Big data, ML and AI for energy systems

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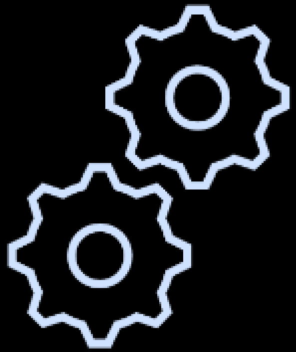
Ever improving, lower cost computation generates big data, which drives machine-learning and AI



Computation & storage & networks

- 50% better performance/year
- less cost/year

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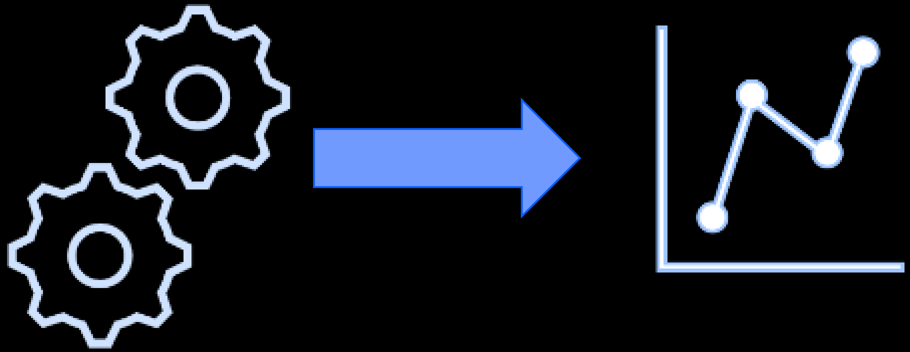

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- 50% better performance/year
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Massive Data

- 90% of all data created in the last two years

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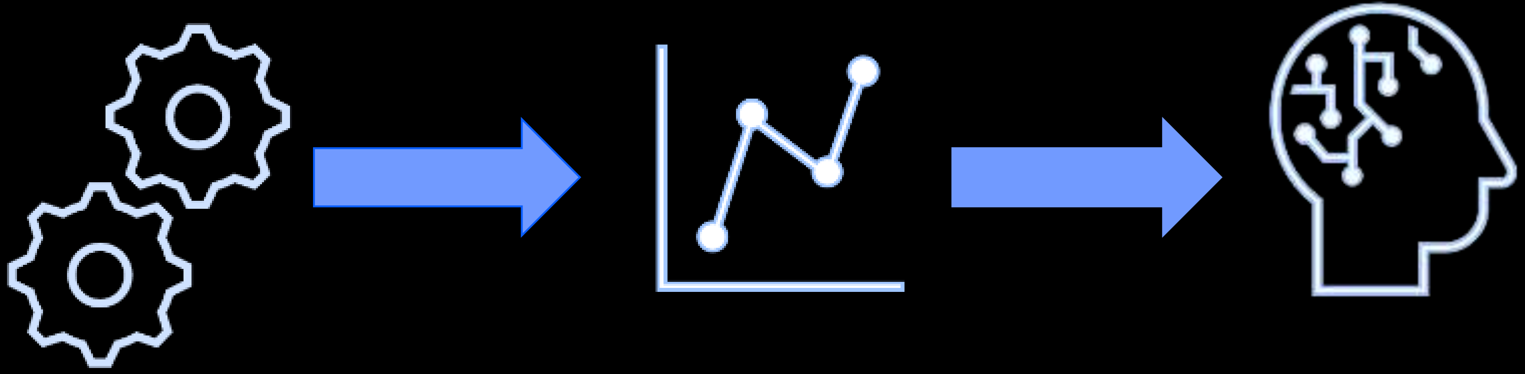


Computation & storage & networks

- 50% better performance/year
- less cost/year

Massive Data

- 90% of all data created in the last two years

Machine Learning & AI Foundation Models

- Already 98% of enterprises already use AI

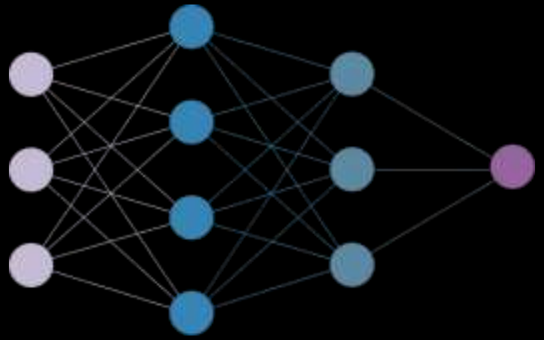
Digitization is progressing quickly

- *Electric Grid*
- *Physical assets*
- *Weather*
- *Climate*
- *Materials*
- ....

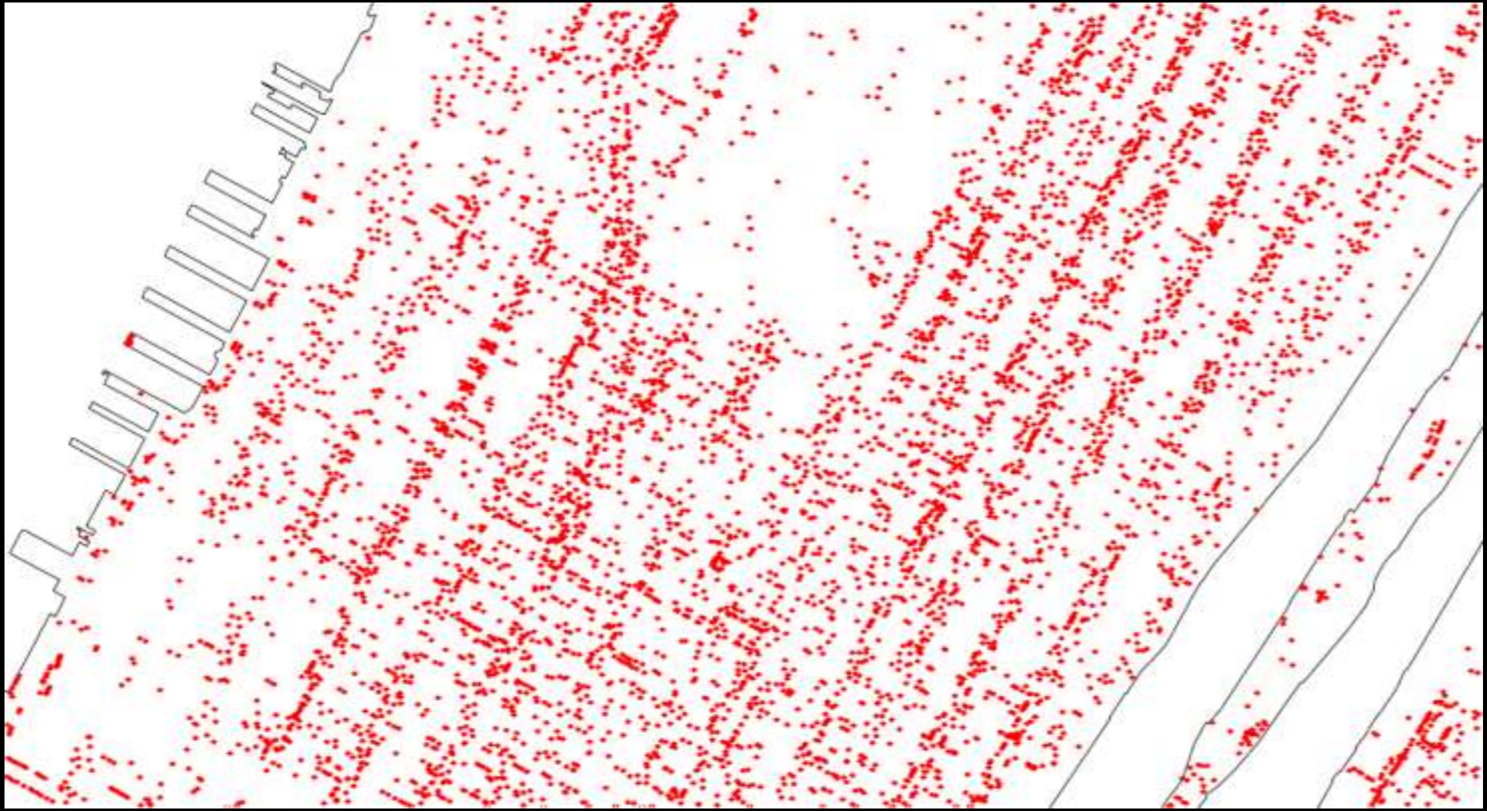
Let's talk Data

Data Challenges - Various modalities

	Sequence	*Time series*	*Geospatial*	*N-dimensional*	….
Text					
Image					
Vector					
Audio					
…					



Data Challenges – Creating Context



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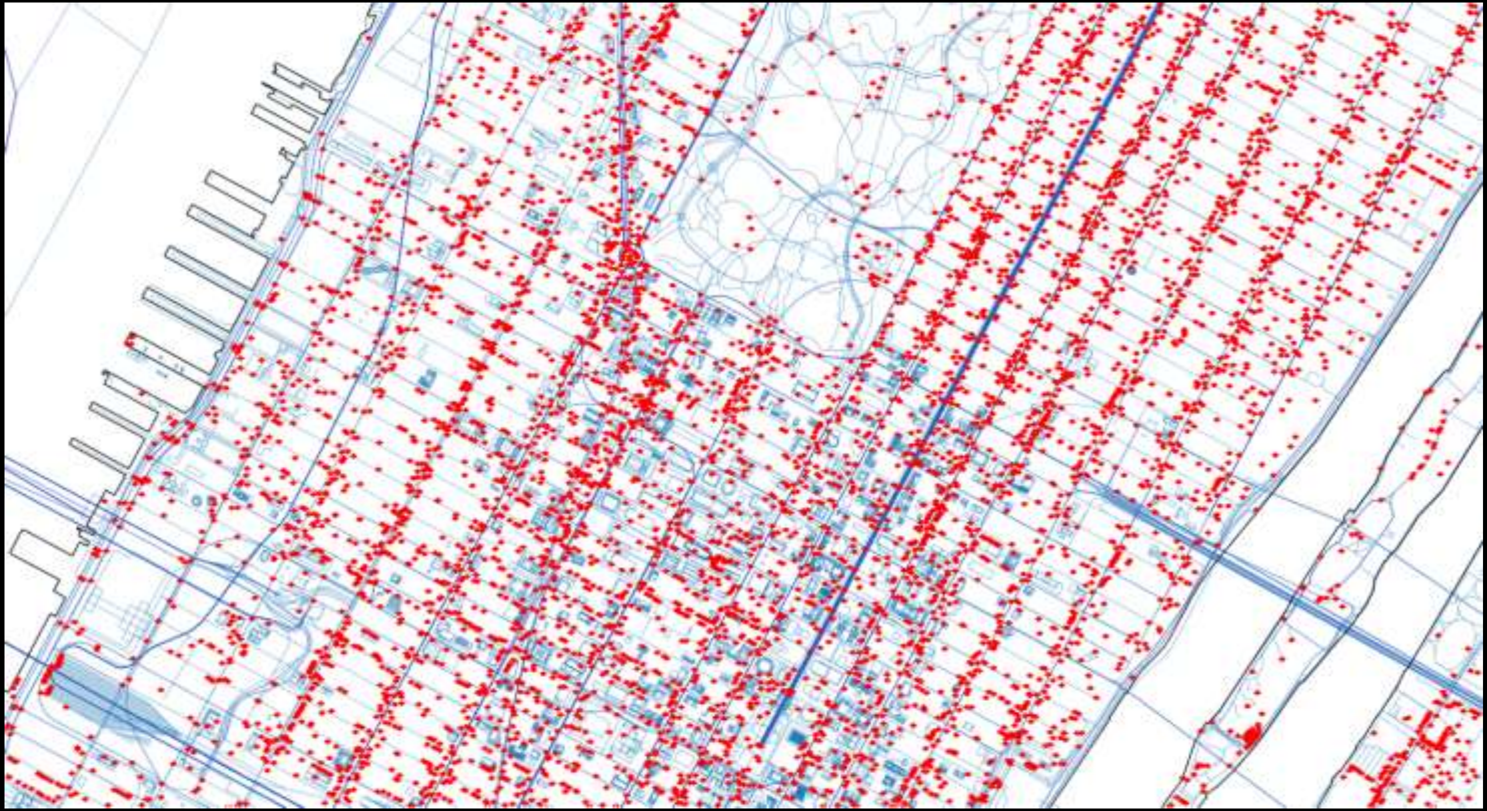
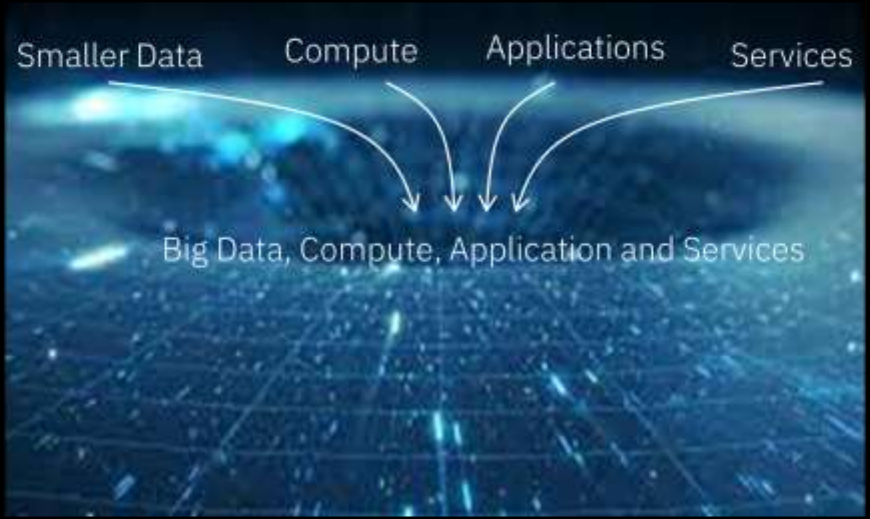
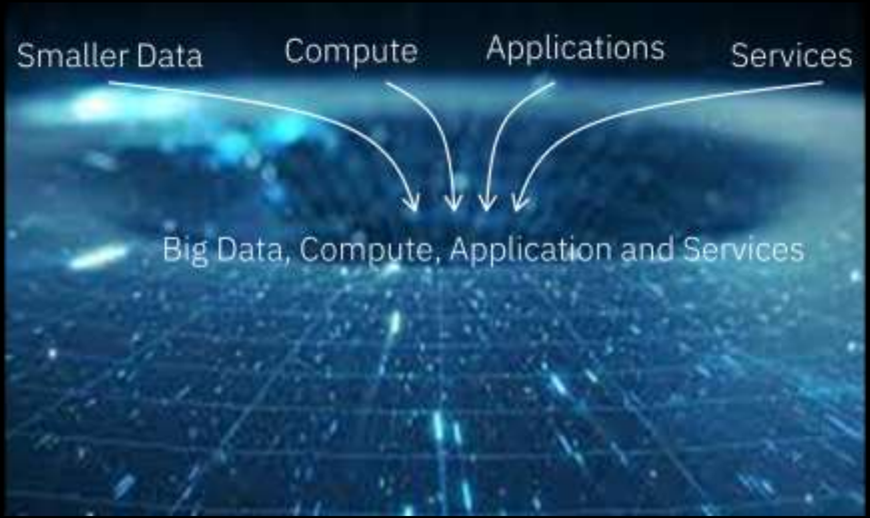


Data Challenges – Creating Context

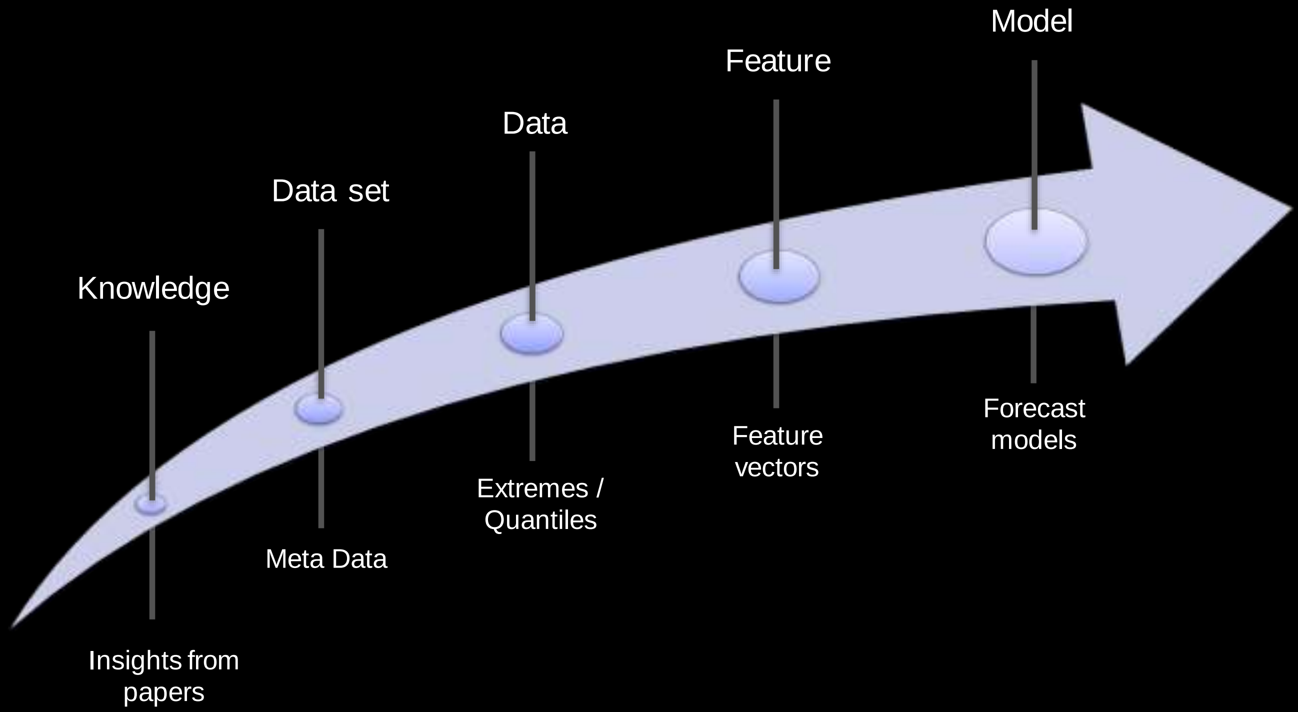
Data Challenges – Gravity



Data Challenges – Gravity vs Entropy



Data Challenges – Lack of Discoverability



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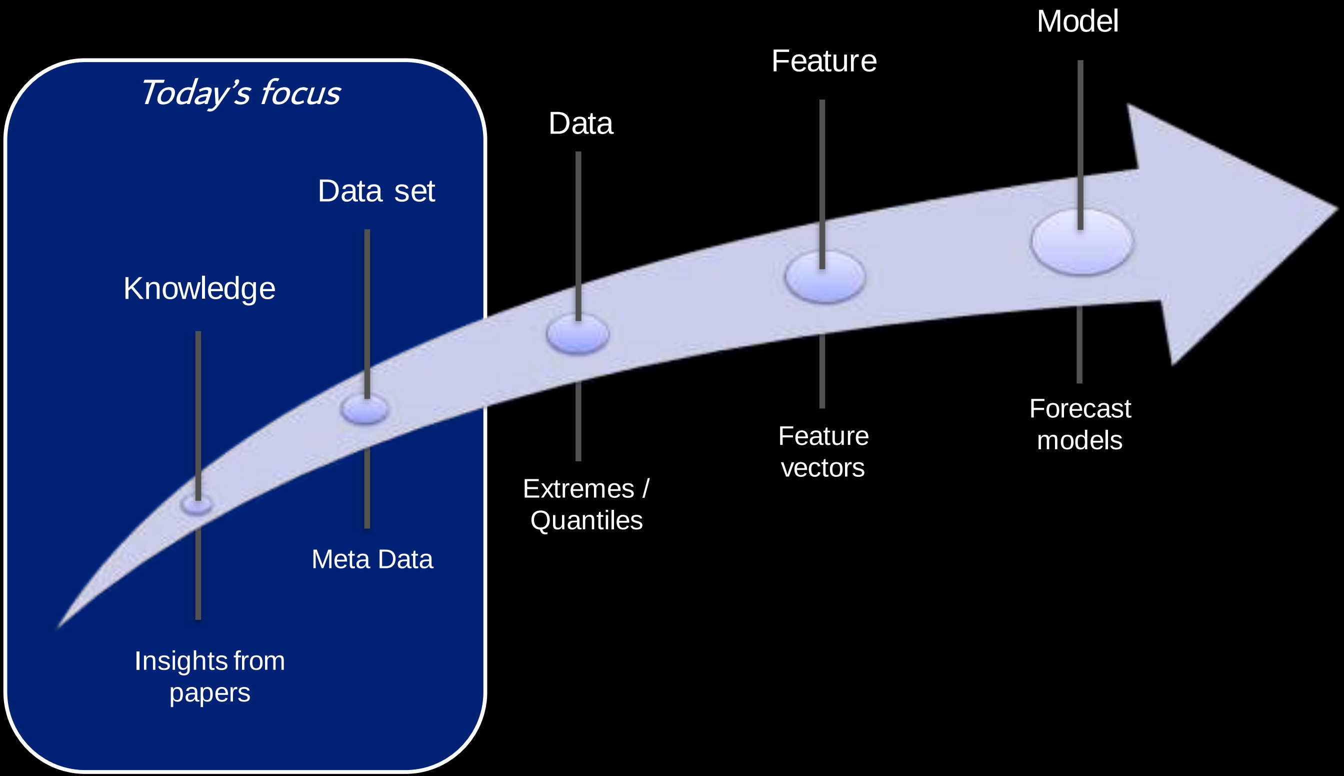
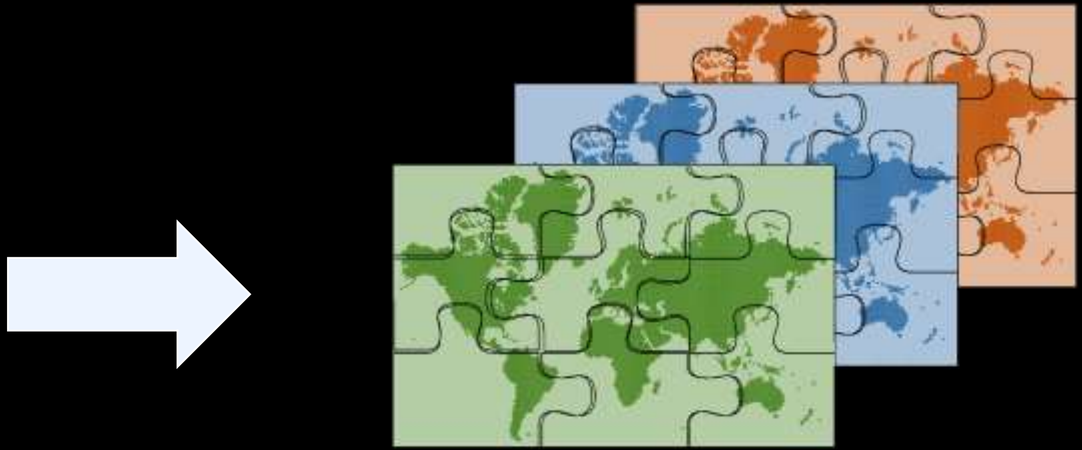


Question – How to envision the next-gen data technology to support AI for energy systems?

Next Gen Data System

Distributed, massive,
multi-modal data

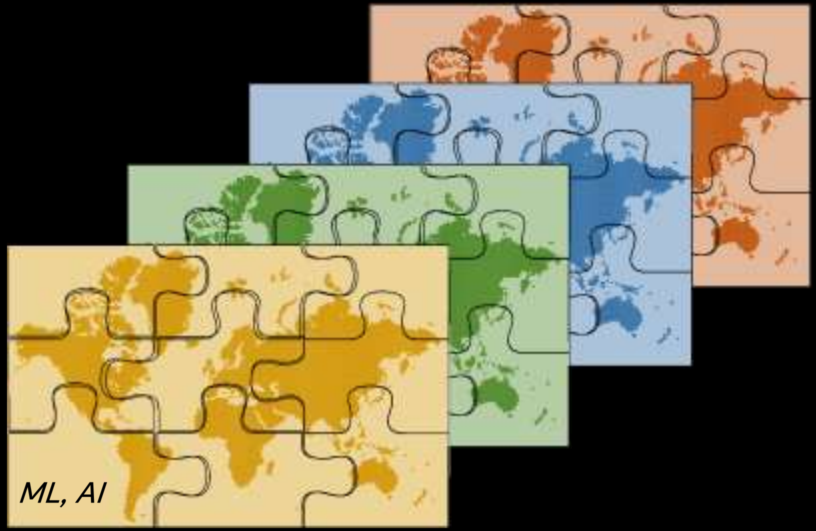
Next Gen Data System



Distributed, massive,
multi-modal data

- Federated, integrated and contextualized
- Scalable search and discovery

Next Gen Data System



Distributed, massive, multi-modal data

- Federated, integrated and contextualized
- Scalable search and discovery
- Rapid insights (with little data movement)

Innovation and Research opportunities for next-gen data technology to support AI for energy systems

- *New federation approaches & distributed computing*
- *New forms of in-data computation*
- *Advanced indexing / novel data structures for energy system specific information*
- *Information discovery (going beyond meta-data)*
- *New forms of representing logical and physical information*

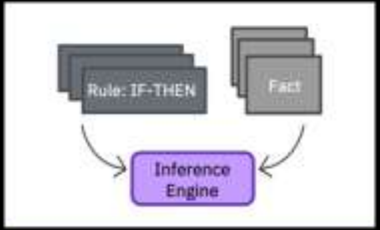
Let's talk ML and AI

The evolution of AI and the emergence of Foundation Models

80s | Big data

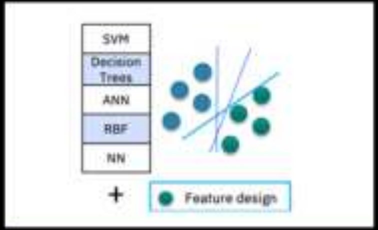
80s to ~2010 | Massive data + Compute

2010 -2017+ | Self-supervision at scale + Massive data + Compute



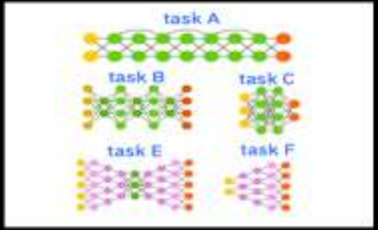
Expert Systems

Hand-crafted symbolic representations



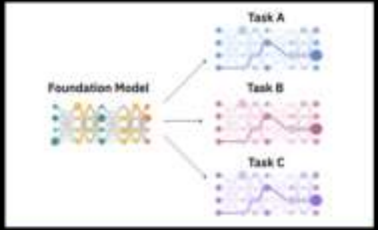
Machine Learning

Task-specific hand-crafted feature representations



Deep Learning

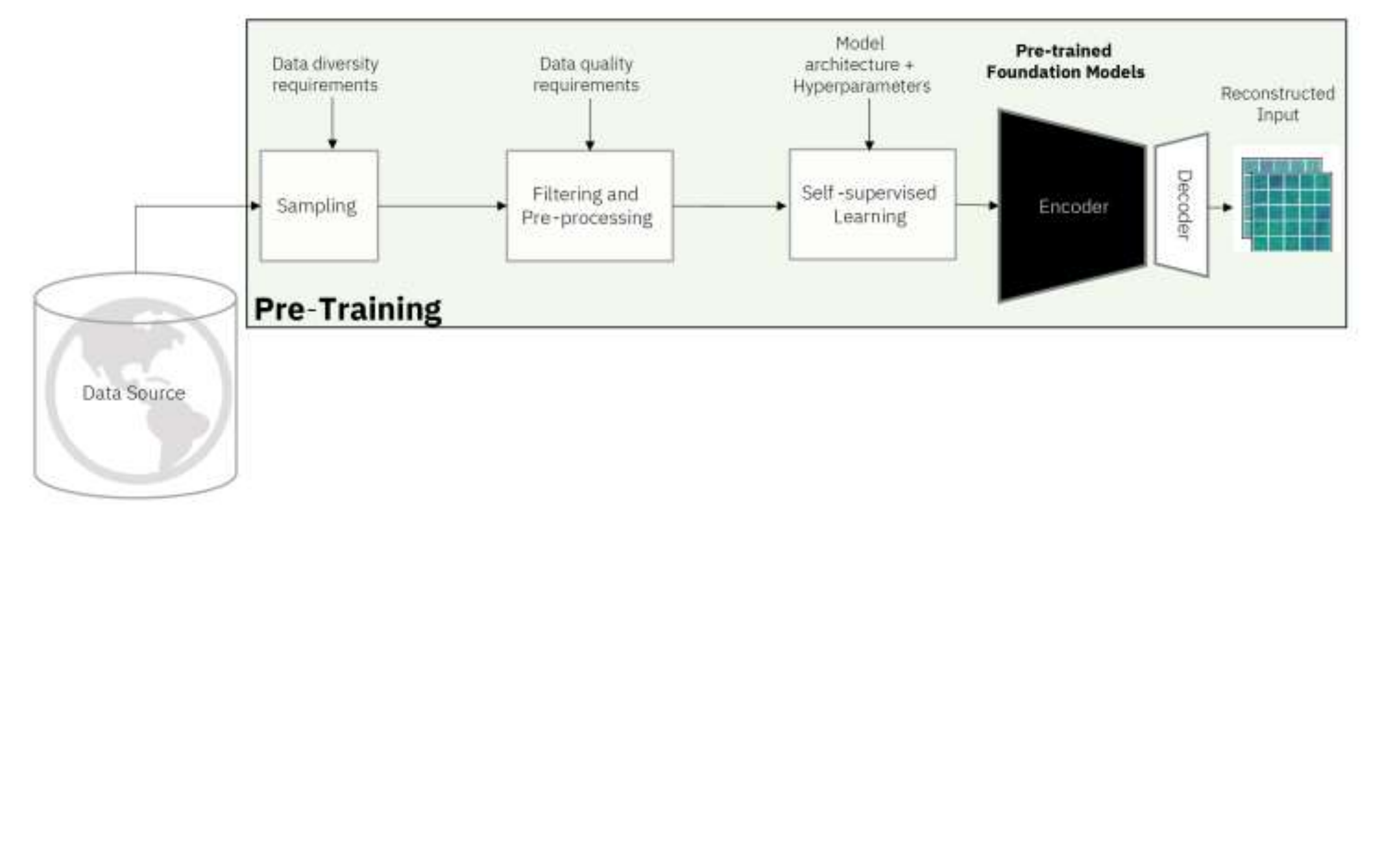
Task-specific learnt feature representations



Foundation Models

Generalizable & adaptable learnt representations

Foundation Models – how do they work ?



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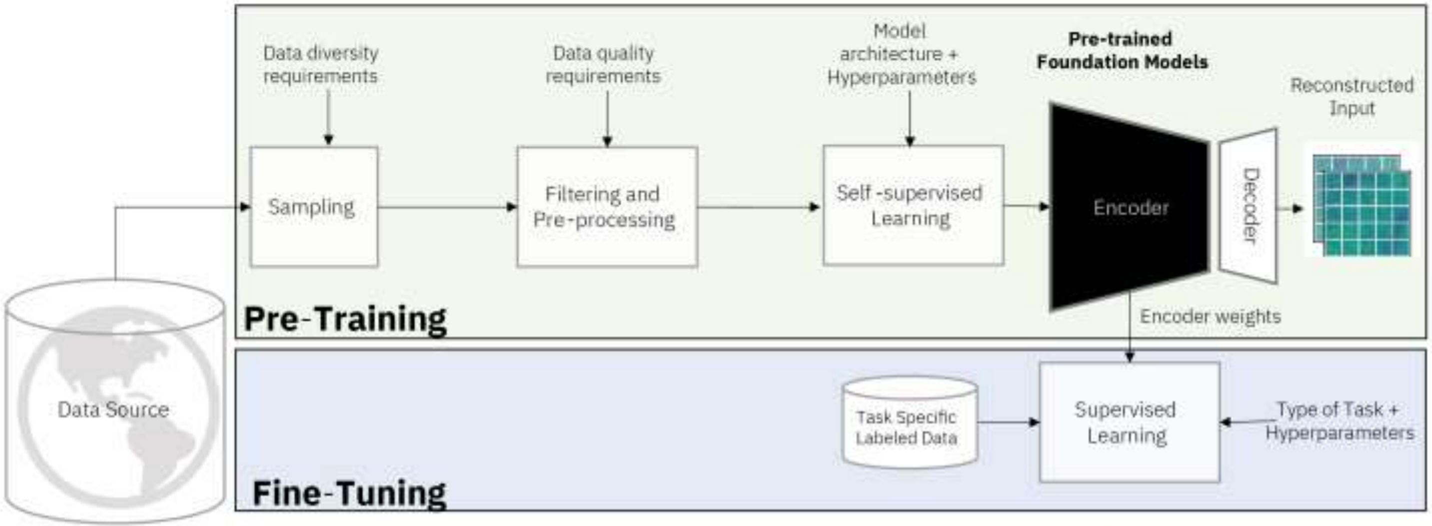

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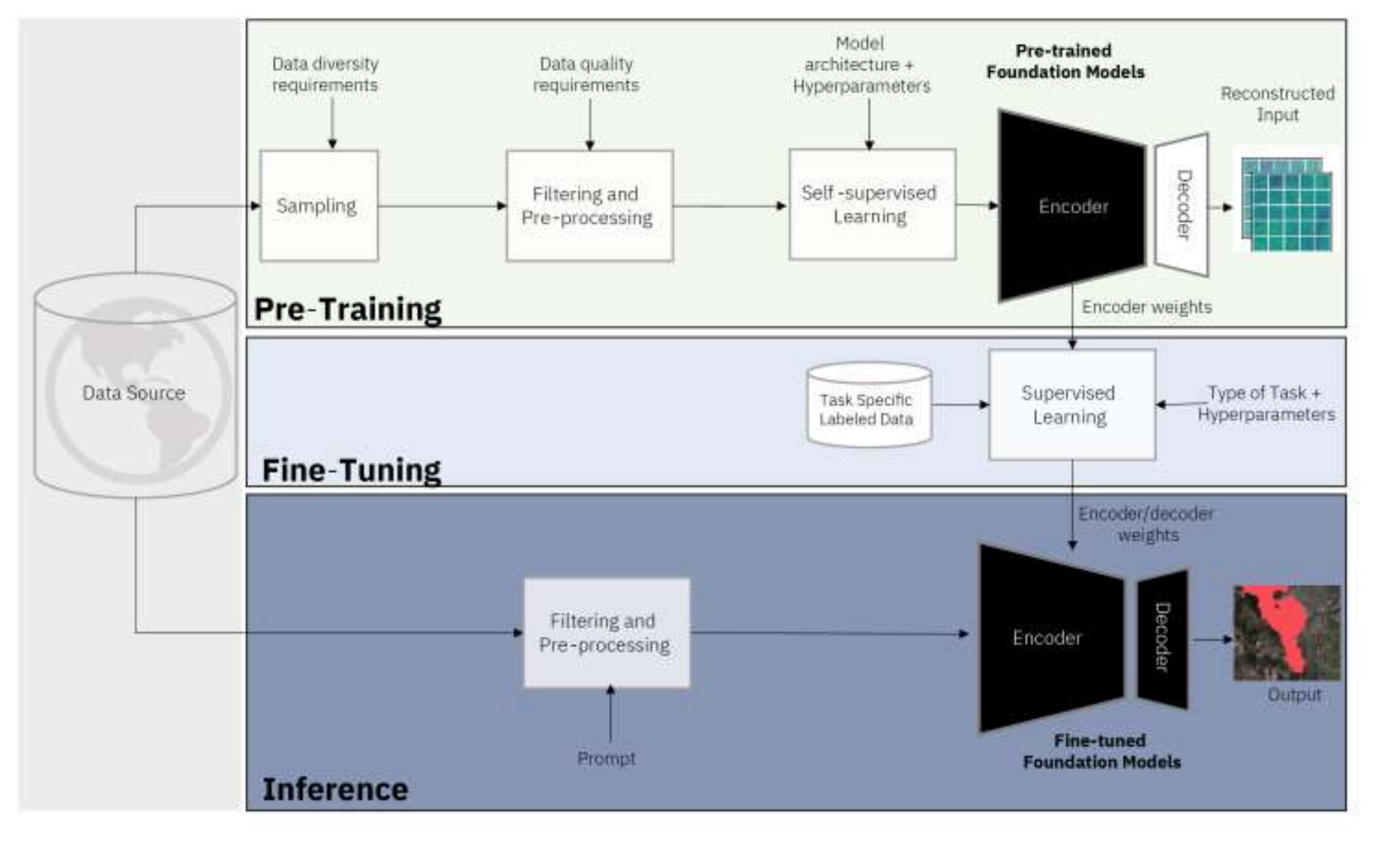
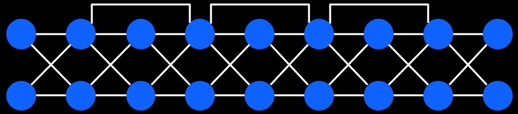
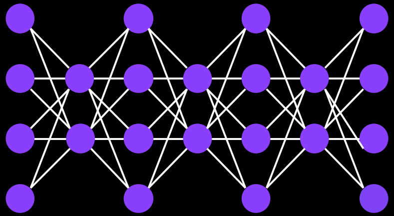
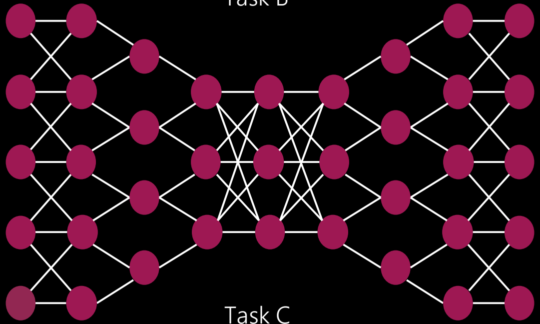


Why Foundation Models?

Classical AI models:
Purpose-built and siloed







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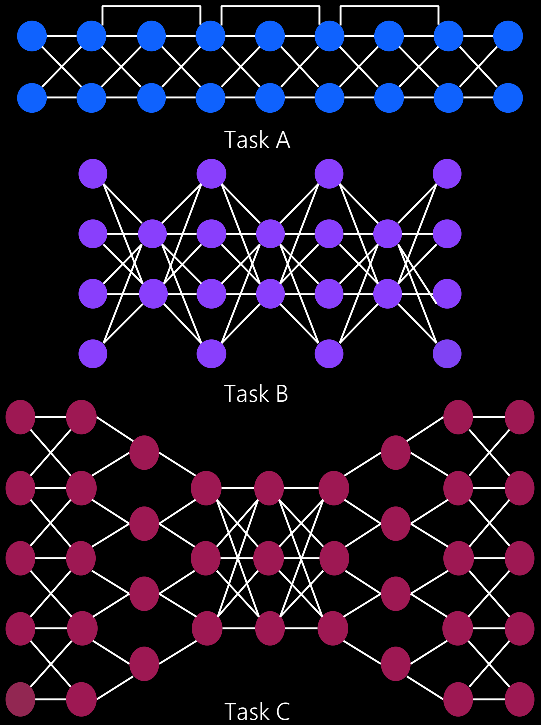
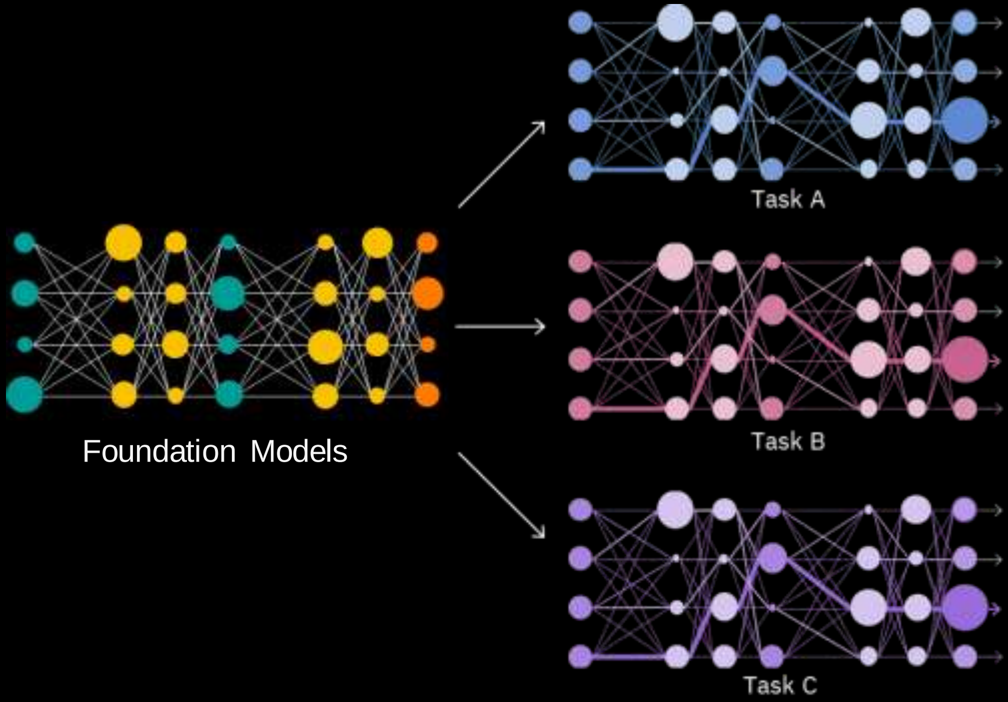


Foundation Models:
One base supports multiple tasks



Why Foundation Models?

Less labeling means less effort and lower upfront costs

Effort mostly on fine tuning and inferencing means faster deployment

Equal or better accuracy than state-of-the-art for multiple use cases

Better performance means incremental revenue

Economy of scale drives the development of Foundation Models

NLP Foundation models are taking the world by storm

CBS NEWS **ChatGPT bot passes law school exam**

FOX 10 PHOENIX ChatGPT may be smart enough to graduate law school

SCALE

Foundation Models Are The New Public Cloud

Forbes

As AI Advances, Will Human Workers Disappear?

'GODFATHER OF AI' RESIGNS FROM GOOGLE, WARNS OF THE DANGER OF ARTIFICIAL INTELLIGENCE

BBC

Sting warns against AI songs as he wins prestigious music prize

THE WALL STREET JOURNAL.

ChatGPT Fever Has Investors Pouring Billions Into AI Startups, No Business Plan Required

Amid broader venture-capital doldrums, it is boom times for startups touting generative artificial intelligence tech

Question – Can we develop “foundation models” for energy systems?

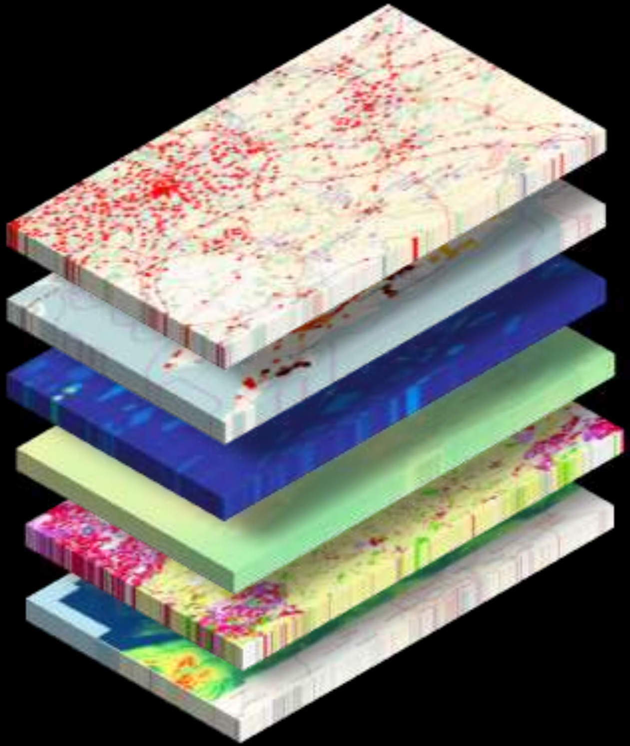
AI Energy systems go beyond text data

	Text
Downstream applications	High value & Many
Data availability	Available
Data type	Sequence
Data variety	Limited numbers of words
Context	Relative complete
Base Model	Grammar / rules
Architectures	Transformers

An important modality for energy systems is geospatial

- ✓ Weather
- ✓ Satellite imagery
- ✓ LIDAR point clouds
- ✓ AMI
- ✓ Drone imagery

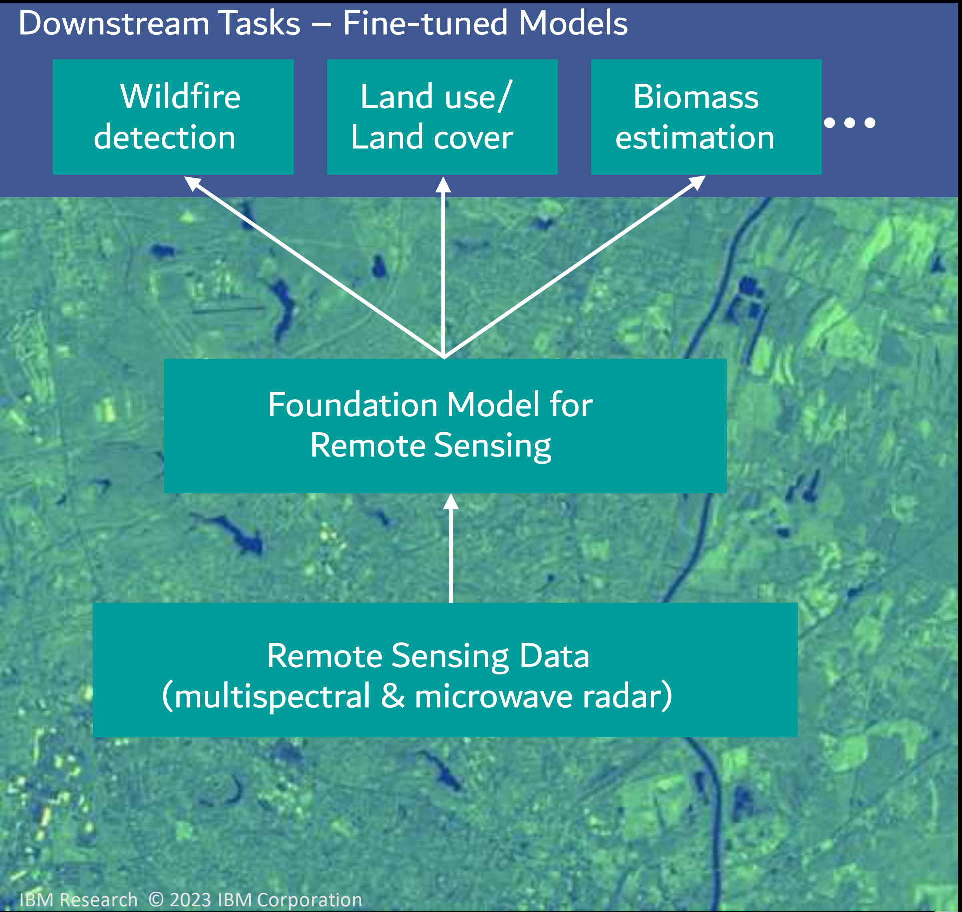
…and many others



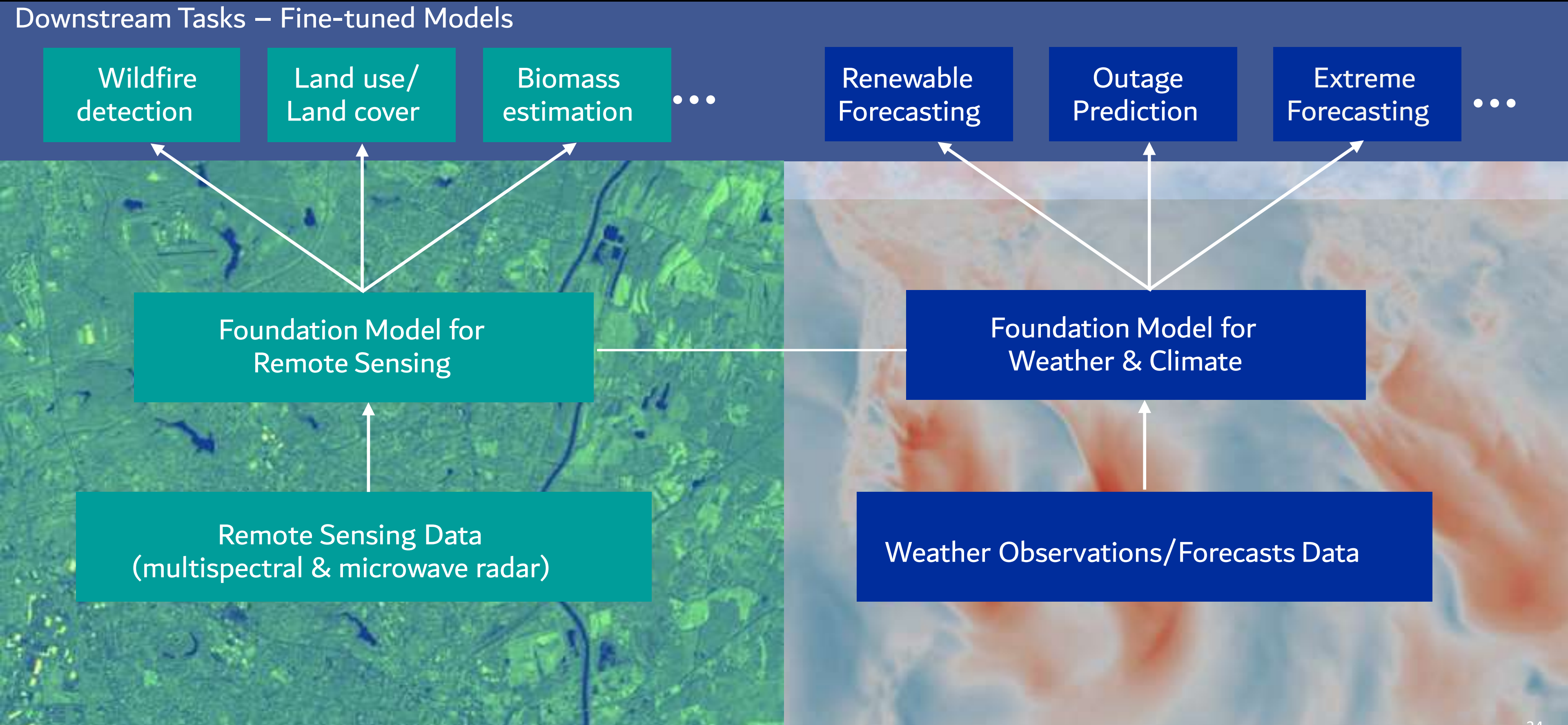
AI Energy systems go beyond text data

	Text	Geospatial/Weather
Downstream applications	High value & Many	TBD
Data availability	Available	TBD
Data type	Sequence	Multi-modal, multi-dimensional
Data variety	Limited numbers of words	TBD
Context	Relative complete	TBD
Base Model	Grammar / rules	NWP / Physics
Architectures	Transformers	TBD: Transformers, Graphs, Operators

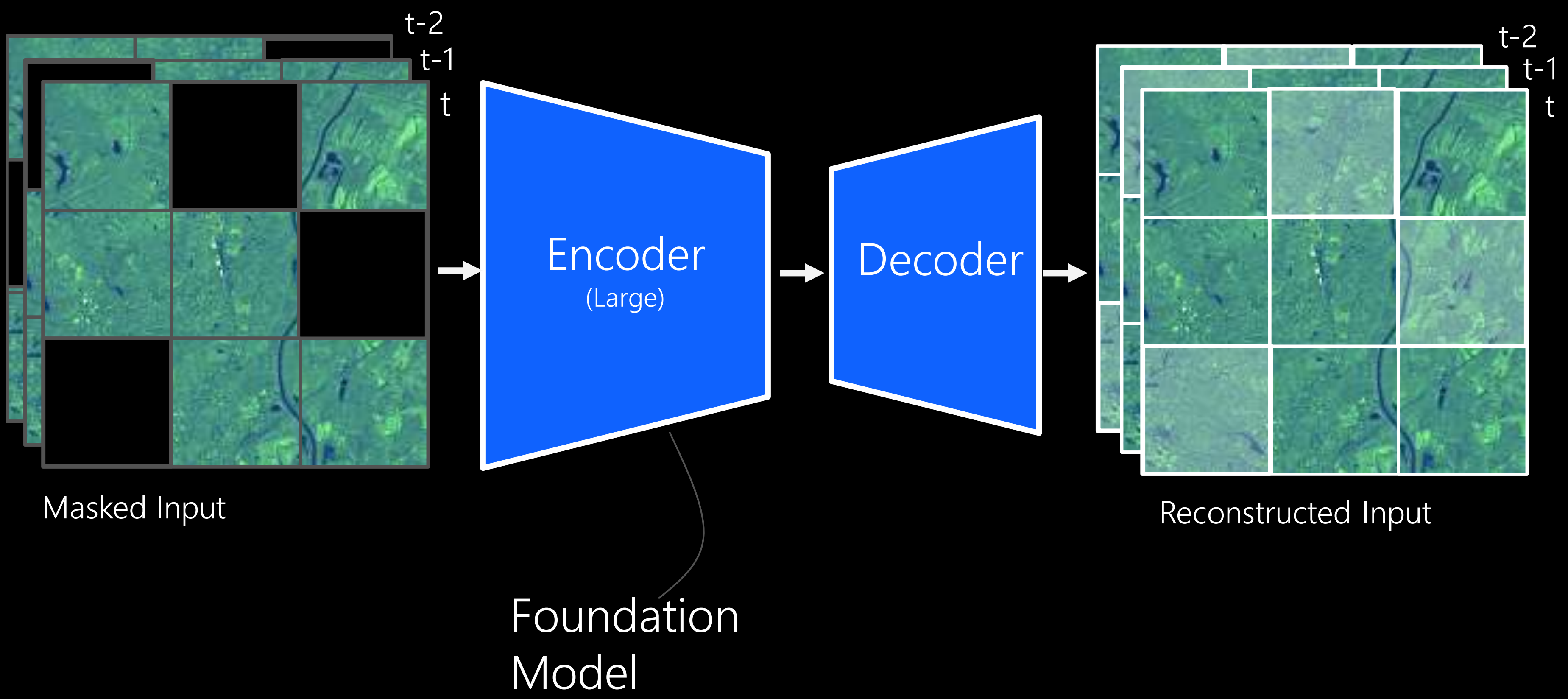
Building Geospatial Foundation Models



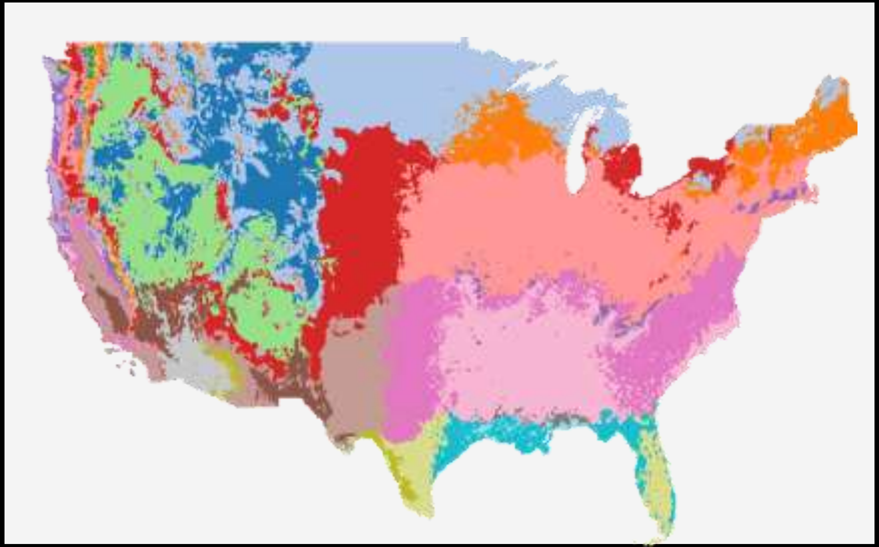
Building Geospatial Foundation Models



Self-supervised learning to build Foundational Models



Data sampling procedure



Selecting pre-training data

Requirement → ***diversified*** pre-training dataset.

– For a given region, images can look similar across time.

– Random sampling → can bias towards most common landscapes.

Intelligent sampling scheme based on ***geospatial statistics***.

Sampling data from across US

Sampling scheme

1. Aggregate various geospatial statistics (land use, climate zone etc.).
2. Divide the region into groups based on these statistics.
3. Sample data as equally as possible from each group.

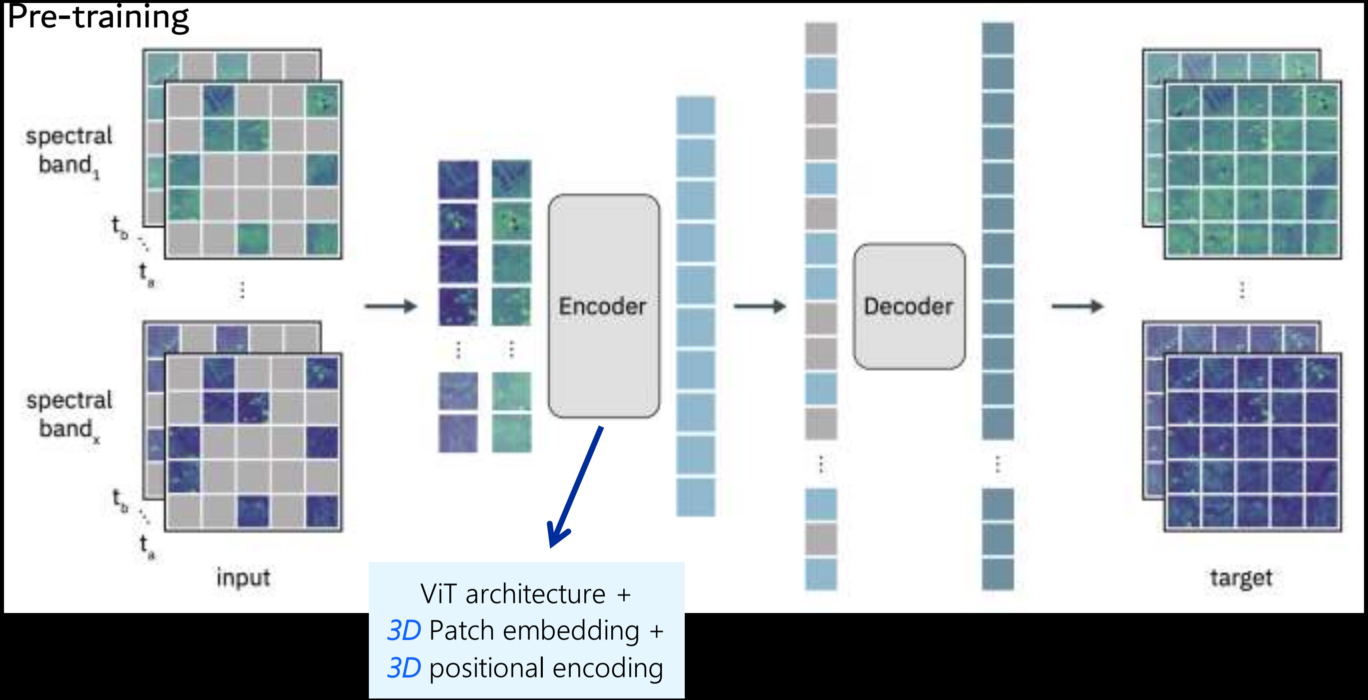
Model architecture (MAE = Masked AutoEncoder)

- Pre-training task: reconstruct ***masked*** patches → target = original data.
- MSE loss on ***masked*** patches.

Encoder → Vision transformer (***ViT/Swin***) for multispectral ***3D data***.

- 3D patch embeddings
- 3D positional encoding

Decoder → Transformer blocks + linear projection layer to match the target patch size.



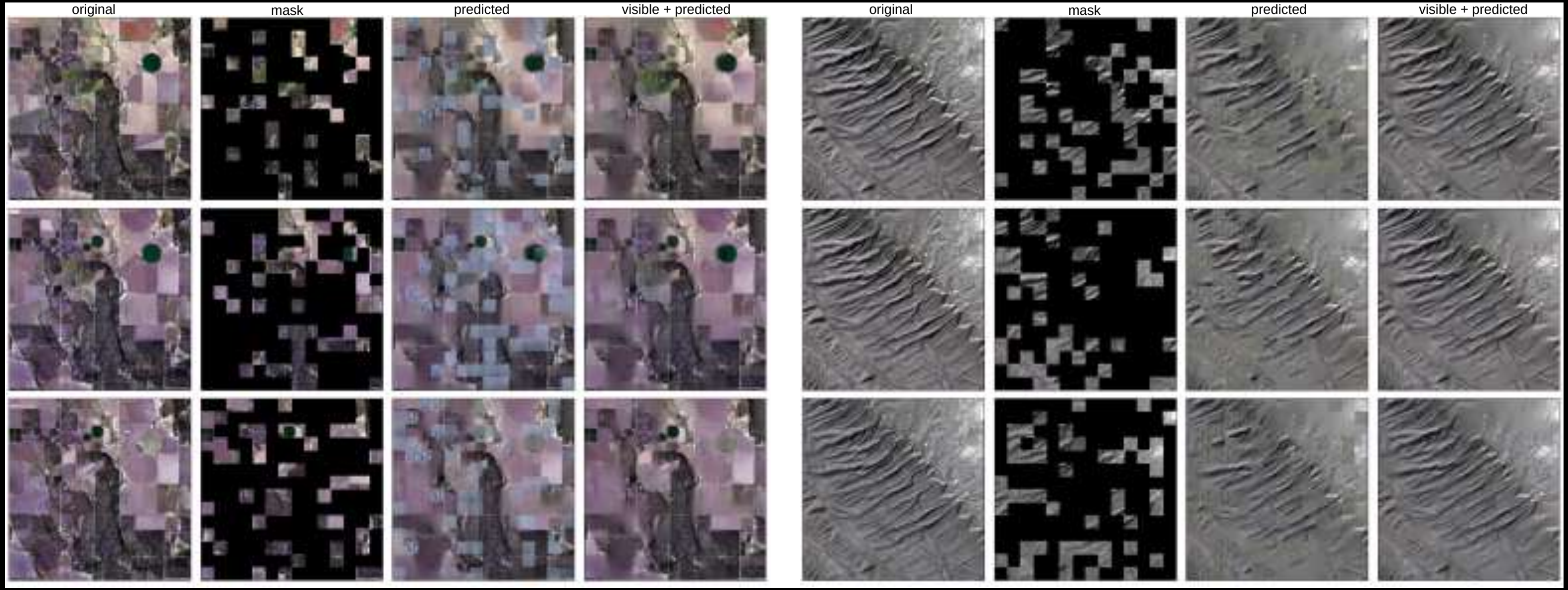
Pre-training results

original mask predicted visible+ predicted original mask predicted visible+ predicted

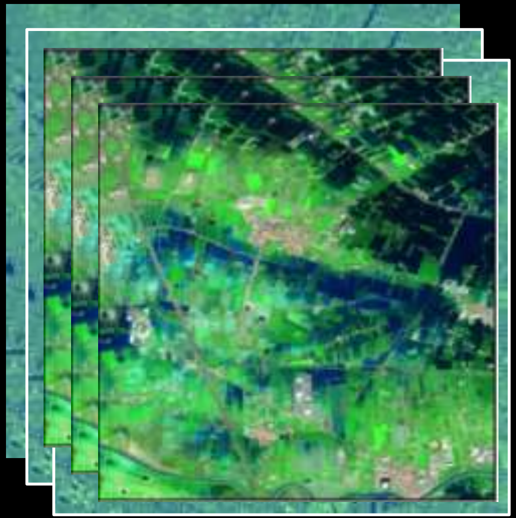
t0

t1

t2



Example fine-tuning workflow for satellite



Input remote sensing data

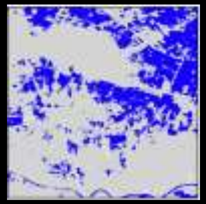
Encoder
(Large Transformer)

Foundation model for remote sensing

Example fine-tuned models

Wildfire detection

Semantic Segmentation



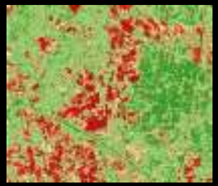
Land Use/Land Cover

Classification

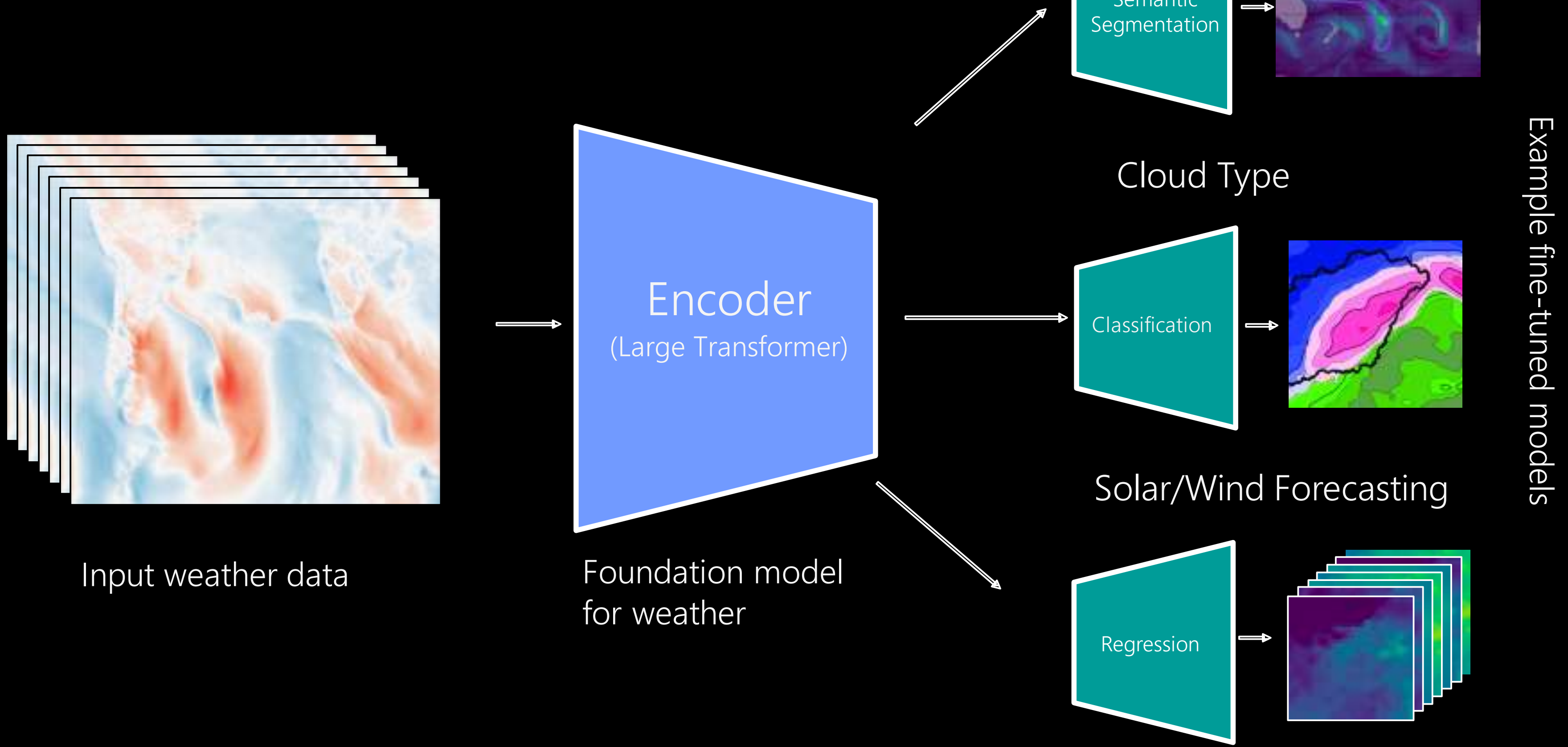
Bare
Developed
Forest
Shrub
Water
...

Above/Below Ground Biomass

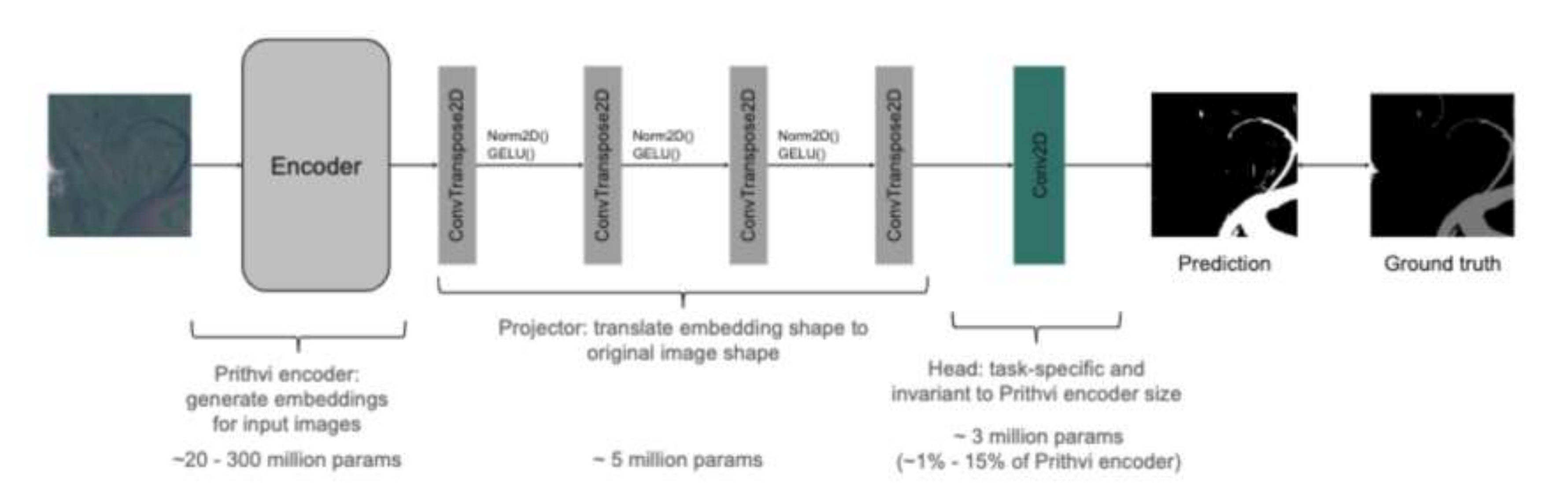
Regression



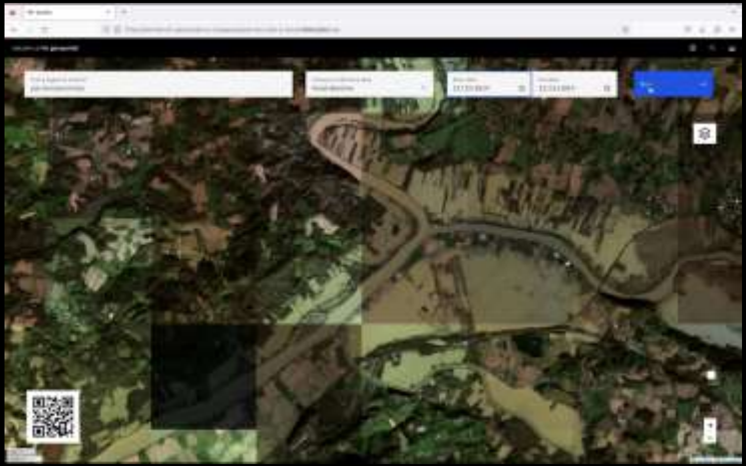
Example fine-tuning workflow for weather



Fine-tuning – Segmentation, classification and regression tasks

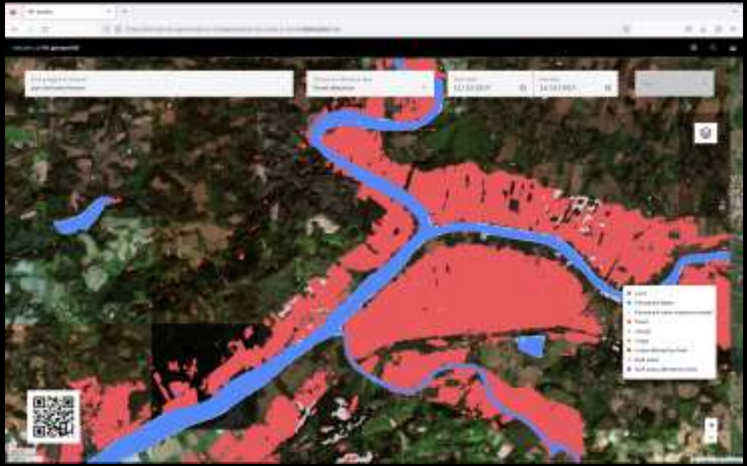


Inference insights: Flood detection



<< Inference>>
(e.g., flood task)

Insights: Flood detection

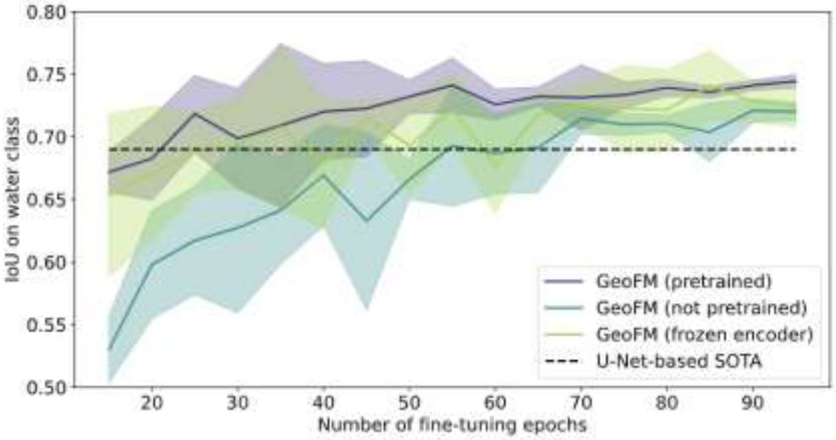


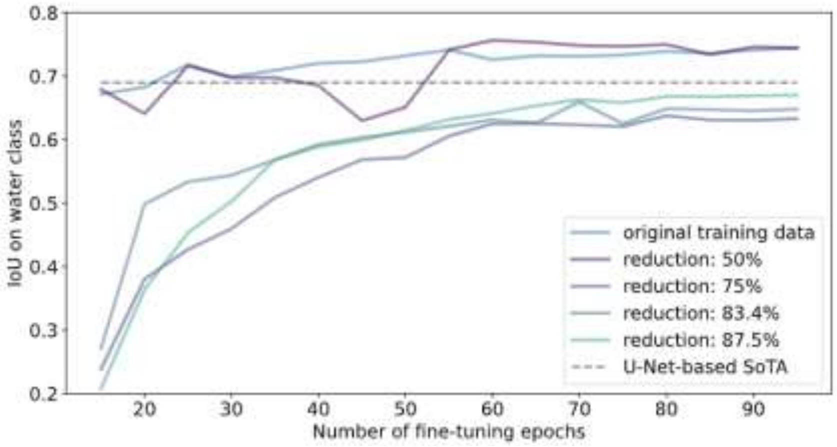
Insights: Flood impact

"**Prompt**": Image(s) (spatial + temporal domains)

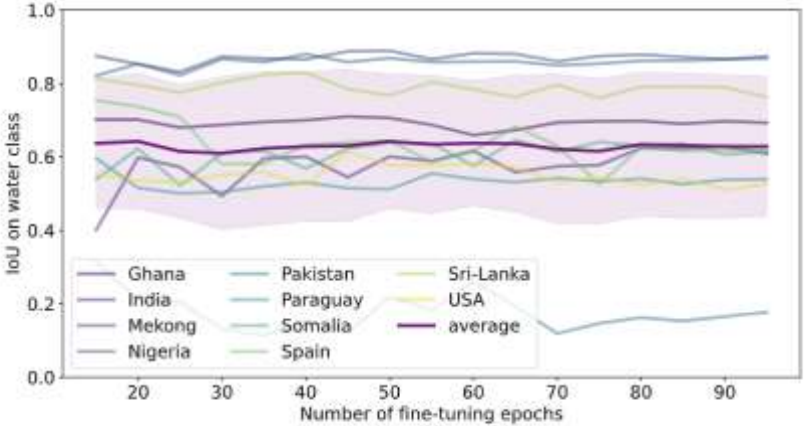
	IoU (water class)	F1 (water class)	IoU	F1 score	Accuracy
Baseline [44]	24.21	–	–	–	–
U-Net-based SOTA [45]	69.12	81.74	93.85	96.65	96.44
ViT-base [19]	66.52	79.89	90.92	94.97	94.97
Swin [46]	74.75	85.55	92.38	95.90	94.73
Prithvi (not pretrained)	79.23	88.41	94.52	97.09	97.07
Prithvi (pretrained)	**80.10**	**88.95**	**94.78**	**97.23**	**97.23**

Flood detection example - fine-tuning analysis





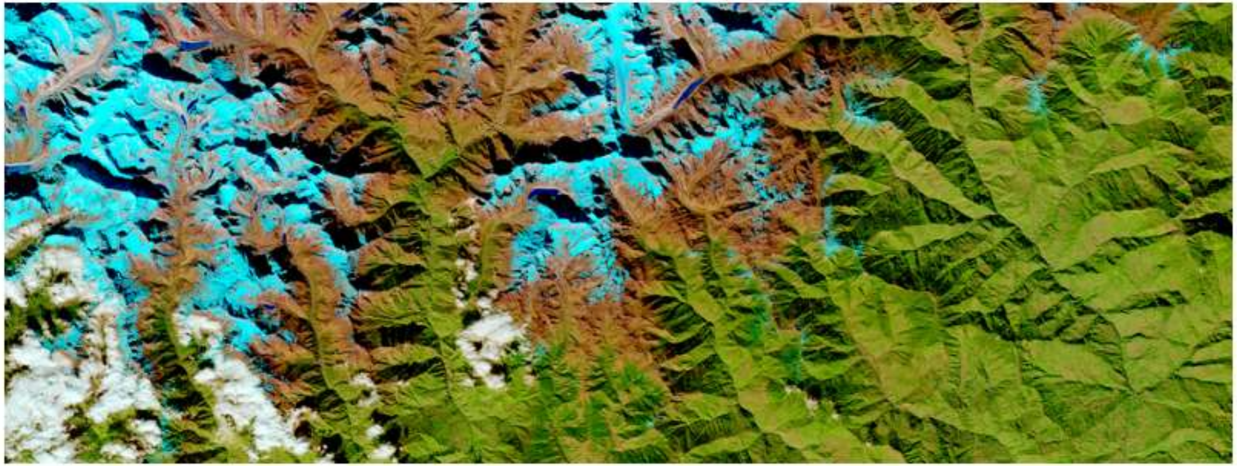
- ✓ Pre-trained model achieves higher IoU with a smaller number of training epochs and more consistently.
- ✓ It is robust to a reduction of 50% in the training data and performs consistently in most regions where it has not been trained.



IBM and NASA Open Source Largest Geospatial AI Foundation Model on Hugging Face

Effort aims to widen access to NASA earth science data for geospatial intelligence and accelerate climate-related discoveries

Aug 3, 2023



Innovation and Research opportunities for AI and Foundation Models for energy systems

- *What (high-value) downstream tasks need to be addressed?*
- *What content is required for pre-training, finetuning and inference?*
- *What is the pre-training/masking approach?*
- *What architectures are required?*
- *How to derive most efficiently knowledge from foundation models*

Thank you

