

IMPROVING NO₂ EPISODE DETECTION WITH TROPOMI: A DECOMPOSITION APPROACH ACROSS DIVERSE OROGRAPHY

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INTRODUCTION

NEW European Union Air Quality Directive (2024/2881).
TROPOMI comparatives rely on simple temporal averages [4-5].
 No studies examining whether **terrain complexity** affects TROPOMI retrievals.
INNOVATION
 Decomposition framework to satellite and in-situ observations.

$$Model_t = T_t + C_t + F_t, t=1, \dots, n$$

OBJECTIVES: Assessing to...
 ... detect pollution episodes and evaluate $Model_t$ under complex terrain.

- DATASETS**
- Sentinel 5P NO₂ Level 2 product [1] (TrC)
 - Surface NO₂ concentration (OBS) from 150 stations (Fig. 1).
 - Digital Elevation Model (EU-DEM) from the European Environmental Agency (resolution of 25 x 25 m) [3].

PERIOD
 From May 2018 to December 2023.

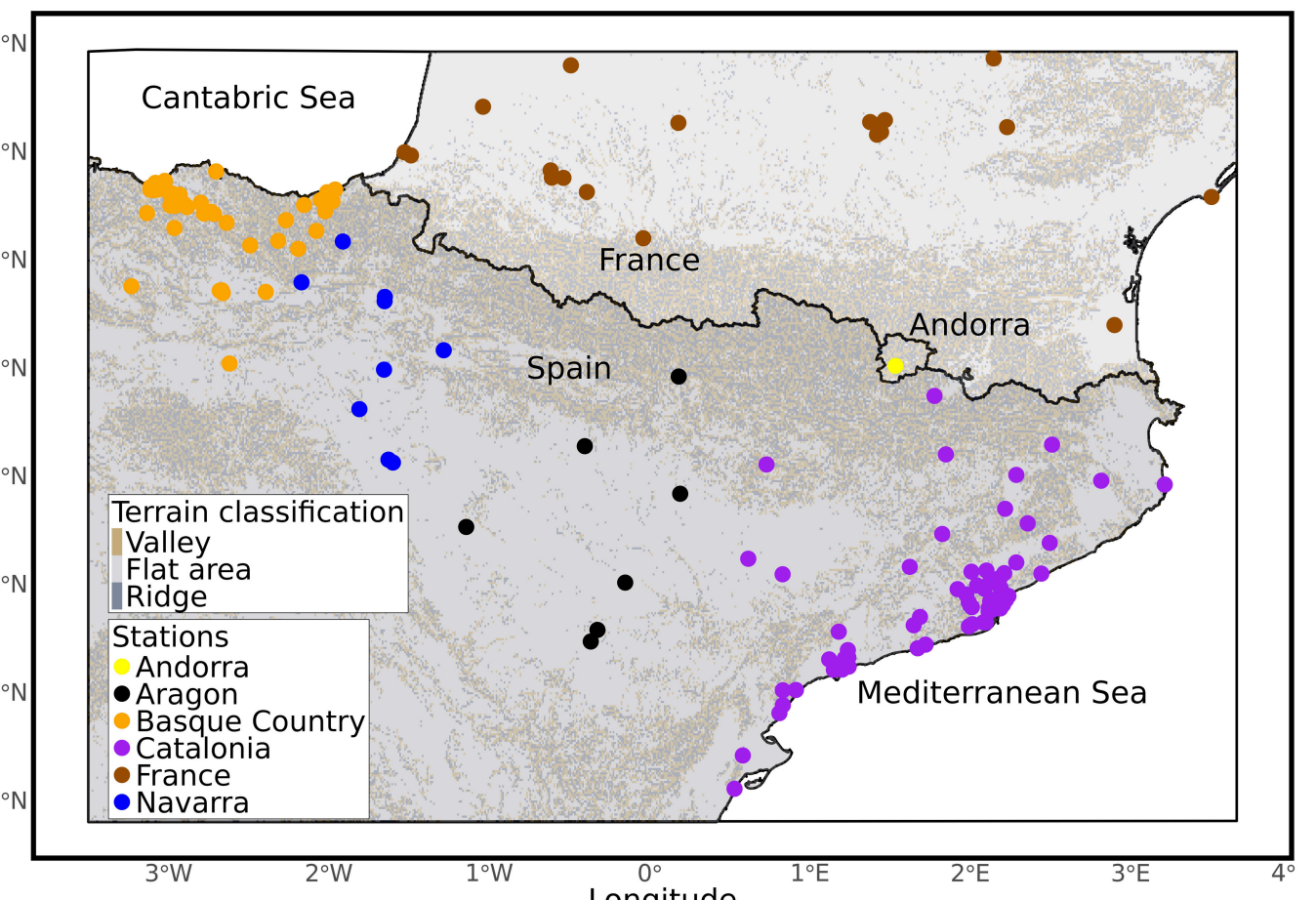


Fig. 1. Domain showing the terrain classification and stations.

METHODOLOGY

DECOMPOSITION FRAMEWORK
 The general additive model for a time series Y_t
 $Y_t = T_t + C_t + F_t + \epsilon_t, t=1, \dots, n$
 Steps:
 • Y_t filtered with a moving-average \hat{Y}_t
 • T_t and C_t estimated with \hat{Y}_t
 • $Y_t - T_t - C_t \neq 0 \Rightarrow F_t$
 • F_t calculated with a moving-average window (d_F).
STATISTICAL TOOLS
 • R_{Final} : Pearson correlation between $Model_t^{TrC}$ and $Model_t^{OBS}$
 • **Alarm rates:** TROPOMI's evaluation to detect pollution episodes
 $TPR = \frac{TP}{TP + FN}; FPR = \frac{FP}{FP + TN}$

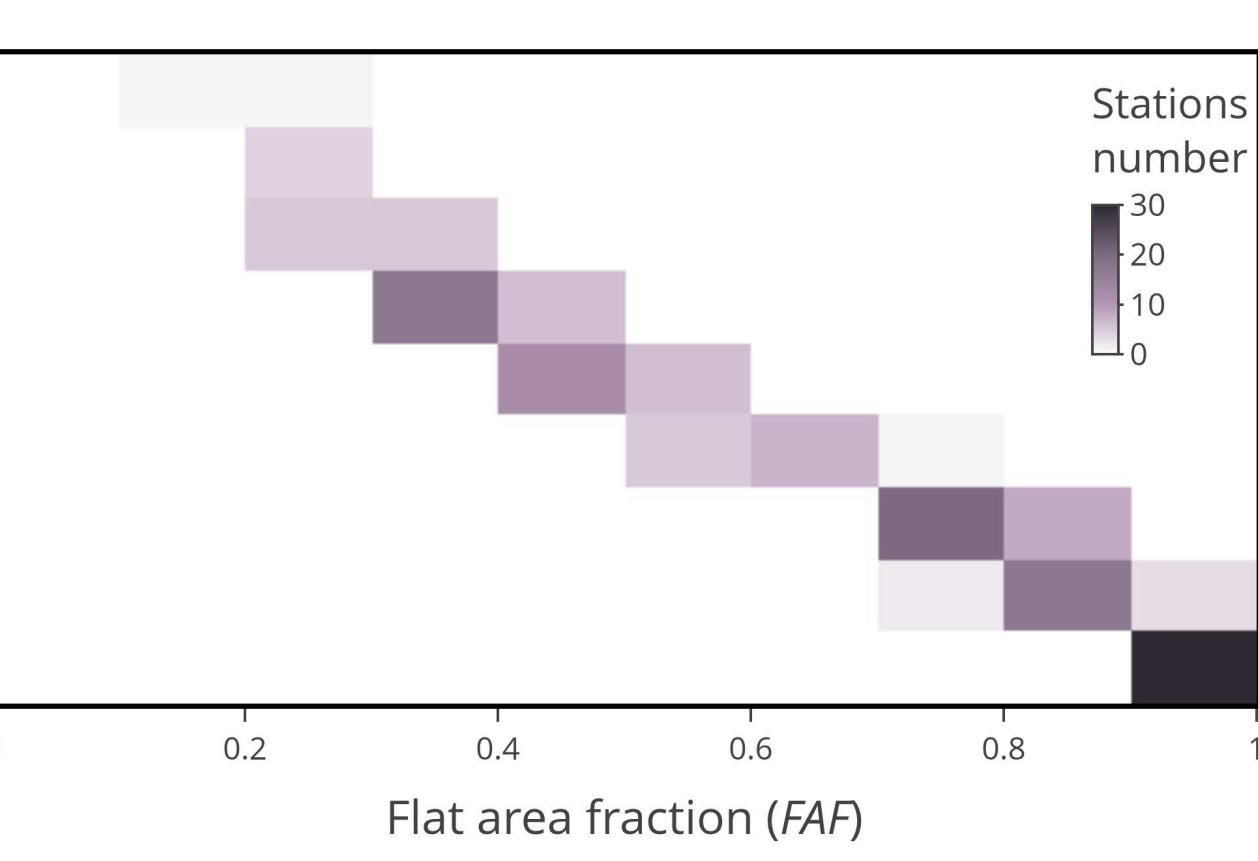
Definition	$F_{TrC} \geq Q$	$F_{TrC} < Q$
$F_{OBS} \geq Q$	TP	FN
$F_{OBS} < Q$	FP	TN

 through F_t for $Q \in (Q_{25}, Q_{50}, Q_{75})$:

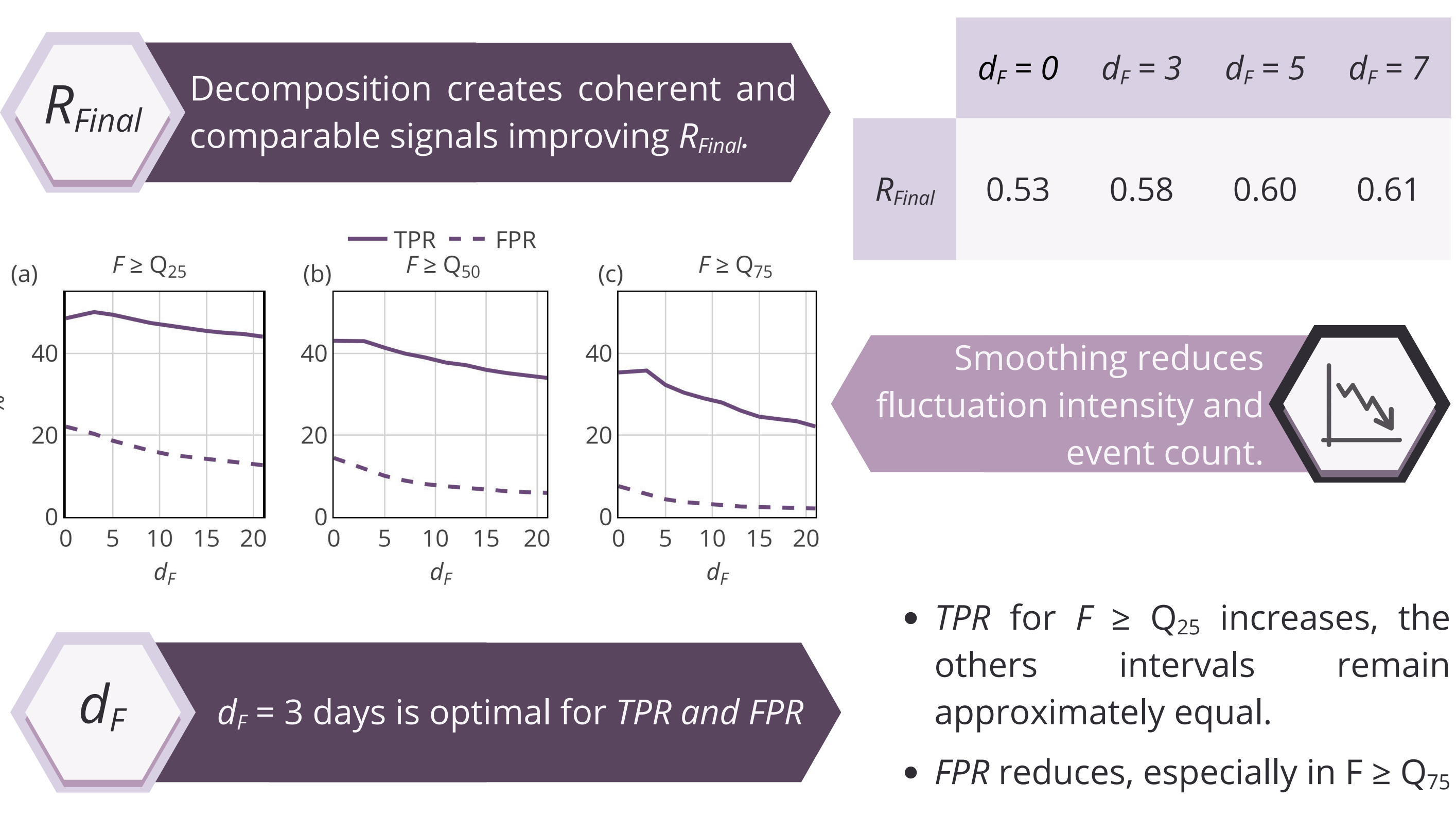
Q values	Q_{25}	Q_{50}	Q_{75}
$TrC (\mu\text{mol}/\text{m}^2)$	5.33	12.87	28.29
$OBS (\mu\text{g}/\text{m}^3)$	1.28	3.59	8.83

TERRAIN-COMPLEXITY INDEX
 To assess TROPOMI performance on complex terrain

- Topographic Index Position (TPI) [2] to each pixel from EU-DEM.
- Valleys ($TPI < -\sigma_{TPI}/2$)
 Flat ($-\sigma_{TPI}/2 < TPI < \sigma_{TPI}/2$)
 Ridges ($TPI > \sigma_{TPI}/2$)
- Terrain-fraction in an influence radius ($r_i = 7.17$ km) around each stations.
- The Flat Area Fraction (FAF) is selected as terrain-complexity index.



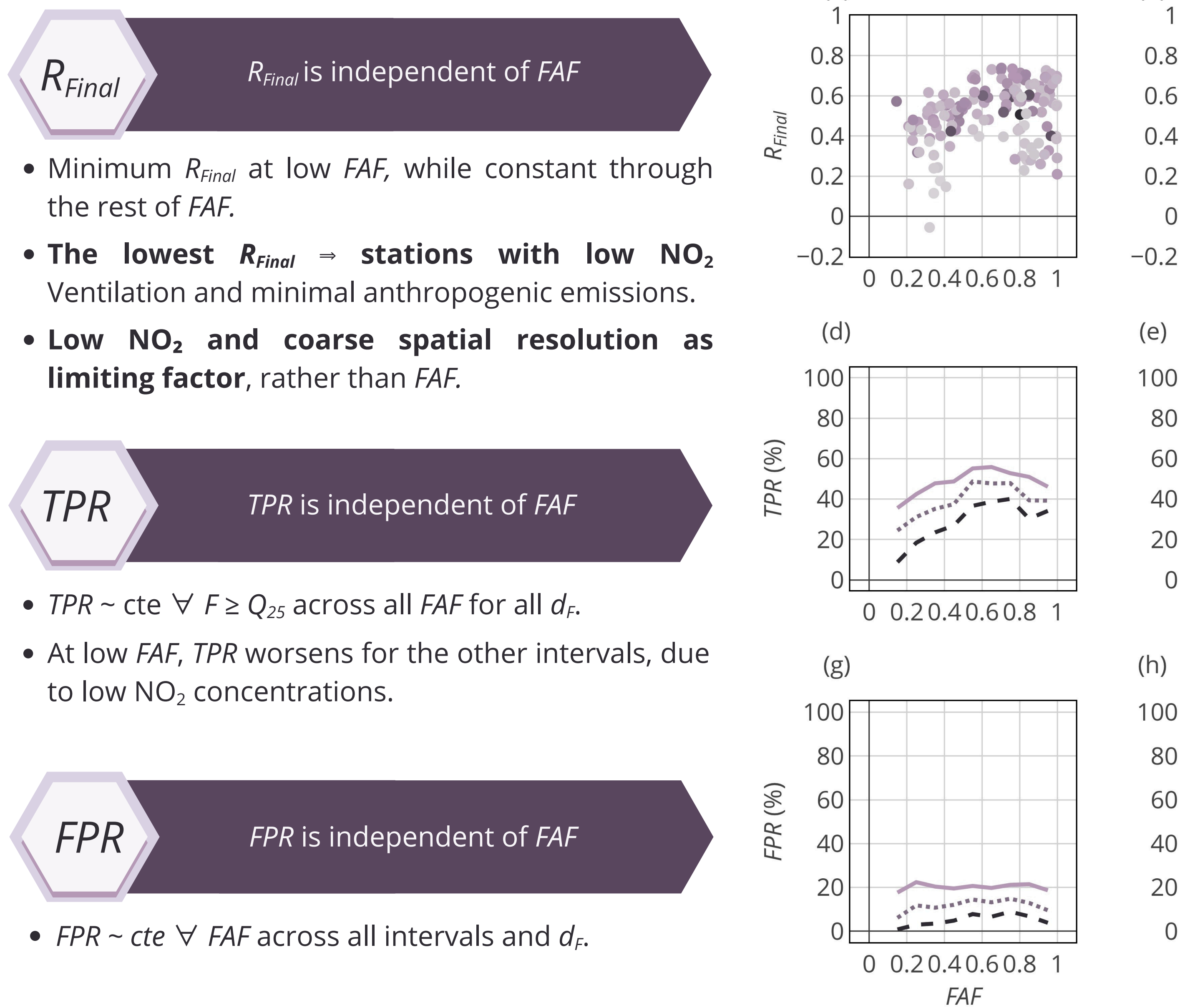
RESULTS



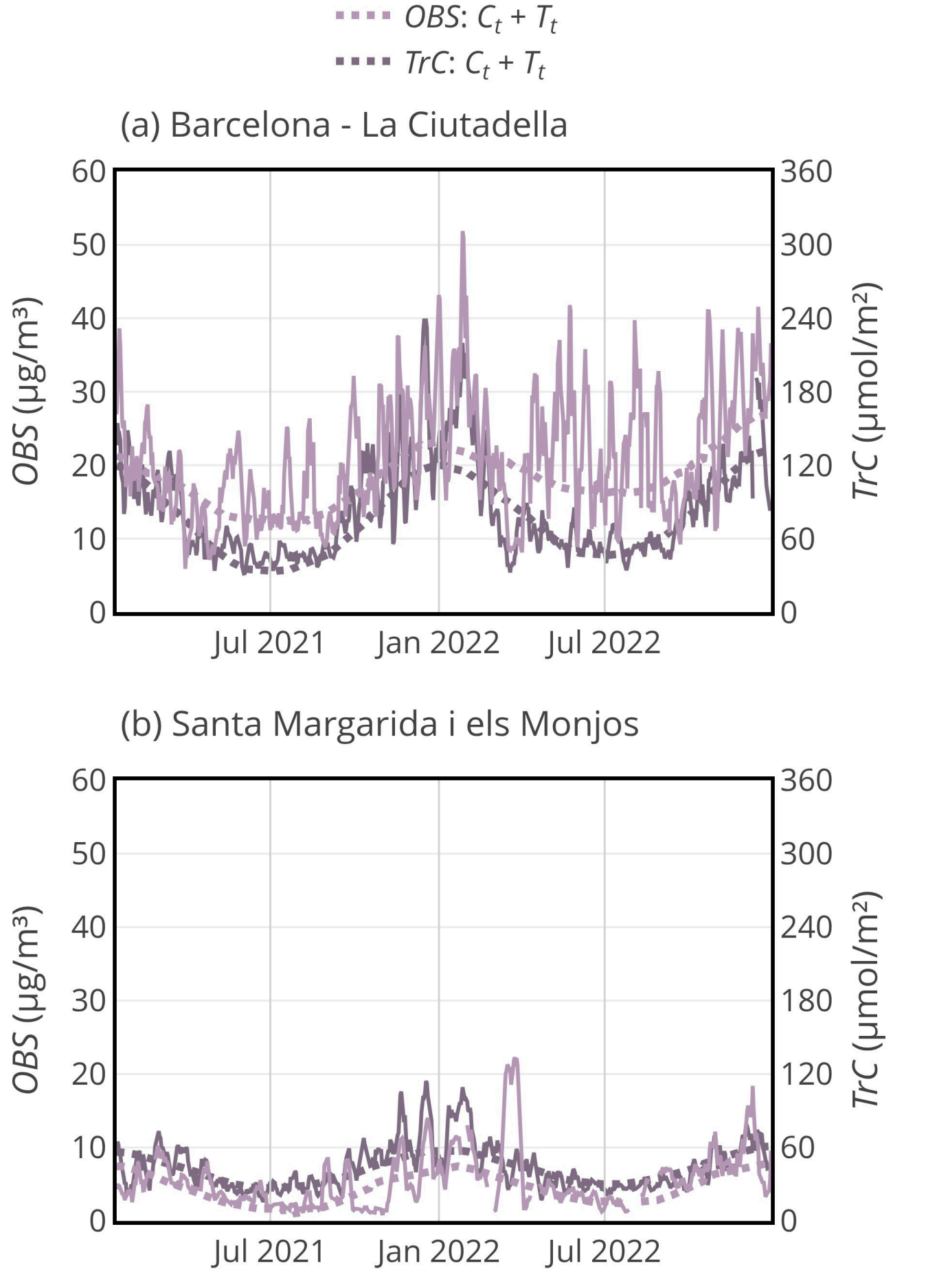
CONCLUSIONS

- Improving detection of 3-day NO₂ episodes:**
 - similar TPR to raw data
 - reduced uncertainty due to lower FPR
 - higher R_{Final}
- Terrain complexity does not systematically influence satellite-ground agreement**
- Possible limiting factors:**
 - Low NO₂ concentrations (consistent with the algorithm theoretical basis)
 - TROPOMI's coarse spatial resolution

EVALUATION UNDER COMPLEX-TERRAIN



WHY F_t
 Normalise for overall pollution level.



GLOSSARY
 T_t : trend component
 C_t : seasonal component
 F_t : fluctuation component
 ϵ_t : remainder
 OBS : Surface NO₂ concentration
 TrC : TROPOMI tropospheric NO₂ column density
 σ_{TPI} : standard deviation of TPI
 $d_F = 0$ means no filter
 FAF: Flat area fraction

REFERENCES
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