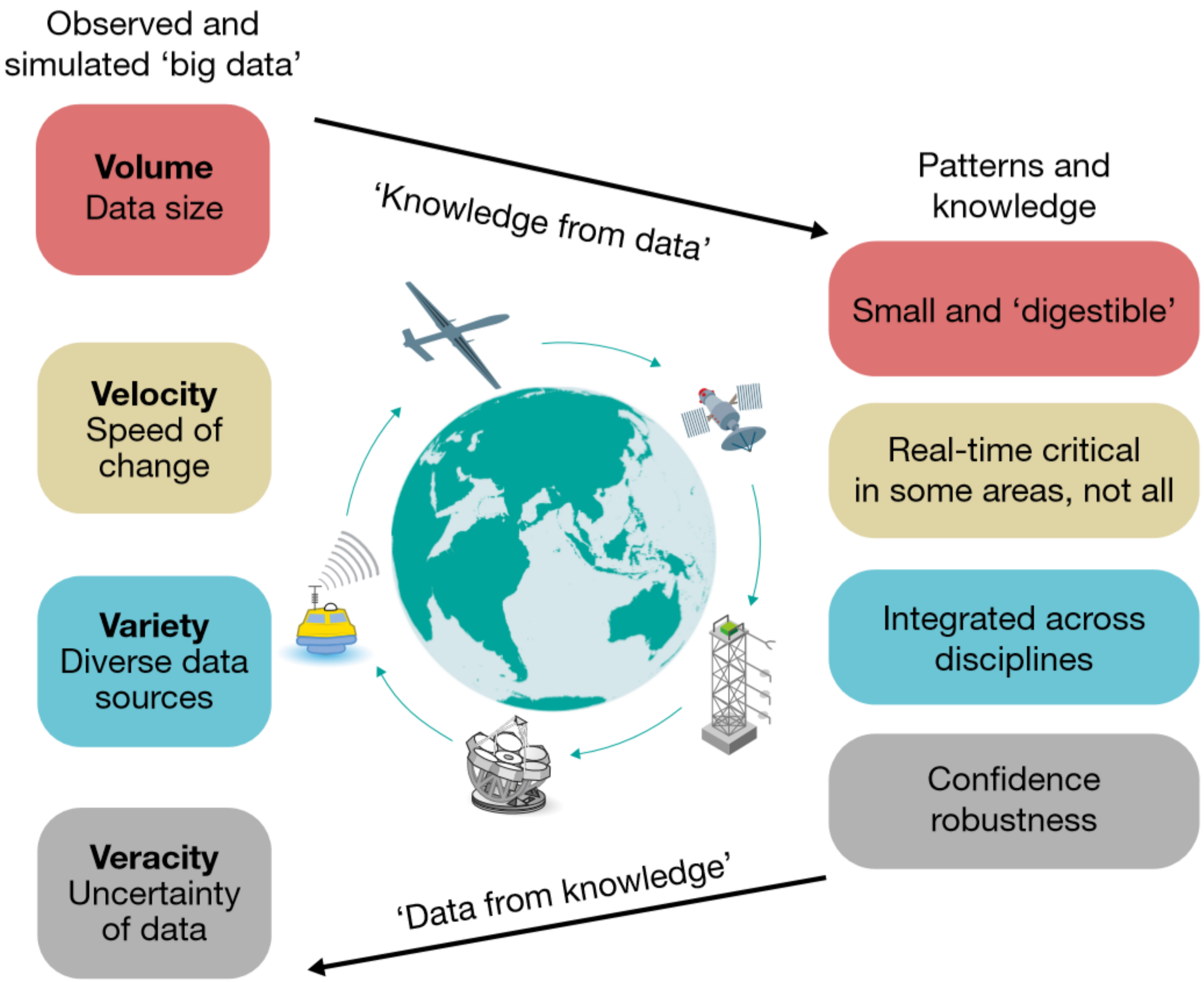
Deep learning and process understanding for data-driven Earth system science

Introduction



Big data challenges in the geoscientific context.

Introduction

Two major tasks in the coming years:

(1) extracting knowledge from the data deluge, and

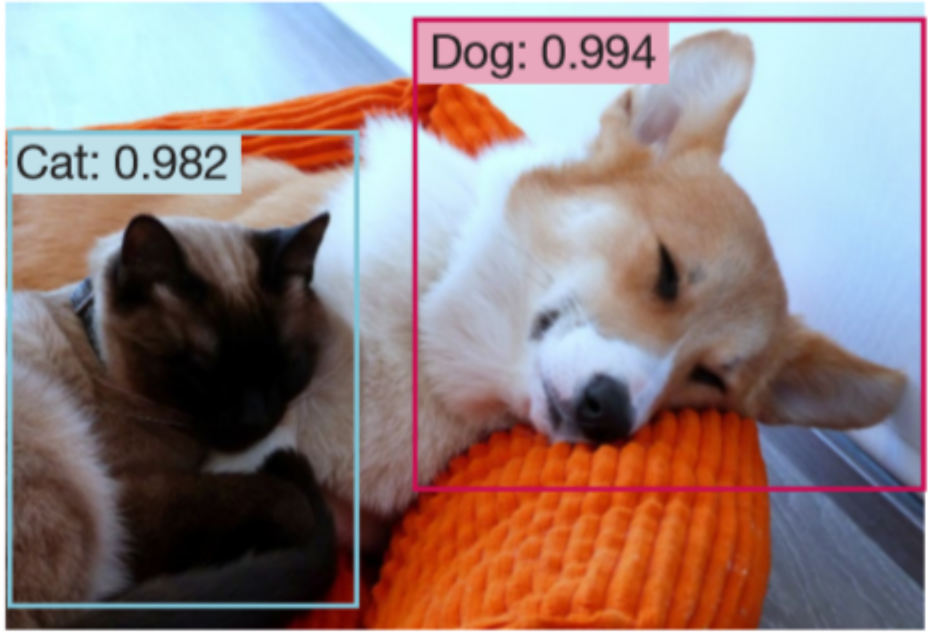
(2) deriving models that learn much more from data than traditional data assimilation approaches can, while still respecting our evolving understanding of nature’ s laws.

Background

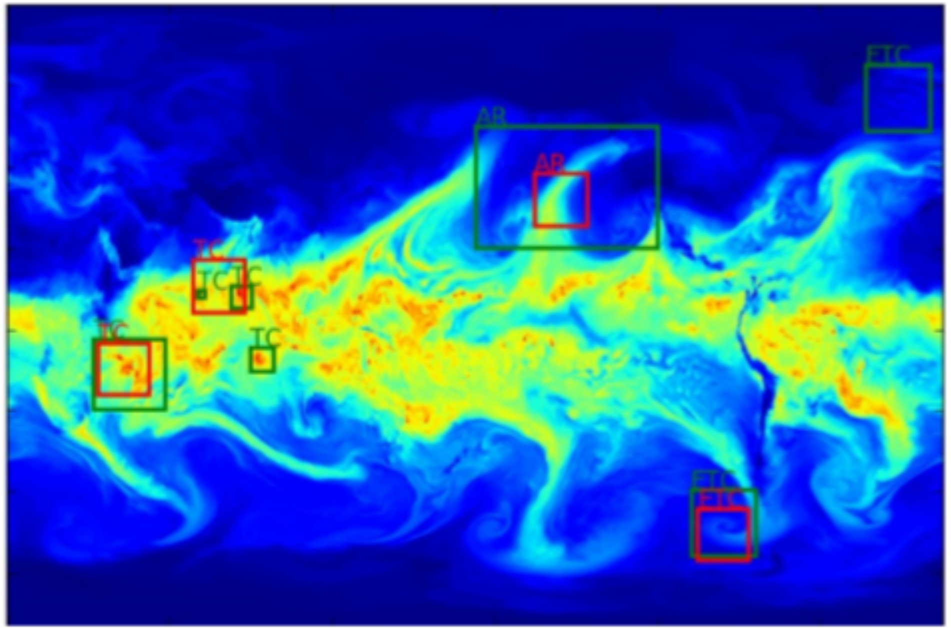
Machine learning tasks

Earth science tasks

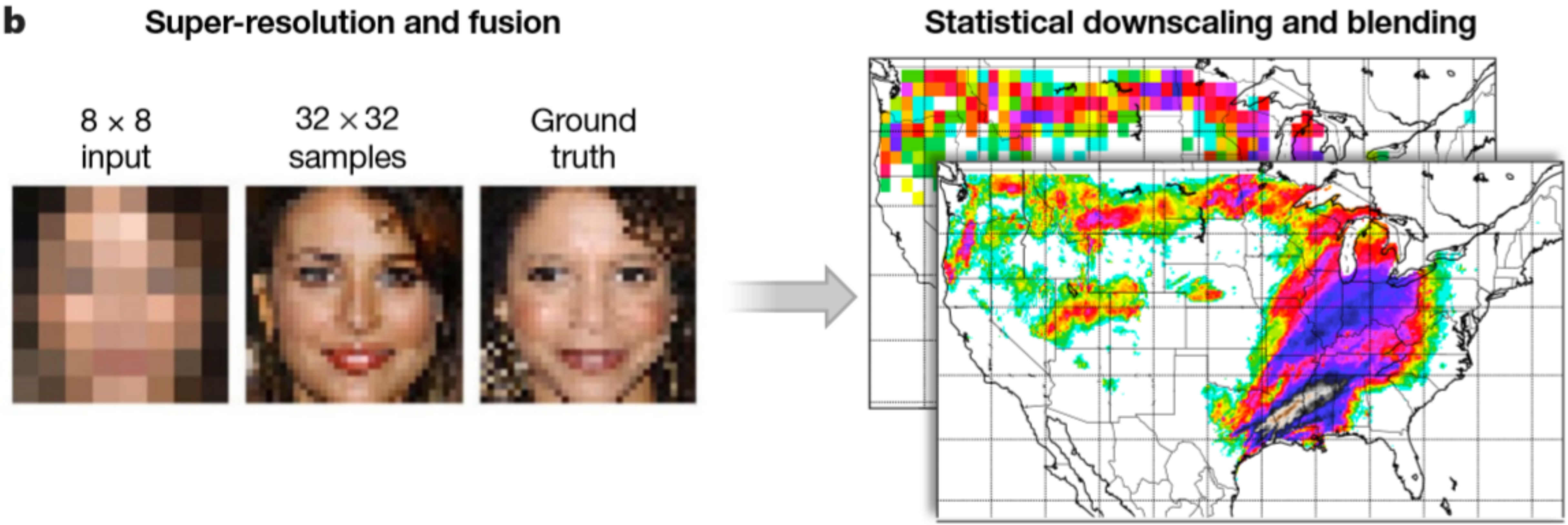
a **Object classification and localization**



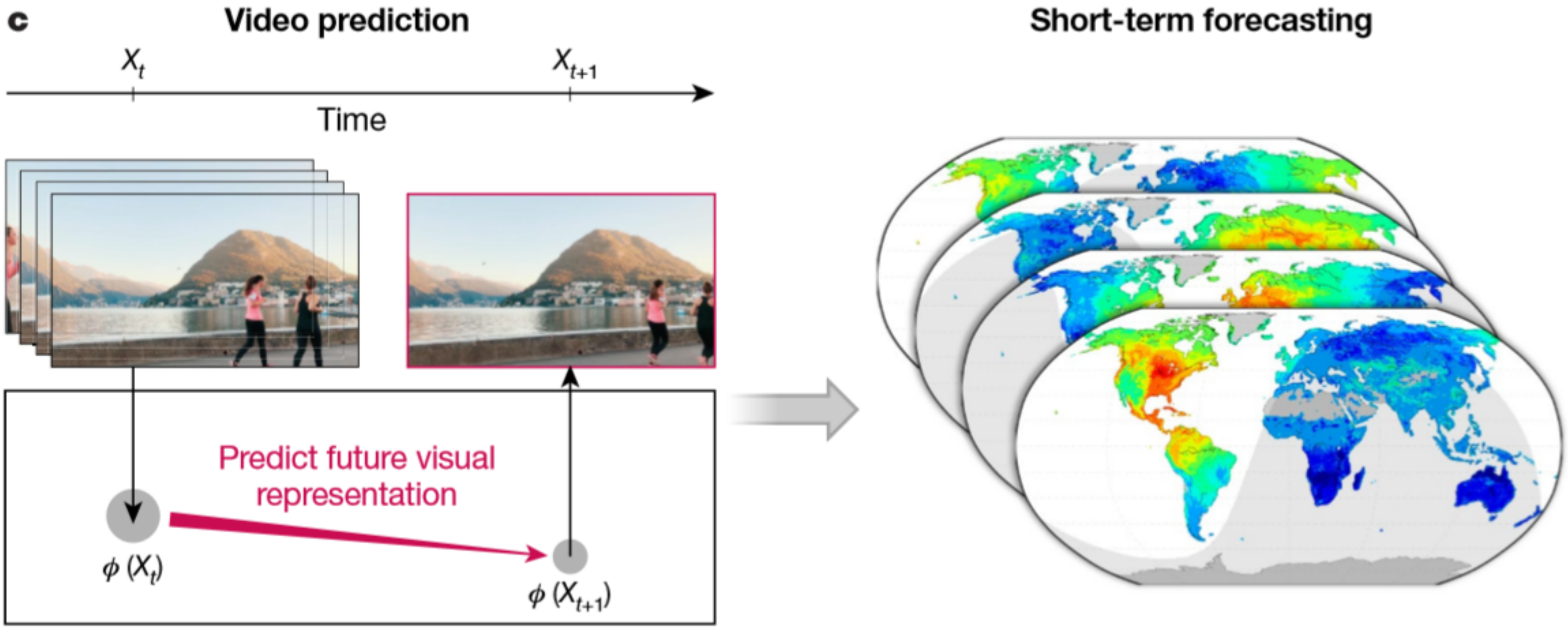
Pattern classification



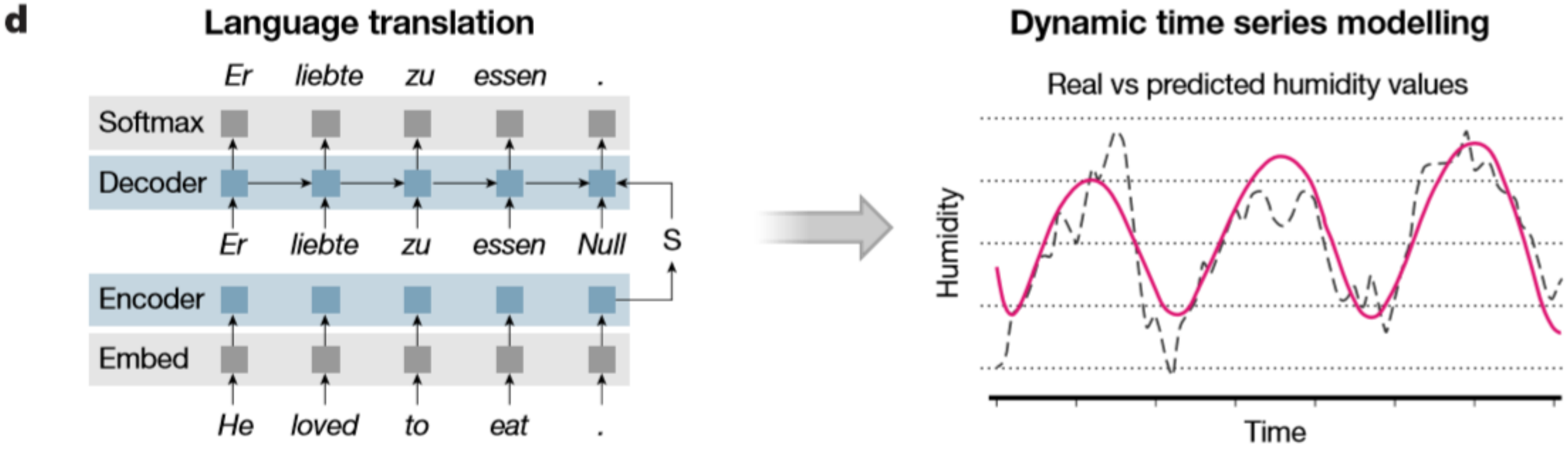
Background


b
Super-resolution and fusion
8 × 8
input
32 × 32
samples
Ground
truth
Statistical downscaling and blending

Background


c
Video prediction
X_t
X_{t+1}
Time
Predict future visual representation
$\phi\,(X_t)$
$\phi\,(X_{t+1})$
Short-term forecasting

Background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Softmax
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Dynamic time series modelling
Real vs predicted humidity values
Humidity
Time

DL challenges in Earth system science

Five major challenges and avenues:

(1) Interpretability

(2) Physical consistency

(3) Complex and uncertain data

(4) Limited labels

(5) Computational demand

Integration with physical modelling

Five points of potential synergy:

(1) Improving parameterizations

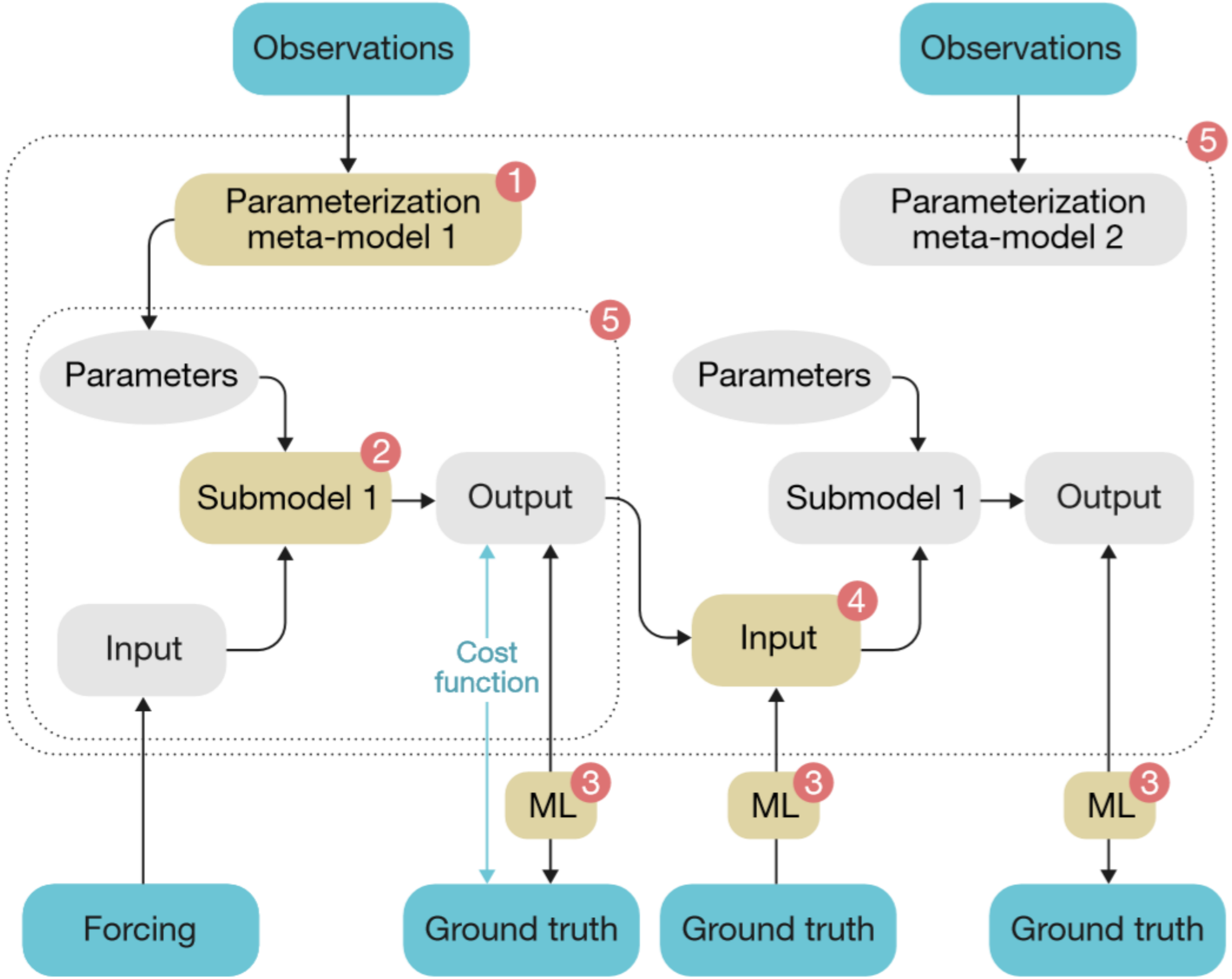
(2) Replacing a ‘physical’ sub-model with a machine learning model

(3) Analysis of model–observation mismatch

(4) Constraining submodels

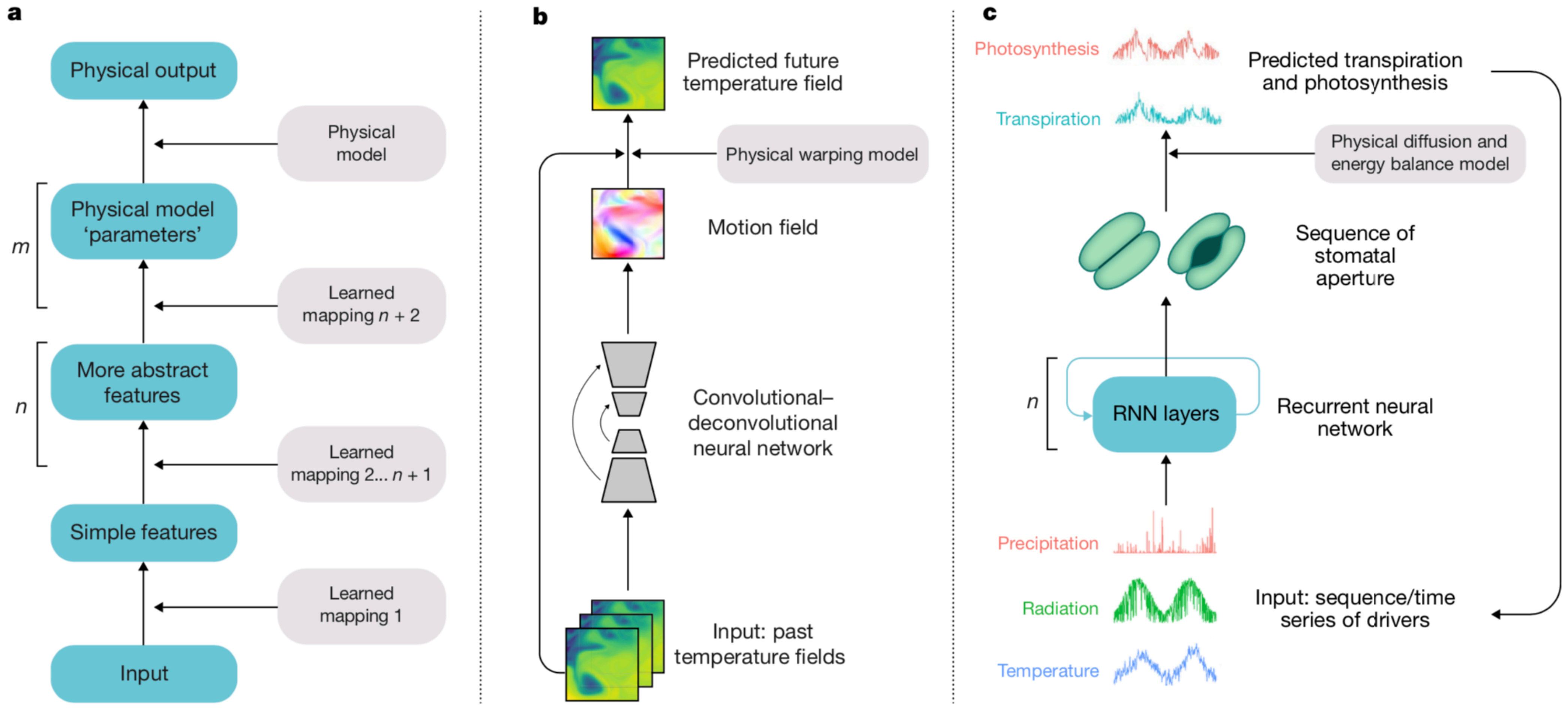
(5) Surrogate modelling or emulation

Integration with physical modelling



Linkages between physical models and machine learning.

Integration with physical modelling



Interpretation of hybrid modelling as deepening a deep learning architecture by adding one or several physical layers after the multilayer neural network to make the model more physically realistic.

Conclusion

(1) Recognition of the particularities of the data

(2) Plausibility and interpretability of inferences

(3) Uncertainty estimation

(4) Testing against complex physical models