THE UNIVERSITY OF MELBOURNE

Physics-guided statistical modelling of flood inundation for rapid deployment

用于快速部署的洪水淹没物理指导统计模型

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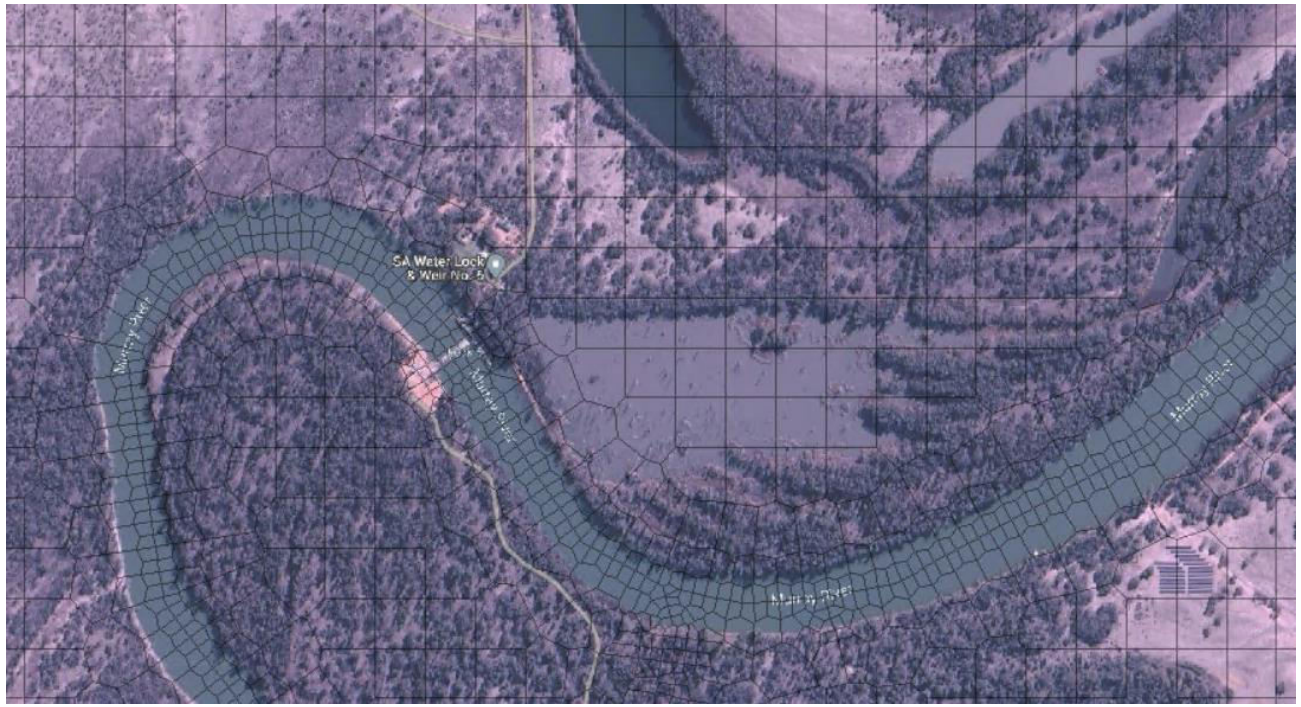
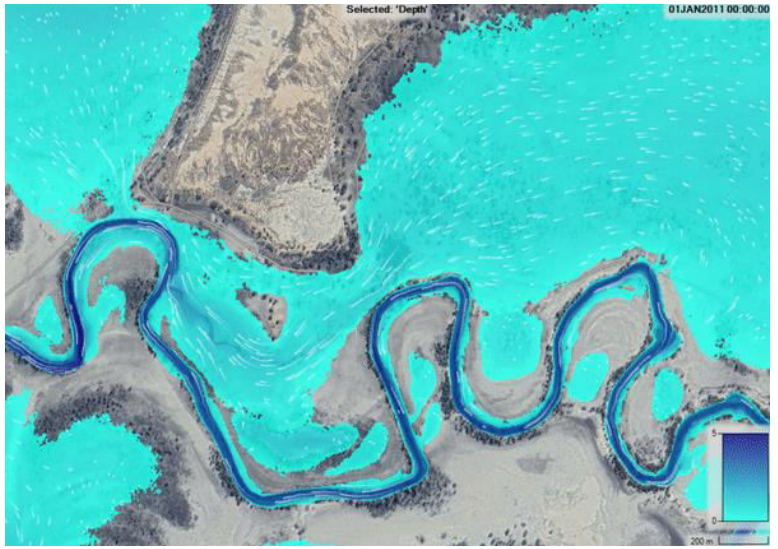
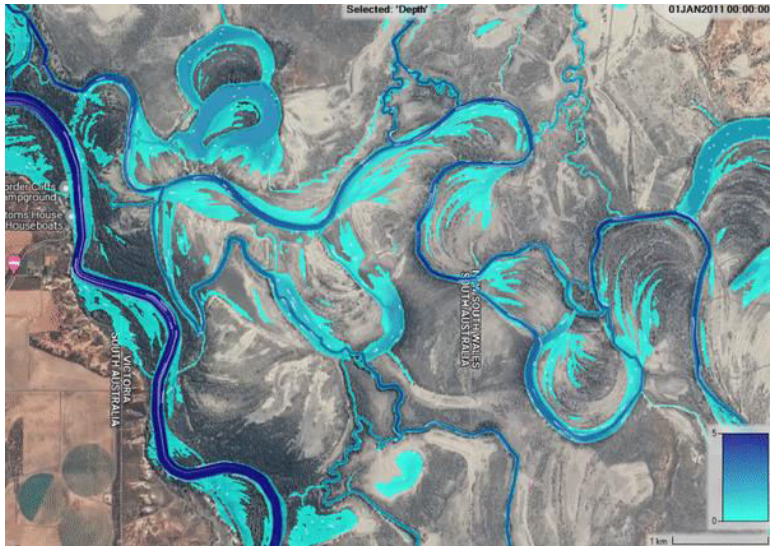
The problem: flood inundation modelling
问题：洪水淹没模拟

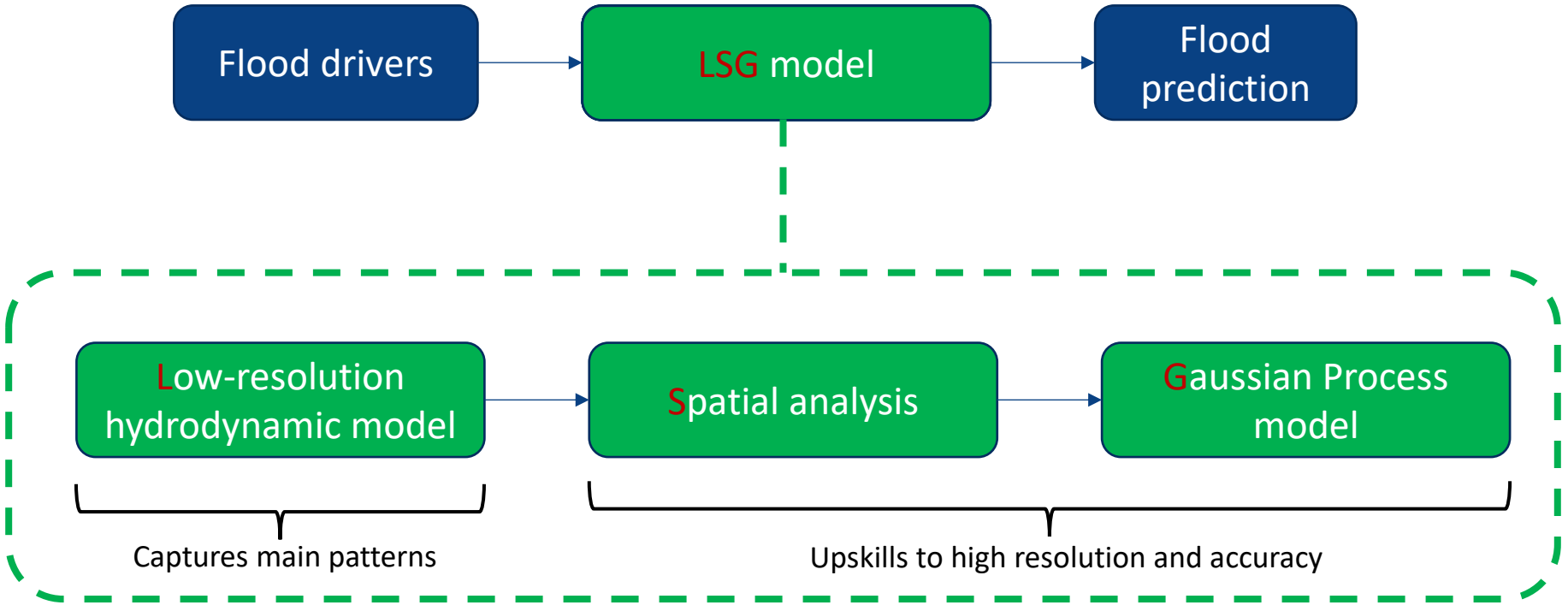
- Hydrodynamic models (MIKE, TUFLOW, HEC-RAS)







Our approach 我们的方法



Our approach 我们的方法

Feature/pattern matching ?

Our approach 我们的方法

- Reducing dimensions 减维
- Statistical upskilling/calibration of the reduced variables 改进/校准减维后的变量
- Reverse back to high dimensions 反算回到高维

Our approach 我们的方法

- Reducing dimensions 减维
  - Empirical orthogonal function (EOF) analysis 经验正交函数分析

- Statistical upskilling/calibration of the reduced variables 改进/校准减维后的变量
  - Gaussian process 高斯过程

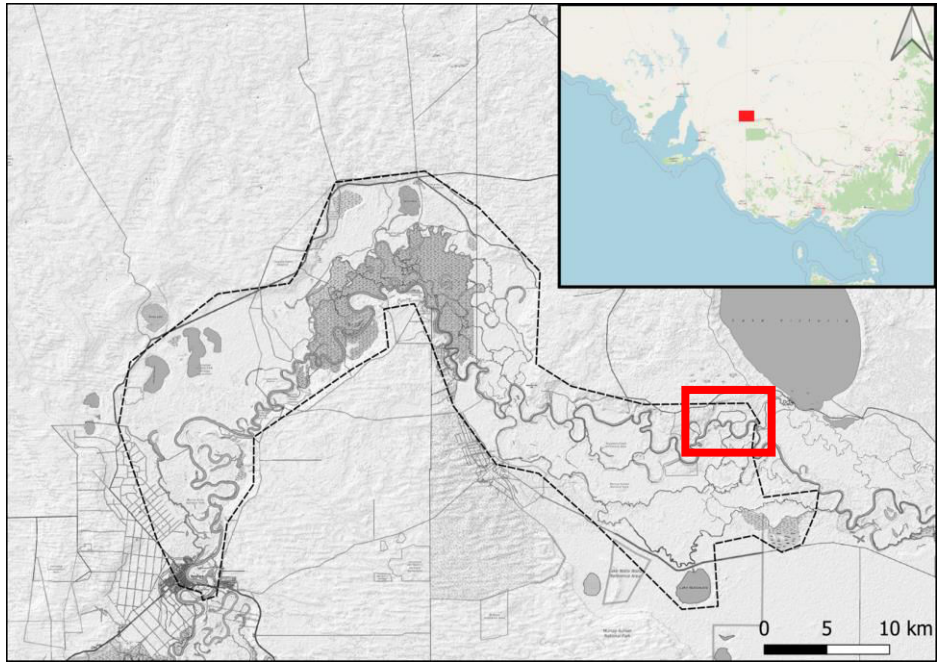
Reverse back to high dimensions 反算回到高维
  - Reverse EOF analysis

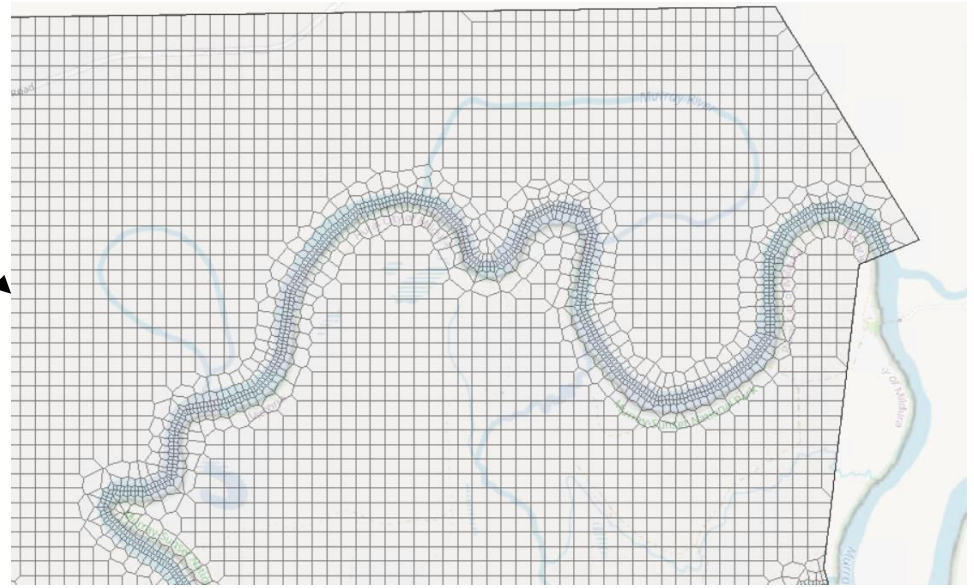
Case studies
案例研究

Chowilla floodplain (740 km²)

- Part of the Murray river
- Flat and complex topography
- Slow moving water

Low-resolution model: HEC-RAS (1,434 cells)
High-resolution model: HEC-RAS (109,914 cells)





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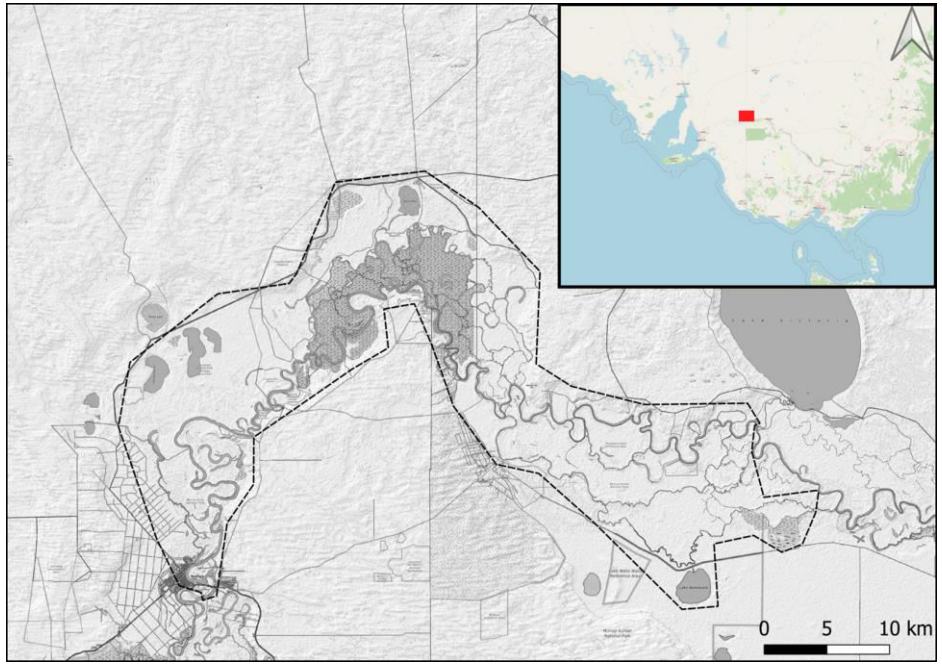


Burnett river (1,479 km²)

- Coastal river
- Steep and canyon like topography
- Fast flowing water

Low-resolution model: HEC-RAS (15,256 cells)
High-resolution model: TUFLOW (3,697,597 cells)

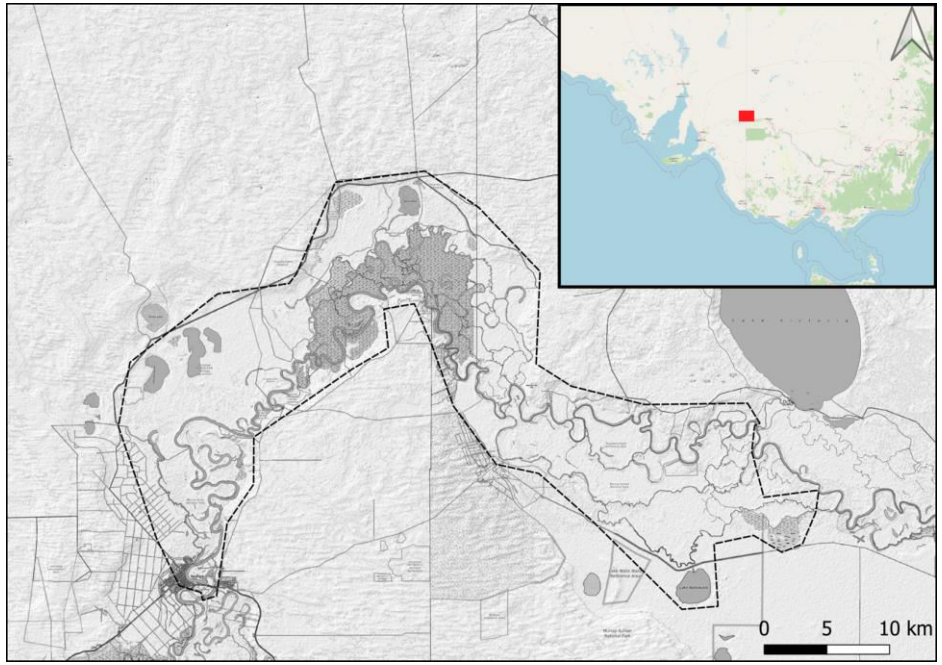
Results – Computational time
结果 - 计算时间

Chowilla floodplain (3.5 month event)

Low-resolution model: HEC-RAS
- 28 s

Upskilling
- 5 s

High-resolution model: HEC-RAS
- 10 hr 43 min 34 s



Burnett river (430 hr event)

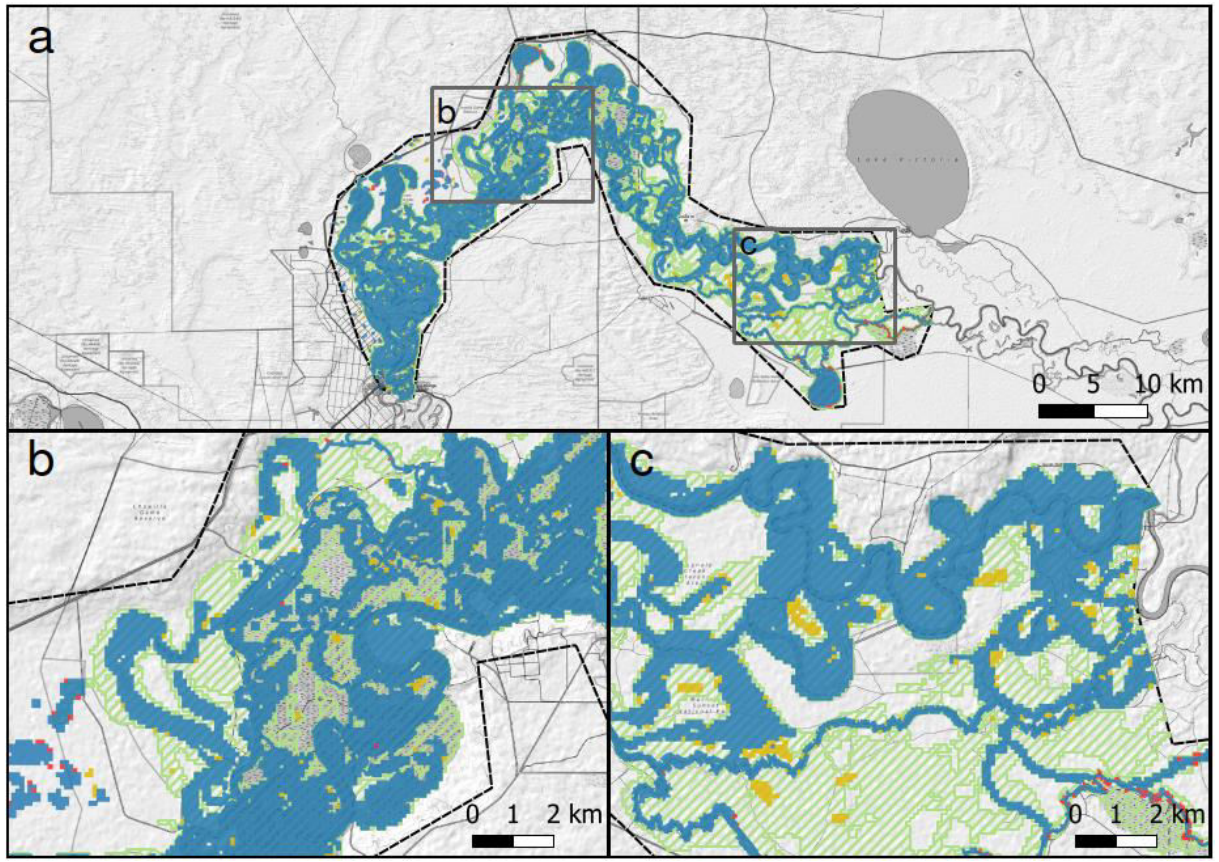
Low-resolution model: HEC-RAS
- 10 s

Upskilling
- 17 s

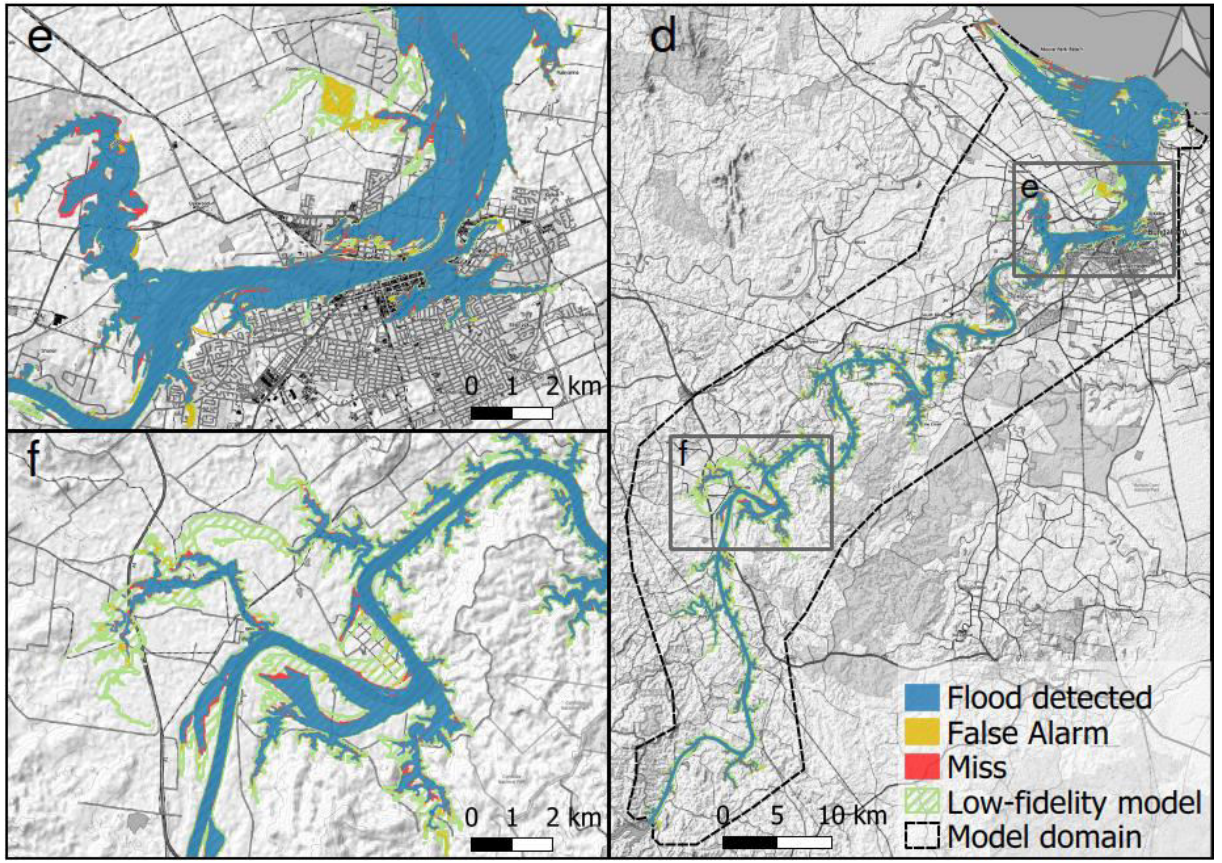
High-resolution model: TUFLOW
- 36 hr 20 min 0 s

Results – Inundation extent
结果 - 淹没范围

Chowilla floodplain

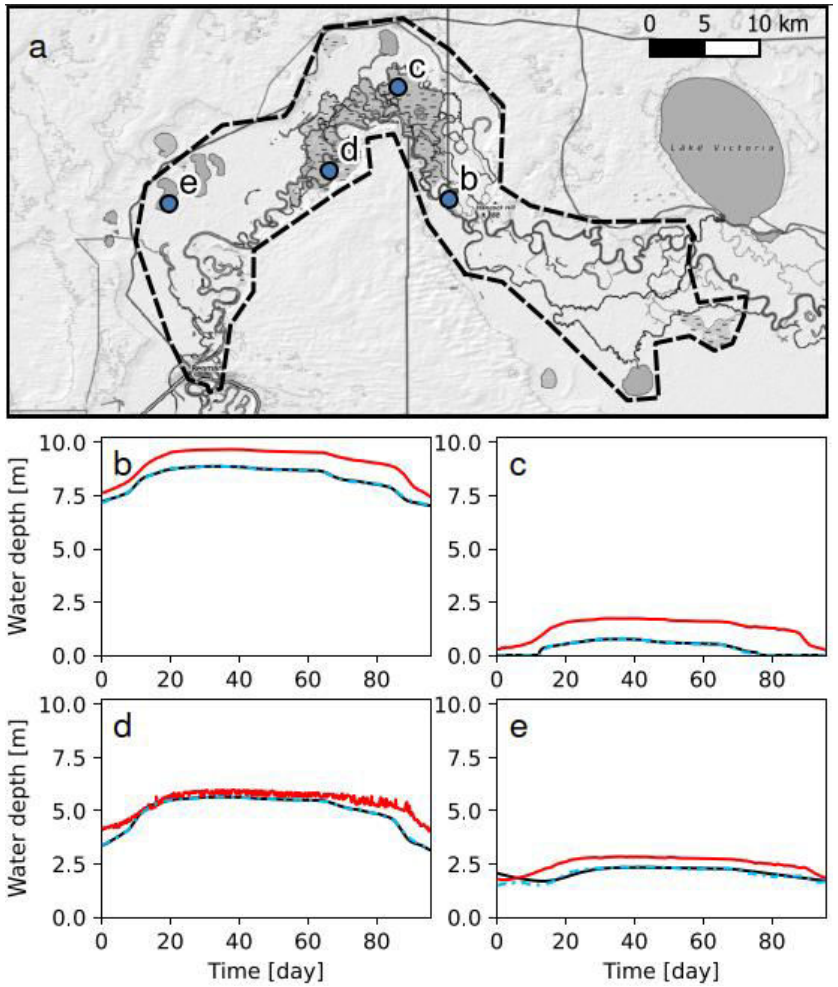


Burnett river

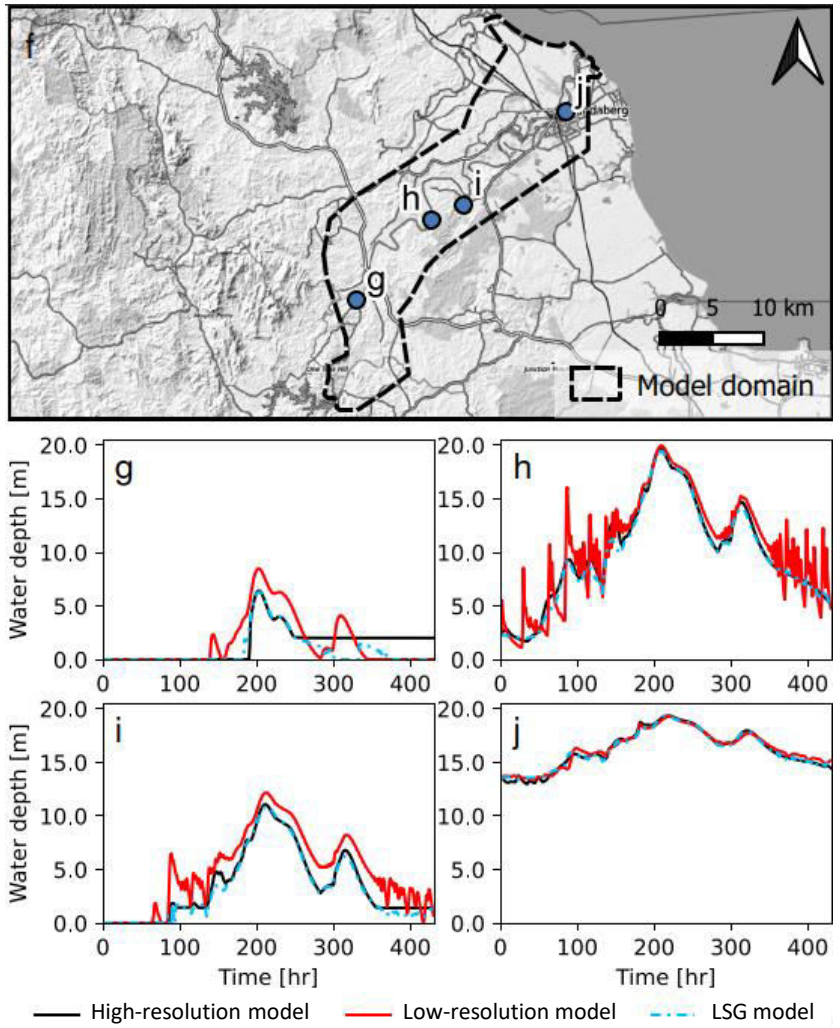


Results – Water depth
结果 – 淹没深度

Chowilla floodplain



Burnett river



Conclusions 结论

- The LSG model compared to traditional high-resolution models
  - Over 1000 times faster
  - Has similar accuracy
- Real-time flood forecasts for large domains
- Informed decisions by emergency response
- Probabilistic design flood for infrastructure planning

Publications

- Fraehr N, Wang QJ, Wu W and Nathan R (2022) Upskilling low-fidelity hydrodynamic models of flood inundation through spatial analysis and Gaussian Process learning, **Water Resources Research**, 58, e2022WR032248. https://doi.org/10.1029/2022WR032248

- Fraehr N, Wang QJ, Wu W and Nathan R (2023) Development of a fast and accurate hybrid model for floodplain inundation simulations, **Water Resources Research**, 59, e2022WR033836. https://doi.org/10.1029/2022WR033836

- Fraehr N, Wang QJ, Wu W and Nathan R, Supercharging hydrodynamic inundation models for instant flood insight , **Nature Water**, 11 September 2024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Flood inundation modelling

- Machine learning
  - Zhou Y, Wu W, Nathan R and Wang QJ (2022) Deep learning-based rapid flood inundation modelling for flat floodplains with complex flow paths, **Water Resources Research**, https://doi.org/10.1029/2022WR033214
  - Yang Q, Wu W, Wang QJ and Vaze J (2022) A 2D hydrodynamic model-based method for efficient flood inundation modelling, **Journal of Hydroinformatics**, https://doi.org/10.2166/hydro.2022.133
  - Zhou Y, Wu W, Nathan R and Wang QJ (2021) Python program for spatial reduction and reconstruction method in flood inundation modelling, **MethodsX**, DOI: https://doi.org/10.1016/j.mex.2021.101527
  - Zhou Y, Wu W, Nathan R and Wang QJ (2021) A rapid flood inundation modelling framework using deep learning with spatial reduction and reconstruction, **Environmental Modelling and Software**, DOI: 10.1016/j.envsoft.2021.105112
  - Xie S, Wu W, Mooser S, Wang QJ, Nathan R and Huang Y (2020) Artificial Neural Network based Hybrid Modeling Approach for Flood Inundation Modeling, **Journal of Hydrology**, https://doi.org/10.1016/j.jhydrol.2020.12560547.
  - Chu H, Wu W, Wang QJ, Nathan R and Wei J (2019) An ANN-based emulation modelling framework for flood inundation modelling: application, challenges and future directions, **Environmental Modelling & Software**, https://doi-org/10.1016/j.envsoft.2019.104587
- Library maps
  - Wang W, Wang QJ, Nathan R and Velasco-Forero C (2022) Rapid prediction of flood inundation by interpolation between flood library maps for real-time applications, **Journal of Hydrology**, https://doi.org/10.1016/j.jhydrol.2022.127735