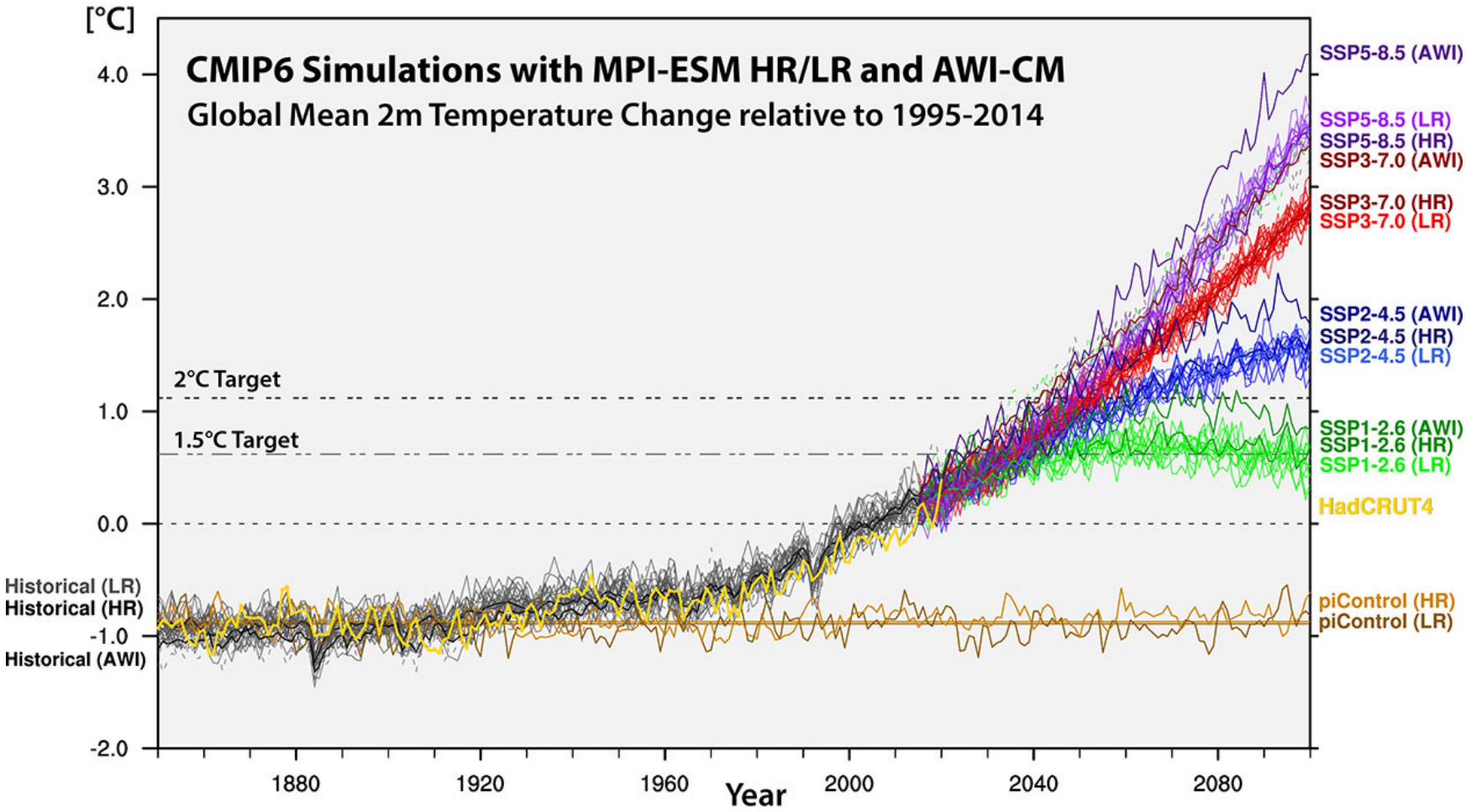
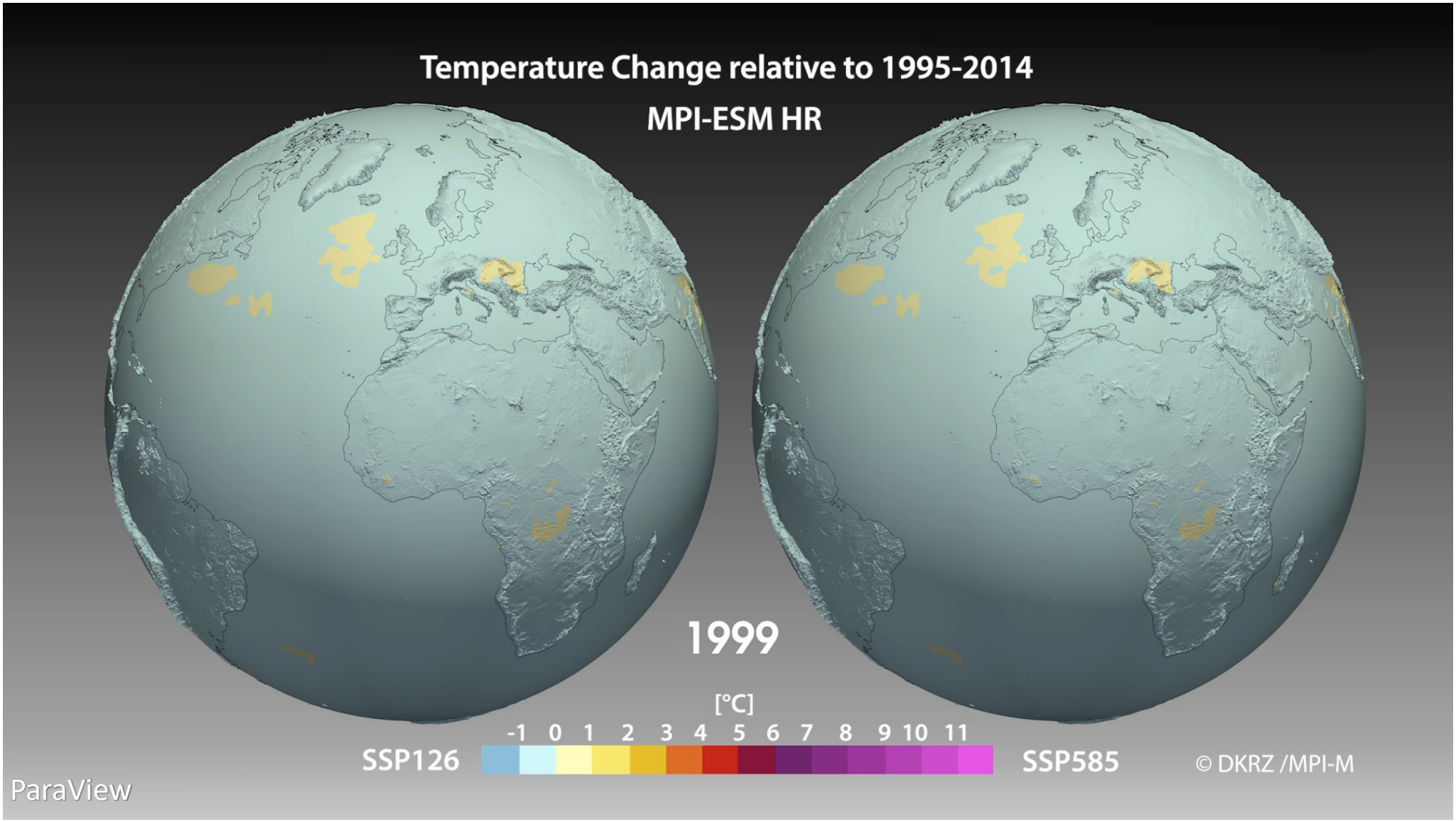

NVIDIA
VISUALIZATION WITH AI MODEL - OMNIVERSE

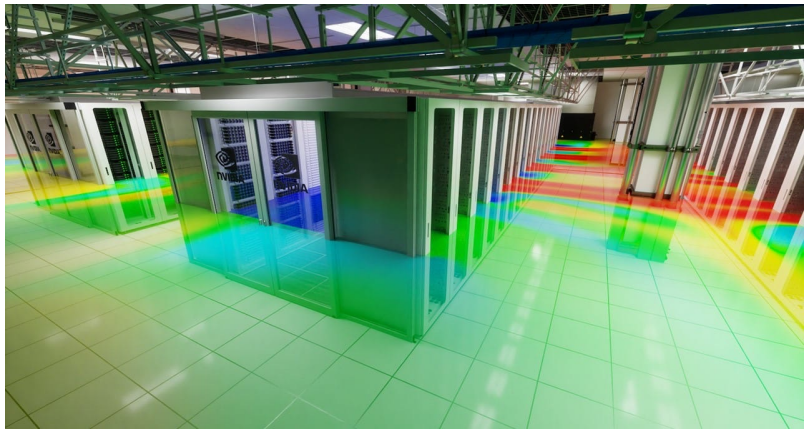

[°C]
CMIP6 Simulations with MPI-ESM HR/LR and AWI-CM
Global Mean 2m Temperature Change relative to 1995-2014
4.0
3.0
2.0
1.0
0.0
-1.0
-2.0
2°C Target
1.5°C Target
Historical (LR)
Historical (HR)
Historical (AWI)
1880
1920
1960
2000
2040
2080
Year
SSP5-8.5 (AWI)
SSP5-8.5 (LR)
SSP5-8.5 (HR)
SSP3-7.0 (AWI)
SSP3-7.0 (HR)
SSP3-7.0 (LR)
SSP2-4.5 (AWI)
SSP2-4.5 (HR)
SSP2-4.5 (LR)
SSP1-2.6 (AWI)
SSP1-2.6 (HR)
SSP1-2.6 (LR)
HadCRUT4
piControl (HR)
piControl (LR)

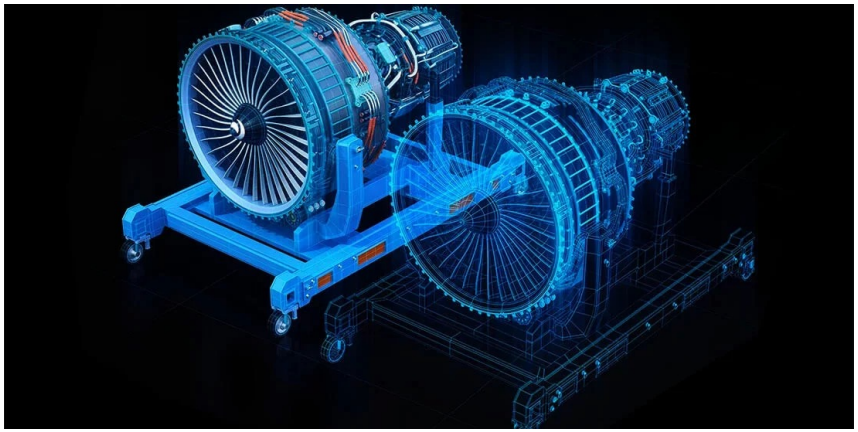

Temperature Change relative to 1995-2014
MPI-ESM HR
1999
[°C]
-1 0 1 2 3 4 5 6 7 8 9 10 11
SSP126
SSP585
© DKRZ /MPI-M
ParaView

NVIDIA MODULUS

One Step Closer to Real-time Digital Twin

From physics-informed neural networks (PINNs) to neural operators, developers have long sought after the ability to build real-time digital twins with true-to-form rendering, robust visualizations, and synchronization with the physical system in the real world by streaming live sensor data. The latest release of Modulus brings us closer to this reality.





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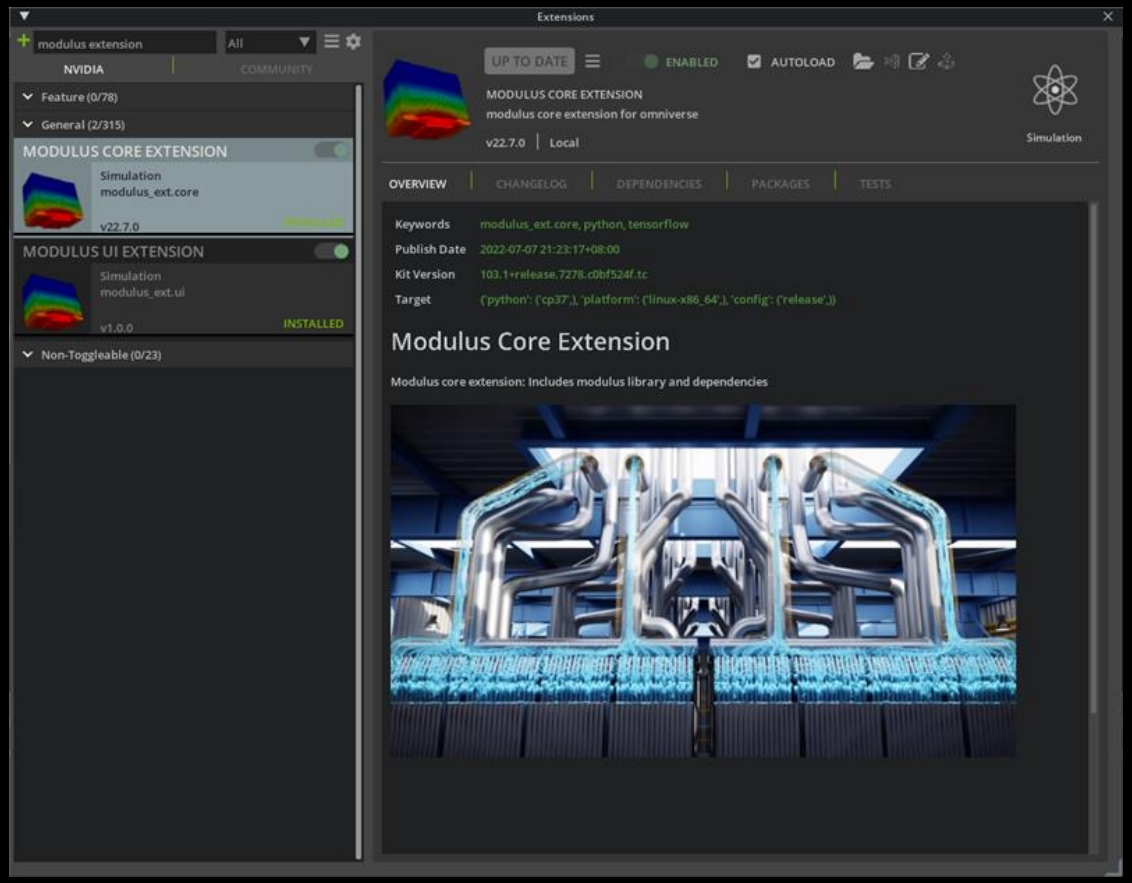
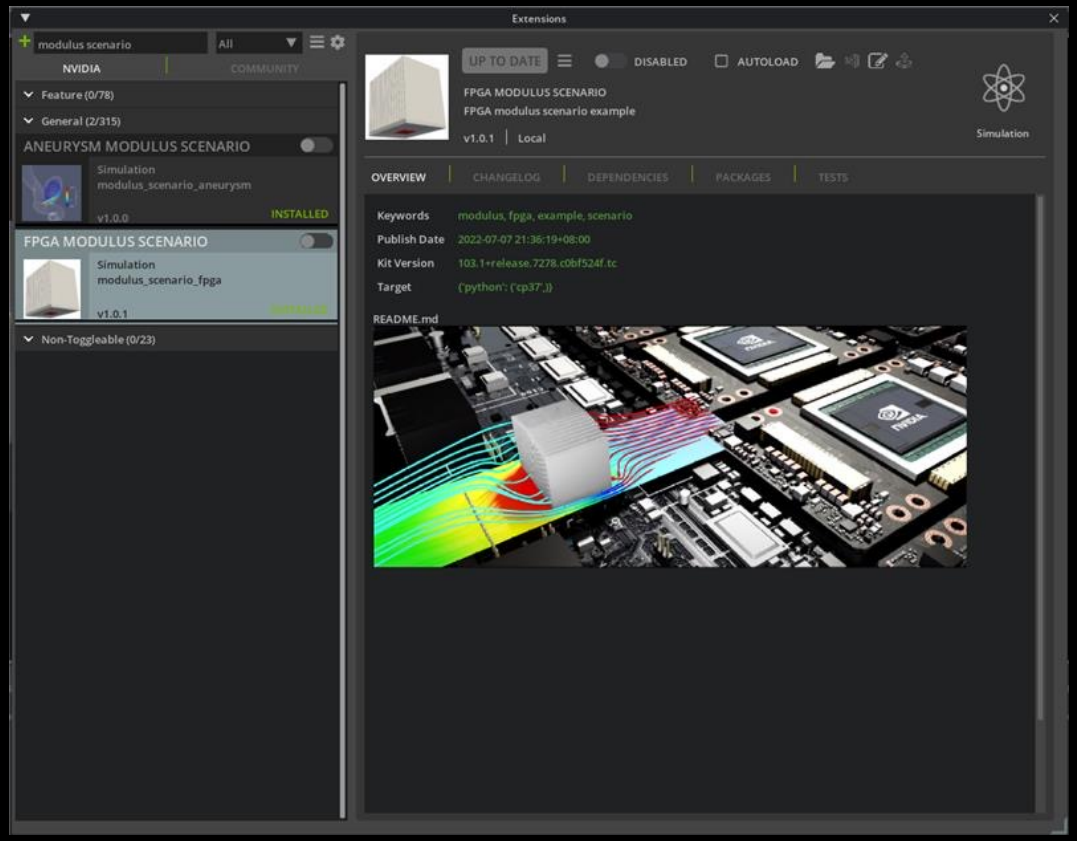
MODULUS WITH OMNIVERSE



Recent release has included Modulus Extension

- Utilizes vtkm_bridge to import vtk data into USD format
- Works well with PINNs results
- Particularly interesting for parameterized problem where we can visualize the results with different parameters

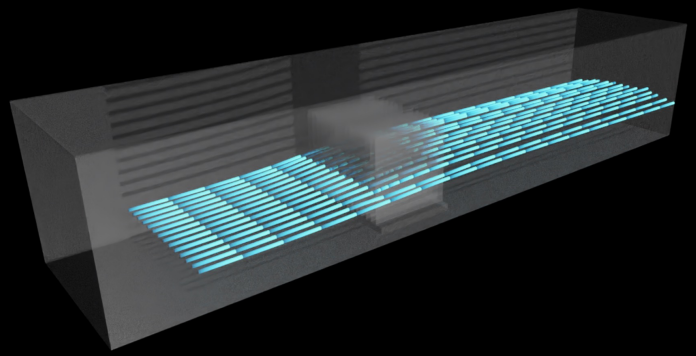
MODULUS WITH OMNIVERSE

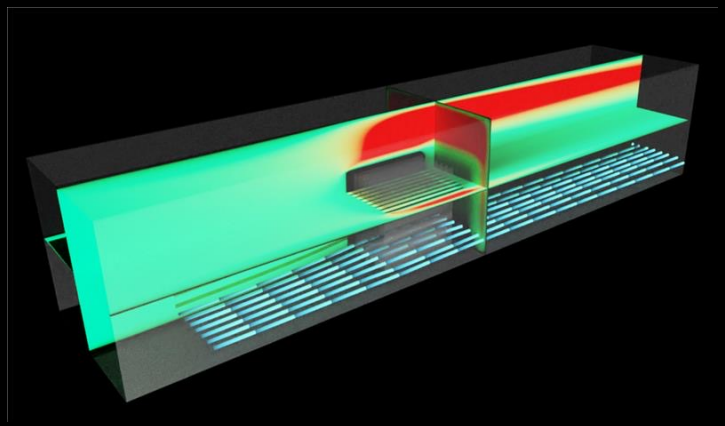


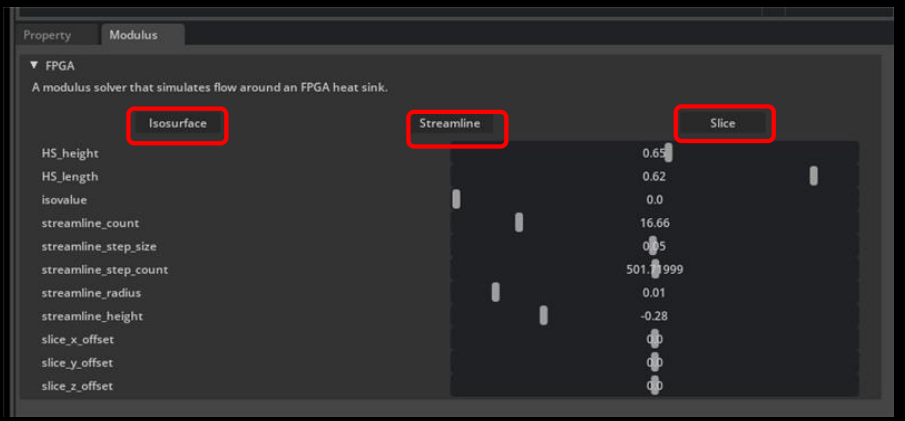
Recent release has included Modulus Extension

- Two modulus trained scenario are included
- One is FPGA heat sink parametrized design
- The other is the aneurysm scenario

MODULUS WITH OMNIVERSE



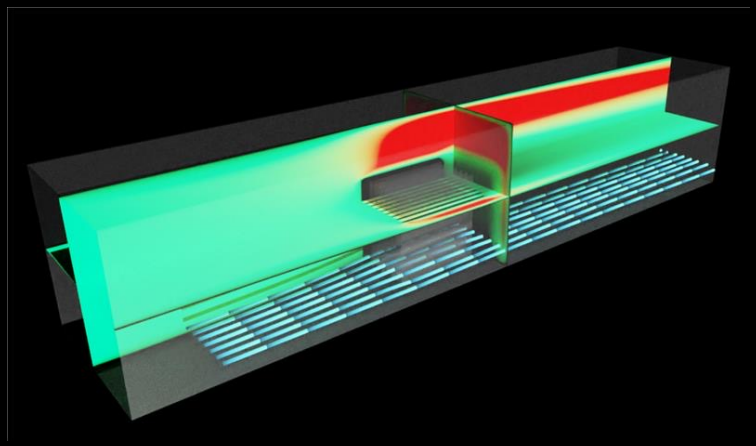


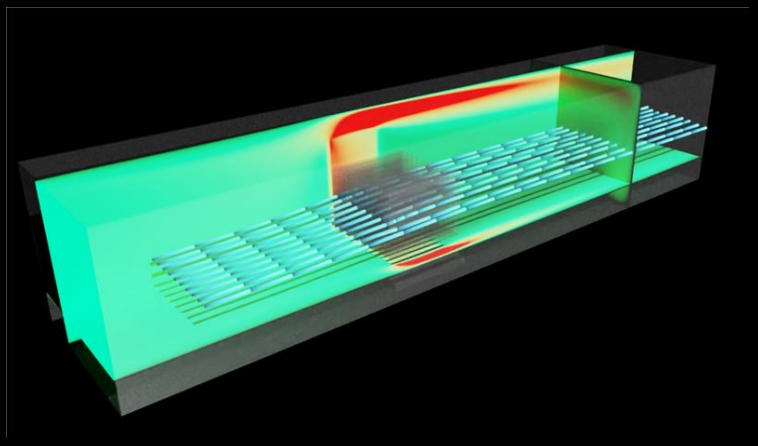


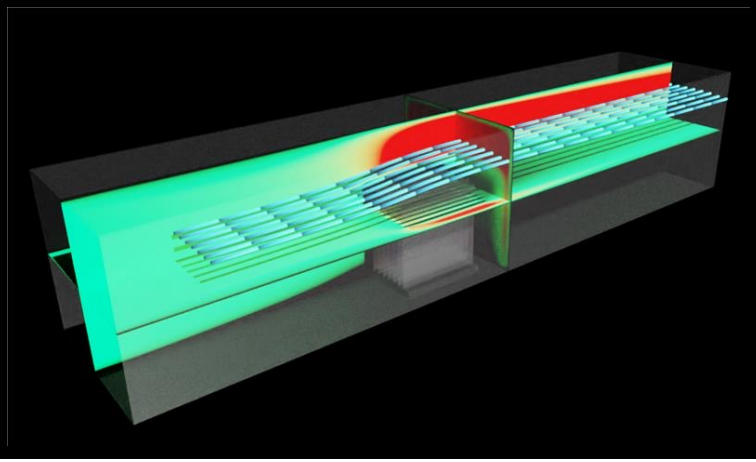
Recent release has included Modulus Extension

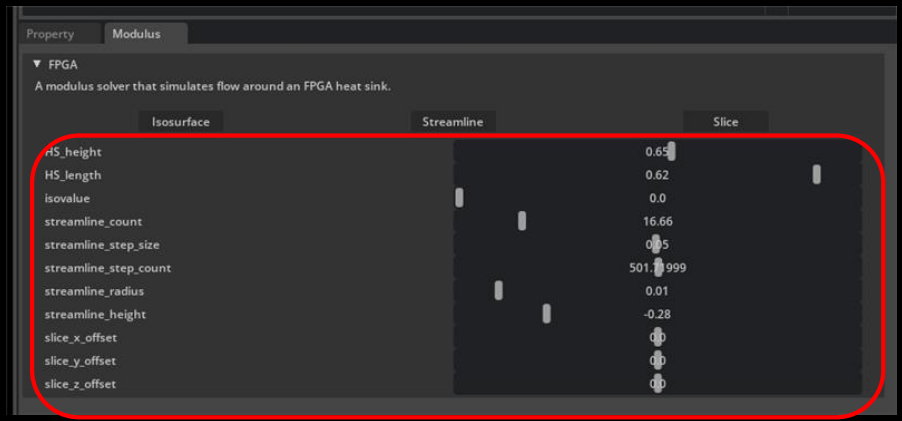
- Options to include isosurface, streamlines and slices

MODULUS WITH OMNIVERSE

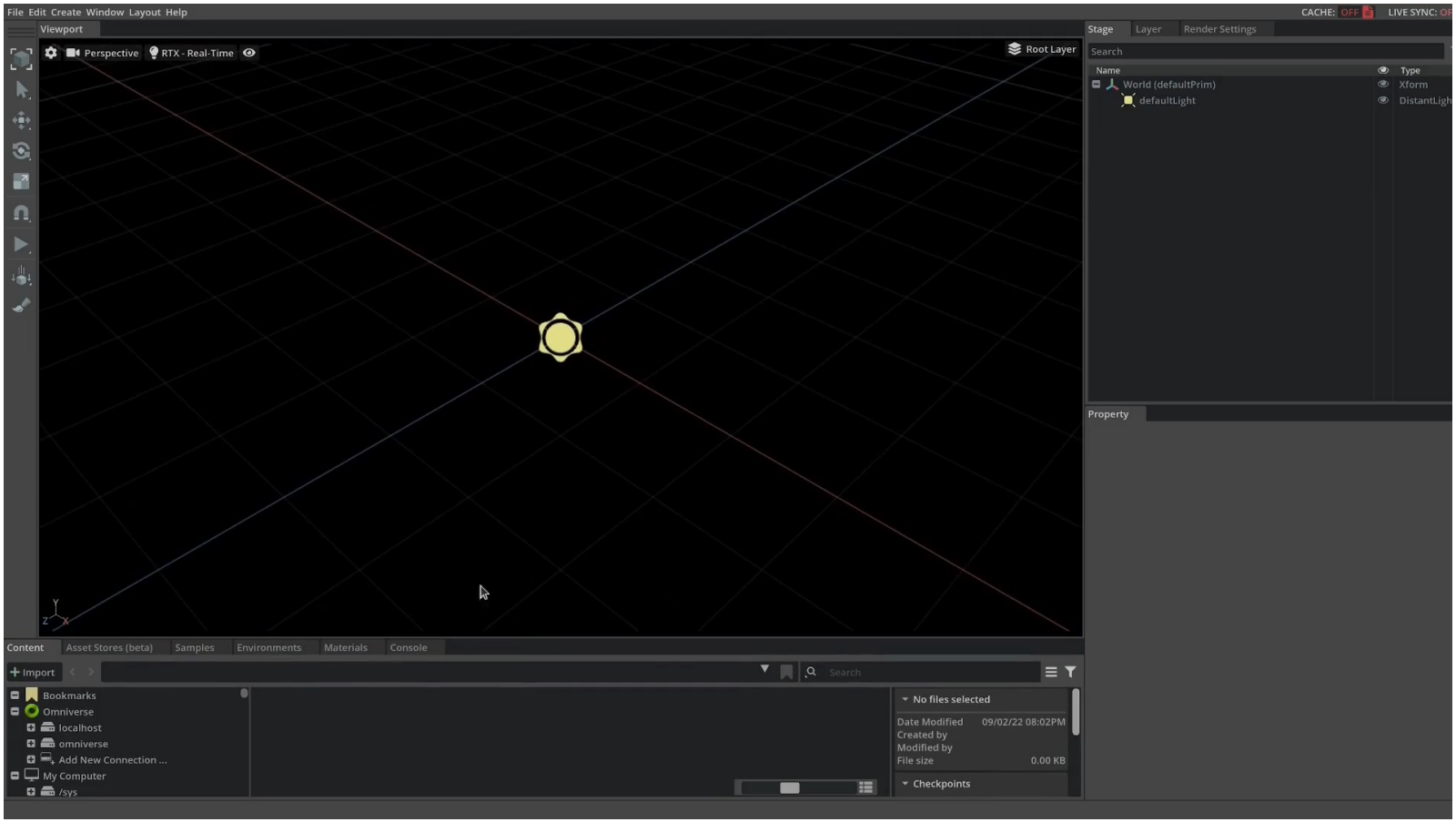








VISUALIZING WITH FOURCASTNET OUTPUT



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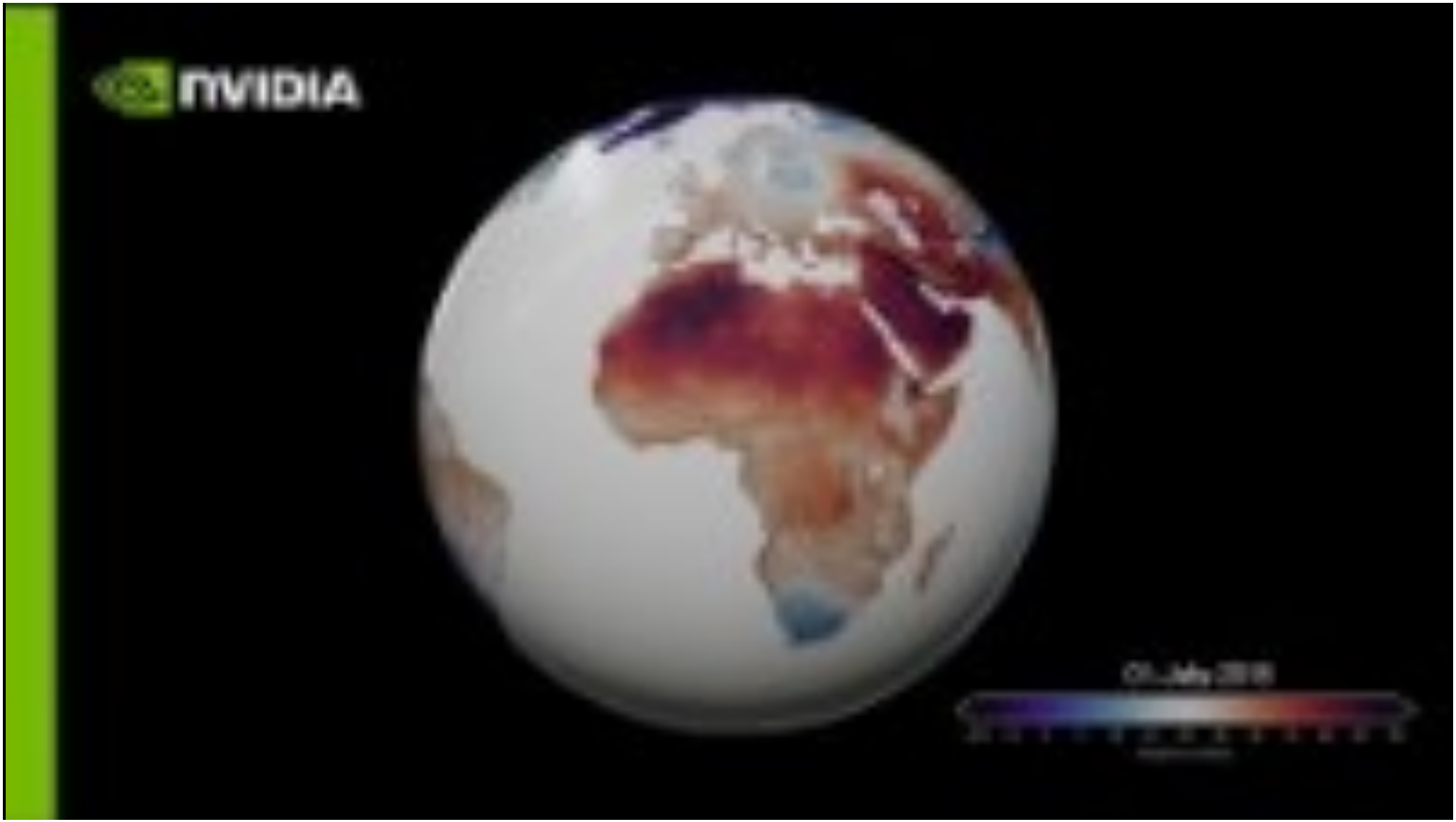
NVIDIA EARTH-2: DIGITAL TWIN OF EARTH WITH AI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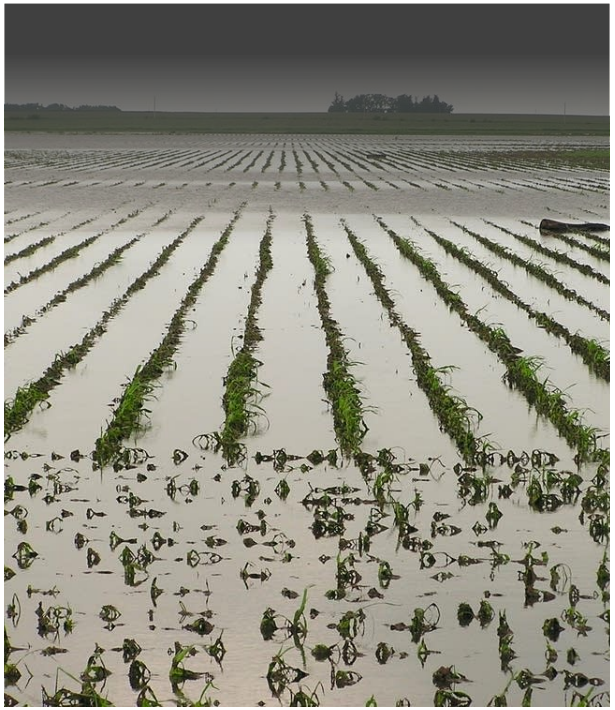
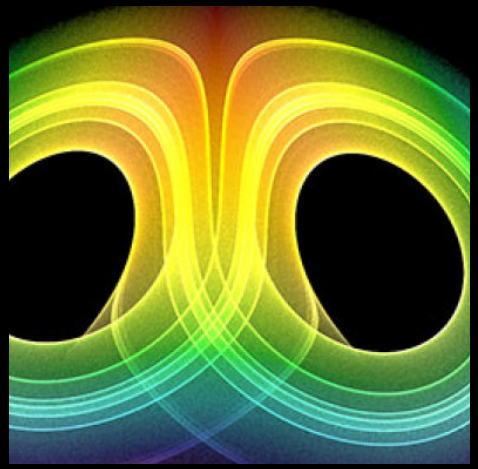
THE FUTURE UNDER CLIMATE CHANGE WILL BE HARSH

We urgently need better tools to prepare for it

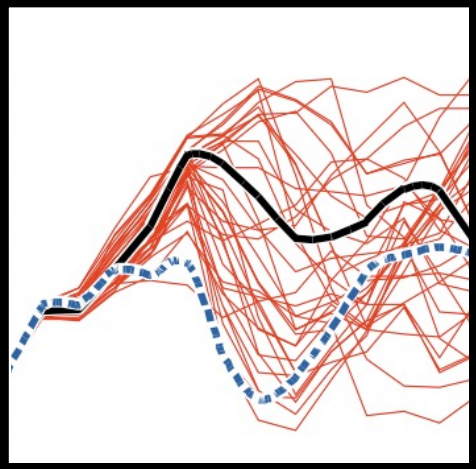


CHALLENGES

Why is it so difficult to predict the weather?



CHAOS
Sensitivity to initial conditions. Small difference grow rapidly over time.



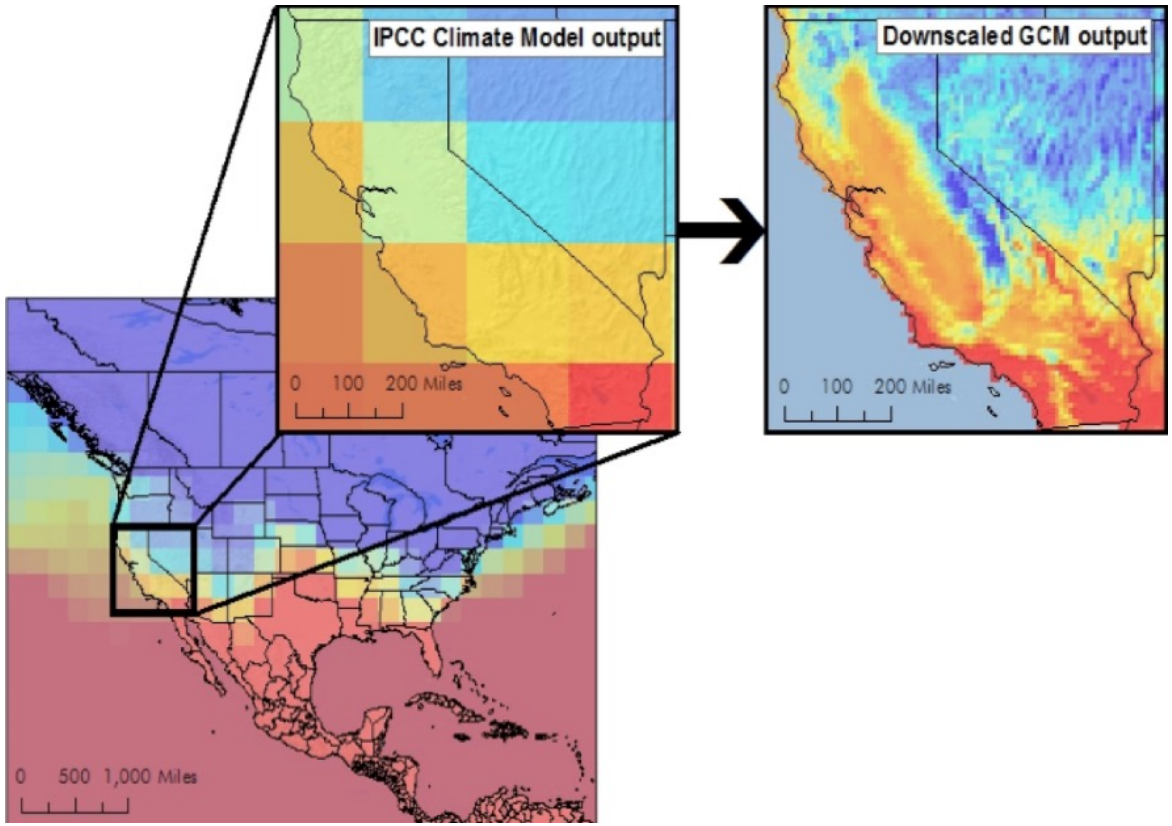
INCOMPLETE OBSERVATIONS
Can't determine the initial conditions exactly. Need to minimize the error.

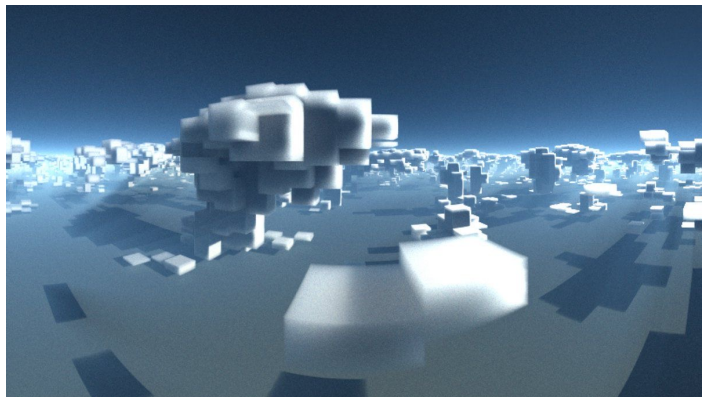
SHORT TIME-TO-SOLUTION
Time between observations and prediction must be small in order to accurately represent the system.

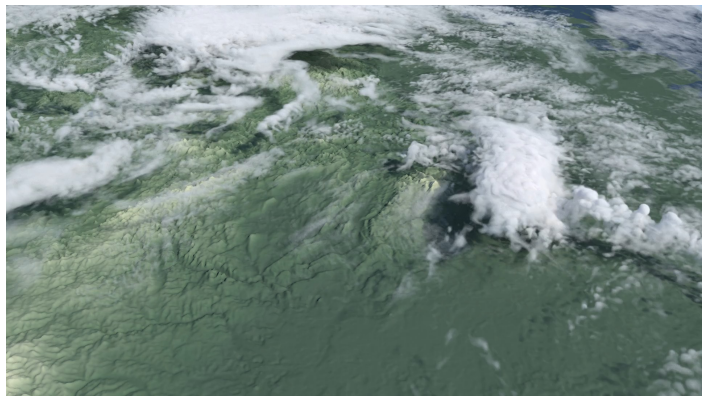
FINITE RESOURCES
Never enough compute to represent the full system or to assimilate all possible data sources.

Today's Climate Predictions are too Low Resolution

Detailed Plans require Detailed Information and Predictions with Credible Cloud Feedbacks







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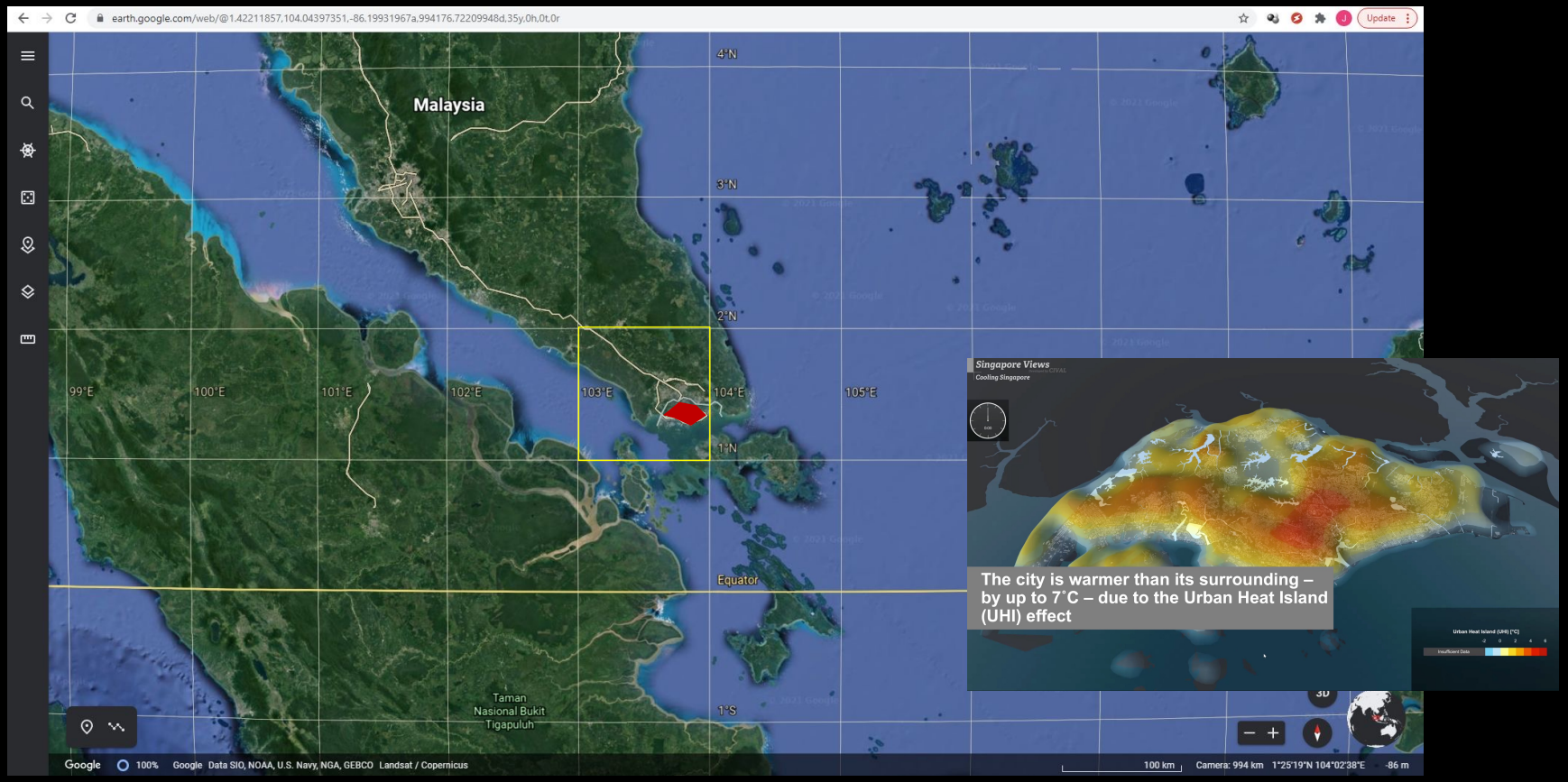
CLIMATE SCIENCE REQUIRES MILLION-X SPEEDUPS

Computational constraints limit model resolution



CLIMATE SCIENCE REQUIRES MILLION-X SPEEDUPS

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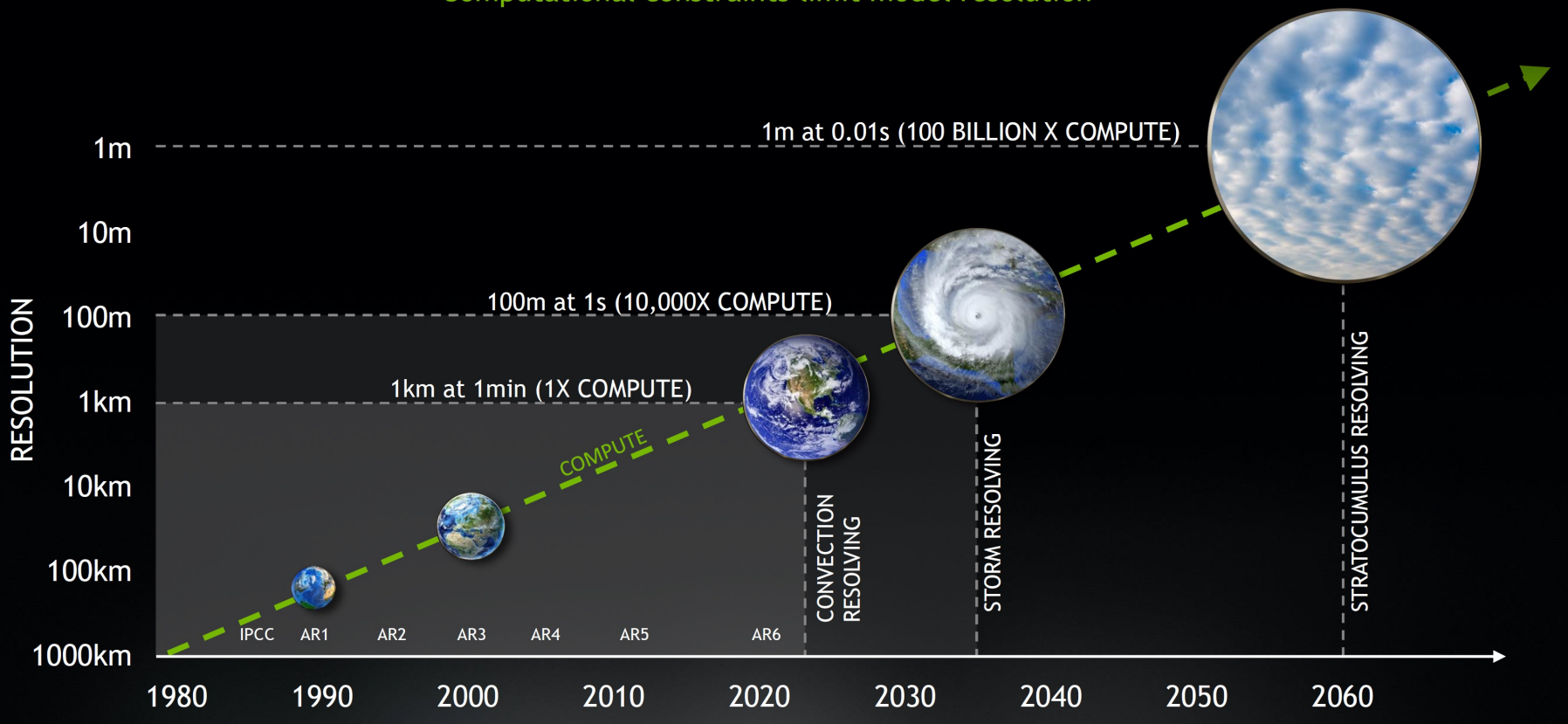


Figure adapted from: Schneider, T., Teixeira, J., Bretherton, C. *et al.* Climate goals and computing the future of clouds. *Nature Climate Change* **7,** 3–5 (2017). https://doi.org/10.1038/nclimate3190

NVIDIA.

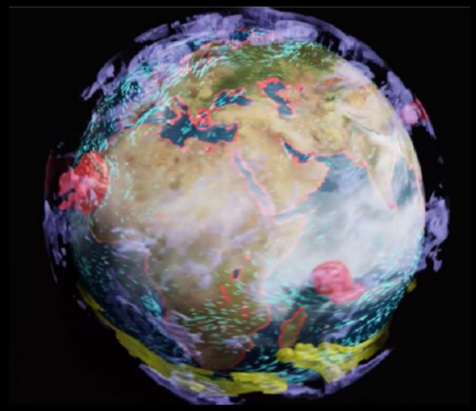
NVIDIA EARTH-2 ANNOUNCEMENT – GTC NOV 2021

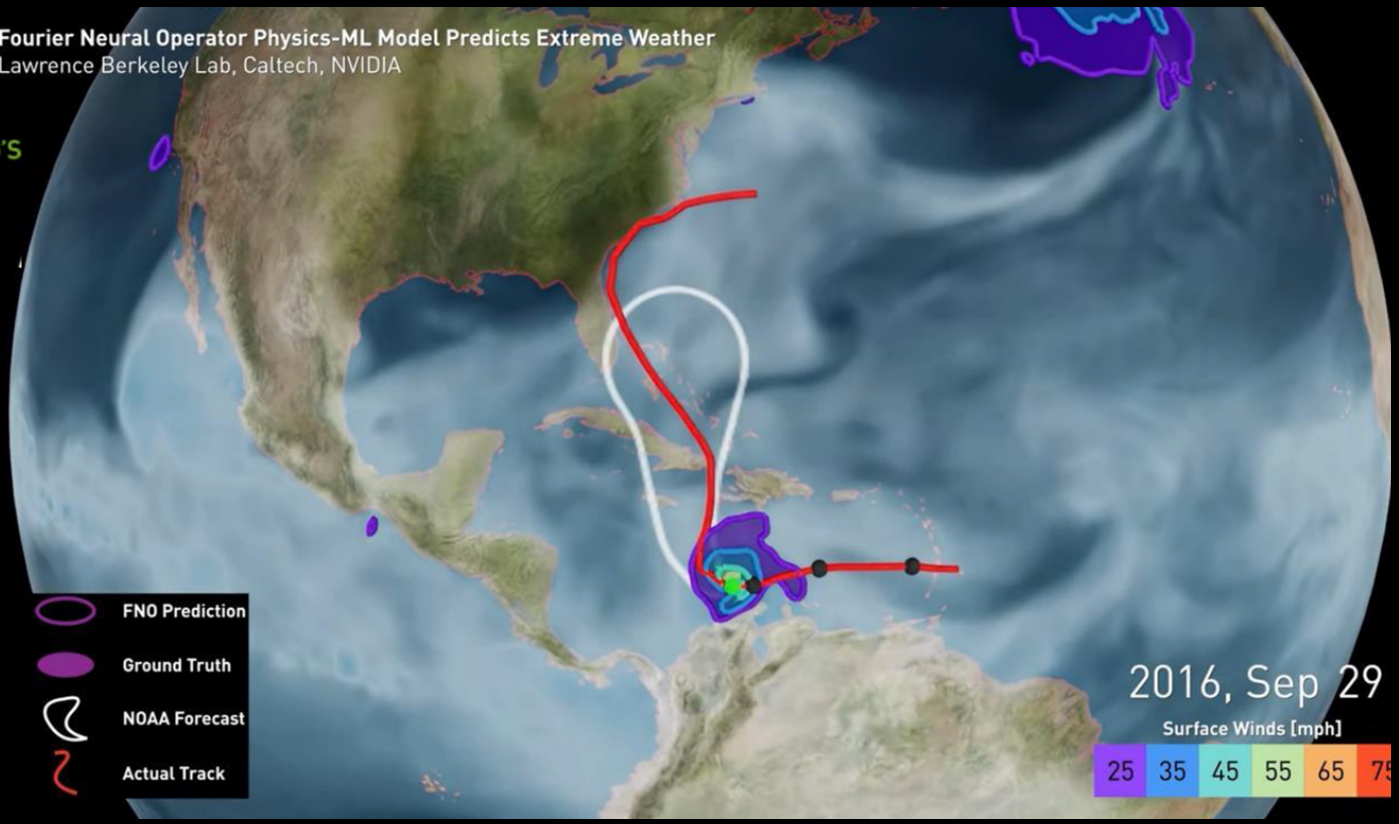
WHAT WILL JENSEN HUANG'S KEYNOTE REVEAL?

November 9, 2021 | 9:00 a.m. (CET)

SAVE THE DATE >

Omniverse

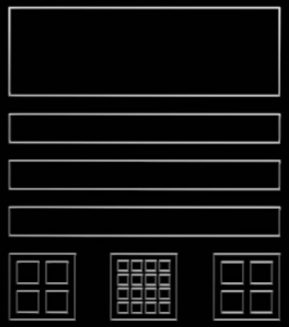




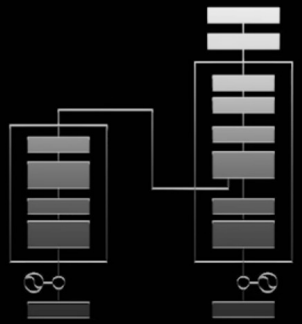
November 12, 2021 by JENSON HUANG https://blogs.nvidia.com/blog/2021/11/12/earth-2-supercomputer/

THREE MIRACLES FOR DIGITAL TWIN EARTH 2

NVIDIA
ACCELERATED COMPUTING

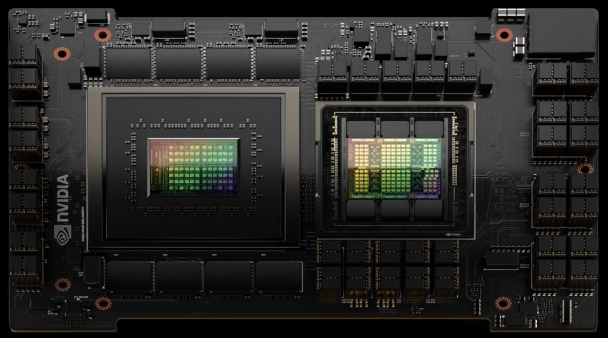


MODULUS PHYSICS-ML
FOURCASTNET



OMNIVERSE
DIGITAL TWINS

NVIDIA GH200
THE MOST ADVACNED ACCELERATED COMPUTING PLATFORM



Grace CPU + H100 GPU

72 Arm Neoverse V2 Cores with SVE2 4x128b

Transformer Engine and ~4PFLOPS of FP8

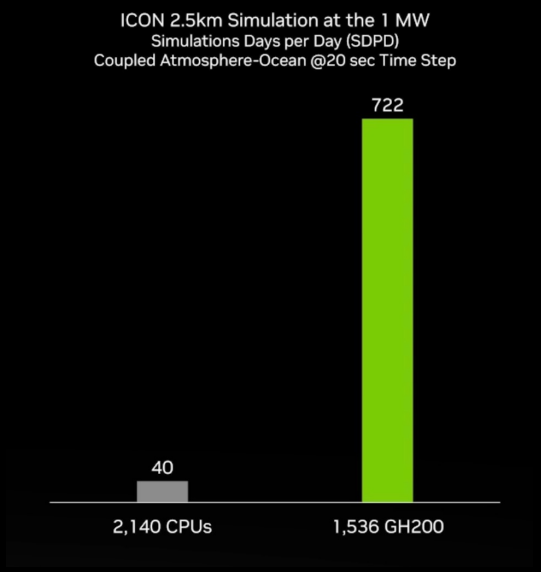
Fast NVLink-C2C Connection

900GB/s bi-directional bandwidth CPU to GPU

7X faster than PCIe Gen 5

Full NVIDIA Compute Stack

HPC, AI, Omniverse

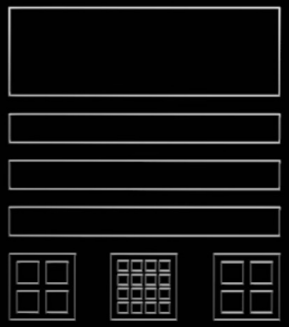


256 Grace Hopper Superchips | **144TB** unified fast memory

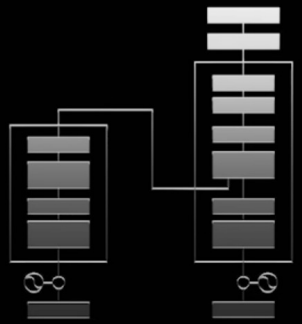
36 L2 NVLink switches | **900 GB/s** GPU-to-GPU bandwidth | **128 TB/s** bisection bandwidth

THREE MIRACLES FOR DIGITAL TWIN EARTH 2

NVIDIA
ACCELERATED COMPUTING



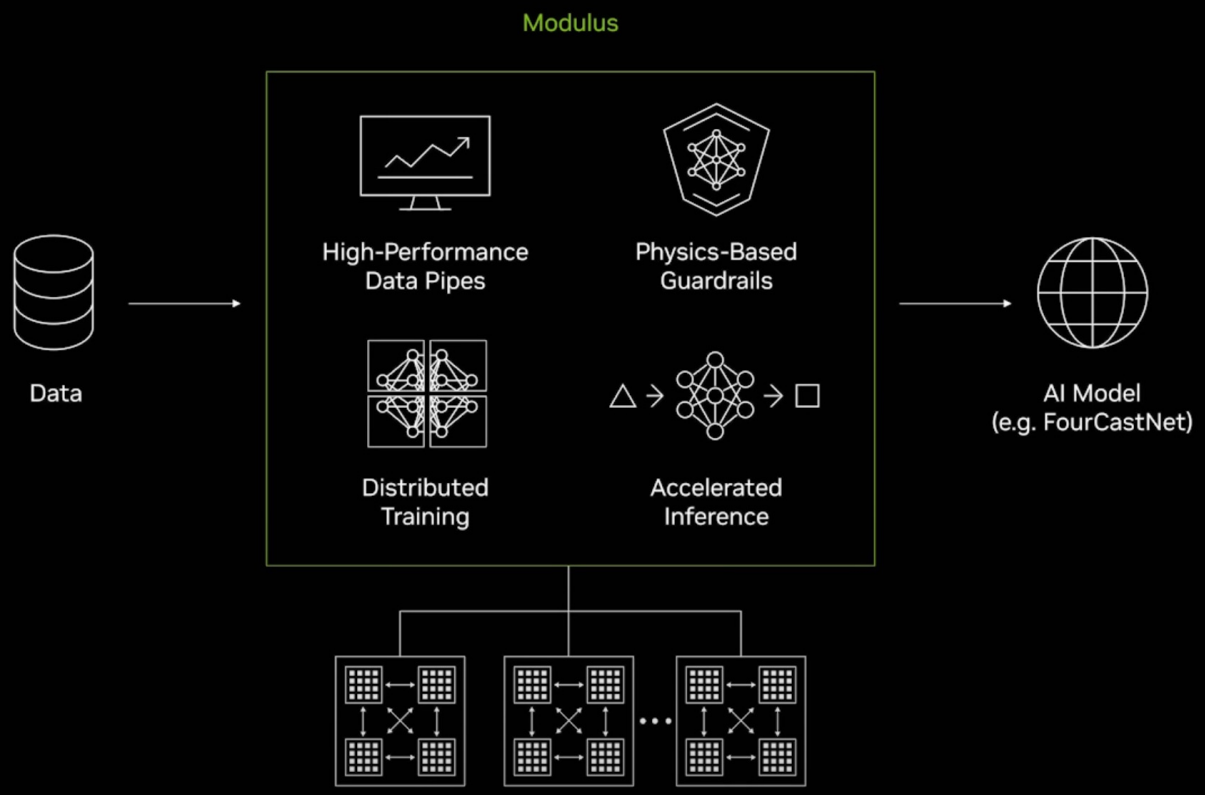
MODULUS PHYSICS-ML
FOURCASTNET

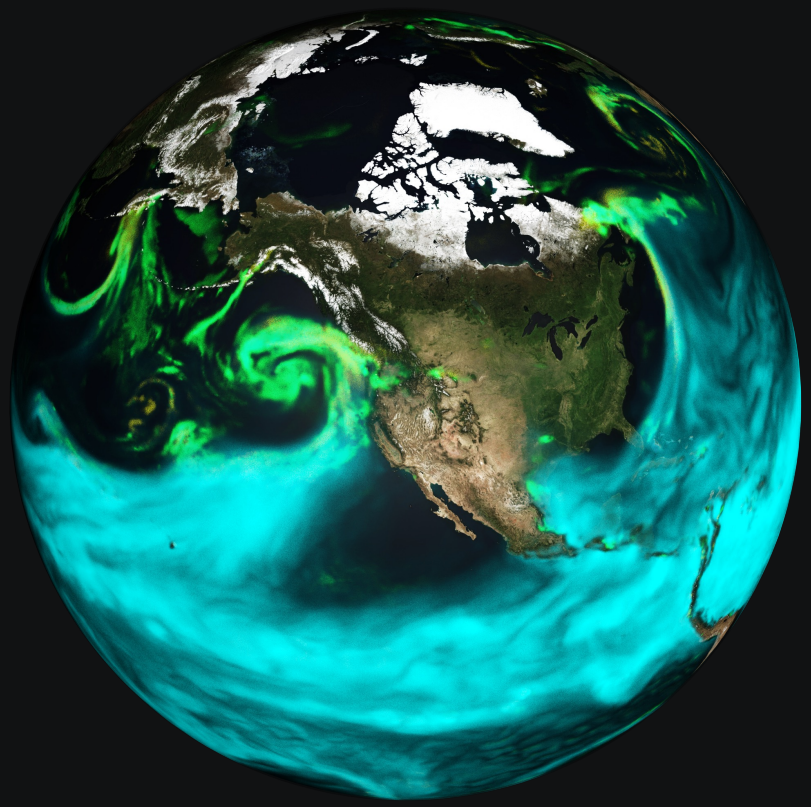


OMNIVERSE
DIGITAL TWINS

NVIDIA MODULUS

Open-Source, Physics-ML Platform and Earth-2 ML Framework





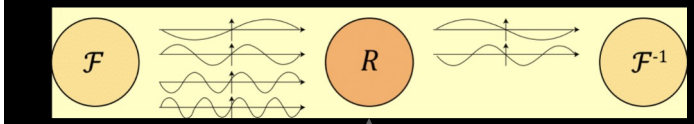
Earth-2 Began by Exploring Data-Driven Weather Prediction

FourCastNet

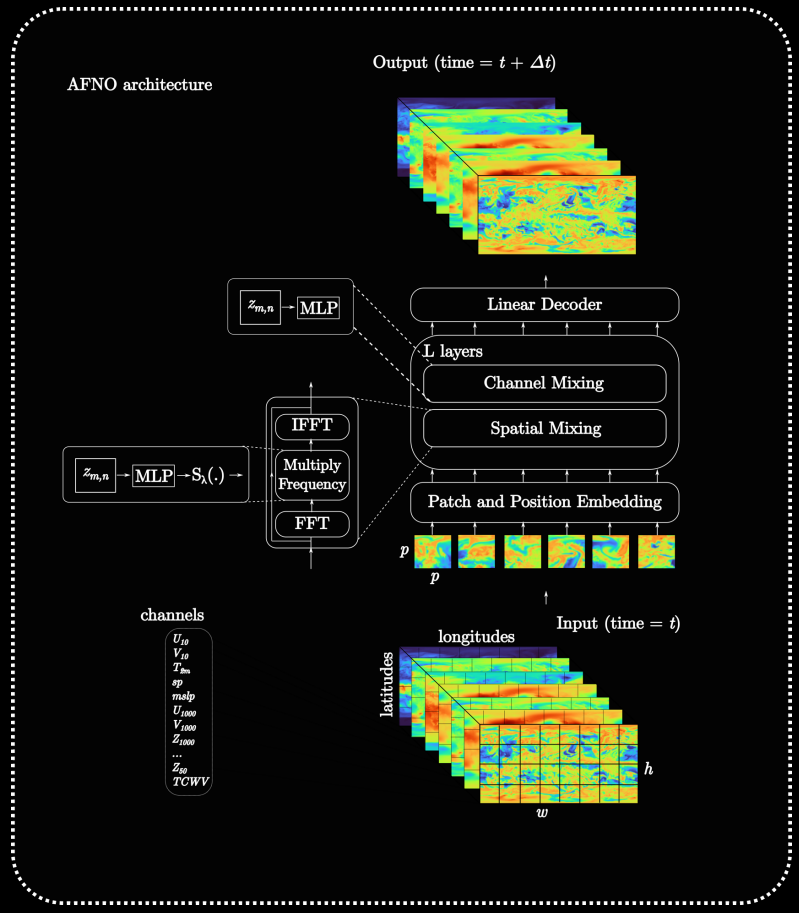
• Scope	Global, Medium Range
• Model Type	Full-Model AI Surrogate
• Architecture	AFNO (Adaptive Fourier Neural Op.)
• Resolution:	25km
• Training Data:	ERA5 Reanalysis
• Initial Condition	GFS / UFS
• Inference Time	0.25 sec (2-week forecast)
• Speedup vs NWP	$O(10^4\text{-}10^5)$
• Power Savings	$O(10^4)$

FourCastNet (FCN) uses a novel transformer architecture

With Fourier Neural Operator Blocks - in search of grid-free, high-resolution, machine-learnt simulations.



Input: Coefficient Function → Convolution Operator → Non-linearity → • • → Output: Solution Function



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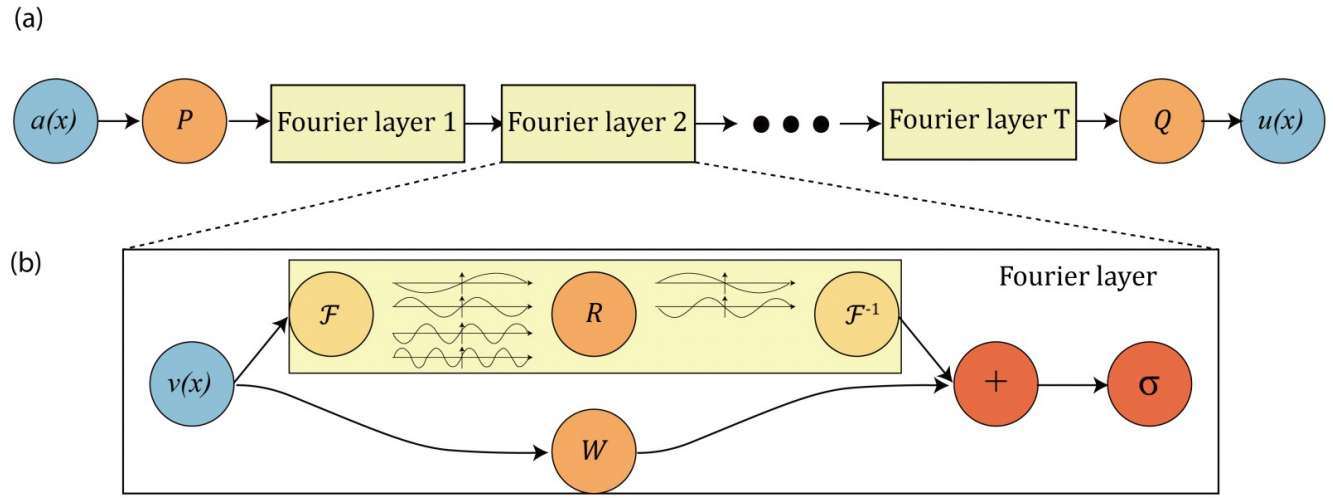
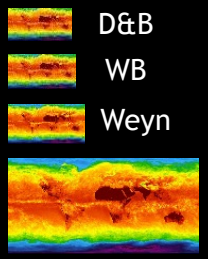


(a) The full architecture of neural operator: start from input a. 1. Lift to a higher dimension channel space by a neural network P. 2. Apply four layers of integral operators and activation functions. 3. Project back to the target dimension by a neural network Q. Output u. **(b) Fourier layers**: Start from input v. On top: apply the Fourier transform $\mathcal{F}$; a linear transform R on the lower Fourier modes and filters out the higher modes; then apply the inverse Fourier transform $\mathcal{F}^{-1}$. On the bottom: apply a local linear transform W.

Figure 2: **top:** The architecture of the neural operators; **bottom:** Fourier layer.

UNPRECEDENTED DATA RESOLUTION



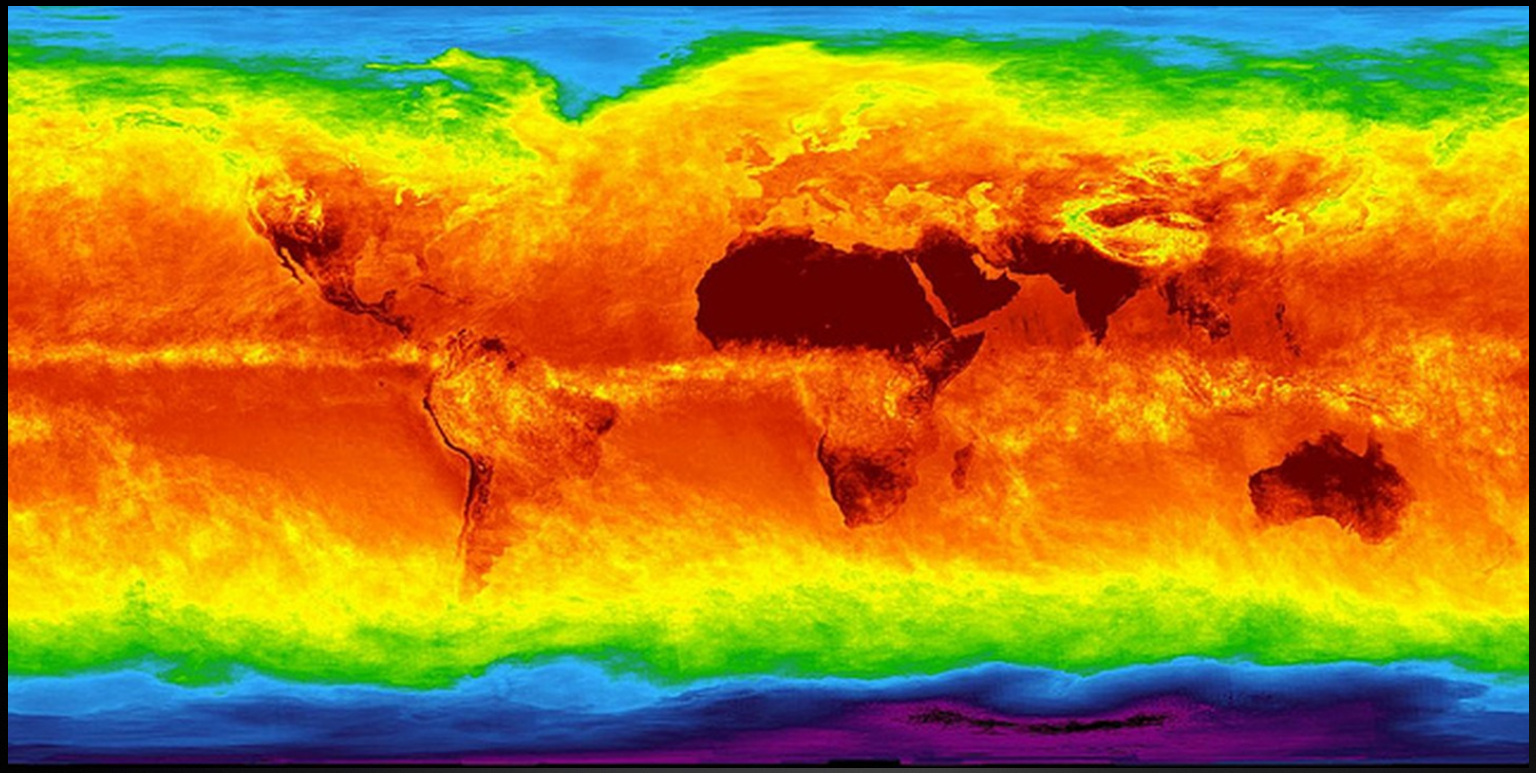
D&B

WB

Weyn

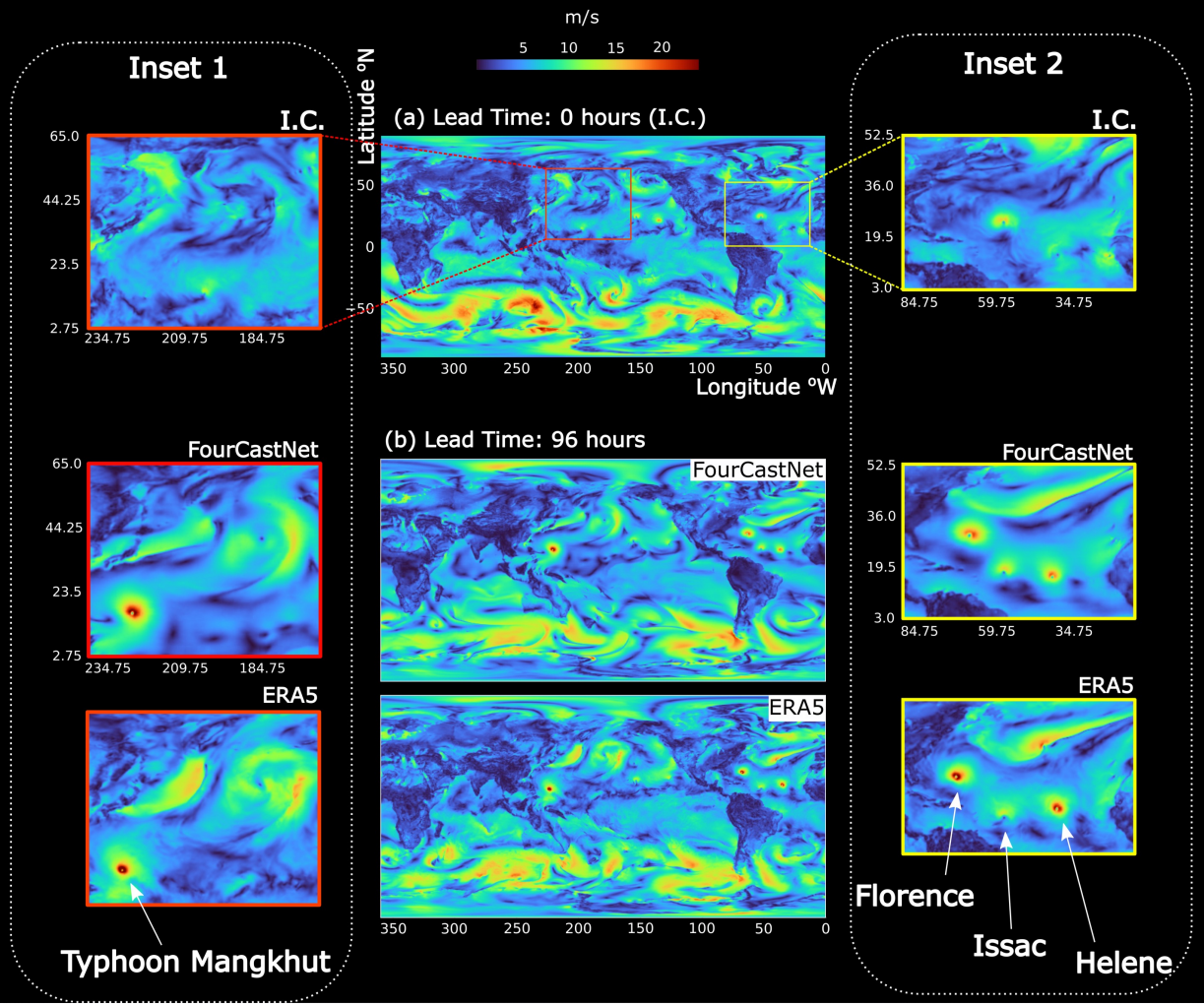
DLWP

- Deuban & Bauer (2018), 6° , 60x30, 1.8K pixels, MLP
- WeatherBench, Rasp, et al (2020). 5.625°, 64x32, 2K pixels, CNN
- Weyn, et al (2019), 2.5° N.H only, 72x36, 2.6k pixels, ConvLSTM
- DLWP, Weyn, et al (2020). 2°, 180x90, 16K pixels, Deep CNN on Cubesphere/(2021) ResNet
- FourCastNet, Pathak, et al (2022), 0.25°, 1440x720, 1M Pixels, ViT+AFNO

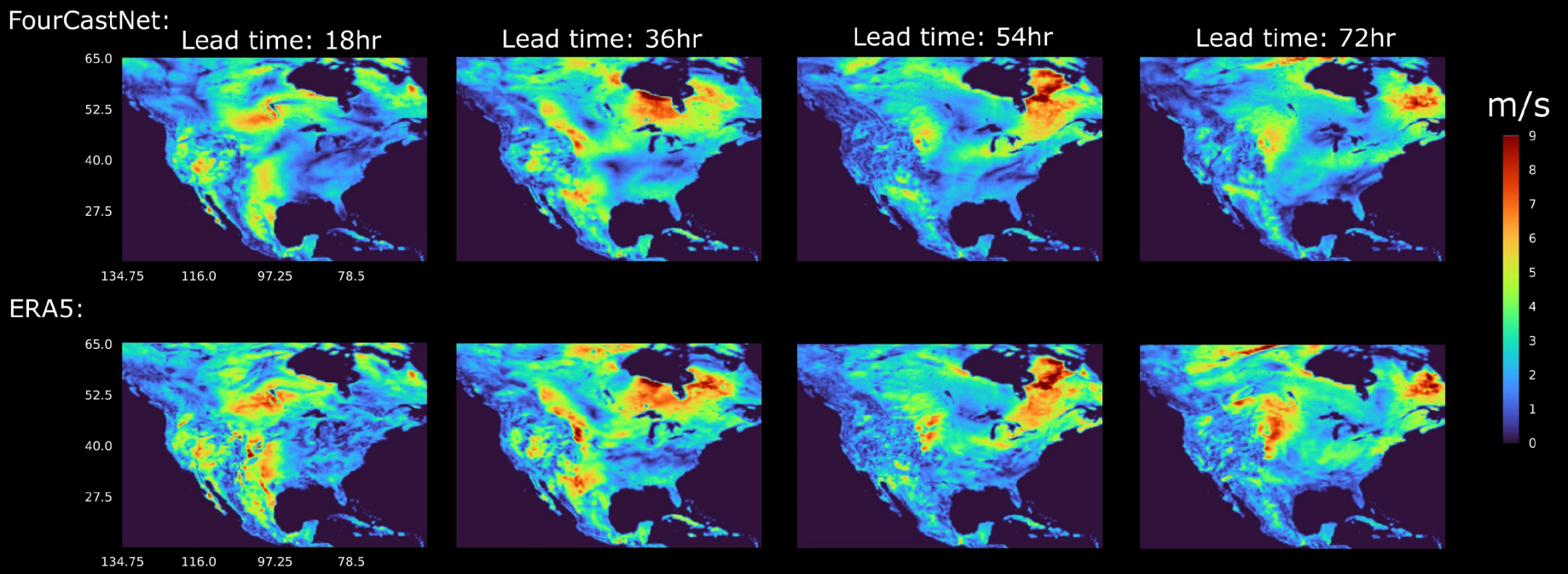


FCN

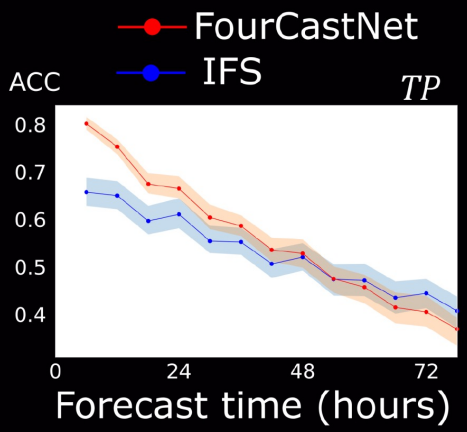
EXCELLENT SKILL ON FORECASTING SURFACE WINDS AND PRECIPITATION



FOURCASTNET PREDICTS NEAR-SURFACE WIND FIELDS OVER LAND ACCURATELY: IMPORTANT IMPLICATIONS FOR WIND ENERGY PLANNING

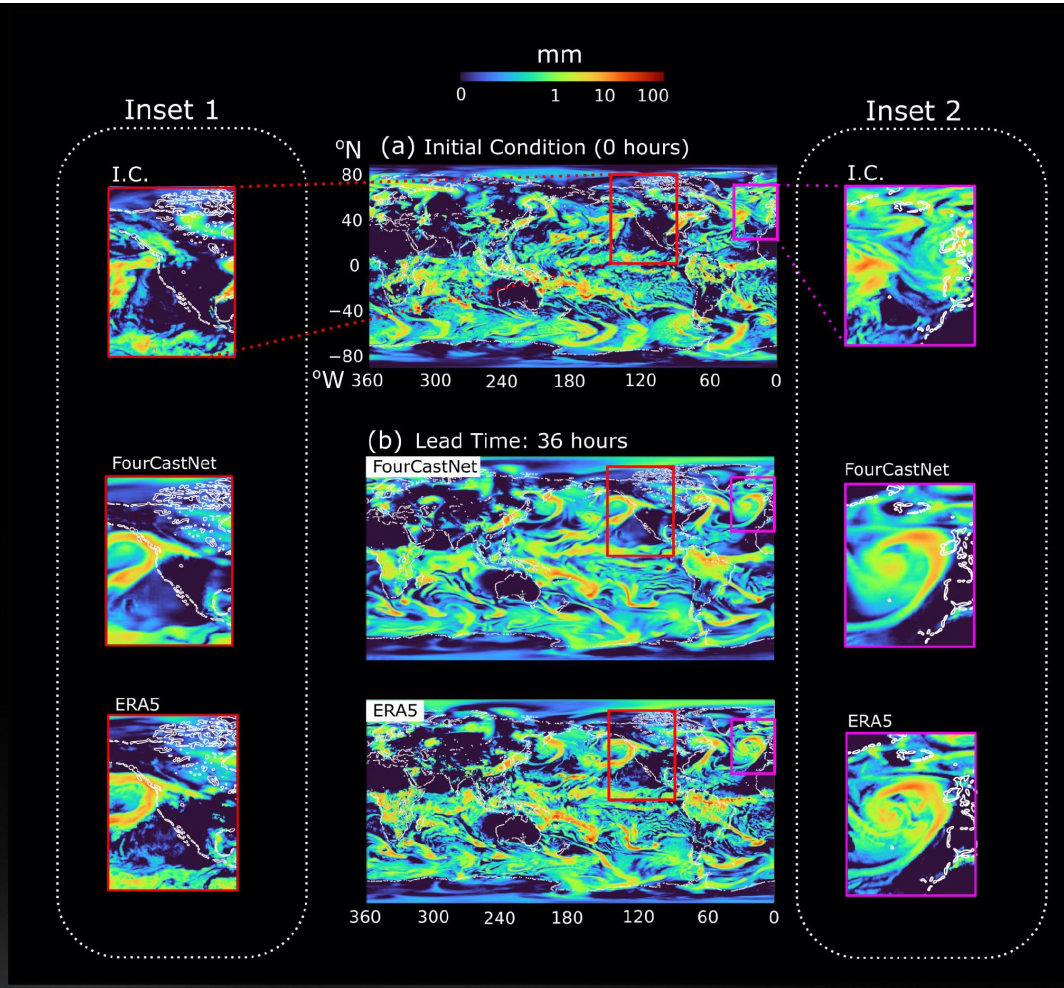


PRECIPITATION



Excellent performance on forecasting precipitation with small scale features captured really well.

Currently we compare our forecasts to ERA5 rather than observations

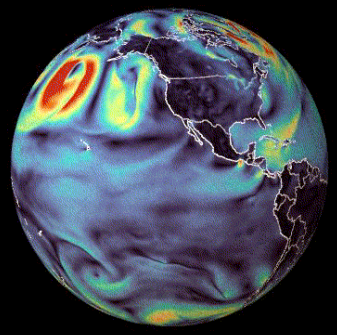


Pathak et al. (2022), FourCastNet: A Global Data-driven High-resolution Weather Model using Adaptive Fourier Neural Operators, arXiv:2202.11214

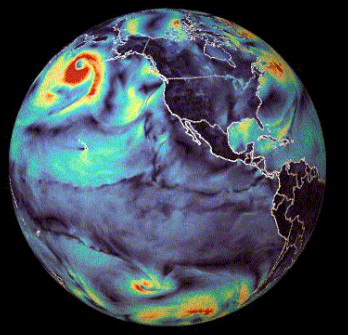
SPHERICAL FOURIER NEURAL OPERATORS

Spherical Harmonic Transform

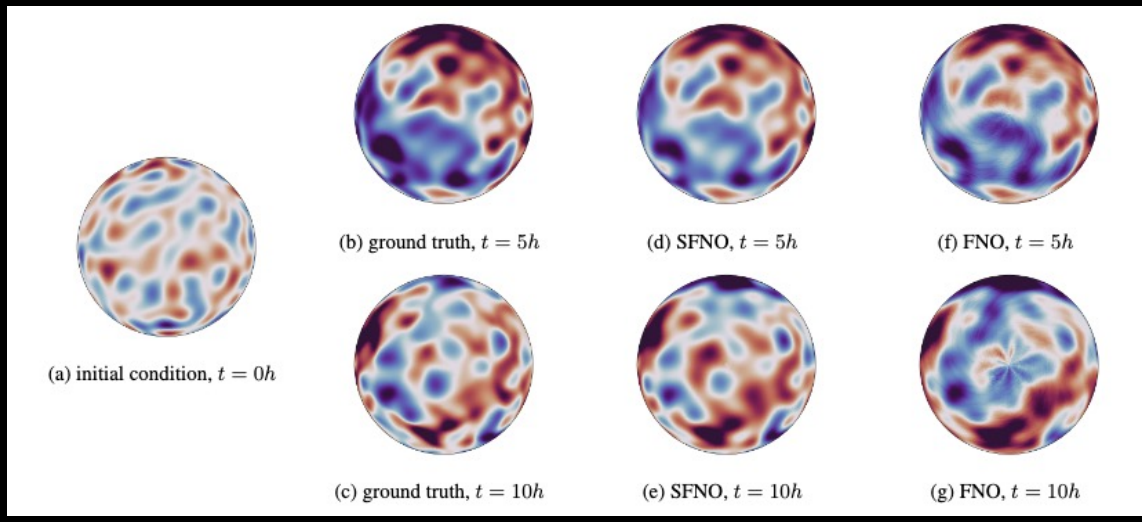
2018-01-08



SFNO

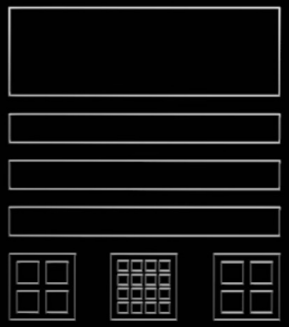


Ground truth

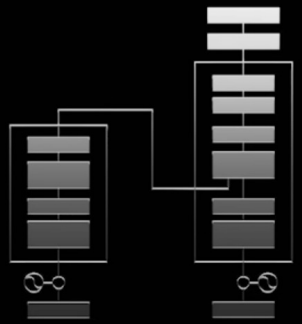


THREE MIRACLES FOR DIGITAL TWIN EARTH 2

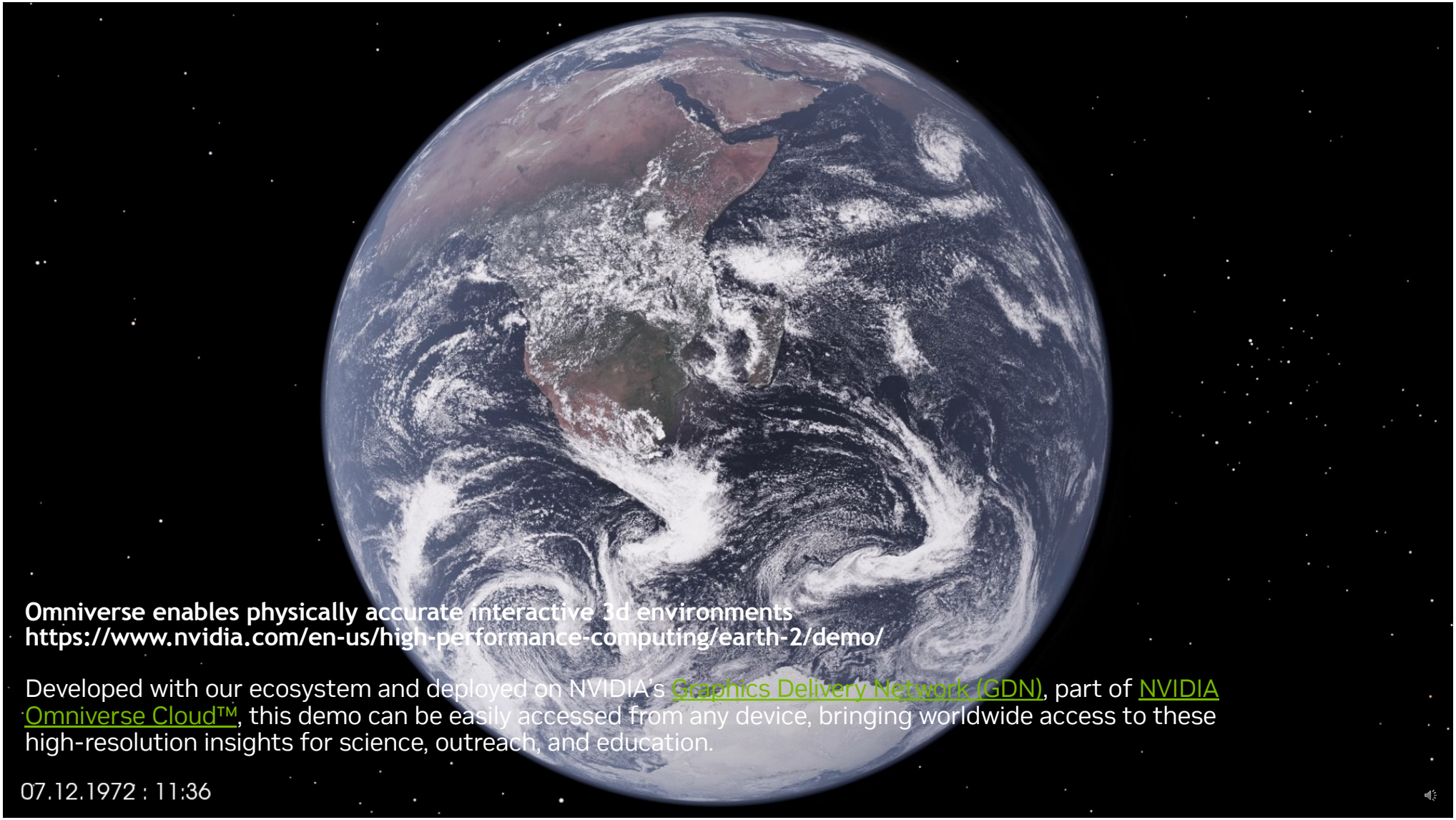
NVIDIA
ACCELERATED COMPUTING



MODULUS PHYSICS-ML
FOURCASTNET

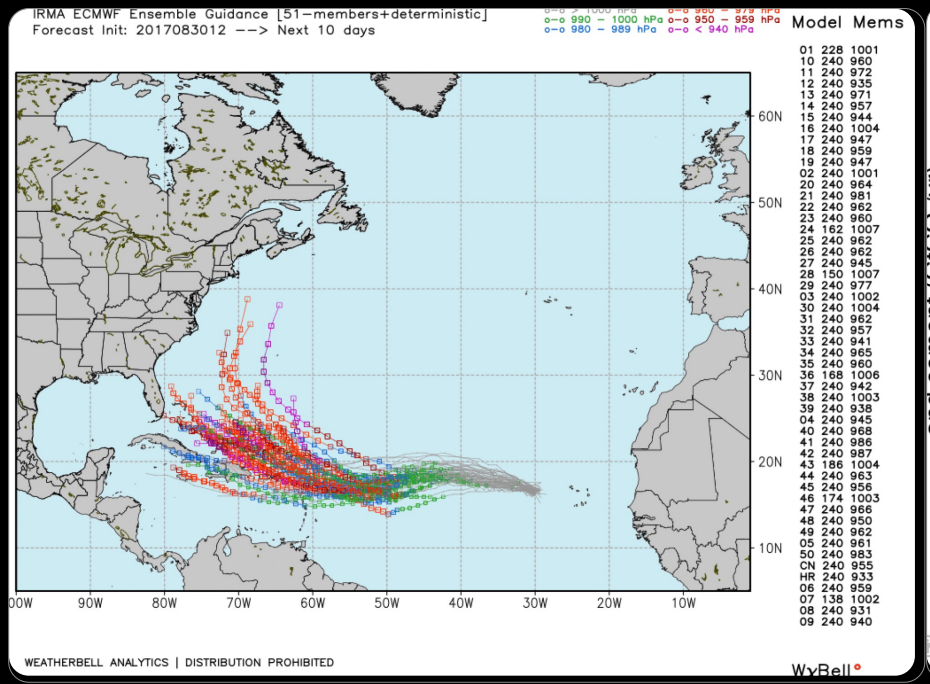


OMNIVERSE
DIGITAL TWINS


Omniverse enables physically accurate interactive 3d environments
https://www.nvidia.com/en-us/high-performance-computing/earth-2/demo/
Developed with our ecosystem and deployed on NVIDIA's Graphics Delivery Network (GDN), part of NVIDIA Omniverse Cloud™, this demo can be easily accessed from any device, bringing worldwide access to these high-resolution insights for science, outreach, and education.
07.12.1972 : 11:36

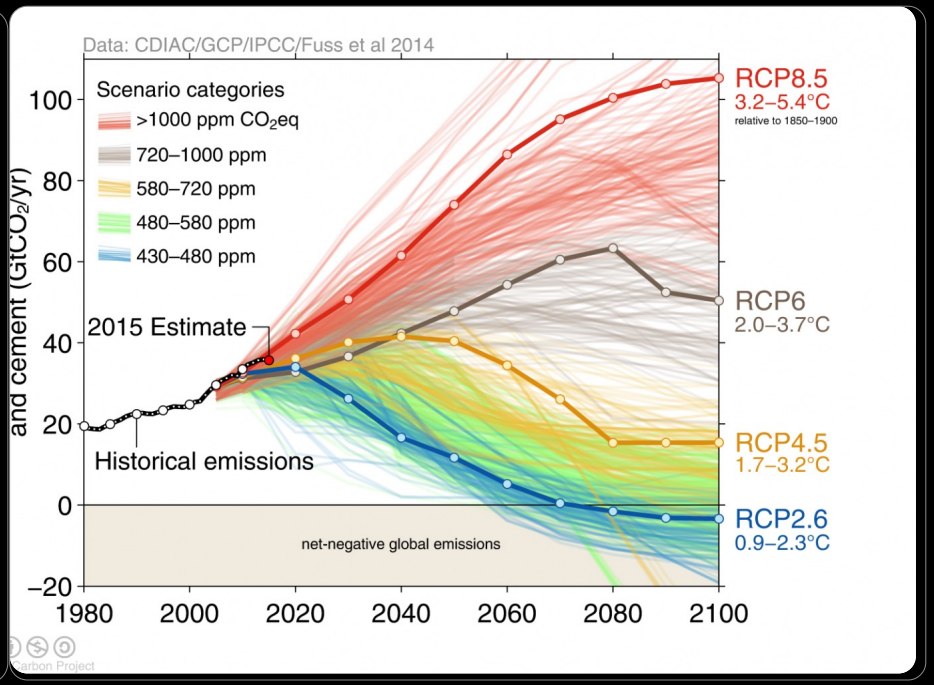
Earth-2 will predict extreme weather and climate across many possible futures

From Weather to Climate



Sample Weather Ensembles Over Time

ECMWF



Sample across many possible climate futures

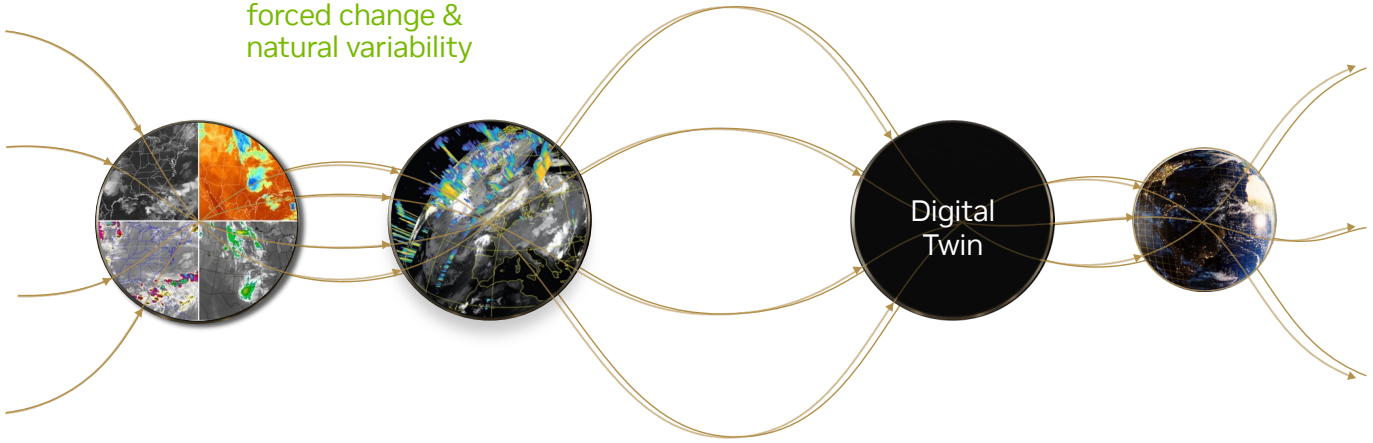
IPCC 2014

TO BEGIN, WE CAN TETHER TO EXISTING CLIMATE PREDICTIONS.

Using the world's current data library of 100-km resolution intergovernmental climate predictions.

Sampling scenarios

Physical projections of forced change & natural variability

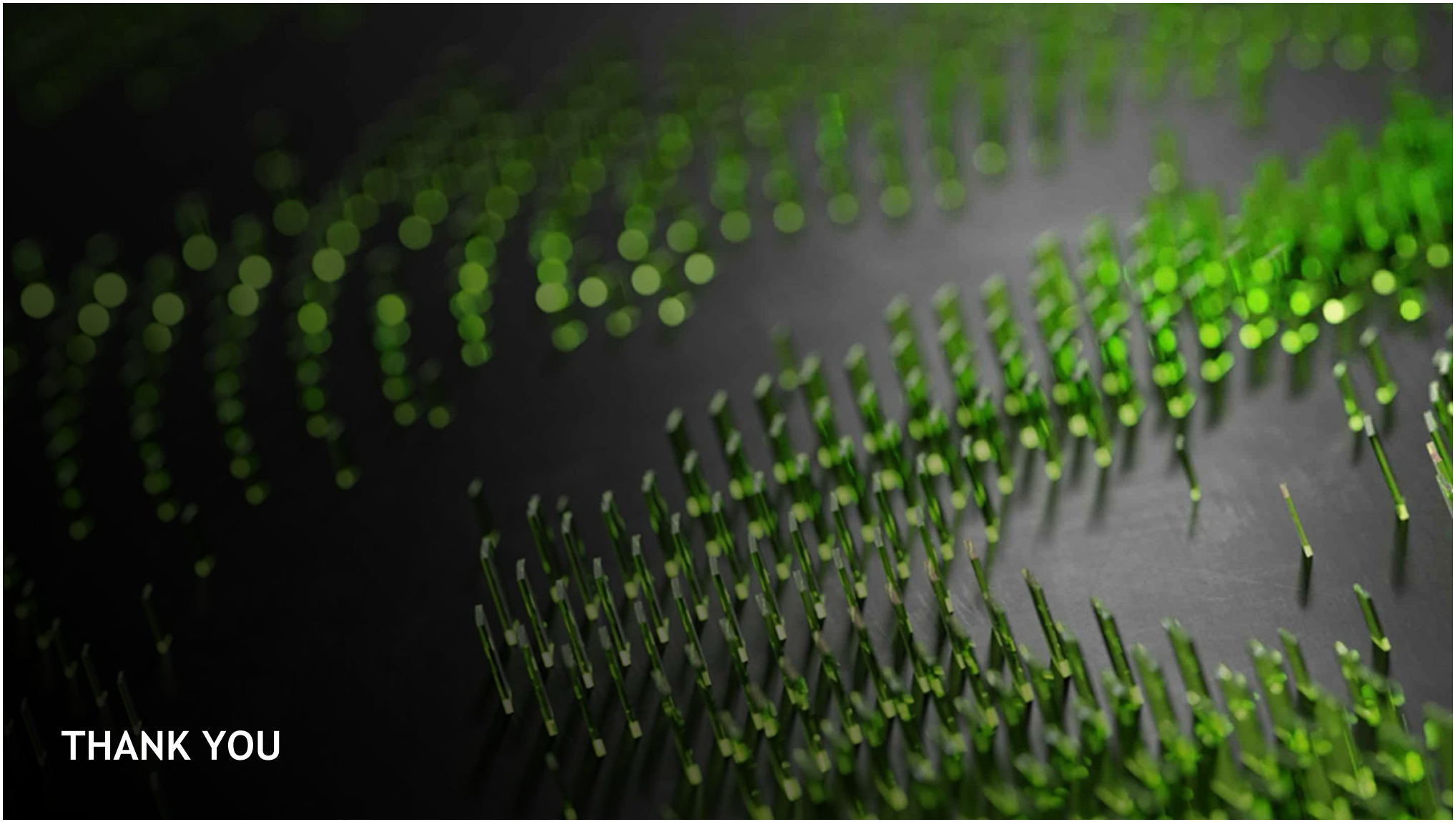


RAPIDS | CuNumeric

DALI | Modulus | CUDA-X AI | TRITON | TensorRT

Omniverse

NVIDIA


THANK YOU