



UNIVERSITY  
OF COLOGNE

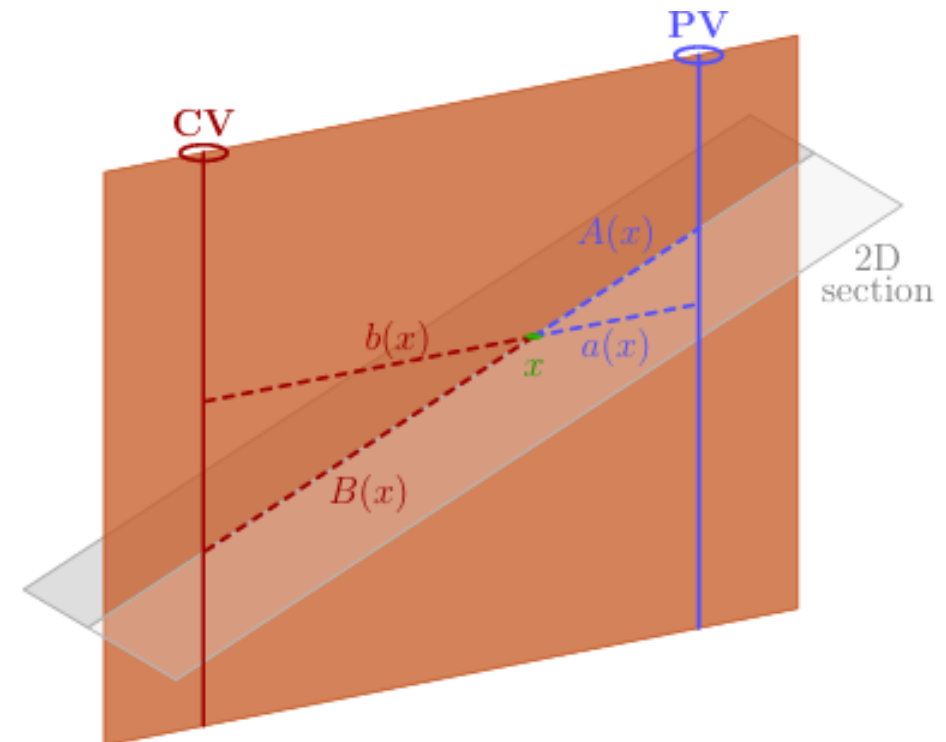
# ZONAR: A PROBABILISTIC FRAMEWORK FOR LIVER ZONATION MAPPING USING ANATOMICAL REGULARIZATION

M A. Debebe, K Möllenhoff, J Rahnenführer, J G. Hengstler, A Tresch

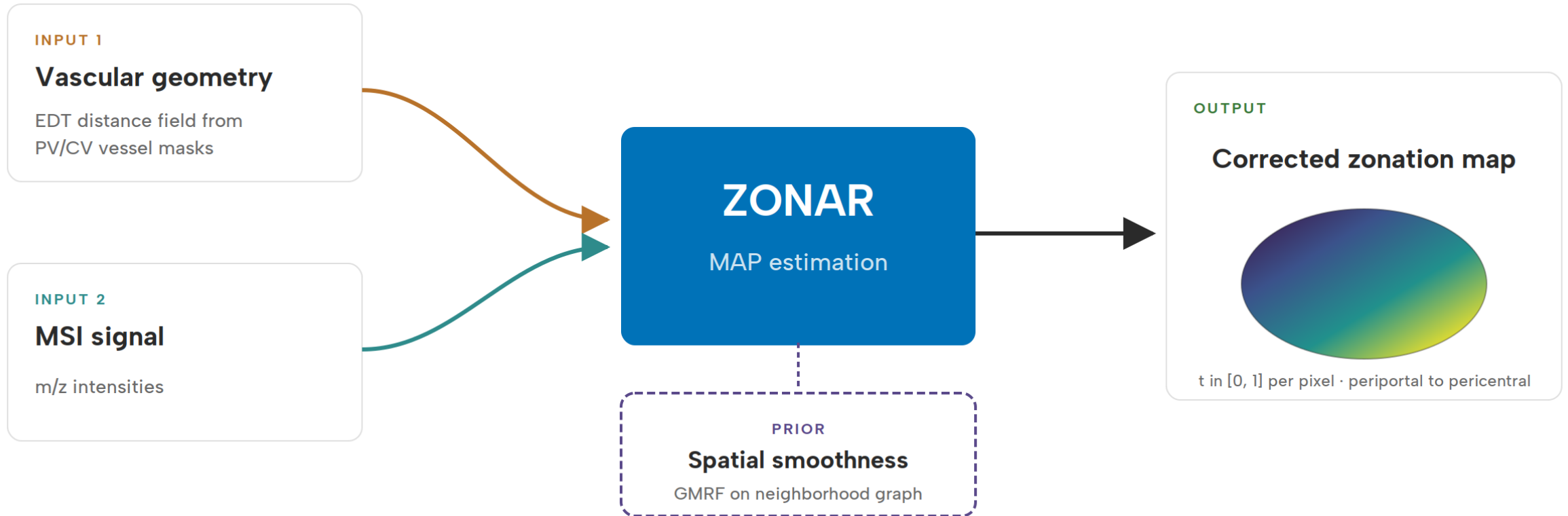
# Background

## The 3D → 2D Problem

- Histology collapses a 3D organ into a thin 2D section
- Many portal and central veins do not intersect the section plane, they are invisible
- The 2D distance to the nearest vessel is therefore only an **upper bound** on the true 3D distance
- Hepatocytes may appear distant from vessels in 2D despite being proximal in 3D
- This leads to systematically biased distance estimates and incorrect zonation assignments



# The ZONAR method



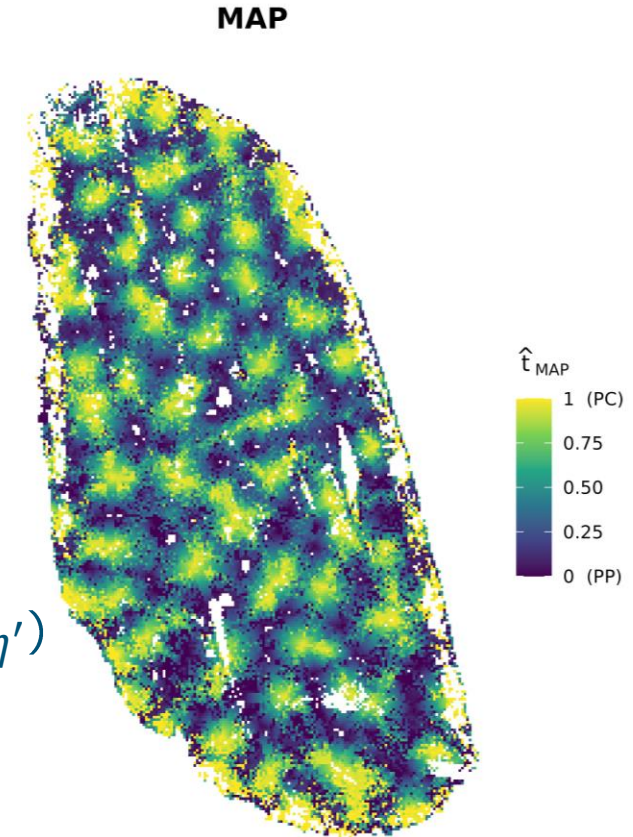
# The ZONAR method

## MAP Fusion

The final zonation field is obtained by maximum a posteriori estimation combining all three terms:

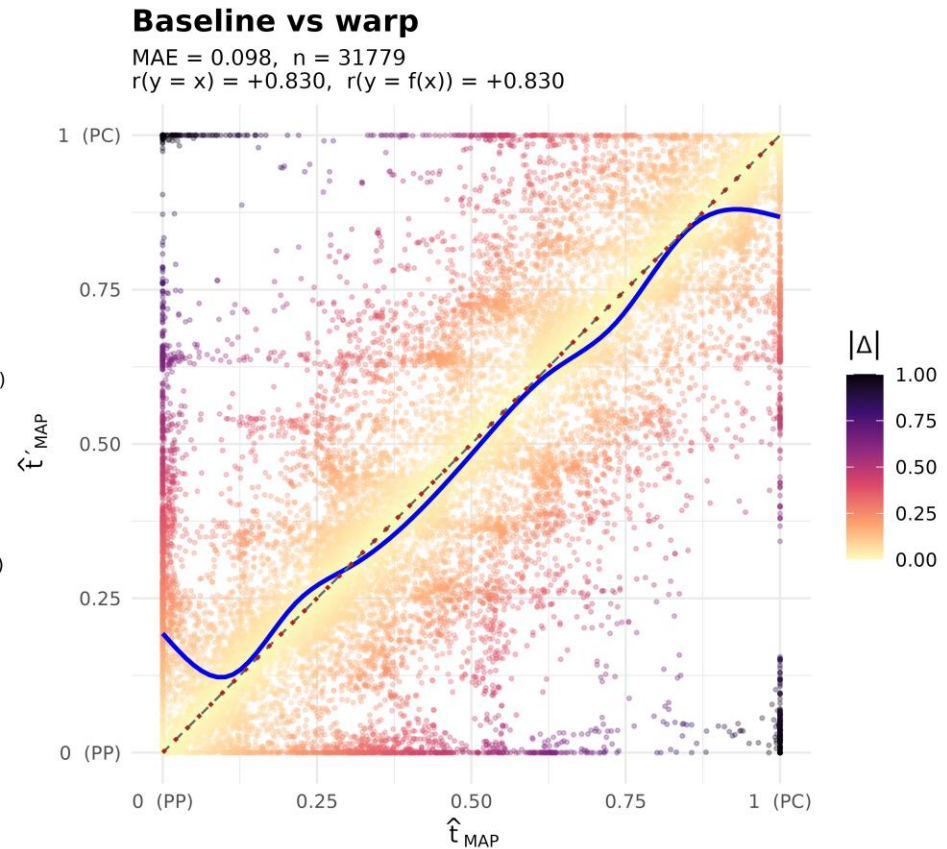
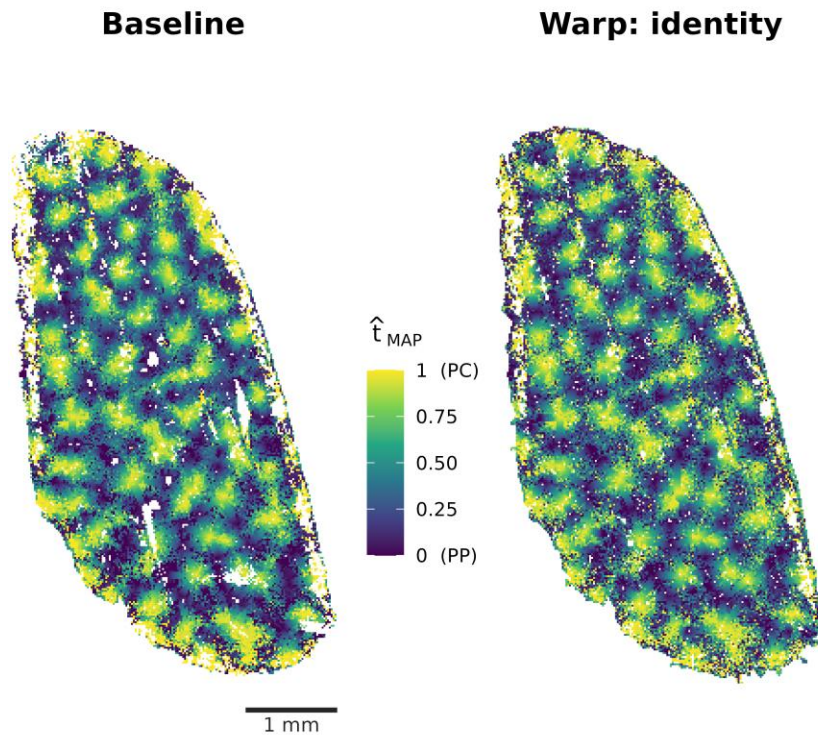
$$\hat{t} \in \arg \min_{\{t_i\}_{i \in U}} \frac{\tau}{2S_M} \sum_{i \in U} \ell_i(t_i) + \frac{1}{2S_V} \sum_{i \in U} \beta_i(t_i - T_i)^2 + \frac{\eta'}{2S_E} \sum_{(i,j) \in E} w_{ij}(t_i - t_j)^2$$

Three terms: MSI likelihood ( $\tau$ ), geometric anchoring ( $\beta_i$ ), spatial smoothness ( $\eta'$ )



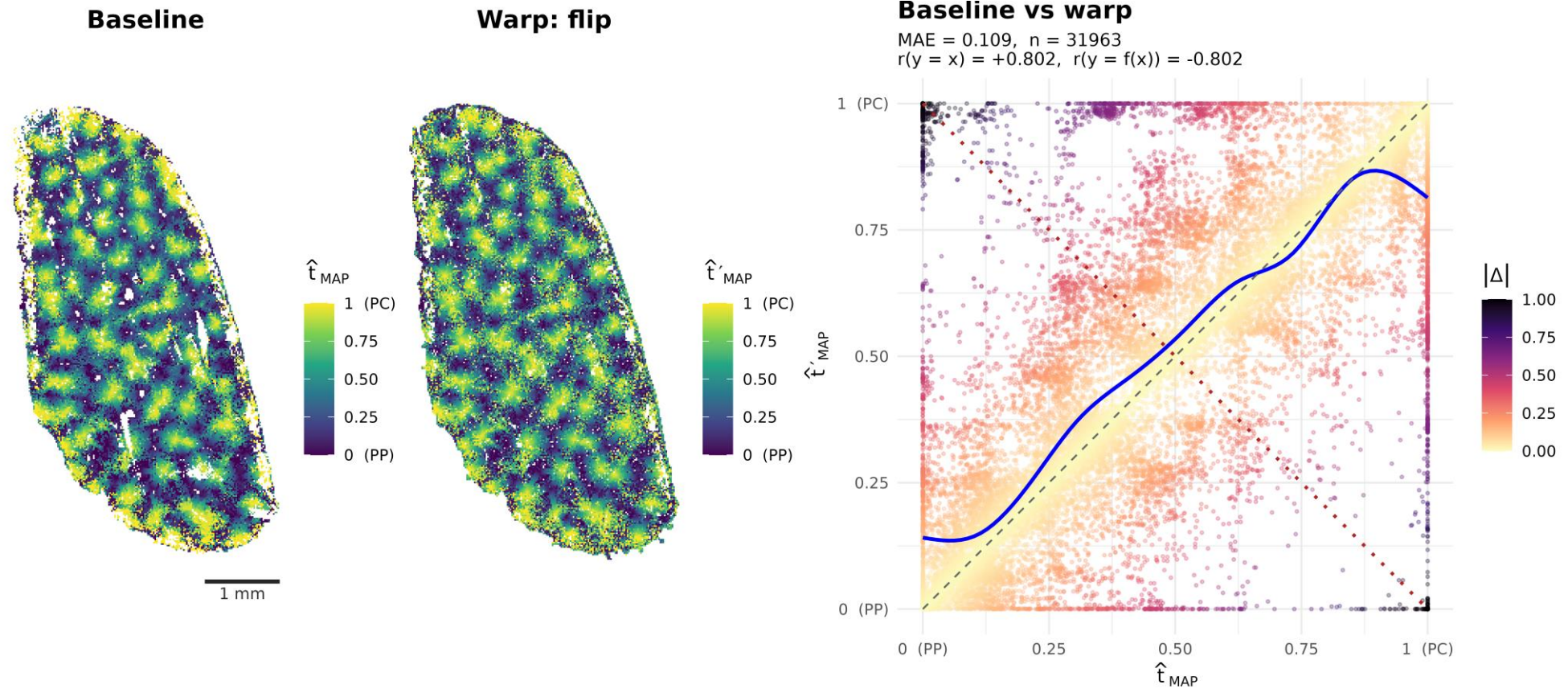
# Results & Diagnostics

## Experiment: identity resampling



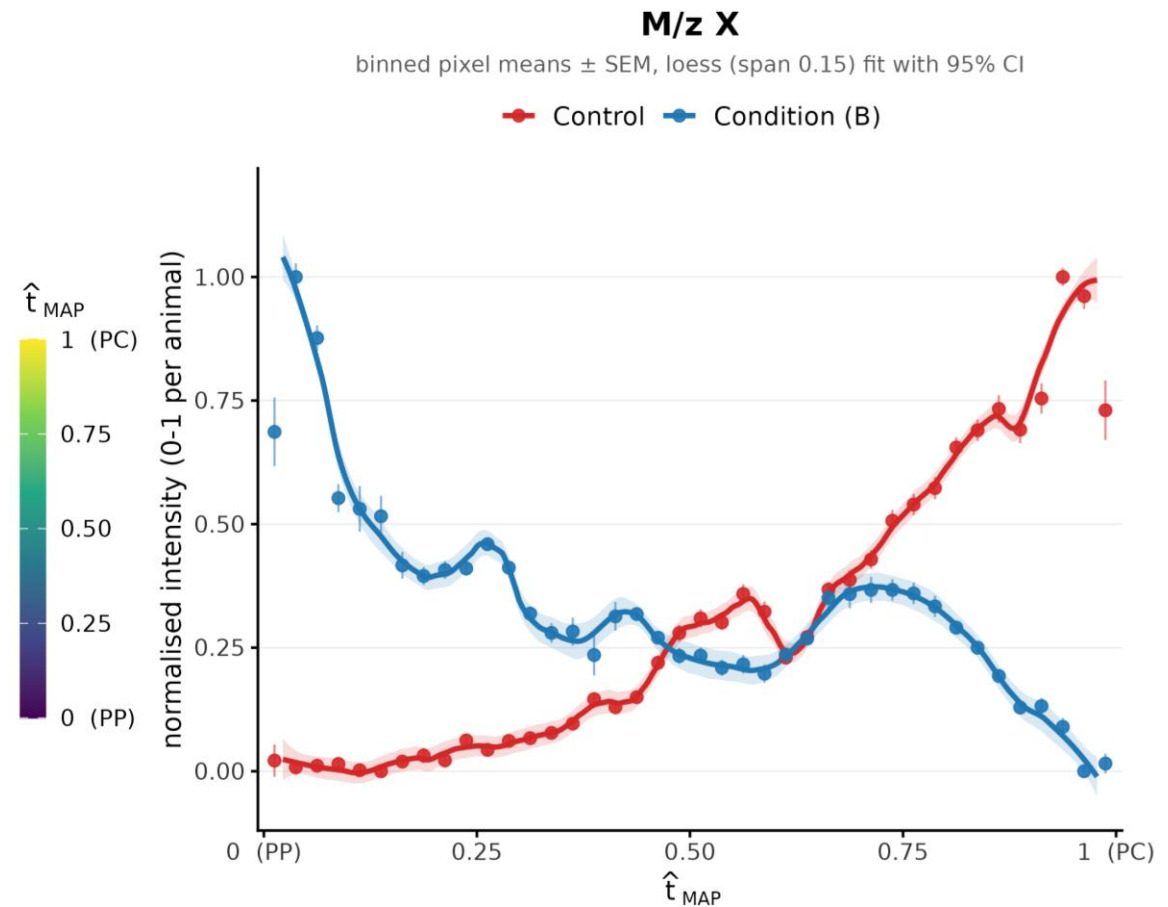
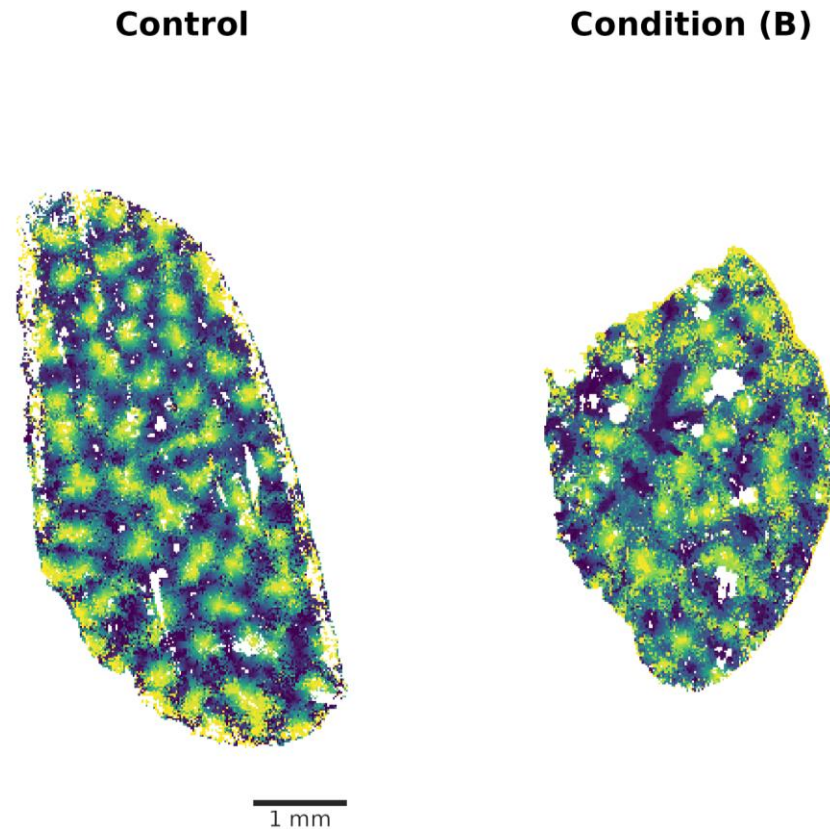
# Results & Diagnostics

## Experiment: full inversion of molecules



# Results & Diagnostics

## Illustrative example – profile comparison between conditions



# Conclusion

## ZONAR: Anatomically-anchored zonation with per-cell calibrated uncertainty

- Combines vascular geometry, MSI signal, and spatial smoothing in a MAP estimate
- Robust to molecular perturbation: the coordinate reflects geometry, not any single metabolite ( $r = +0.80$  even under full signal inversion)
- Cross-sample comparable: enables statistical analysis across treatment groups
- Open-source web app, runs locally: no data sharing required

Manuscript in preparation

Code and app (upon publication): [github.com/IMSBCompBio/ZONAR](https://github.com/IMSBCompBio/ZONAR)

**THANKS FOR YOUR ATTENTION!**

QUESTIONS AND COMMENTS ARE ALWAYS WELCOME:  
[MICHAEL.DEBEBE@UNI-KOELN.DE](mailto:MICHAEL.DEBEBE@UNI-KOELN.DE)

**LET'S COLLABORATE:**

WORKING WITH SPATIAL OMICS OR VASCULAR DATA? REACH OUT IF YOU WANT TO  
APPLY ZONAR TO YOUR OWN DATASETS OR EXPLORE JOINT VALIDATION STUDIES.

