The Seismic Wavefield Common Task Framework

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> **SciML methods overpromise results against weak baselines, reporting bias, inconsistent evaluations, a lack of *hidden* test sets**

The paper is organized as follows. In Section 2, we present two network architectures of DeepONet: the stacked DeepONet and the unstacked DeepONet, and then introduce the data generation procedure. In Section 3, we present a theoretical analysis on the number of sensors required to represent the input function accurately for approximating ODE operators. In Section 4, we test the performance of FNN, stacked DeepONet, and unstacked DeepONet for different examples, and demonstrate the accuracy and convergence rates of unstacked DeepONet. Finally, we conclude the paper in Section 5.

DeepONet

If we remove the dependence on the function a and impose $\kappa_\phi(x, y) = \kappa_\phi(x - y)$, we obtain that (3) is a convolution operator, which is a natural choice from the perspective of fundamental solutions. We exploit this fact in the following section by parameterizing κ_ϕ directly in Fourier space and using the Fast Fourier Transform (FFT) to efficiently compute (3). This leads to a fast architecture that obtains state-of-the-art results for PDE problems.

FNO

univariate model (Das et al., 2024). Across 9.3×10^3 held-out systems, we find *Panda* outperforms the baselines across a variety of prediction horizons and error metrics (Fig. 2). While we train our model exclusively on $d = 3$-dimensional dynamical systems, the evaluation set includes arbitrary dimension systems, indicating that channel attention enables multivariate generalization. Moreover,

Panda

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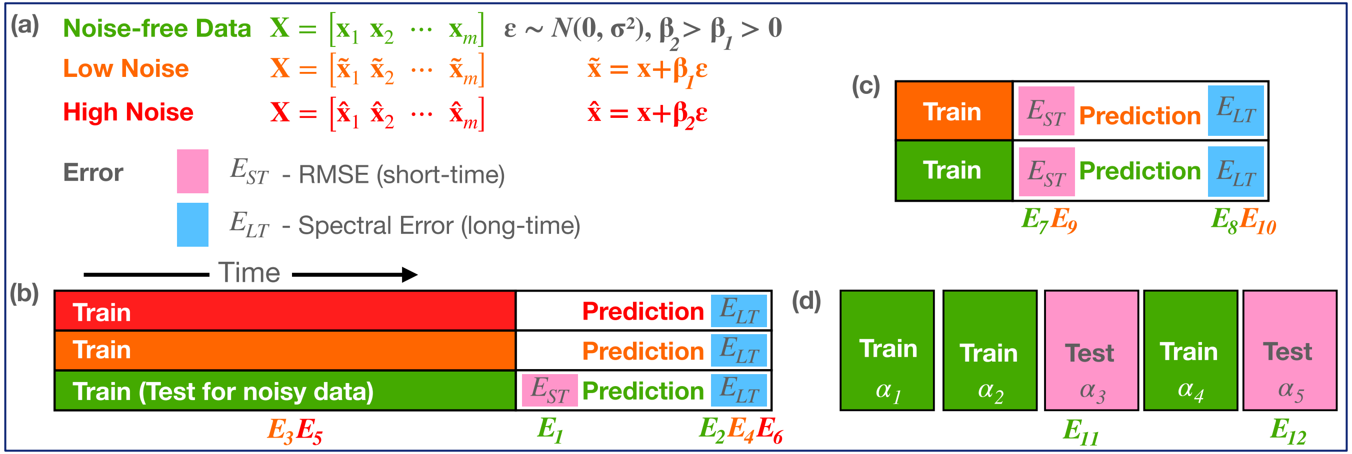
> The Seismic Wavefield CTF extends the CTF4Science provides a rigorous foundation to benchmark SciML



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Score	Test	Task	Train / Burn-in File(s)	Ground Truth File
E_1	Forecasting	Short-time	$\mathbf{X}_{1\text{train}}$	$\mathbf{X}_{1\text{test}}$
E_2	Forecasting	Long-time	$\mathbf{X}_{1\text{train}}$	$\mathbf{X}_{1\text{test}}$
E_3	Noisy (medium)	Reconstruction (denoising)	$\mathbf{X}_{2\text{train}}$	$\mathbf{X}_{2\text{test}}$
E_4	Noisy (medium)	Forecast (long-time)	$\mathbf{X}_{2\text{train}}$	$\mathbf{X}_{3\text{test}}$
E_5	Noisy (high)	Reconstruction (denoising)	$\mathbf{X}_{3\text{train}}$	$\mathbf{X}_{4\text{test}}$
E_6	Noisy (high)	Forecast (long-time)	$\mathbf{X}_{3\text{train}}$	$\mathbf{X}_{5\text{test}}$
E_7	Limited Data (clean)	Forecast (short-time)	$\mathbf{X}_{4\text{train}}$	$\mathbf{X}_{6\text{test}}$
E_8	Limited Data (clean)	Forecast (long-time)	$\mathbf{X}_{4\text{train}}$	$\mathbf{X}_{6\text{test}}$
E_9	Limited Data (noisy)	Forecast (short-time)	$\mathbf{X}_{5\text{train}}$	$\mathbf{X}_{7\text{test}}$
E_{10}	Limited Data (noisy)	Forecast (long-time)	$\mathbf{X}_{5\text{train}}$	$\mathbf{X}_{7\text{test}}$
E_{11}	Parametric Generalization	Interpolation forecast	$\mathbf{X}_{6,7,8\text{train}}$ / $\mathbf{X}_{9\text{train}}$	$\mathbf{X}_{8\text{test}}$
E_{12}	Parametric Generalization	Extrapolation forecast	$\mathbf{X}_{6,7,8\text{train}}$ / $\mathbf{X}_{10\text{train}}$	$\mathbf{X}_{9\text{test}}$

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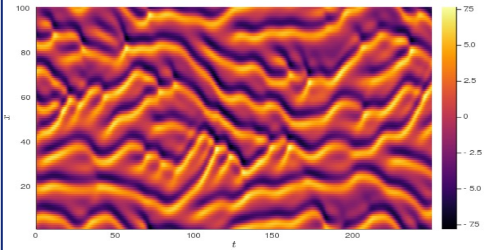
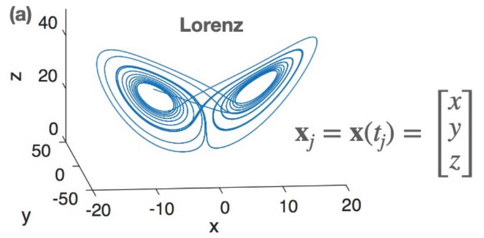
NeurIPS 2025

Kuramoto-Sivashinsky

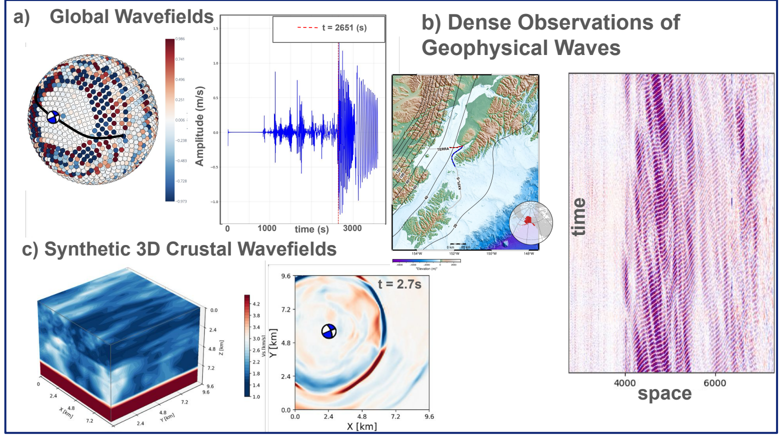


Lorenz



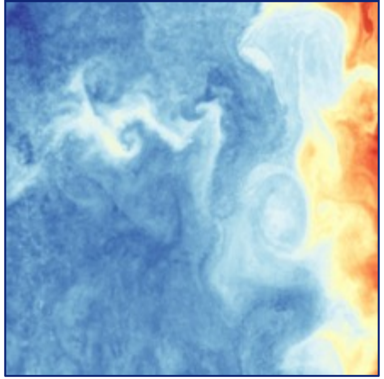
ICLR 2026

Seismic Wavefields



Kaggle (TBD)

Sea-Surface Temperature



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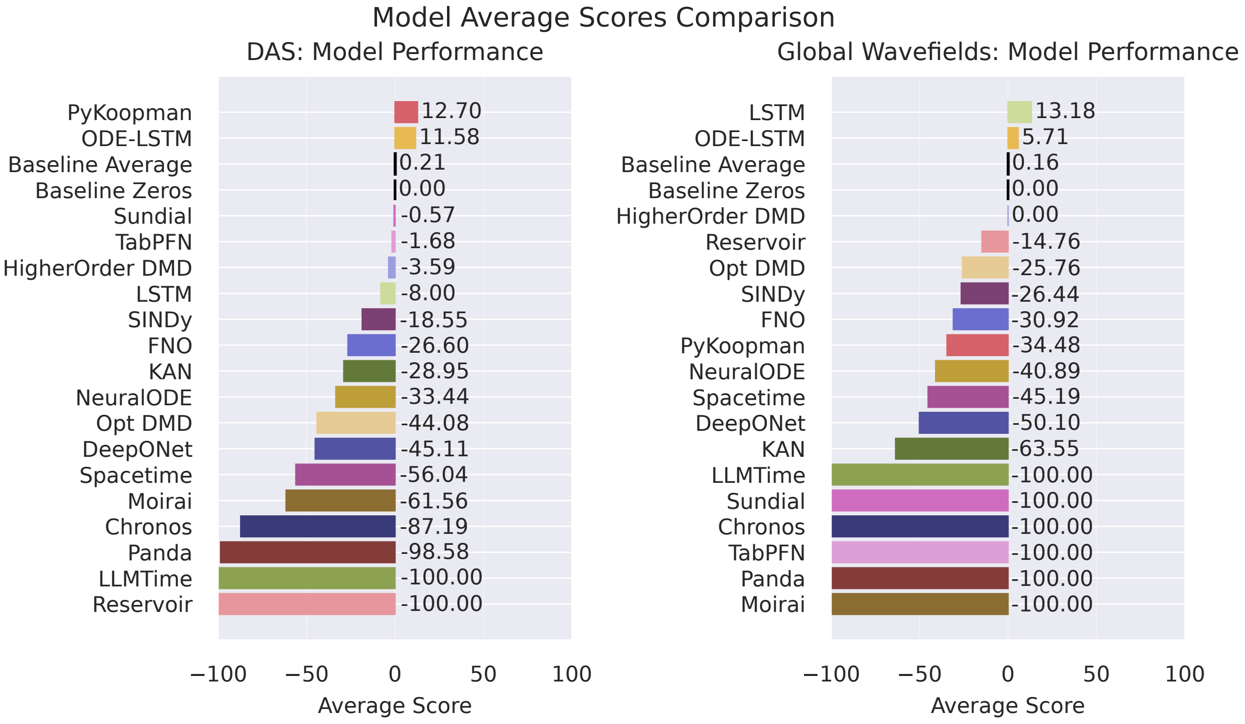

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Global Wavefields Dataset													
Model	**Avg Score**	**E1**	**E2**	**E3**	**E4**	**E5**	**E6**	**E7**	**E8**	**E9**	**E10**	**E11**	**E12**
LSTM	13.18	-1.11	13.8	69.7	**19.84**	48.83	24.32	-40.07	11.34	-18.38	**30.97**	**4.09**	-5.22
ODE-LSTM	5.71	-0.07	6.67	65.78	-20.36	41.1	24.1	-67.04	**13.16**	-0.29	5.31	-0.38	-5.23
Baseline Average	0.16	0.0	0.0	0.0	0.02	3.59	0.03	-1.73	0.01	-0.02	0.02	-0.03	-0.02
Baseline Zeros	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.0**
HigherOrder DMD	0.0	0.0	0.0	-0.01	0.0	-0.02	0.0	0.0	0.02	0.0	0.0	0.0	**0.0**
Reservoir	-14.76	-0.96	6.73	75.37	-100.0	-100.0	**33.63**	**6.03**	1.61	1.06	-100.0	1.15	-1.75
Opt DMD	-25.76	-2.65	9.12	2.81	-91.47	0.49	2.67	-36.52	-100.0	-10.73	-82.21	-0.55	-0.03
SINDy	-26.44	0.0	0.02	-100.0	3.89	-100.0	0.13	-19.12	2.69	-1.65	-100.0	-3.12	-0.08
FNO	-30.92	**4.91**	-100.0	**80.82**	-100.0	**75.81**	-100.0	-23.72	-9.36	-28.82	-100.0	-35.29	-35.4
PyKoopman	-34.48	-0.16	5.08	4.51	-100.0	-0.21	-100.0	2.2	0.21	-9.95	-100.0	-15.44	-100.0
NeuralODE	-40.89	-58.12	**17.81**	-100.0	-25.08	-100.0	9.49	-100.0	9.95	-63.55	30.73	-57.47	-54.39
Spacetime	-45.19	-11.2	-100.0	10.5	-100.0	-15.75	-100.0	-48.9	3.26	-19.18	-100.0	-34.2	-26.83
DeepONet	-50.1	-100.0	-100.0	-100.0	0.08	-100.0	-100.0	-6.95	5.73	0.0	0.0	-0.08	-100.0
KAN	-63.55	-0.43	3.51	3.3	-100.0	1.66	-7.51	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0
Moirai	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0
Panda	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0
Chronos	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0
TabPFN	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0
LLMTime	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0
Sundial	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0

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Distributed Acoustic Sensing Dataset													
Model	**Avg Score**	**E1**	**E2**	**E3**	**E4**	**E5**	**E6**	**E7**	**E8**	**E9**	**E10**	**E11**	**E12**
PyKoopman	12.7	7.11	14.5	33.38	0.42	71.52	3.0	7.35	**25.06**	2.94	2.55	-15.41	-0.01
ODE-LSTM	11.58	-1.2	0.39	36.65	**7.24**	82.88	14.39	-9.63	15.76	-16.0	14.79	-27.93	8.79
Baseline Average	0.21	-0.04	0.01	0.02	0.2	0.0	0.0	2.79	1.67	-0.22	3.5	-2.99	-2.45
Baseline Zeros	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sundial	-0.57	**49.57**	0.82	-63.34	3.77	-49.28	7.09	**33.24**	23.33	**13.83**	**20.43**	-30.52	-15.81
TabPFN	-1.68	-7.09	-3.32	**82.28**	-4.75	89.83	0.16	-5.94	-100.0	-11.66	-2.03	-55.8	-1.83
HigherOrder DMD	-3.59	-0.01	0.0	-0.02	0.0	0.0	0.0	0.04	-1.14	-0.19	0.0	-41.64	-0.07
LSTM	-8.0	-21.7	19.39	38.47	-17.39	88.96	15.87	-26.4	-10.61	-36.66	-60.52	-95.21	9.81
SINDy	-18.55	-4.77	4.2	-100.0	3.3	-100.0	**18.84**	-38.93	16.81	-38.93	16.81	0.17	-0.07
FNO	-26.6	-24.15	-100.0	77.11	-100.0	88.54	-0.97	-44.24	-100.0	1.36	-70.49	-30.52	-15.81
KAN	-28.95	-13.68	4.77	13.17	-100.0	65.16	2.39	-100.0	-100.0	-1.78	-1.99	-100.0	-0.17
NeuralODE	-33.44	-55.37	**21.16**	-100.0	-41.64	-100.0	10.37	-57.66	18.58	-100.0	-36.08	**24.68**	**14.63**
Opt DMD	-44.08	-10.84	-100.0	81.66	-100.0	**91.49**	-100.0	-34.38	-49.86	-6.97	-100.0	-100.0	-100.0
DeepONet	-45.11	-100.0	-100.0	0.05	-42.97	0.03	-100.0	-0.05	-100.0	0.03	1.61	-100.0	0.0
Spacetime	-56.04	-40.51	-100.0	-36.97	-100.0	60.73	-100.0	-27.47	-100.0	-100.0	-100.0	-4.35	-23.91
Moirai	-61.56	18.11	-20.93	-100.0	-100.0	-100.0	-100.0	8.01	-100.0	-51.81	-100.0	-30.52	-15.81
Chronos	-87.19	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-30.52	-15.81
Panda	-98.58	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-82.98	-100.0
LLMTime	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0

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> **Takeaways:**
  - Most advanced SciML/Foundation models underperform
  - The field is far from anything useful for practitioners
  - The Seismic Wavefield CTF is important in developing the field

The Seismic Wavefield CTF

- Large team effort (16 people, 7 institutions)
  - Experts in ML, SciML, Dynamical Systems, etc..
- Codebase:
  - Open source, extendable (both datasets and models), and reproducible
    https://github.com/CTF-for-Science/ctf4science ☆ 38 stars
- Website:
  - https://ctf-for-science.github.io/ctf4science/
- In Progress:
  - Kaggle Competition (KS + Sea-Surface Temperature, 2026)

Thank you!