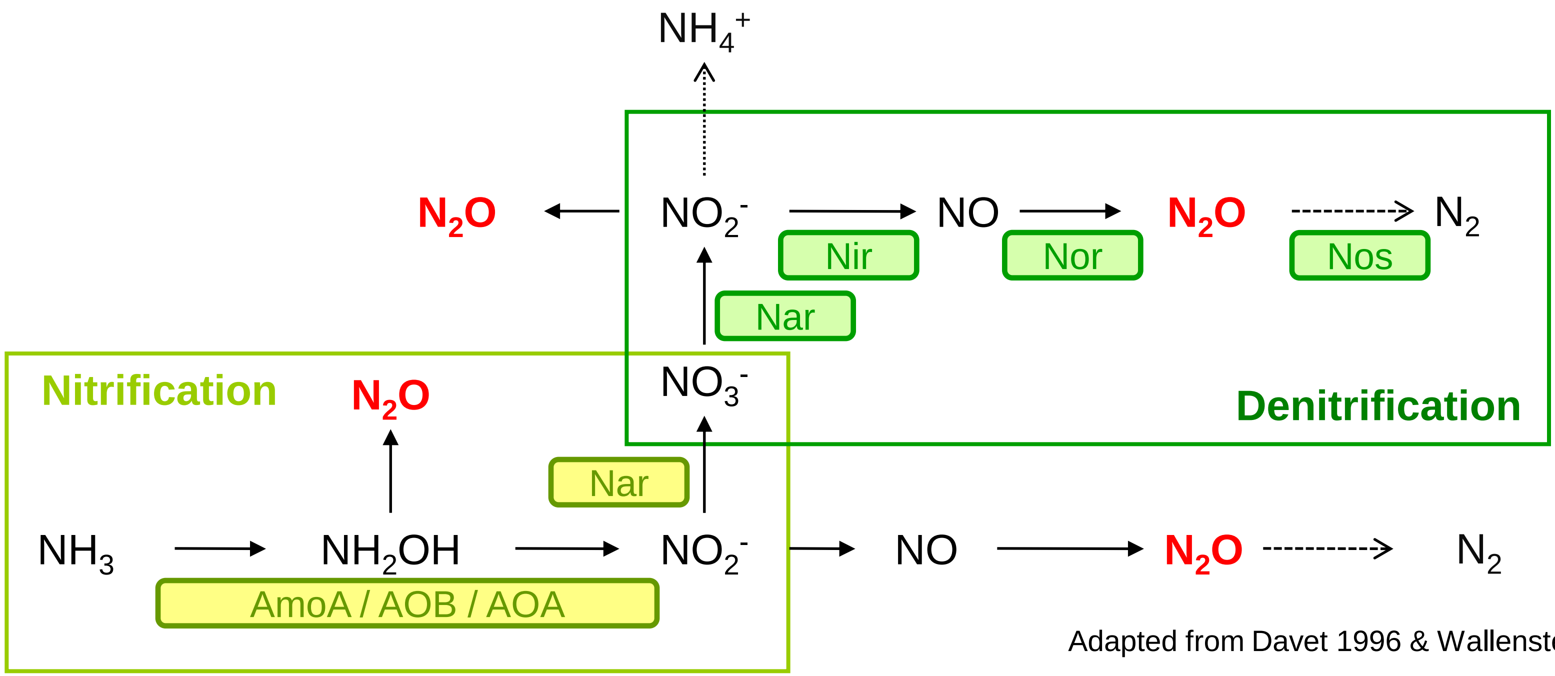


- N_2O trace gas
  - Third greenhouse gazes after carbon dioxide and methane
  - Strong global warming potential (~ 320 > CO_2)
  - Depletion of the stratospheric ozone layer (Ravishankara *et al.* 2009)

N_2O production and microbial processes

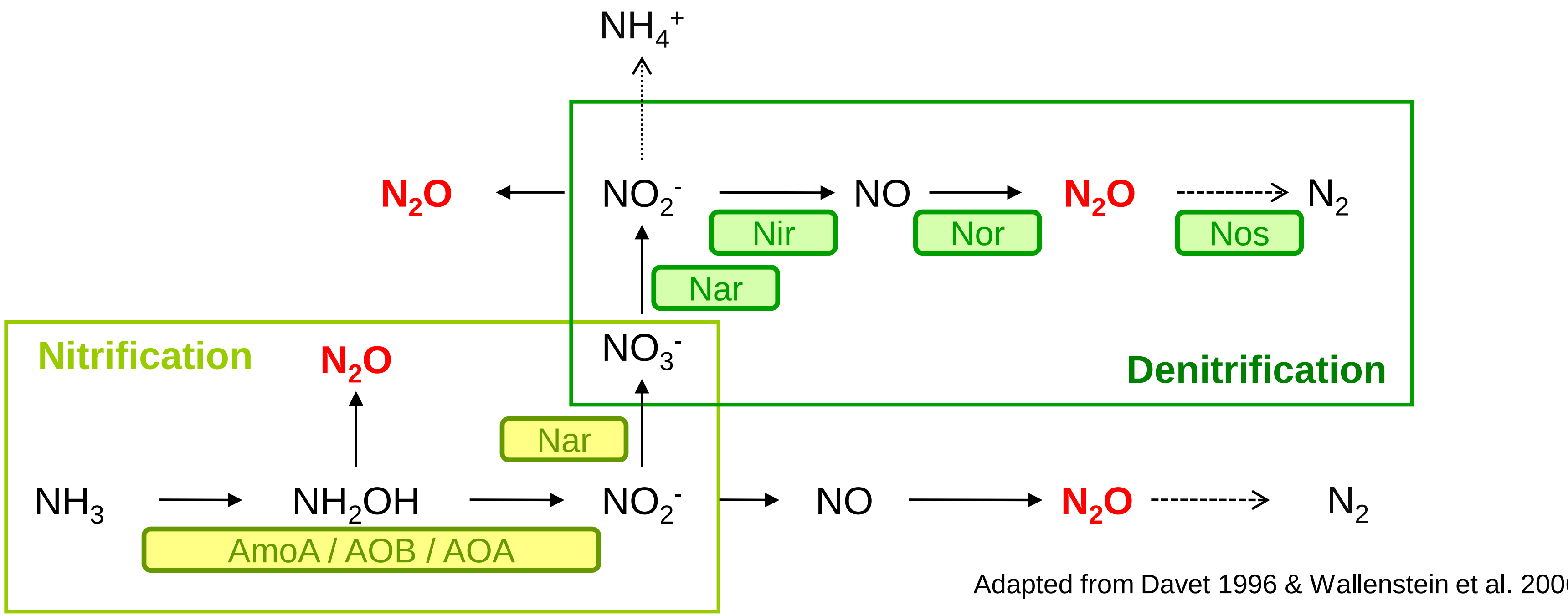


N_2O production and microbial processes



Adapted from Davet 1996 & Wallenstein et al. 2006

N_2O production and microbial processes



- Changes in nitrification and denitrification may be linked to changes in:
  - Microbial population size
  - Microbial community structure

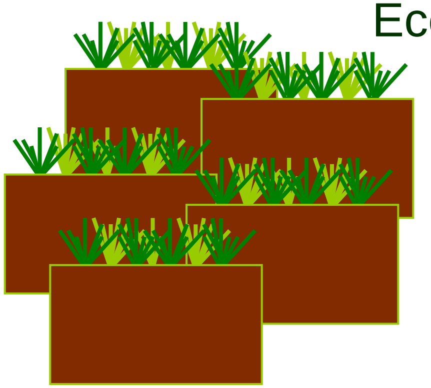
Study aims

- What are the effects of climate change drivers (elevated temperature, drought and elevated atmospheric CO_2 concentrations) on nitrous oxide (N_2O) fluxes in grasslands?
- How do climate change drivers affect the microbial processes linked to N_2O fluxes?

Experimental design

THEIX(850m)

Ecosystem: Acid grassland, no fertilizers



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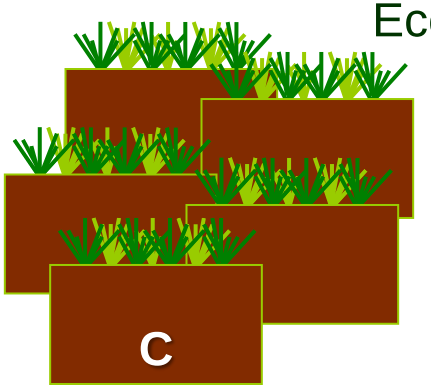

Control

Experimental design

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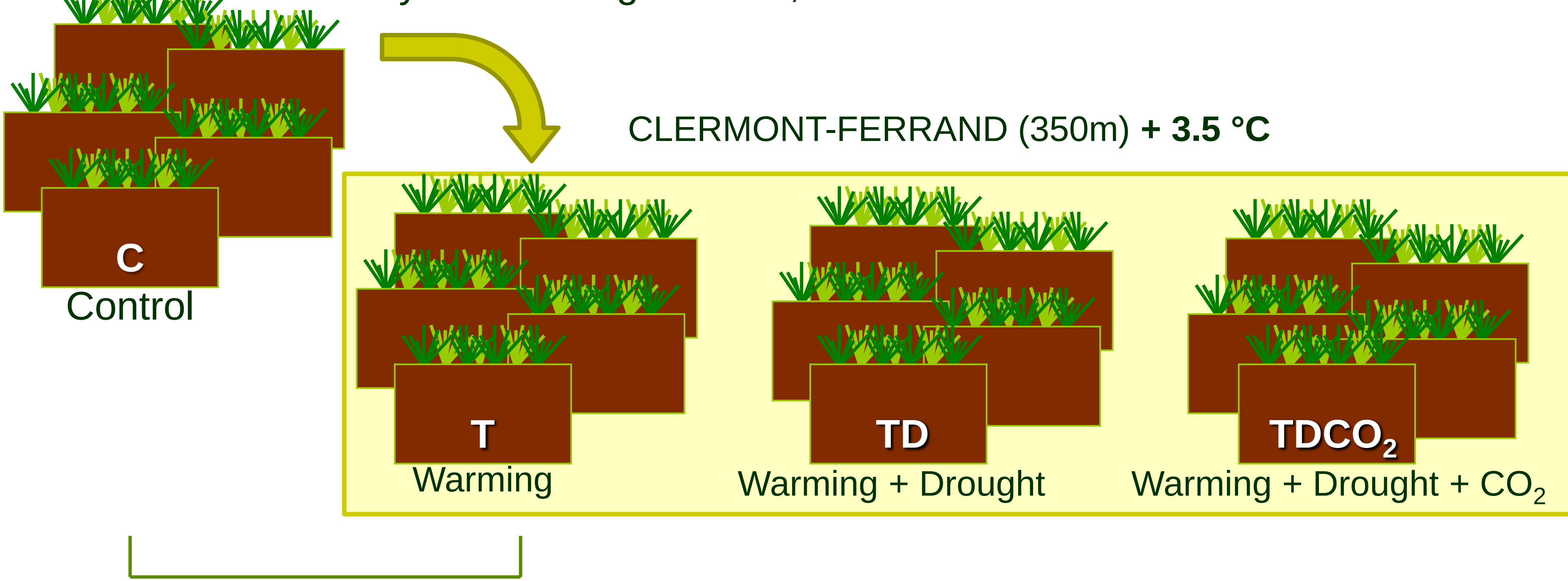

Temperature effect

C vs T

Transplantation along an altitudinal gradient

Same watering regime

Experimental design

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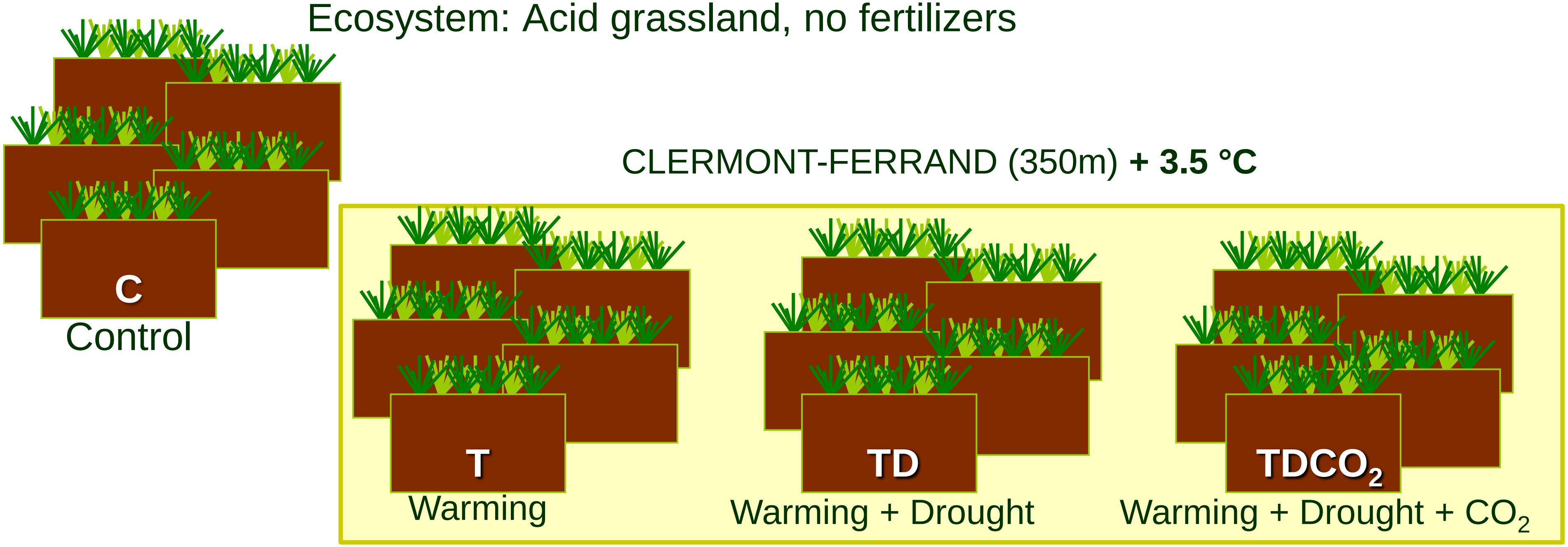

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Drought effect (-20% rainfall)

T vs TD

Using rainscreens during June, July and August

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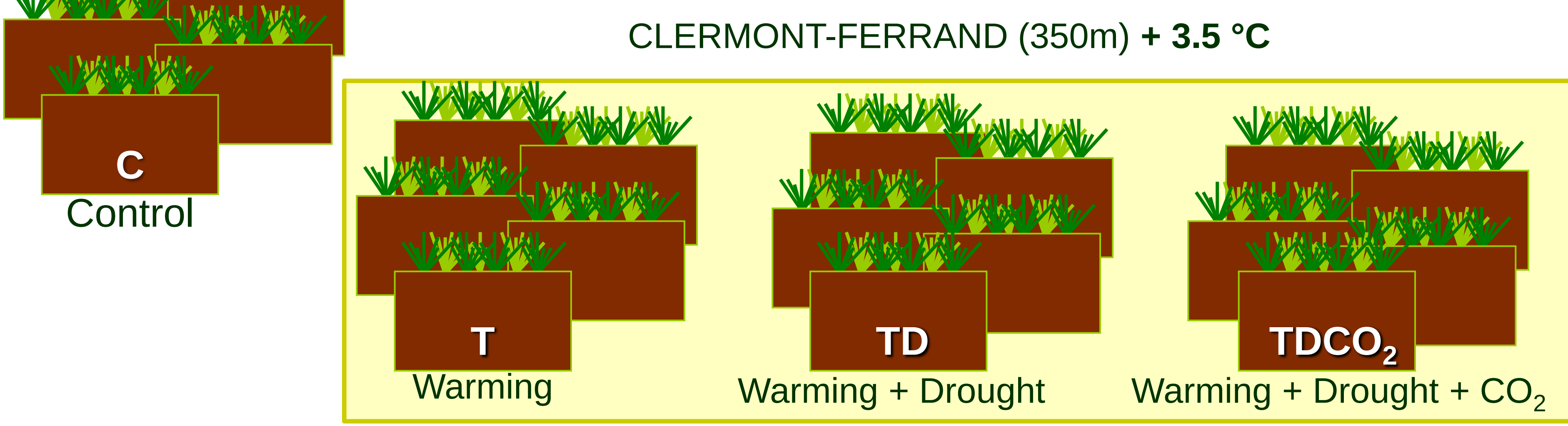
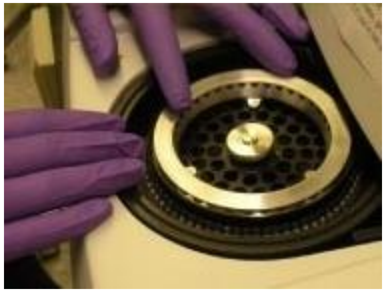


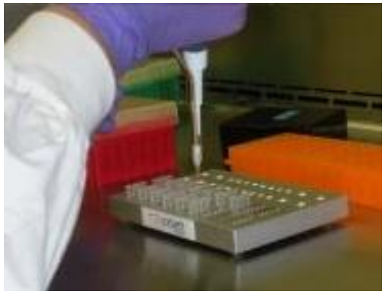
Temperature effect	Drought effect (-20% rainfall)	Elevation of atmospheric $[CO_2]$ + 200ppm ($[CO_2]$ = 600 ppm)
C vs T	T vs TD	TD vs $TDCO_2$
Transplantation along an altitudinal gradient Same watering regime	Using rainscreens during June, July and August	Using Mini-FACE technology IPCC scenario for 2080 for Central France

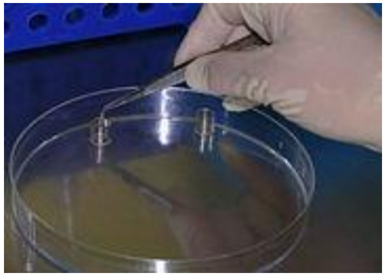
N_2O fluxes and soil sampling

- Nitrous oxide (N_2O) flux measurements
  - 4 dates of N_2O flux measurements in 2009
    - May, July, September and November
    - N_2O measurements using closed static chambers and a photoacoustic gas analyzer (INNOVA)
- Soil sampling following each flux measurement
  - 3 soil cores (Ø 1.5 cm) from 0-10 cm layer in each monolith
    - Sieved at 4 mm

Microbial analyses

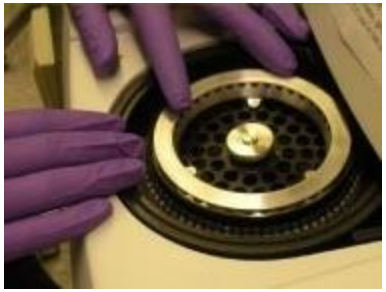


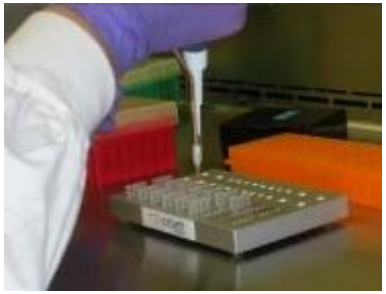


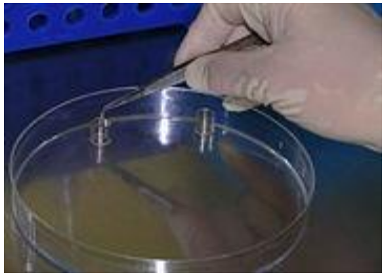


- Nitrifying and denitrifying activities
  - Potential nitrification measured in optimal conditions and analysed by ion chromatography
  - Potential N_2O emissions by denitrification measured by gas chromatography

Microbial analyses







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  - Denitrifying population : nirK

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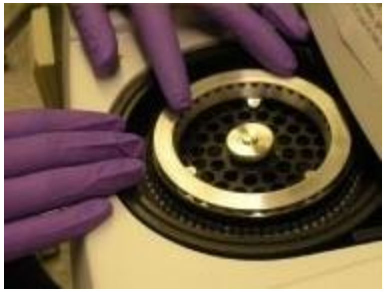

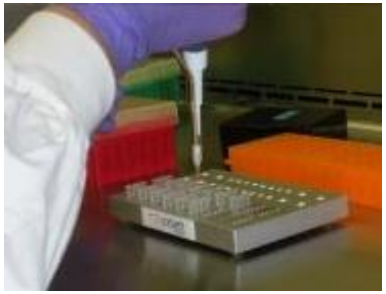

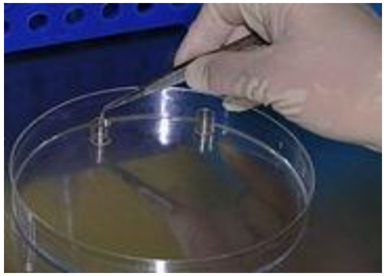

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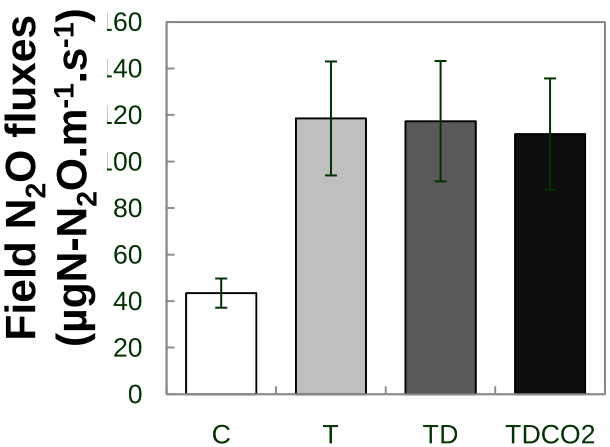
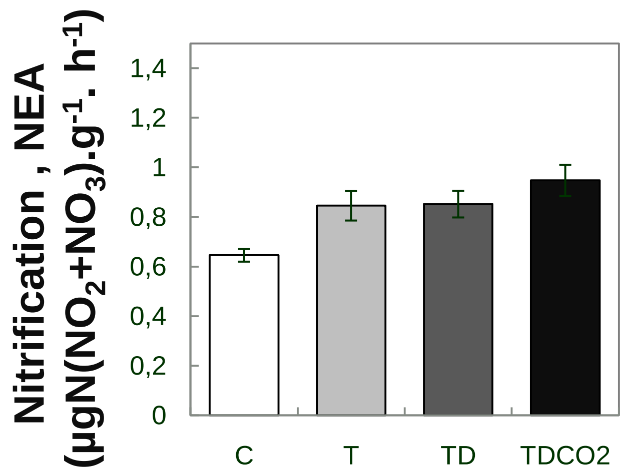
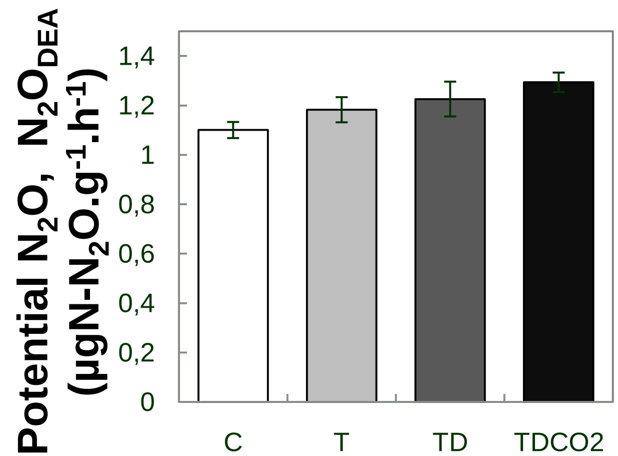
- Characterization of denitrifying communities (*nir*K) by cloning-sequencing

N_2O fluxes and microbial activities







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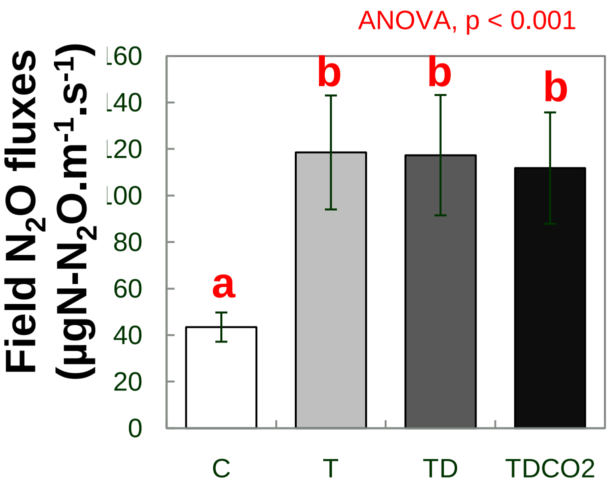
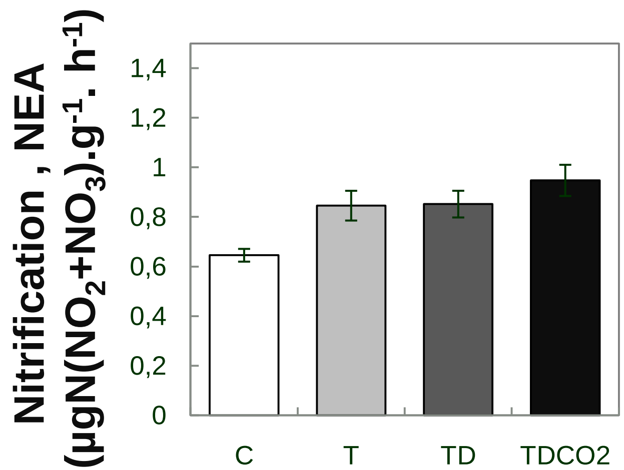
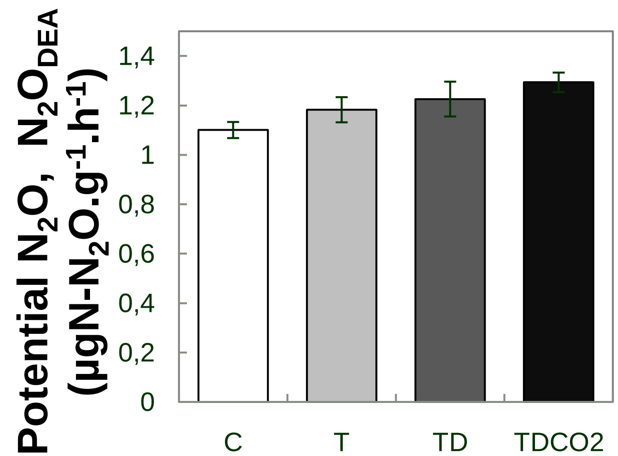
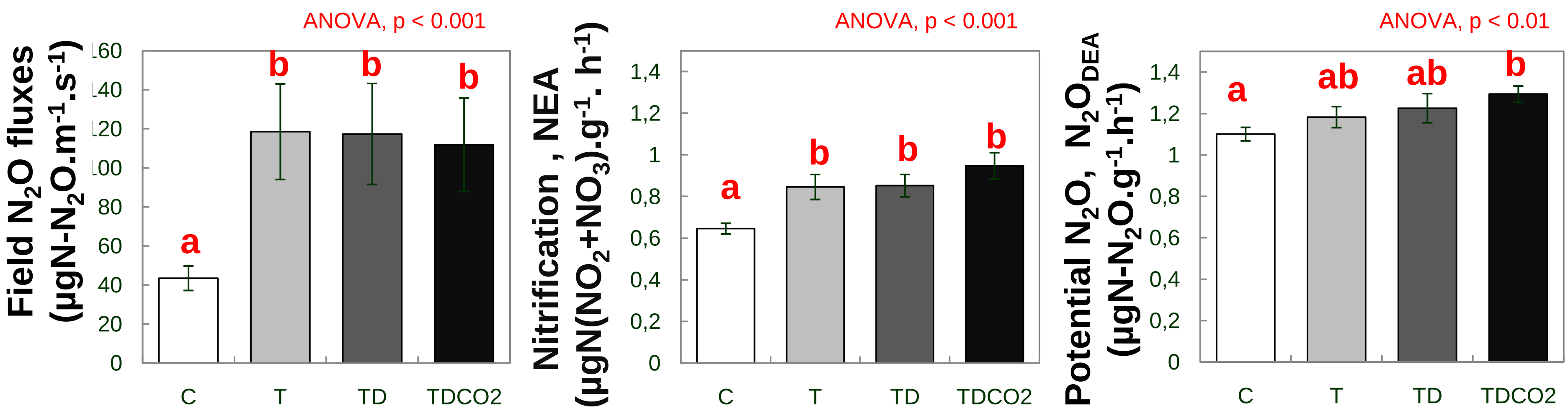






- Positive effect of air warming on N_2O emissions (C *vs* T)

N_2O fluxes and microbial activities



- Positive effect of air warming on N_2O emissions (C *vs* T)

- Effects of climate change on nitrification and denitrification activities mirrored changes in N_2O fluxes

N_2O fluxes and microbial populations size

- Warming effects on microbial activities may be related to changes in microbial population size or community structure

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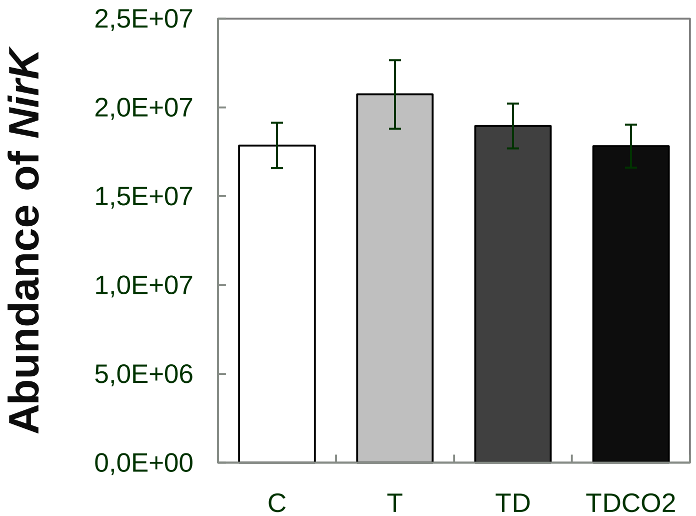

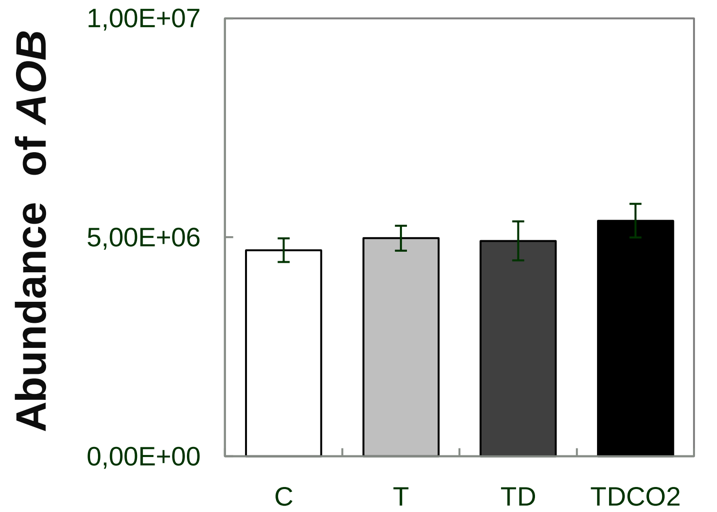

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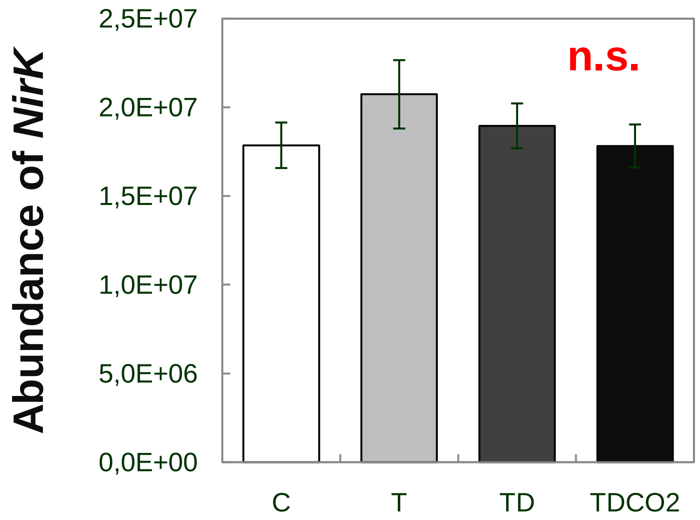
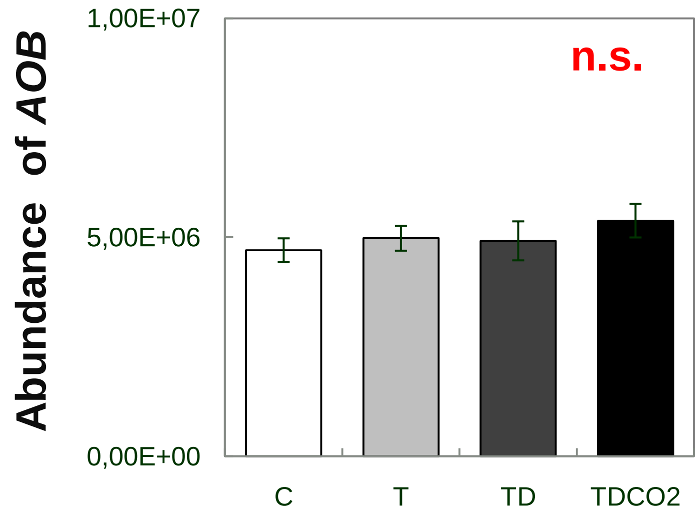
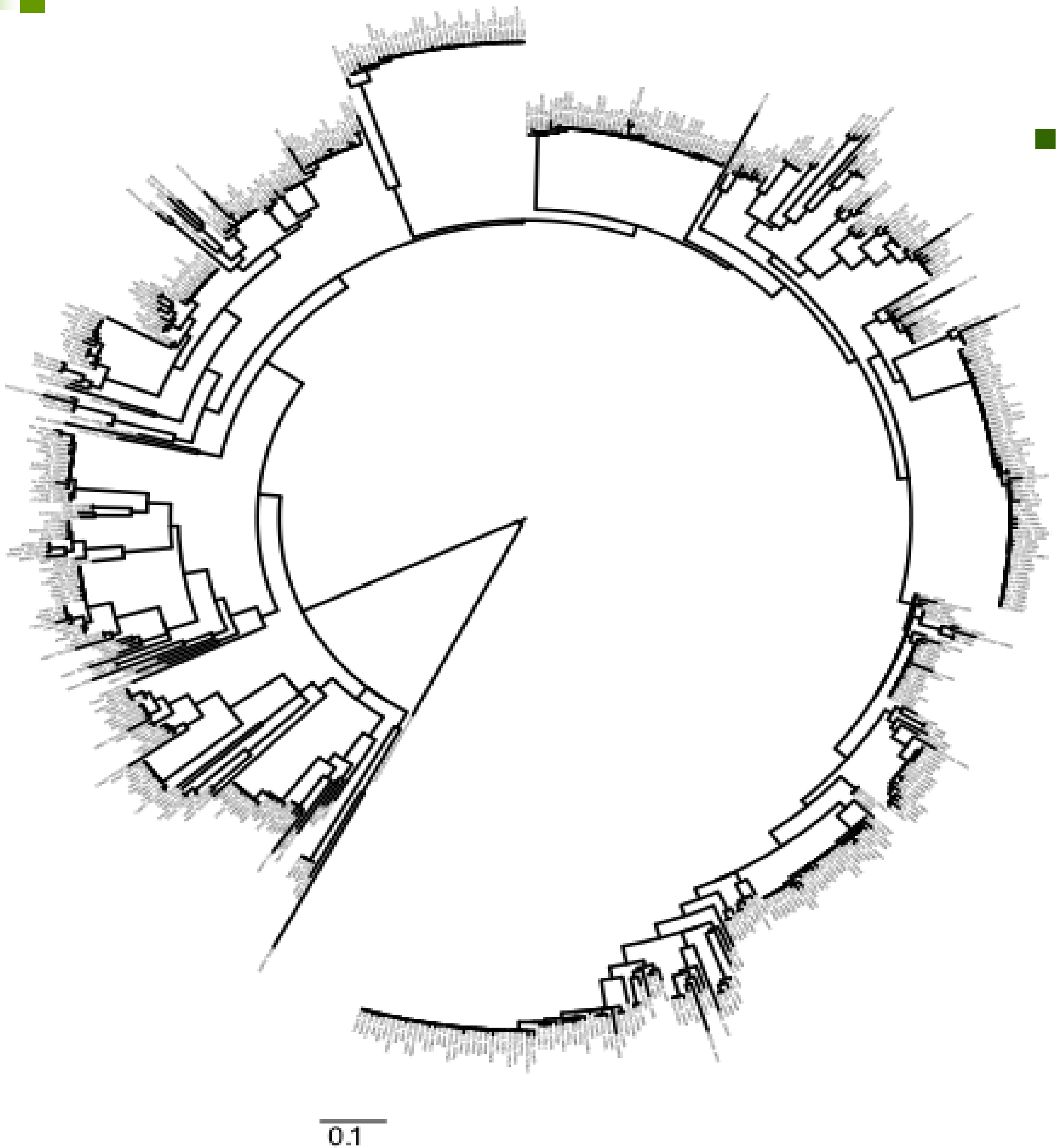




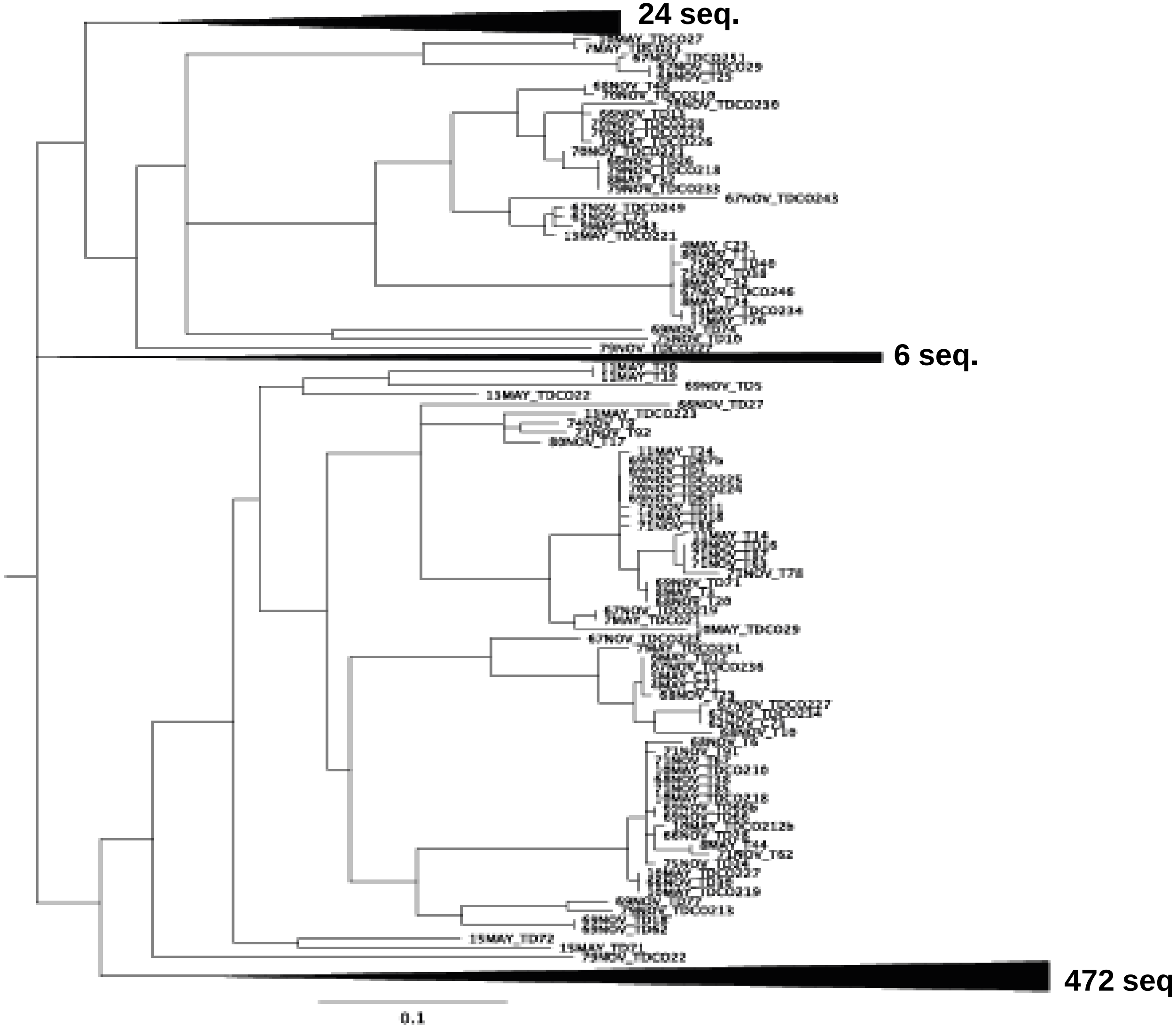
- No significant climate effects on size of denitrifying bacterial populations (*NirK*) or on nitrifying bacterial populations (AOB) but tendancy for increased *nirK* abundance in response to warming

nirK community structure



- Phylogenetic tree of *nirK* communities
    - on 600 sequences greater than 250 bp
    - Statistical analyses with Unifrac software

nirK community structure



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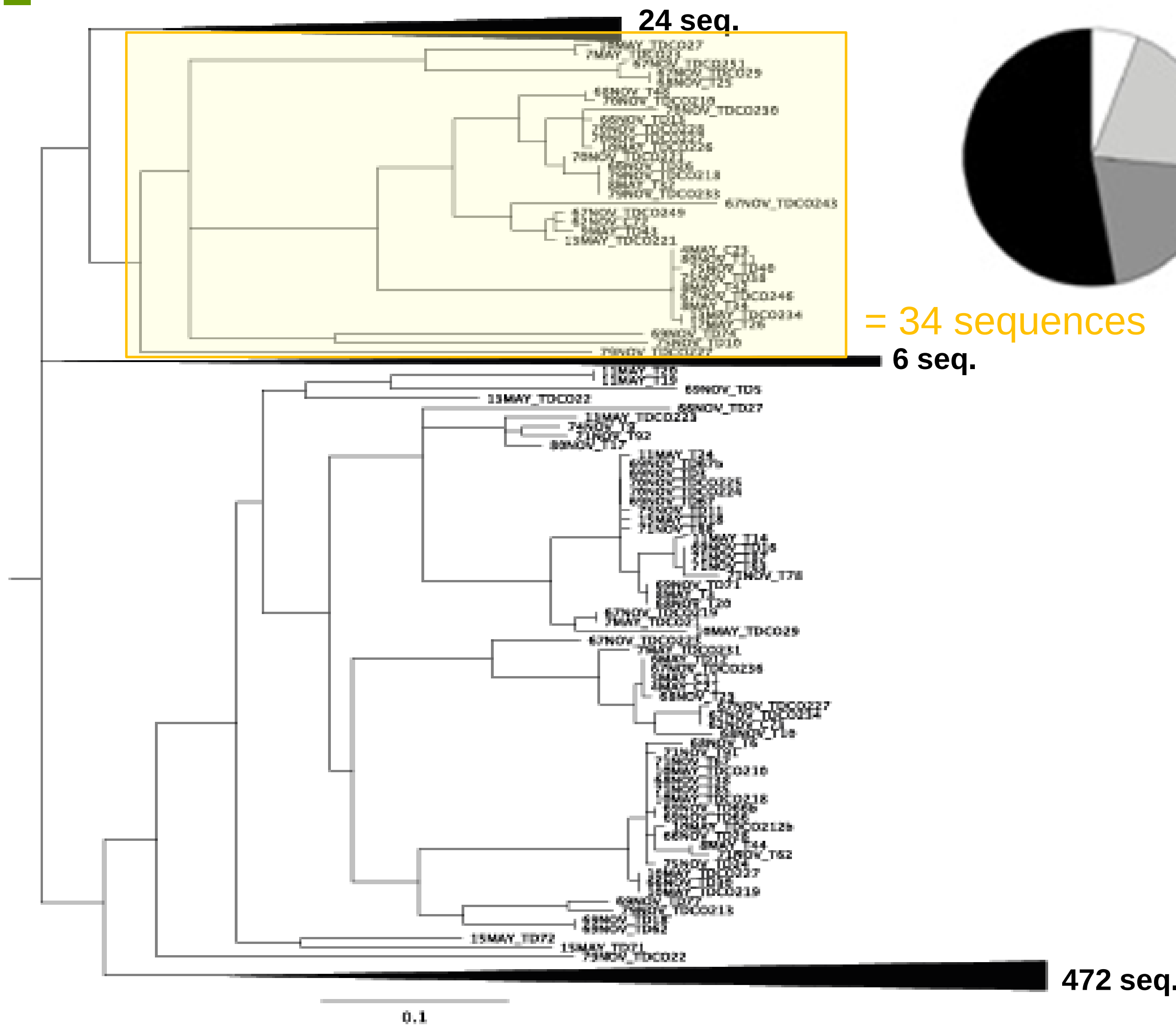

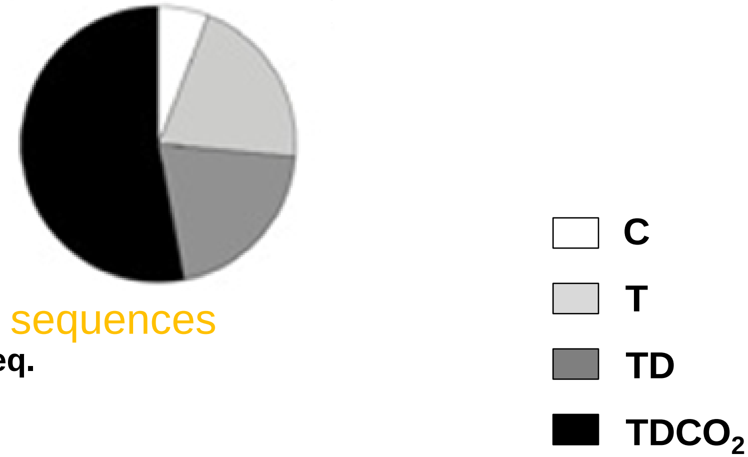

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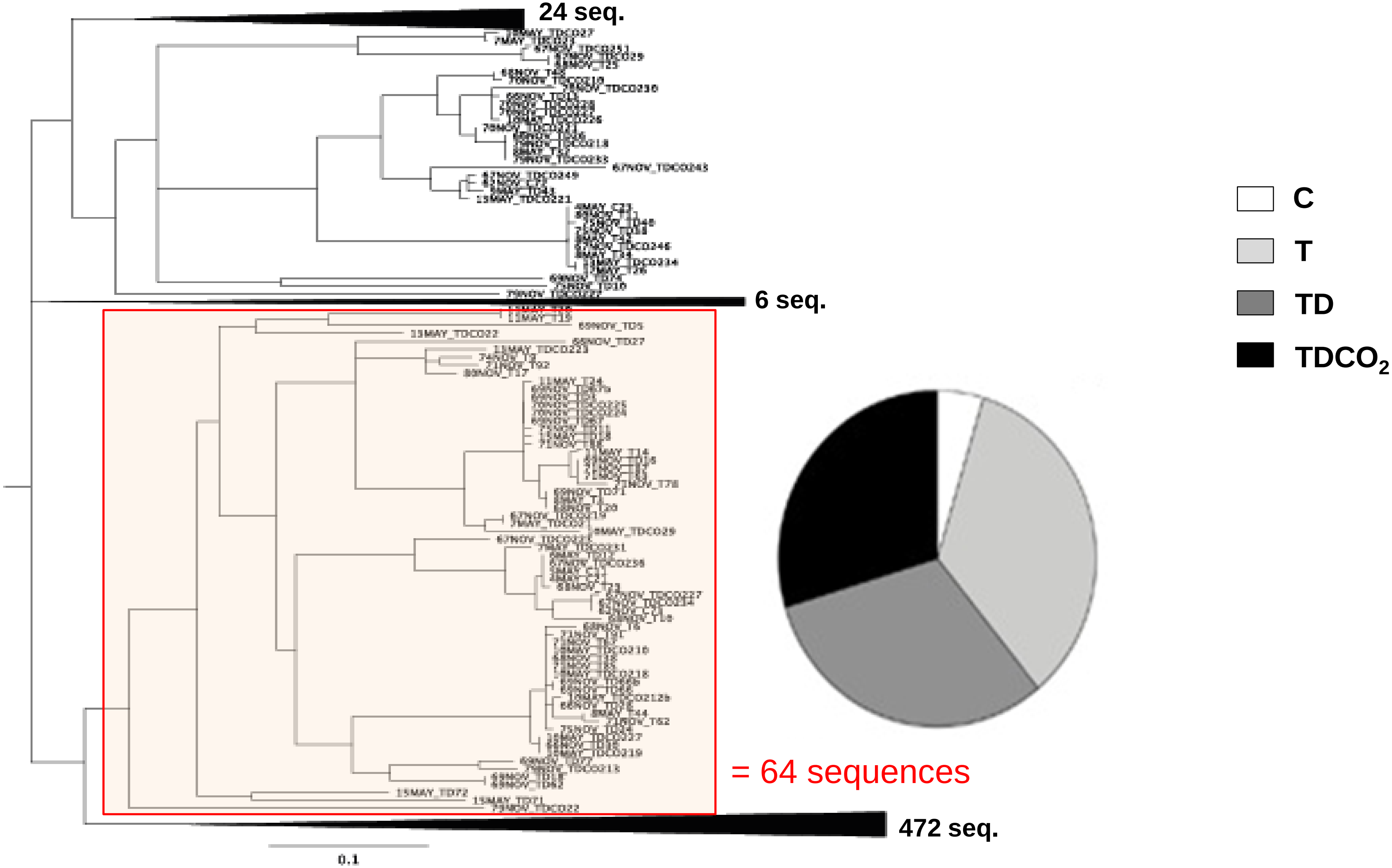

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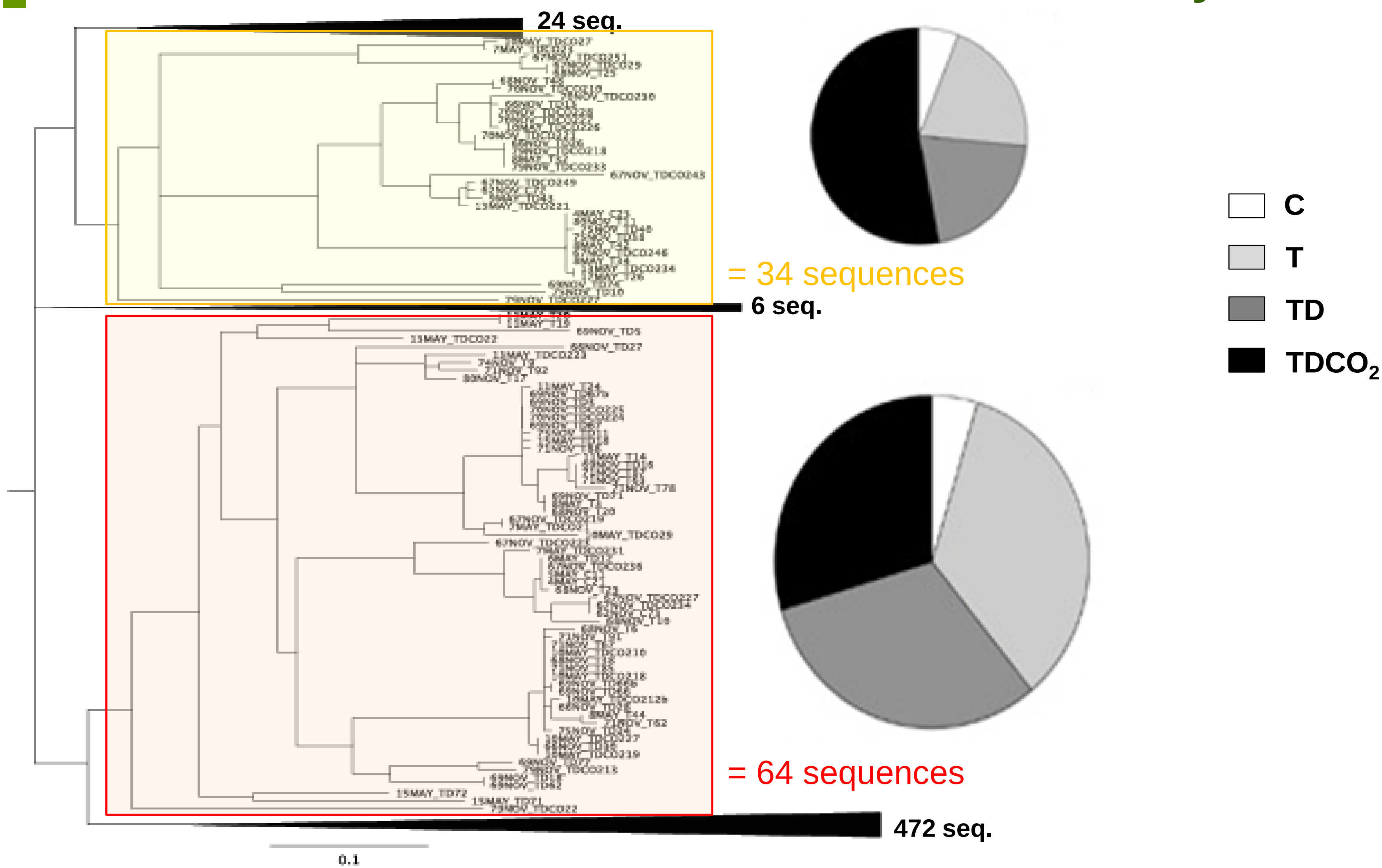
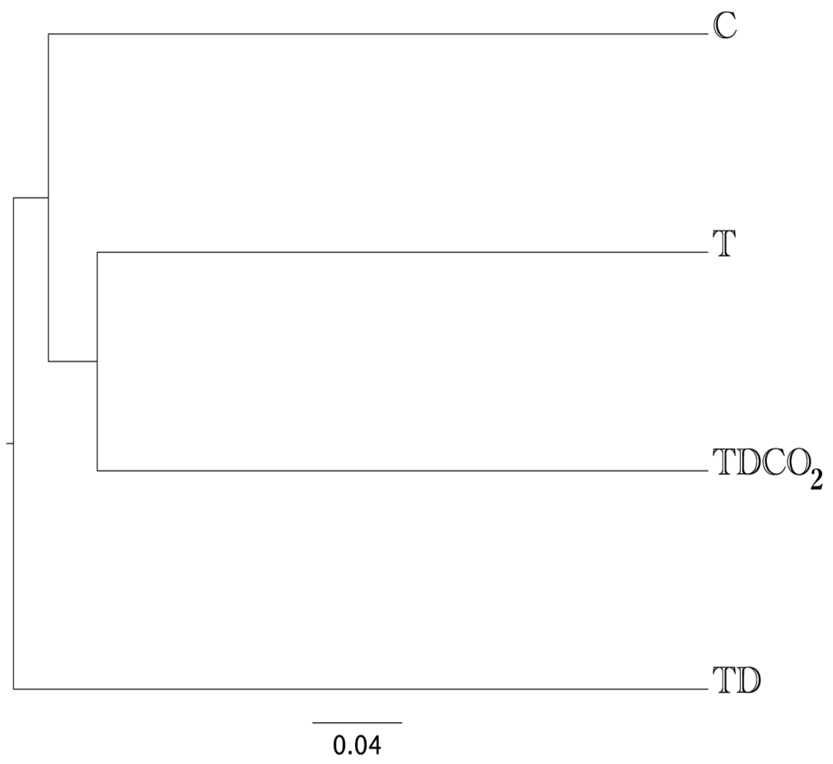


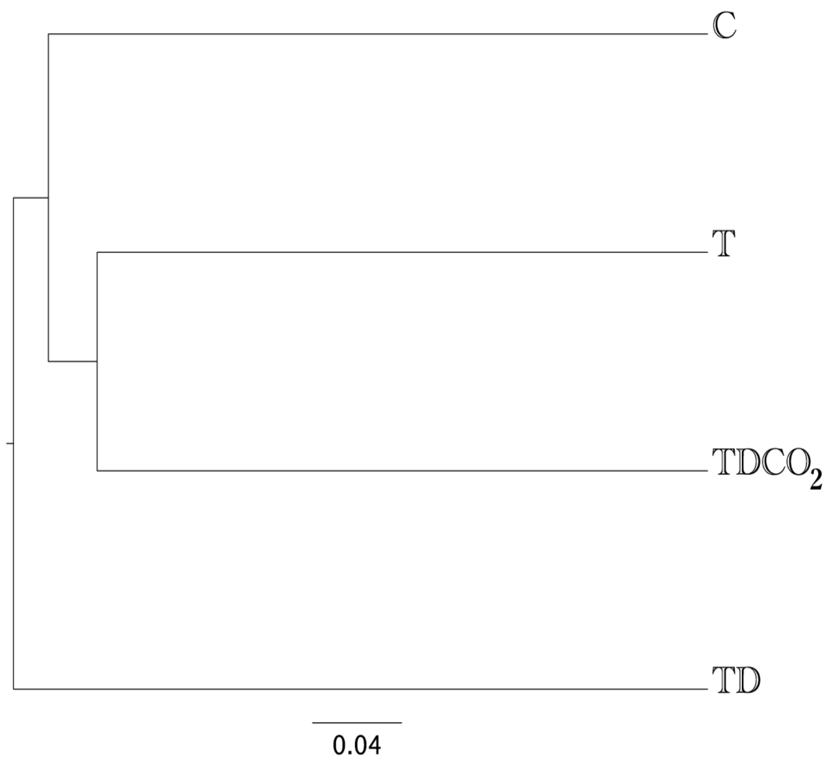
- Five years of climate change has selected specific lineages of *nirK* denitrifiers (two deeply branched lineages respond differently to warming and elevated CO_2)

nirK community structure



- Climate treatments show significantly different communities (Jackknife Environment Clusters, $p<0.001$)

nirK community structure



- Climate treatments show significantly different communities (Jackknife Environment Clusters, $p<0.001$)
- *NirK* community structure in warmed, dry conditions is an outgroup compared to the other climate treatments
  - Greater selective effect of drought on denitrifier community structure?

Conclusions

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  - *nirK* community structure show significant responses to climate treatment after five years
  - Further work is needed to test effects of climate on microbial enzyme upregulation
- We find evidence for specific *nirK* lineages in response to climate change

Thank you for your attention !

Thanks to Deltroy Nicolas, Pichon Patrick, Gaumy Laurent, Tardif Antoine and Jouve Amandine