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Defining the Digital Twin - Exploiting the Maximum Potential of the Technology

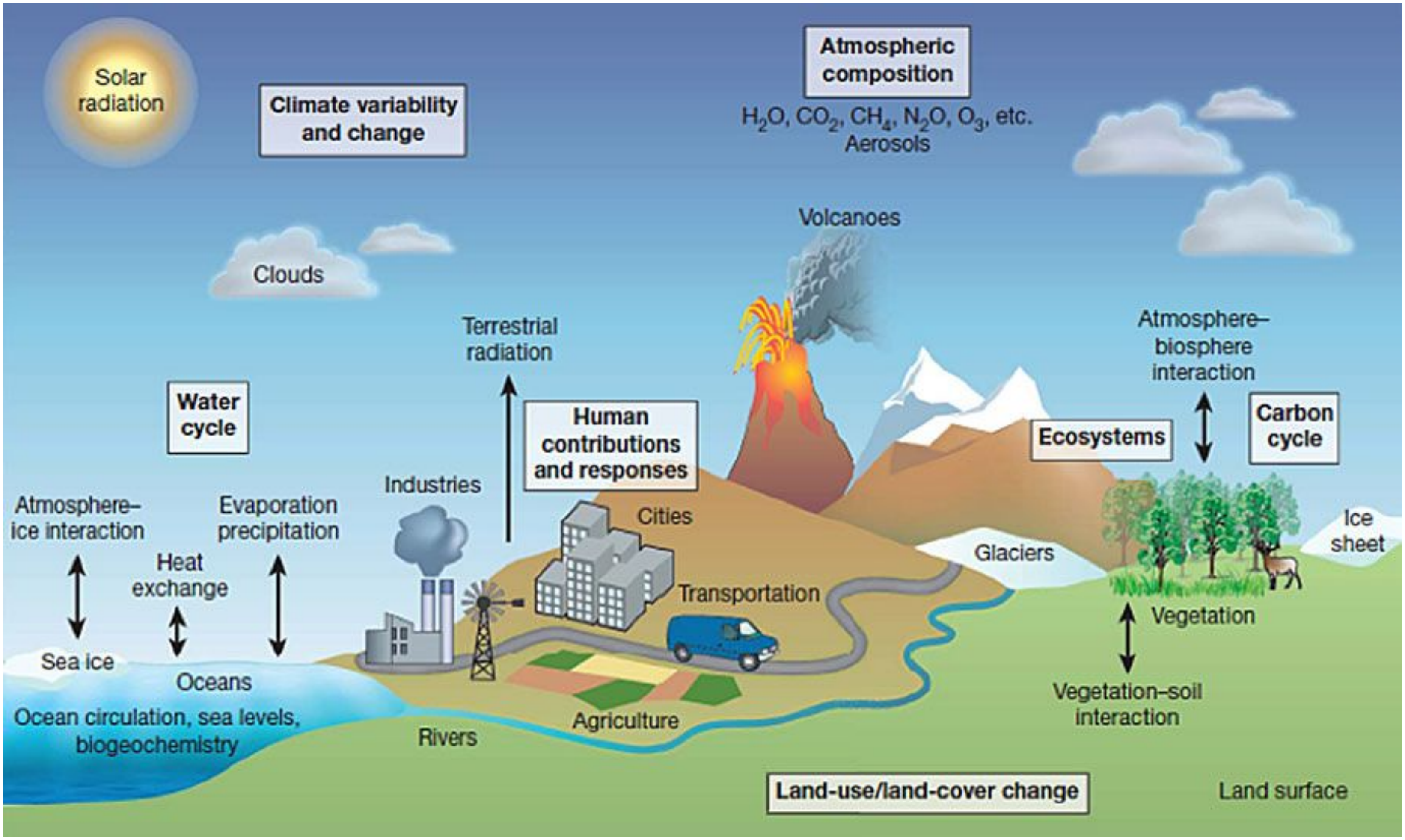
Gordon Blair

Background on the speaker

- Distinguished Professor of Distributed Systems, School of Computing and Communications, Lancaster University
- Track record of research in distributed systems, middleware, adaptive systems
- EPSRC Senior Fellow in Digital Technology and Living with Environmental Change (DT/LWEC)
- Co-Director of the Centre of Excellence in Environmental Data Science (CEEDS)
- Head of Environmental Digital Strategy, UKCEH

… and part-time shepherd!

The changing nature of environmental science



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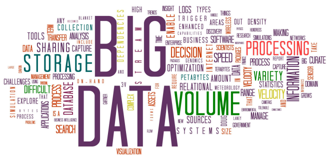
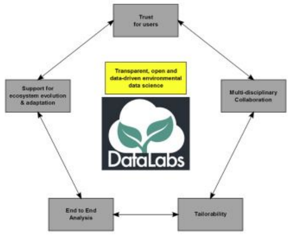
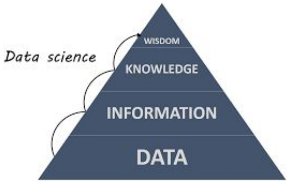
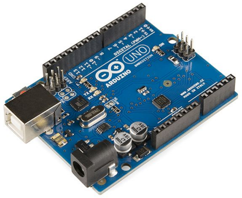
Potential of digital technology

- New forms of data acquisition leading to unprecedented amounts of environmental data
- New forms of data processing providing substantial and elastic resources to store and process this data…
- … along with collaborative environments to support transdisciplinary science
- New forms of data analytics providing novel ways of making sense of this highly complex data
- New forms of (digitally inspired) communication to speak effectively to a range of audiences



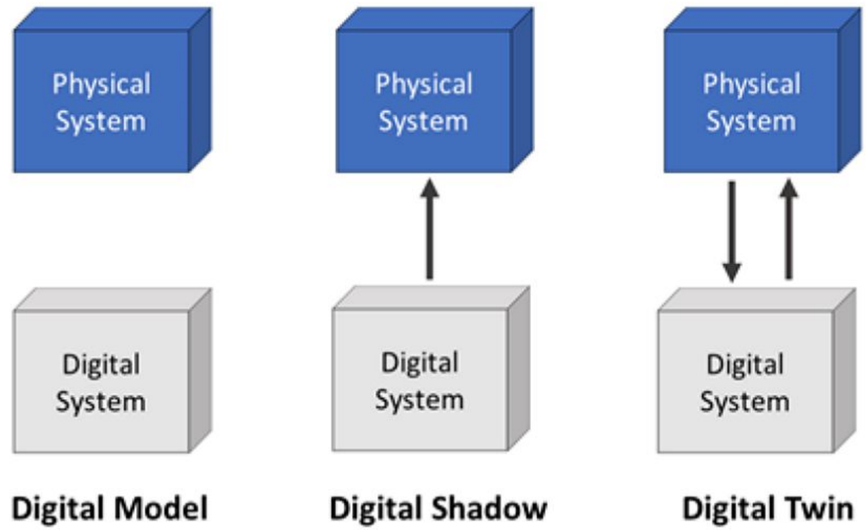






A focus on digital twins

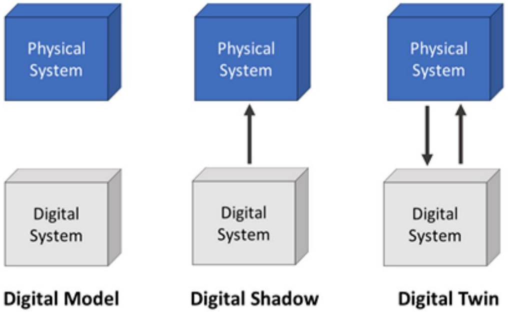
- Digital twins emerged in the engineering domain to be a digital/virtual representation of a physical artifact, and one that is constantly updating to represent the structure and behaviour of that artifact



From: Enabling a national cyber-physical infrastructure to catalyse innovation BEIS, March 2022

Digital twins of the natural environment

- There is a compelling case to look to digital twin technology to help us understand and manage the natural environment
- Builds on the strong tradition of process understanding and process models in environmental science
- Also takes advantage of the unprecedented amount of environmental data that is now available (as discussed earlier)
- Important to have seek a step change in nowcasting and forecasting capabilities
    - Not just better models
    - Not just better data assimilation
    - Not just global scale models

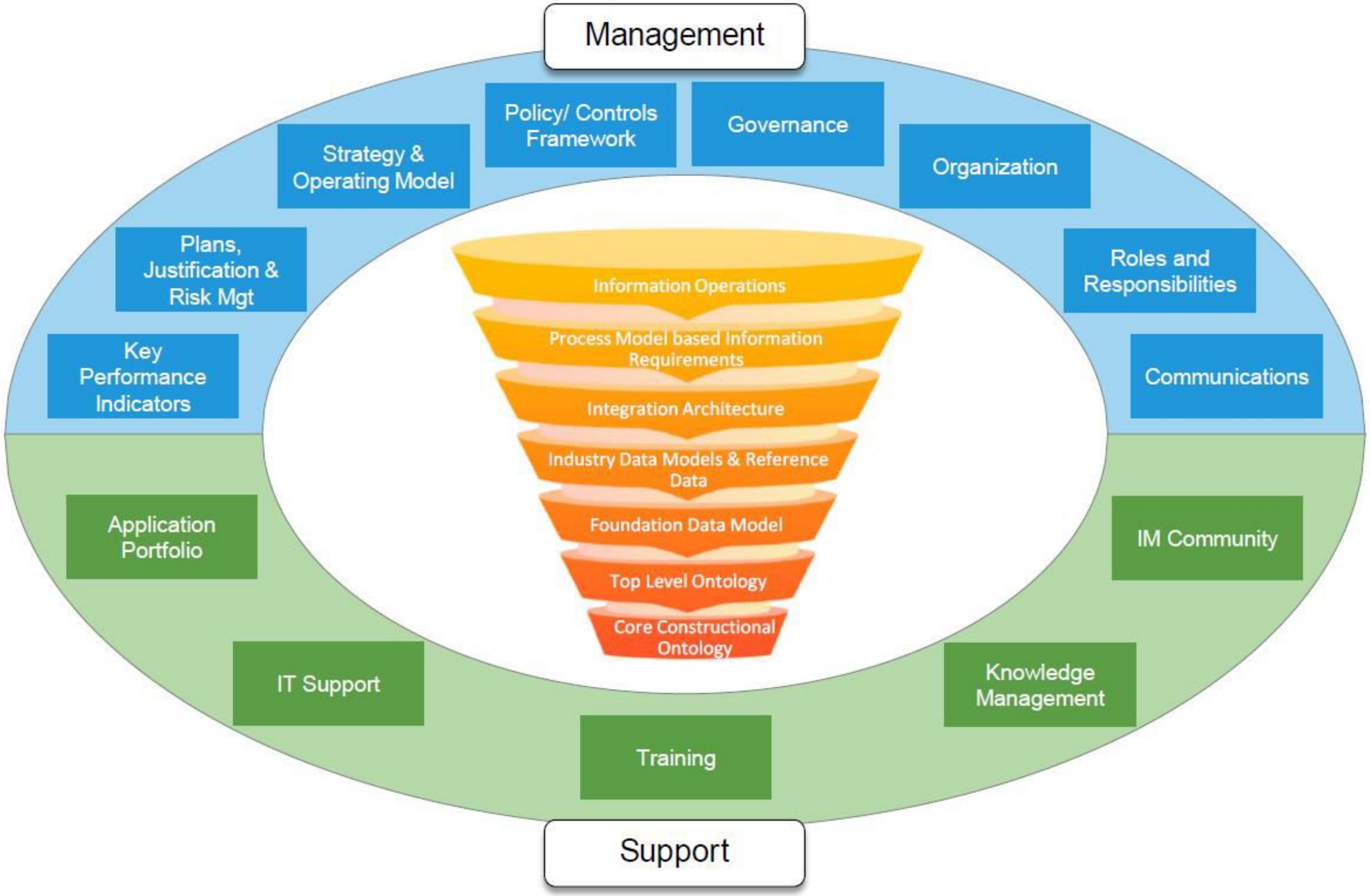


Challenges

- ‘Bread and butter’ challenges
  - Integration of all related environmental assets
  - Interoperability between assets including across federated systems
  - Scalability in terms of underlying computational resources
- ‘Jam’ challenges
  - Data science and AI techniques tailored for the natural environment
  - Process and data model integration
  - Managing complexity and understanding interactions
  - Governance

DSNE
Data Science of the Natural Environment

Case study 1: Information Management Framework for the Environment (IMFe)



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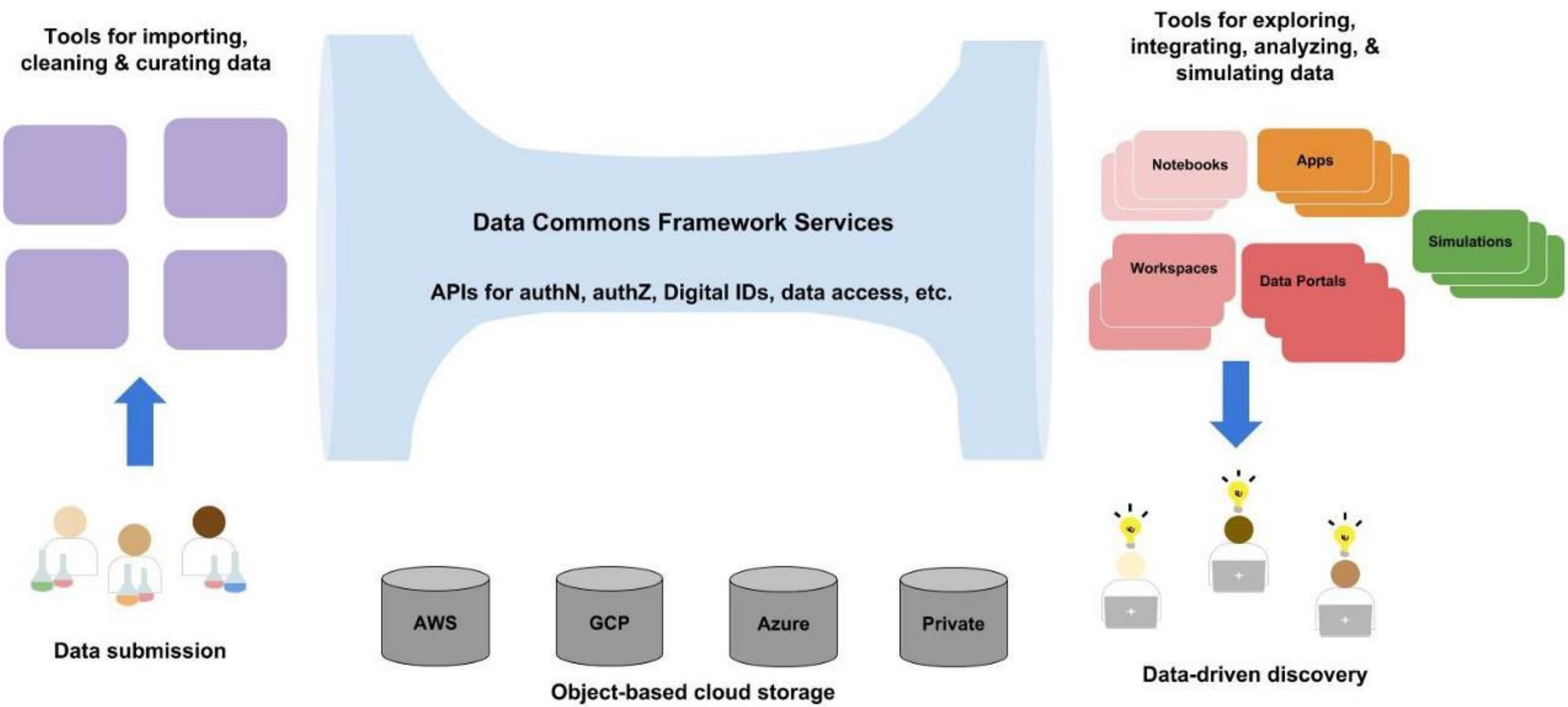
A commons based approach



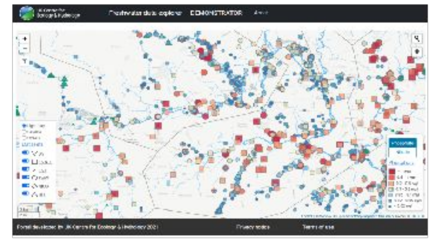
Case study 2: LandInsight

Infrastructure for digital twins

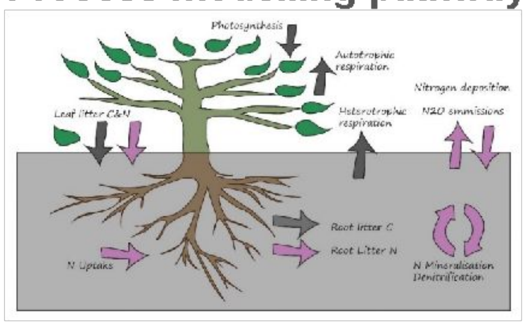
DataLabs

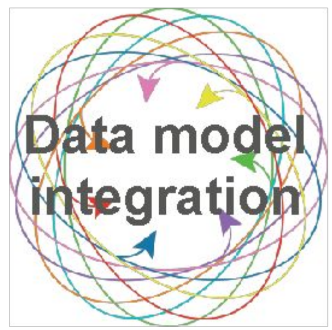
DAFNI

Integrated sensor networks

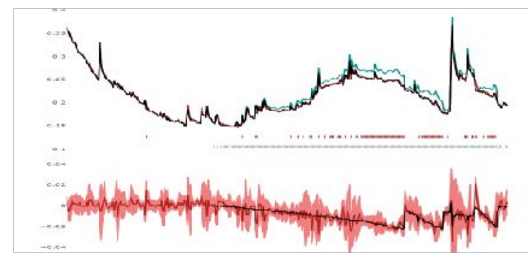


Process modelling pathways





Data-driven modelling pathways (stats, ML, AI)



User delivery

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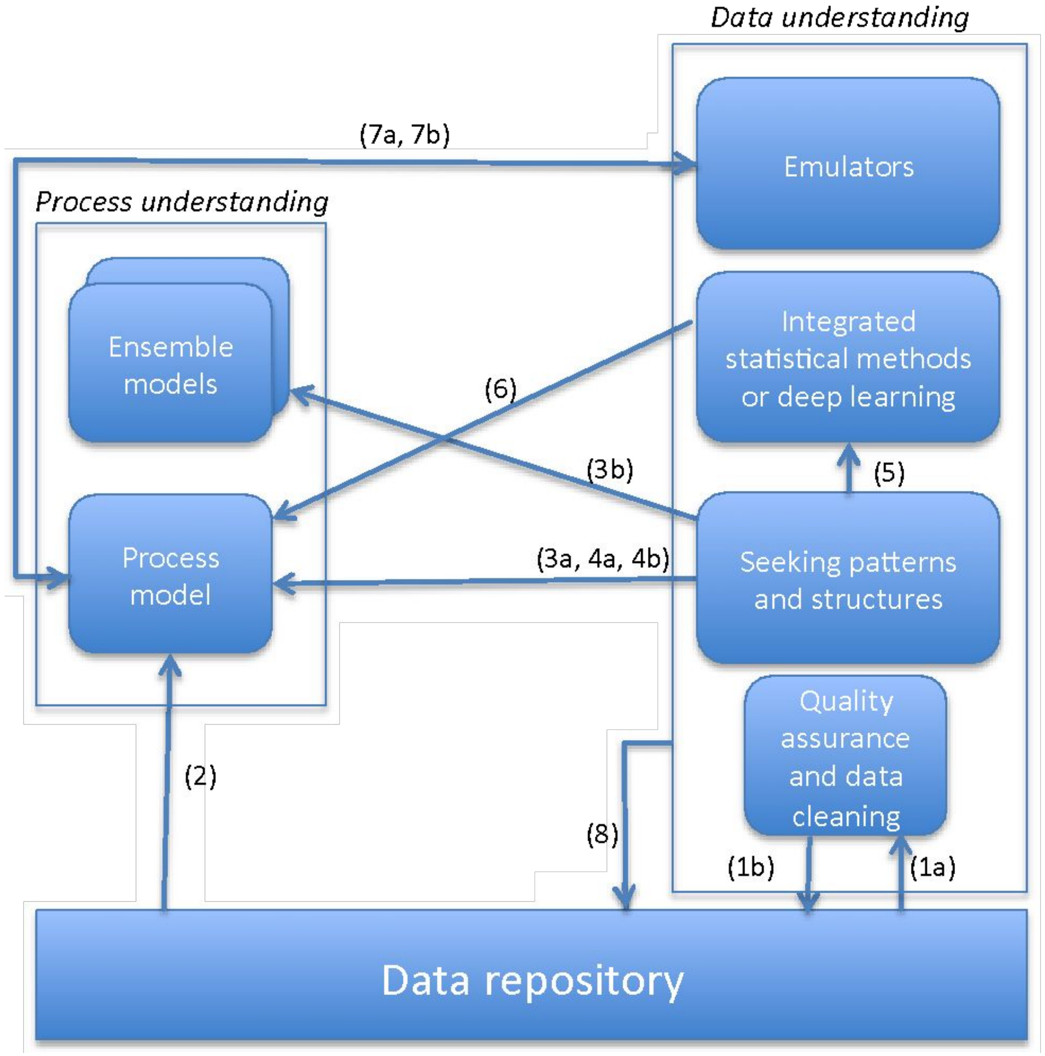
Modelling as a learning process



See Annexe: In praise of arrows

In conclusion

- I believe that digital twins have enormous potential in supporting the challenges of contemporary environmental science, especially in advancing the state of the art in modelling and prediction
- To deliver against these challenges, there is a crucial need for common architectures and platforms to support federation and interoperability of digital twins from the outset
- There is a similar need to fully develop the synergy between process and data understanding, modelling as a learning process

Further reading

Siddorn, J. et al. (2022). An Information Management Framework (IMFe) for Environmental Digital Twins, in preparation.

Blair, GS. (2021). Digital twins of the natural environment. Patterns, 2.

Blair, GS, Henrys, PH. (2022). The Role of Data Science in Environmental Digital Twins: In Praise of the Arrows. In submission to Environmetrics.

Blair, GS, et al. (2019). Models of Everywhere Revisited: A Technological Perspective. Environmental Modelling & Software, 122.

Blair, GS, Henrys, PA, Leeson, A, Watkins, J, Eastoe, E, Jarvis, S, Young, P. (2019). Data Science of the Natural Environment: A Research Roadmap. Frontiers in Env. Science, 7.

Thank you for listening…

… and I am happy to answer any questions you might have.

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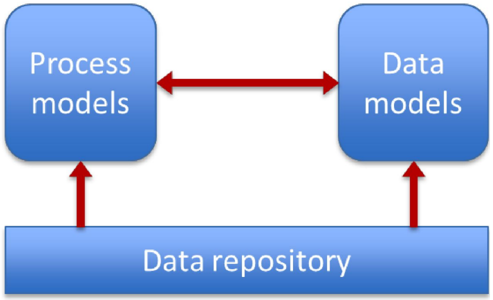
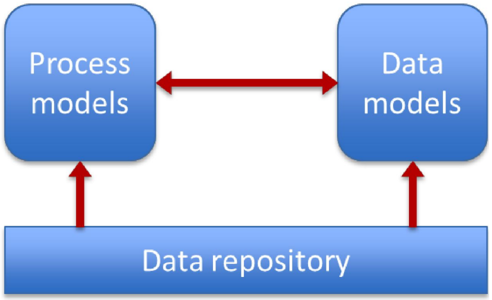
Annexe: In praise of arrows

- Data models can quality assure (1a) and clean the data (1b)
- Process models can be nudged into a new state based on observations, cf. data assimilation (2)
- Patterns or insights derived from the data can be used to validate (3a) or invalidate (3b) process models
- Process models can be adapted either as black box structures (4a) or in terms of underlying software architectures (4b)



Annexe: In praise of arrows (continued)

- Exploration of potential emergent behaviour through more complex data models: deep learning, integrated statistical modelling (5)
- Injection of new behaviours into process models representing this new discovery (6)
- Train emulators to explore uncertainties or sensitivities in models or to support integrated modelling (7a), resulting in further adaptations to process models (7b)
- Implement adaptive sampling strategies to reduce uncertainties in model estimations (8)



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