

Towards Quantum(-assisted) forecasts: Quantum Reservoir Computing for Weather and Climate prediction

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IMPERIAL

Non-linearities on a linear machine

- Quantum computers are fundamentally *linear* machines
- All approaches to perform nonlinear operations utilise (perhaps tacitly) linear embeddings. For instance
 - Carleman embedding
 - Liouville/Fokker-Planck equation
 - Koopman-van Neumann embedding
 - Hybrid Quantum-Classical (coupling to environment!)
- The key question is: which embedding is most resource-efficient for my dynamical system?

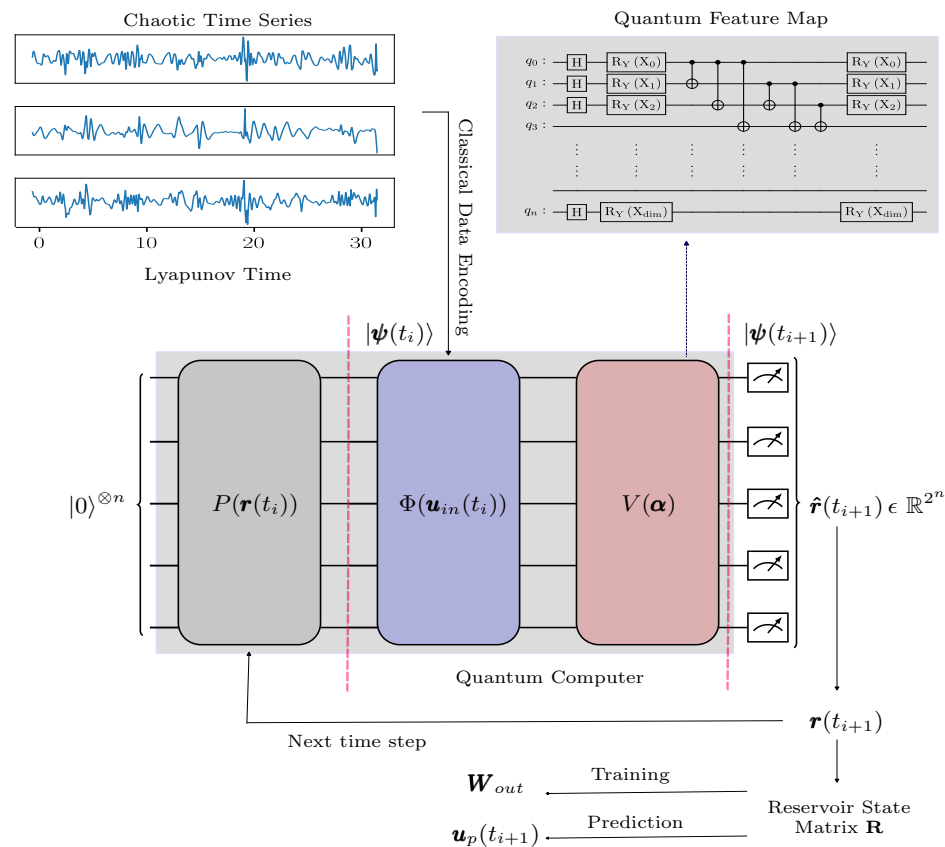
Three major avenues

- Mean-field solvers (to be paired with trapped-ion devices): proven quantum advantage but exceeding current hardware limitations
- Linear embedding solvers: proven quantum advantage but requires scalable universal quantum computers
- Hybrid approaches: executable on current hardware but no theoretical bounds on quantum advantage exist

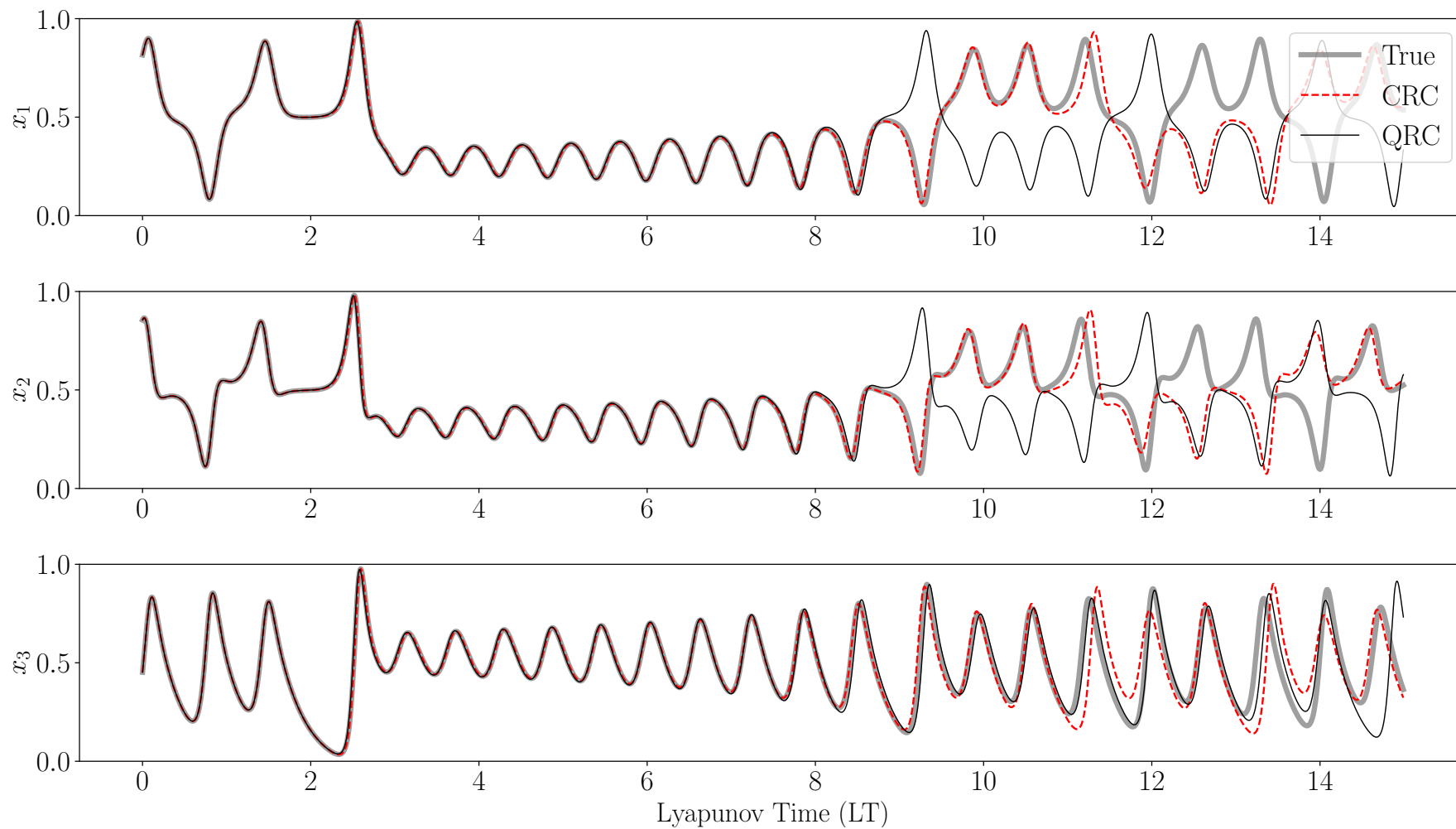
Big challenge: read-in and read-out of data!

Quantum Reservoir Computing (QRC)

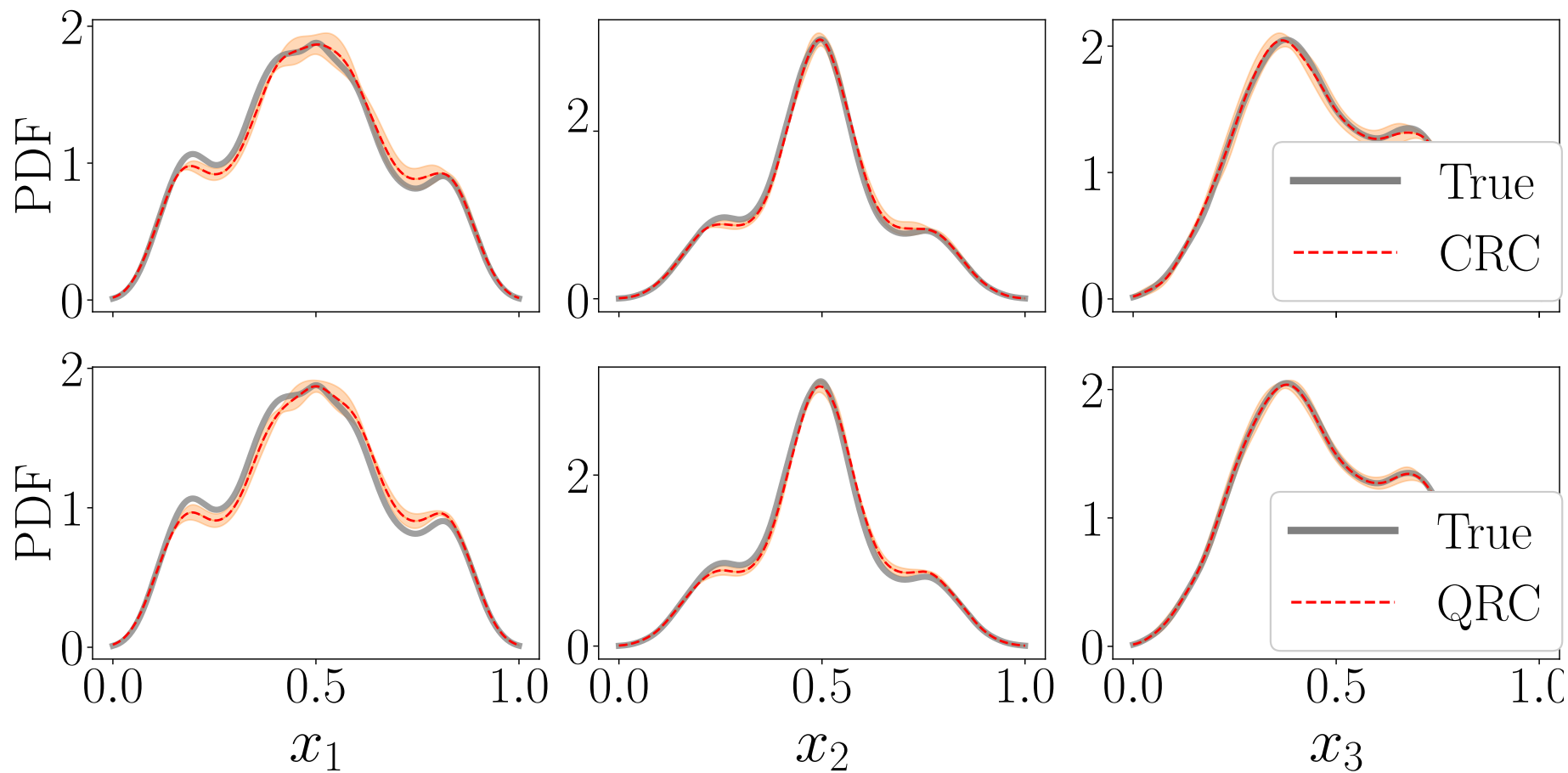
- QRC is a form of a Quantum Neural Network
- Suitable for Noisy Intermediate Scale Quantum Hardware
- Assessment of quantum advantage by a proof-by-demonstration approach



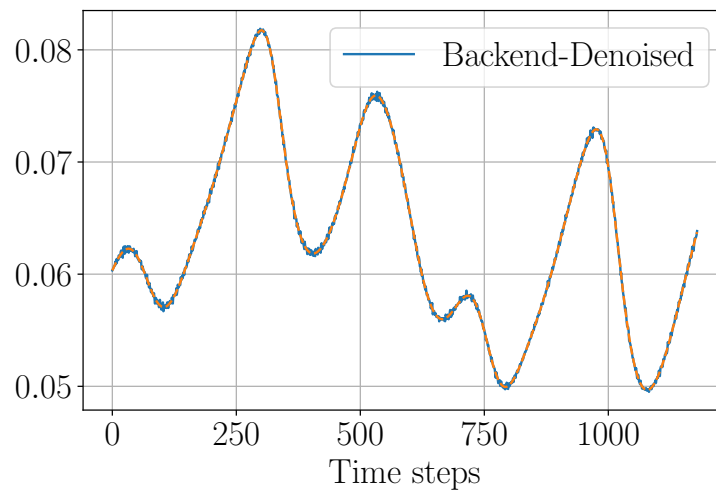
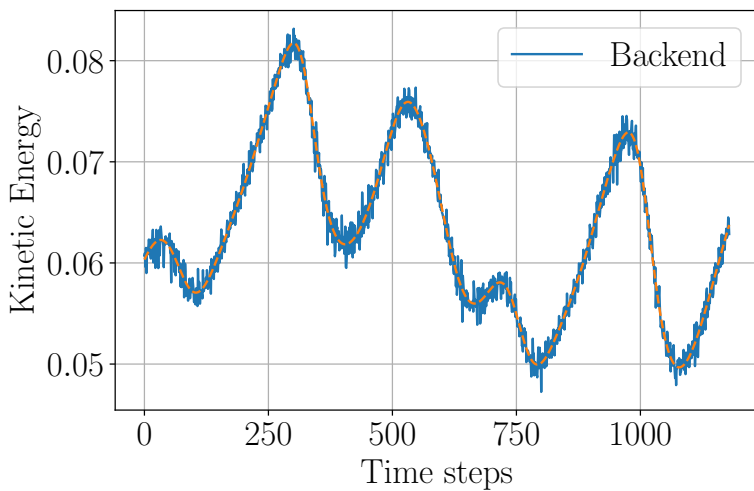
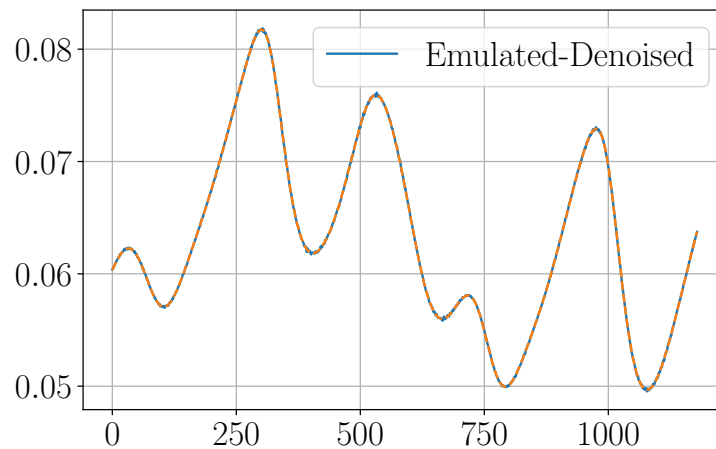
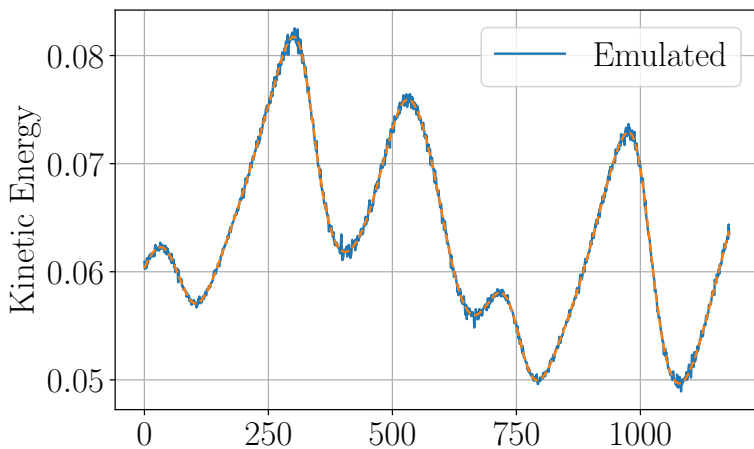
Example: Lorenz '63



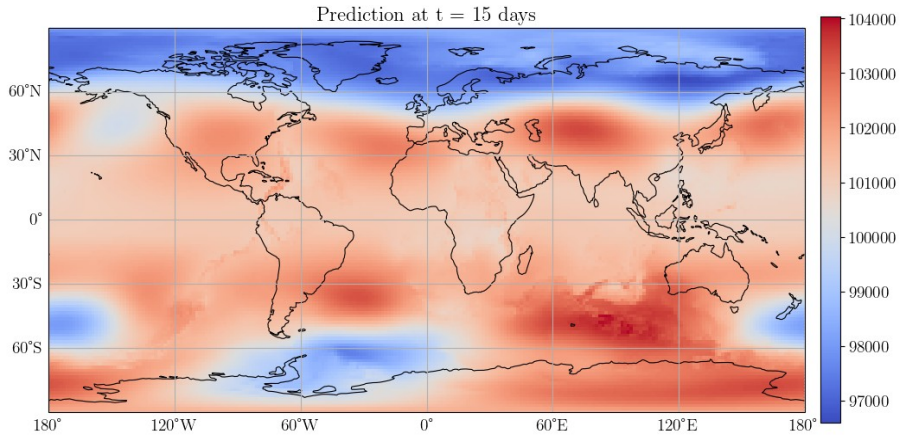
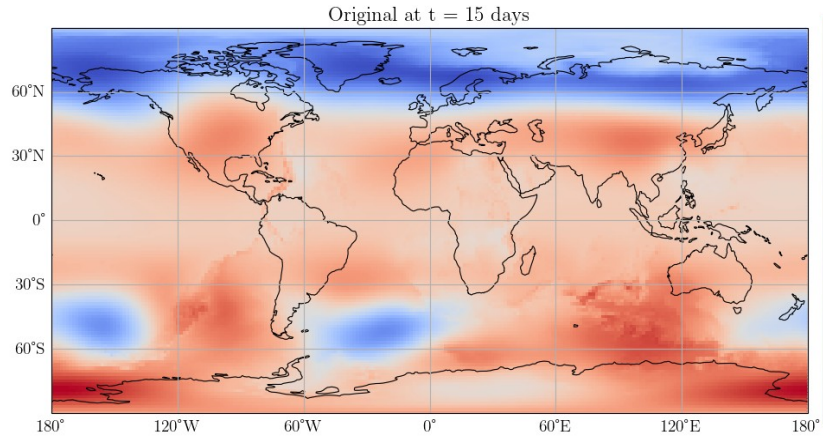
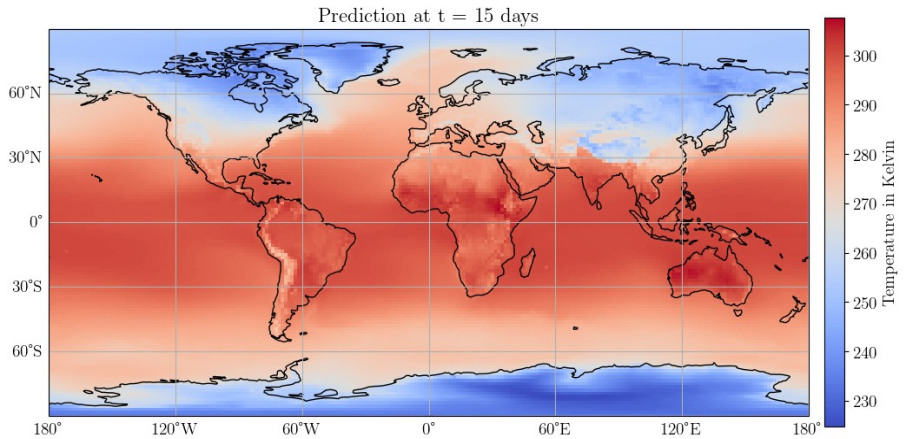
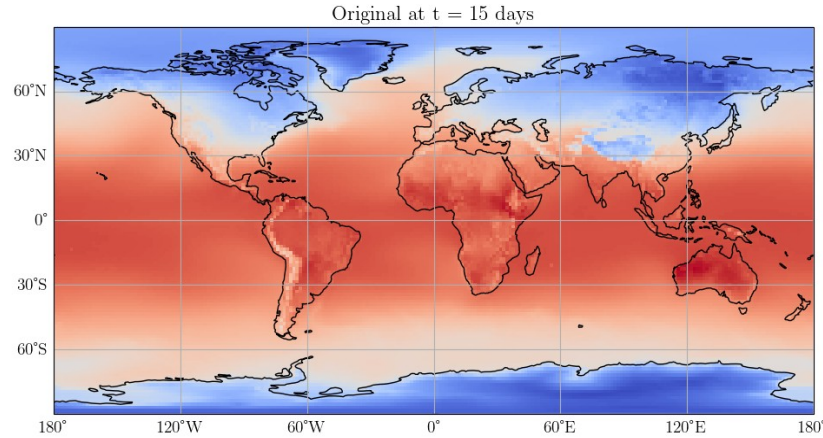
Example: Lorenz '63



MFE flow



QRC Weather Forecasting



2m temp and MSLP – 14 Qubit reservoir predictions

Summary and Outlook

- QRC is the first workable approach to large scale quantum assisted weather forecasts
- Hybrid structure utilises high-dimensionality of the quantum reservoir while keeping the number of required measurements low
- De-quantised scheme already deployed
- Future work to focus on industrial upscaling



Link to the papers