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# Assessing the use of different state variable observations to decrease groundwater flow models uncertainties: An application to the Neogene aquifer, Belgium.

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## INTRODUCTION

- Several studies have suggested the implementation of **unconventional** *state-variable* observations (*Delsman et al. 2016; Colombani et al. 2016; Siade et al. 2018; Schilling et al. 2019, and many others*). Their implementation comes with several challenges; therefore these observations are **underrepresented** in the general practice of groundwater modelling.
- This research aims at the identification of optimal **unconventional** observation types, **assess** their information content and **evaluate** the standard calibration procedure against a **joint** model **inversion** approach.
- A section of the Neogene aquifer within the Nete catchment in Belgium will be investigated using the current generation of numerical groundwater flow and heat/solute transport models developed at SCK•CEN which **solely** uses groundwater **heads** as state variable observations of the hydrogeological system (*Gedeon 2008, Gedeon et al. 2011, Vandersteen et al. 2012, Rogiers et al. 2014*).
- Here, we focus on age tracers, particularly $^{14}$C.

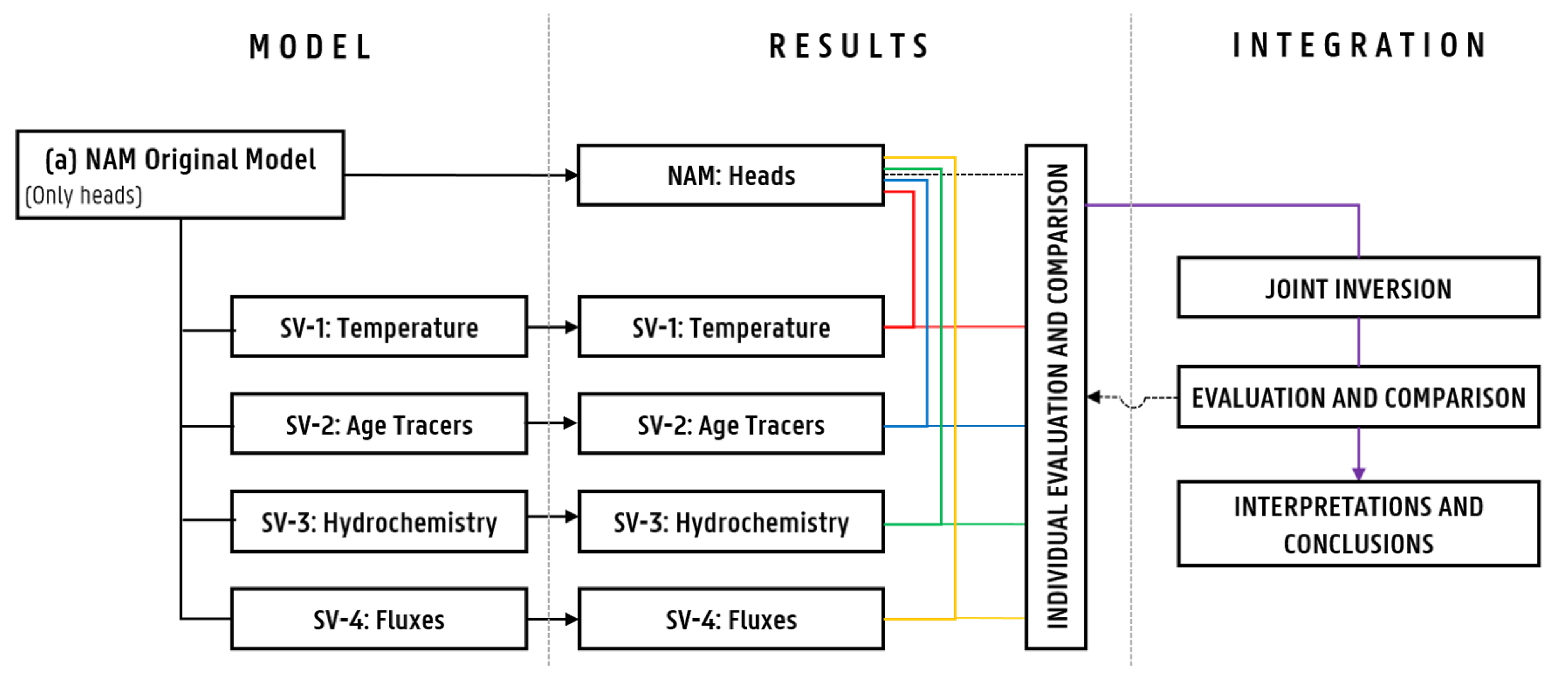


Fig 1. Evaluation and approach for state-variables

## SITE DESCRIPTION

- The Neogene aquifer is located in the Campine area, northeast of Flanders. ▪ Considered to be the most important groundwater reservoir in the region (*Coetsiers and Walraevens 2006*). ▪ Characterized by a very low relief with altitudes (~5 to 60 mts). ▪ The hydrography is characterized by an east-west drainage system. ▪ Consist of fine to medium grained sands with some iron-rich sandstone layers and lignite layers. ▪ To the east, several shallow normal faults crosscut the strata, e.g. the Rauw fault (*Verbeeck et al. 2017*). ▪ Clay content is found to vary in certain units (e.g. the Kasterlee, Lillo, and Diest formations) while basal gravels are present between the formations (*Laga et al. 2001*). ▪ The aquifer is well flushed and in most parts decalcified, leading to low mineralization and pH values in the shallow groundwater. ▪ The reactions that influence the hydrochemical composition are mainly calcite dissolution, oxidation of organic matter and methanogenesis (*Coetsiers and Walraevens 2009*).

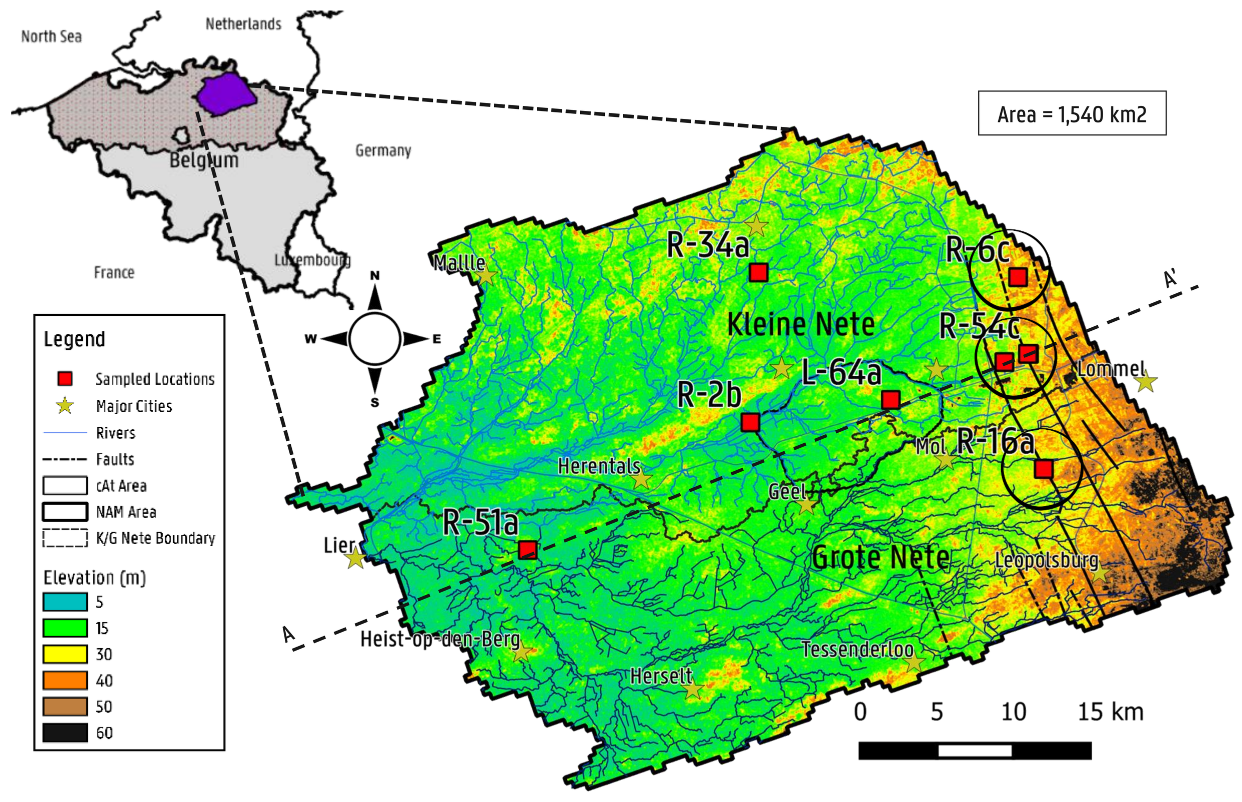


Fig 2. Geographical location of a) Belgium and Flanders within Europe, b) the Nete catchment showing the surface elevation of the study area.

Fig 3. Groundwater sampling setup in the field

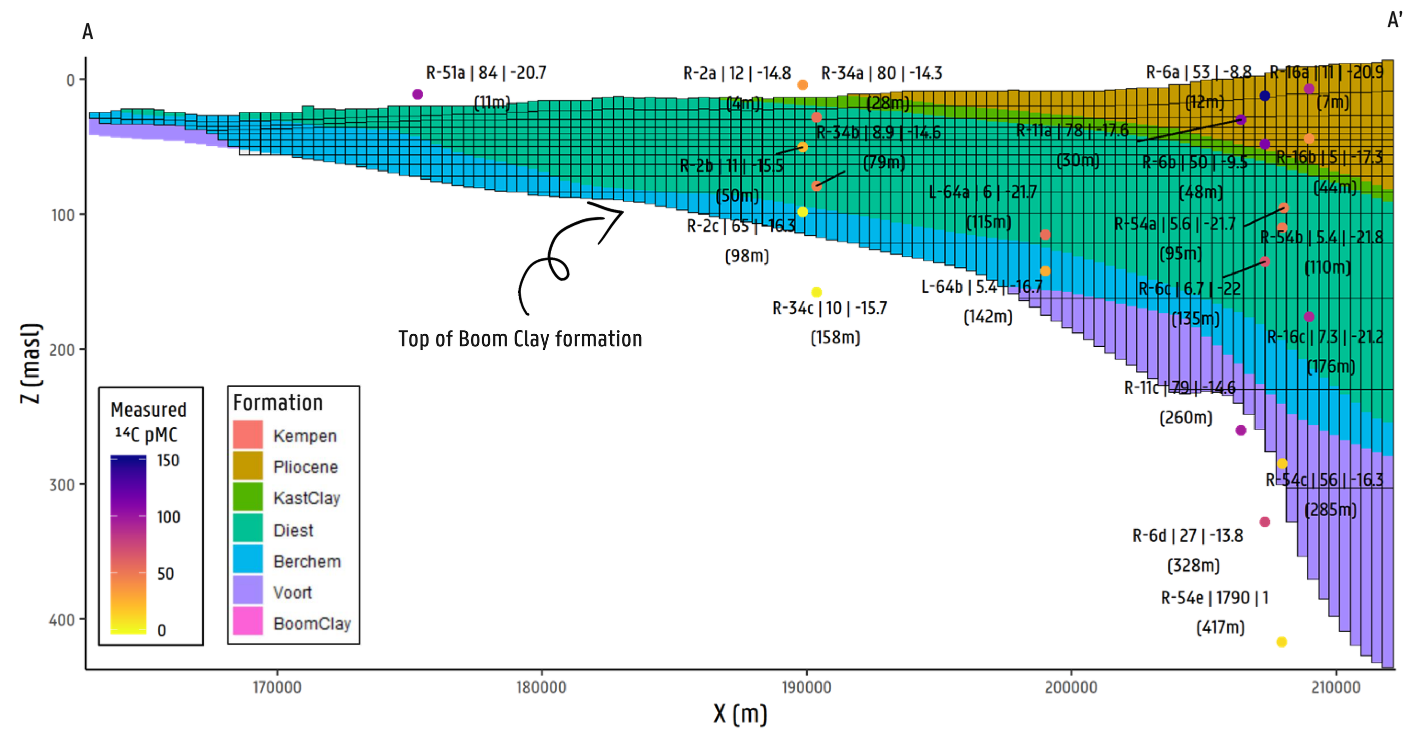


Fig 4. Profile (fig. 2) A-A' presenting well number, $\delta^{13}$C (in VPDB), chloride concentration (in mg/l) in groundwater, and $^{14}$C values in color (in pMC).

## MATERIALS AND METHODS

- Twenty-two samples collected at varying depths (4 – 400 m) across the Neogene aquifer.
- Analyzed for major and minor ions, $\delta^{13}$C, $^{14}$C, $\delta^{2}$H, $\delta^{18}$O, $^{3}$H, $^{3}$He, $^{4}$He and Ne.
- The **correction model** for $^{14}$C initial activity by Coetsiers and Walraevens (2009) was followed to:

i) *reproduce* their presented results (10 samples, 'MCo' fig.4, 5 & 6),
ii) *correct* for the current gathered values following the same methodology (22 samples, 'ACa' fig.4, 5 & 6), and
iii) *estimate* a $^{14}$C corrected age to previously measured $^{14}$C values from the PHYMOL project (SCK•CEN project, fig.4 & 6; *Van Keer et al. 1999*). Resulting $^{14}$C ages were compared with $^{14}$C ages determined from other models for $^{14}$C correction.

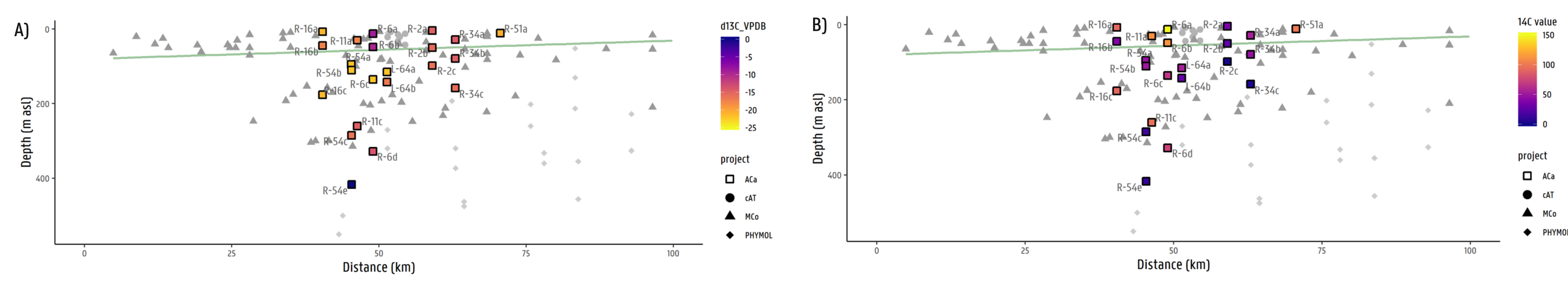

Fig 5 Evolution of a) $\delta^{13}$C and b) $^{14}$C following the flow direction measured from the Campine Plateau.

## PRELIMINARY RESULTS

- The $\delta^{13}$C and $^{14}$C values suggest an evolution of both terms following the flow direction (Fig. 5).
- The sampled $^{14}$C and $\delta^{13}$C values in the Neogene aquifer in the current campaign are within the ranges presented by Coetsiers and Walraevens (2009) supporting their findings (Fig. 5).
- The calculated and measured $\delta^{13}$C values show a good agreement. This correspondence demonstrates that the assumed reaction quantities approach the real situation (Fig. 6).
- The produced age following other $^{14}$C correction models (Pearson (1965) model results as example) are higher than uncorrected values (Fig. 7).
- Peculiarly, low 14C ages were found for deep piezometers near the faults (Fig. 2 & 7, circles).

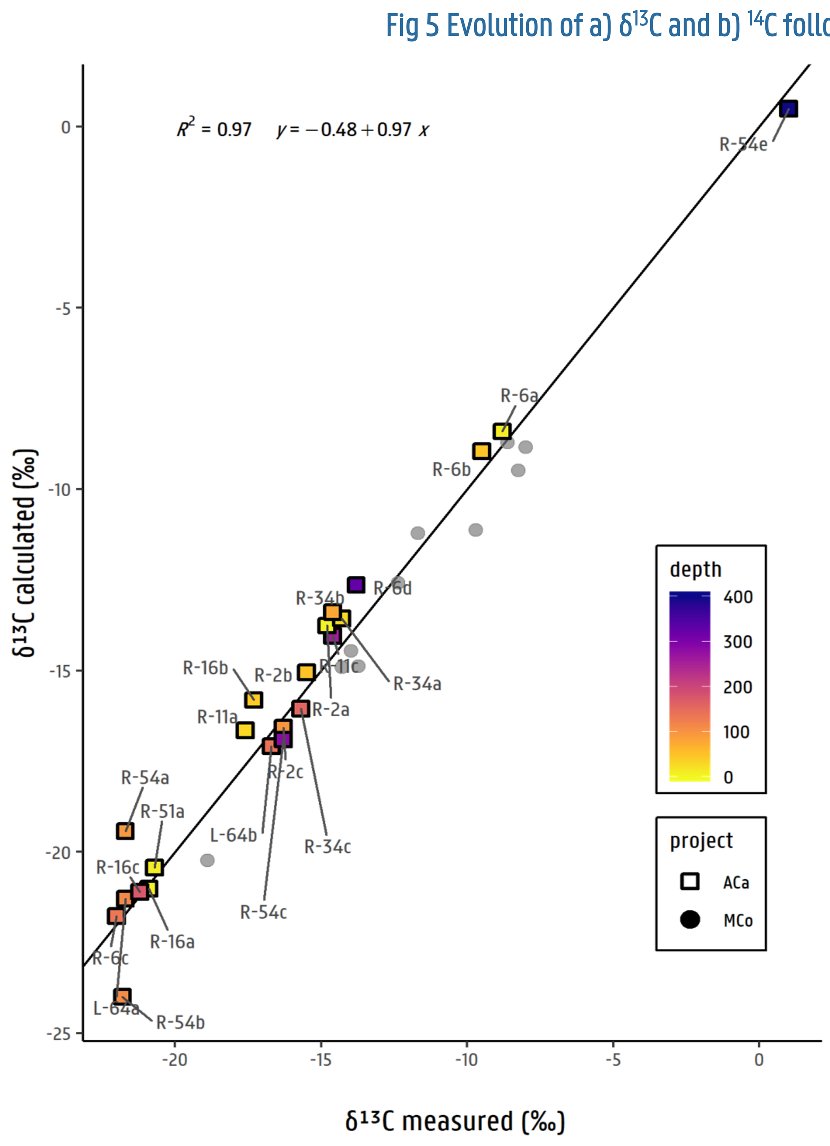


Fig 6. Relation between $\delta^{13}$C measured and calculated values

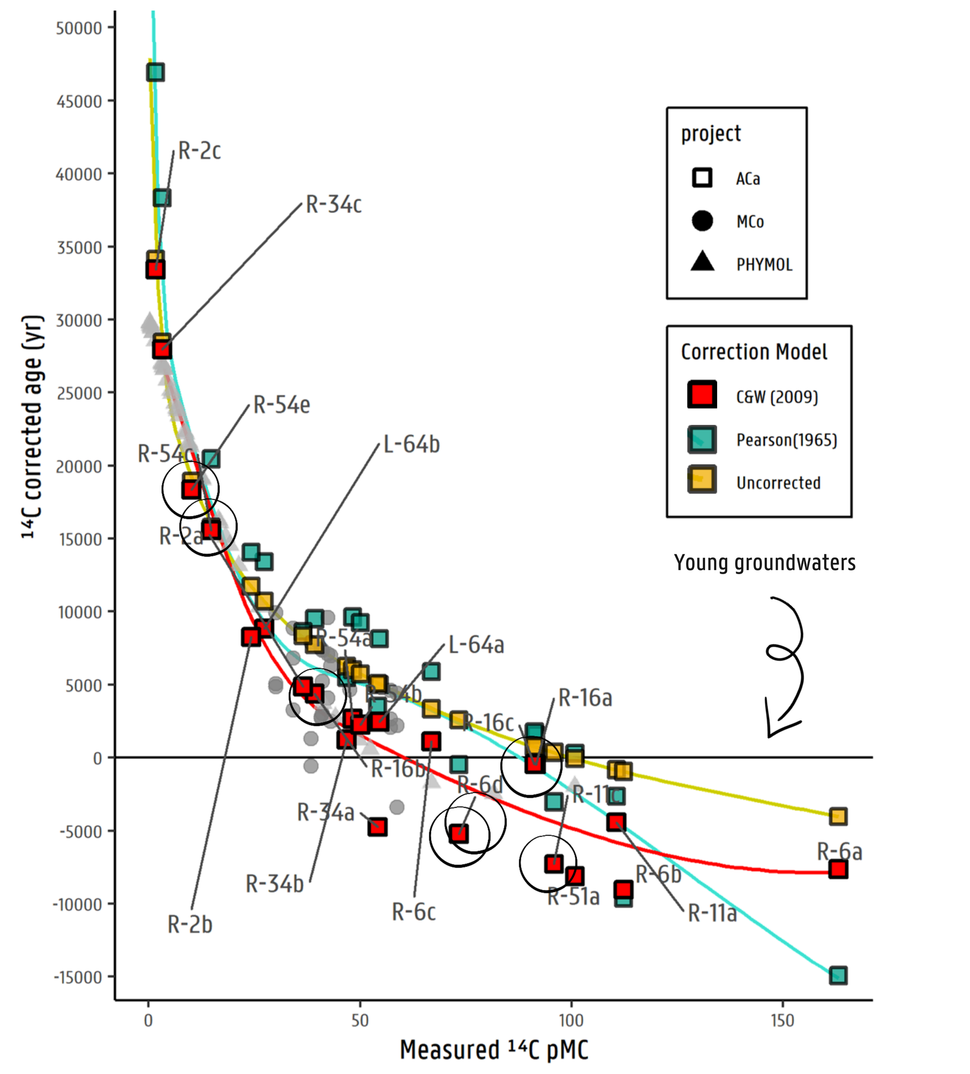


Fig 7. Relation between $^{14}$C ages derived by Coetsiers and Walraevens (2009), Pearson (1965) and uncorrected conventional ages.

## DISCUSSION

- Low $\delta^{13}$C and high $^{14}$C values vs depth/distance might indicate local recharge areas and the influence of the local river network influencing groundwater flow.
- **Preferential** vertical **flow** potentially mixes younger and older groundwater in the northeast, as suggested by the results of several deep piezometers.

## WAY FORWARD

- Testing various scenarios to confirm preferential flow paths including **faults** into the flow and transport models as **horizontal** barriers and/or **vertical** conducts.
- Interpretation of $^{3}$H, $^{3}$He, $^{4}$He analyses together with $^{14}$C values to determine regional groundwater age distribution as a first step prior performing a model inversion.

## REFERENCES

SCAN ME

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