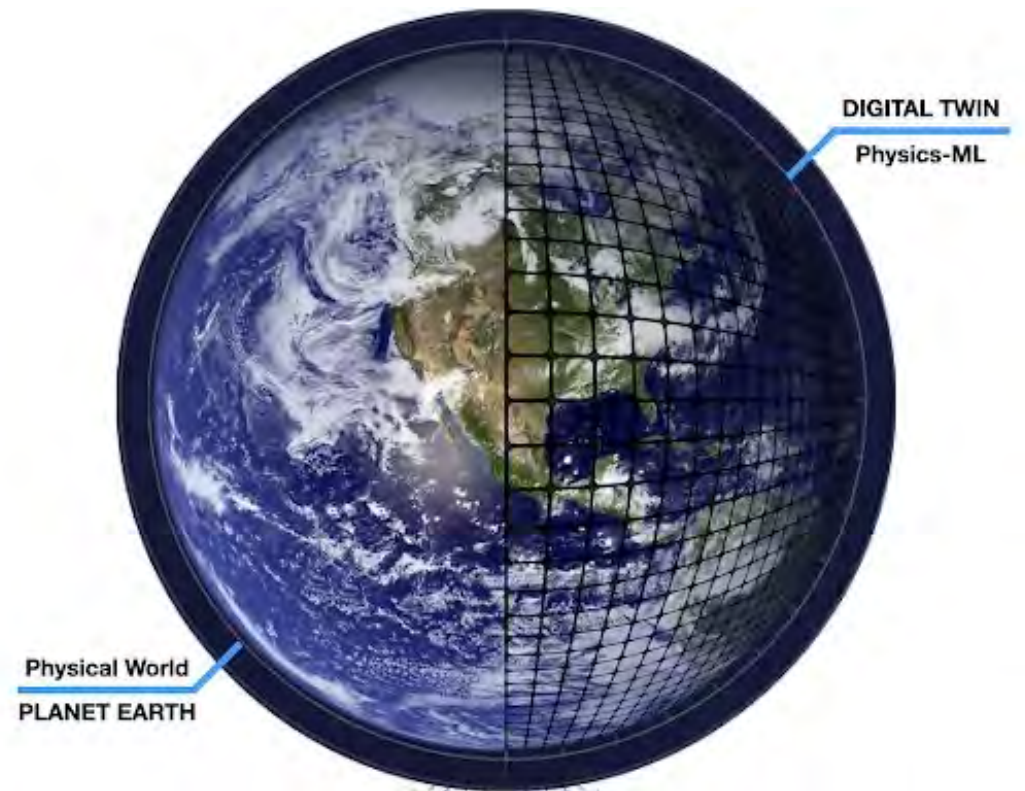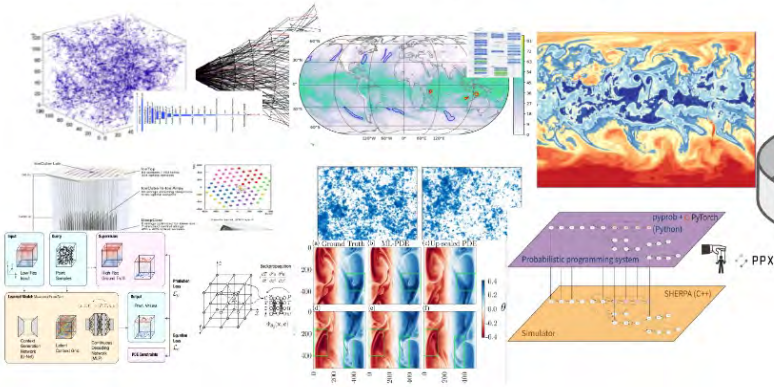# NERSC-AI AND DATA-DRIVEN MODELING OF ATMOSPHERE USING DEEP LEARNING

SHASHANK SUBRAMANIAN

NERSC

AI @ NERSC

- ◦ ***Deploy*** optimized hardware and software systems
- ◦ ***Apply*** AI for science using cutting-edge methods (NESAP)
- ◦ ***Empower*** through seminars and trainings

NESAP for Learning (N4L)
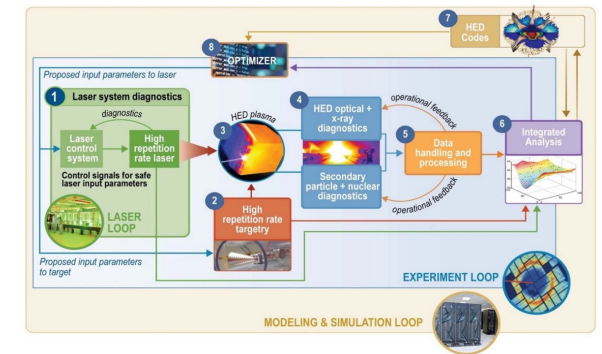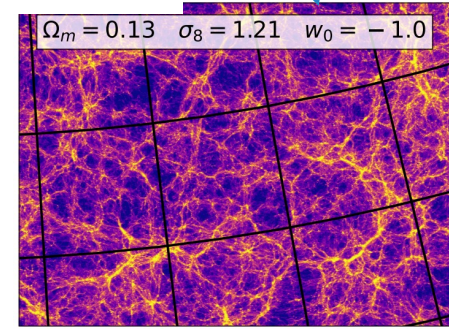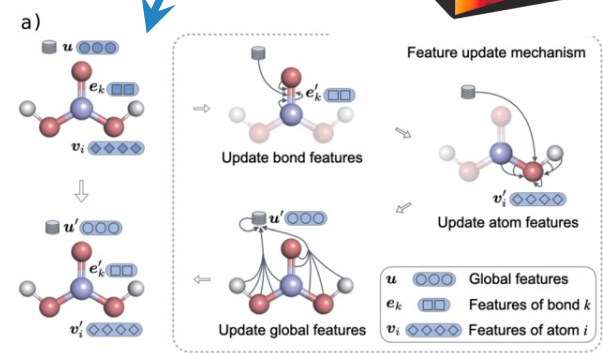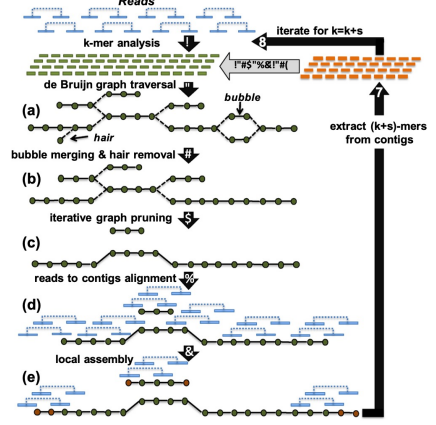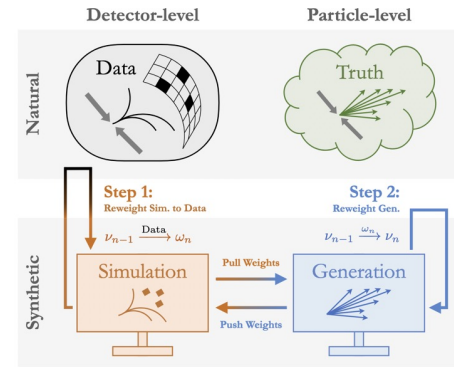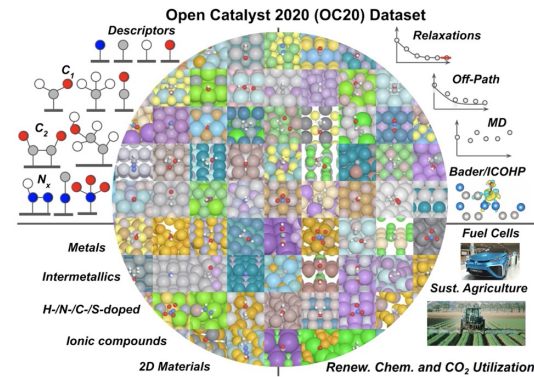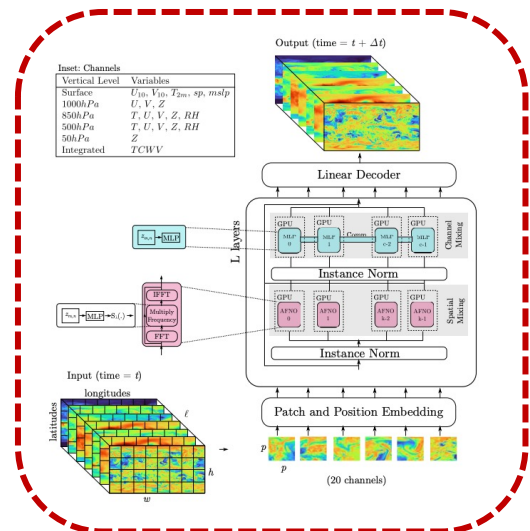
Jaideep P.
NVIDIA

Shashank S.
LBL

Peter H.
LBL

Sanjeev R.
U Michigan

Ashesh C.
Rice U.

Morteza M.
NVIDIA

Thorsten K.
NVIDIA

David H.
NVIDIA

Zongyi L.
Caltech

Kamyar A.
Purdue

Pedram H.
Rice U.

Karthik K.
NVIDIA

Anima A.
NVIDIA / Caltech

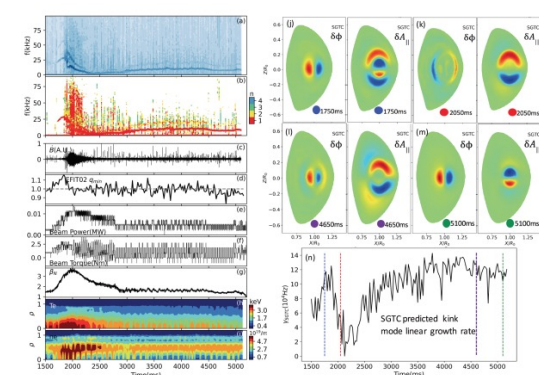Pathak et al. "FourCastNet: A Global Data-driven High-resolution Weather Model using Adaptive Fourier Neural Operators." *arXiv:2202.11214* (2022).

Dramatic rise in extreme weather events across the globe

Weather Hazards for Northern Hemisphere Summer 2021
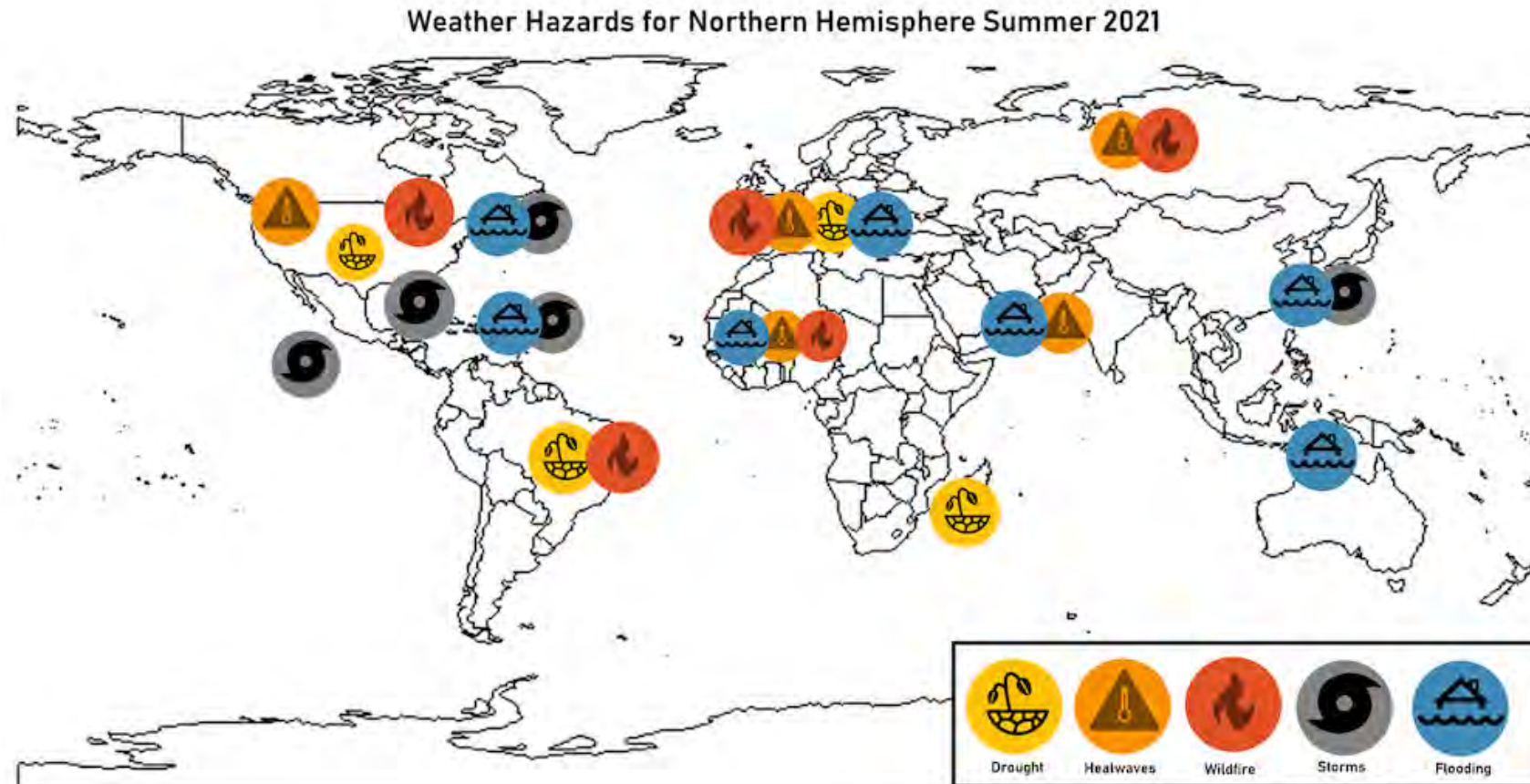
Climate science requires million-x speedups and is challenging

Figure adapted from: Schneider, T., Teixeira, J., Bretherton, C. *et al*. Climate goals and computing the future of clouds. *Nature Climate Change* 7, 3–5 (2017). https://doi.org/10.1038/nclimate3190

FourCastNet is a SOTA deep-learning based weather emulator

Scalable, data-driven global weather forecasting surrogate model

- Model complexity

  1 FourCastNet is a data-driven model and shows excellent skill on important variables

- Computational cost

  2 FourCastNet enables 40000x faster forecasting

- Scalability and performance

  3 FourCastNet scales to about 4000 GPUs enabling exascale weather/climate computing

Kurth et al. "FourCastNet: Accelerating Global High-resolution Weather Forecasting using Adaptive Fourier Neural Operators." *PASC 2023*.
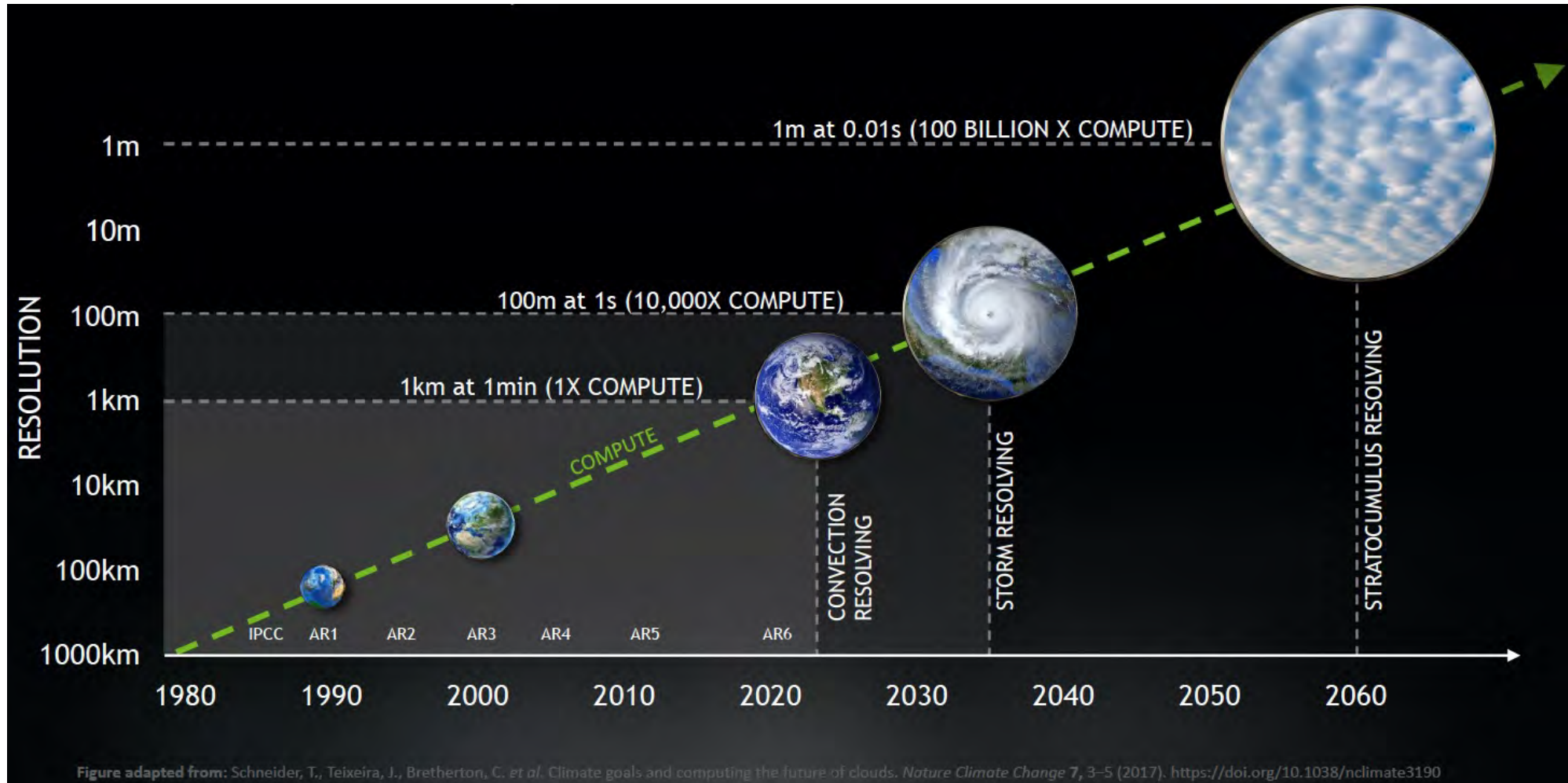
Pathak et al. "FourCastNet: A Global Data-driven High-resolution Weather Model using Adaptive Fourier Neural Operators." *arXiv:2202.11214* (2022).

# FourCastNet is trained on historical reanalysis data

◦ Training data from 40 years of reanalysis dataset = model + observations

◦ Best available estimate of the earth's atmospheric state (incorporates observations)

◦ 25km resolution
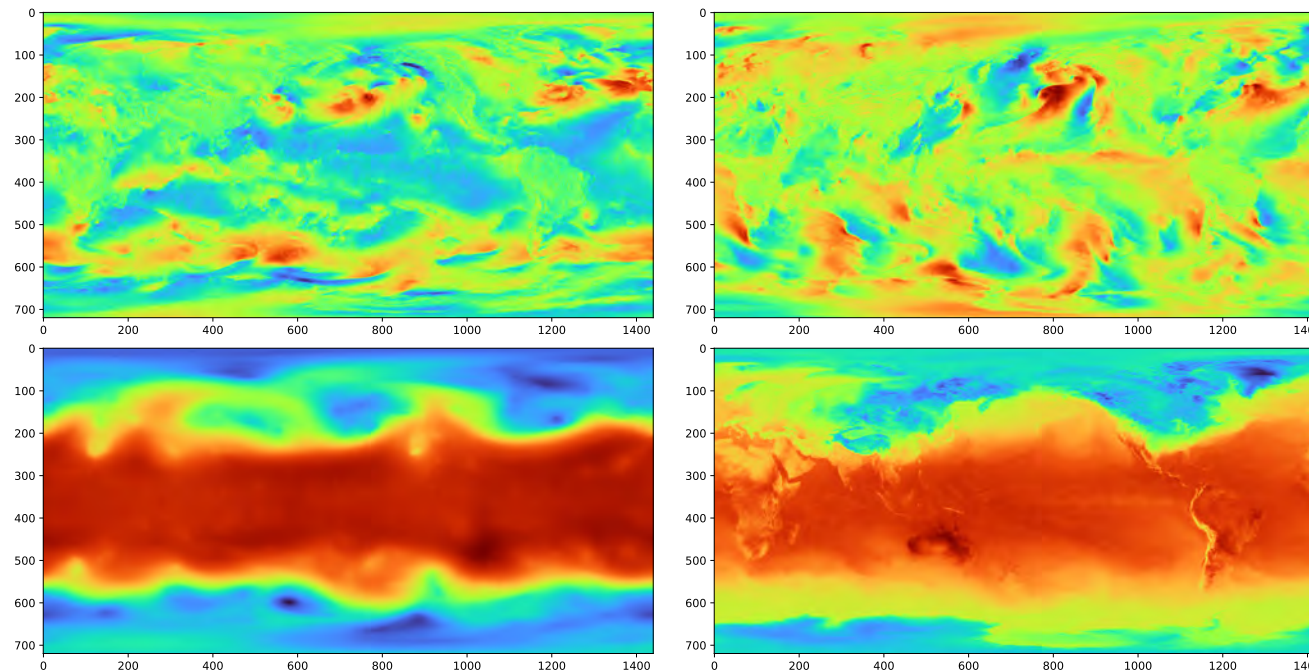
CV and PDE modeling ideas are merged into FourCastNet

- Vision Transformer (SOTA CV) backbone and Fourier Neural Operator (SOTA PDE surrogate) mixing
- Trained on full, high-resolution inputs
- Training on 1979 – 2015
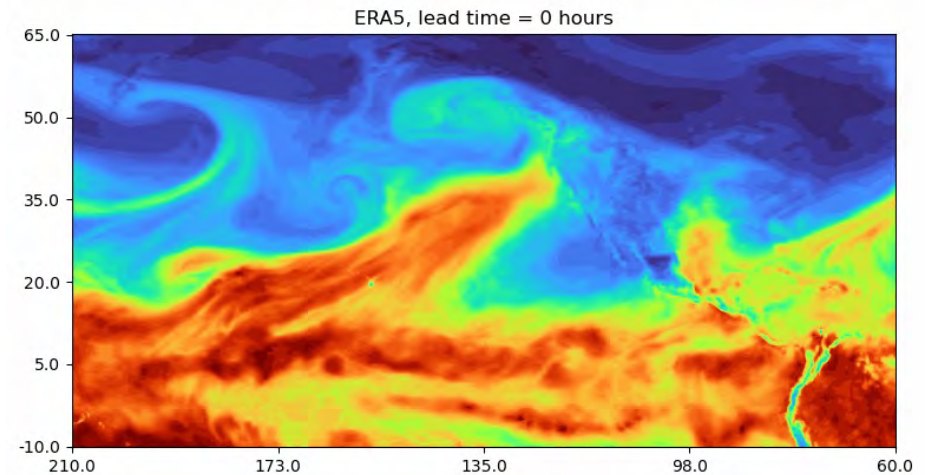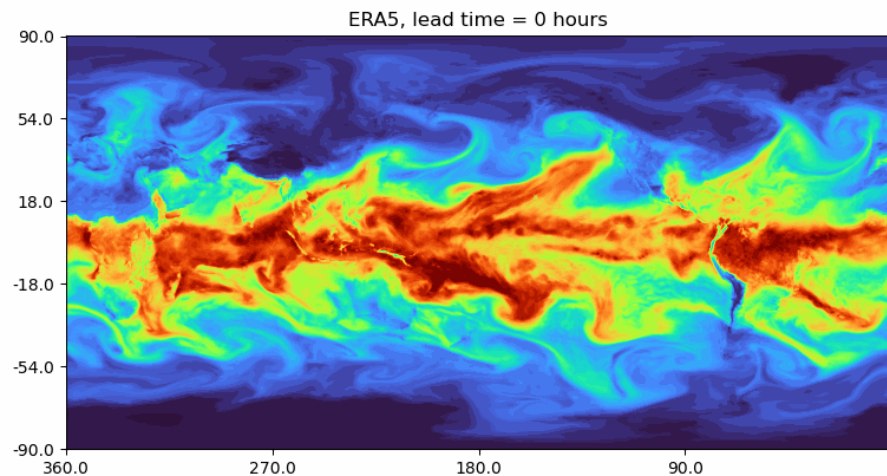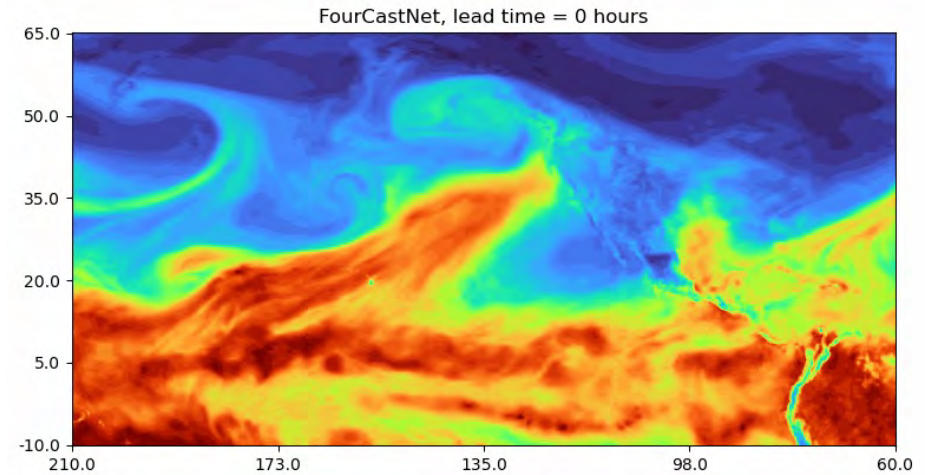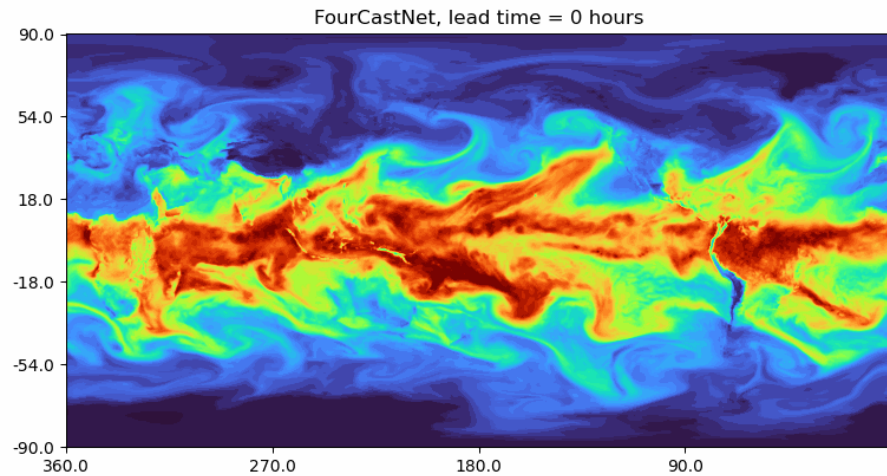- Testing on 2018+
- Total data size ~ 5TB
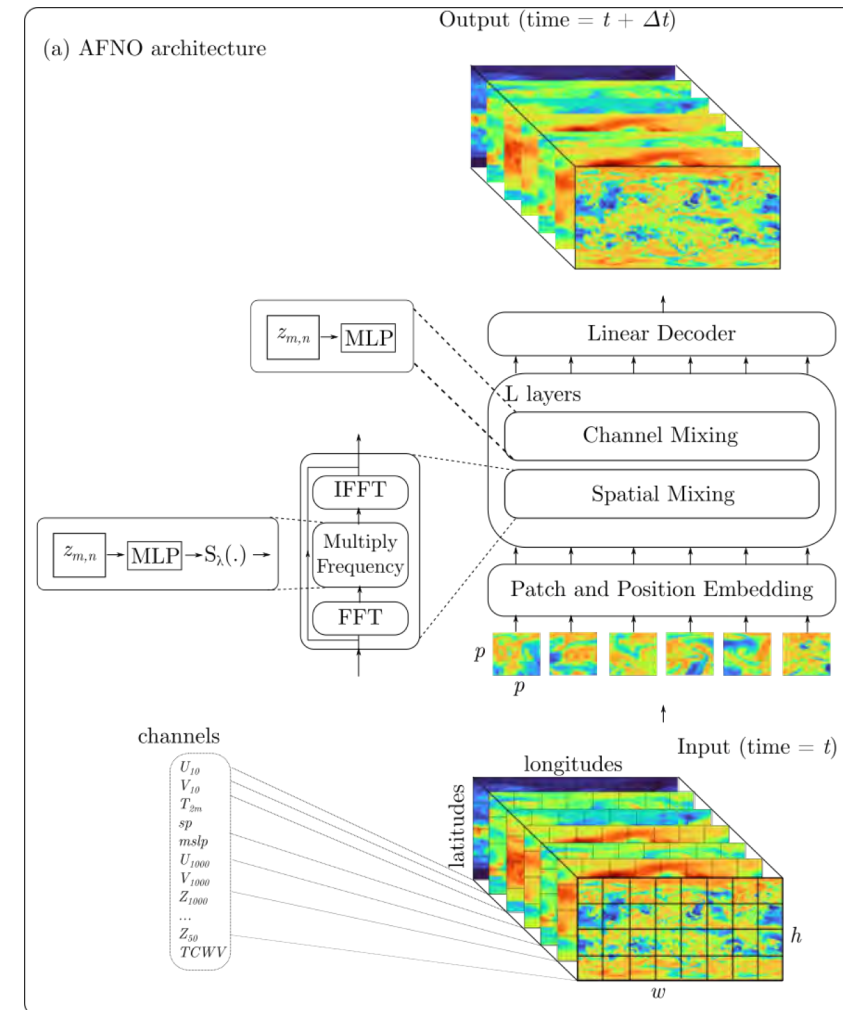
FourCastNet shows excellent skill in predicting many variables

◦ Quantitative metrics comparable to the NWP at high resolution
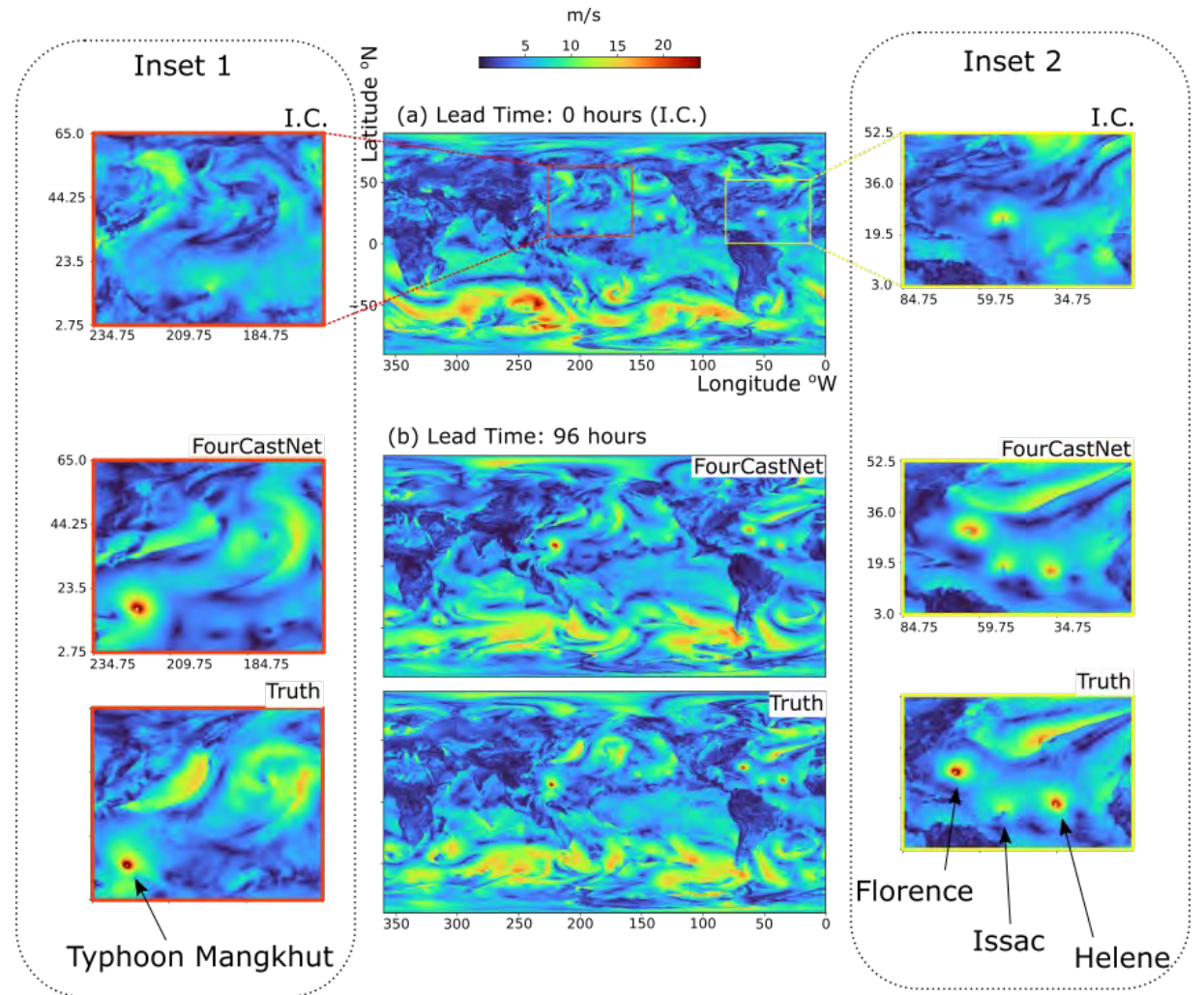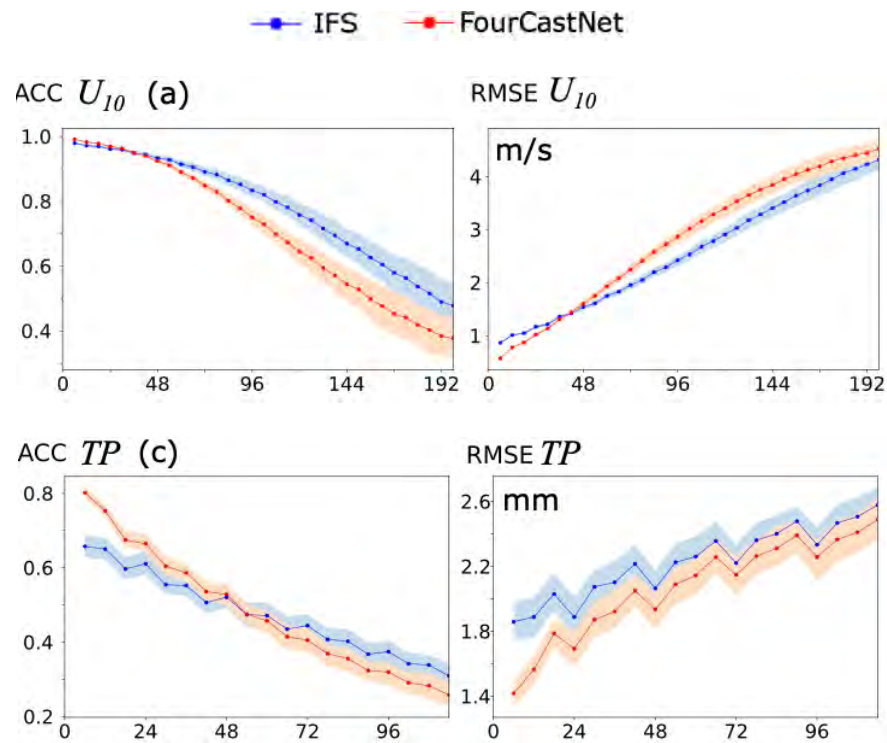
FourCastNet shows excellent skill in predicting many variables

Accuracies come with enormous computational advantage

Latency and Energy consumption for a 24-hour 100-member ensemble forecast				
	IFS	FCN - 30km (actual)	FCN - 18km (extrapolated)	IFS / FCN(18km) Ratio
Nodes required	3060	1	2	**1530**
Latency (Node-seconds)	984000	7	22	**44727**
Energy Consumed (kJ)	271000	7	22	**12318**

◦ 100 member ensemble forecast in 7 seconds with 7 kJ energy consumed

◦ 4 to 5 orders of magnitude speedup

◦ 4 orders of magnitude smaller energy footprint

FourCastNet is scalable and efficient
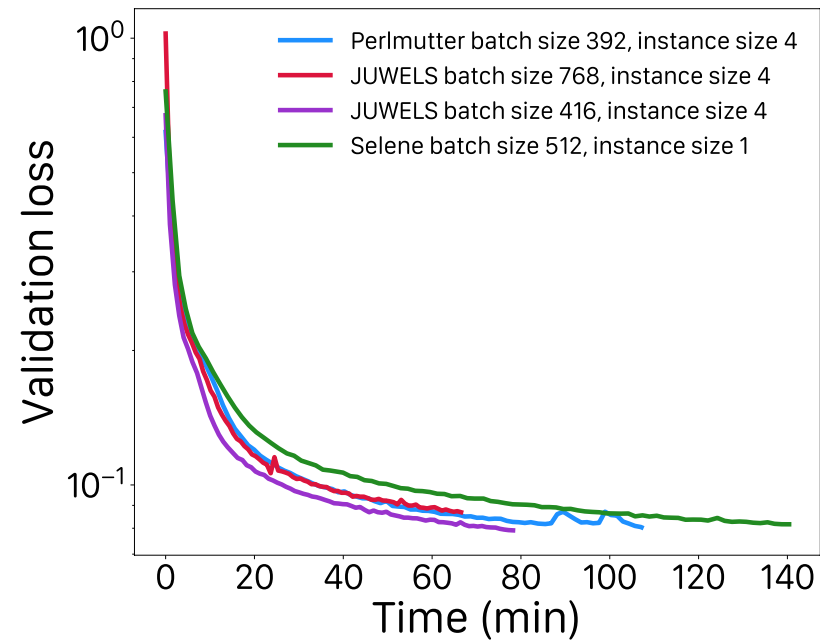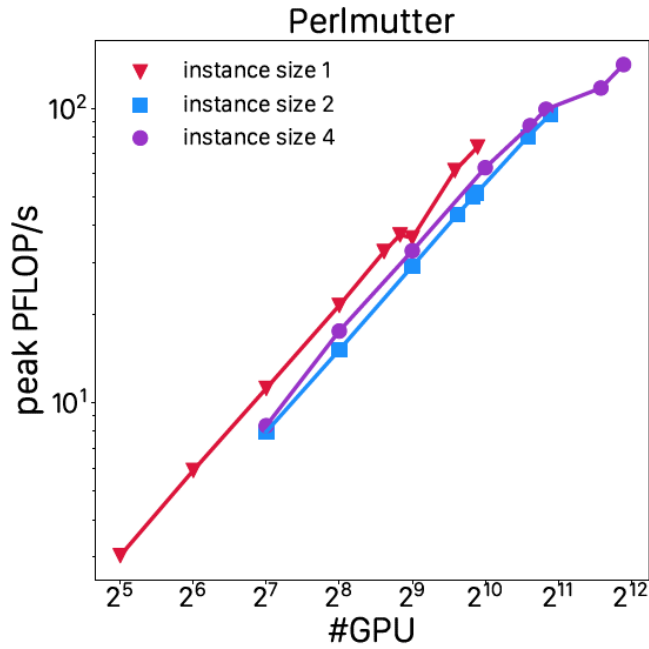
- Scalable training algorithms (model development), optimized software implementations (performance engineering)
- Training time in an hour with supercomputing resources

FourCastNet holds great promise towards DL weather models

◦ Model complexity

1 FourCastNet is a data-driven model and shows excellent skill on important variables

◦ Computational cost

2 FourCastNet enables 40000x faster inference and hence larger ensembles

◦ Scalability and performance

3 FourCastNet scales to about 4000 GPUs enabling exascale weather/climate computing

Scalable, data-driven global weather model surrogate enabling interactivity at scale

Kurth et al. "FourCastNet: Accelerating Global High-resolution Weather Forecasting using Adaptive Fourier Neural Operators." *PASC 2023*.

Pathak et al. "FourCastNet: A Global Data-driven High-resolution Weather Model using Adaptive Fourier Neural Operators." *arXiv:2202.11214* (2022).

Thank you

Ground Truth
FourCastNet
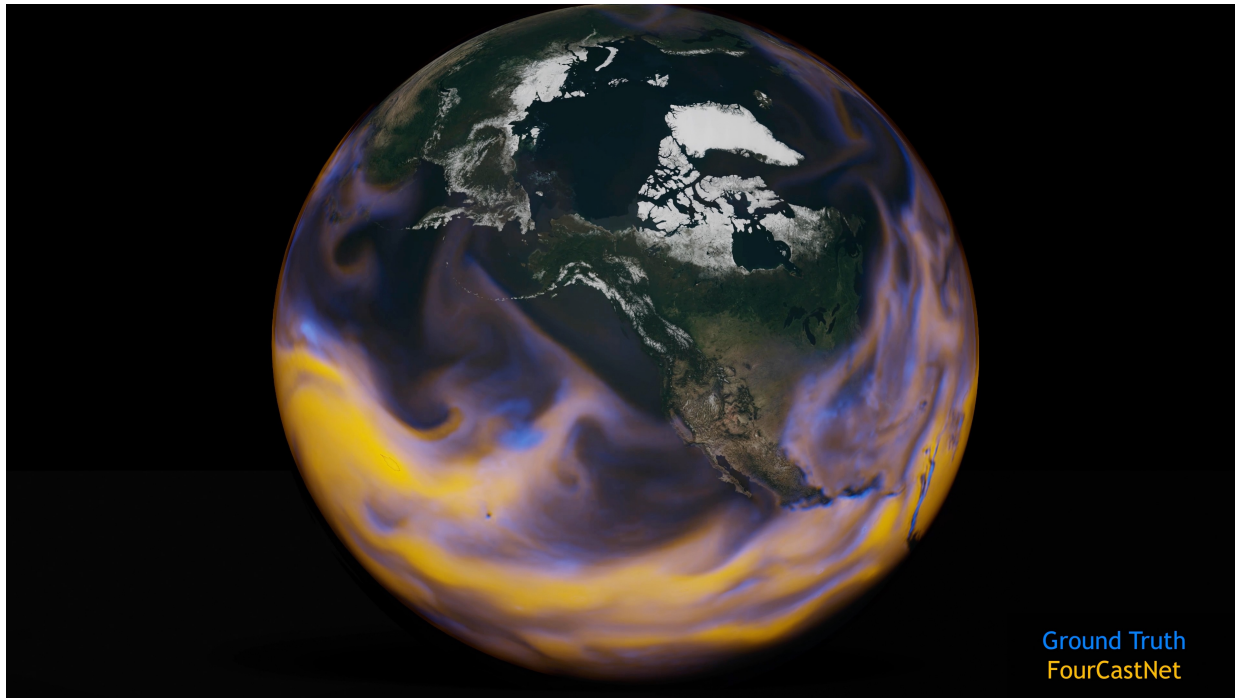
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