

SYMPOSIUM ON AI FOR SCIENCE & ENGINEERING, IIT HYDERABAD, 2026

Teaching Climate Science to Machines

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Weather vs Climate

What is the difference between weather and climate?

- Will it rain today?
- Should I carry my umbrella?
- Will my house sink in 50 years?
- Will my city get more storms in 100 years?

Weather vs Climate

- <https://weather-and-climate.com/>
- Climate is the long-term average of weather



The image shows a screenshot of the 'Weather & Climate' website. At the top, there is a logo featuring a red umbrella with a yellow sun and a blue cloud. Below the logo is a search bar with the placeholder text 'Search city / country'. To the right of the search bar are three links: 'Home', 'Bucket List', and 'Weather Planner'. Below these links is a temperature selector with '°C' and '°F' options. Further down, there are several navigation links: 'Countries', 'India', 'Maharashtra', 'Mumbai', and 'Rainfall'. Below these links is a small icon of the Indian flag. To the right of the flag are three more links: 'India', 'Maharashtra', and 'Mumbai'. Below these links is a weather icon showing a yellow sun partially obscured by a grey cloud with two blue raindrops. Below the weather icon is the text 'Mumbai (IN)' and 'Average rainfall'. At the bottom, there is a series of links: 'Climate', 'Forecast', 'July', 'August', 'January', 'February', 'March', 'April', 'May', 'June', 'July', 'August', 'September', 'October', and 'November'.

Weather & Climate

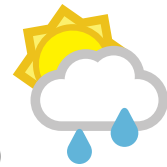
Search city / country

- [Home](#)
- [Bucket List](#)
- [Weather Planner](#)

°C ☐ °F

 [Countries](#) [India](#) [Maharashtra](#) [Mumbai](#) [Rainfall](#)

 [India](#) [Maharashtra](#) [Mumbai](#)

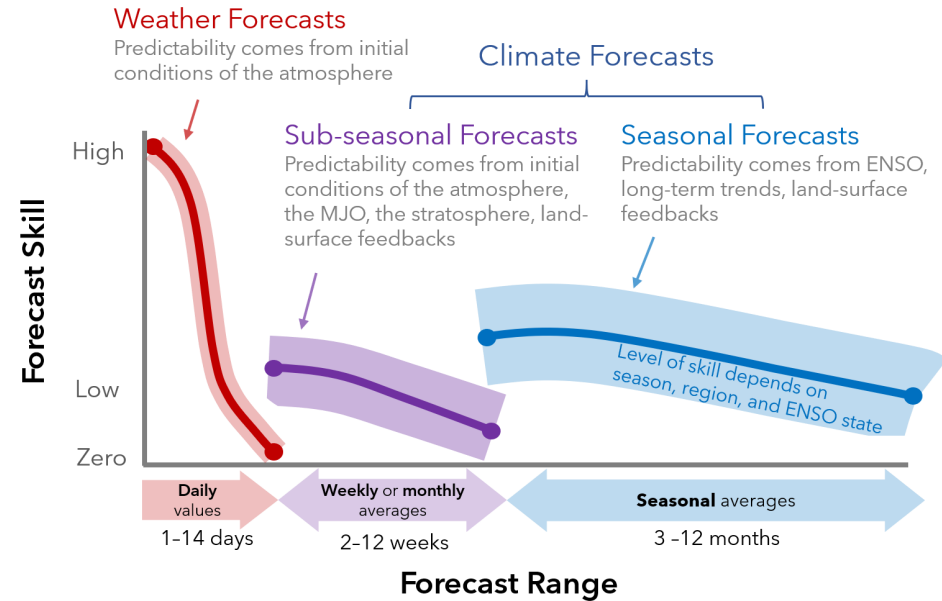


Mumbai (IN)
Average rainfall

[Climate](#) ▶ [Forecast](#) ▶ [July](#) ▶ [August](#) ▶
[January](#) [February](#) [March](#) [April](#) [May](#) [June](#) [July](#) [August](#) [September](#) [October](#) [November](#)

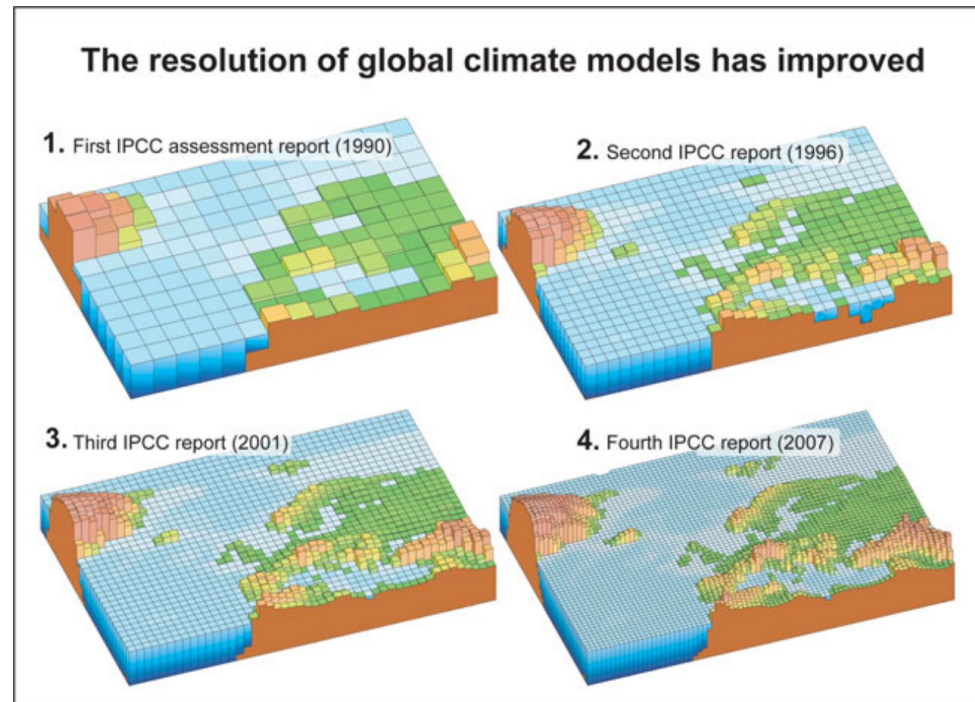
Weather vs Climate

- For weather forecasts, solo atmospheric model suffices
- For anything longer than that you need to couple the atmospheric model to an ocean model, a land model, and a sea ice model
- Lukas and Payton (2020)



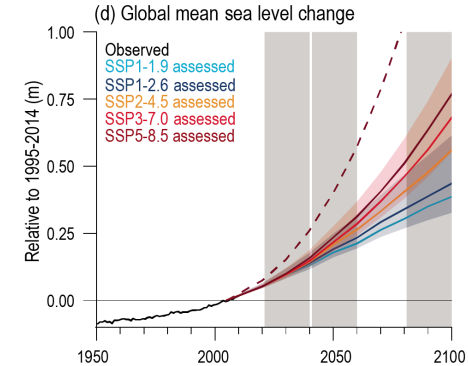
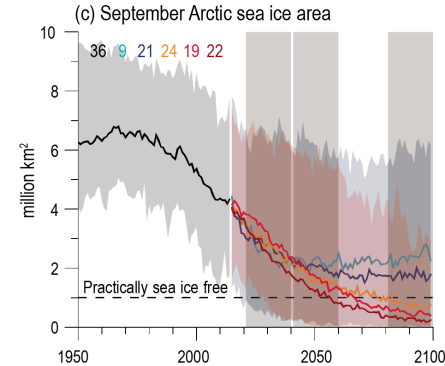
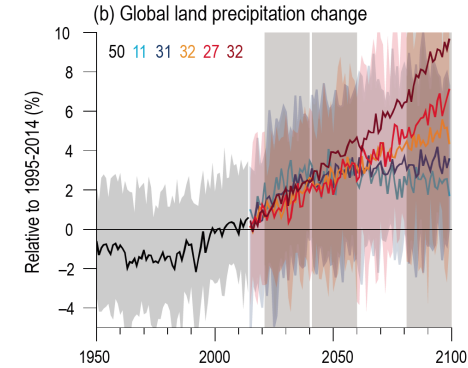
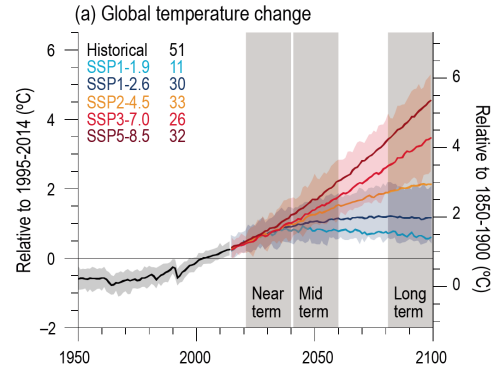
What is a Climate Model

- Climate Model: Atmosphere + Ocean + Land + Sea + Aerosol (optional) + Biogeochemistry (optional)
- Atmospheric Grid Points: $64,800 \times 50$ layers $\approx$ **3.24** million 3D points
- Oceanic Grid Points: $(64,800 \times 0.70) \times 60$ layers $\approx$ **2.72** million 3D points
- 1000 to 5000 CPU core-hours per simulated year
- Increasing resolution leads to quartic growth in computational resources ($\sim N^4$)



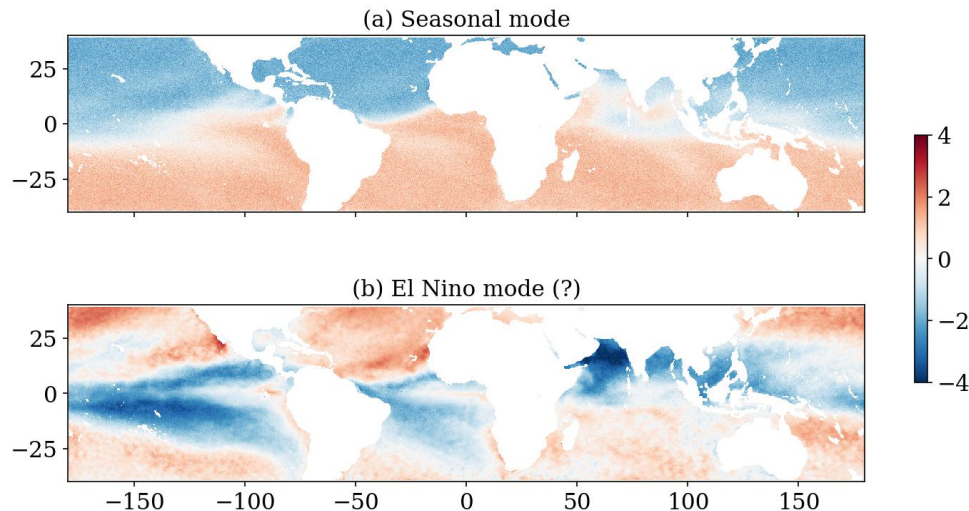
IPCC Projections

- Intergovernmental Panel on Climate Change (<https://ipcc.ch>)
- Projections from 1850-2100
- Forcing Scenarios
- Assessment Report 6 (2023)
- SSP: Shared Socioeconomic Pathways



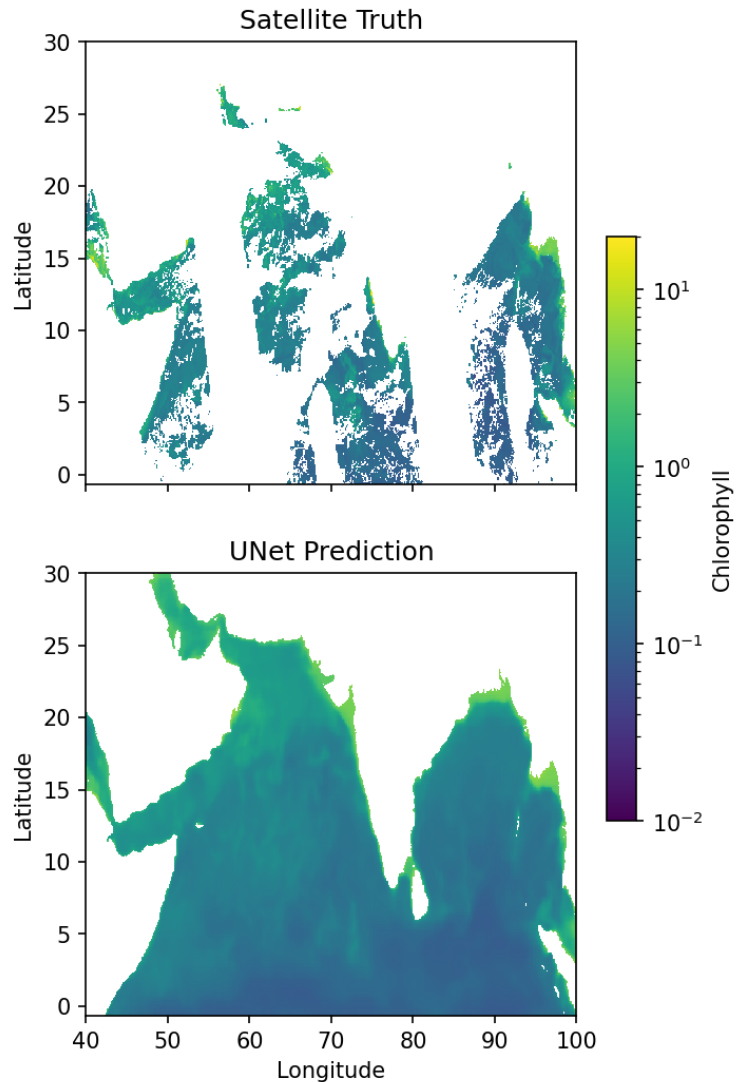
Dimensionality Reduction

- Principal Component Analysis/Empirical Orthogonal Functions
- Matrix Factorization, $Z(x, t) = X(x) \cdot T(t)$
- Linear but highly interpretable
- Ongoing research: Non-linear yet interpretable decomposition



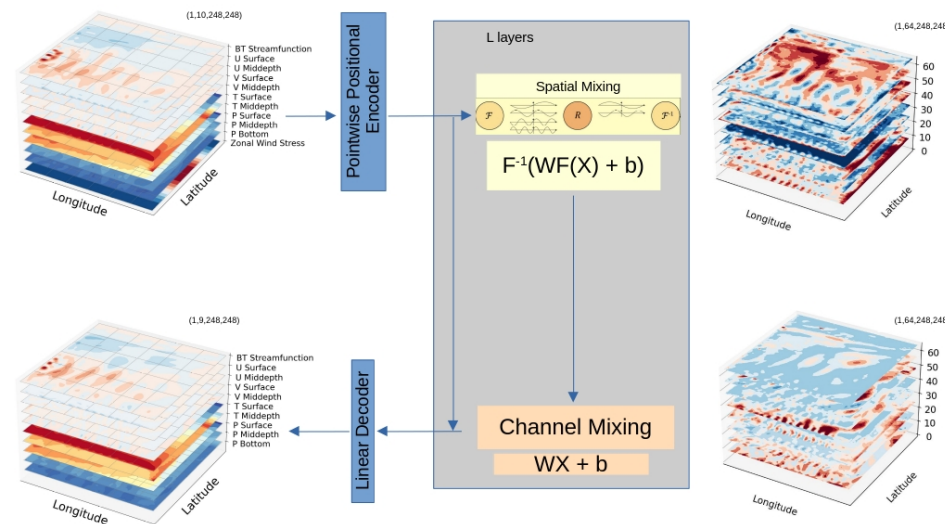
Downscaling/Data Assimilation/Gap filling

- Downscaling (upsampling): Take coarse resolution data and increase its resolution
- Data Assimilation: Combine observations with model simulations
- Gap-filling: Estimate missing data
- Ongoing research: Uncertainty quantification, novel NN architectures



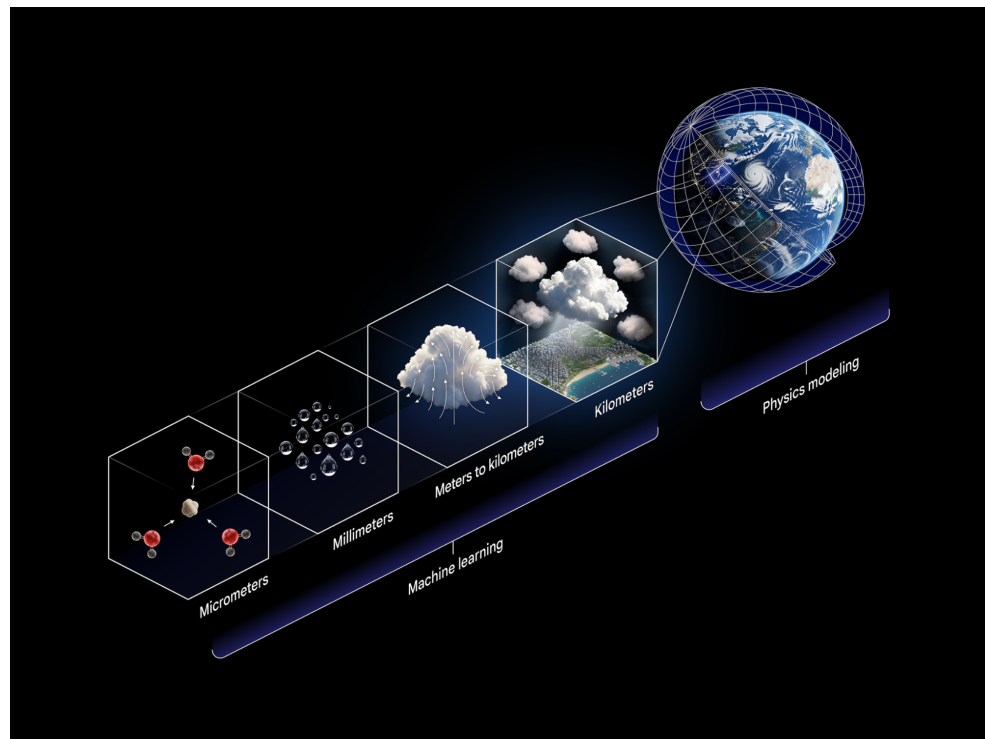
Emulation (Surrogate modeling)

- Instead of full numerical model let a neural network estimate it
- $Z(t + \Delta t) = \mathbb{N}(t; w)$
- Learn w from training data generated from the numerical model
- Ongoing research: novel loss functions, Δt , stability in long rollouts



Parameterization

- Parameterization: represent the effects of unresolved small scale processes in terms of large-scale resolved flow
- Let the physics equations learn the large-scale flow
- Let a neural network handle the small-scale processes
- Neural general circulation models for weather and climate (Nature, 2024)



Summary

- Weather vs Climate
- Problems in climate modeling
- Dimensionality reduction, downscaling, data assimilation, emulation, parameterization
- Thank you!