



**HAL**  
open science

## Climate change drivers modify N<sub>2</sub>O fluxes via changes in microbial populations in a grassland experiment

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

### ► To cite this version:

Amélie Cantarel, Juliette Bloor, Thomas Pommier, Nadine Guillaumaud, Jean-François J.-F. Soussana. Climate change drivers modify N<sub>2</sub>O fluxes via changes in microbial populations in a grassland experiment. BES Annual Meeting, Sep 2011, Sheffield, United Kingdom. hal-02804220

**HAL Id: hal-02804220**

**<https://hal.inrae.fr/hal-02804220>**

Submitted on 5 Jun 2020

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

# *Climate change drivers modify N<sub>2</sub>O fluxes via changes in microbial populations in a grassland experiment*

**Cantarel A.A.M.<sup>1,2</sup>, Bloor J.M.G.<sup>2</sup>, Pommier T.<sup>1</sup>, Guillaumaud N.<sup>1</sup>, Moiret C.<sup>1</sup>, Soussana J.F.<sup>3</sup> & Poly F.<sup>1</sup>**

<sup>1</sup> Ecologie microbienne Lyon, UMR 5557 Lyon, France

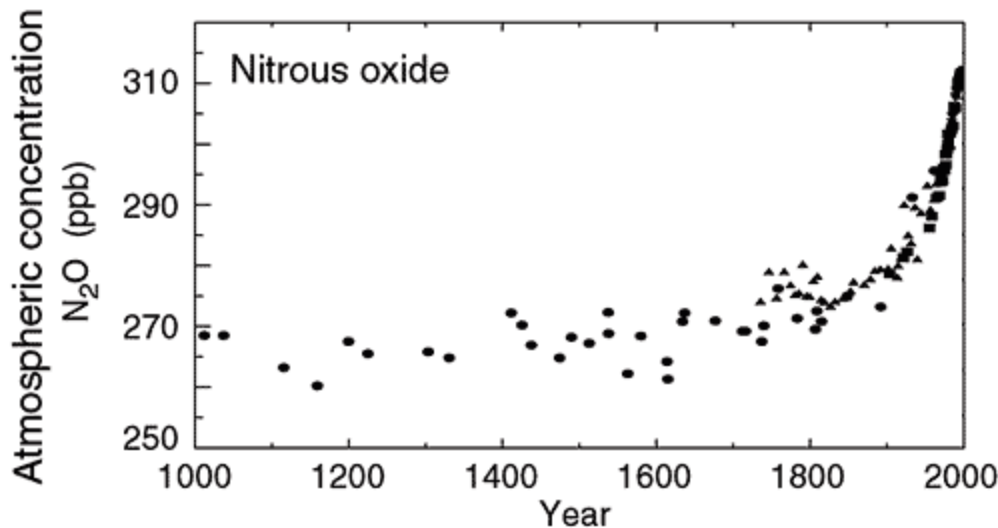
<sup>2</sup> Grassland Ecosystem Research Group (UREP), INRA Clermont-Theix, France

<sup>3</sup> CODIR Environnement, INRA Paris, France

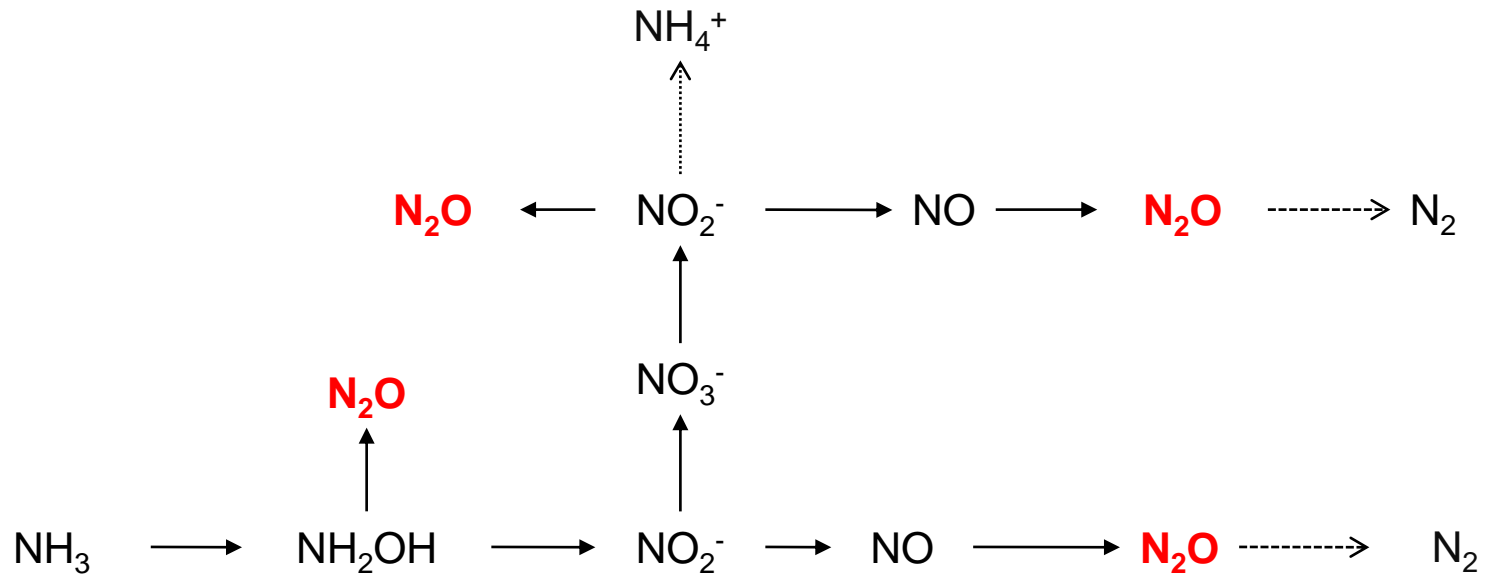
- Current climate models predict (IPCC 2001, 2007)
  - ↑ global air temperatures
  - Changes in regional patterns of rainfall
  - ↑ atmospheric greenhouse gases concentrations (as carbon dioxide, CO<sub>2</sub>)

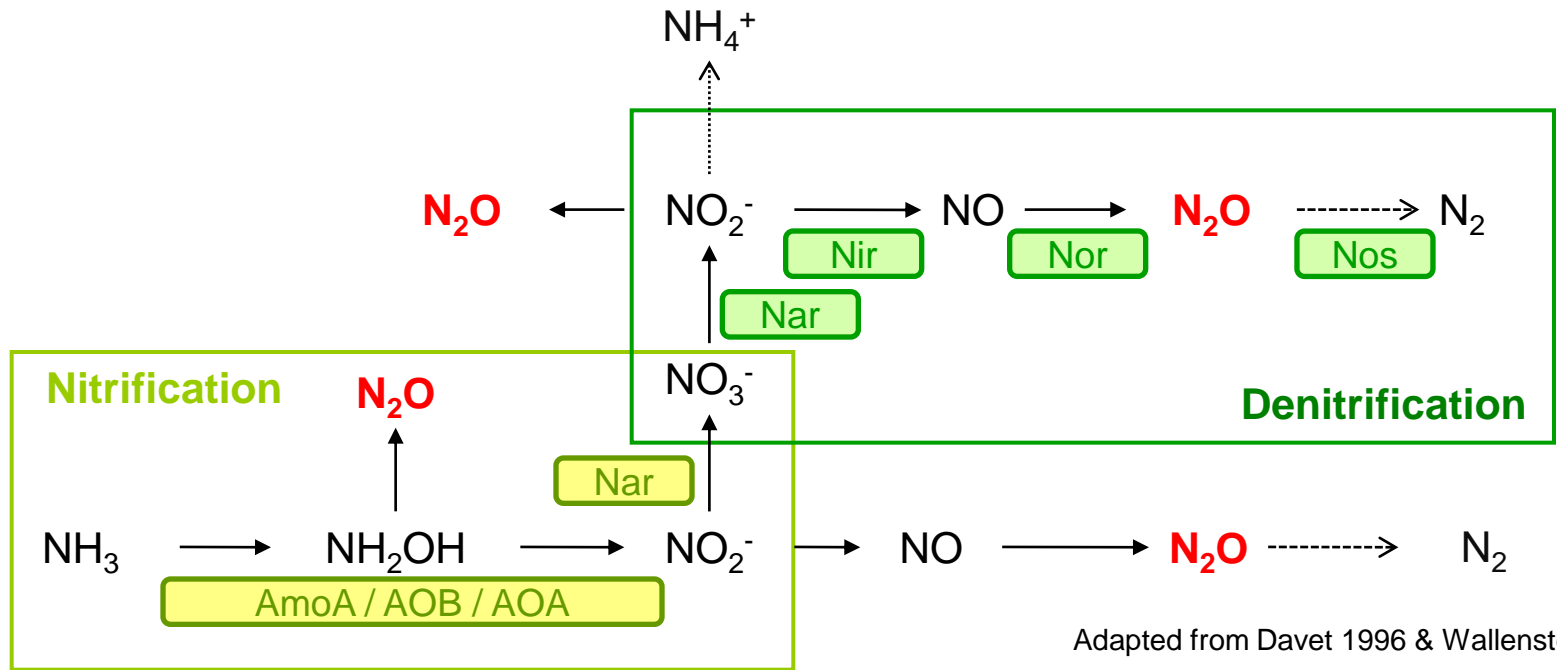
- Current climate models predict (IPCC 2001, 2007)
  - ↑ global air temperatures
  - Changes in regional patterns of rainfall
  - ↑ atmospheric greenhouse gases concentrations (as carbon dioxide, CO<sub>2</sub>)
  
- Climate change is known to have significant effects on global cycle of nitrogen (N) and gaseous N losses contributing to global changes in the atmosphere (Galloway *et al.* 2004)

- Current climate models predict (IPCC 2001, 2007)
  - ↑ global air temperatures
  - Changes in regional patterns of rainfall
  - ↑ atmospheric greenhouse gases concentrations (as carbon dioxide, CO<sub>2</sub>)
- Climate change is known to have significant effects on global cycle of nitrogen (N) and gaseous N losses contributing to global changes in the atmosphere (Galloway *et al.* 2004)

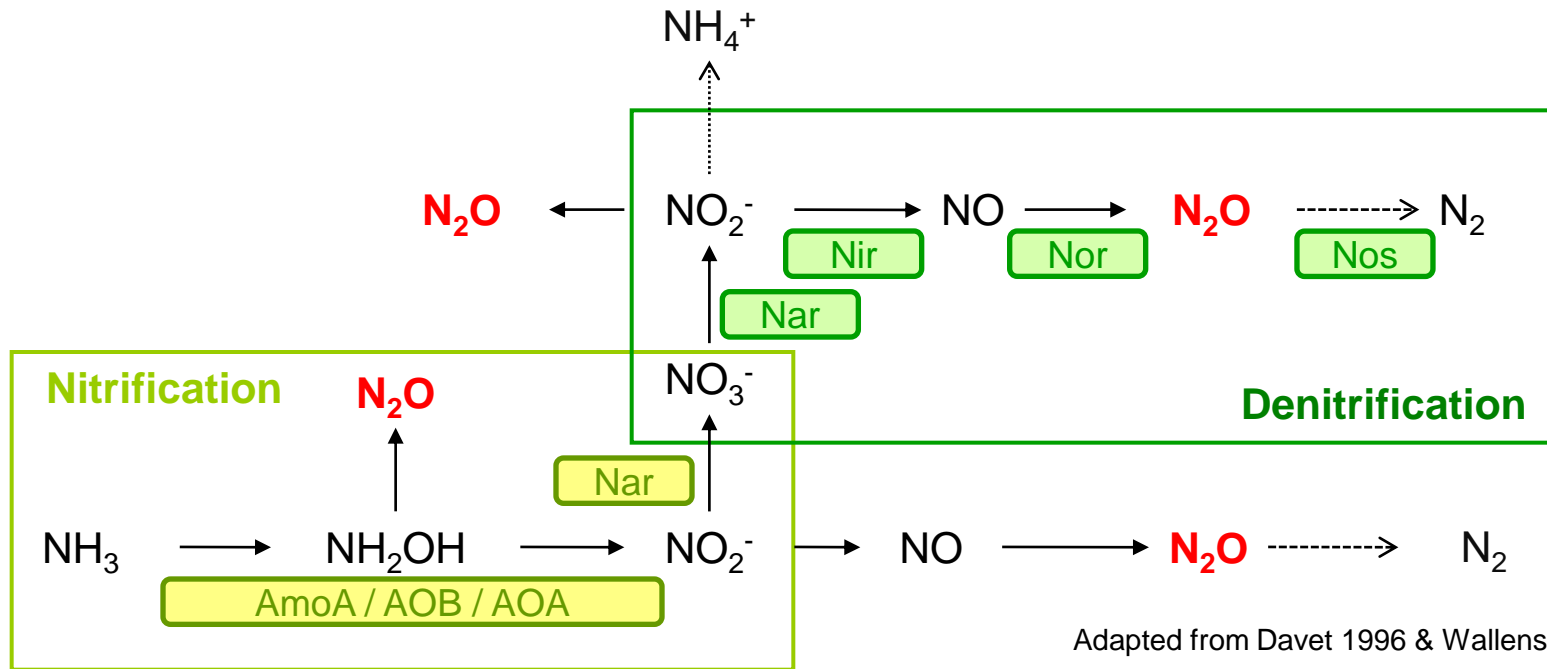


- N<sub>2</sub>O trace gas
  - Third greenhouse gases after carbon dioxide and methane
  - Strong global warming potential (~ 320 > CO<sub>2</sub>)
  - Depletion of the stratospheric ozone layer (Ravishankara *et al.* 2009)





Adapted from Davet 1996 & Wallenstein et al. 2006



- Changes in nitrification and denitrification may be linked to changes in:

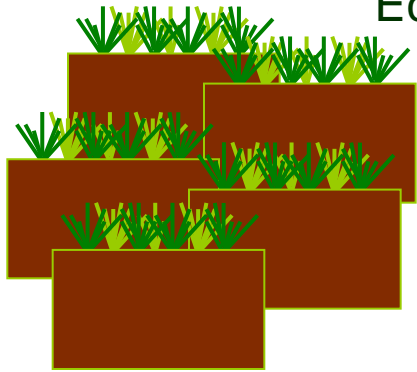
- Microbial population size
- Microbial community structure



- What are the effects of climate change drivers (elevated temperature, drought and elevated atmospheric CO<sub>2</sub> concentrations) on nitrous oxide (N<sub>2</sub>O) fluxes in grasslands?
- How do climate change drivers affect the microbial processes linked to N<sub>2</sub>O fluxes?

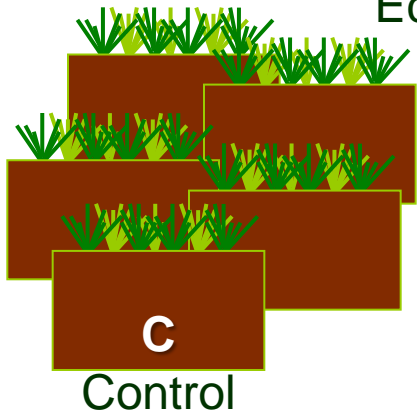
THEIX(850m)

Ecosystem: Acid grassland, no fertilizers



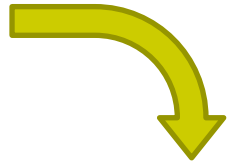
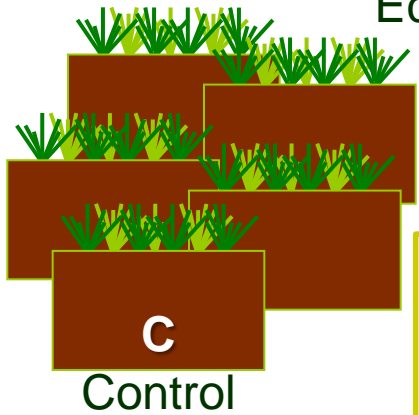
THEIX(850m)

Ecosystem: Acid grassland, no fertilizers

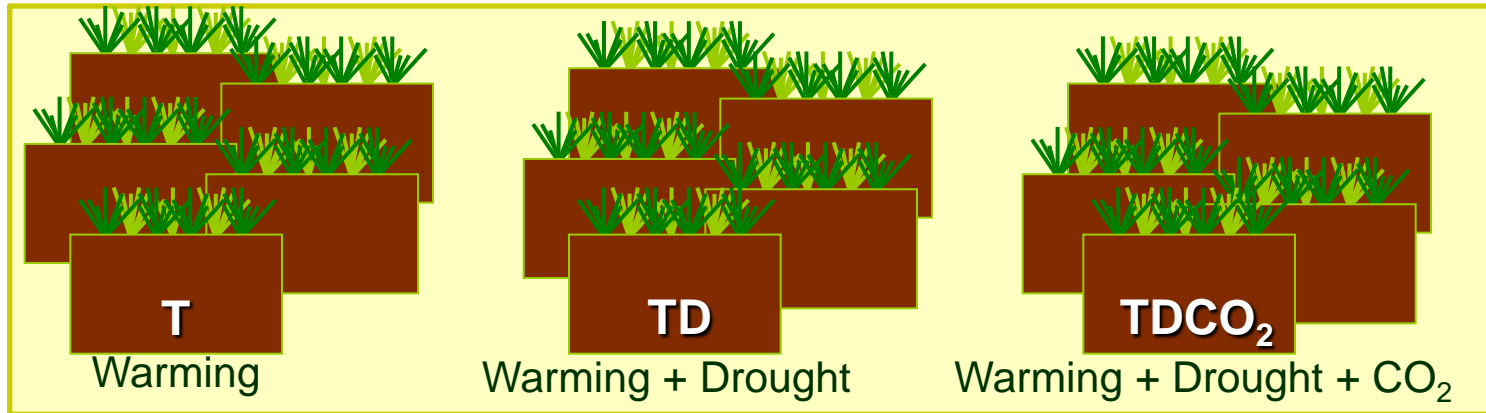


THEIX(850m)

Ecosystem: Acid grassland, no fertilizers



CLERMONT-FERRAND (350m) + 3.5 °C



Temperature effect

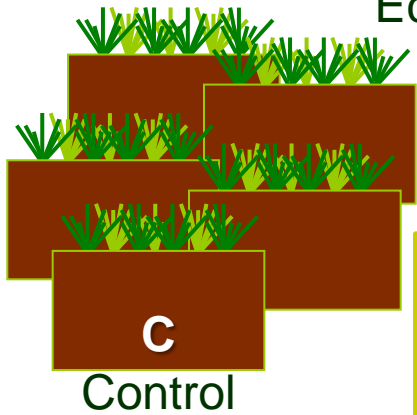
C vs T

Transplantation along an altitudinal gradient

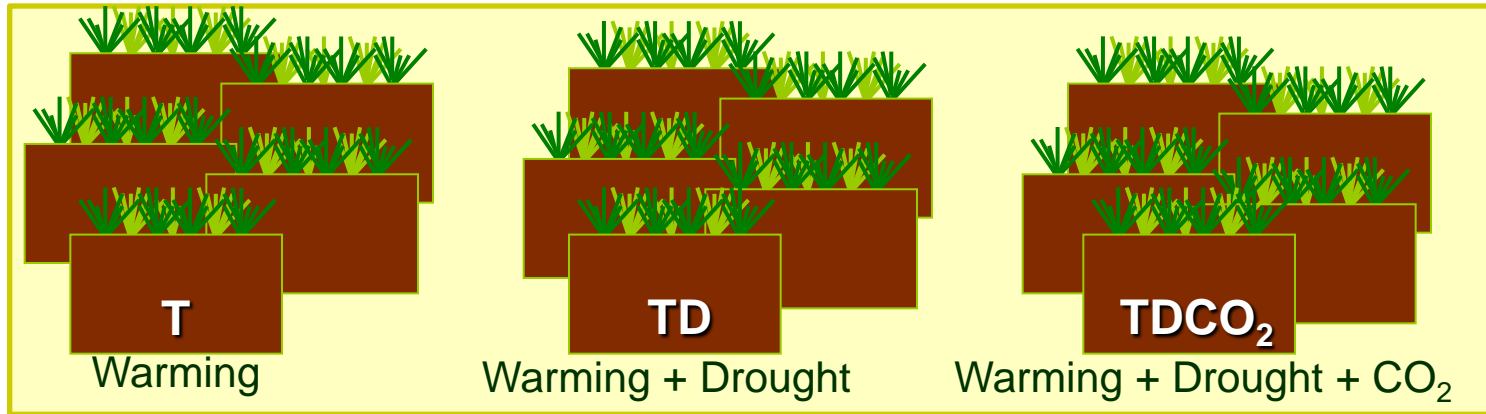
Same watering regime

THEIX(850m)

Ecosystem: Acid grassland, no fertilizers



CLERMONT-FERRAND (350m) + 3.5 °C



Temperature effect

**C vs T**

Drought effect (-20% rainfall)

**T vs TD**

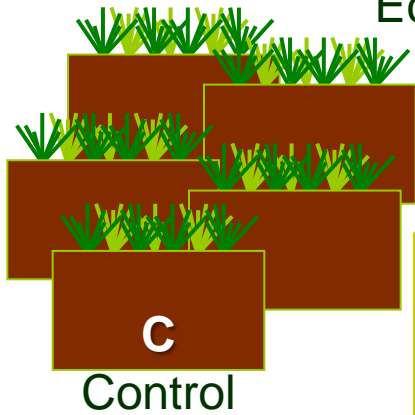
Transplantation along an altitudinal gradient

Same watering regime

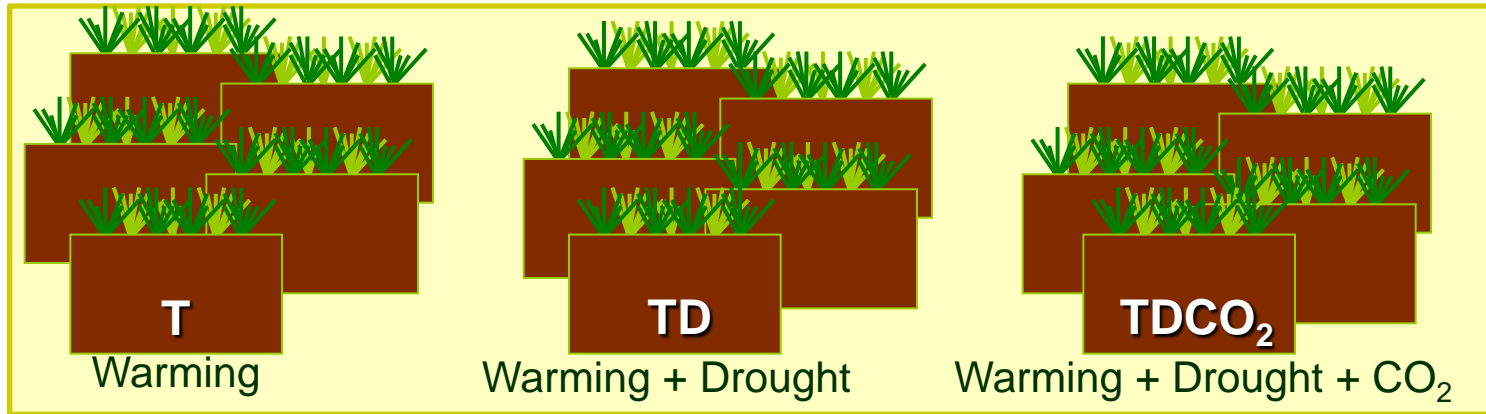
Using rainscreens during June, July and August

THEIX(850m)

Ecosystem: Acid grassland, no fertilizers



CLERMONT-FERRAND (350m) + 3.5 °C



Temperature effect

**C vs T**

Drought effect (-20% rainfall)

**T vs TD**

Elevation of atmospheric [CO<sub>2</sub>] + 200ppm

([CO<sub>2</sub>] = 600 ppm)

**TD vs TDCO<sub>2</sub>**

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



- Nitrous oxide (N<sub>2</sub>O) flux measurements

- 4 dates of N<sub>2</sub>O flux measurements in 2009

- May, July, September and November
    - N<sub>2</sub>O measurements using closed static chambers and a photoacoustic gas analyzer (INNOVA)



- Soil sampling following each flux measurement

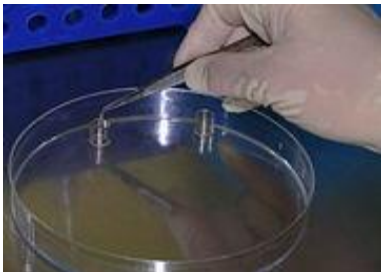
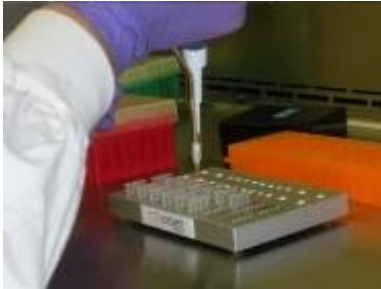
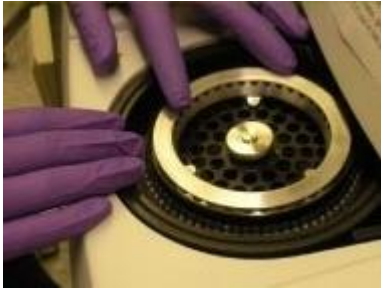
- 3 soil cores (Ø 1.5 cm) from 0-10 cm layer in each monolith

- Sieved at 4 mm

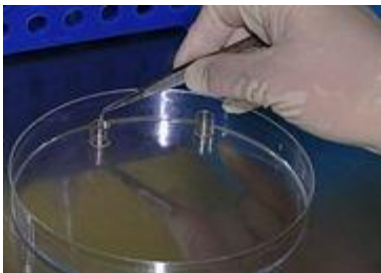
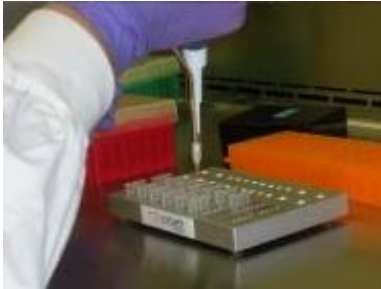
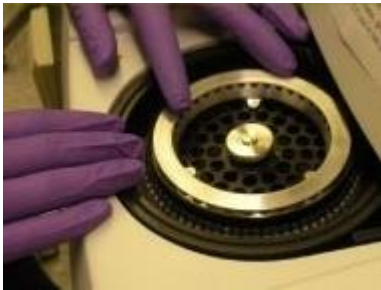




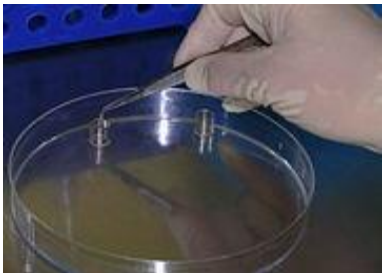
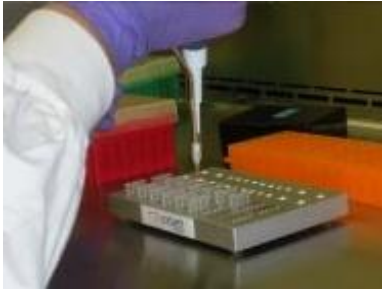
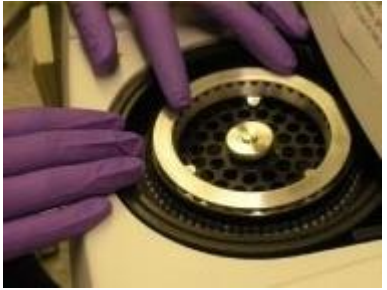
- Nitrifying and denitrifying activities
  - Potential nitrification measured in optimal conditions and analysed by ion chromatography
  
  - Potential N<sub>2</sub>O emissions by denitrification measured by gas chromatography



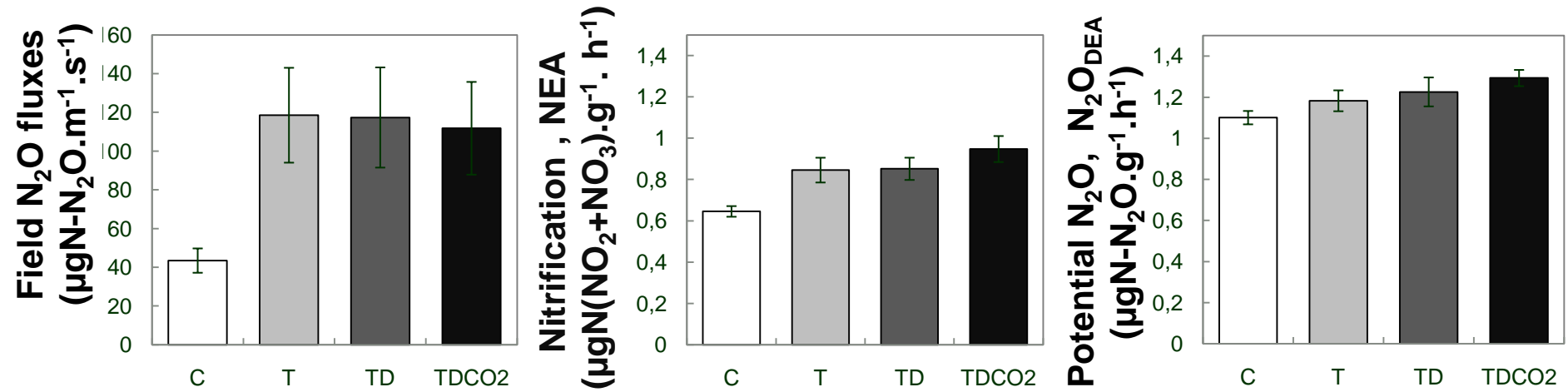


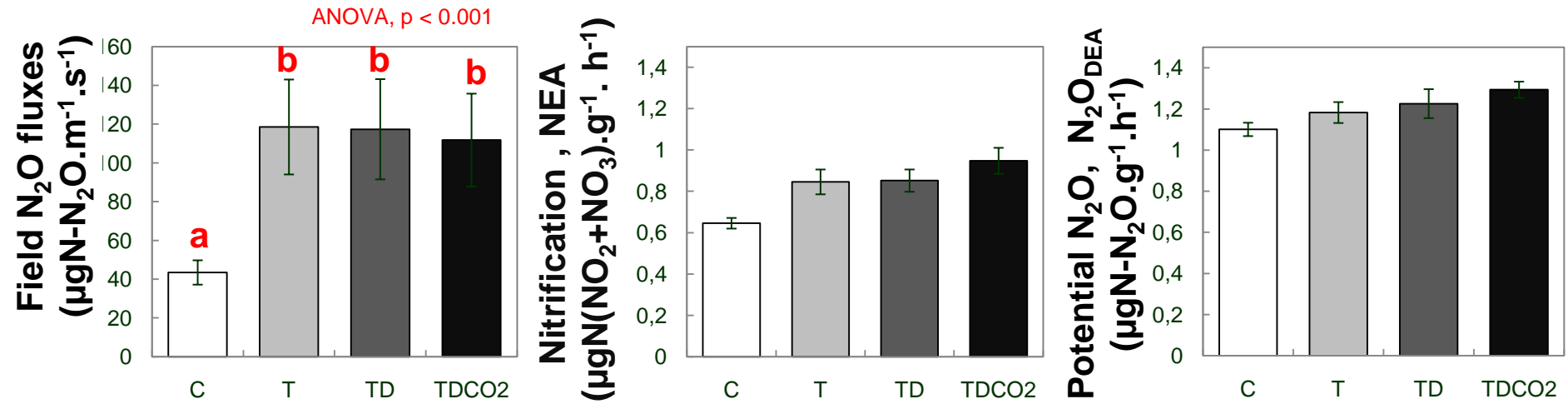


- Nitrifying and denitrifying activities
  - Potential nitrification measured in optimal conditions and analysed by ion chromatography
  - Potential  $N_2O$  emissions by denitrification measured by gas chromatography
  
- Quantification of genes abundances by qPCR
  - Nitrifying population : AOB
  - Denitrifying population : nirK

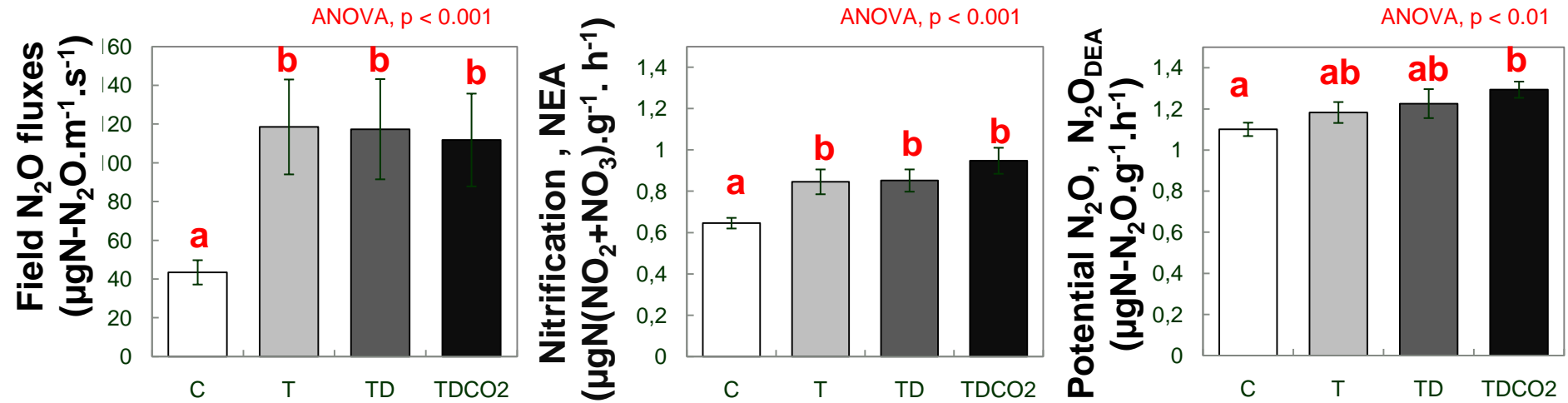


- Nitrifying and denitrifying activities
  - Potential nitrification measured in optimal conditions and analysed by ion chromatography
  - Potential N<sub>2</sub>O emissions by denitrification measured by gas chromatography
- Quantification of genes abundances by qPCR
  - Nitrifying population : AOB
  - Denitrifying population : nirK
- Characterization of denitrifying communities (*nirK*) by cloning-sequencing





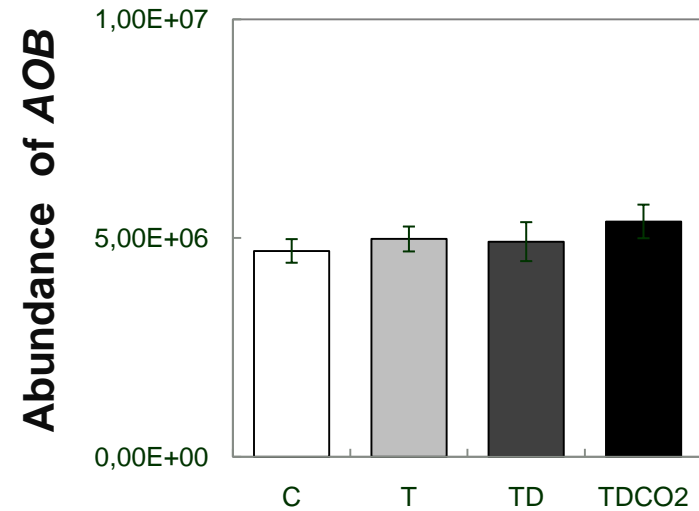
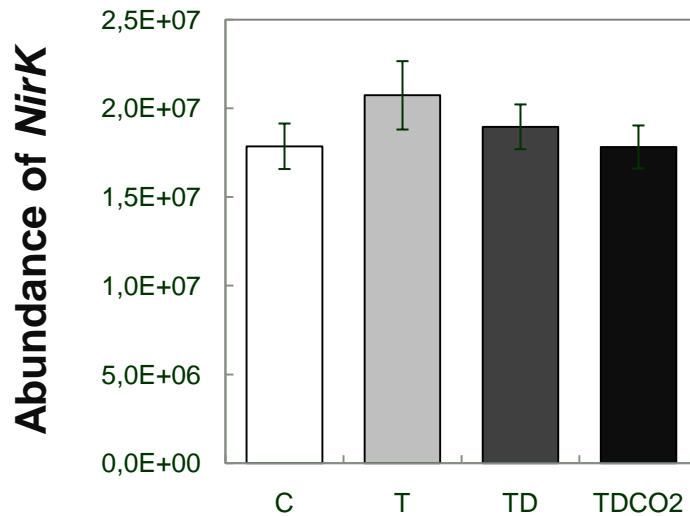
- Positive effect of air warming on N<sub>2</sub>O emissions (C vs T)



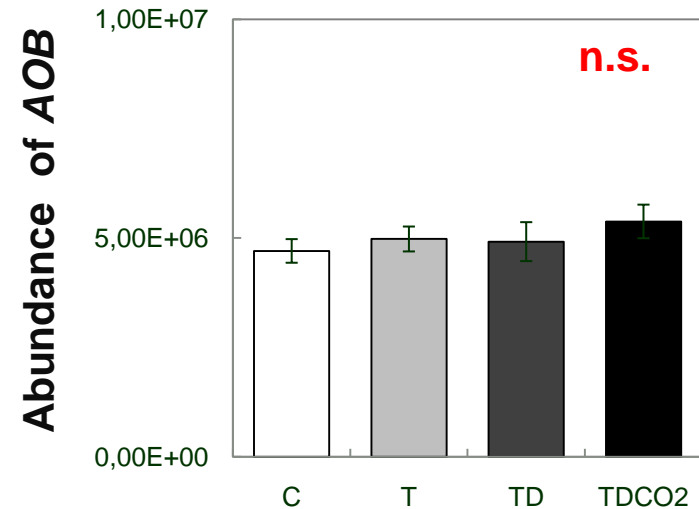
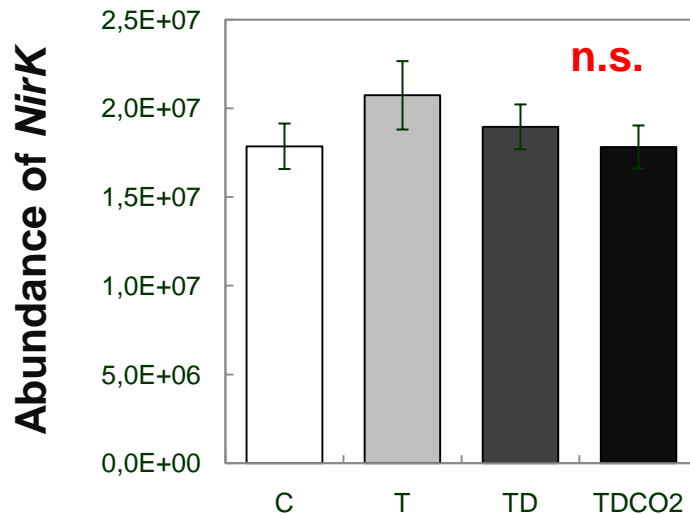
- Positive effect of air warming on N<sub>2</sub>O emissions (C vs T)
- Effects of climate change on nitrification and denitrification activities mirrored changes in N<sub>2</sub>O fluxes

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

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

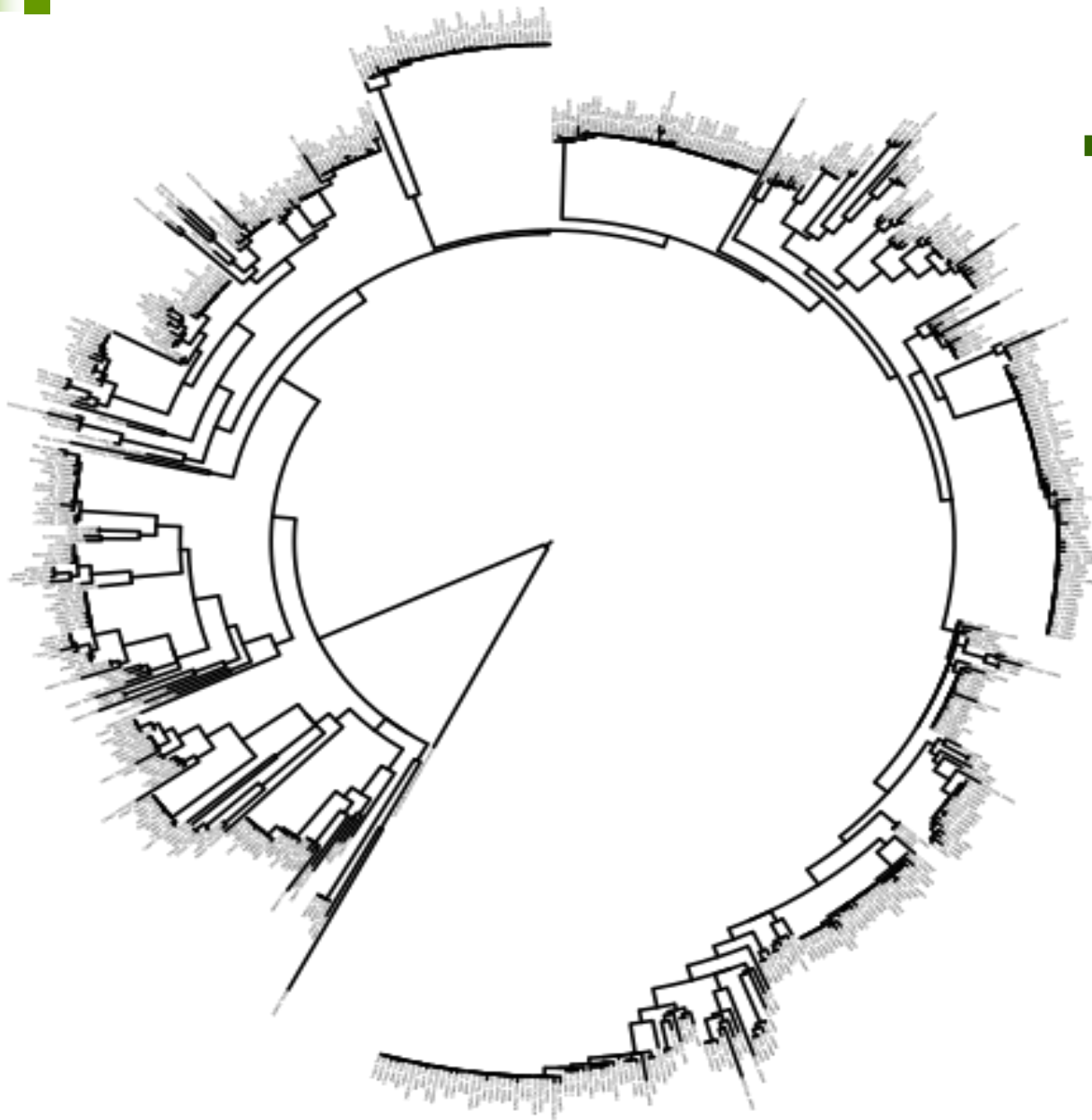


- Warming effects on microbial activities may be related to changes in microbial population size or community structure



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





0.1

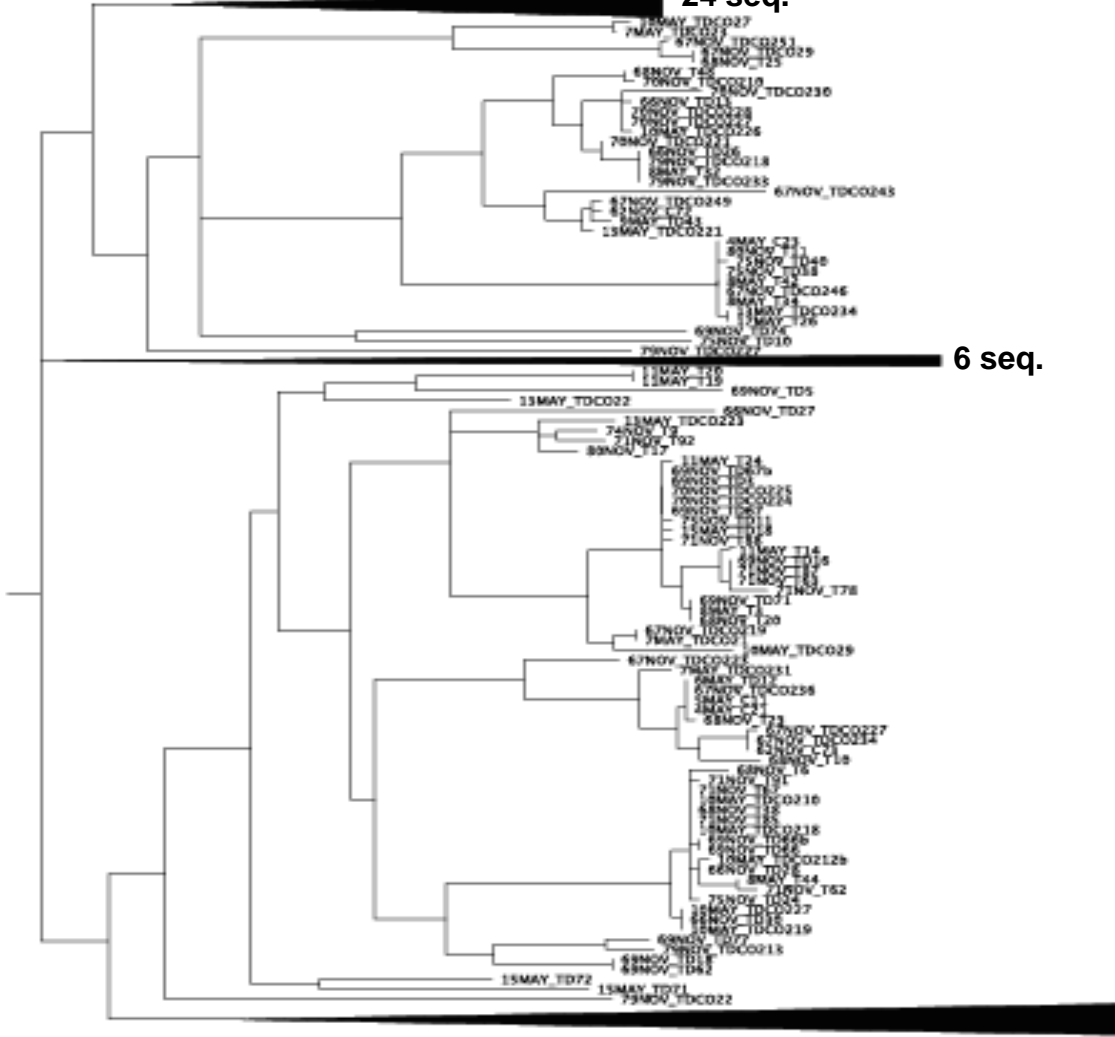
- Phylogenetic tree of *nirK* communities
  - on 600 sequences greater than 250 bp
  - Statistical analyses with Unifrac software

24 seq.

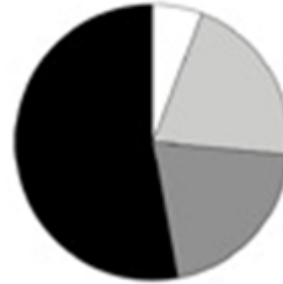
6 seq.

472 seq.

0.1



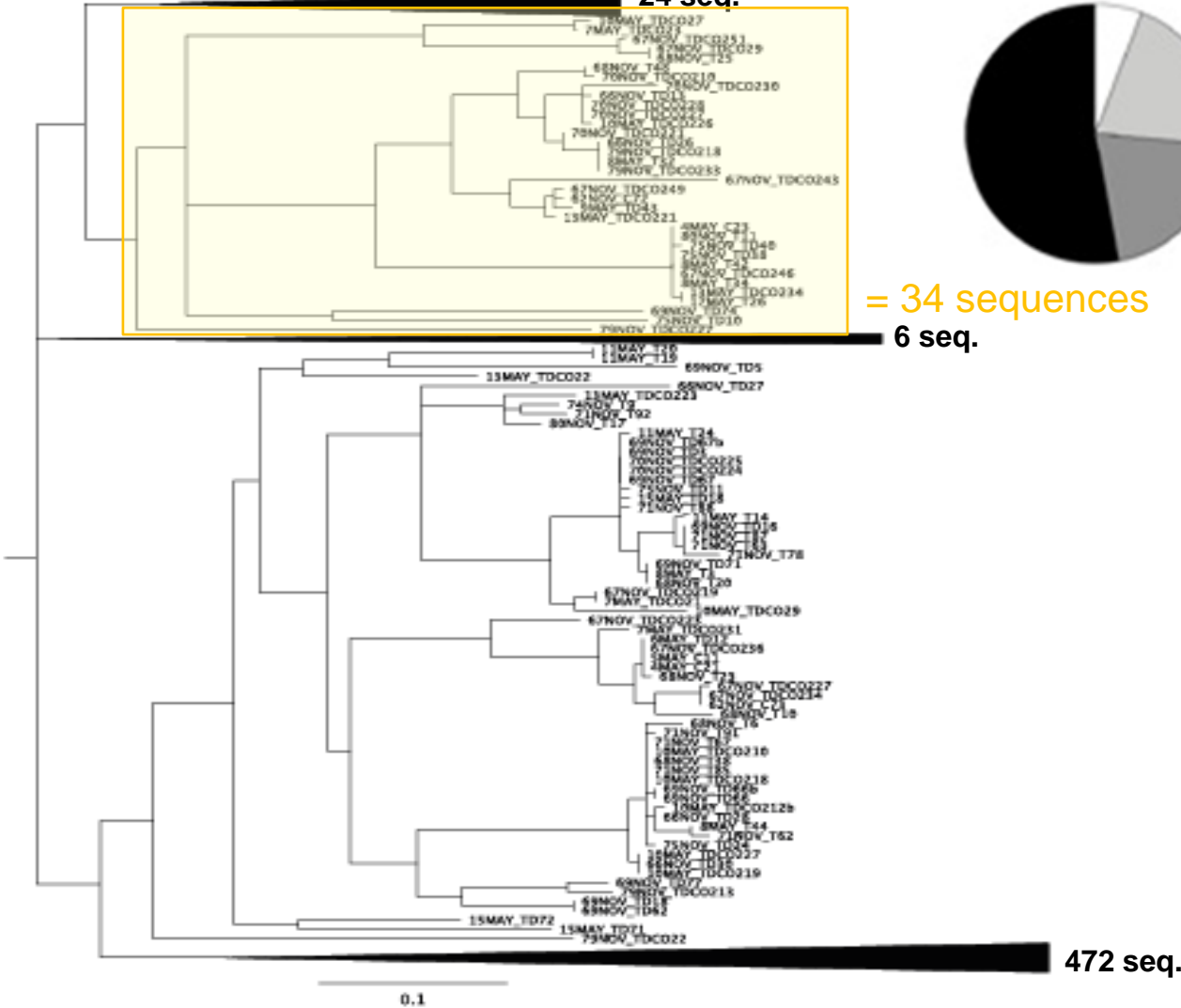
24 seq.



- C
- T
- TD
- TDCO<sub>2</sub>

= 34 sequences

6 seq.

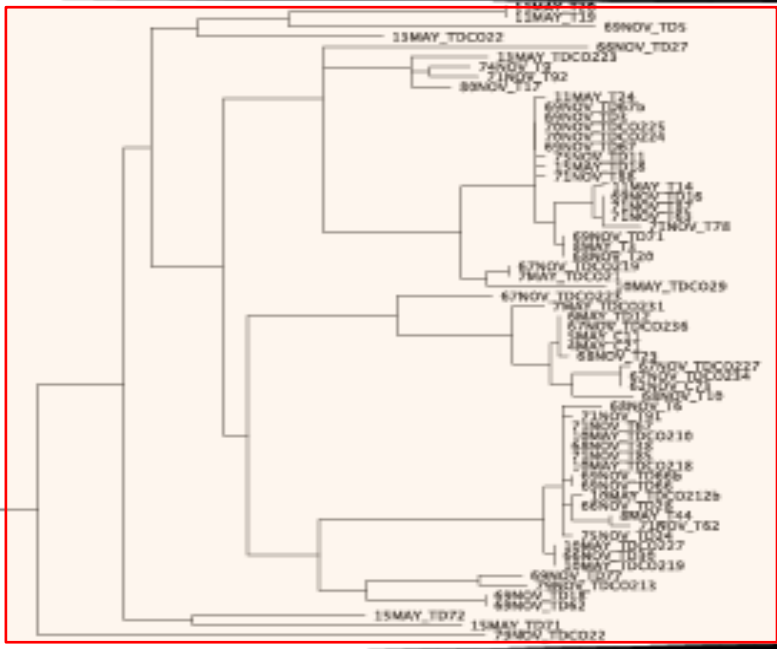


472 seq.

24 seq.

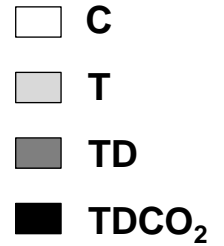


6 seq.



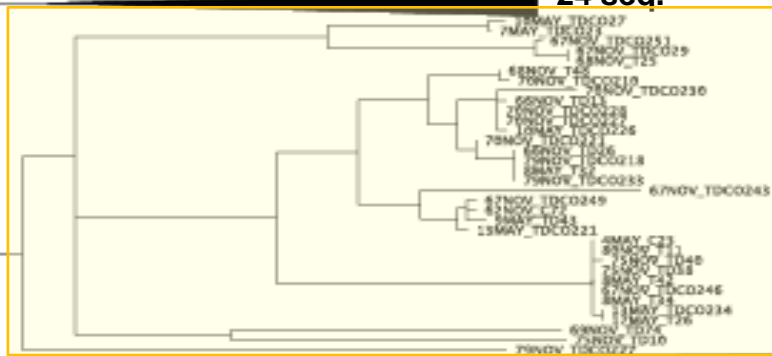
= 64 sequences

472 seq.



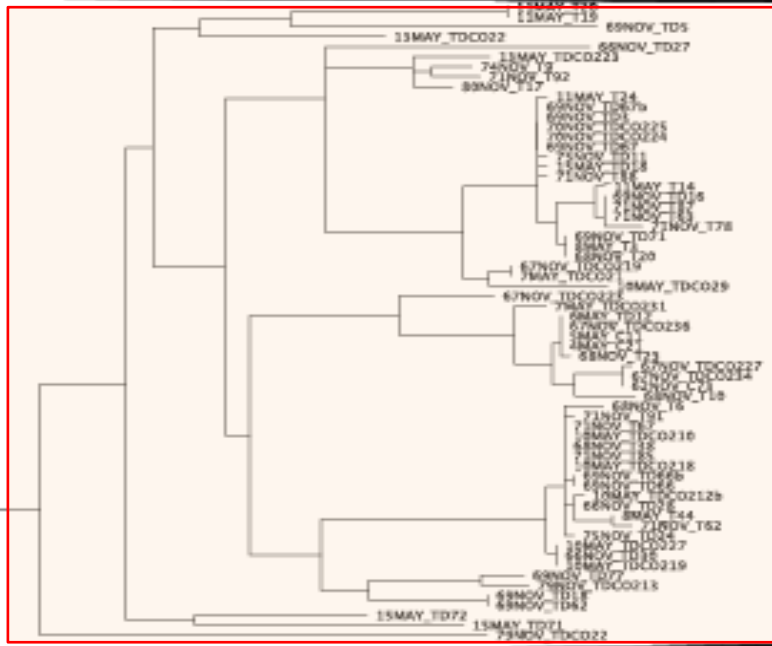
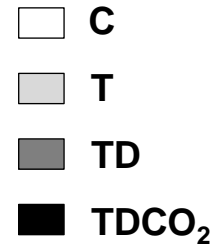
0.1

24 seq.



= 34 sequences

6 seq.



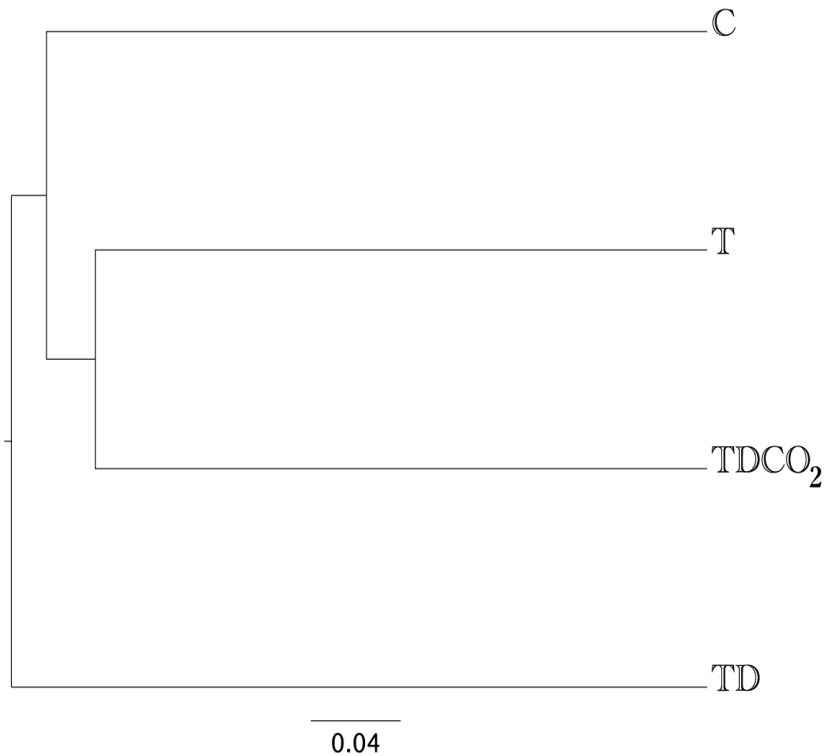
= 64 sequences



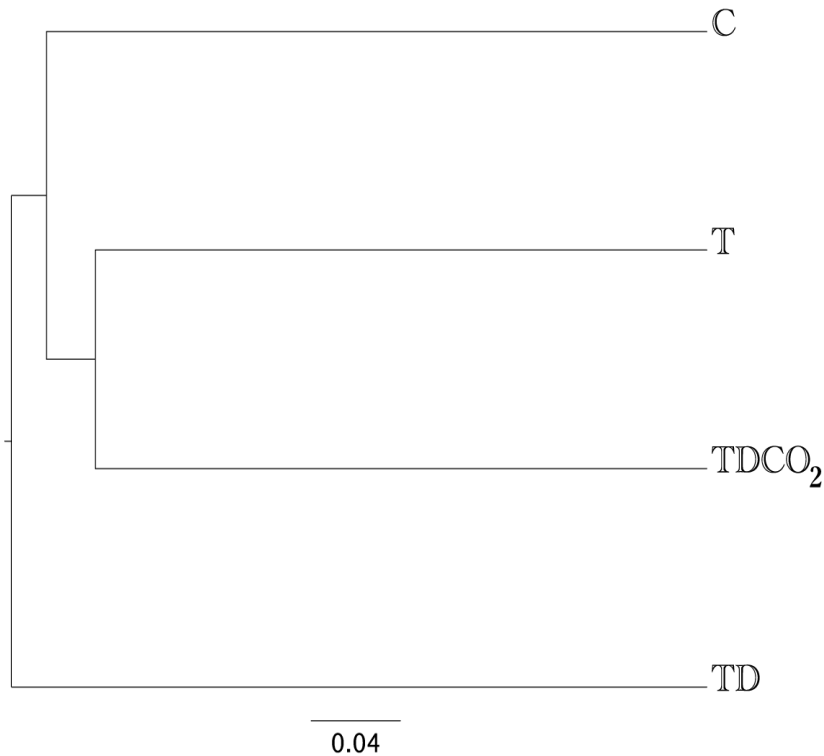
472 seq.

0.1

- Five years of climate change has selected specific lineages of *nirK* denitrifiers (two deeply branched lineages respond differently to warming and elevated CO<sub>2</sub>)



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



- 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?

- Warming is a key driver of climate change for field nitrous oxide ( $\text{N}_2\text{O}$ ) fluxes and microbial processes in our study system



- Warming is a key driver of climate change for field nitrous oxide (N<sub>2</sub>O) fluxes and microbial processes in our study system
- Warming effects on N<sub>2</sub>O fluxes are strongly linked to microbial activities
  - Microbial population sizes do not show strong climate treatment effects
  - *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

- Warming is a key driver of climate change for field nitrous oxide (N<sub>2</sub>O) fluxes and microbial processes in our study system
- Warming effects on N<sub>2</sub>O fluxes are strongly linked to microbial activities
  - Microbial population sizes do not show strong climate treatment effects
  - *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