Le nitrate et la rivière : diagnostic multi-isotopique de la saturation en azote au col du Lautaret

Ilann BOURGEOIS

Thèse soutenue le 8 Décembre 2017 sous la direction de Jean-Christophe CLEMENT et Joël SAVARINO

LECA Laboratoire d'Ecologie Alpine

UNIVERSITÉ Grenoble Alpes

IGE Institut des géosciences de l'environnement

L'eau de montagne…

… un service écosystémique

Conditions naturelles

Service écosystémiques de montagne:
- Qualité de l'eau
- Contrôle de l'érosion
- Contrôle de la chimie des sols
- Valeur patrimoniale et sociétale

EQUILIBRE

Préservation de la biodiversité

CONTEXTE

Activités humaines

Service écosystémiques de montagne:
- Qualité de l'eau
- Contrôle de l'érosion
- Contrôle de la chimie des sols
- Valeur patrimoniale et sociétale

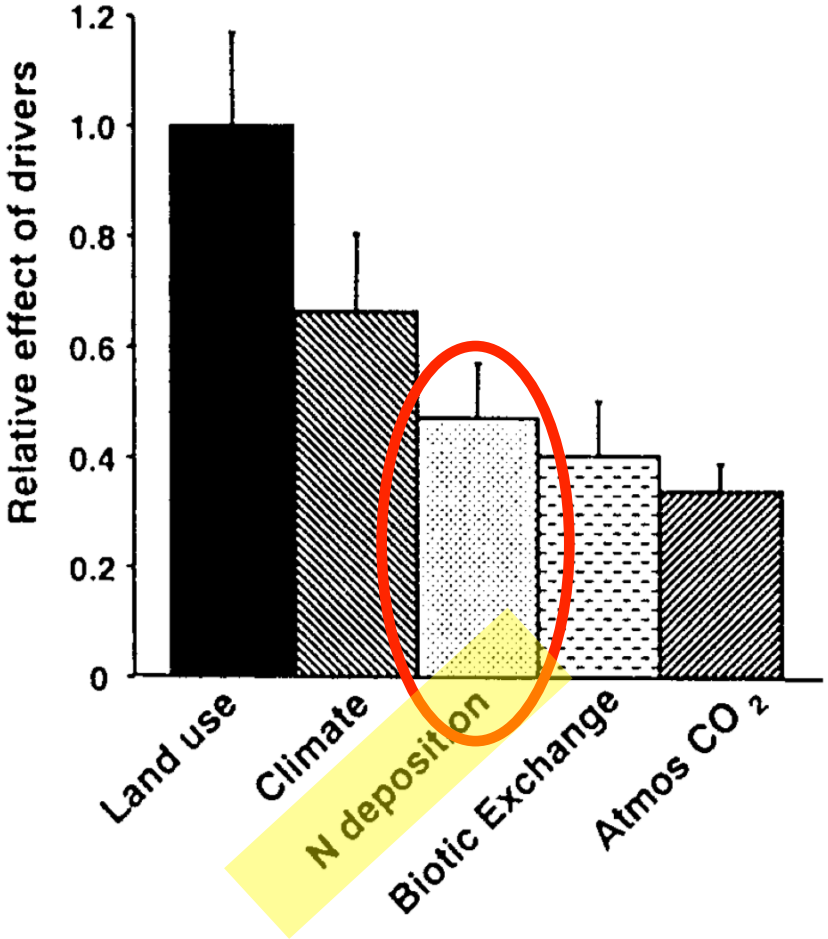
DESEQUILIBRE

Préservation de la biodiversité

CONTEXTE

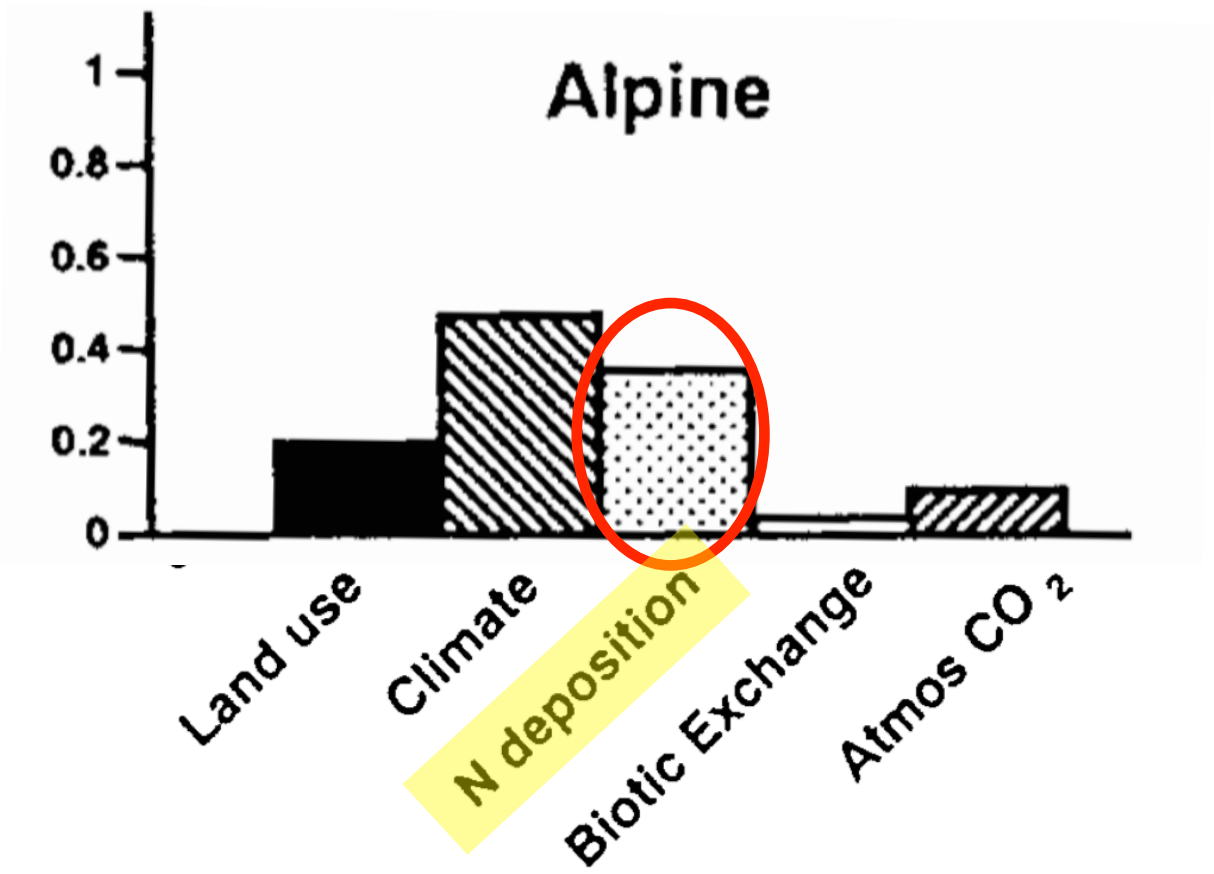
Affluent de la Romanche, un jour d'été 2016

D'ici 2100, les dépôts d'azote devraient être la troisième cause de la perte de biodiversité à l'échelle globale…



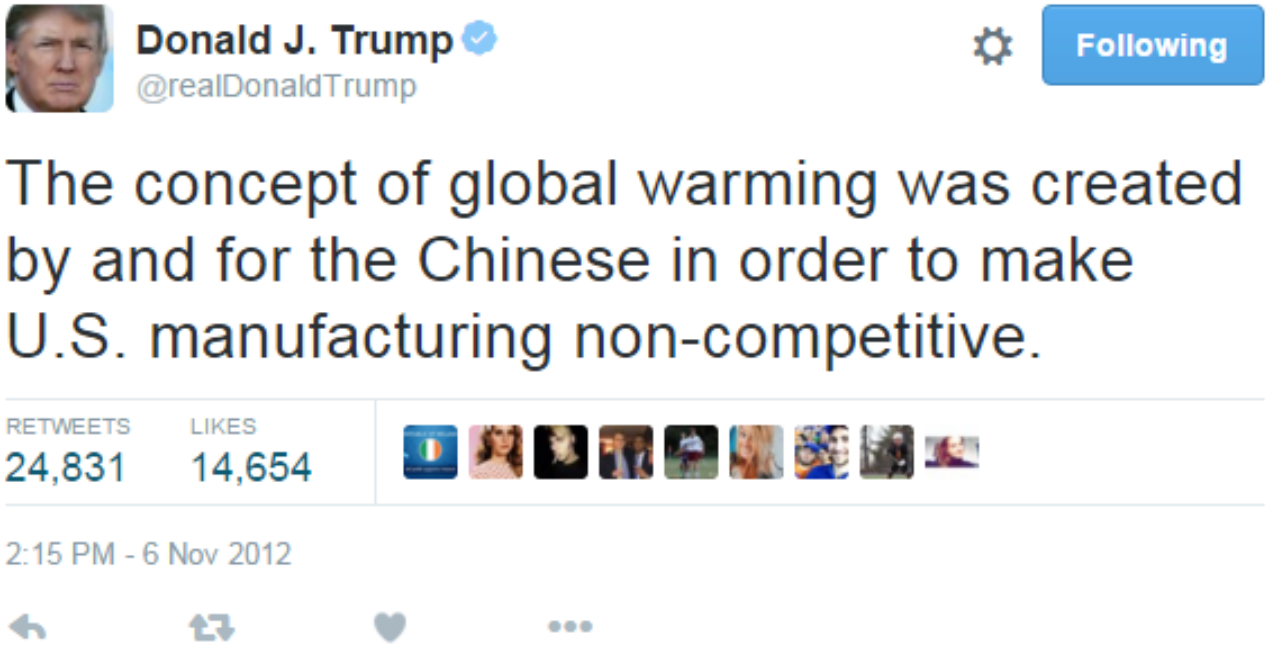
© Sala et al. *Science*, **2000**

… et la deuxième cause de la perte de biodiversité à l'échelle des écosystèmes de montagne



© Sala et al. *Science*, **2000**

CONTEXTE

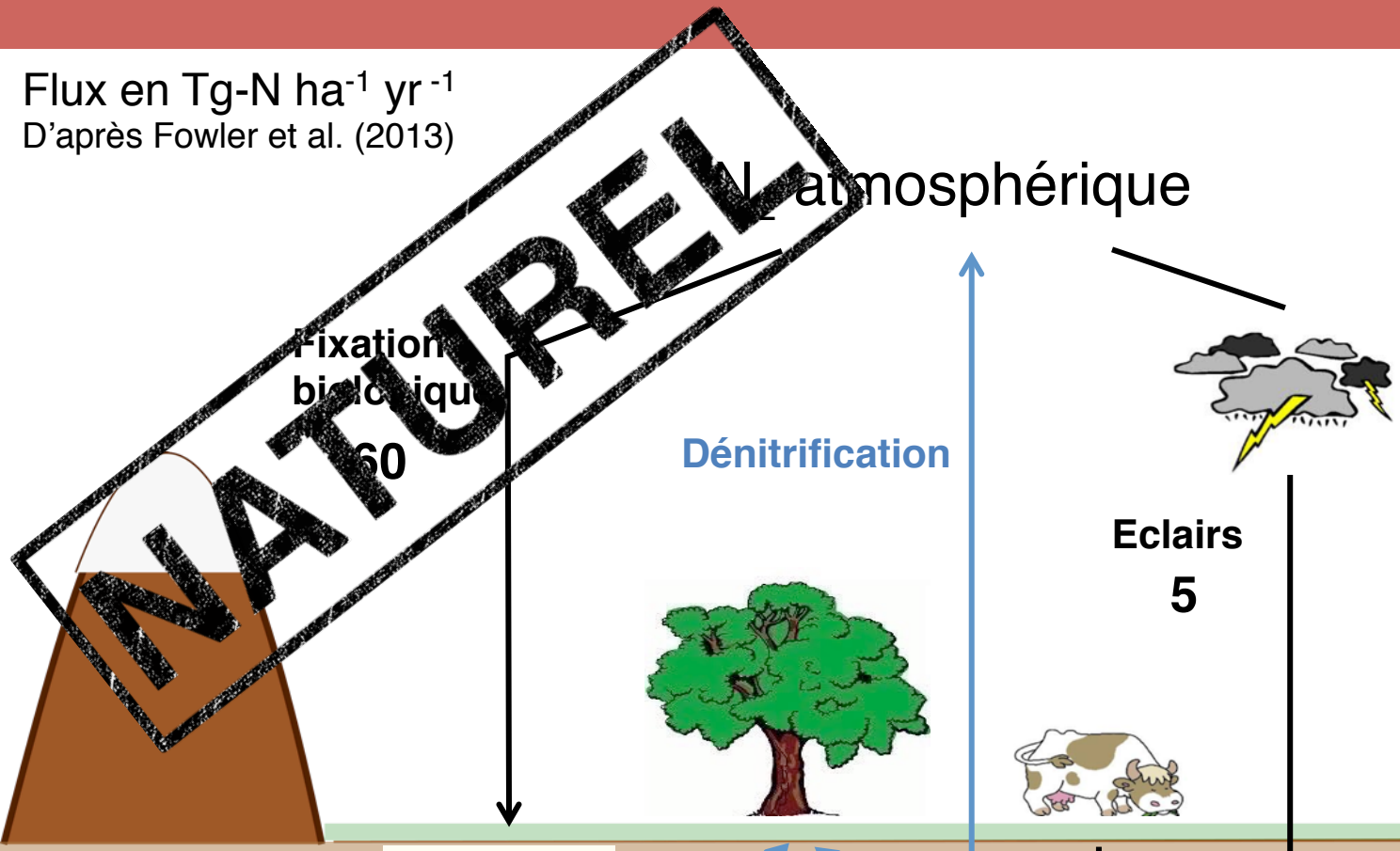


© Trump et al. *Twitter*, **2002**

CONTEXTE

Flux en Tg-N ha^{-1} yr^{-1}
D'après Fowler et al. (2013)

Nr = Azote réactif



CONTEXTE

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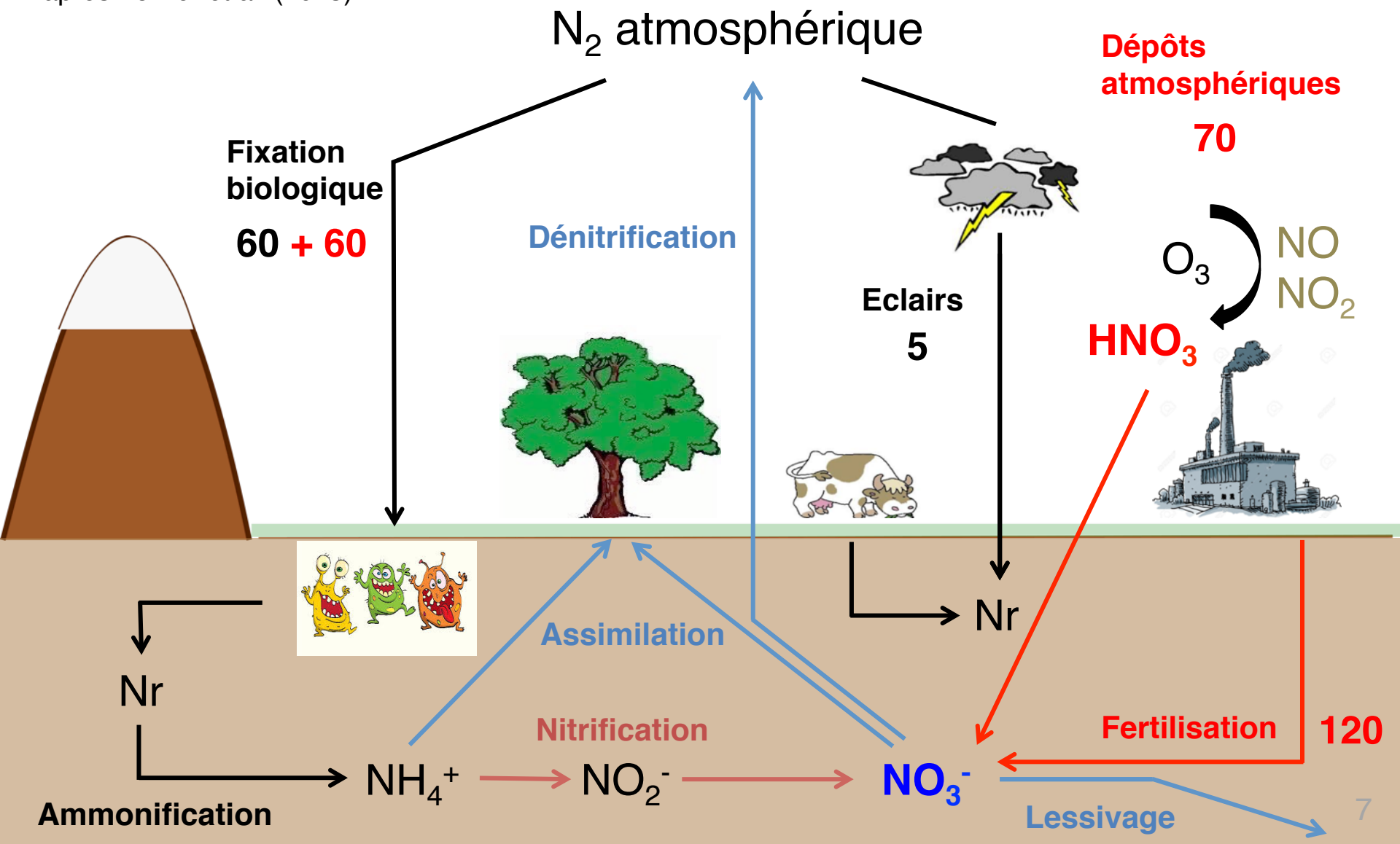
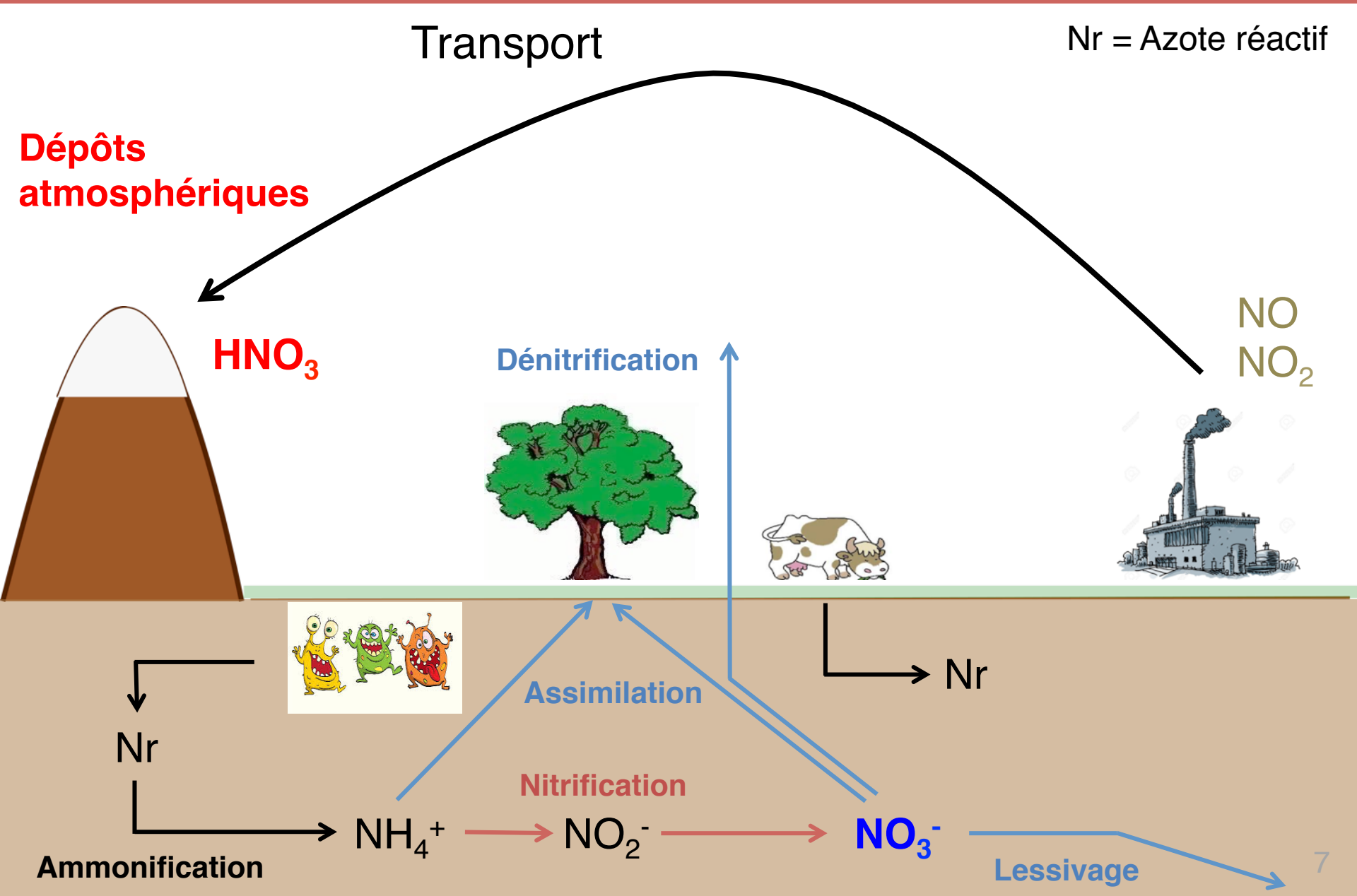
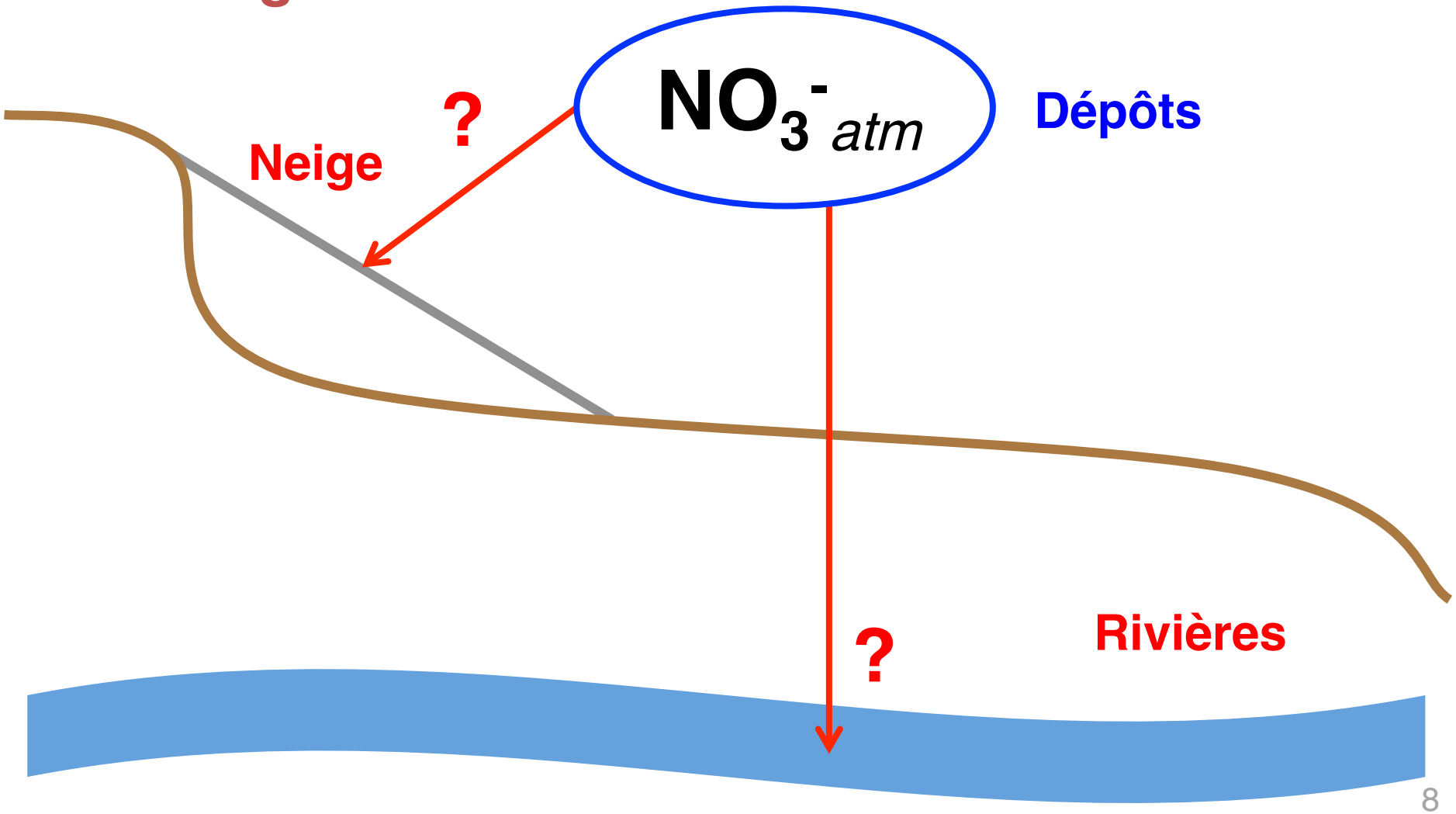


CONTEXTE

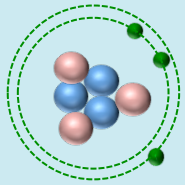

Transport
Nr = Azote réactif
Dépôts atmosphériques
HNO_3
Dénitrification
NO
NO_2
Nr
Nr
Assimilation
Nitrification
NH_4^+
NO_2^-
NO_3^-
Ammonification
Lessivage

Quel est le devenir du nitrate atmosphérique en montagne?

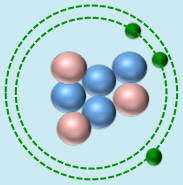


Isotopes?

Isotopes de l'azote:



^{14}N
7 protons
7 neutrons

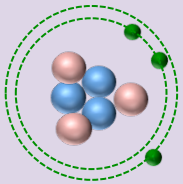


^{15}N
7 protons
8 neutrons

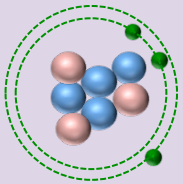
+1

NO_3^-

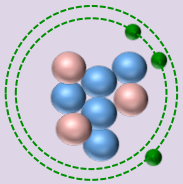
Isotopes de l'oxygène:



^{16}O
8 protons
8 neutrons



^{17}O
8 protons
9 neutrons

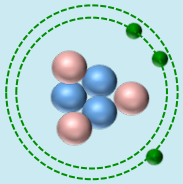


^{18}O
8 protons
10 neutrons

+1

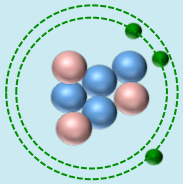
+2

Isotopes de l'azote:



^{14}N

99.63%

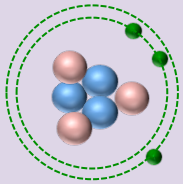


^{15}N

0.37%

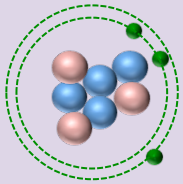
$\delta^{15}N$

Isotopes de l'oxygène:



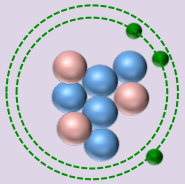
^{16}O

99.76%



^{17}O

0.04%



^{18}O

0.20%

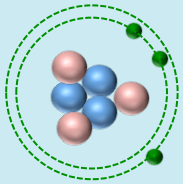
$\delta^{17}O$ $\delta^{18}O$

$$\delta^{n}O = \frac{(^{n}O/^{16}O)_{sample} - (^{n}O/^{16}O)_{ref}}{(^{n}O/^{16}O)_{ref}}$$

(n = 17 ou 18)

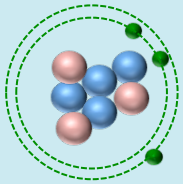
Mesurés en ‰

Isotopes de l'azote:



^{14}N

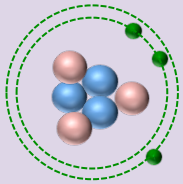
99.63%



^{15}N

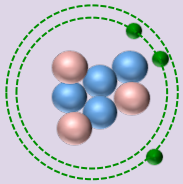
0.37%

Isotopes de l'oxygène:



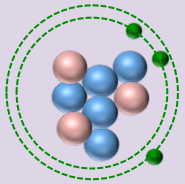
^{16}O

99.76%



^{17}O

0.04%



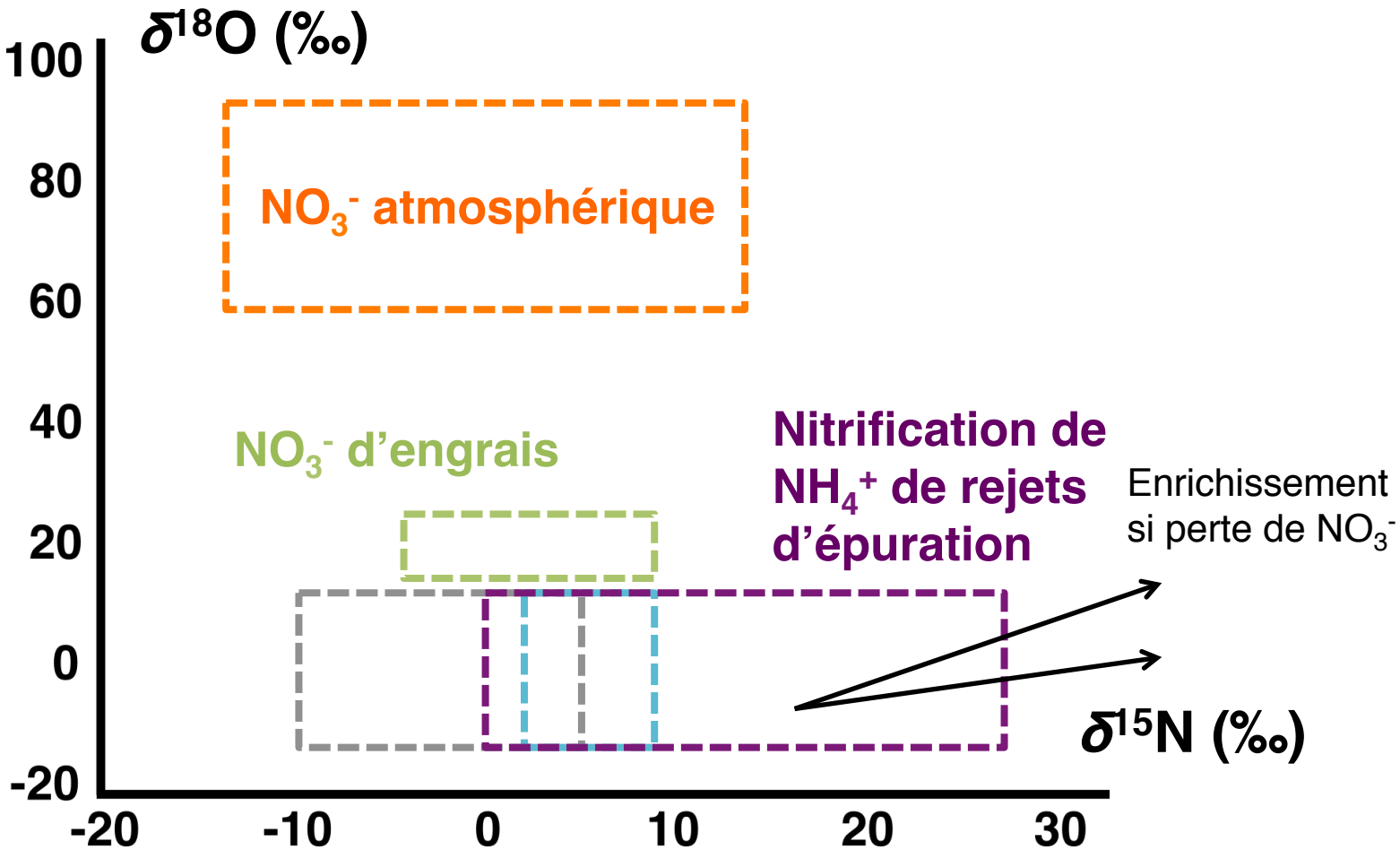
^{18}O

0.20%

$\delta^{15}N$ $\delta^{17}O$ $\delta^{18}O$

D'après Kendall et al. (2007)

Sources de NO_3^-

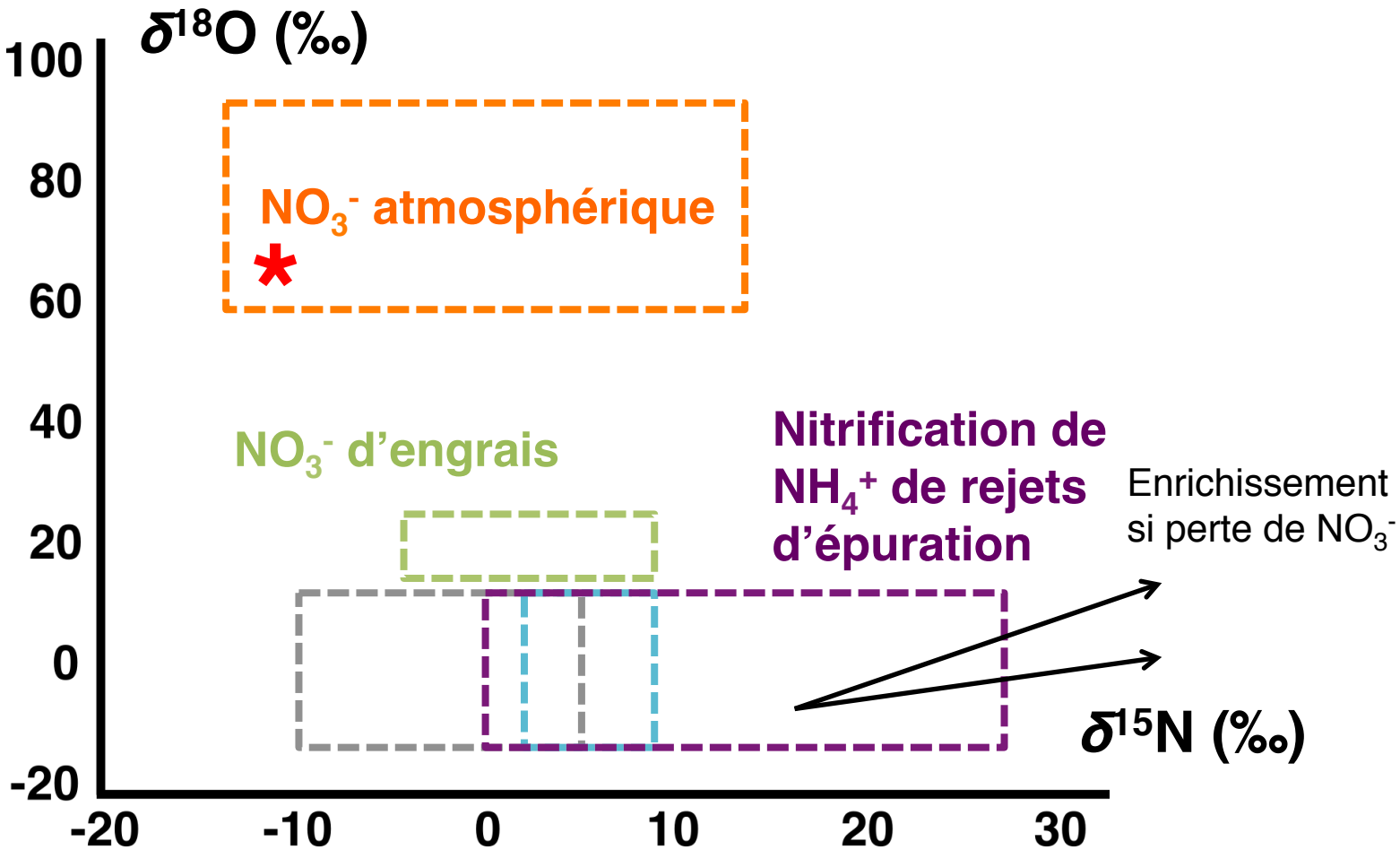


Nitrification de NH_4^+ atmosphérique

Nitrification de NH_4^+ du sol

D'après Kendall et al. (2007)

Sources de NO_3^-



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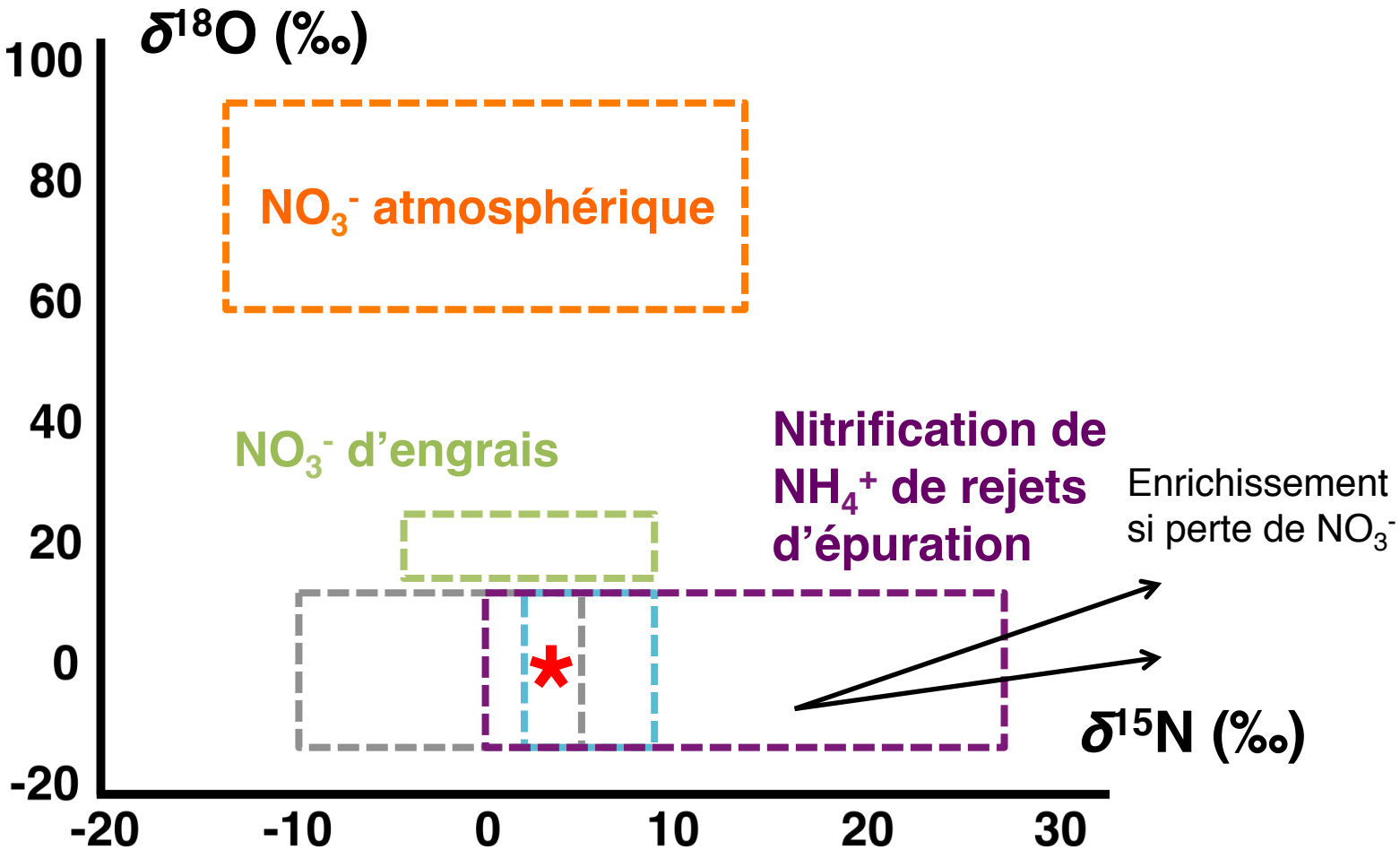

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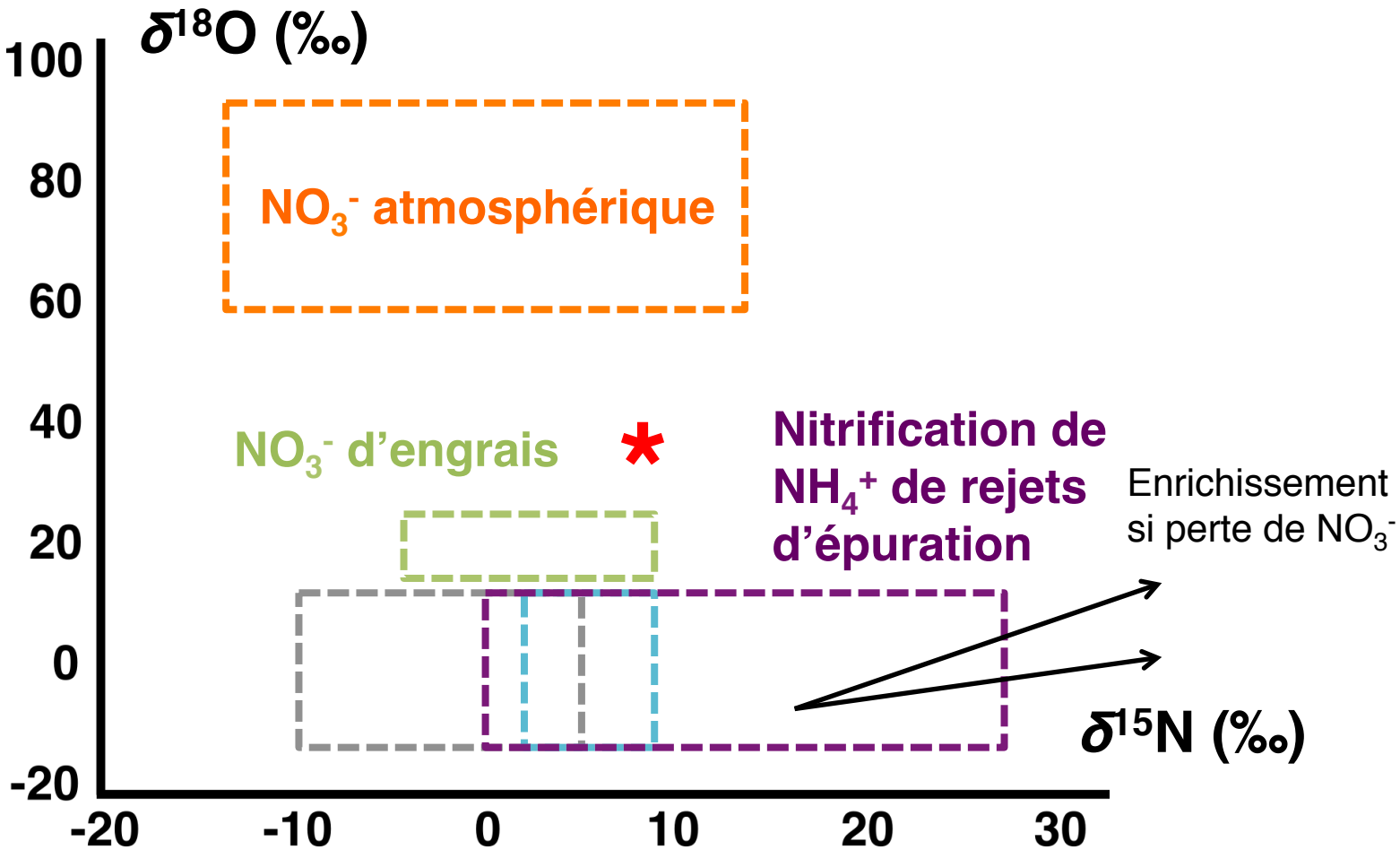
Nitrification de NH_4^+ du sol

D'après Kendall et al. (2007)

Sources de NO_3^-

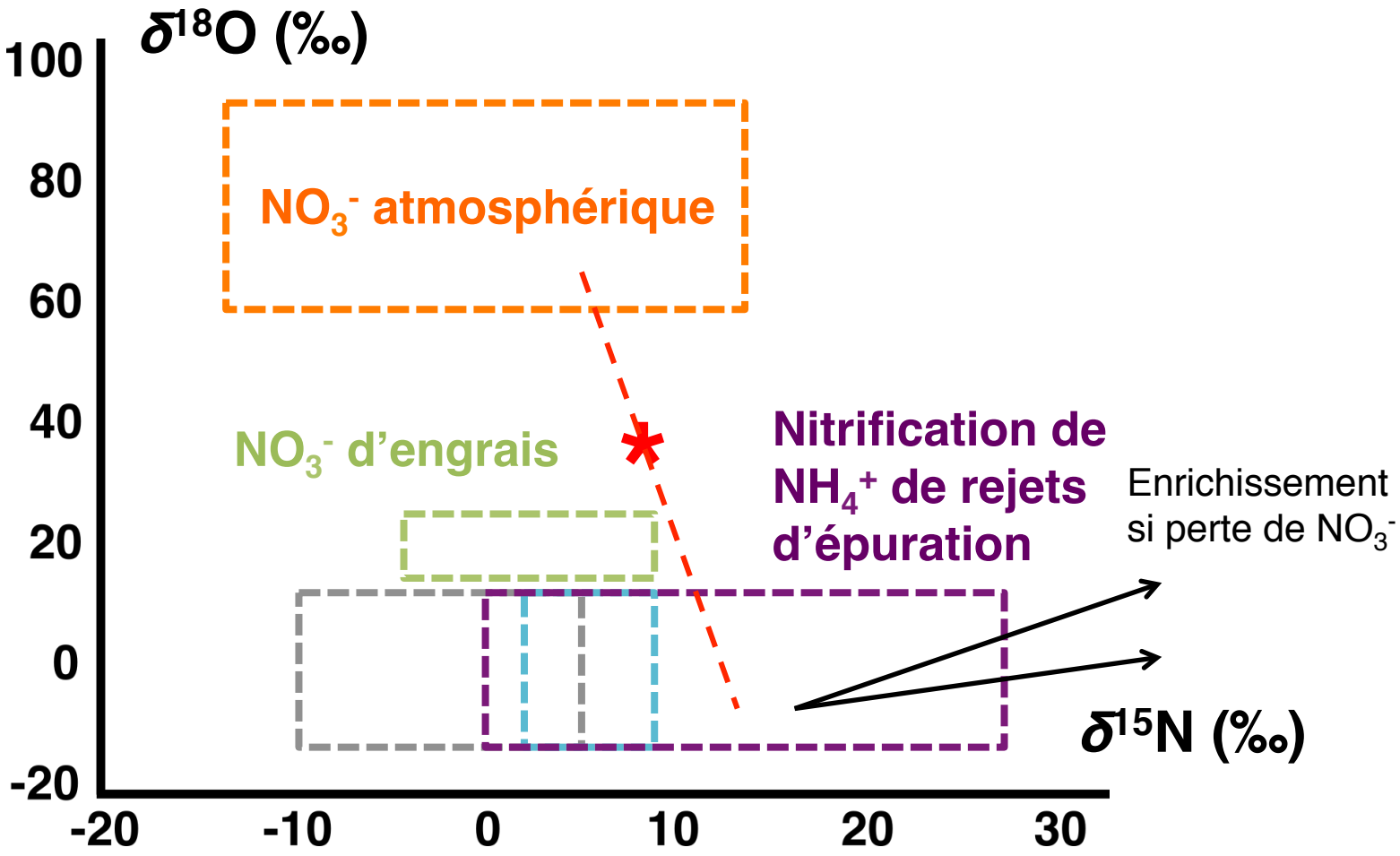


Nitrification de NH_4^+ atmosphérique

Nitrification de NH_4^+ du sol

D'après Kendall et al. (2007)

Sources de NO_3^-

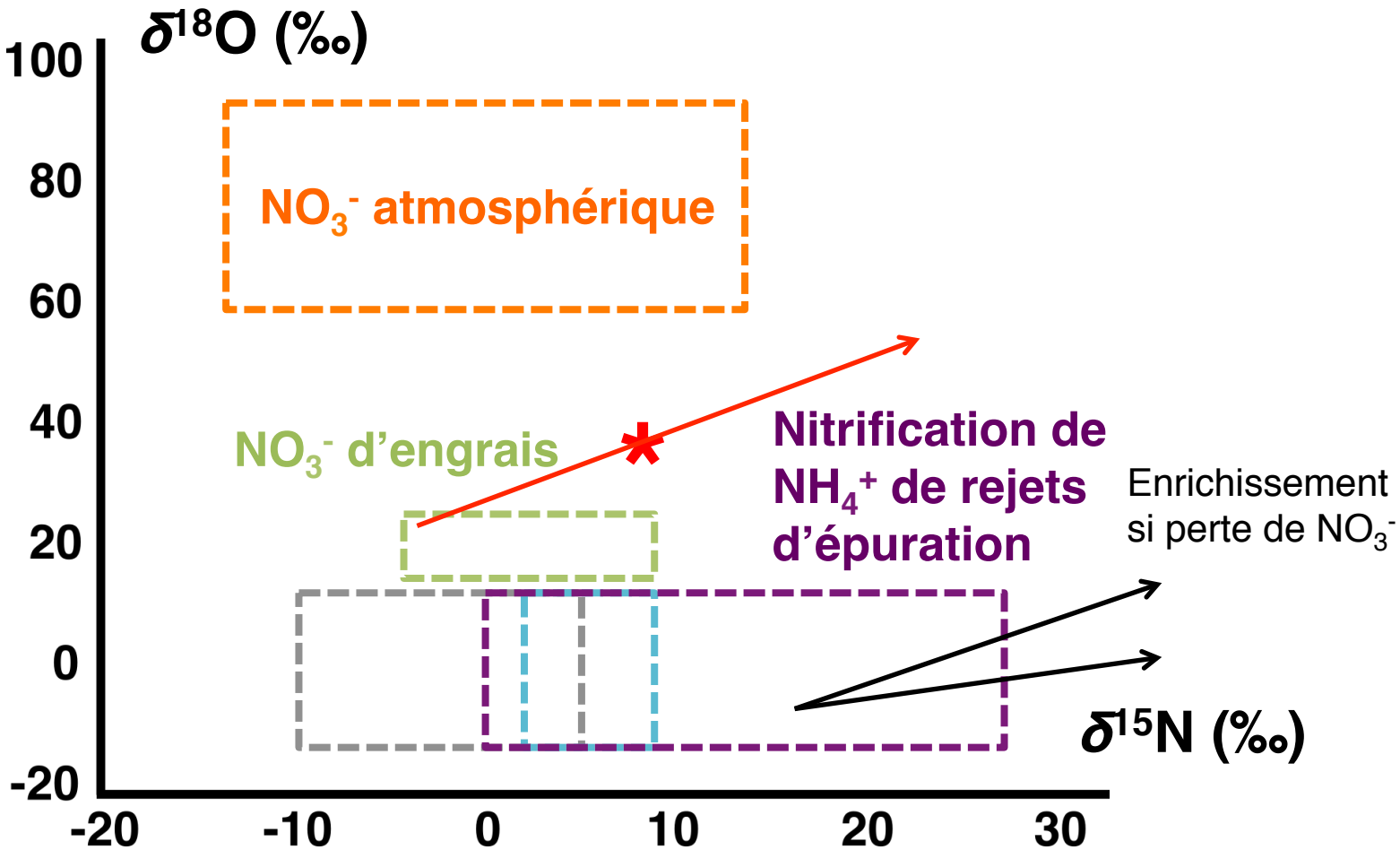


Nitrification de NH_4^+ atmosphérique

Nitrification de NH_4^+ du sol

D'après Kendall et al. (2007)

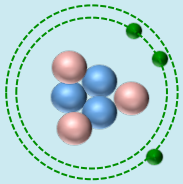
Sources de NO_3^-



Nitrification de NH_4^+ atmosphérique

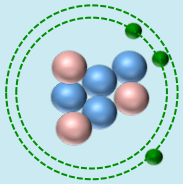
Nitrification de NH_4^+ du sol

Isotopes de l'azote:



^{14}N

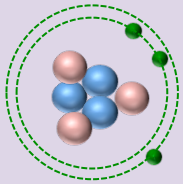
99.63%



^{15}N

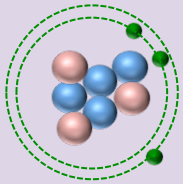
0.37%

Isotopes de l'oxygène:



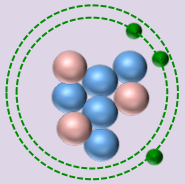
^{16}O

99.76%



^{17}O

0.04%



^{18}O

0.20%

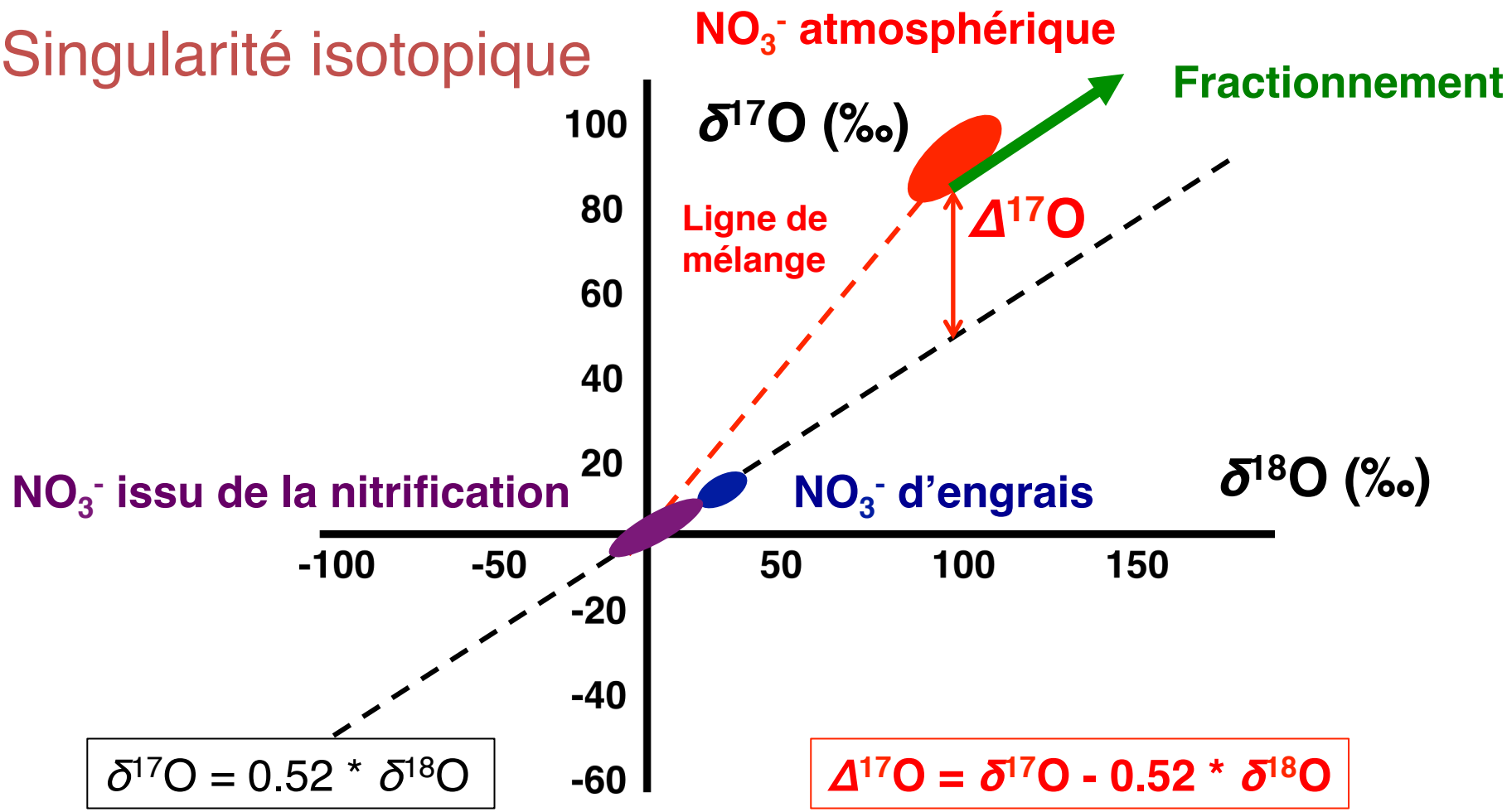
$\delta^{15}N$ $\delta^{17}O$ $\delta^{18}O$

+1

+2

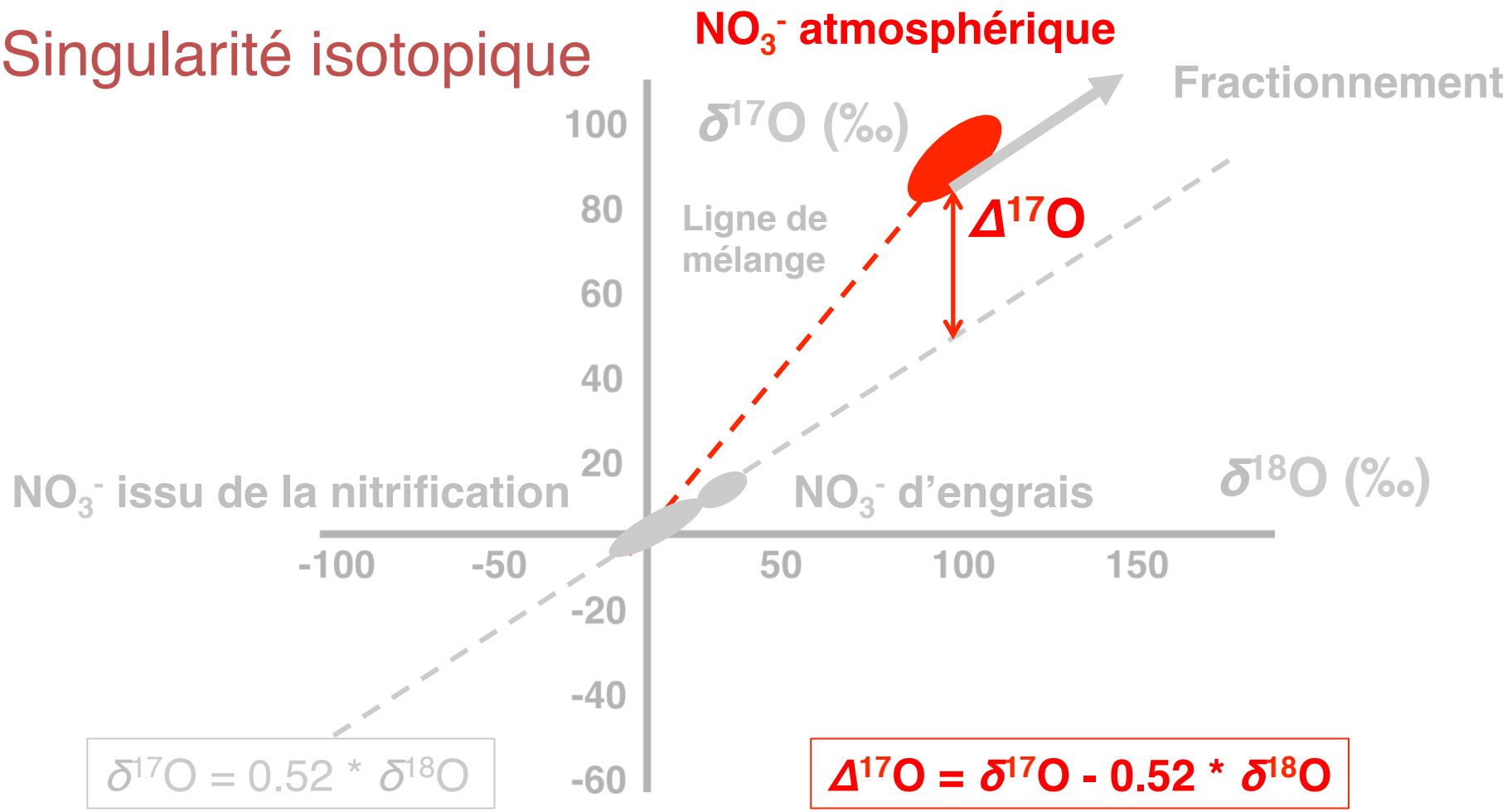
$$\delta^{17}O = 0.52 * \delta^{18}O$$

Singularité isotopique



D'après Michalski et al. (2002)

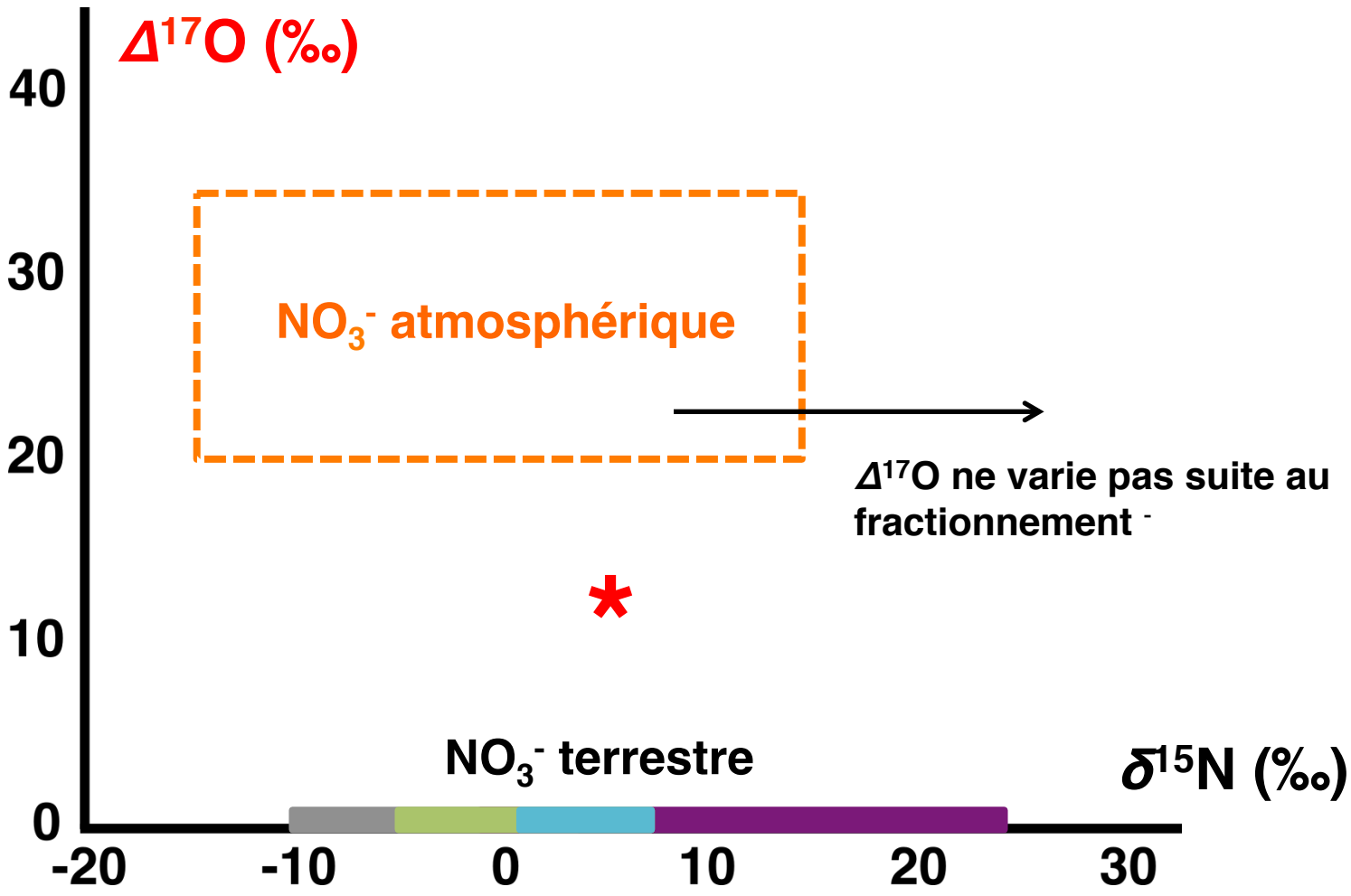
Singularité isotopique



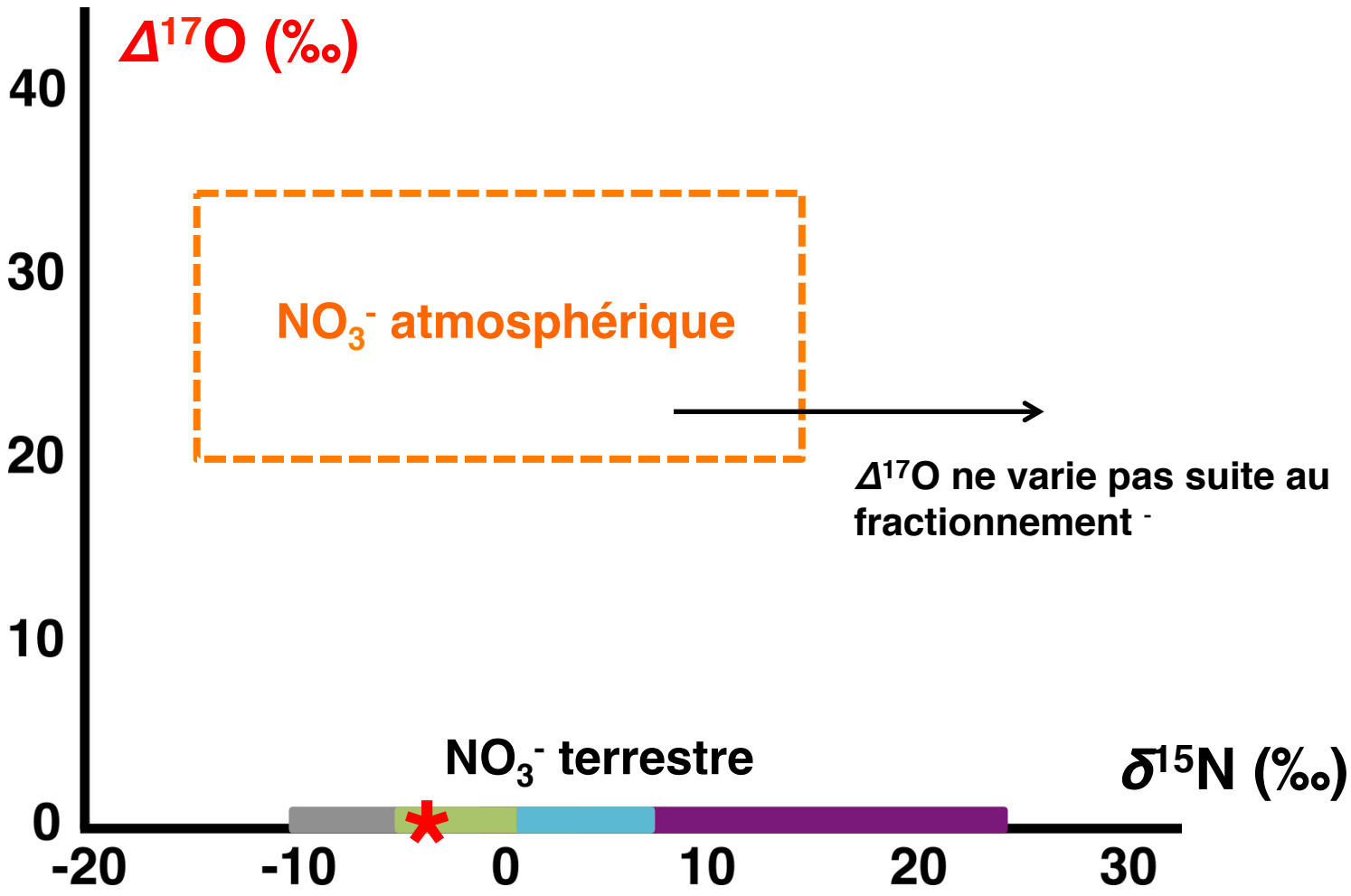
Si $\Delta^{17}O = 0$ Pas de NO_3^- atmosphérique

Si $\Delta^{17}O > 0$ NO_3^- atmosphérique

Sources de NO_3^-



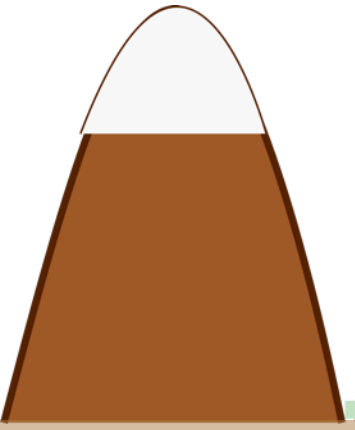
Sources de NO_3^-



N_2 atmosphérique

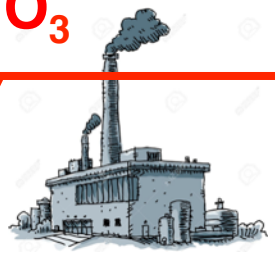
$f_{atm} = (\Delta^{17}O_{éch} / \Delta^{17}O_{atm})$

$\Delta^{17}O_{atm} > 20‰$

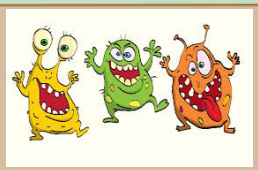


O_3 NO NO_2

HNO_3



Dépôts atmosphériques



Nr

Ammonification

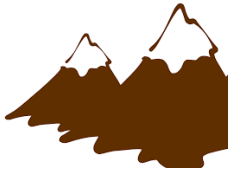
$\Delta^{17}O_{ter} = 0$

Nitrification

$NH_4^+ \rightarrow NO_2^- \rightarrow$ **NO_3^-**

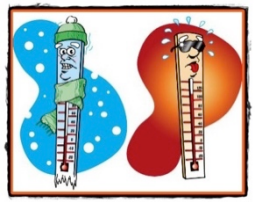
$\Delta^{17}O_{éch}$?

2100 m



600 mm

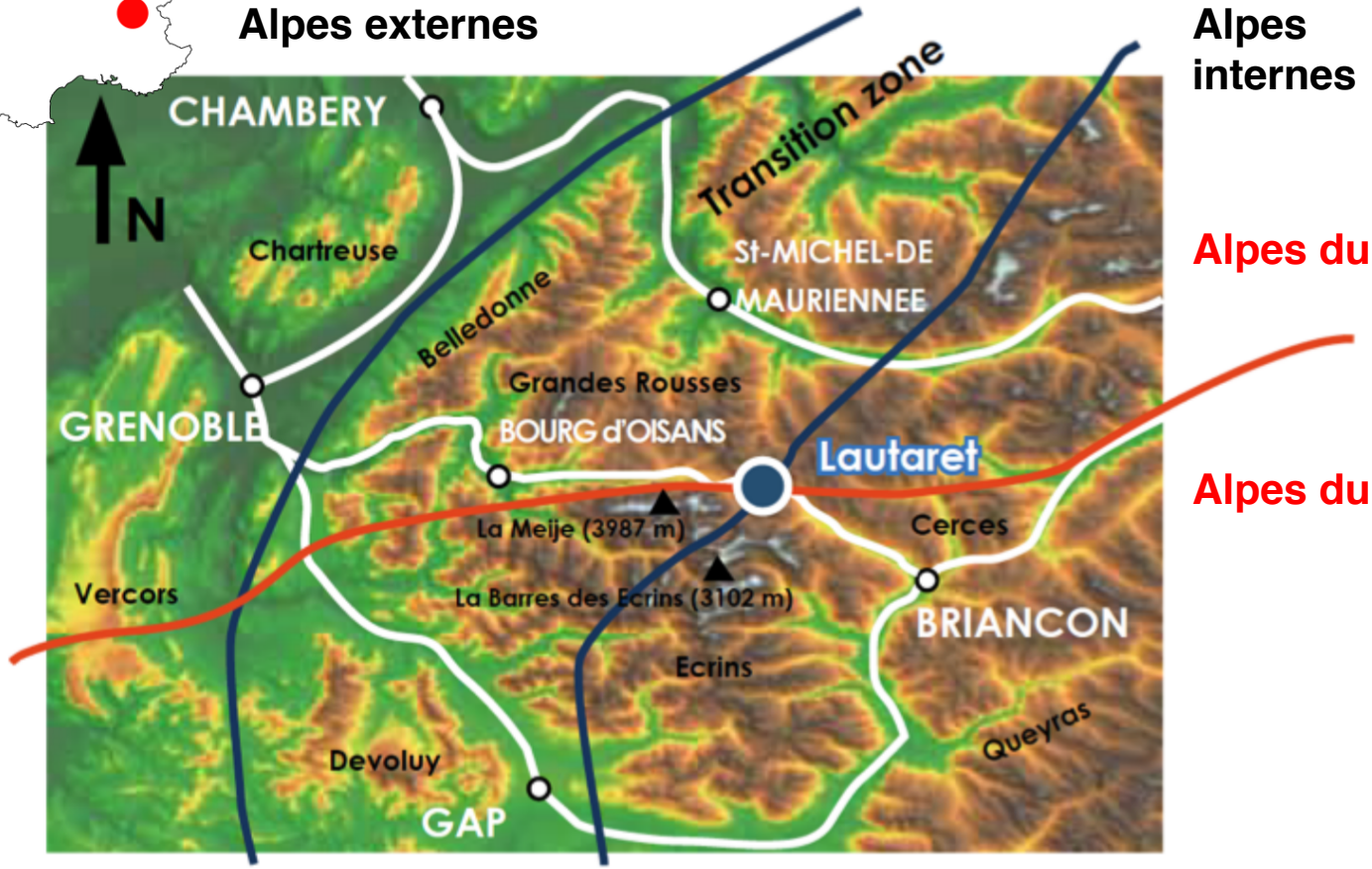
-7°C



14°C

Alpes externes

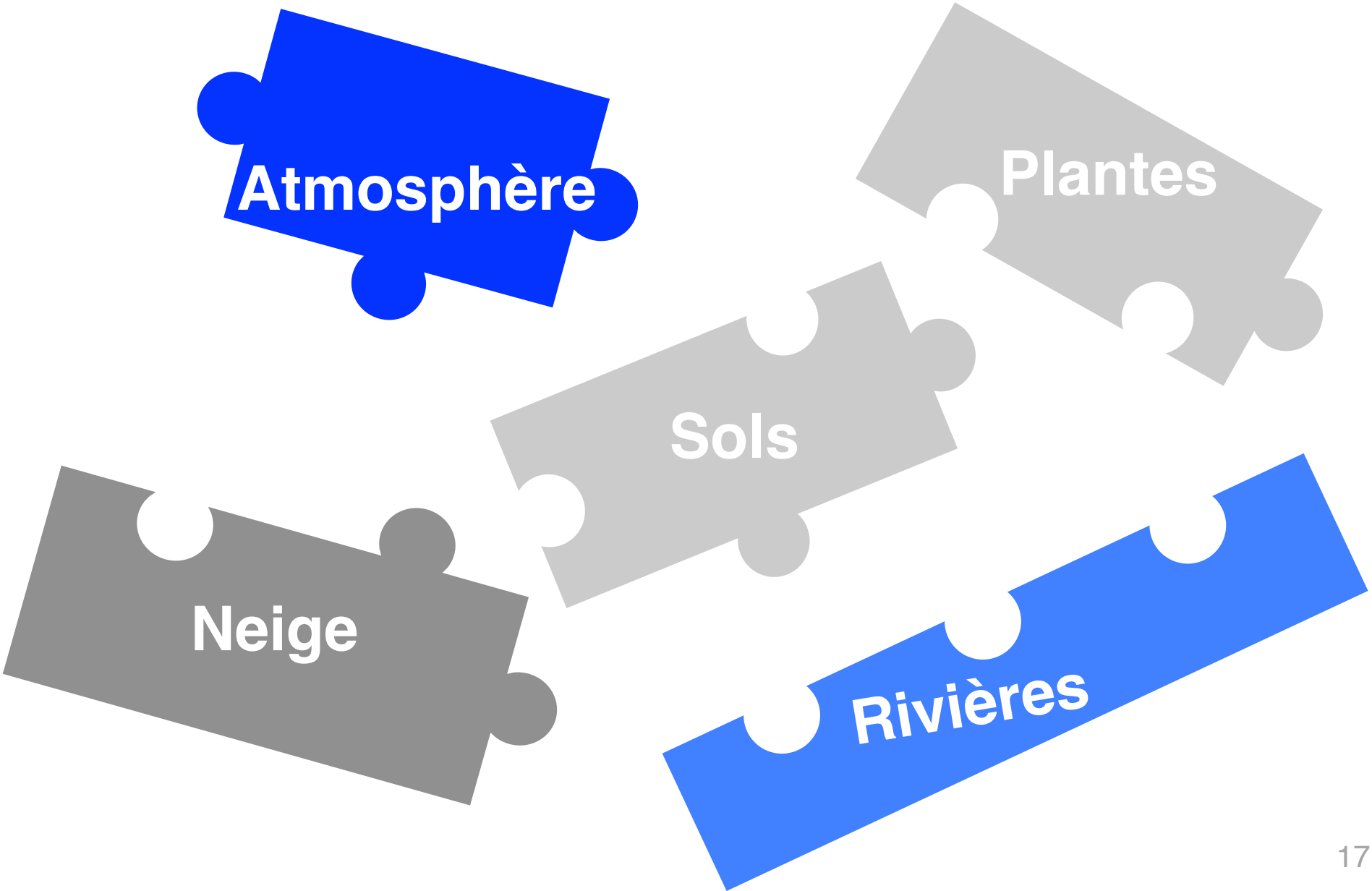
Alpes internes



Alpes du Nord

Alpes du Sud

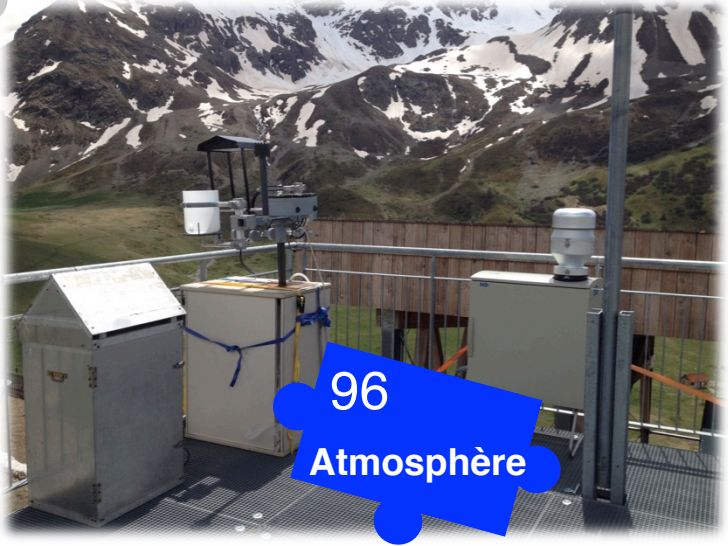
After Baptist (2007)


Atmosphère
Plantes
Sols
Neige
Rivières

164 Neige

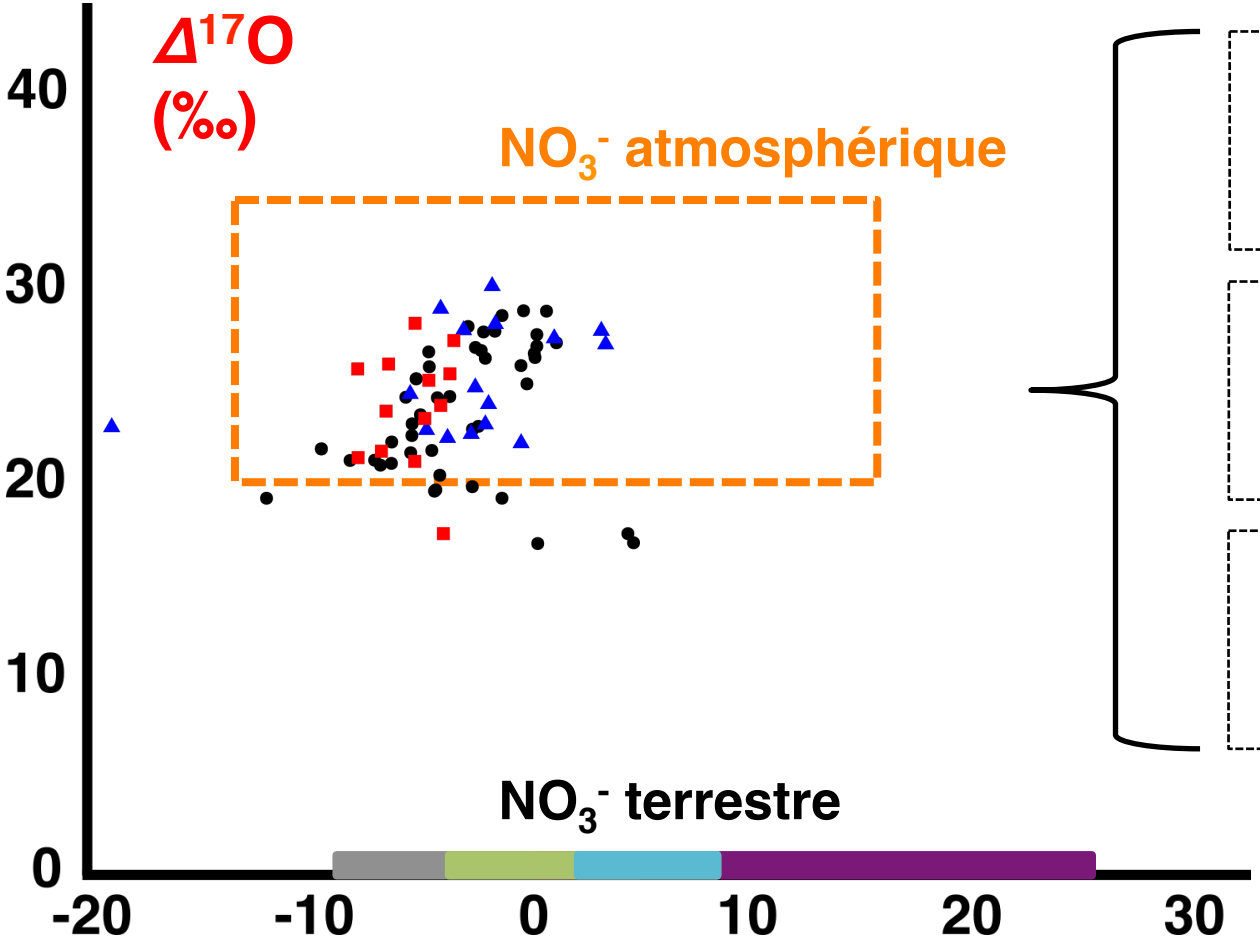
320 Plantes

566 Rivières



96 Atmosphère

231 Sols



Aérosols

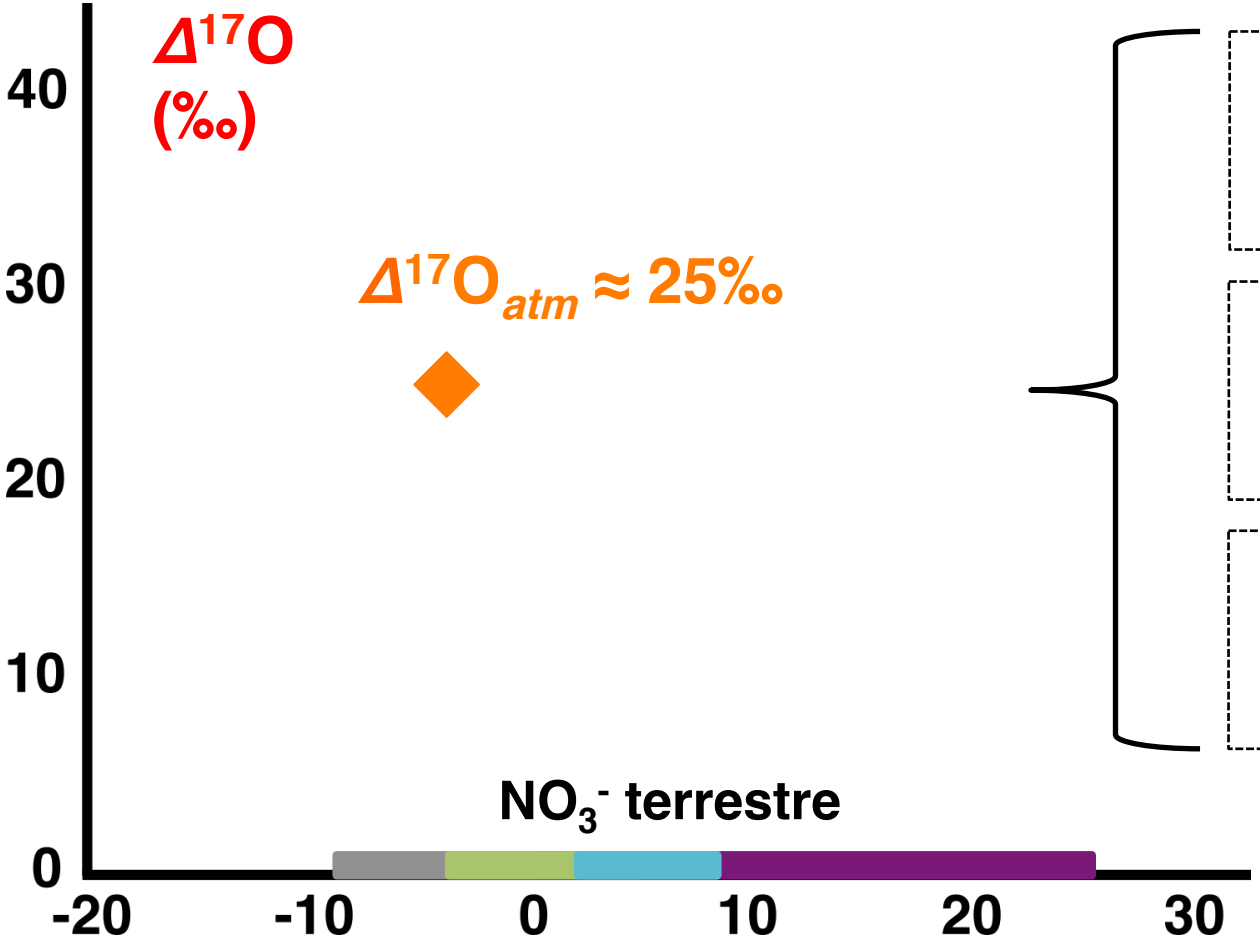
$\Delta^{17}O$ = 24.0 ± 5.1 ‰

Dépôts secs

$\Delta^{17}O$ = 26.4 ± 3.2 ‰

Dépôts humides

$\Delta^{17}O$ = 24.7 ± 3.5 ‰



Aérosols

$\Delta^{17}O = 24.0 \pm 5.1$ ‰

Dépôts secs

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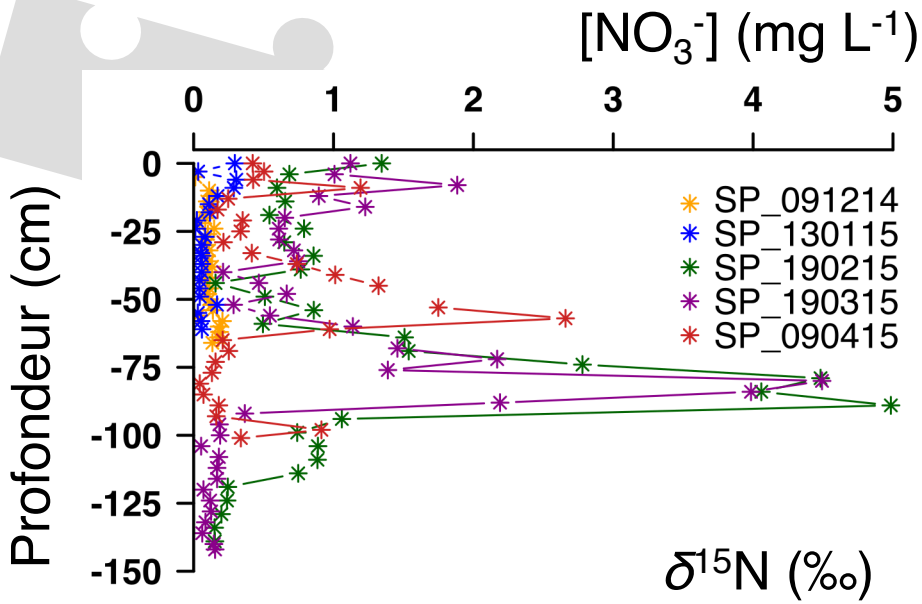
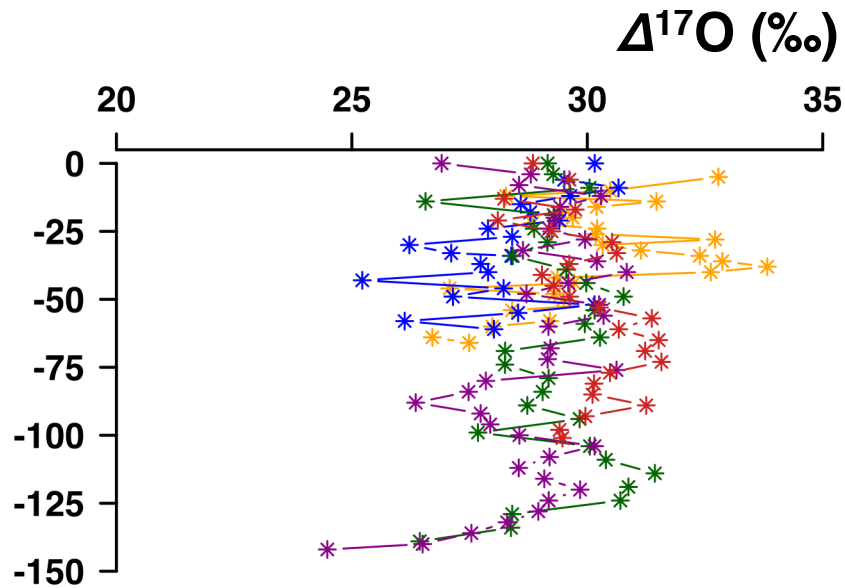
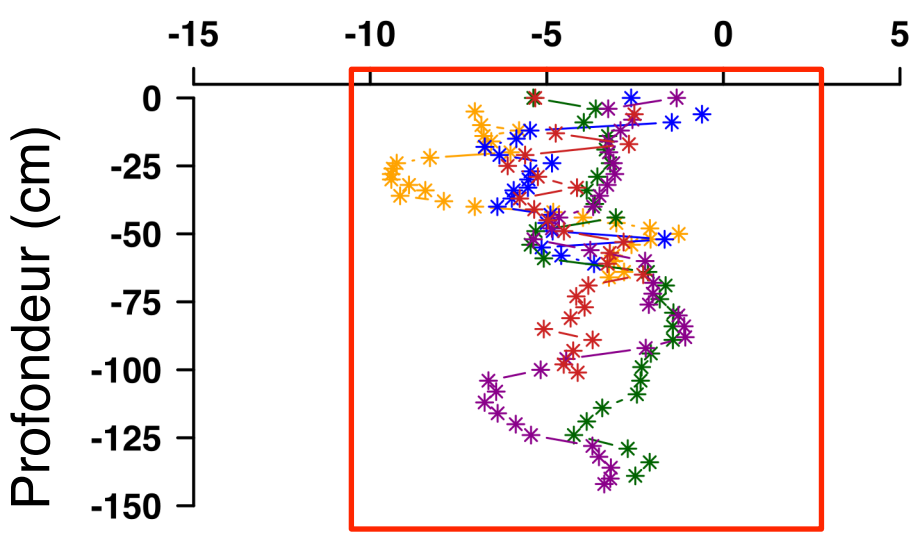
Dépôts humides

$\Delta^{17}O = 24.7 \pm 3.5$ ‰



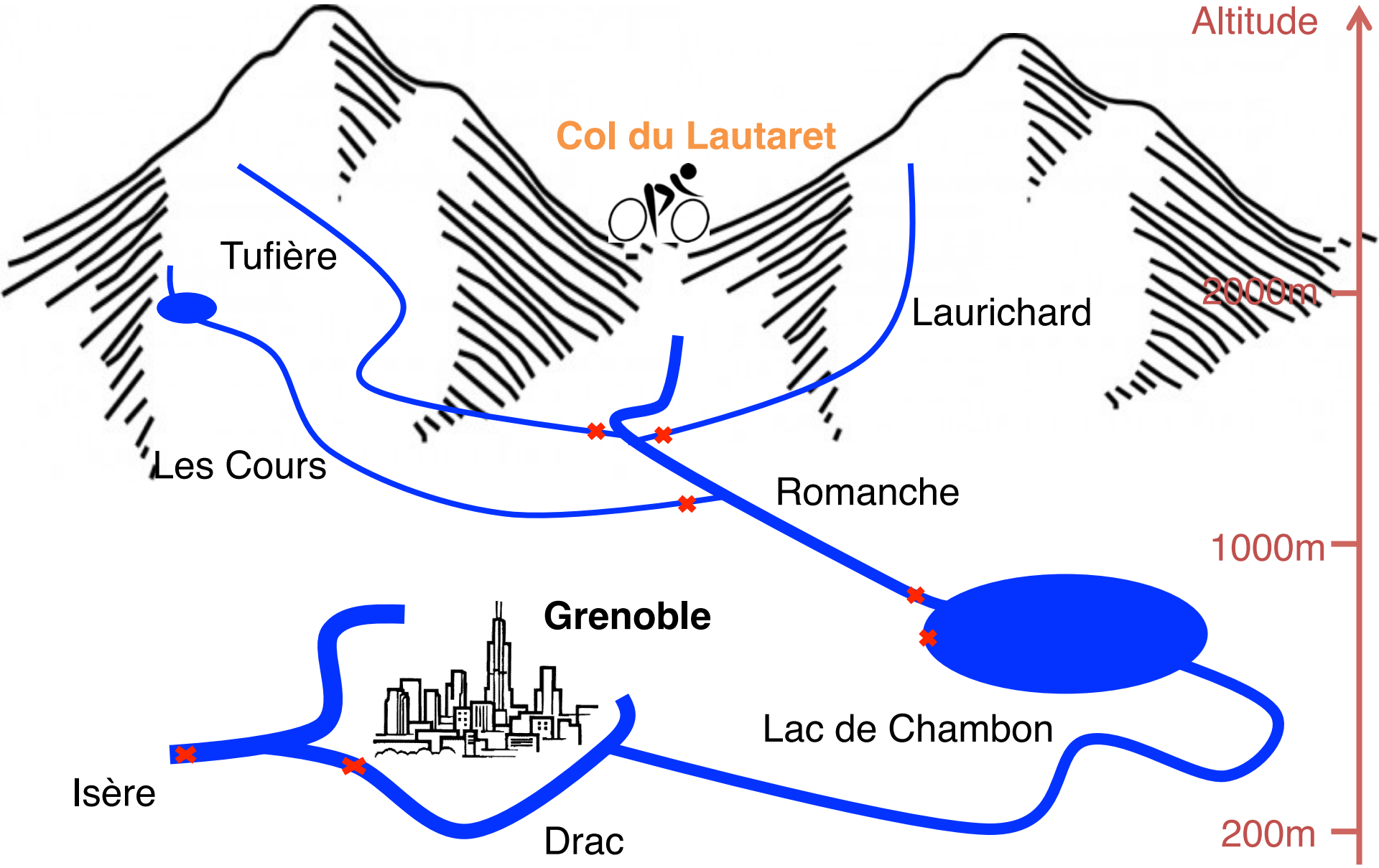


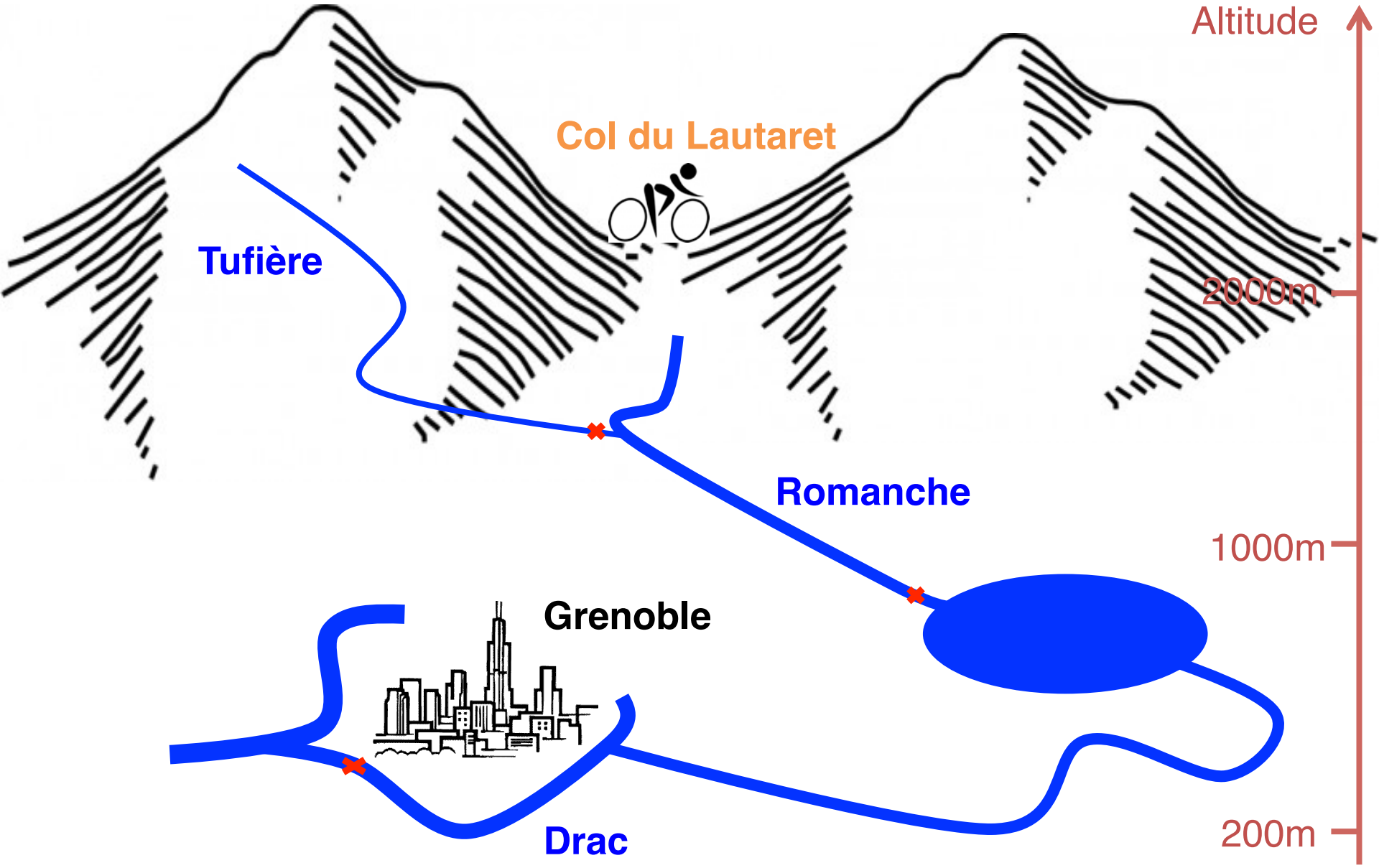


100% $NO_3^-{}_{atm}$

$\Delta^{17}O = 29.3 \pm 1.6$ ‰

Peu de perte de NO_3^-

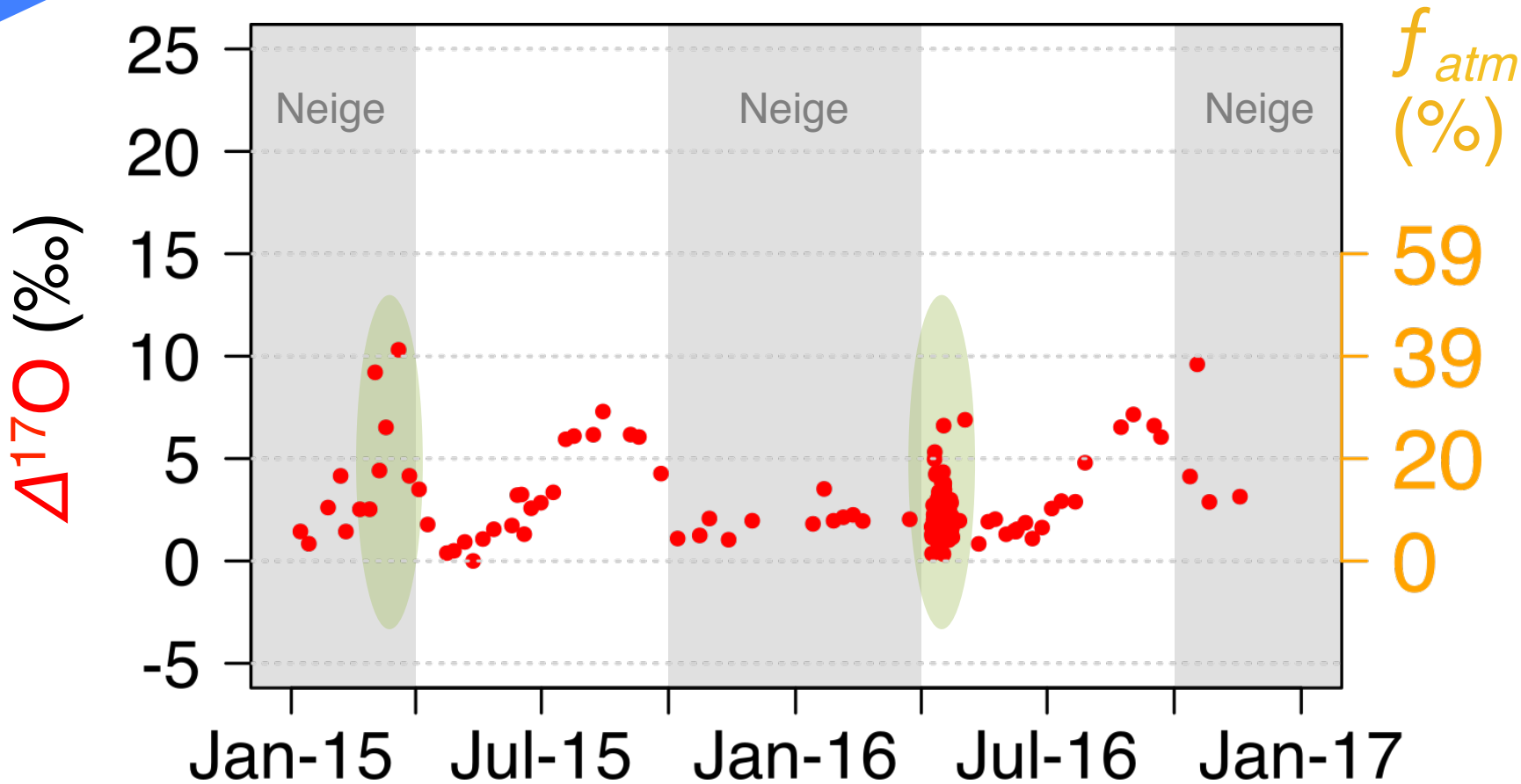

Altitude
Col du Lautaret
Tufière
Laurichard
2000m
Les Cours
Romanche
1000m
Grenoble
Lac de Chambon
Isère
Drac
200m


Altitude
Col du Lautaret
Tufière
2000m
Romanche
1000m
Grenoble
Drac
200m

Rivières

$f_{atm} = (\Delta^{17}O_{éch} / 29.3)$

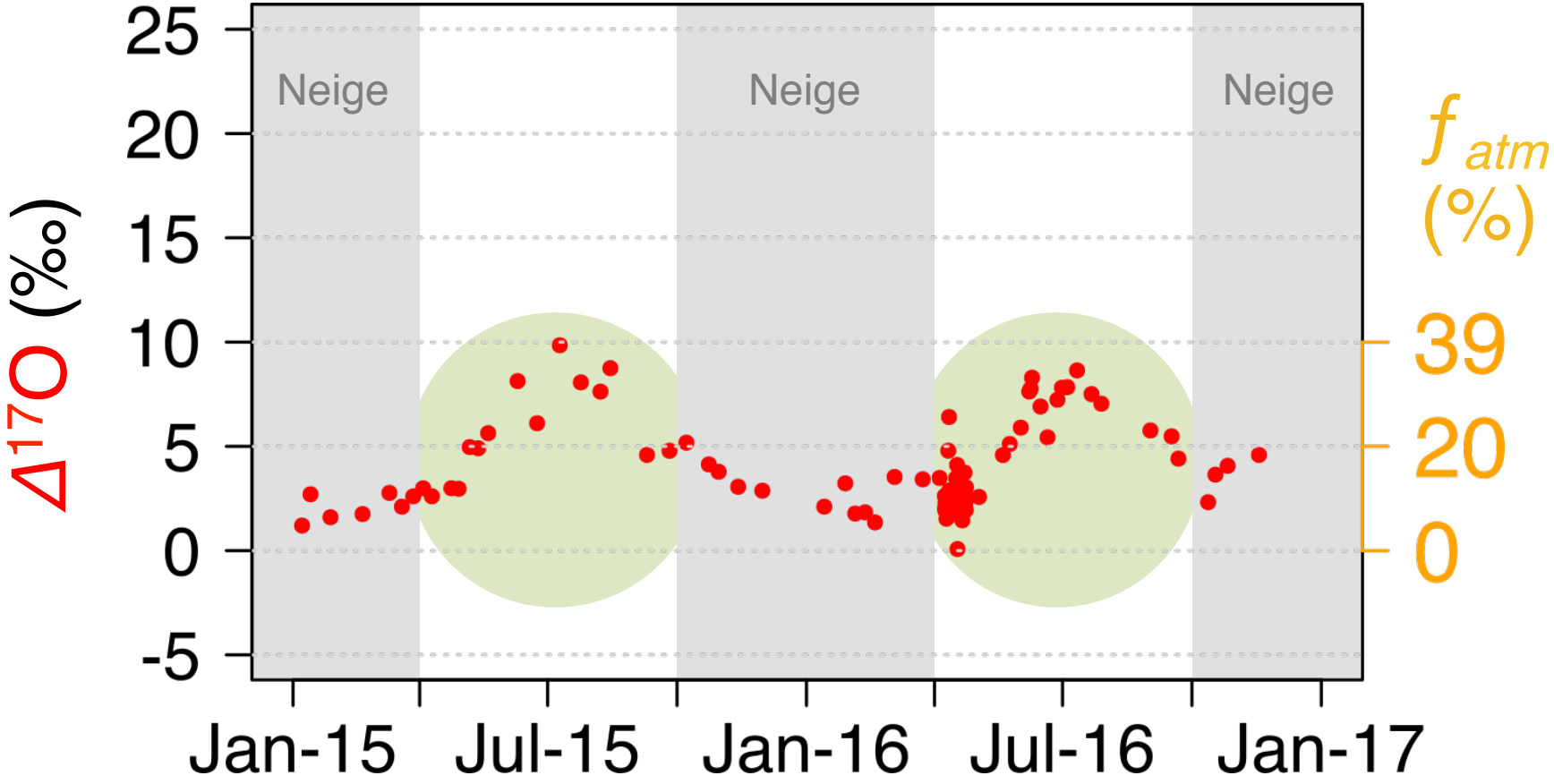
Tufière



$f_{atm} = (\Delta^{17}O_{éch} / 29.3)$

Rivières

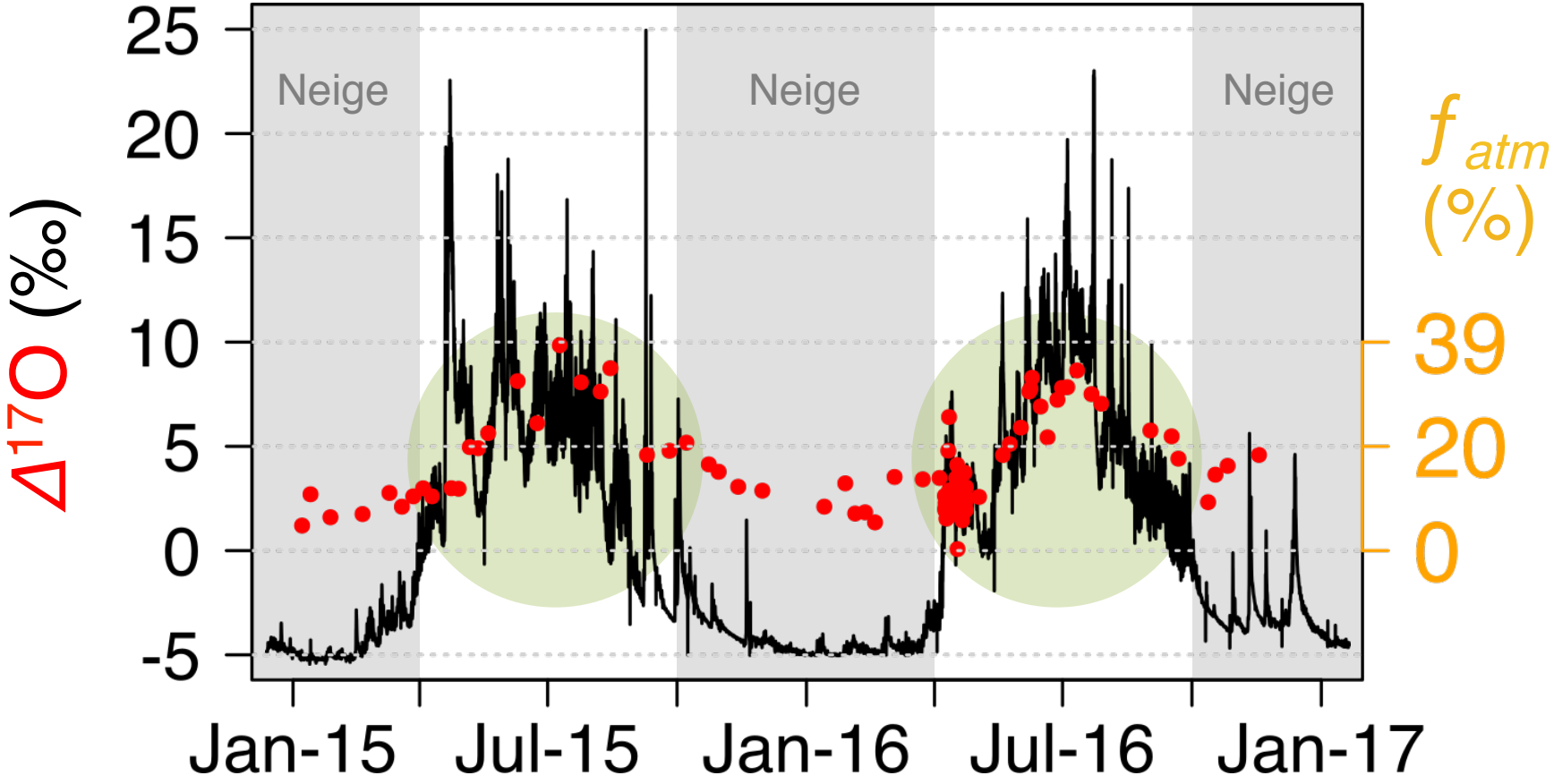
Romanche



$f_{atm} = (\Delta^{17}O_{éch} / 29.3)$

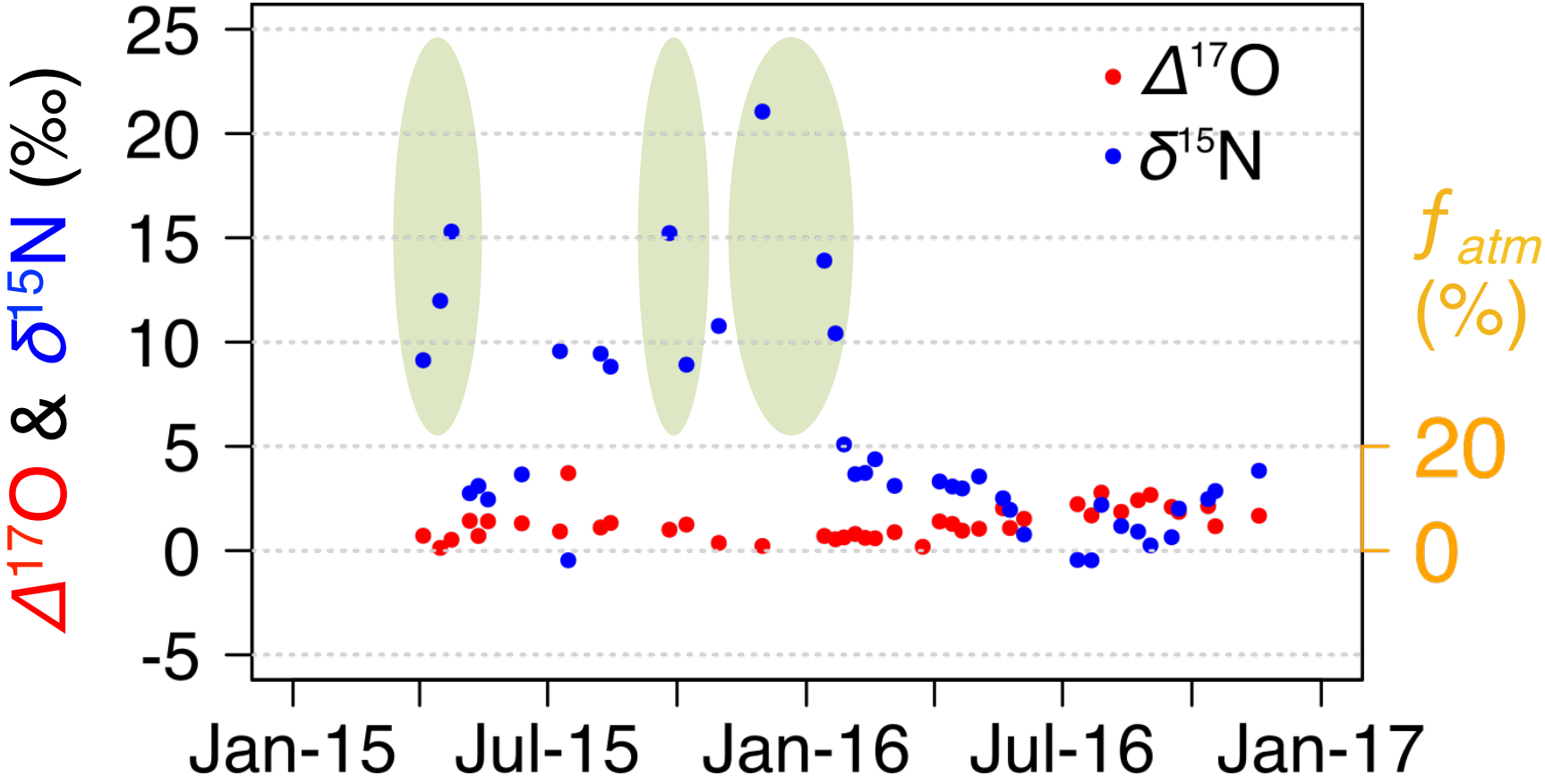
Rivières

Romanche

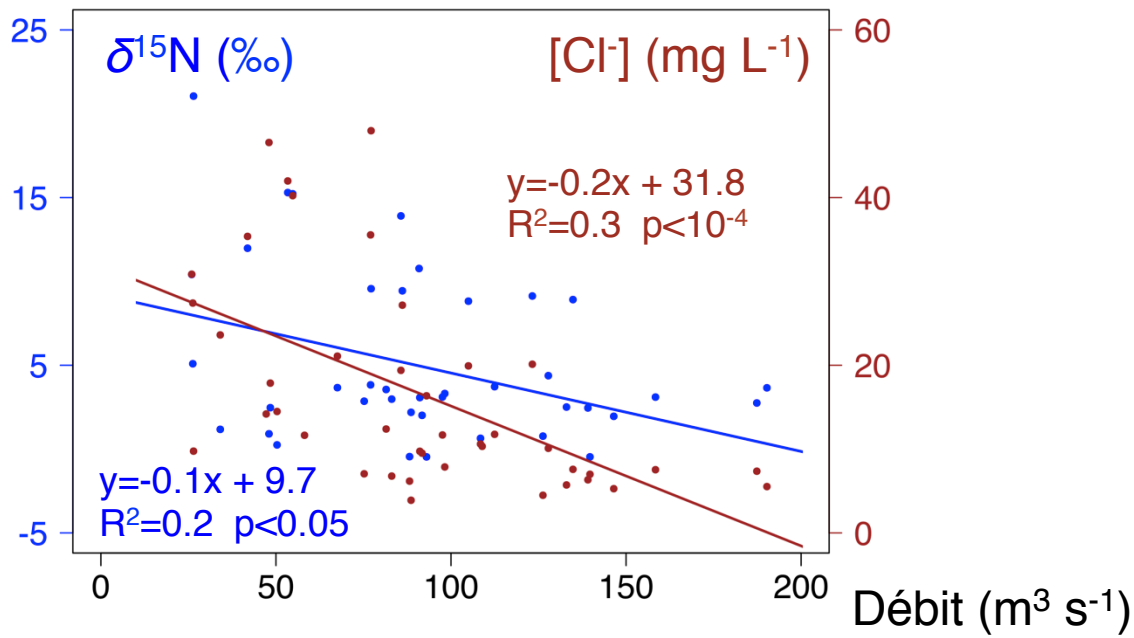


$f_{atm} = (\Delta^{17}O_{éch} / 25.6)$

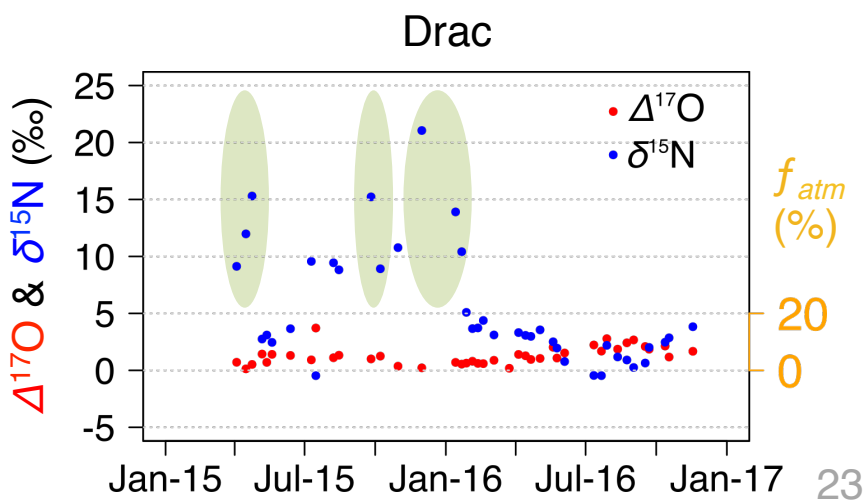
Rivières



Rivières



$\delta^{15}N$ & Cl^- : eaux usées



Rivières

Flux de NO_3^- et de $NO_3^-{}_{atm}$

Romanche

1-2 kg N-NO_3^- ha^{-1} yr^{-1}

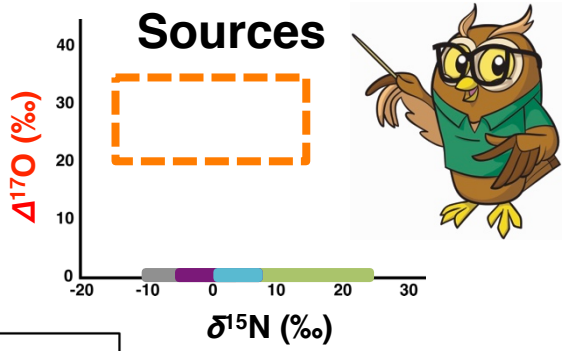
0.3-0.4 kg N-$NO_3^-{}_{atm}$ ha^{-1} yr^{-1}

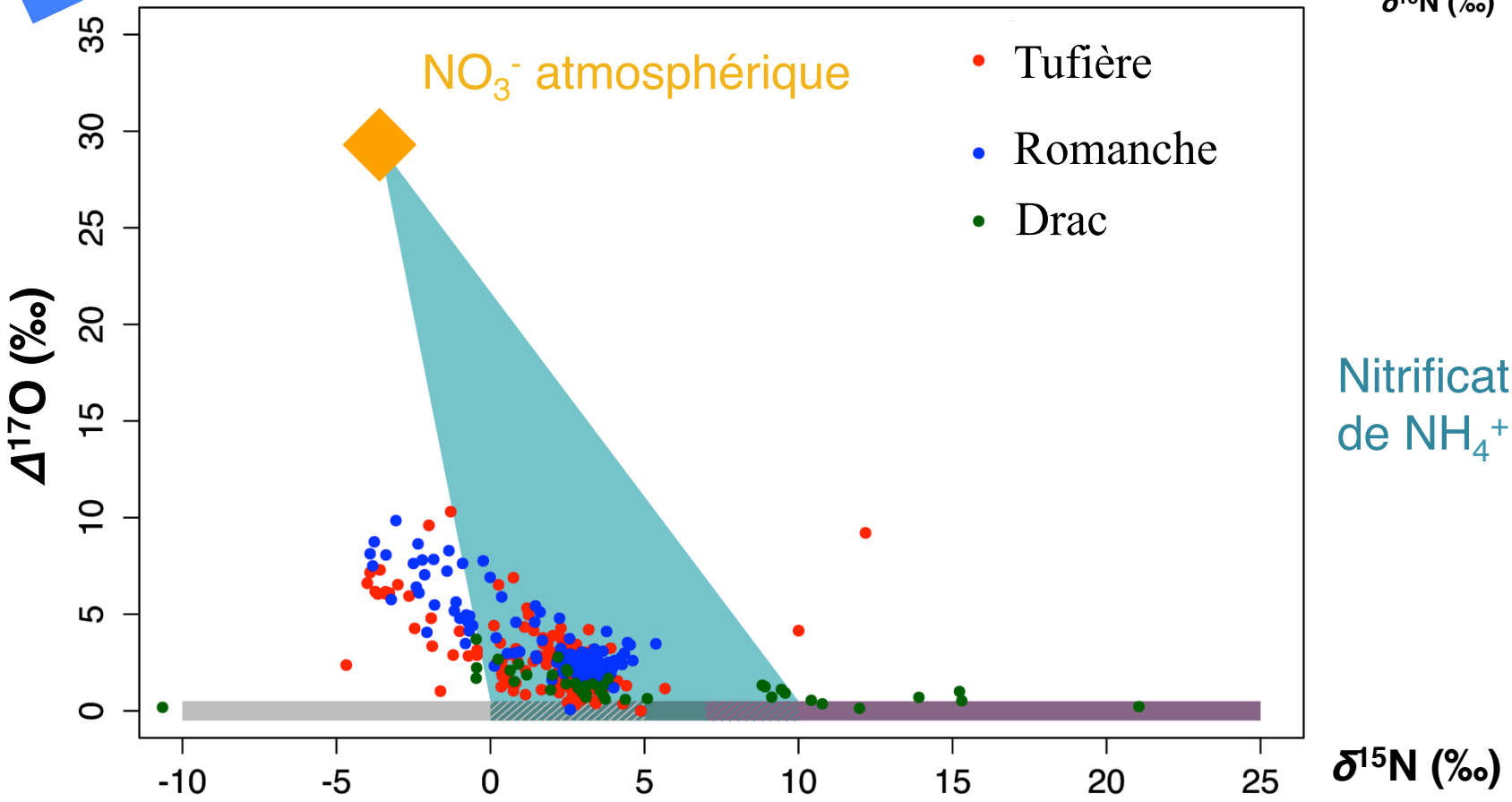
Drac

2-4 kg N-NO_3^- ha^{-1} yr^{-1}

0.1-0.2 kg N-$NO_3^-{}_{atm}$ ha^{-1} yr^{-1}

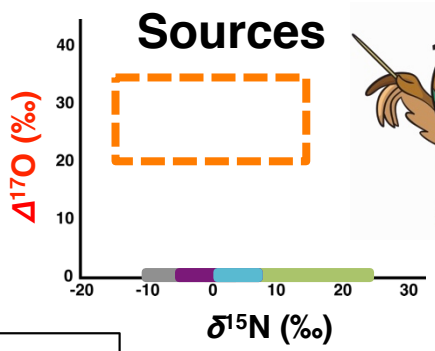
Rivières

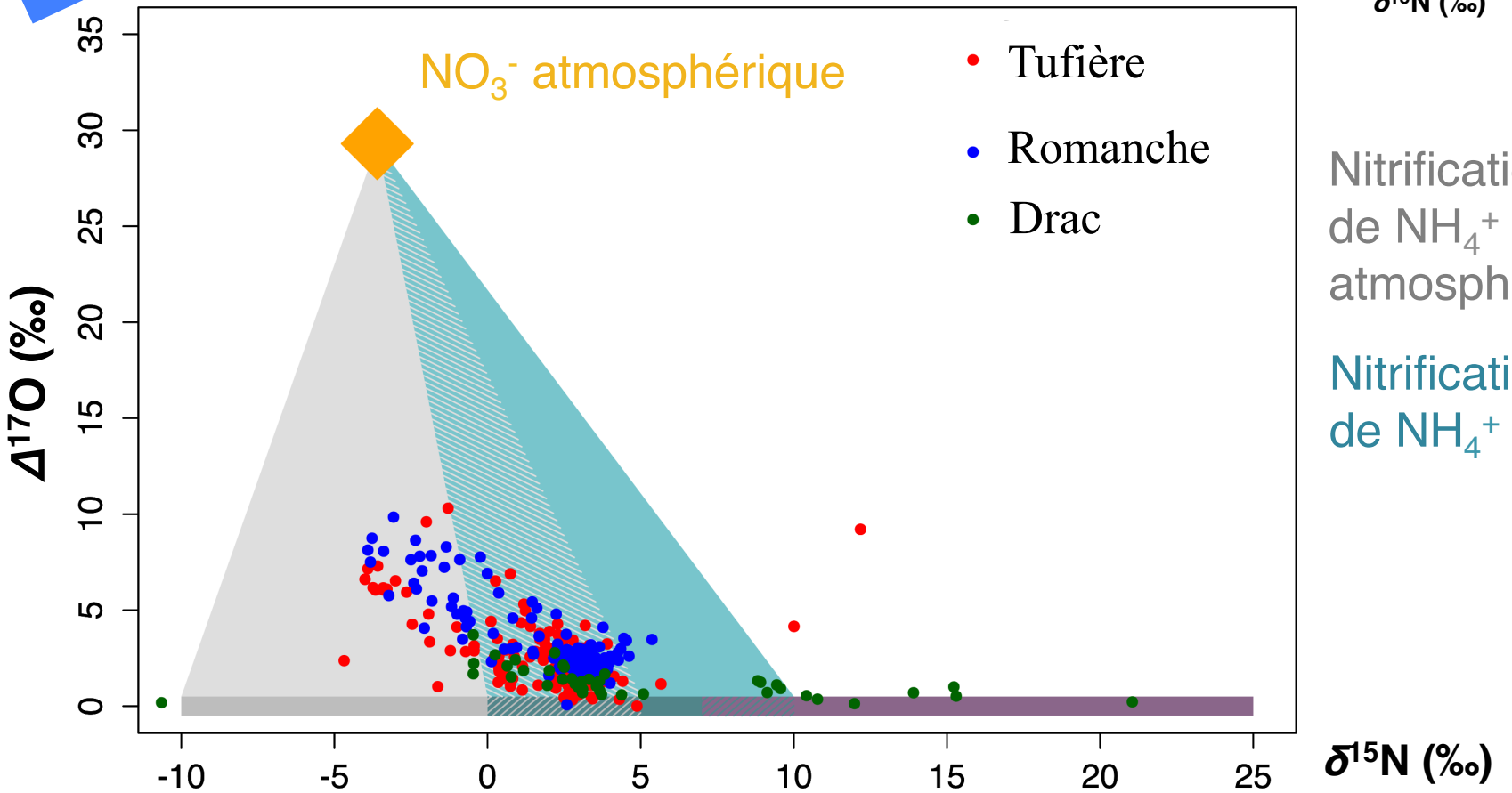




Nitrification de NH_4^+ du sol

Rivières

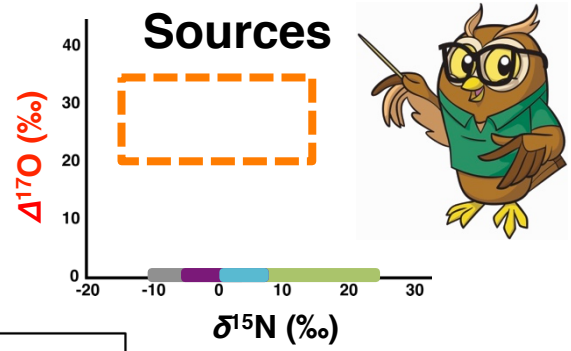


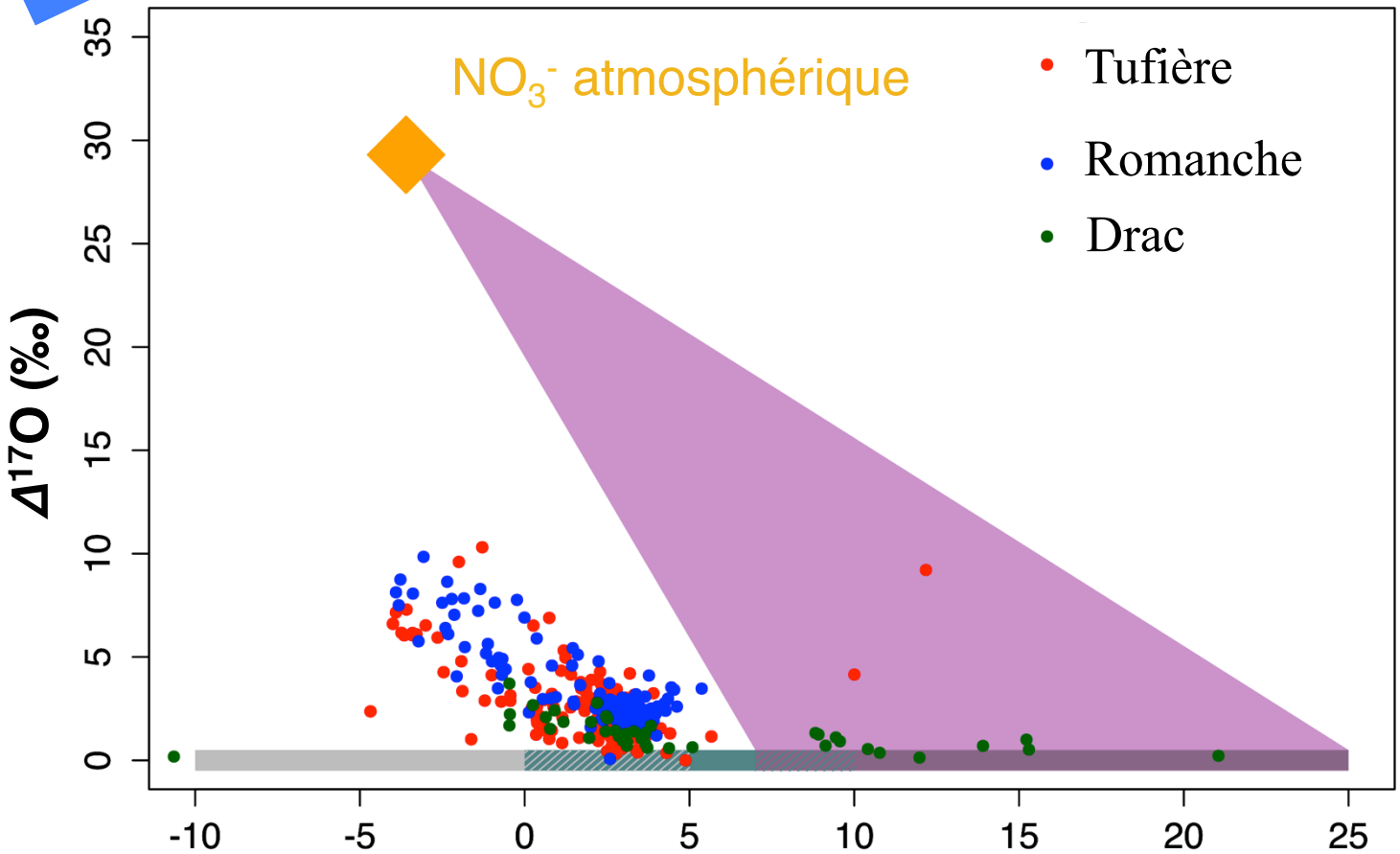


Nitrification de NH_4^+ atmosphérique

Nitrification de NH_4^+ du sol

Rivières



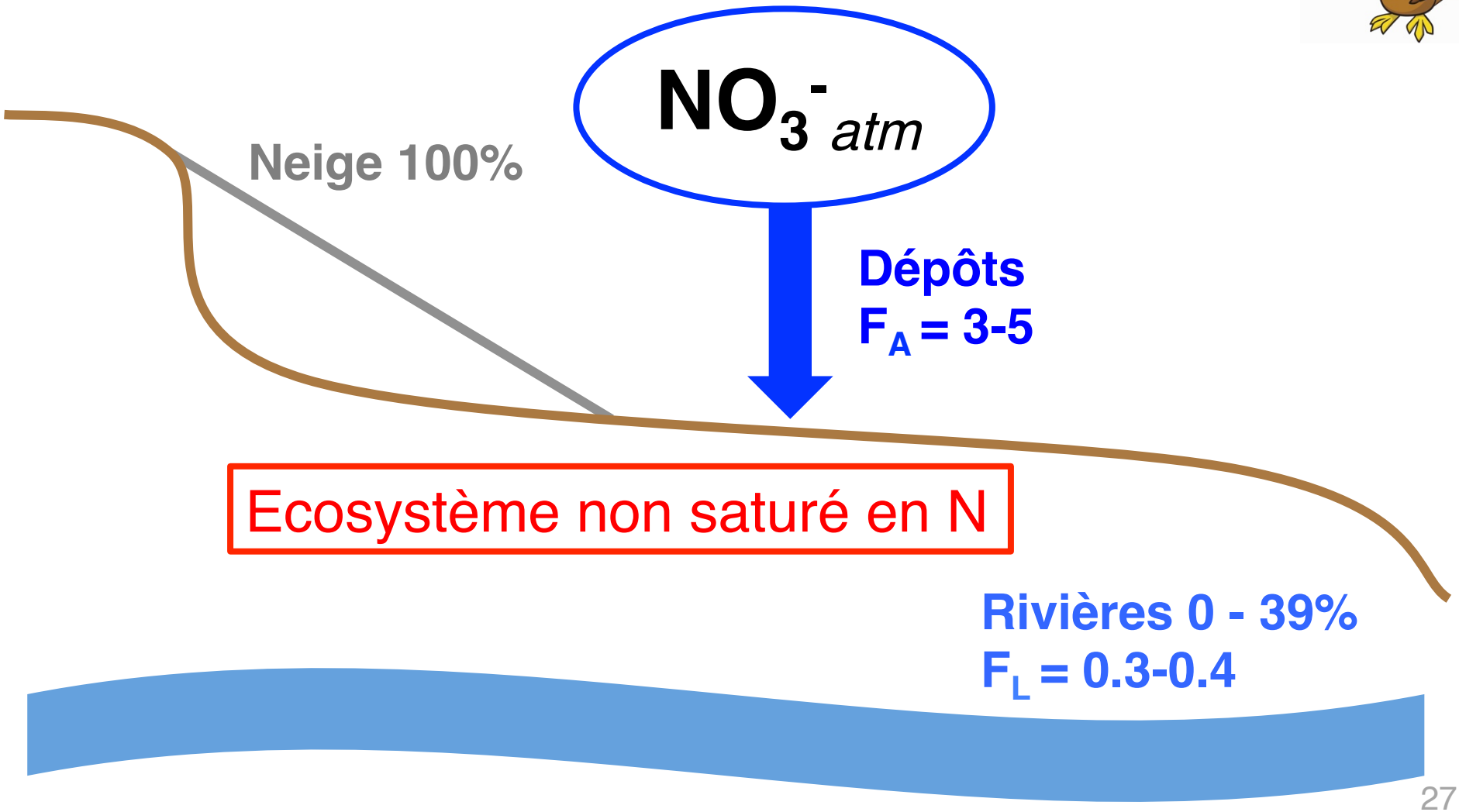


Nitrification de NH_4^+ de rejets d'épuration

$\Delta^{17}O$

Romanche

Flux en
kg N-$NO_3^-{}_{atm}$ ha^{-1} yr^{-1}



CONCLUSION

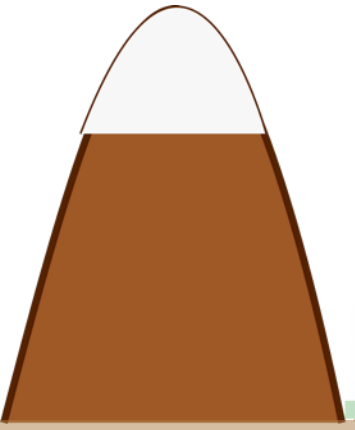
Dépôts atmosphériques

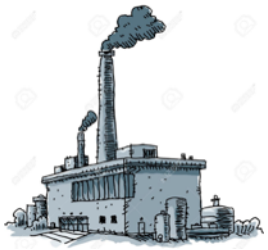
Transport

Seuil critique : 1-4 kg N ha^{-1} yr^{-1}

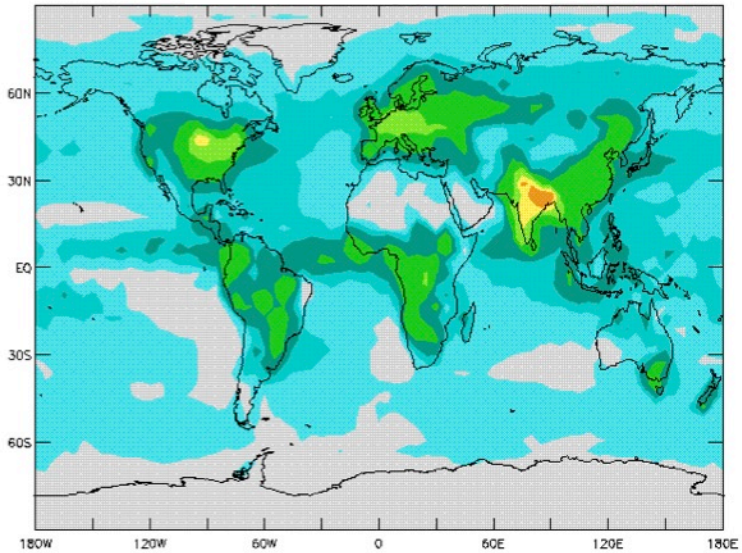
D'après Baron et al. (2011)

Dépôts au col du Lautaret:
3-5 kg N-NO_3^- ha^{-1} yr^{-1}

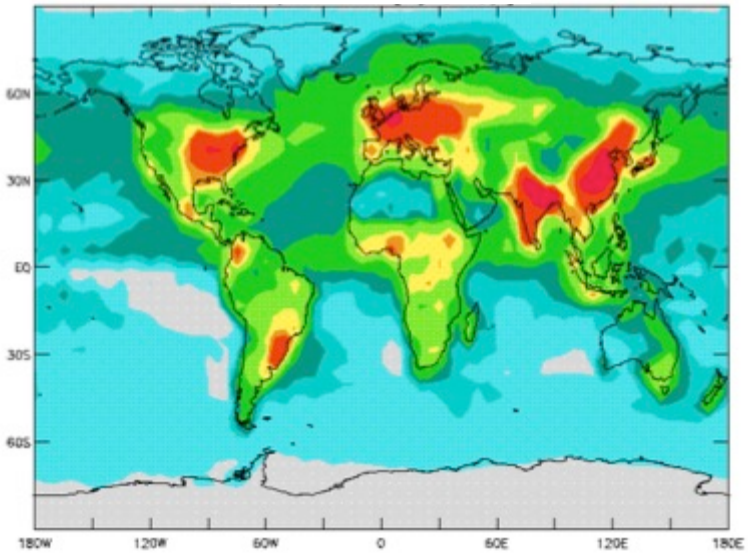


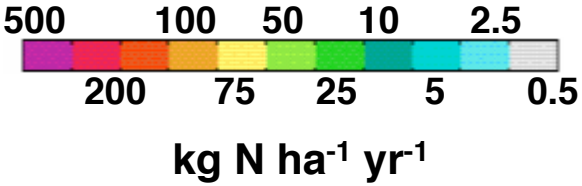


1860 (15 Tg N yr^{-1})

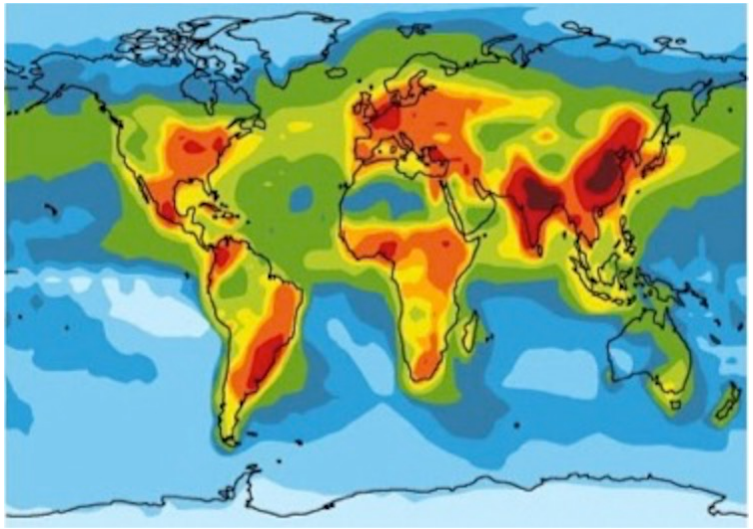


1993 (156 Tg N yr^{-1})





2050 (270 Tg N yr^{-1})



Dépôts atmosphériques de N_r liés aux activités humaines

D'après Galloway et al. (2004)

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