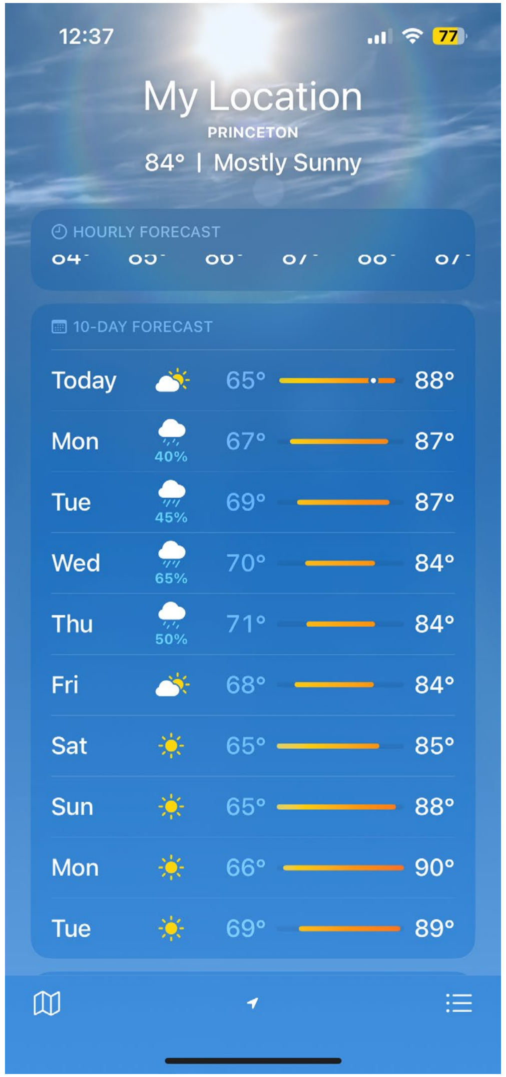
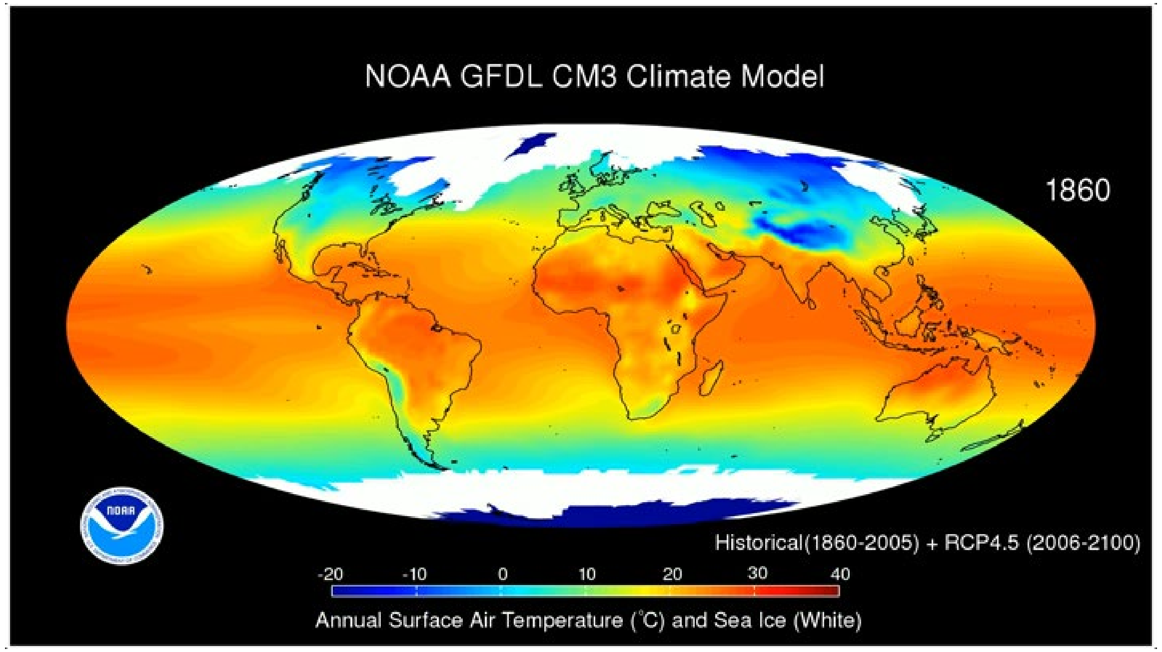
APPLICATION OF PHYSICS-INFORMED NEURAL NETWORKS (PINNS) ON CHAOTIC CLIMATE SYSTEMS

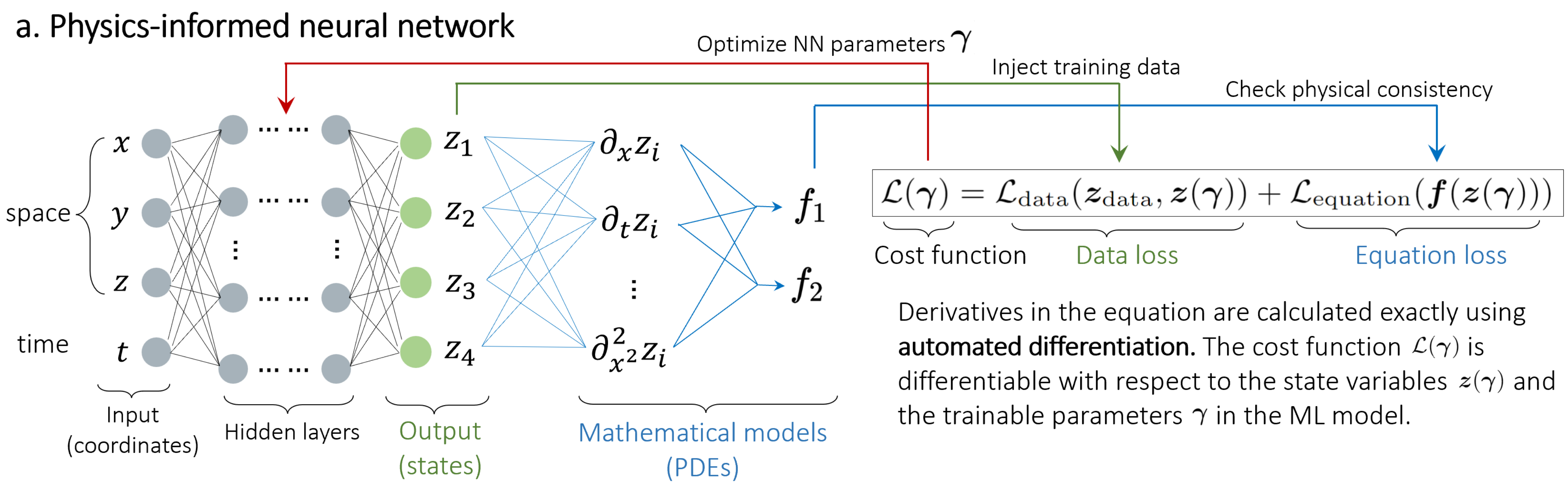
Why is predicting climate so hard?





Horowitz, Larry. "NOAA GFDL CM3 CLIMATE MODEL". Data Visualizations – Climate Predictions. Geophysical Fluid Dynamics Laboratory. https://www.gfdl.noaa.gov/visualization/visualizations-climate-prediction/

What are physics-informed neural networks (PINNs)?



Ching-Yao Lai, Pedram Hassanzadeh, Aditi Sheshadri, Maike Sonnewald, Raffaele Ferrari, Venkatramani Balaji. *Machine Learning for Climate Physics and Simulations* arxiv.org/html/2404.13227v1.

PINN on Lorenz System

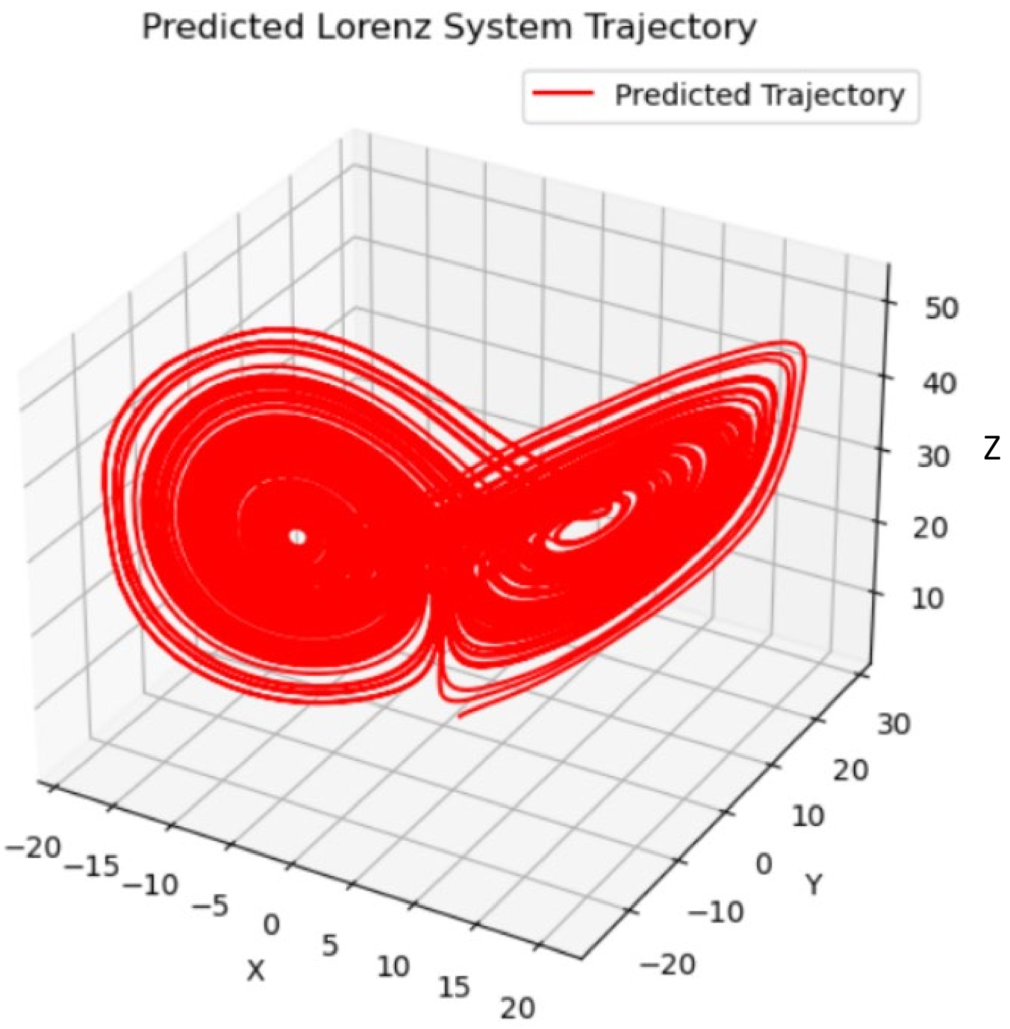


Fig. 1. Our model’s prediction of the Lorenz System

$$\frac{dx}{dt} = \sigma(y - x)$$

$$\frac{dy}{dt} = x(\rho - z) - y$$

$$\frac{dz}{dt} = xy - \beta z$$

where $\sigma = 10,\ \rho = 28,\ \beta = \frac{8}{3}$.

PINN on Burgers’ Equation

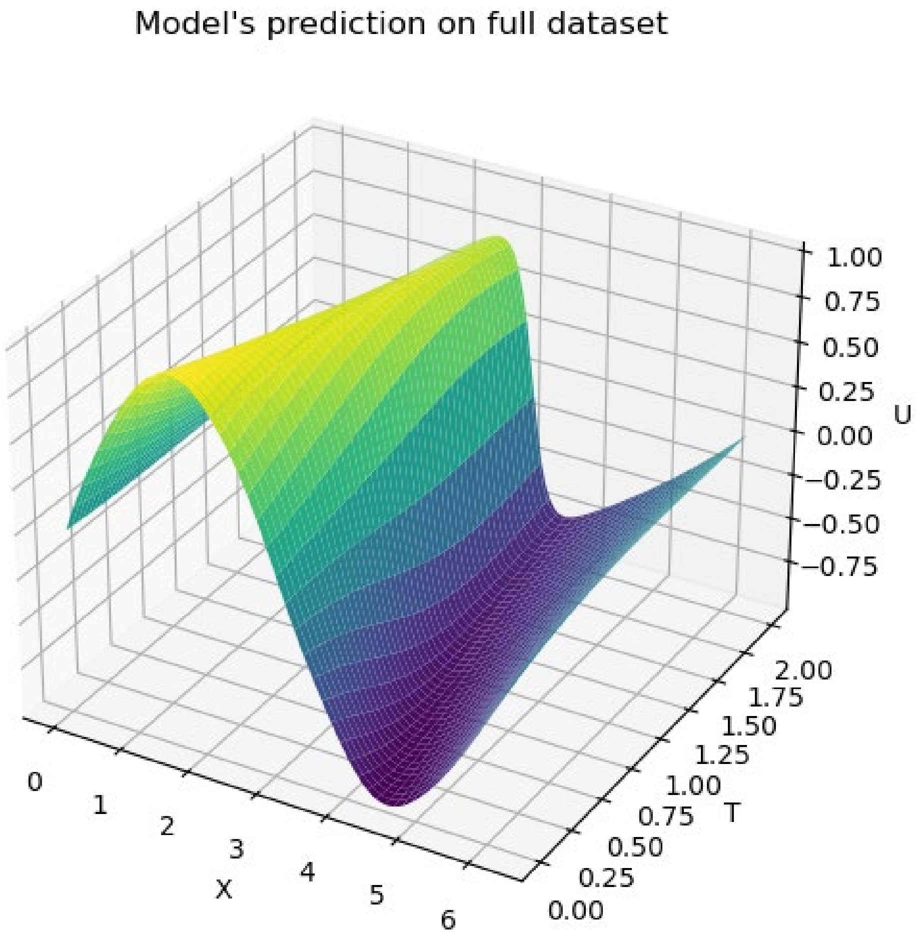
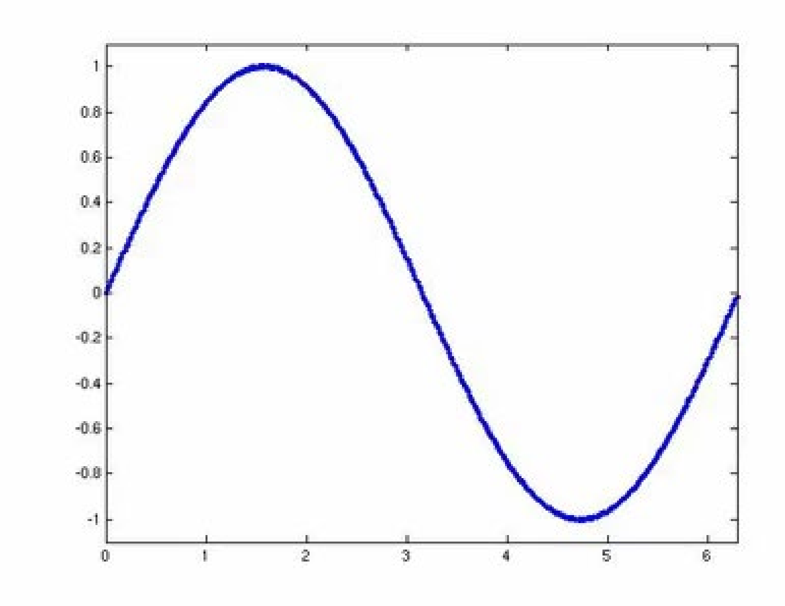


Fig. 2. Our model’s prediction of the Burgers’ Equation

$$\frac{\partial u}{\partial t} = v\frac{\partial^2 u}{\partial x^2} - u\frac{\partial u}{\partial x}$$



Balbás, Jorge. “One Dimensional Burgers' Equation”. California State University, Northridge. https://www.csun.edu/~jb715473/examples/burgers1d.htm#here

PINN on Navier-Stokes Equations

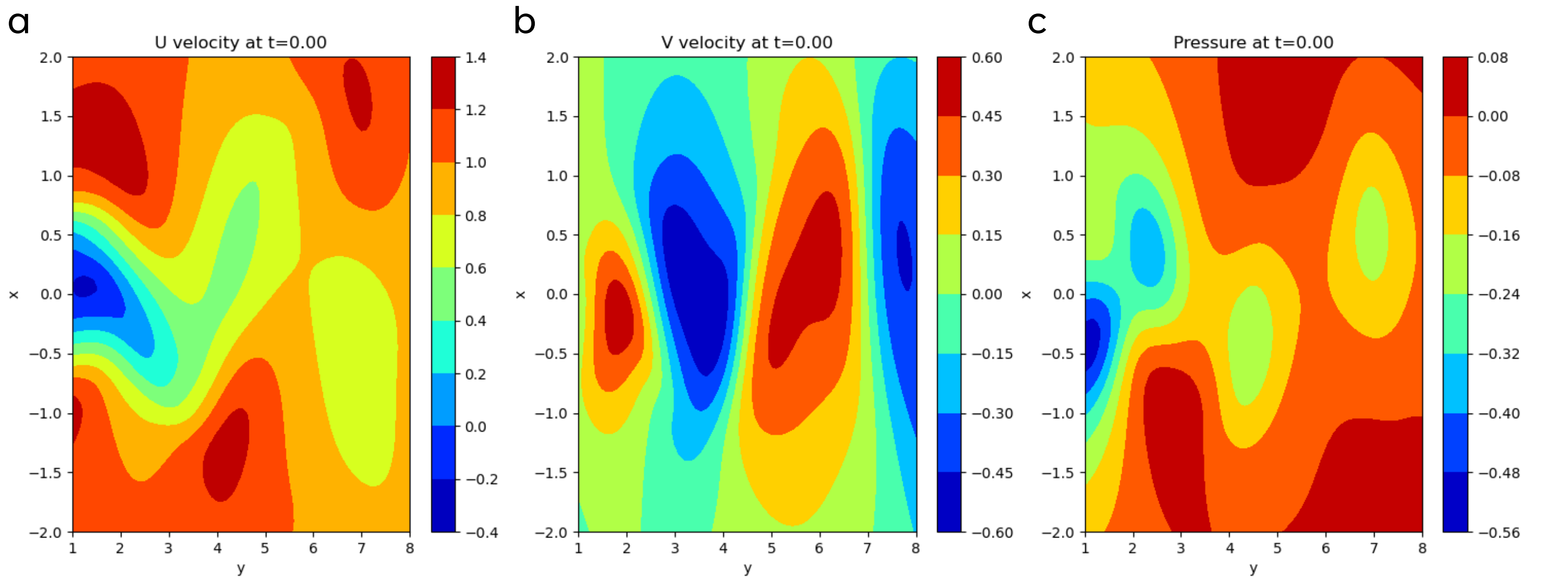


Fig. 3. Our model's prediction of the Navier-Stokes equations.

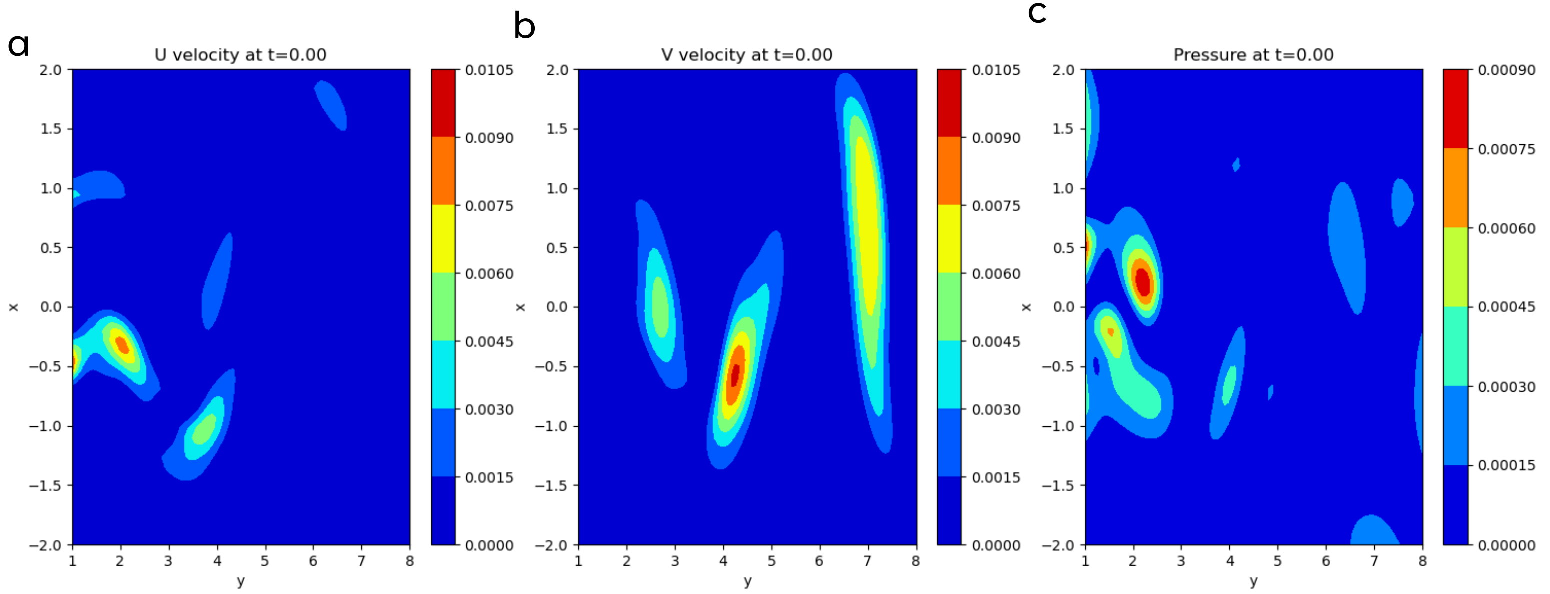


Fig. 4. The residual between the true and predicted solutions of the Navier-Stokes equations.

Continuity equation

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0$$

Momentum equation

$$\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} = -\frac{\partial p}{\partial x} + \nu\left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2}\right)$$

$$\frac{\partial v}{\partial t} + u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} = -\frac{\partial p}{\partial y} + \nu\left(\frac{\partial^2 v}{\partial x^2} + \frac{\partial^2 v}{\partial y^2}\right)$$

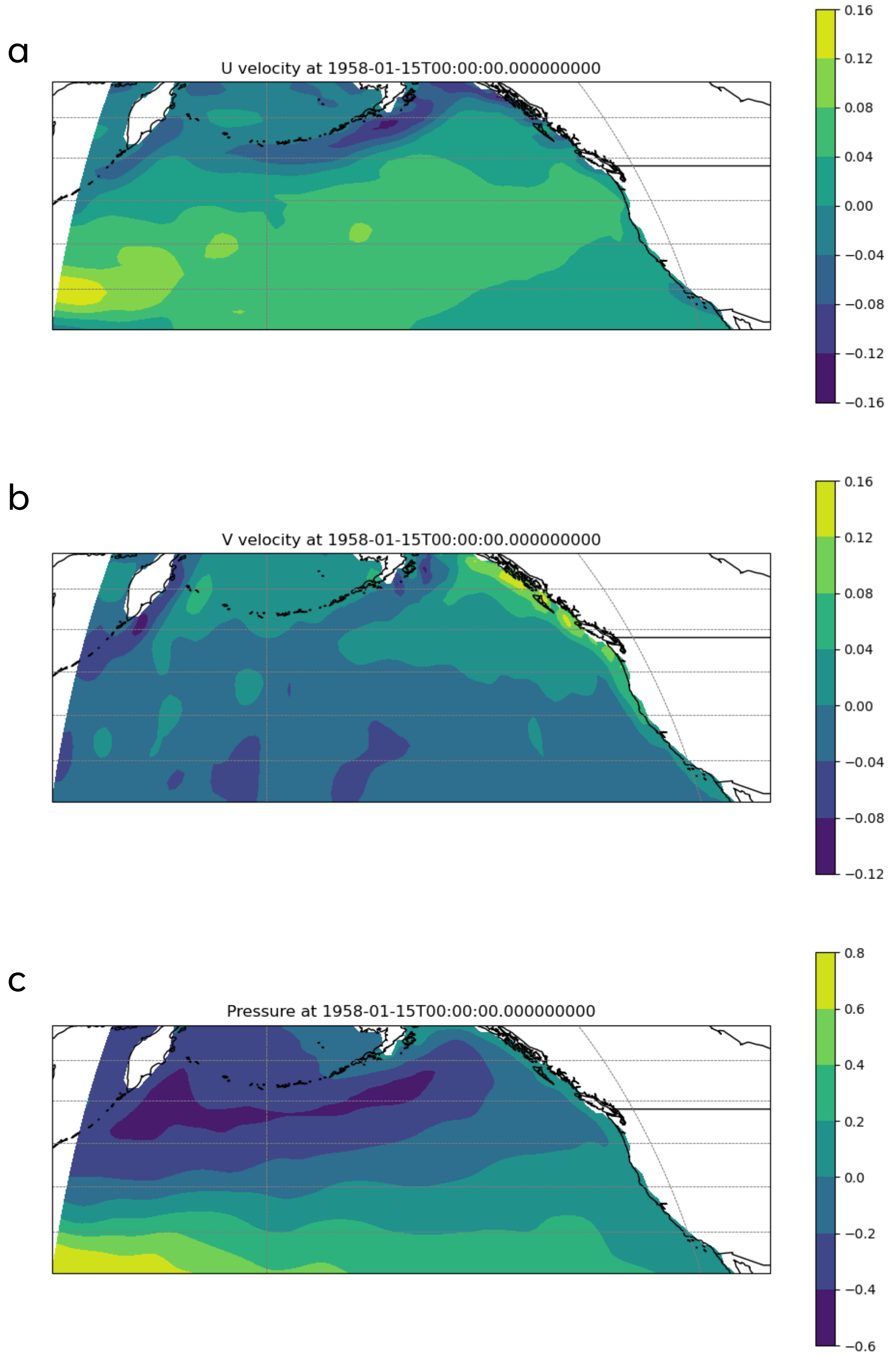


Fig. 5. Colormaps of ORAS4 (Ocean Reanalysis System 4) Data from 1958-2017

Thank you to Gian Giacomo Navarra for being an amazing mentor!

Thank you to Rematch+ and all the staff for giving me the opportunity!

Thank you for listening!