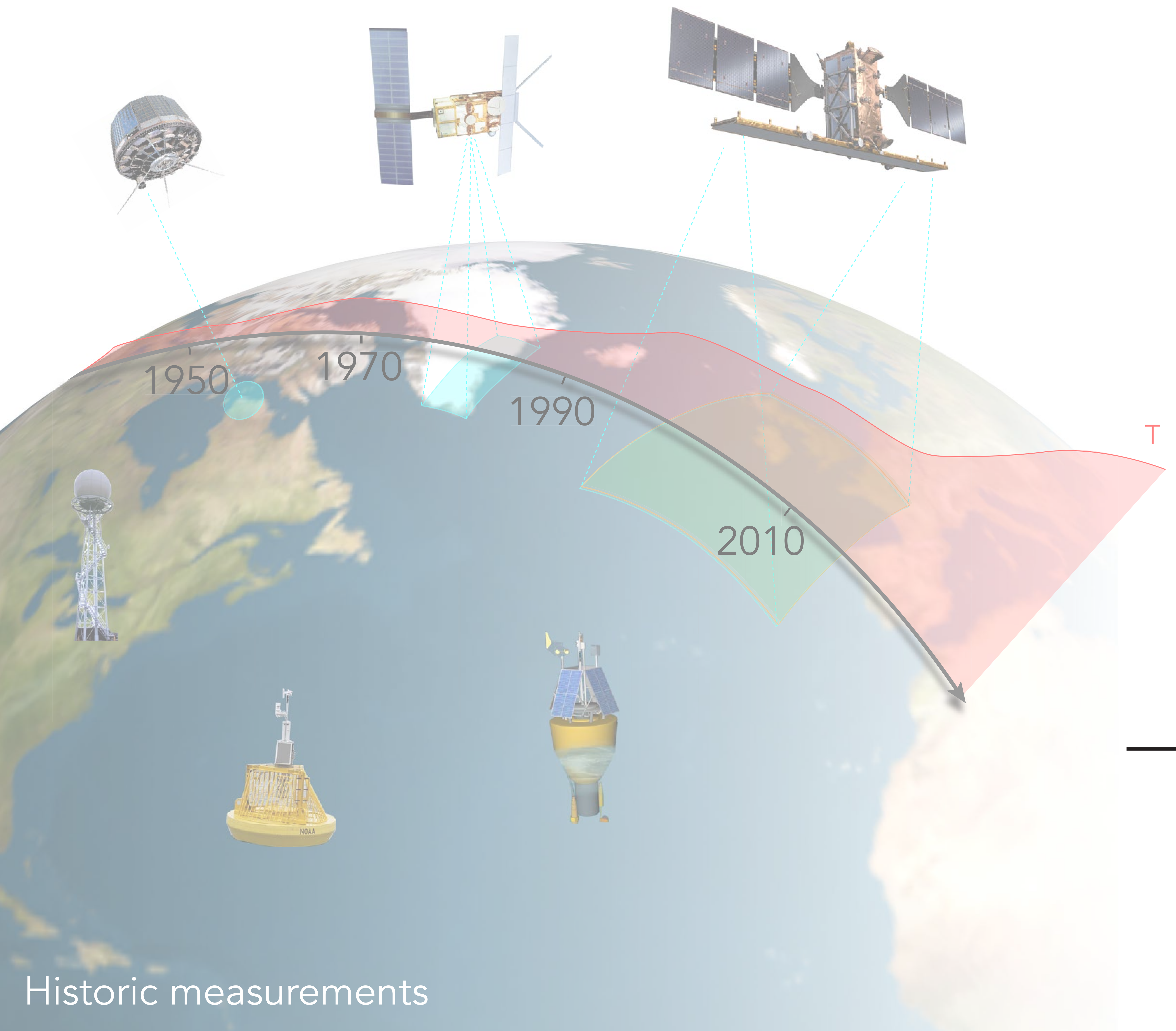

AtmoRep

Representation learning on atmospheric data to address climate change

Ilaria Luise, Maike Sonnewald, Martin Schultz, Annesh Subramanian, Christan Lessig

Motivation

- Climate projections have very significant uncertainties

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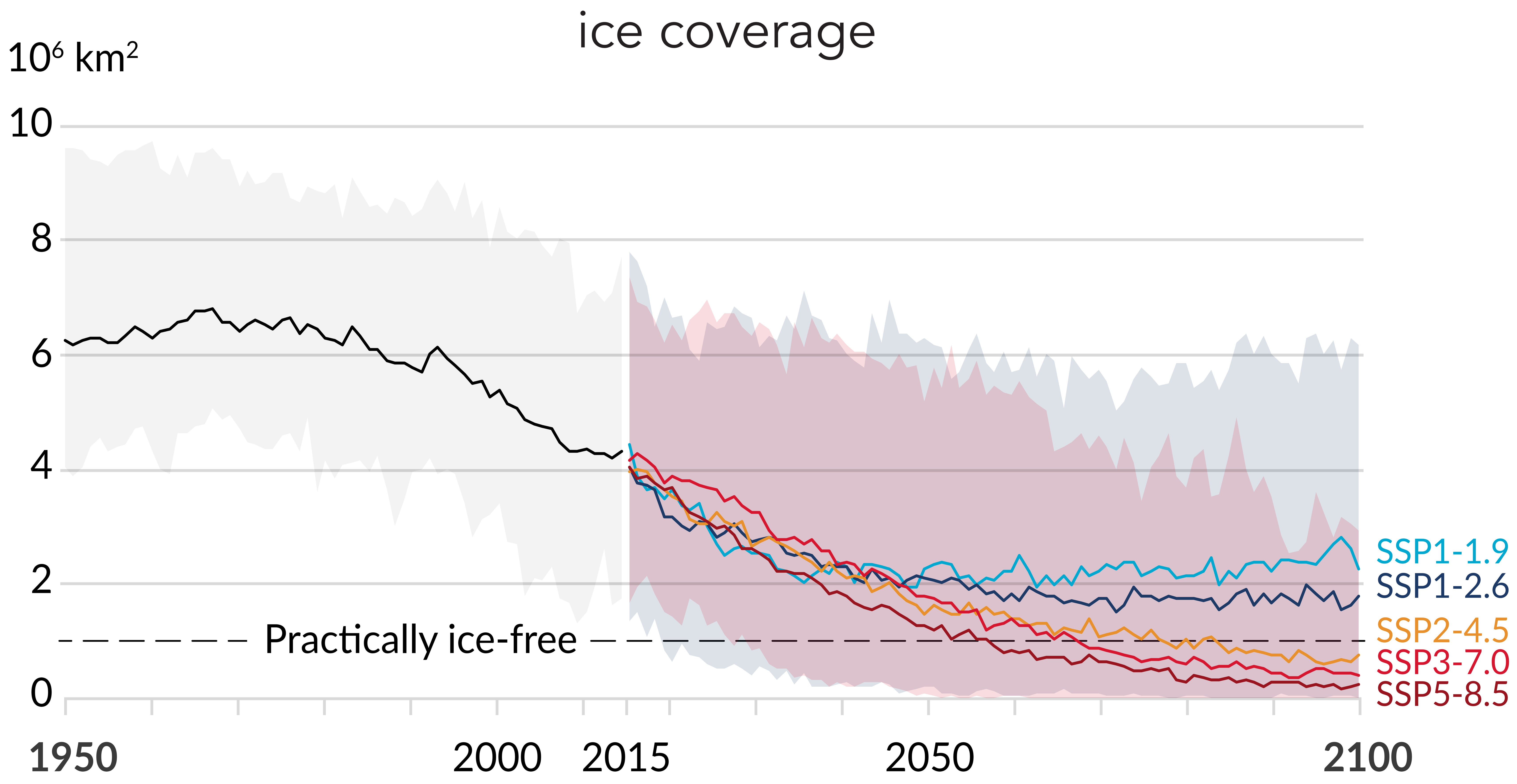

IPCC, 2021: Climate Change 2021: The Physical Science Basis. Masson-Delmotte, V., et al. Cambridge University Press. In Press.

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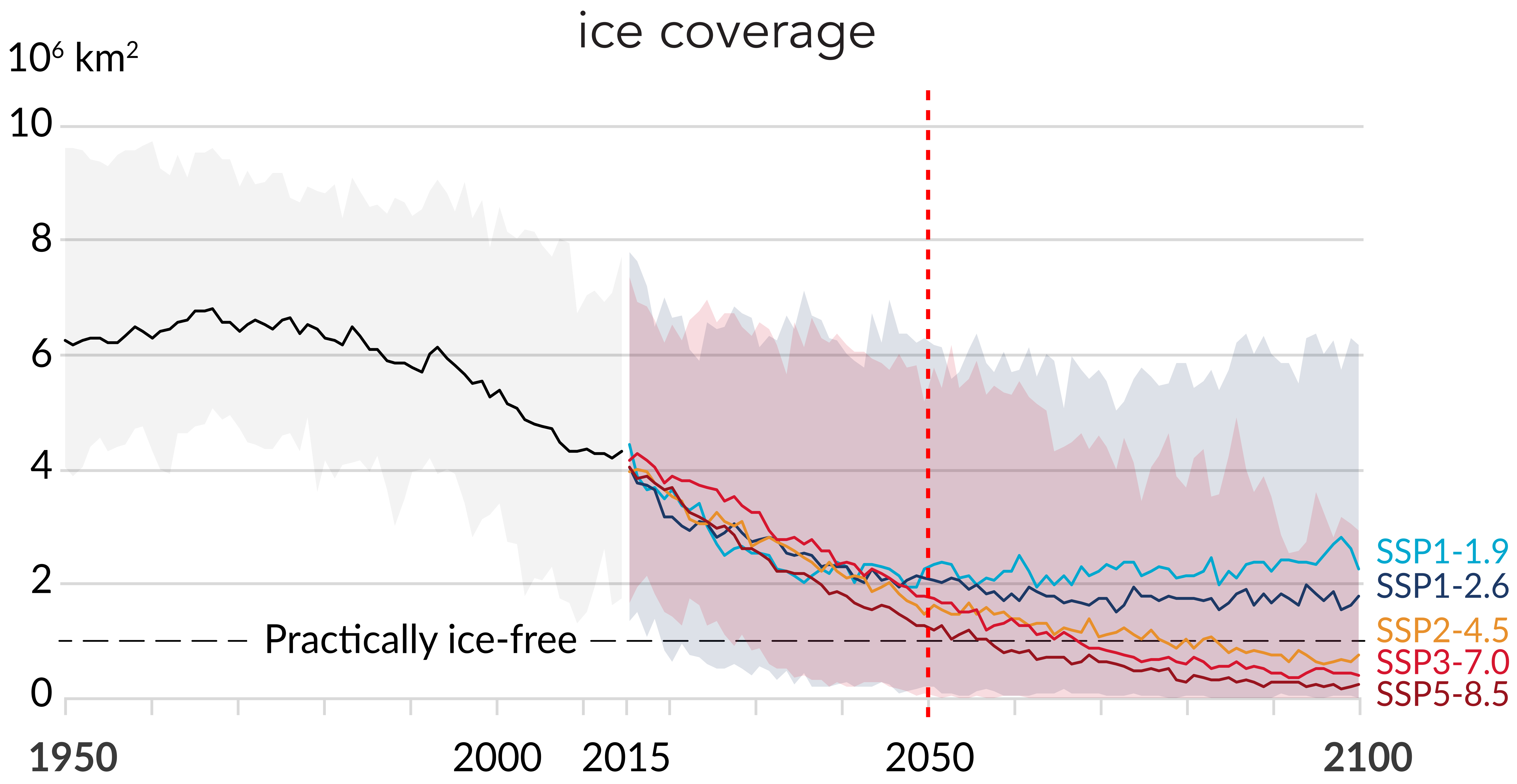

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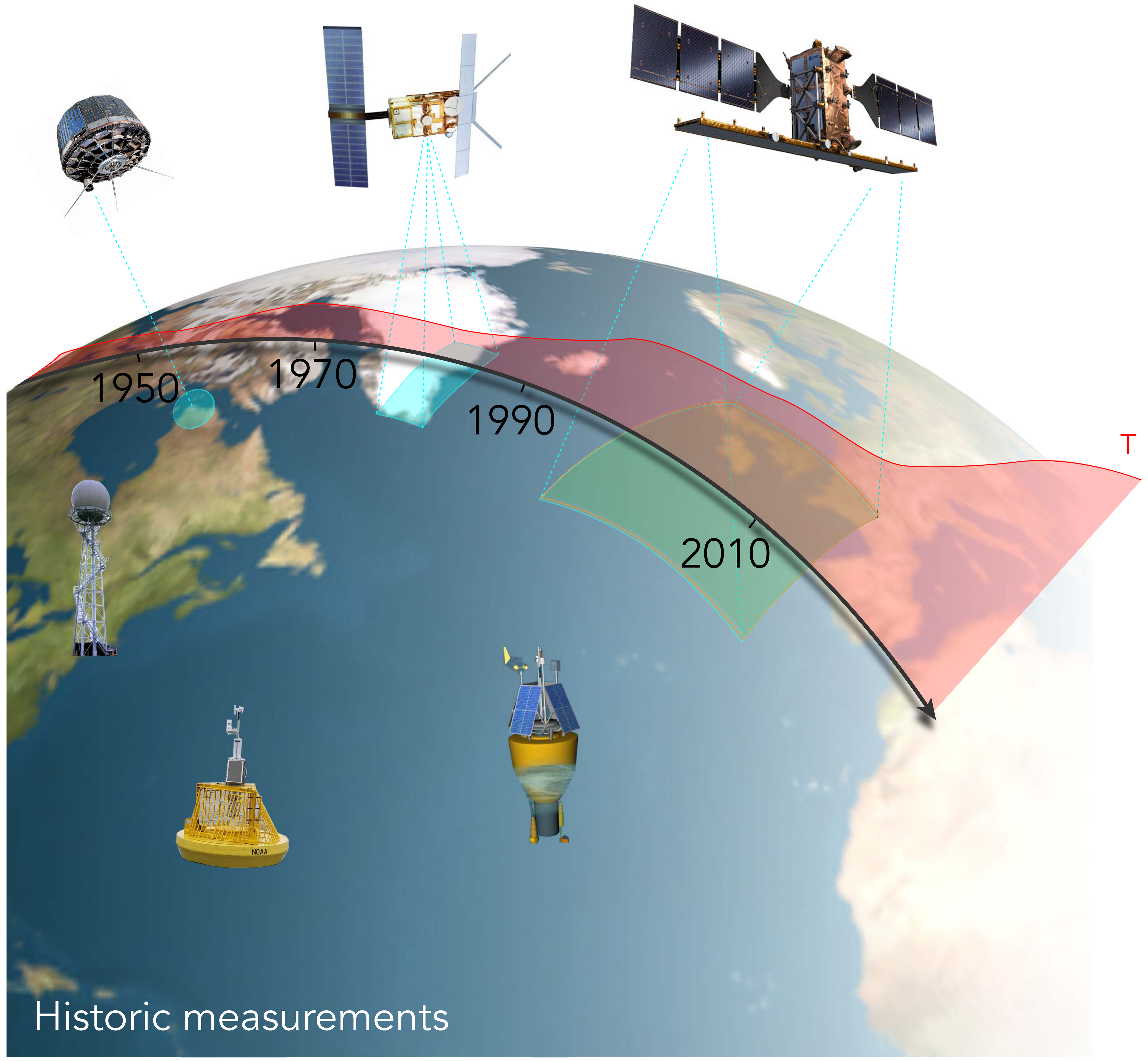
- Climate projections have very significant uncertainties
- Only incomplete description of physical processes in the atmosphere in current simulations
  - No (effective) models for cloud formation, interaction with biosphere, ...
  - Very large number of *interacting* scales (1 m to 10^7 m)
  - ...

Overview



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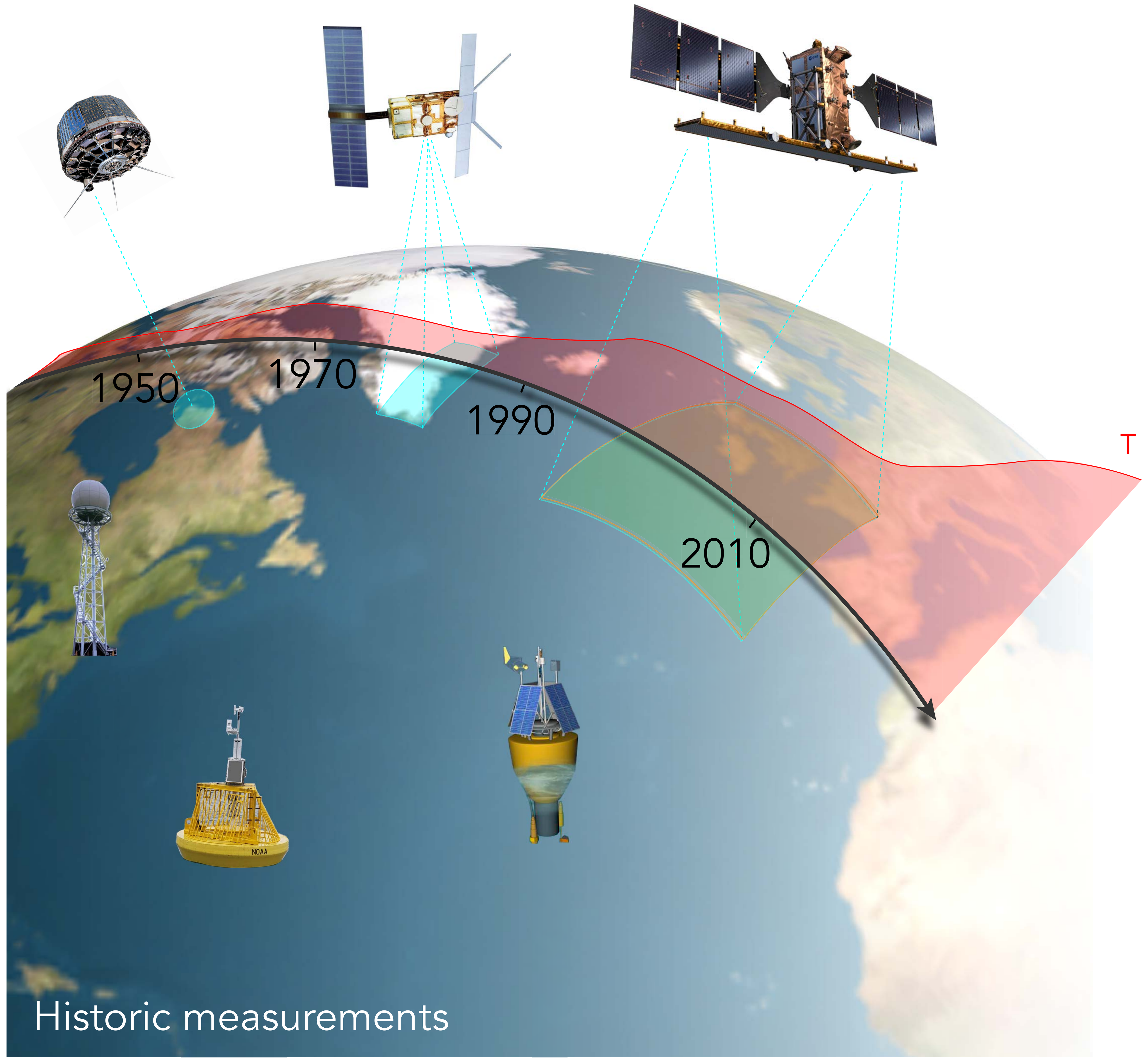
1950
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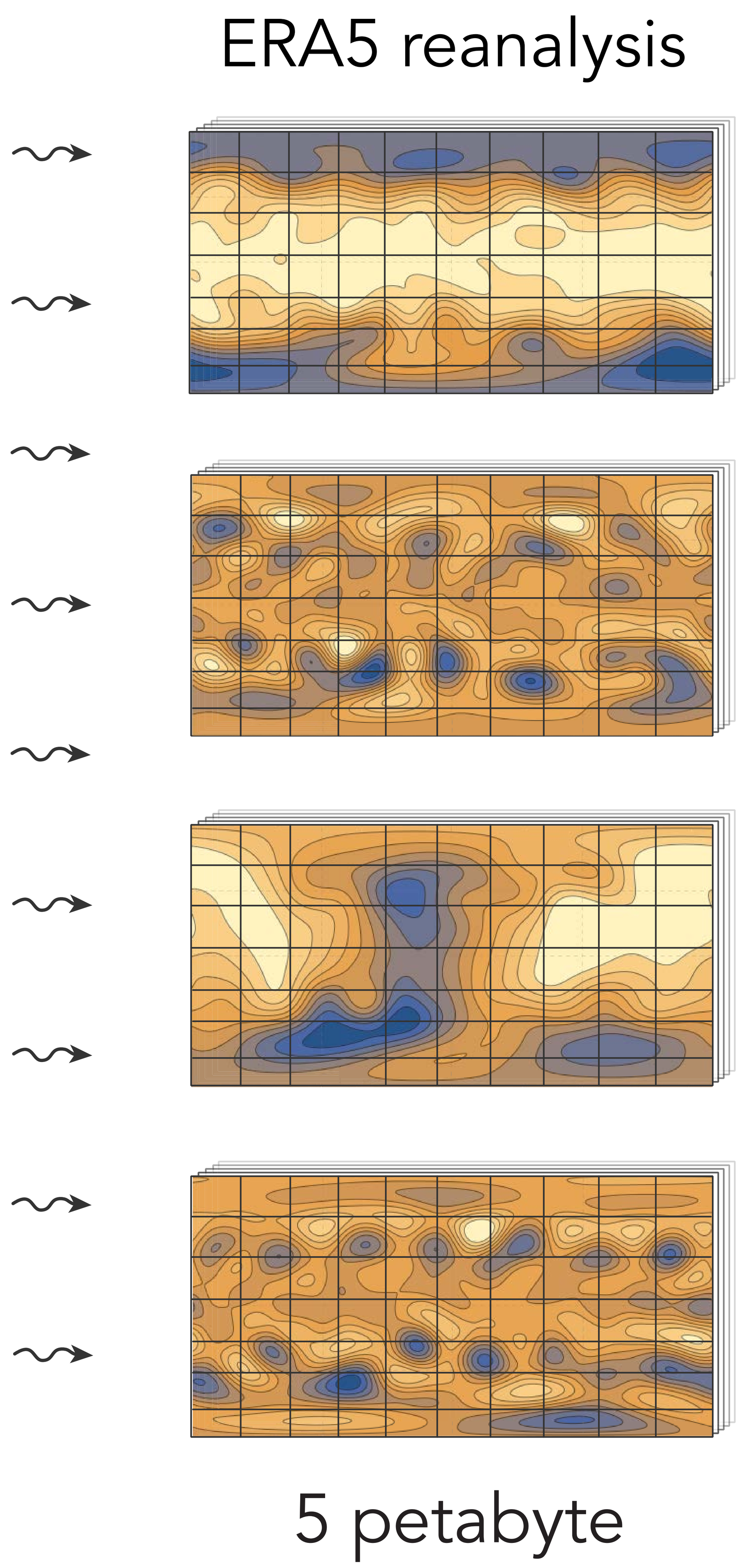
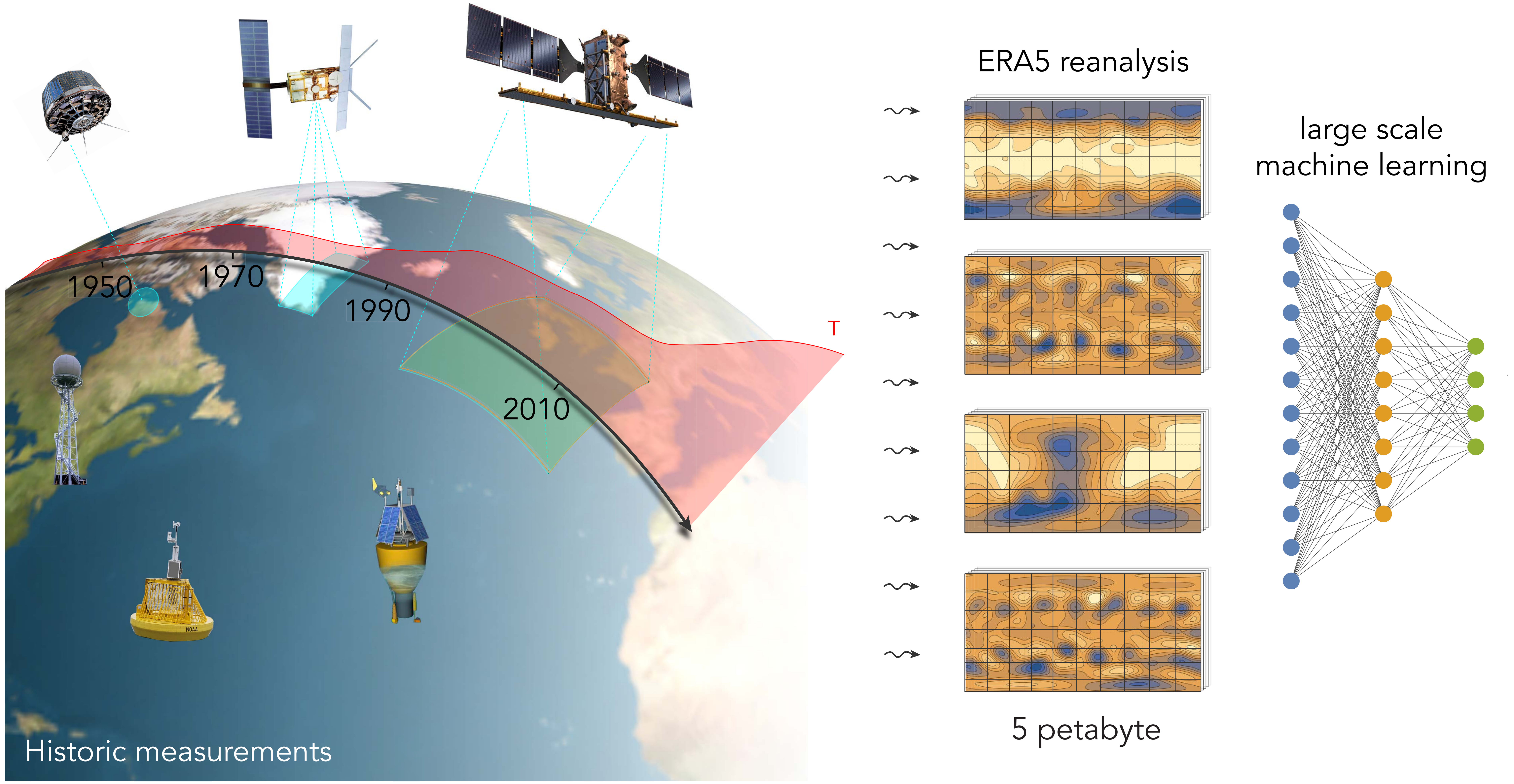
Historic measurements


ERA5 reanalysis
5 petabyte

Overview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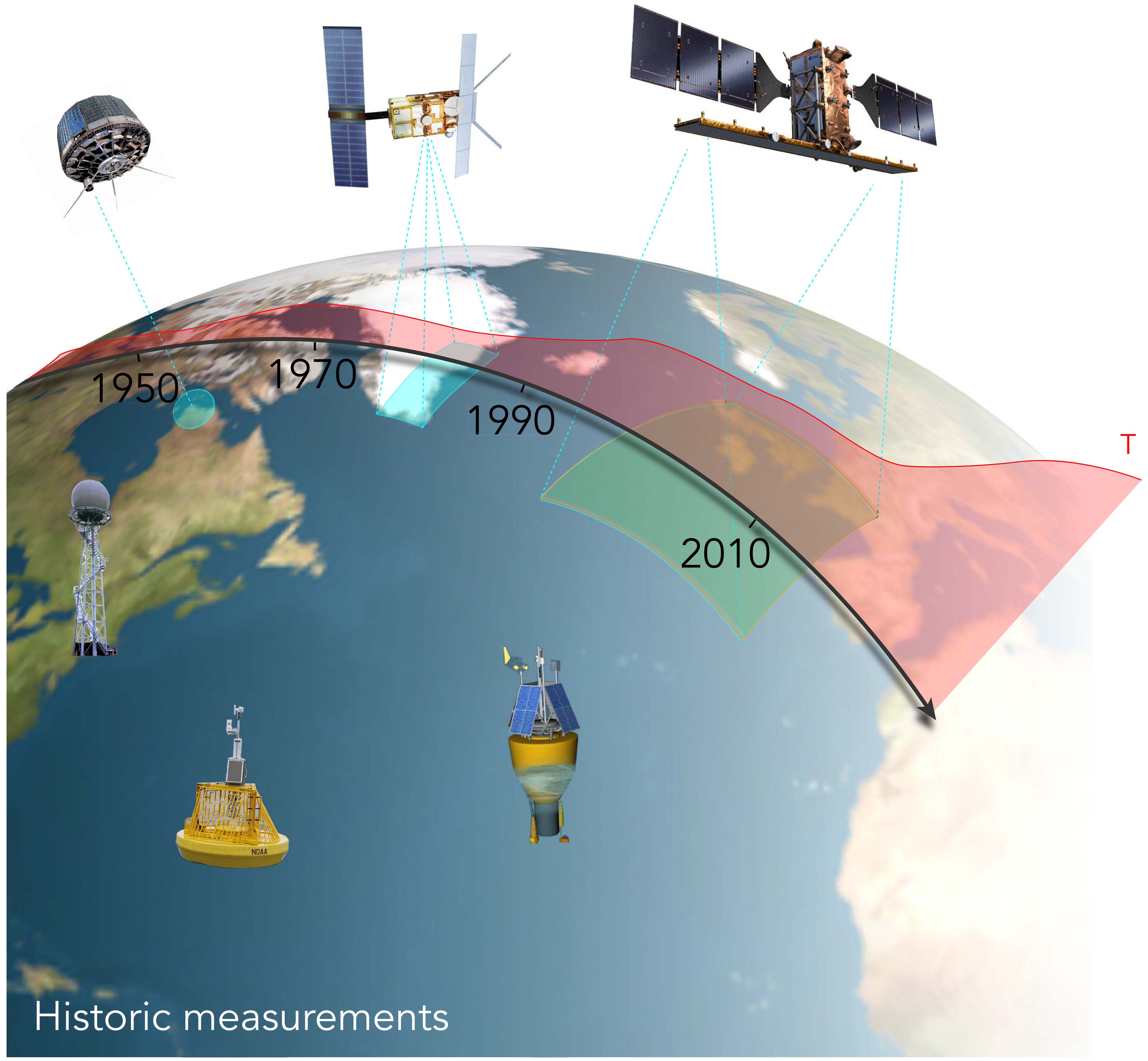
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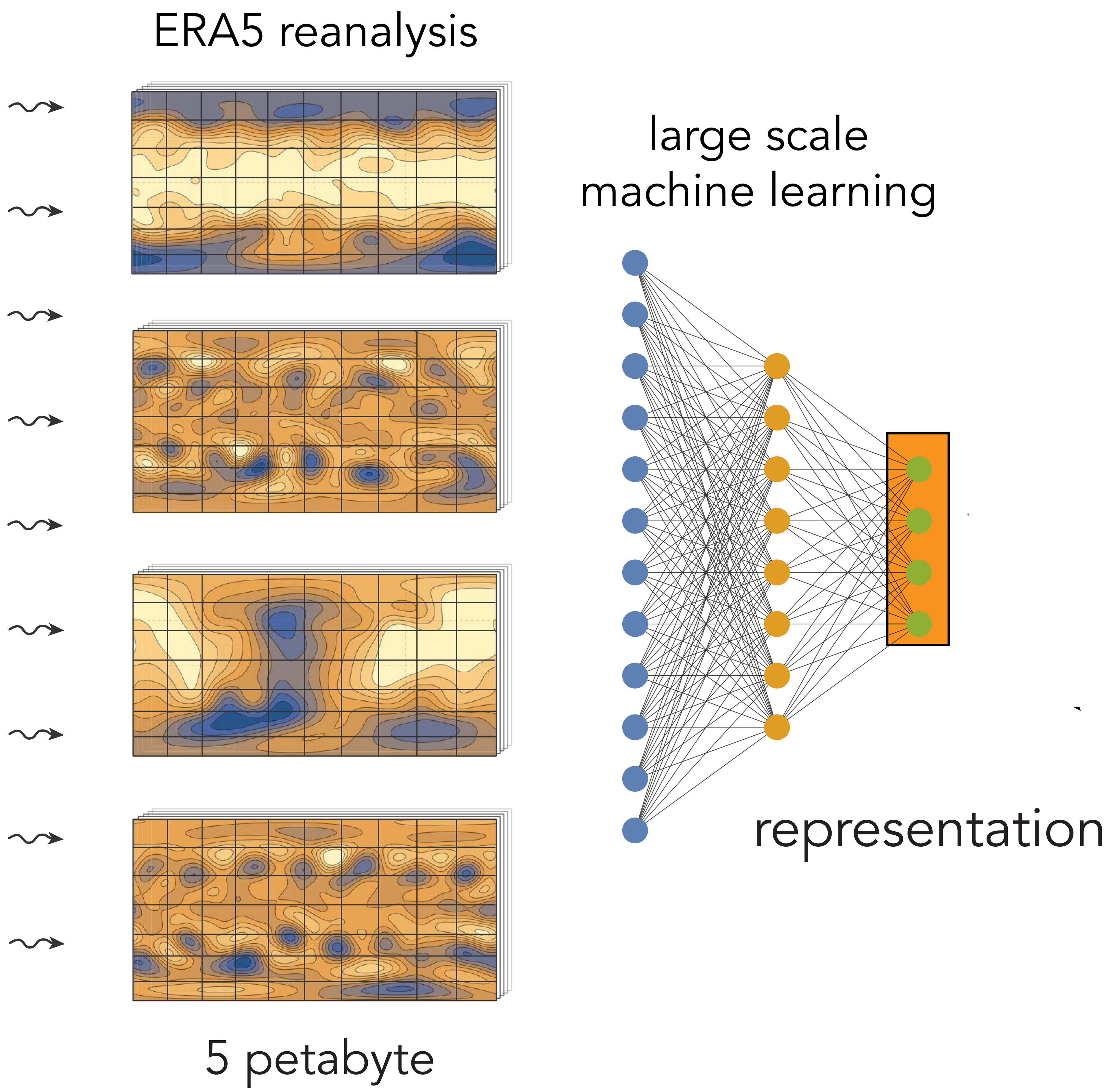
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Why machine learning?

- Incomplete description of physical processes in the atmosphere
- Large amounts of historical atmospheric observations

=> Representation learning on observations

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=> Representation learning on observations

Impact

- Address climate change
  - Super-resolution, classification, predictability, …
  - Machine-learning corrected climate simulations
- Scientific insight
  - Finite space-time description of interaction across scales and phenomena in the atmosphere

AtmoRep@CERN

- CERN expertise of relevance:
  - Handling of large data sets / storage infrastructure
  - Distributed analysis
  - Machine learning
  - Uncertainty / error estimation
  - …

AtmoRep@CERN

- Collaboration with OpenLab (Sofia Vallecorsa) already underway
- Common interests and directions
  - Information extraction from large amounts of data
  - Uncertainty quantification in deep learning
  - Transformer neural networks
  - …

Timeline

AtmoDist: basic prototype

2022

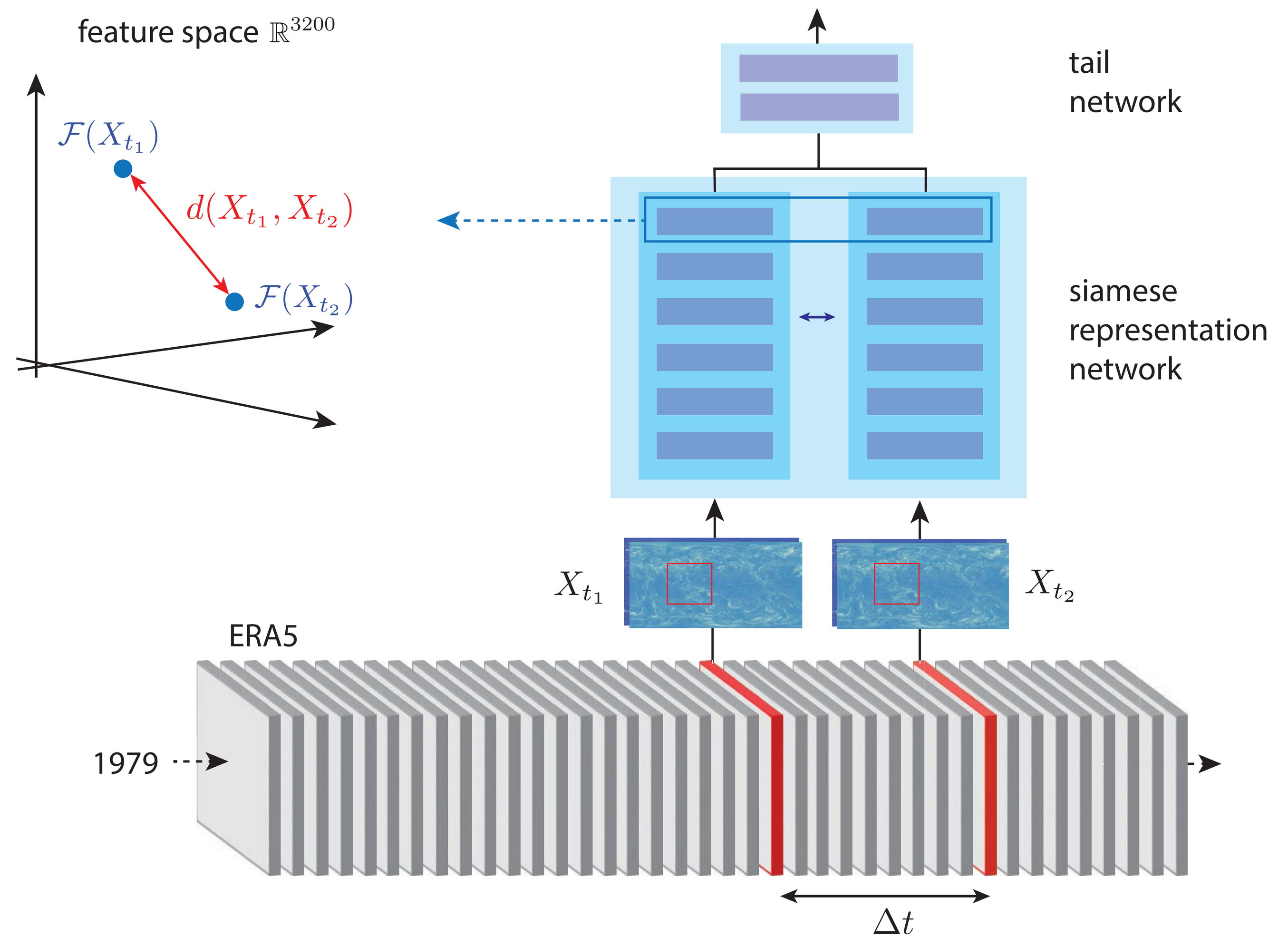
First training and scaling experiments on supercomputer

Proof-of-concept for spatio-temporal attention maps

today

Compute time on Jülich supercomputer

2023



Timeline

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Finalize neural network architecture and training

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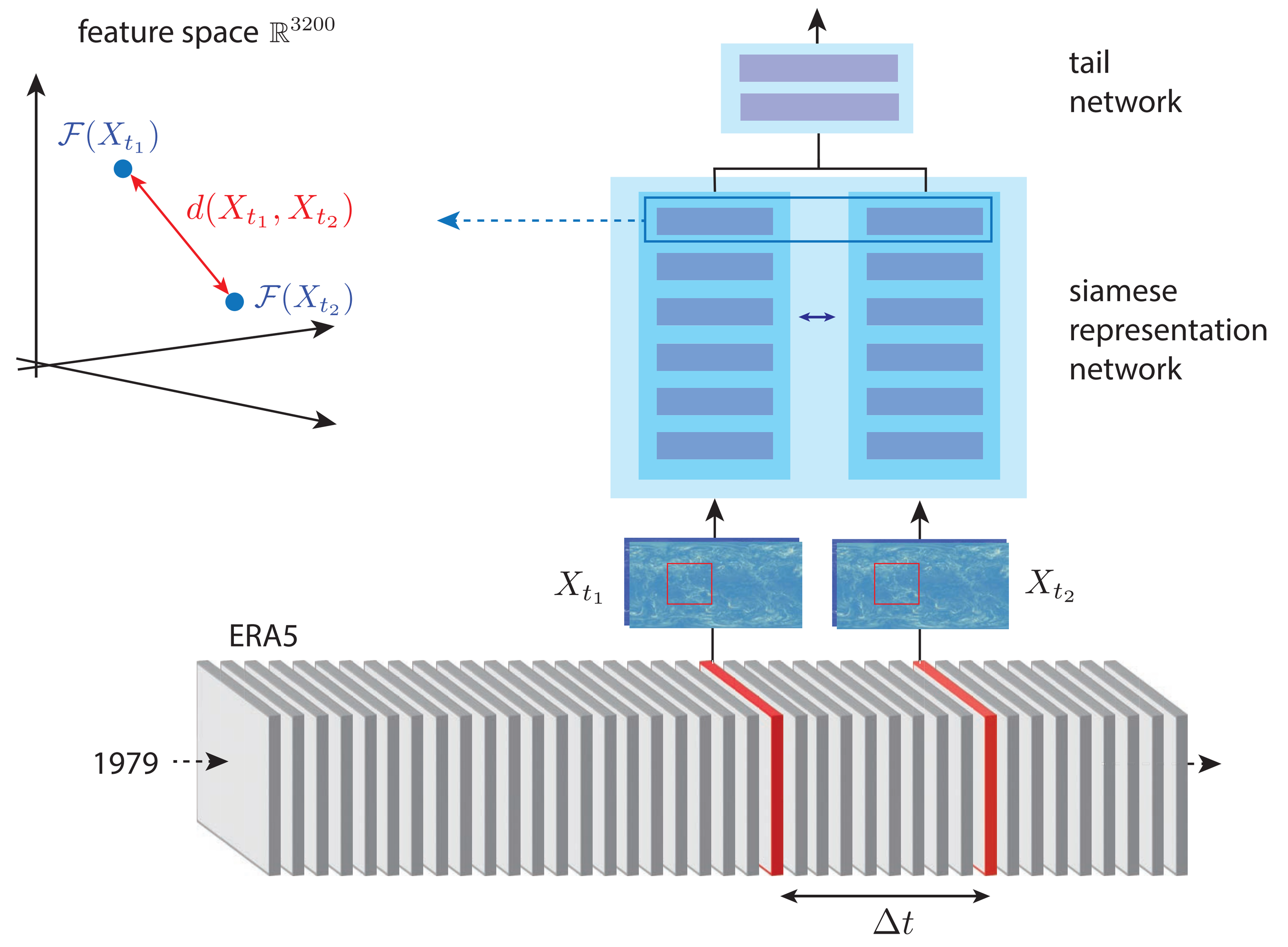

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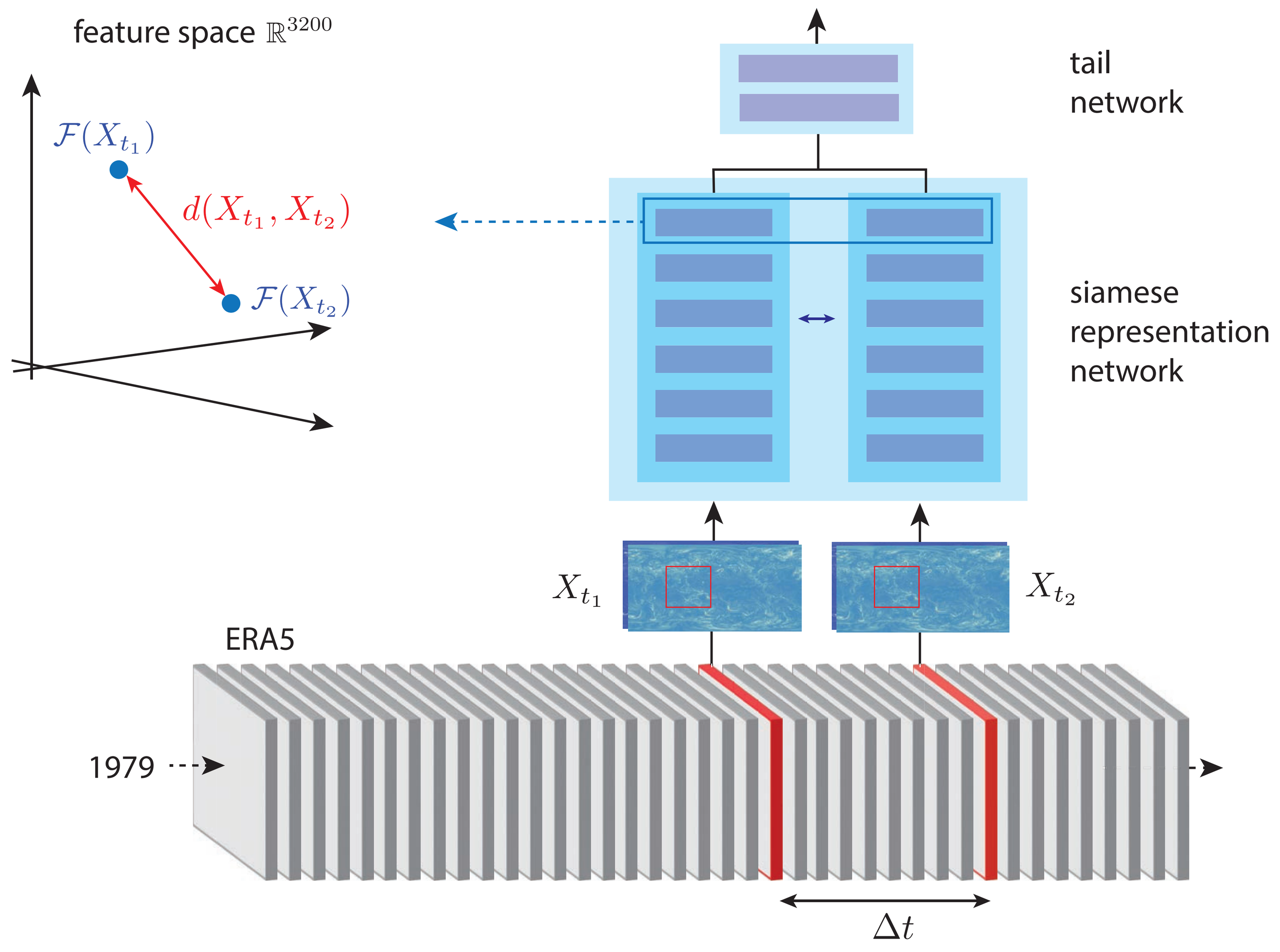
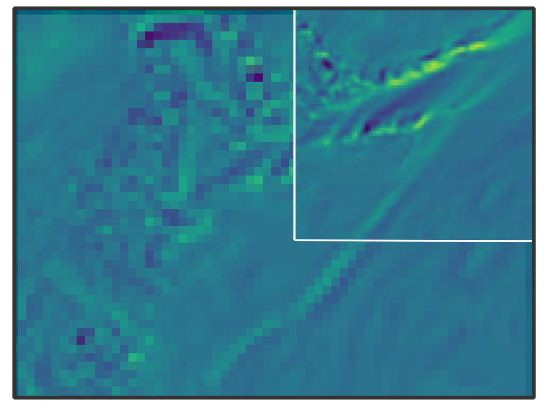
Parallel scaling and training on O(100) TB

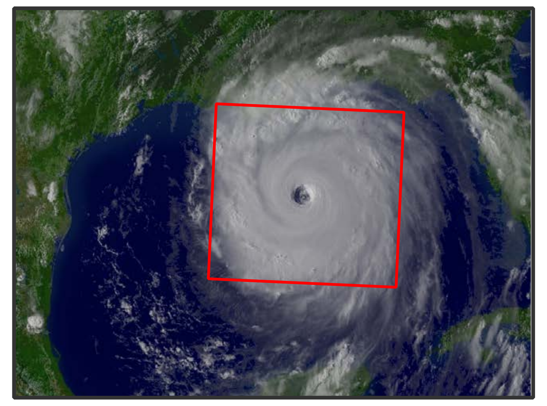
Implementation of demonstration applications

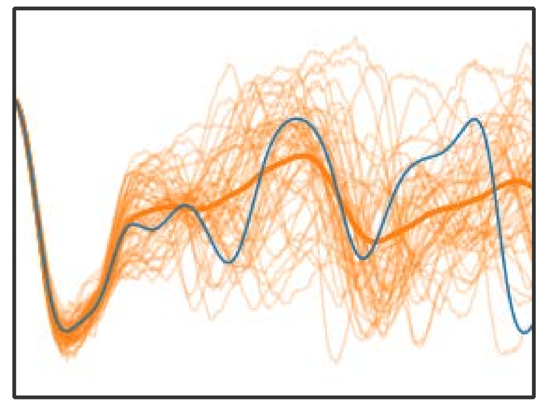
2023

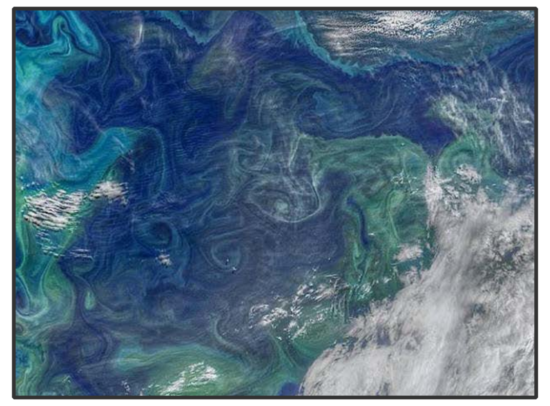


address climate change


Downscaling


Classification


Predictability


Missing data

Timeline

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- AtmoDist: basic prototype
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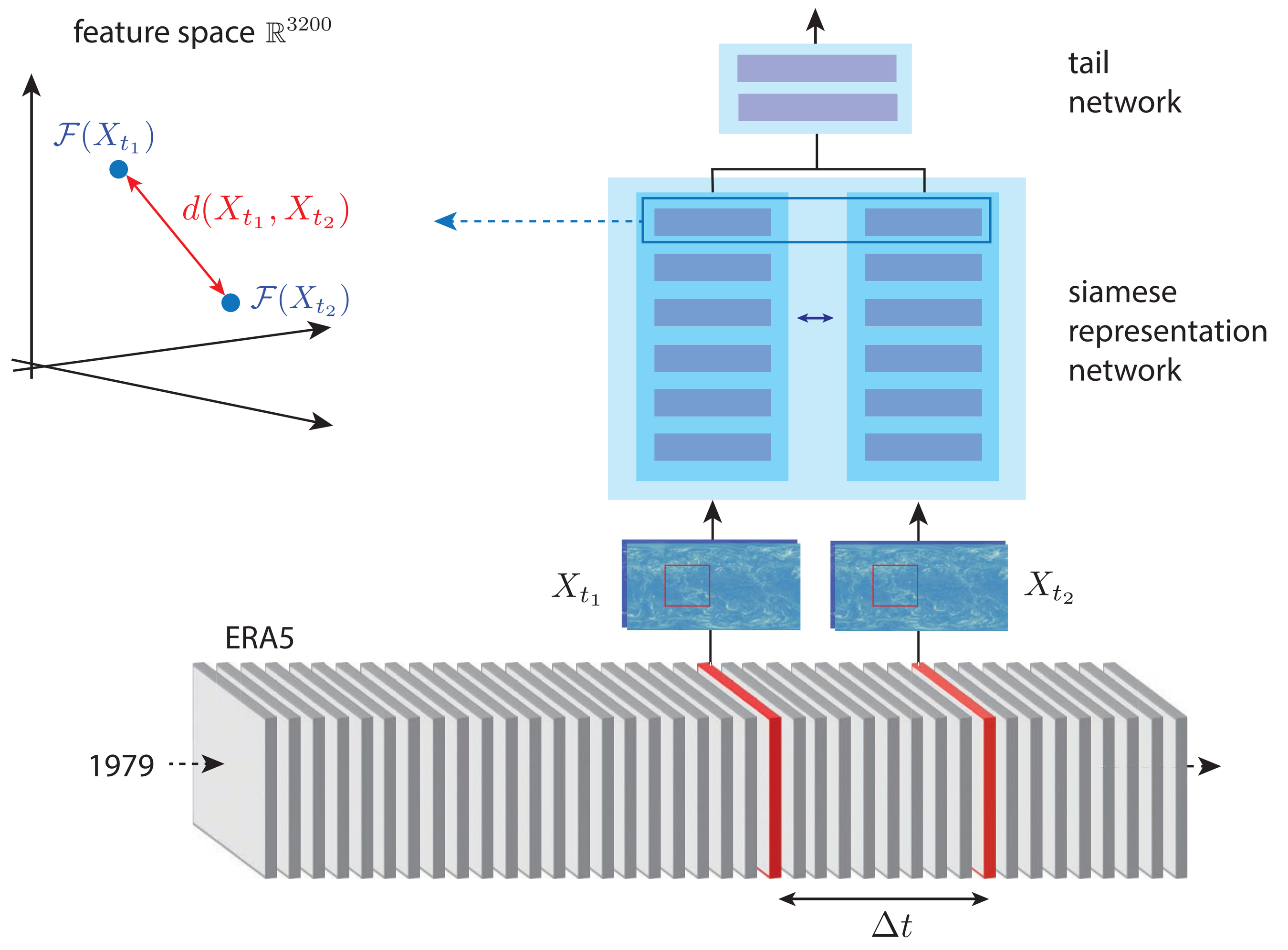
- Finalize applications and publications



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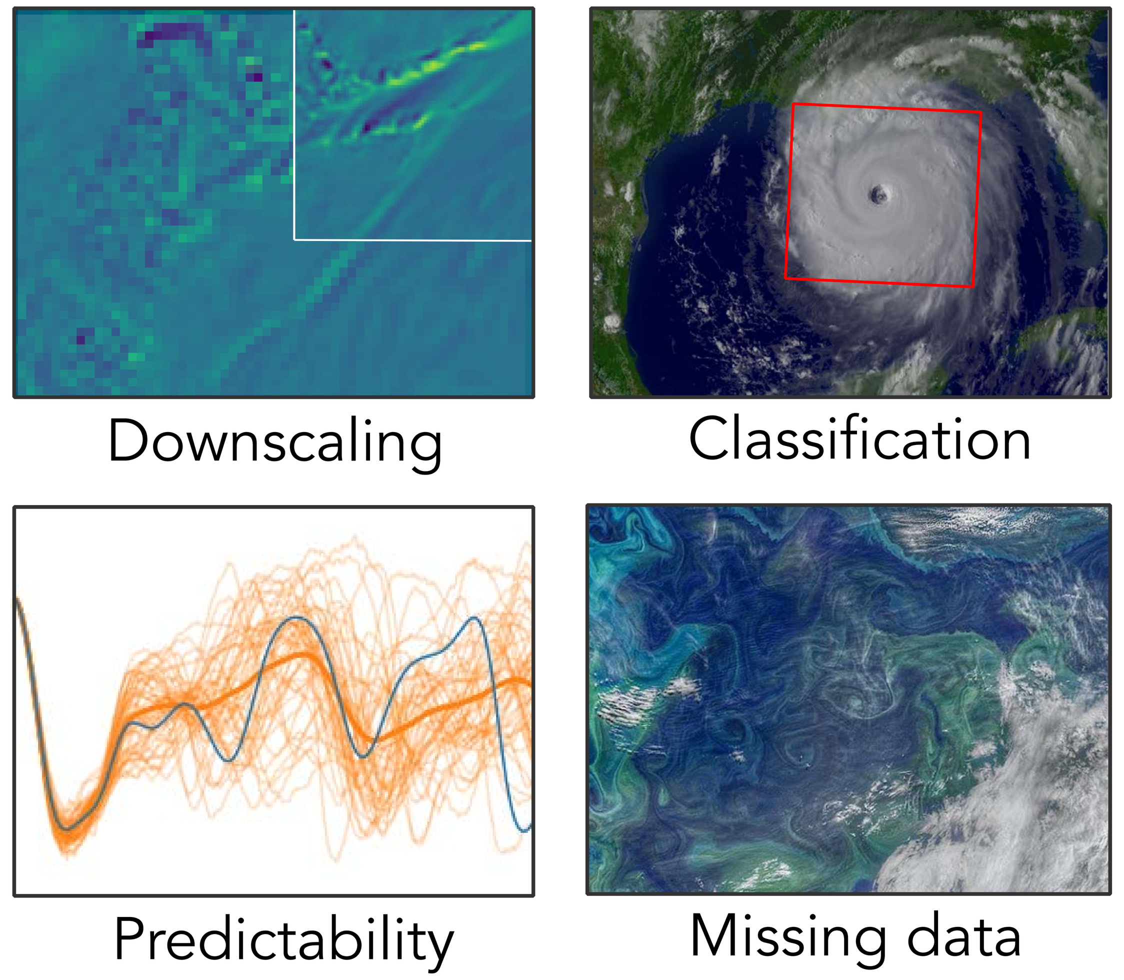

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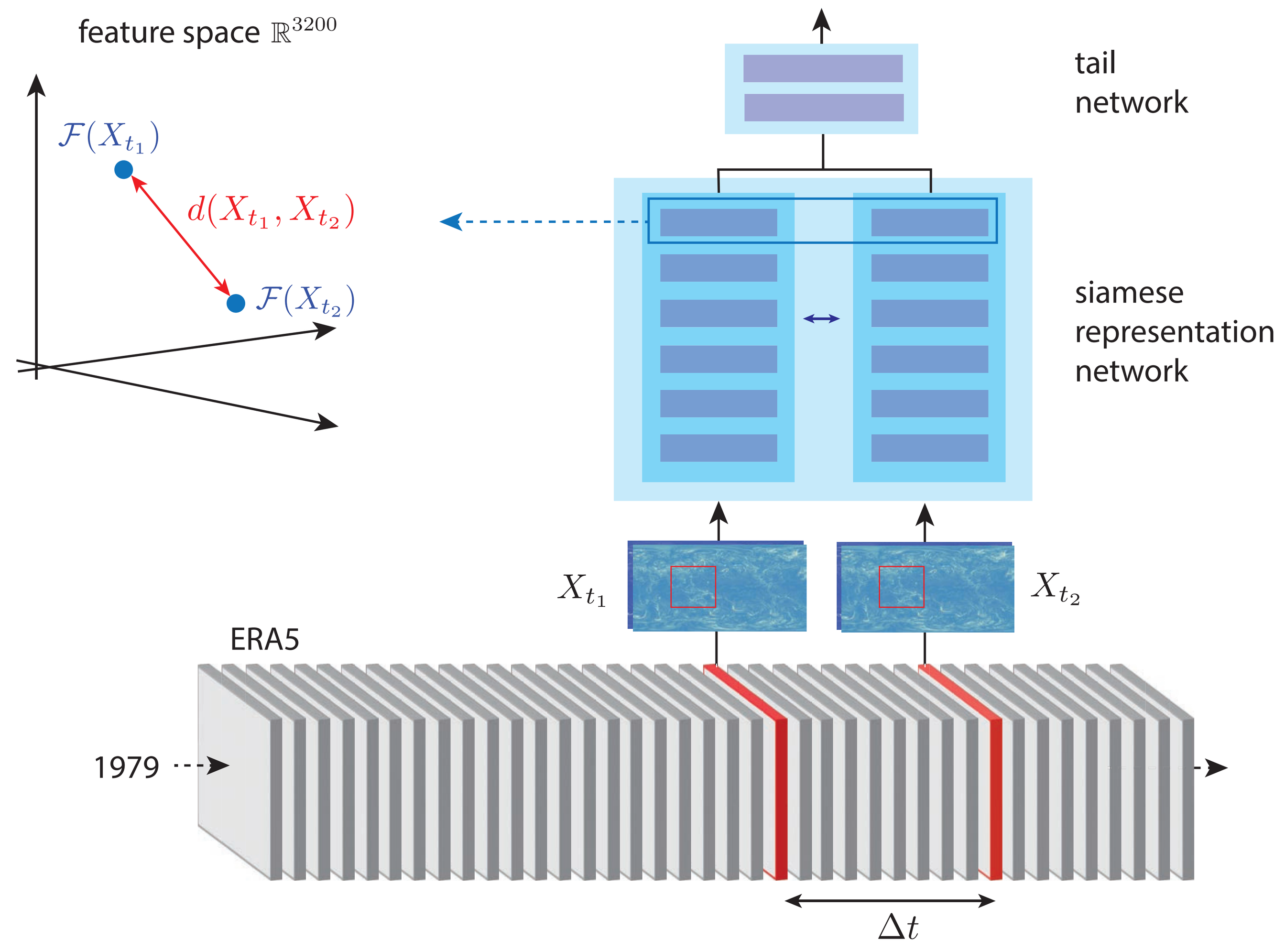
- Finalize applications and publications
- Public availability of pretrained neural network



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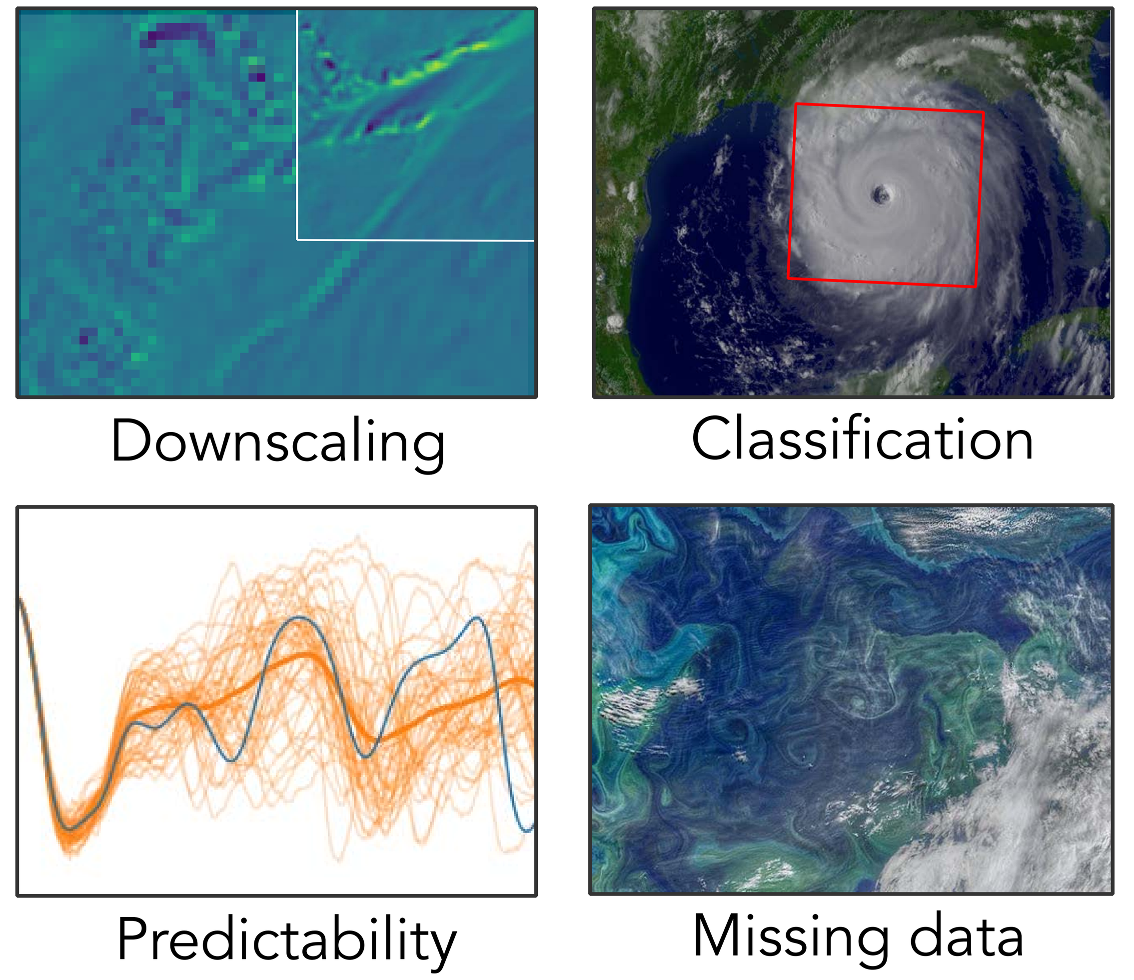


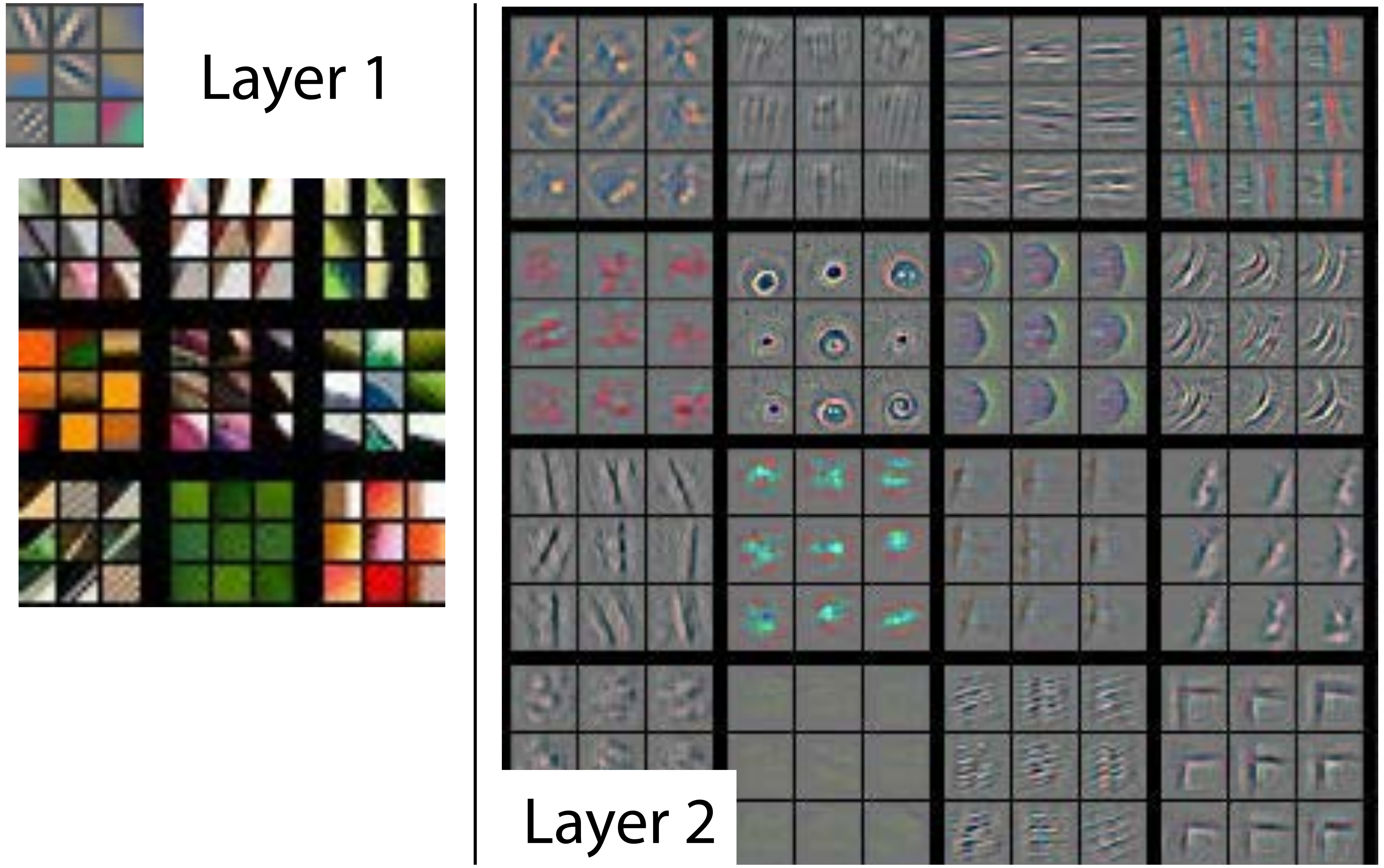
AtmoRep

- Use large amounts of historical observations to improve climate projections and related applications
- Significant potential impact through various applications
- Scientifically interesting and challenging

Representation learning

- What is a representation?
  - Layers of neural network are nonlinear maps of input data to intermediate representation (elements in a vector space)
  - For a trained neural network the intermediate layers hence provide transformed data adapted to a domain
  - Often the same intermediate representations are useful for a range of tasks

Representation learning



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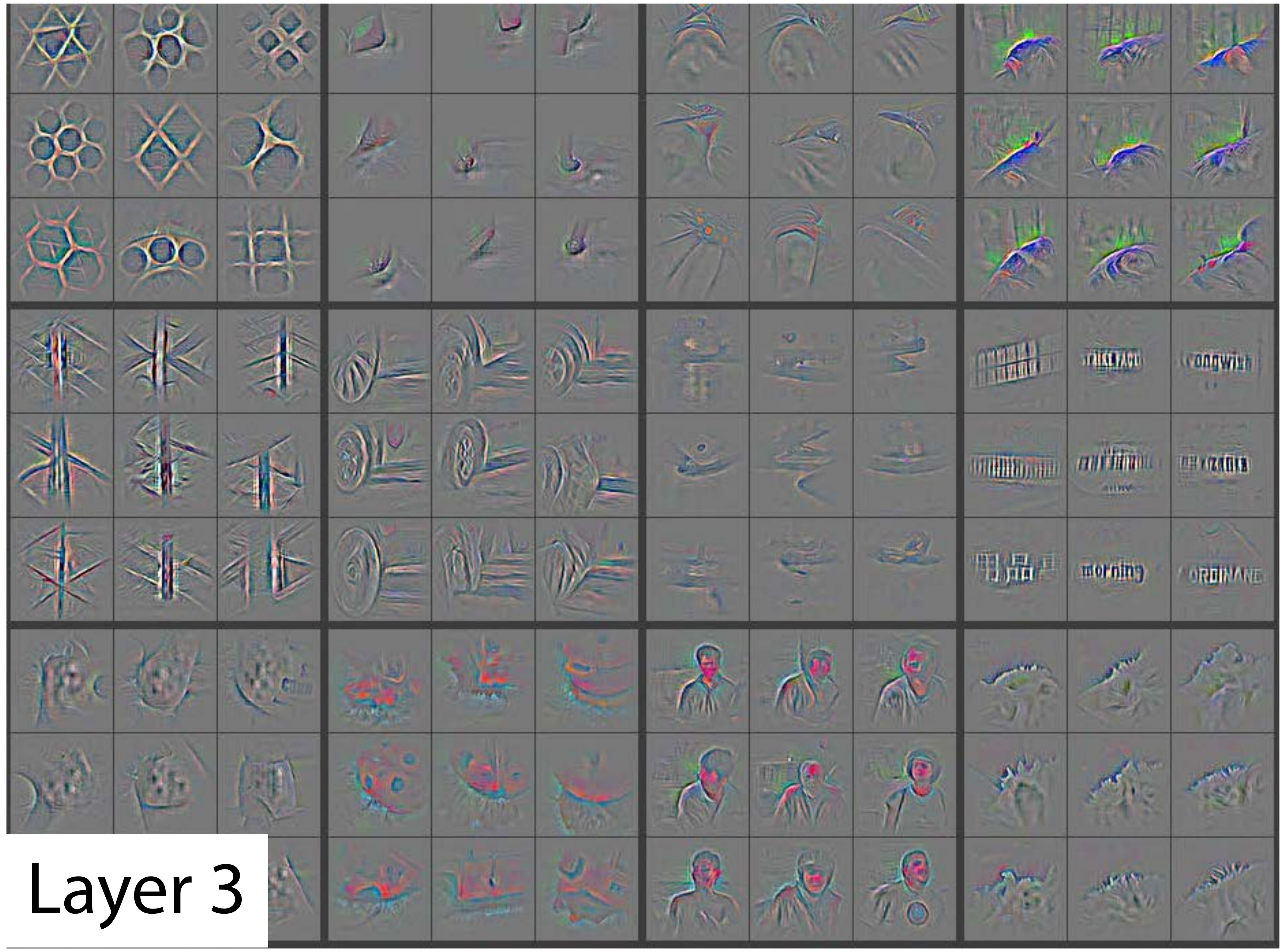

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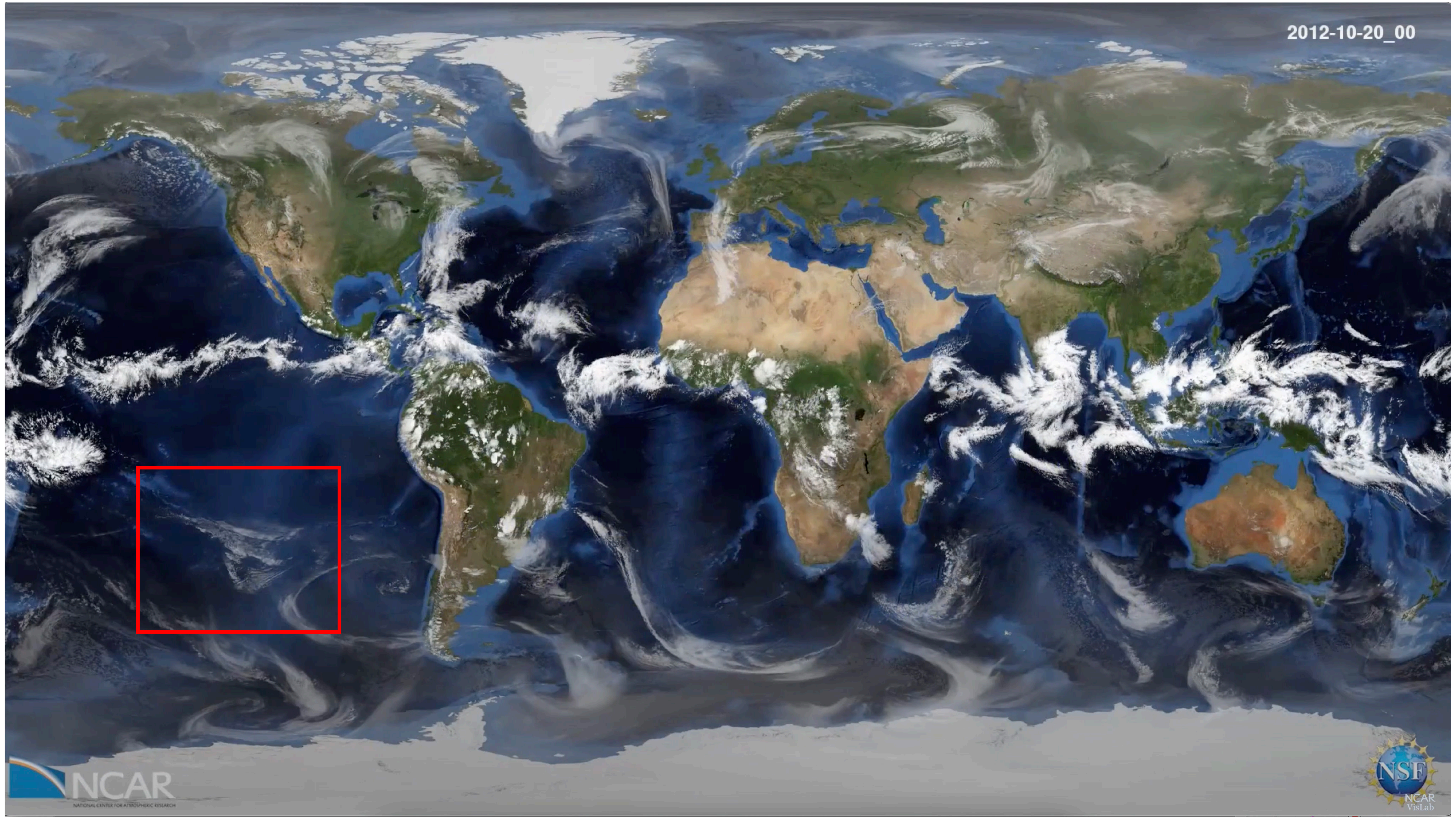
Scientific insight

- Spatio-temporal representation learning:
  - Learn representation that describe finite time spatio-temporal interactions across scales

Scientific insight



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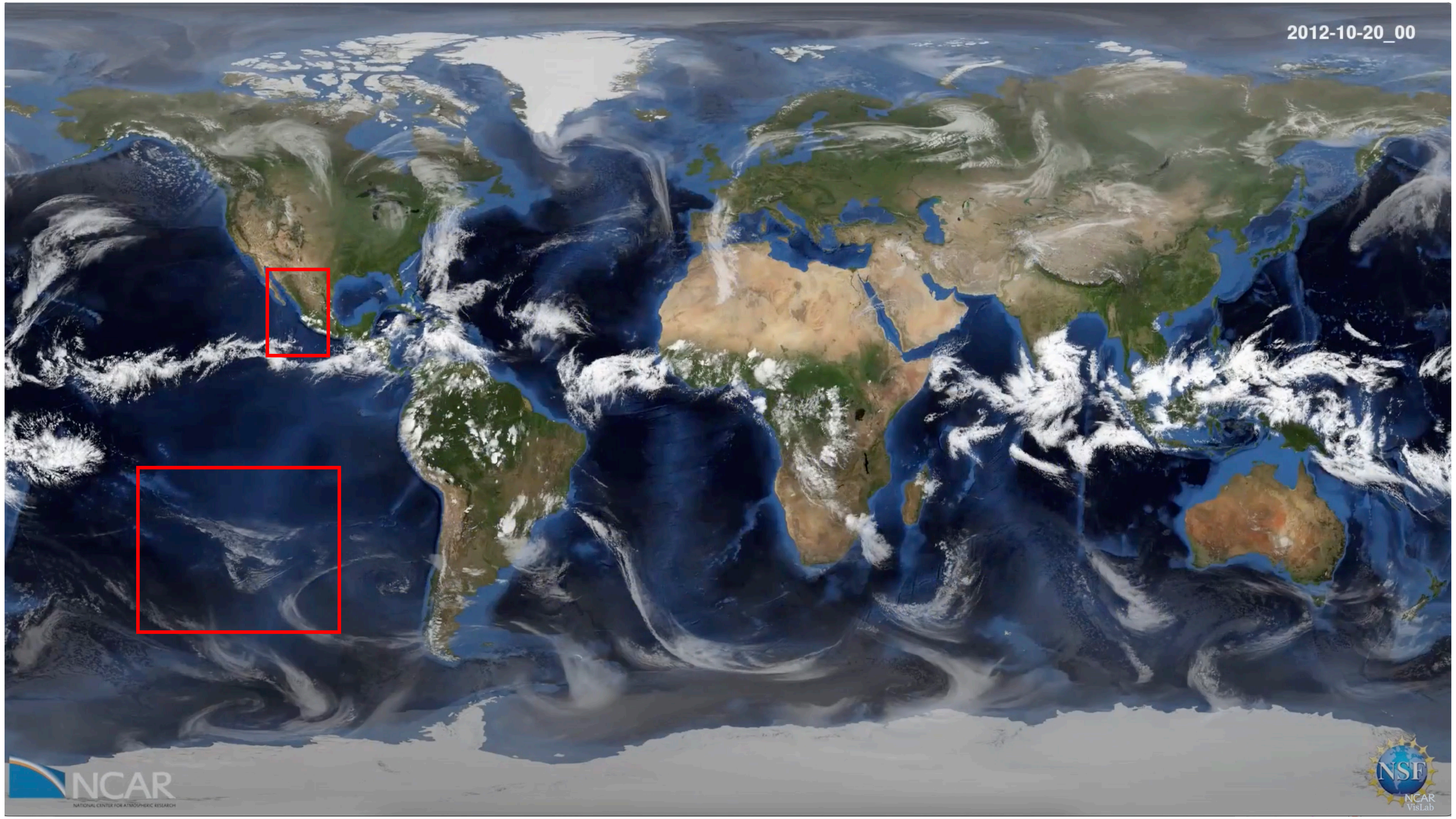

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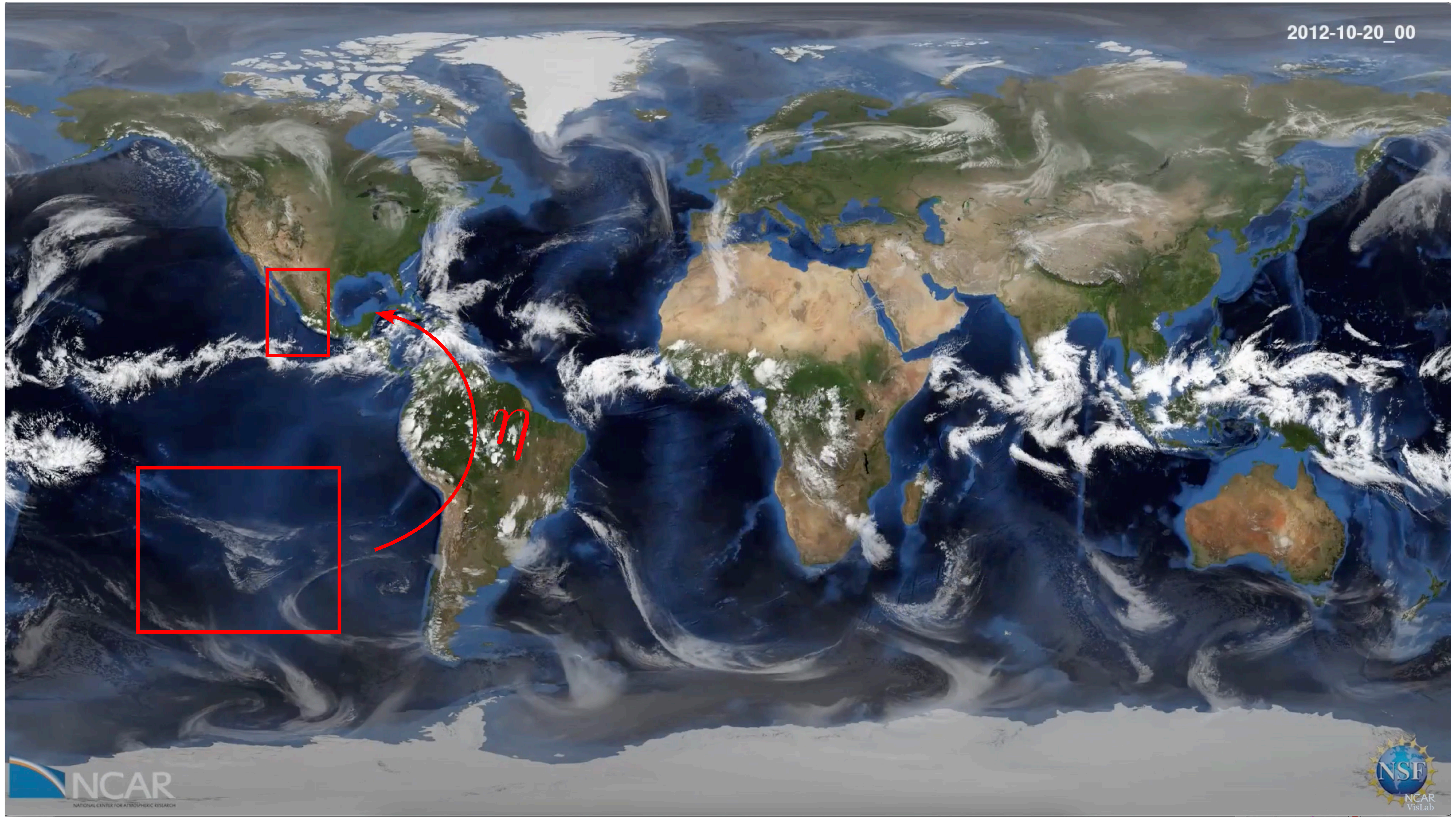

Scientific insight

- Spatio-temporal representation learning:
  - Learn representation that describe finite time spatio-temporal interactions across scales
  - Capture interactions that are difficult to describe with classical approaches
  - Transformer neural networks allow for simple interpretability

Why machine learning?

- Only incomplete description of physical processes in the atmosphere
  - No (effective) models for cloud formation, interaction with biosphere, ...
  - Most models only provide infinitesimal information
  - Very large number of *interacting* scales (1 m to 10^8 m)

=> Machine learning based on observations to capture phenomena and interactions not well described so far