Spatial Mode-based Calibration (SMoC) of Forecast Precipitation Fields from Numerical Weather Prediction Models

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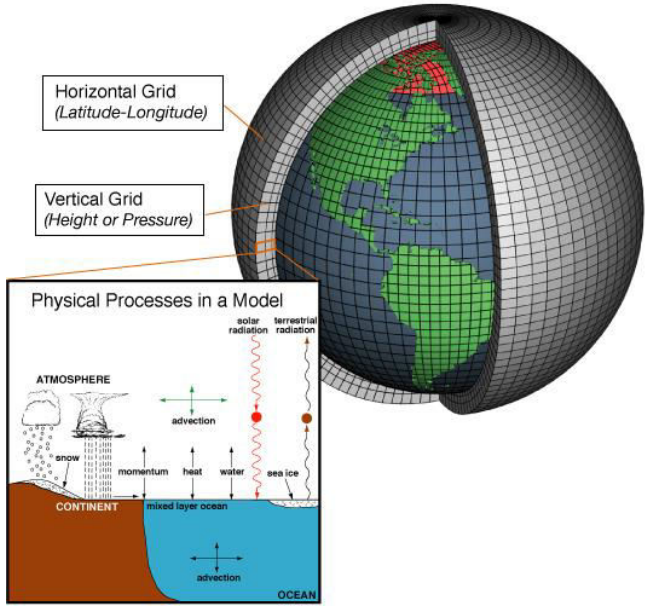
HEPEX workshop 2023 – Forecasting Across Spatial Scales and Time Horizons

1. Background and Motivation

❑ Numerical weather prediction (NWP)

- NWP Precipitation forecasts



Atmospheric model schematic[1]

- Spatial scale
  - from one grid-cell to the globe
- Temporal scale
  - from an hour to two weeks
- Forecast performance
  - low quality due to systematic errors

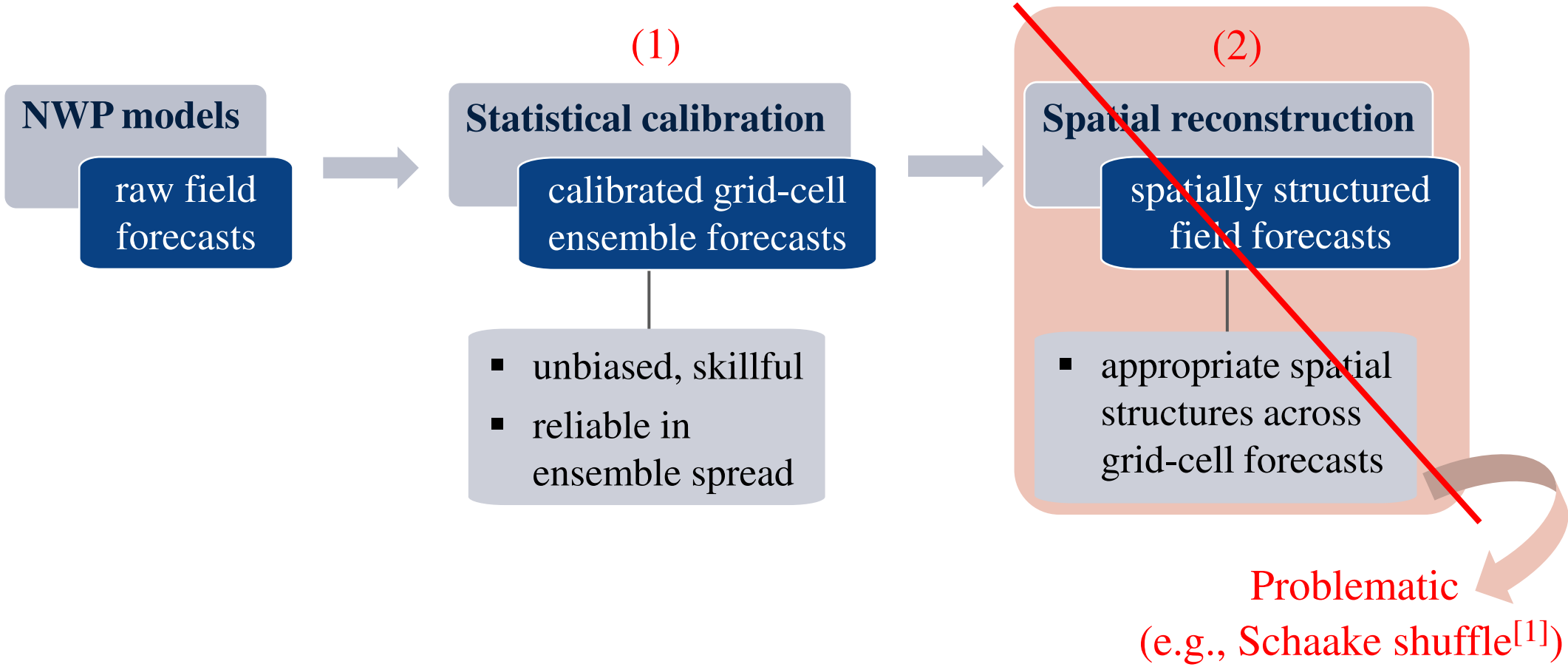
⇩

Post-processing

[1] NOAA (2007). Available at http://celebrating200years.noaa.gov/breakthroughs/climate_model/AtmosphericModelSchematic.png

1. Background and Motivation

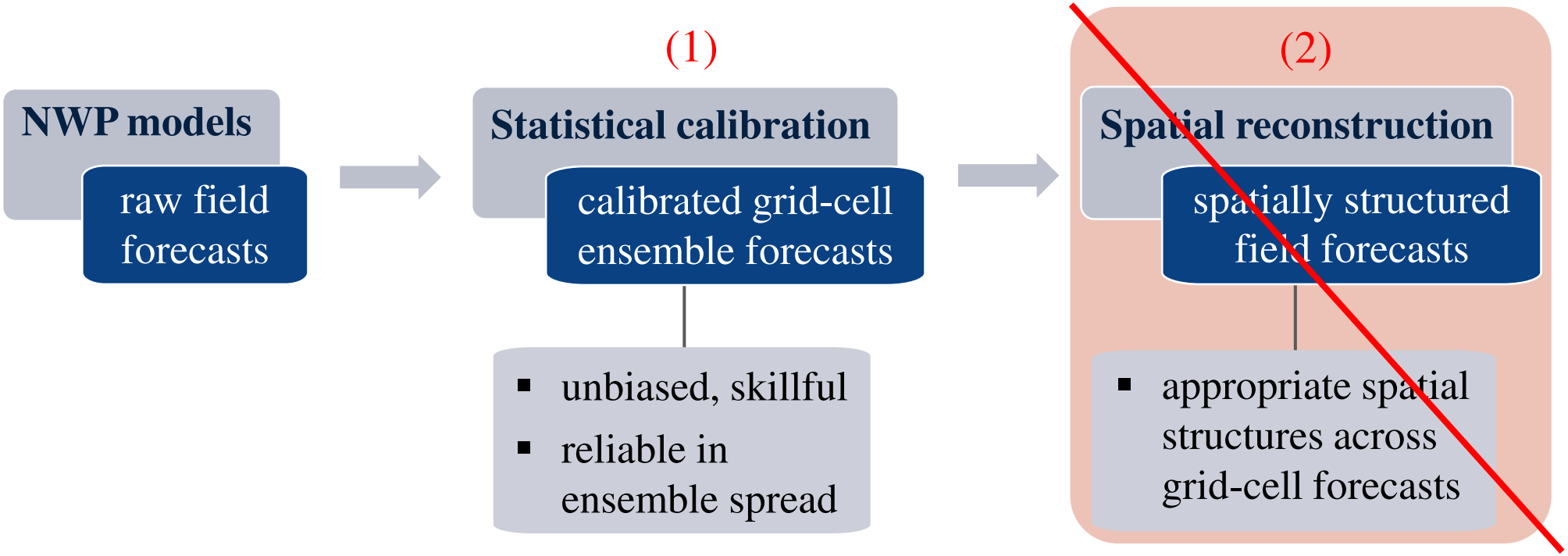
❑ Grid-cell by grid-cell post-processing



[1] Clark, M., Gangopadhyay, S., Hay, L., Rajagopalan, B., & Wilby, R. (2004). The Schaake Shuffle: A Method for Reconstructing Space–Time Variability in Forecasted Precipitation and Temperature Fields. Journal of Hydrometeorology, 5(1), 243-262. https://doi.org/10.1175/1525-7541(2004)005<0243:TSSAMF>2.0.CO;2.

1. Background and Motivation

❑ Grid-cell by grid-cell post-processing



Motivation:

To calibrate forecast precipitation fields as a whole and produce ensemble forecasts with inbuilt spatial structures.

2. Methodology

❑ Challenge

- High spatial dimension of field data

❑ Solution

- **Reduce** spatial dimensions of forecast/observation field data
- **Calibrate** dimension-reduced variables
- **Reverse** back to high dimensions

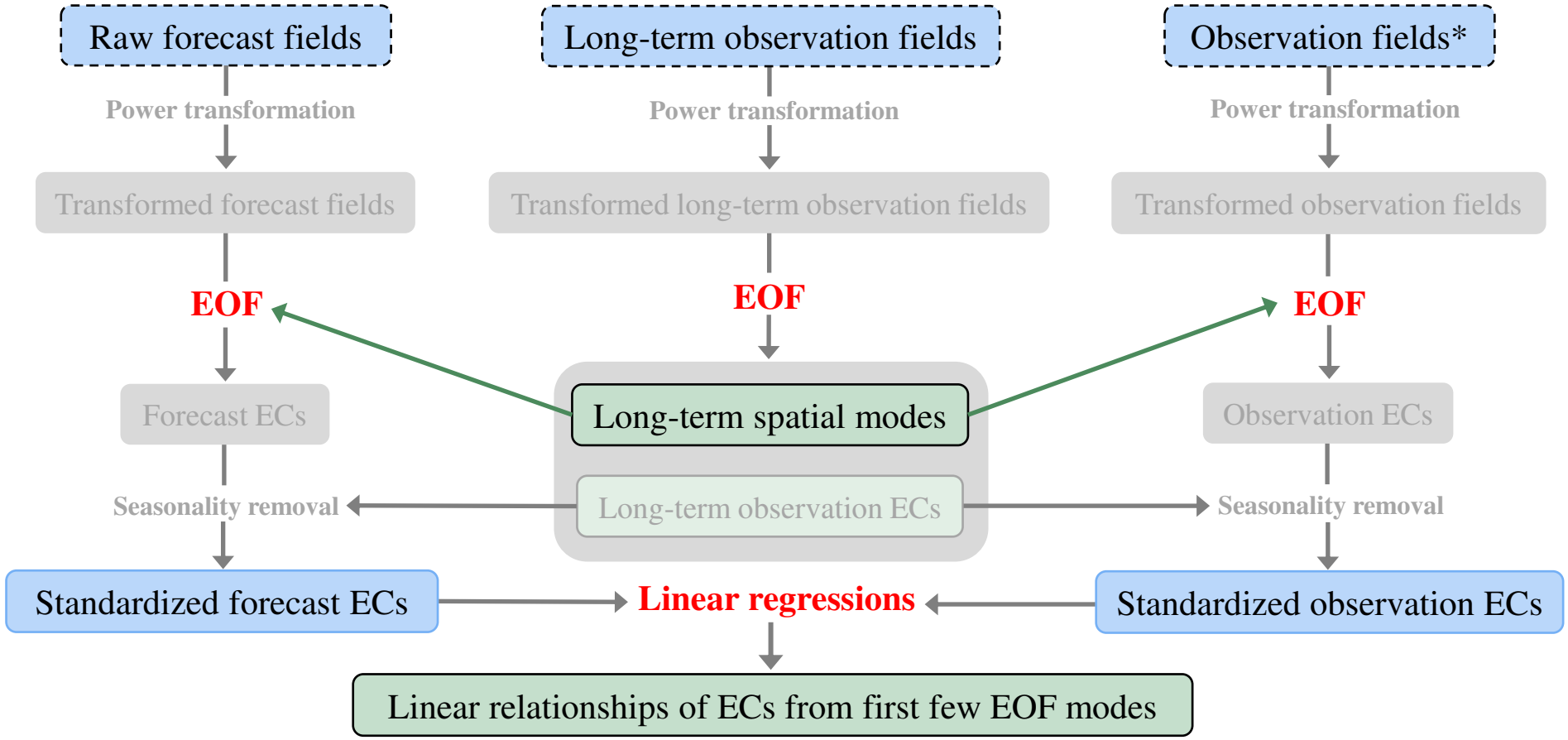
❑ Empirical orthogonal function (EOF)

- Decompose spatial-temporal data into **spatial modes** and **expansion coefficients** (ECs)
- Dominant EOF modes

⇒ A Spatial Mode-based Calibration (SMoC) model

2. Methodology

❑ SMoC

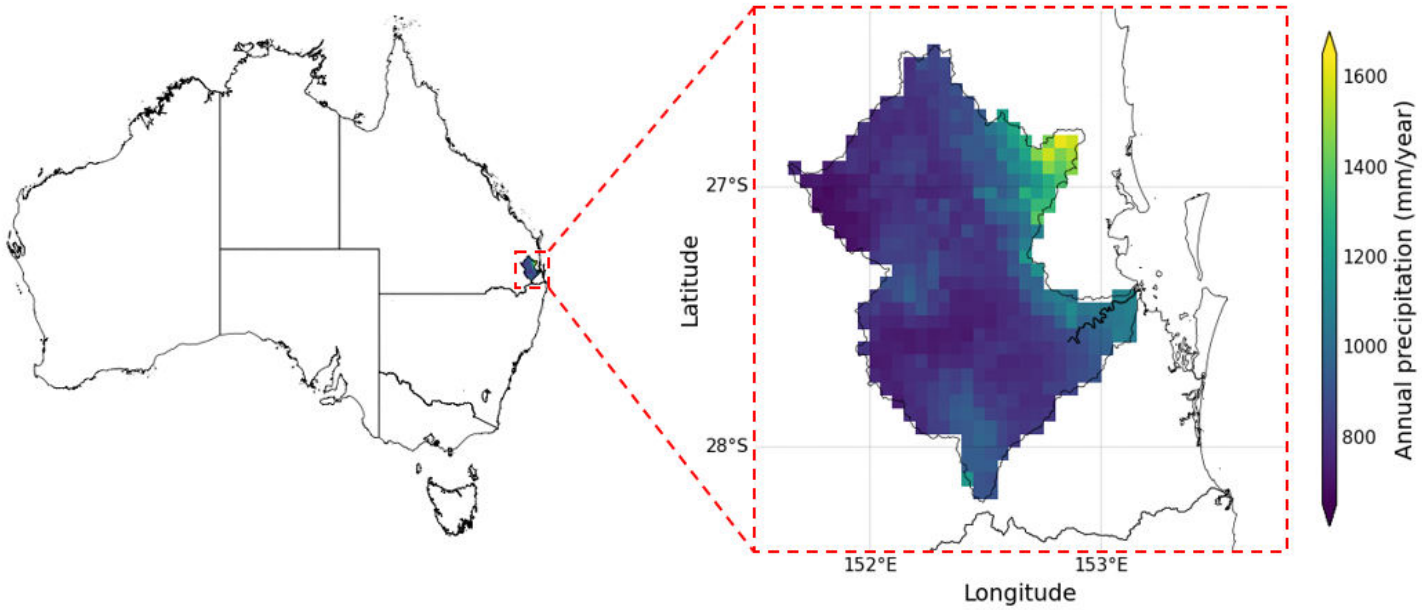


The modelling process of the SMoC model. ECs are derived expansion coefficients from the EOF analysis.

3. A case study

❑ Daily precipitation data

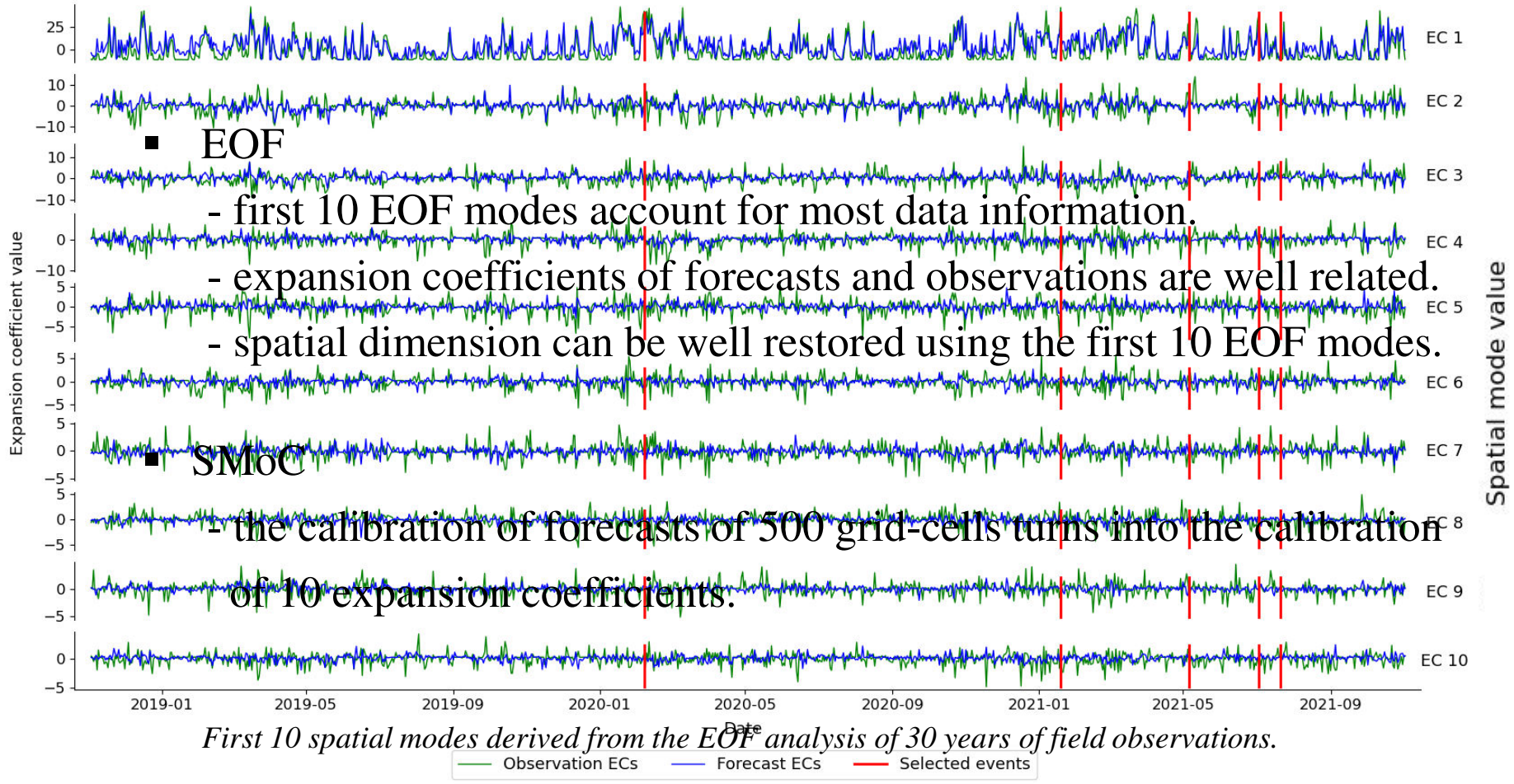
- **Region:** Brisbane Drainage Basin
- **Forecasts:** ACCESS-G3 (Nov 2018 - Oct 2021, 3 years)
- **Observations:** AWAP (Nov 1988 - Oct 2021, 30 + 3 years)



Location and average annual precipitation map of the study region.

3. A case study

❑ Model checking



First 10 spatial modes derived from the EOF analysis of 30 years of field observations.

- EOF
  - first 10 EOF modes account for most data information.
  - expansion coefficients of forecasts and observations are well related.
  - spatial dimension can be well restored using the first 10 EOF modes.
- SMoC
  - the calibration of forecasts of 500 grid-cells turns into the calibration of 10 expansion coefficients.

First 10 expansion coefficients derived from the EOF analysis of 3 years of forecasts and corresponding observations.

EOF reconstructions of 5 selected precipitation events.

3. A case study

❑ SMoC calibration

- Two SMoC models established separately for light events and heavy events
- Forecast lead times: 1, 3, 5, 7, 9 days ahead

❑ SMoC evaluation

- A comparison with raw forecasts
- A comparison with a grid-cell by grid-cell post-processing (SCC+SS)

  (1) statistical calibration: the seasonally coherent calibration (SCC)[1]

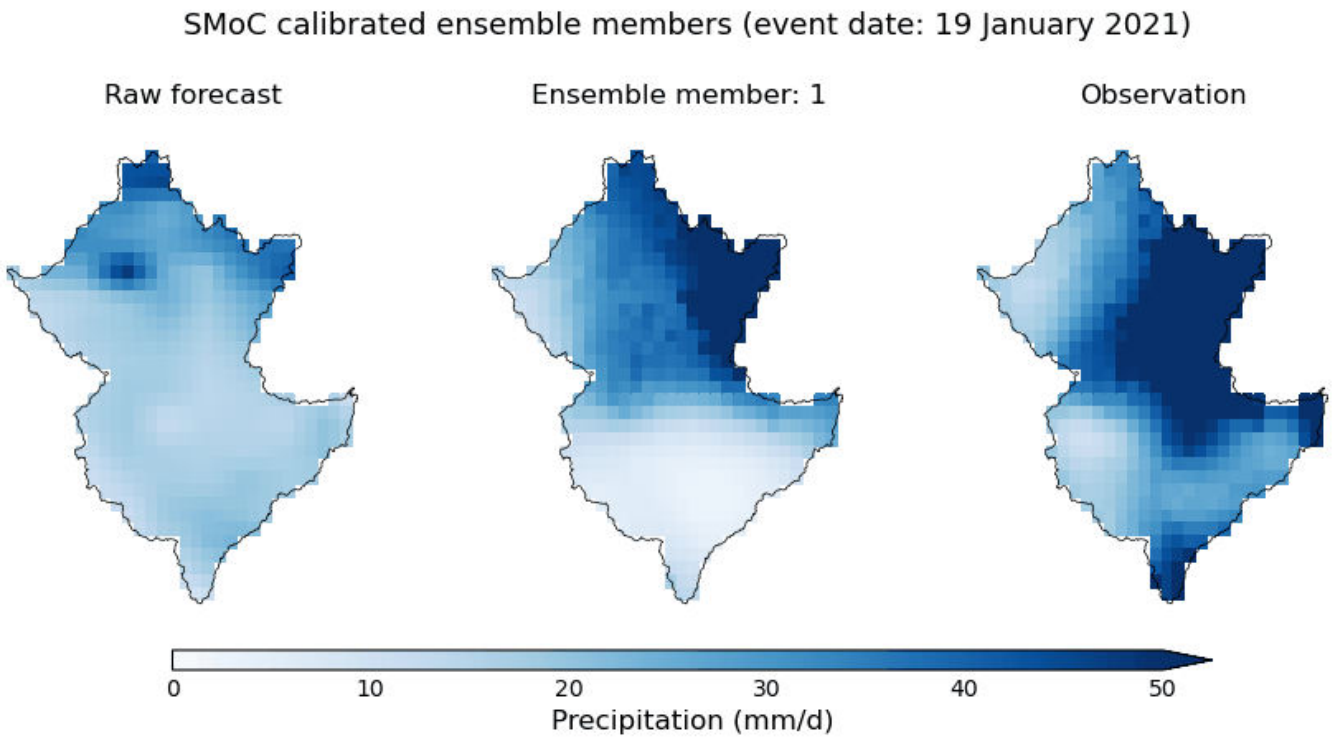
  (2) spatial reconstruction: the Schaake shuffle (SS)

[1] Wang, Q. J., Zhao, T., Yang, Q. and Robertson, D., 2019. A Seasonally Coherent Calibration (SCC) Model for Postprocessing Numerical Weather Predictions. Monthly Weather Review. 147(10), 3633-3647. https://doi.org/10.1175/mwr-d-19-0108.1.

3. A case study

❑ Results – compared with raw forecasts

- A calibration example of SMoC



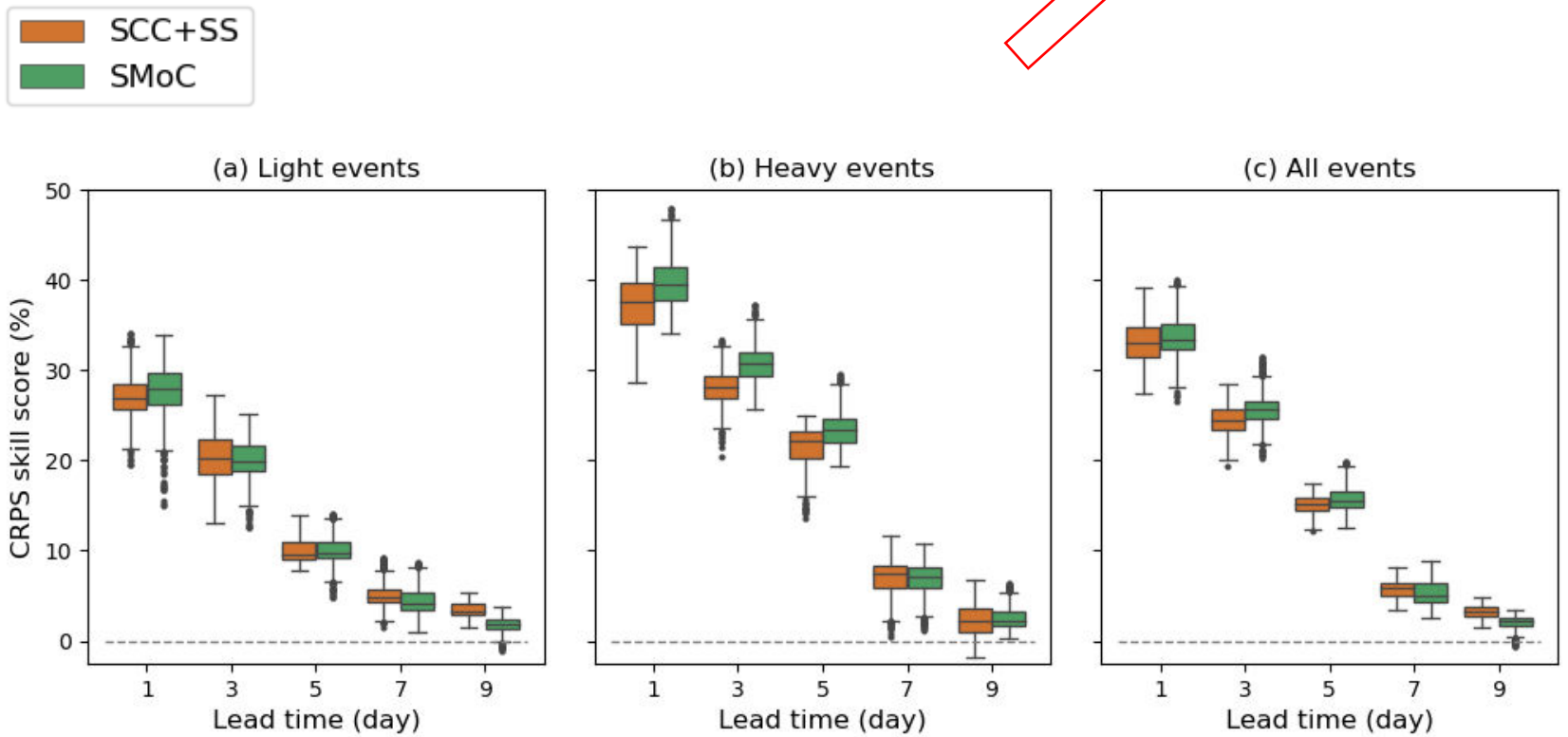
Animation of 100 SMoC calibrated ensemble members (1 day ahead) of the whole basin for a heavy precipitation event on 19 January 2021.

3. A case study

❑ Results – compared with SCC+SS

- Grid-cell forecast skill

Comparable skill



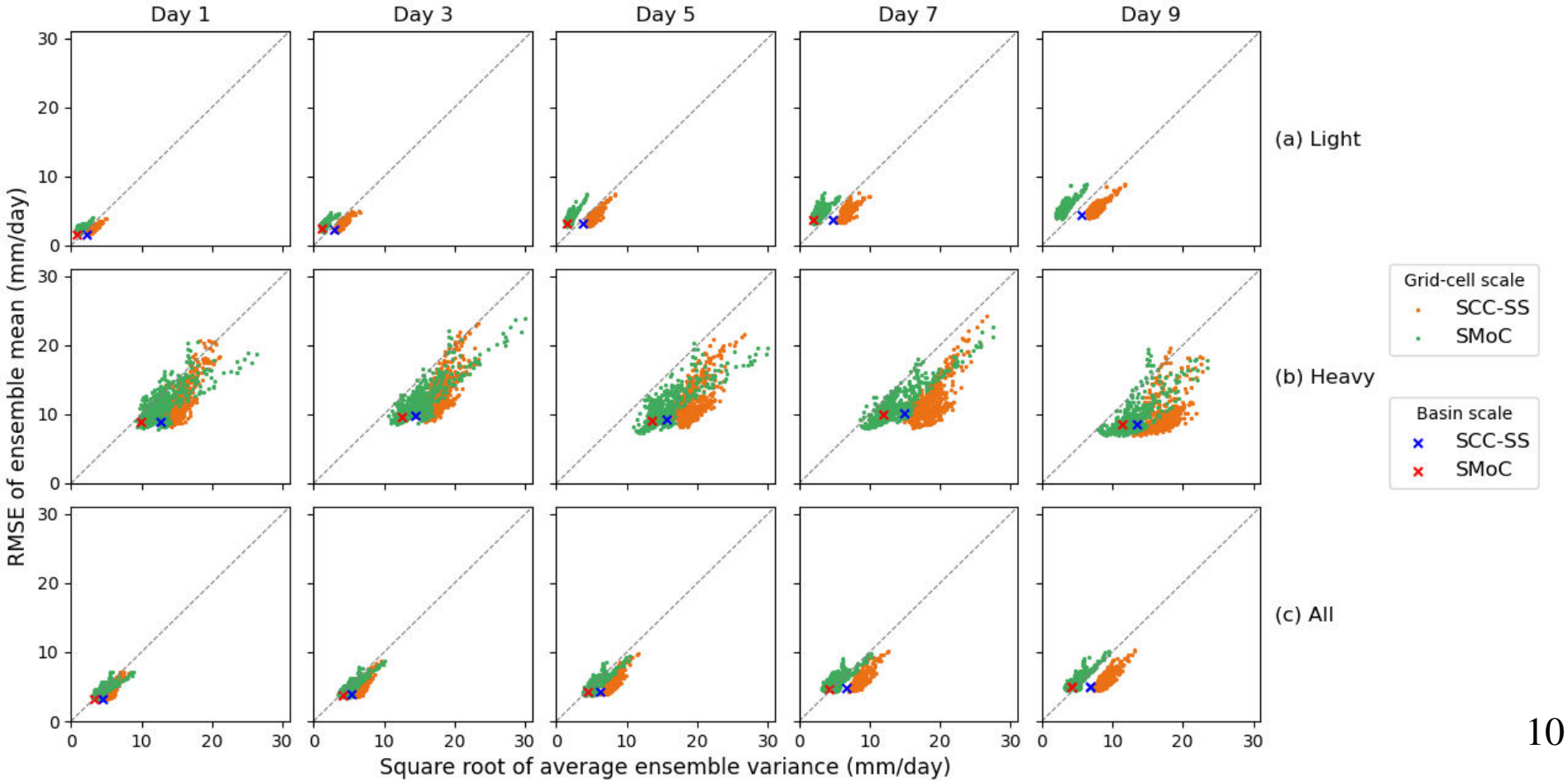
CRPS skill scores of forecasts post-processed by SCC+SS and SMoC at grid-cell scale.

3. A case study

❑ Results – compared with SCC+SS

- Forecast reliability

Better reliability



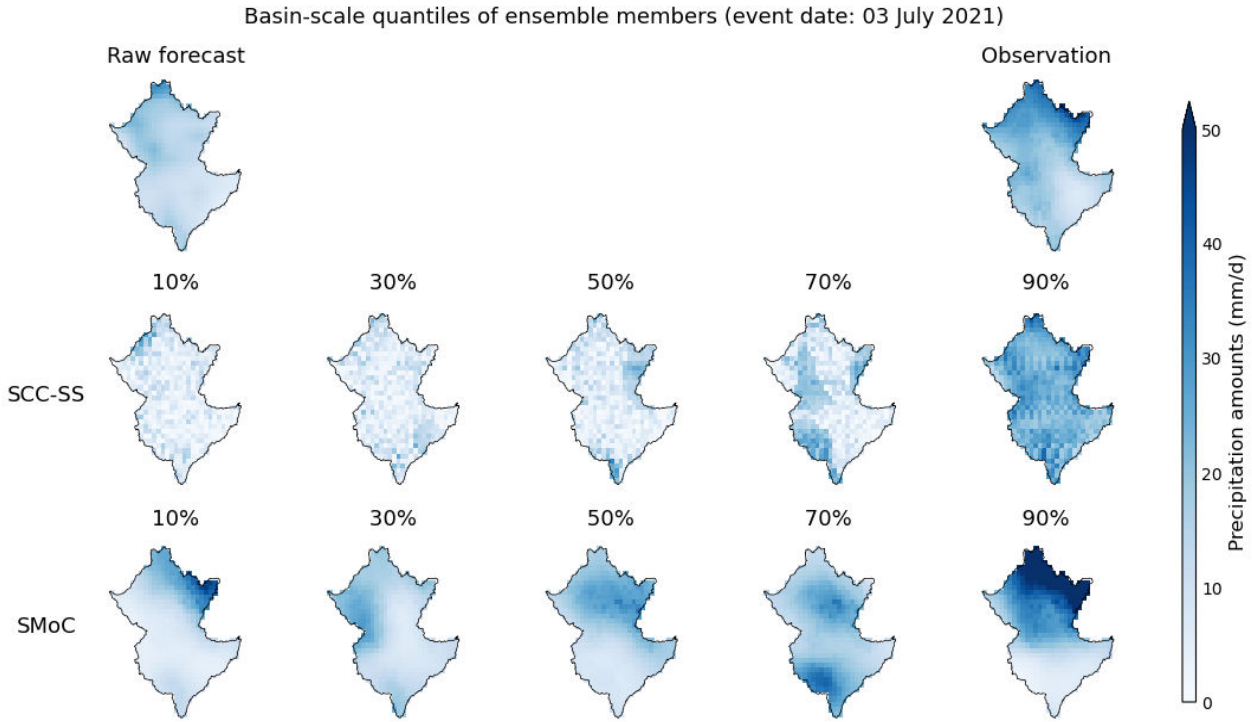
RMSE of ensemble mean forecasts versus square root values of average ensemble variance for (a) light events, (b) heavy events, and (c) all events at a set of lead times, both for grid-cell (ensemble forecasts for each of the 493 grid-cells) and basin (basin average ensemble forecasts) scales.

3. A case study

❑ Results – compared with SCC+SS

Much better spatial structure

- Spatial structure



Spatial plots of post-processed ensemble members selected based on a set of quantiles of basin averages of SCC-SS forecasts and SMoC forecasts at 1 day ahead for a heavy precipitation event on 03 July 2021.

- Computational time*

SCC+SS	SMoC
SCC: 72 h	-
SS: 31 h	-
103 hours	11 mins

Far more efficient

* Post-processing forecasts of one lead time with one CPU in Python program

4. Publications

- Zhao P, Wang QJ, Wu W and Yang Q (2022), Spatial mode-based calibration (SMoC) of forecast precipitation fields from numerical weather prediction models, **Journal of Hydrology**, https://doi.org/10.1016/j.jhydrol.2022.128432

- Zhao P, Wang QJ, Wu W and Yang Q (2023), Spatial mode-based calibration (SMoC) of forecast precipitation fields with spatially correlated structures: an extended evaluation and comparison with grid-cell by grid-cell post-processing, **Journal of Hydrometeorology** (in press)

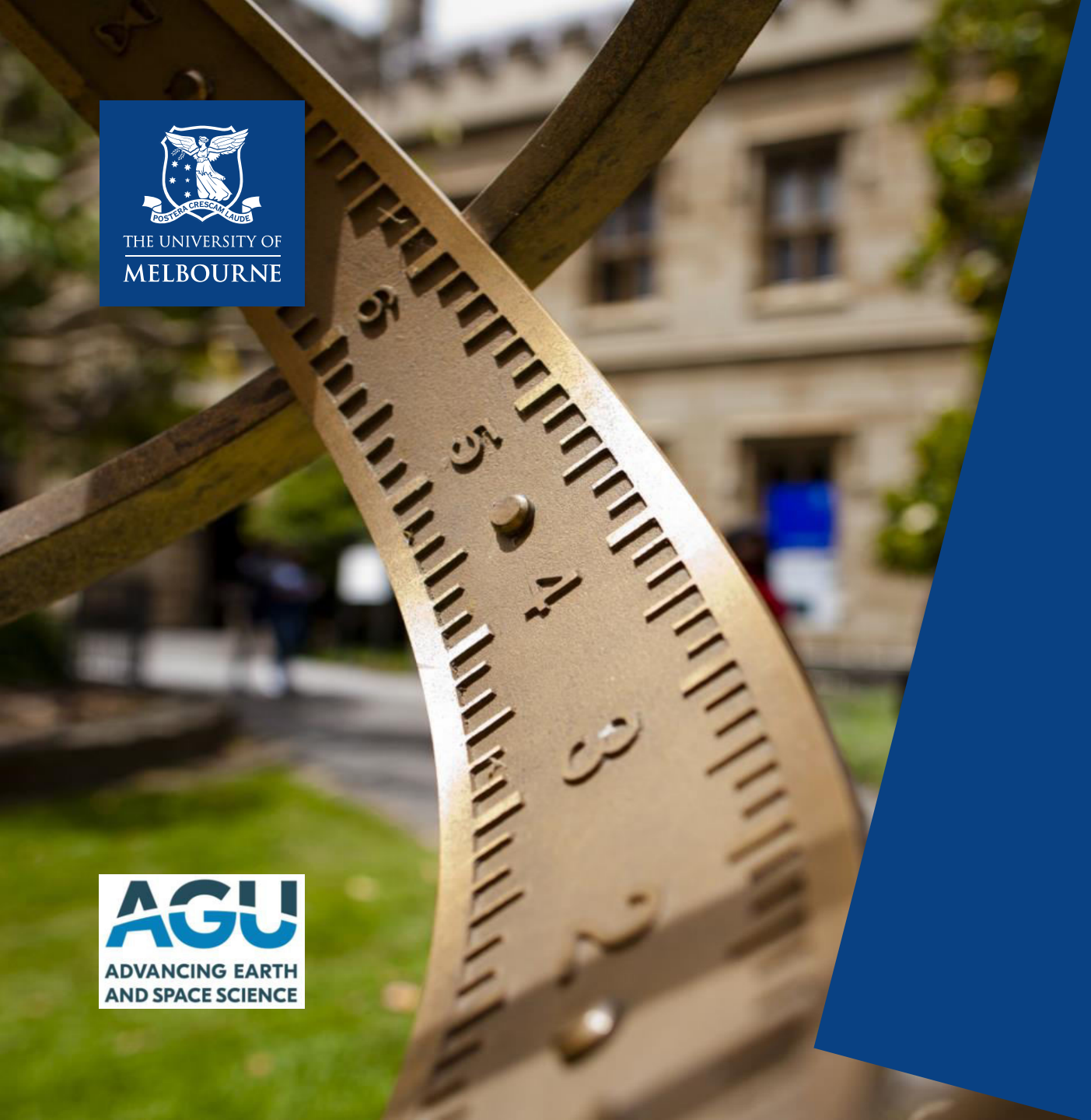
5. Conclusions

❑ A fundamentally new calibration: SMoC

- Inbuilt spatial structures
- Compared with the grid-cell by grid-cell post-processing

  - similar skill, better reliability, and much better spatial structure

  - computationally far more efficient
- Future research: temporal structure



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Thank you

Questions?

For more information
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