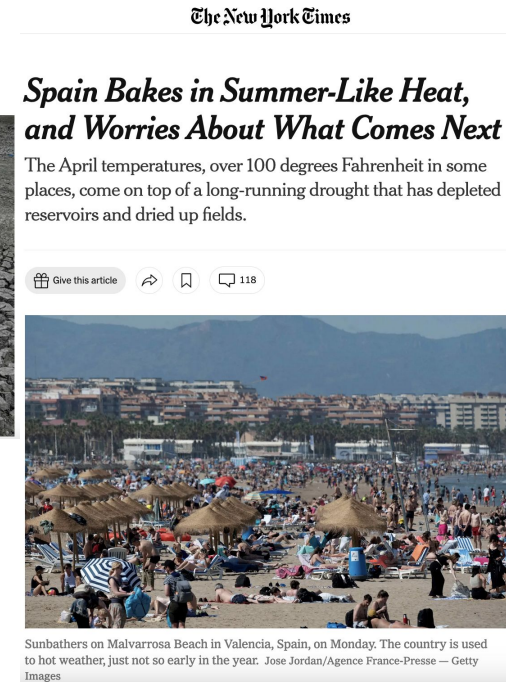# AI for weather and climate forecasting

Pierre Gentine
Columbia University
Director, LEAP center
CTO, Tellus AI

Current gap: Climate Adaptation is Needed
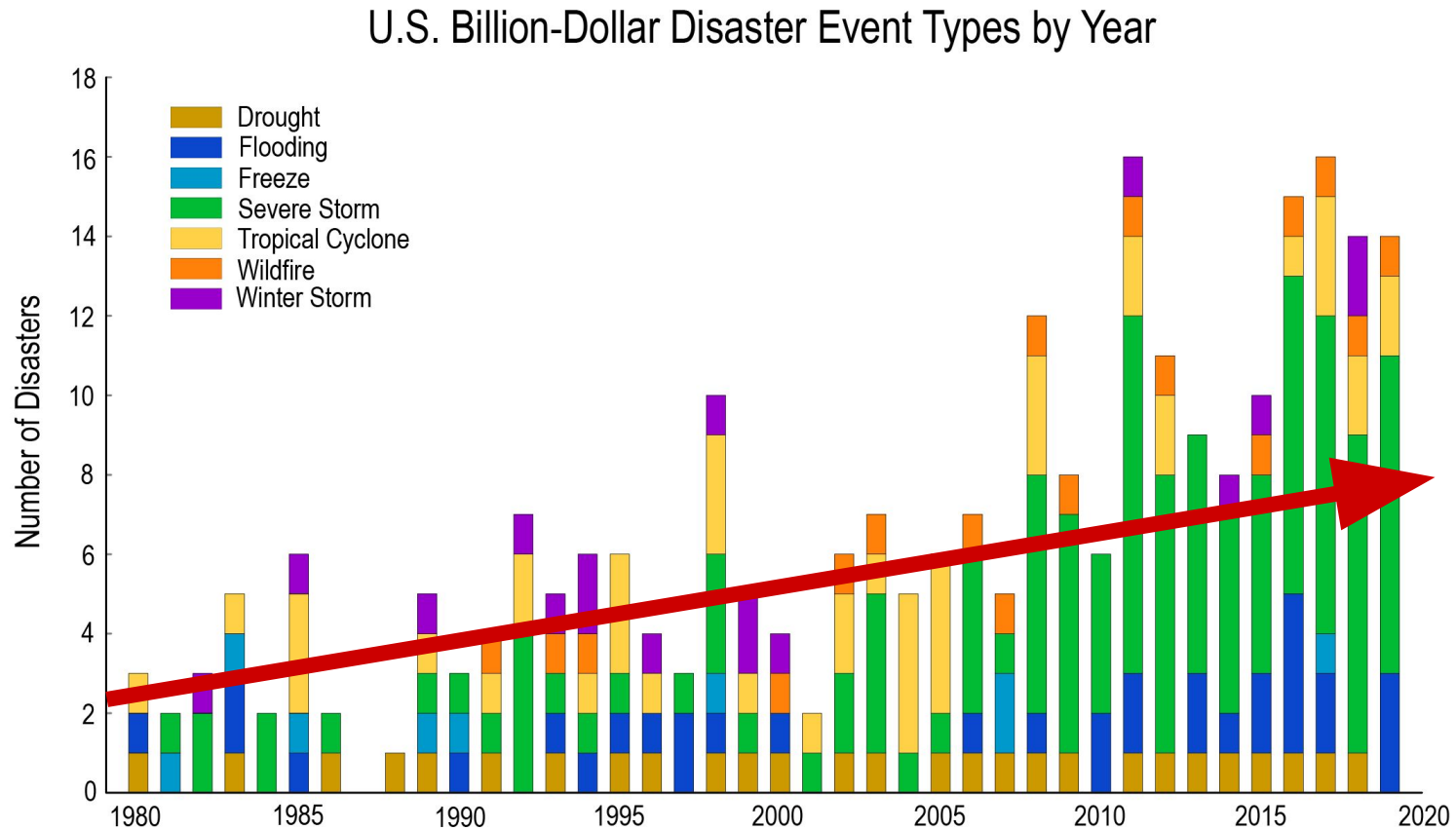

Climate change is happening *now* ...
but we are *too* unprepared

Current gap: Climate Adaptation is Needed

... and their associated cost.

U.S. Billion-Dollar Disaster Event Types by Year

LE∧P

How can AI help? 1. Resilience

Flood forecasting with machine learning models in an operational framework

Sella Nevo, Efrat Morin ✉, Adi Gerzi Rosenthal, Asher Metzger, Chen Barshai, Dana Weitzner, Dafi Voloshin, Frederik Kratzert, Gal Elidan, Gideon Dror, Gregory Begelman, Grey Nearing, Guy Shalev, Hila Noga, Ira Shavitt, Liora Yuklea, Moriah Royz, Niv Giladi, Nofar Peled Levi, Ofir Reich, Oren Gilon, Ronnie Maor, Shahar Timnat, Tal Shechter, Vladimir Anisimov, Yotam Gigi, Yuval Levin, Zach Moshe, Zvika Ben-Haim, Avinatan Hassidim, and Yossi Matias

Short-term, fast, flood prediction

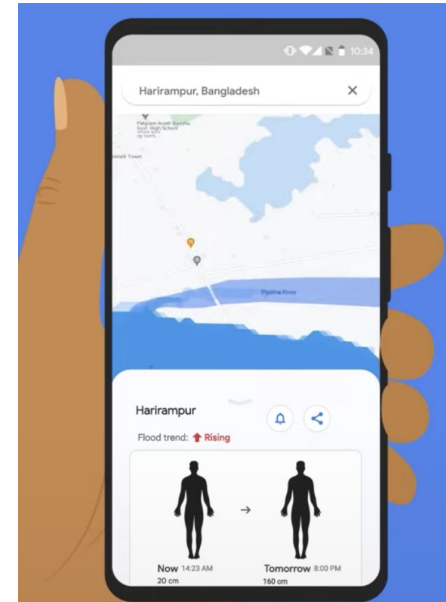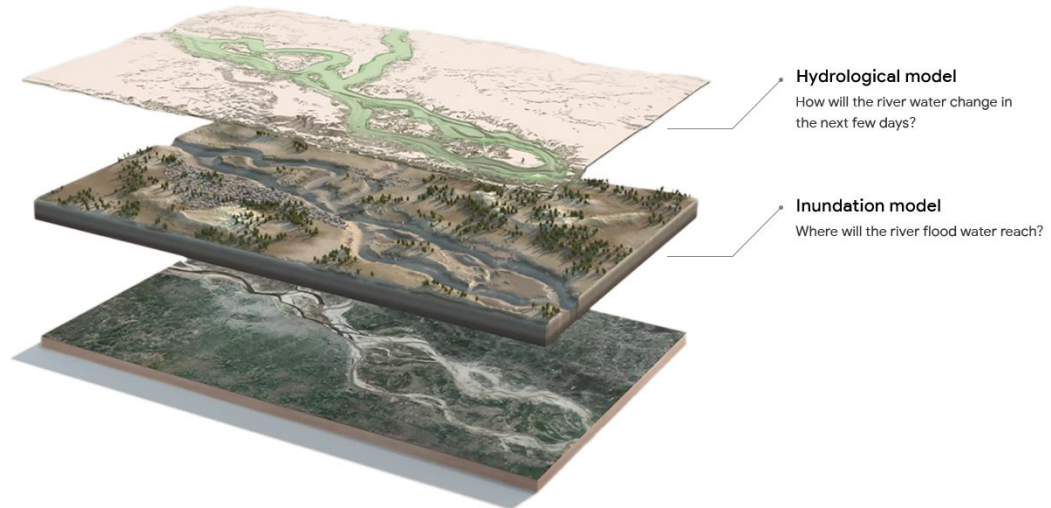Example Google flood forecasting

SUSTAINABILITY

How we're using AI to help address the climate crisis

Nov 02, 2022 · 5 min read

Yossi Matias
VP Engineering & Research and Crisis Response Lead

≪ Share

Hydrological model
How will the river water change in the next few days?

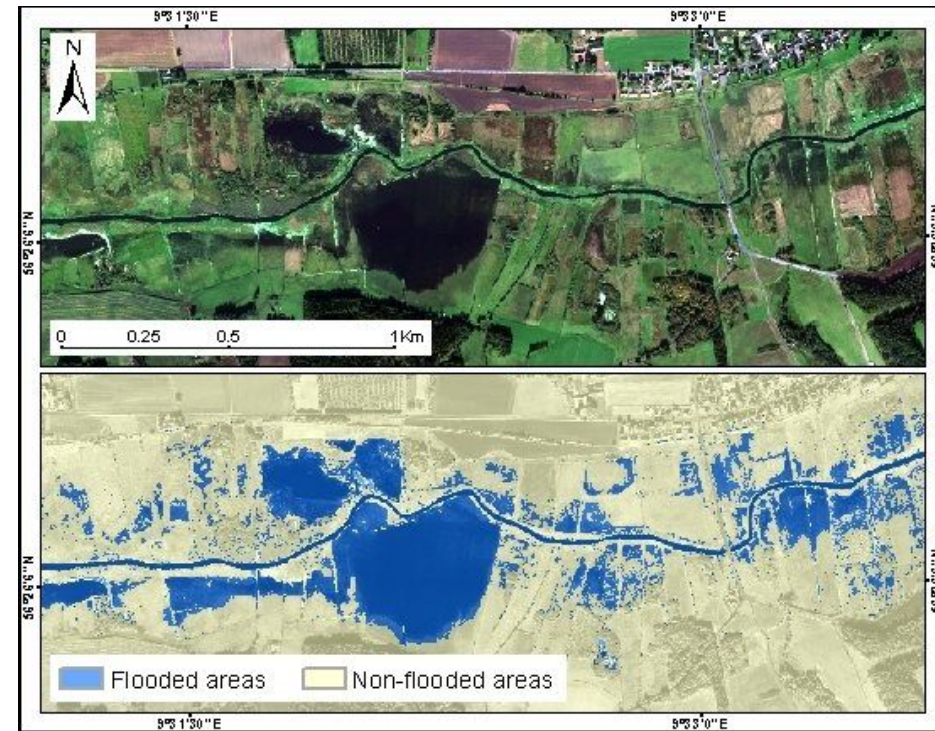Inundation model
Where will the river flood water reach?

LEAP

How can AI help? 1. Resilience

Monitoring: flood mapping
Using deep learning to map inundation, using meter-scale resolution satellite

FLOOD**BASE**

LEAP

How can AI help? 1. Resilience

Monitoring: wildfire progression
Using deep learning to track wildfire progression:
RADR - FIRE/ DOE PNNL
Rapid Analytics for Disaster Response

How can AI help? 2. Improved prediction

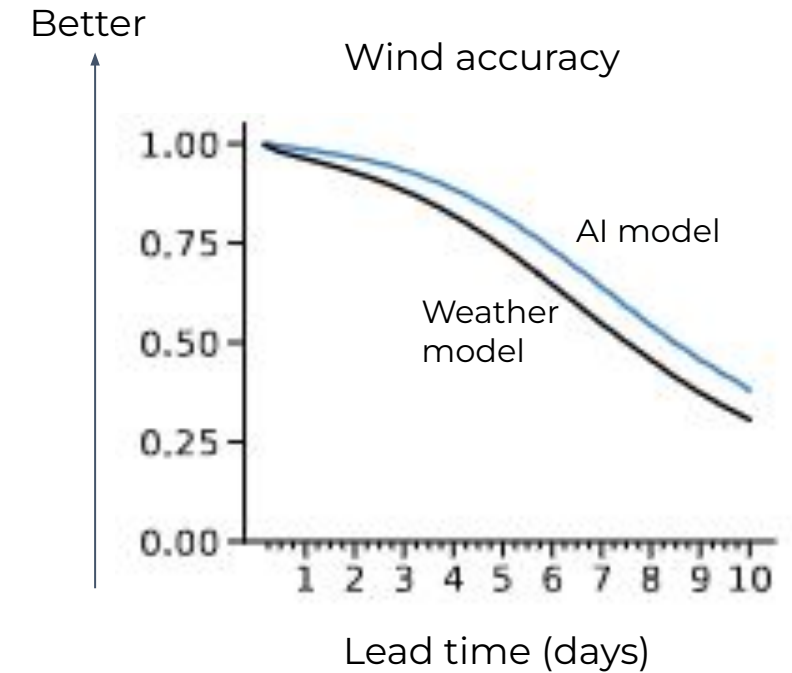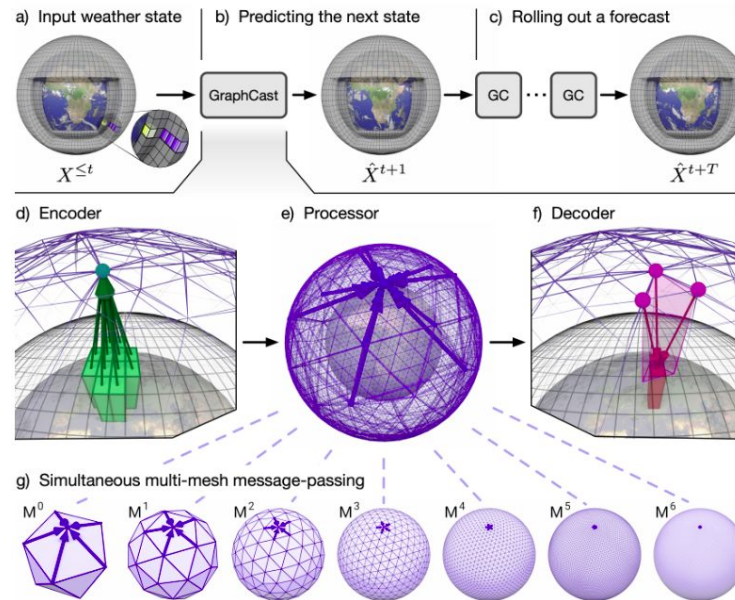## **Weather**: **up to 2 weeks**

AI can have similar or *better* skill than weather centers prediction.
Europe is leading the way (integrating AI in weather forecasting)

GraphCast: Learning skillful medium-range global weather forecasting

Remi Lam[*,1], Alvaro Sanchez-Gonzalez[*,1], Matthew Willson[*,1], Peter Wirnsberger[*,1], Meire Fortunato[*,1], Alexander Pritzel[*,1], Suman Ravuri[1], Timo Ewalds[1], Ferran Alet[1], Zach Eaton-Rosen[1], Weihua Hu[1], Alexander Merose[2], Stephan Hoyer[2], George Holland[1], Jacklynn Stott[1], Oriol Vinyals[1], Shakir Mohamed[1] and Peter Battaglia[1]

[*]equal contribution, [1]DeepMind, [2]Google

and Nvidia, Huawei, ECMWF etc

a) Input weather state   b) Predicting the next state   c) Rolling out a forecast

$X^{\leq t}$ $\hat{X}^{t+1}$ $\hat{X}^{t+T}$

d) Encoder   e) Processor   f) Decoder

g) Simultaneous multi-mesh message-passing

M^0 M^1 M^2 M^3 M^4 M^5 M^6

Better

Wind accuracy

AI model

Weather model

Lead time (days)

How can AI help? 2. Improved prediction

After two weeks no accuracy from AI models (nor from physical models)

t-850

Legend:
- Climatology
- ClimaX/Direct
- PanguWeather/Autoreg
- FourcastNetV2/Autoreg
- GraphCast/Autoreg

Axes: RMSE [K] vs Number of days ahead

Better
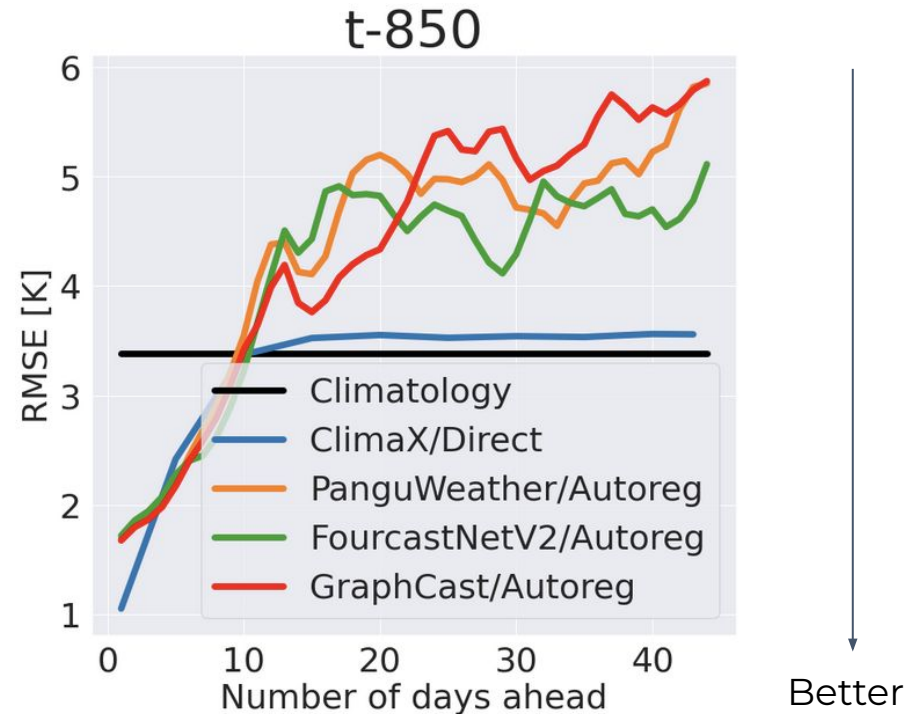
Subseasonal to seasonal prediction is a major challenge
Critical for agriculture, insurance etc
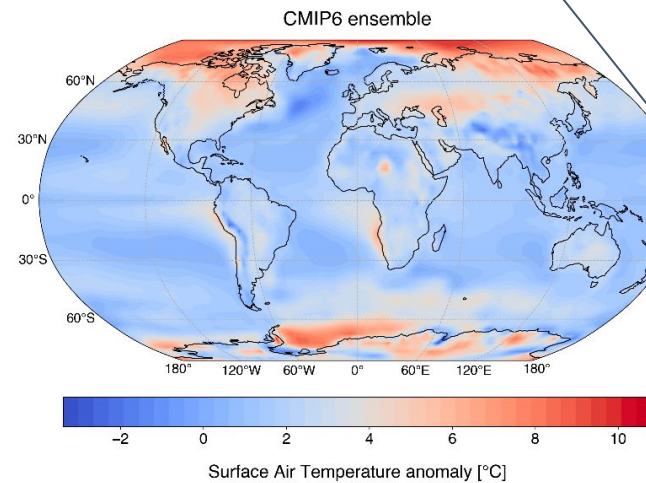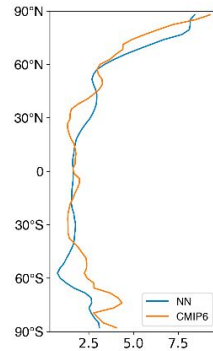Limited data: How many droughts or El Niño have we seen?

How can AI help? 3. Improved projections

AI can post-process climate models to correct them
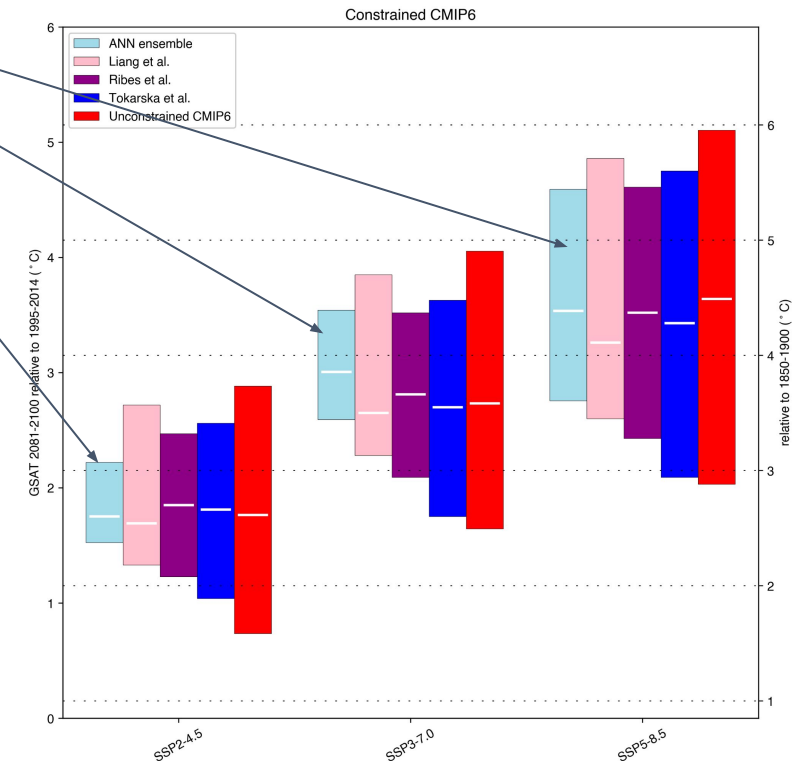and provide better estimate of climate change (here, temperature)
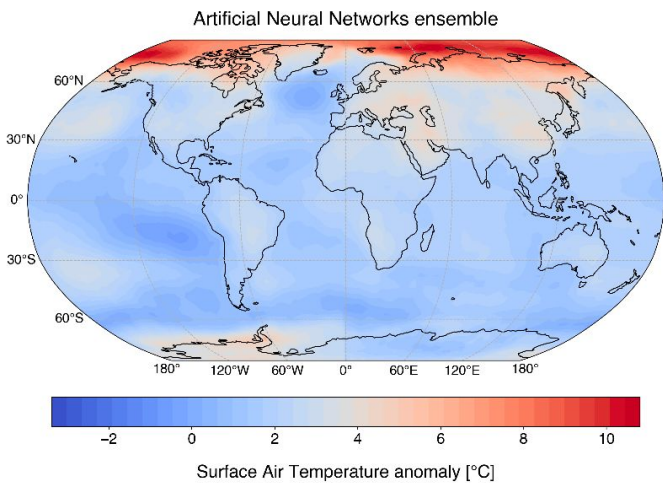
Machine learning projections

Physical model projections

More pessimistic greenhouse gas scenario

Summary

AI can help climate change adaptation & resilience in many ways

- Real-time Monitoring
- Prediction
    - Short-term weather forecasting
    - Short-term climate predictions (a few weeks to year)
    - Climate projections (>10 years)

Still some gaps:

- Seasonal to multi-year predictions, empirical indices for risks...
- Training data!

But we are in a *much better place to face risks* than a few years ago.

Not just academic work, tremendous private interest, boundaries are porous.

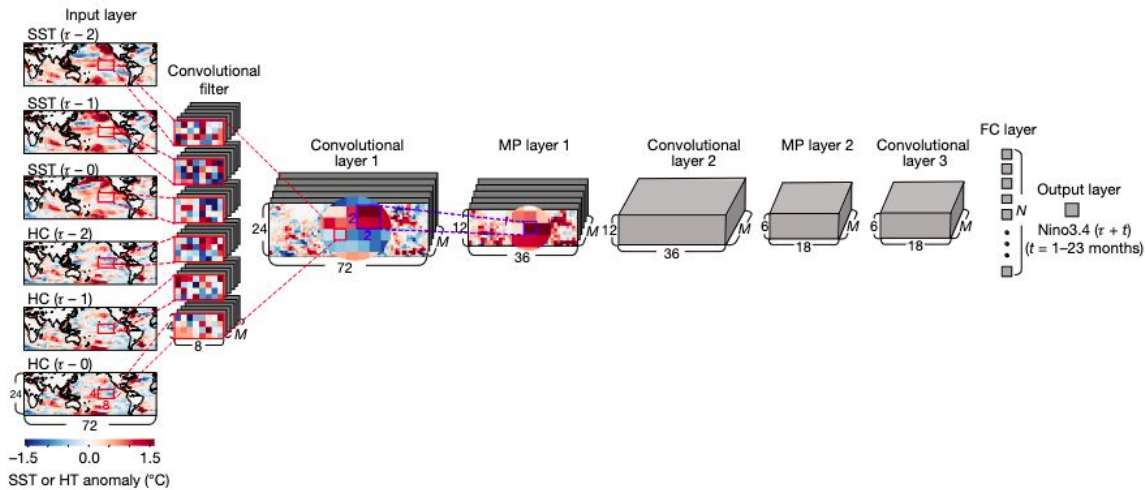Feel free to reach out: pg2328@columbia.edu

L E ∧ P

Seasonal to yearly **climate** prediction:
El Niño
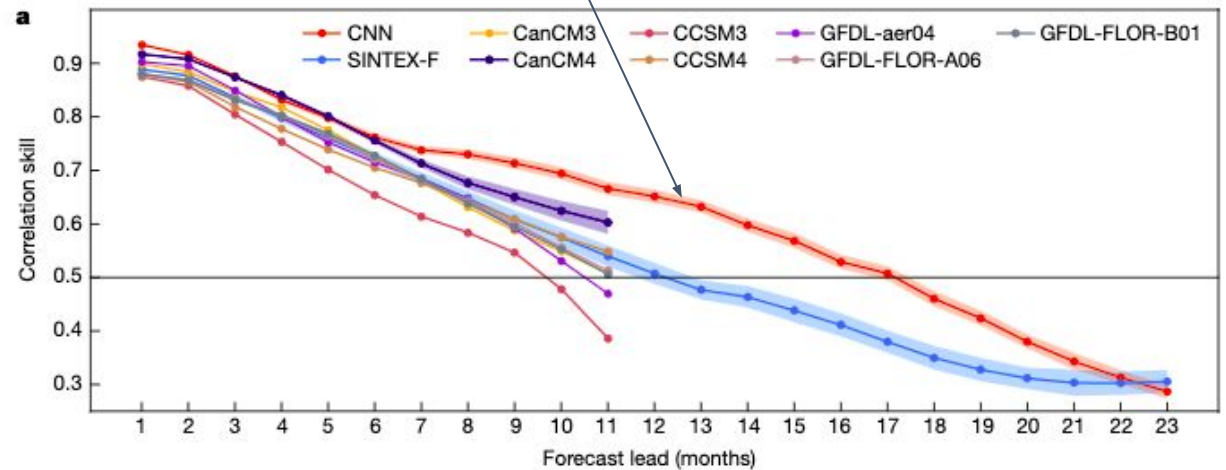
Current gap: Climate Adaptation is Needed
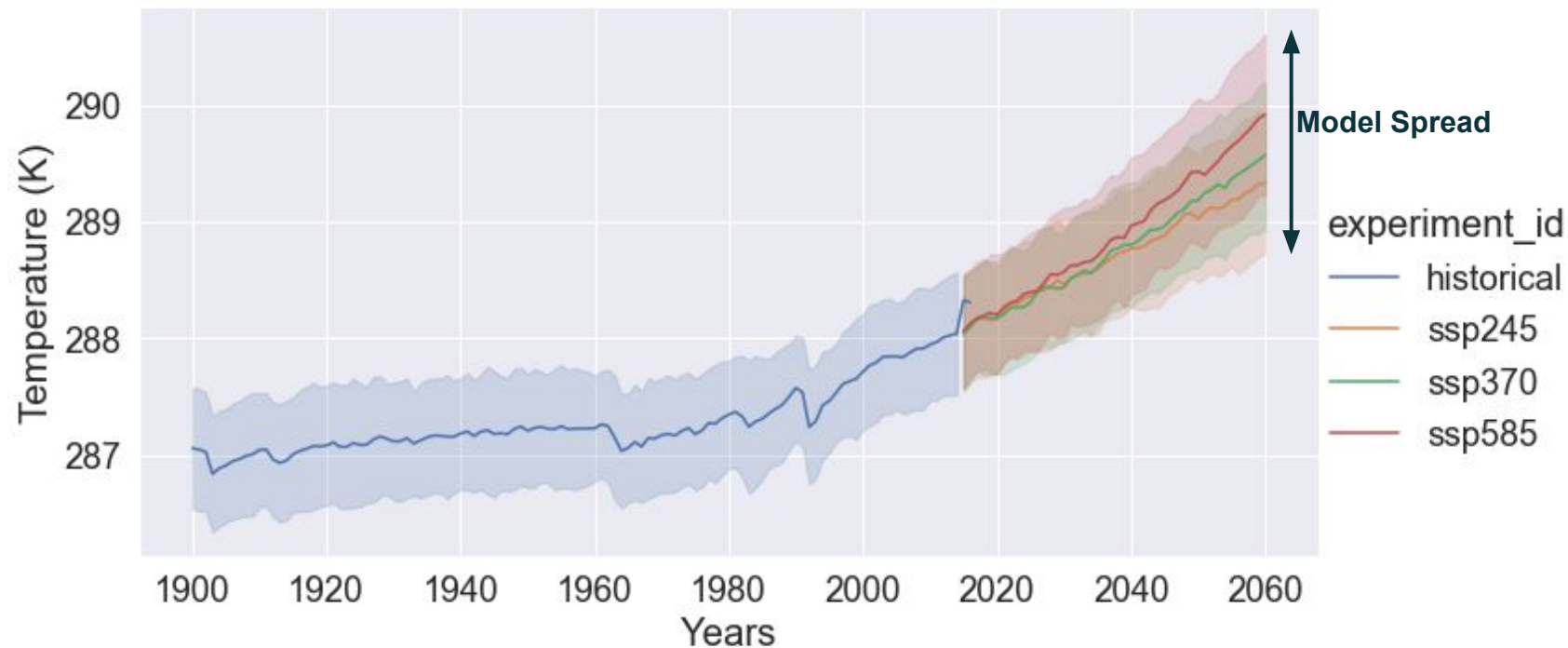## but Requires Reliable Predictions and Projections

Current climate models are too uncertain

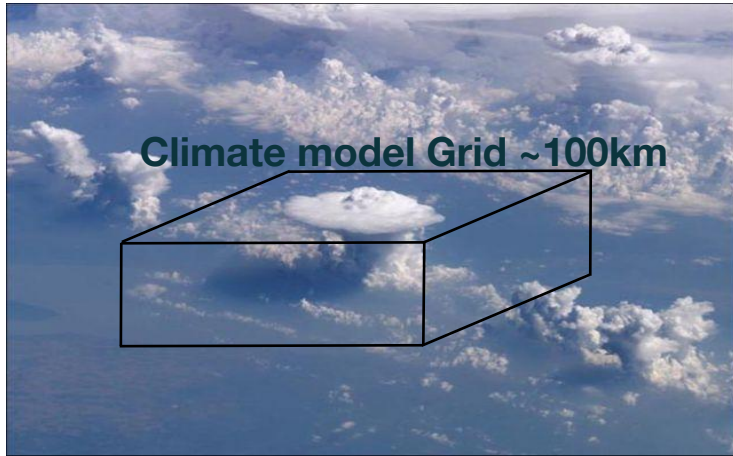
Global Air Temperature - CMIP6 (New Generation)

Climate models' forecasts do not translate into actionable adaptation

LEAP

How can AI help? 3. Improved projections

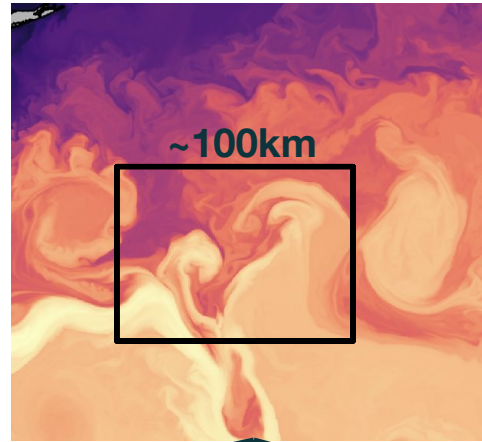## AI can help improve climate models:
unresolved physical processes cause model errors
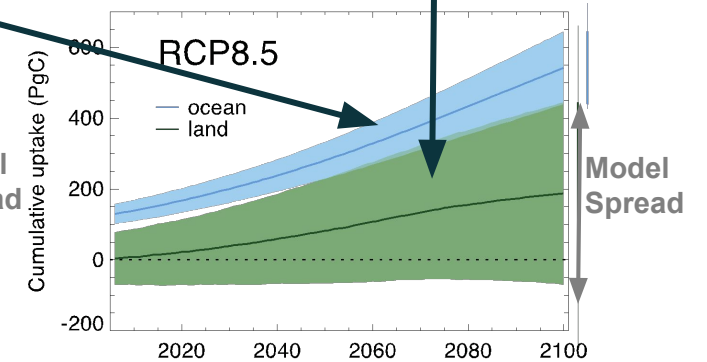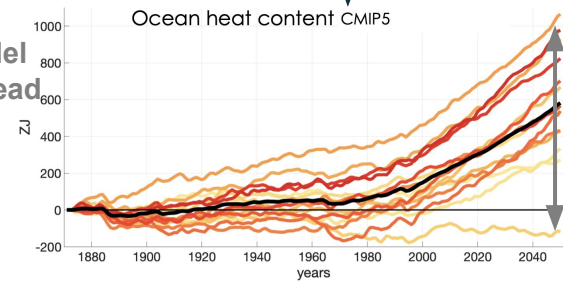

Clouds

Physical + Biological Processes

Climate model Grid ~100km

Ocean Eddies

~100km

Photosynthesis

Light
CO$_2$
O$_2$
H$_2$0
carbohydrates
energy
O$_2$
H$_2$0
CO$_2$

TAS, global, CMIP6.

Historical 44
SSP1-2.6 31
SSP2-4.5 30
SSP5-8.5 32

Model Spread

Ocean heat content CMIP5

Model Spread

RCP8.5

ocean
land

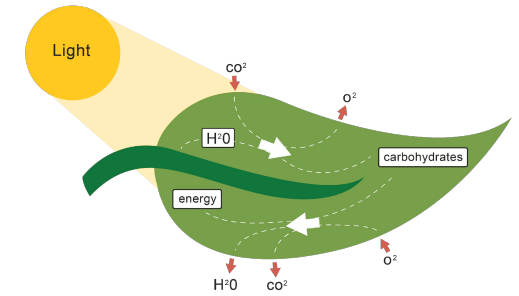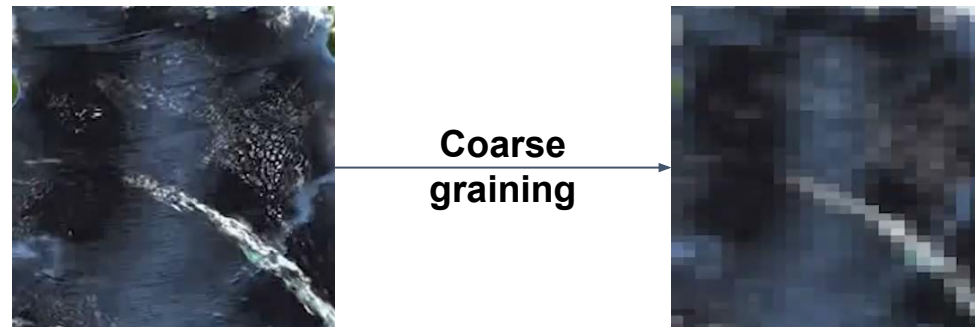Model Spread

LEAP
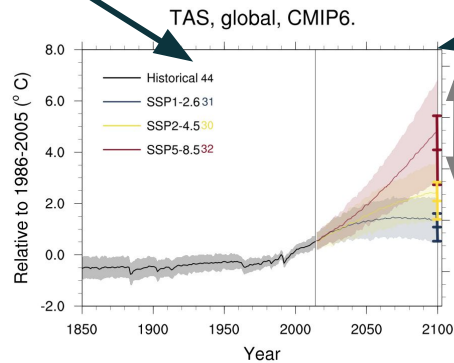
How can AI help? 3. Improved projections

Example of deep clouds (convection)

Deep learning to emulate physical processes at coarse resolution

Coarse graining

Gentine et al., 2018 *GRL*; Rasp et al., 2018 *PNAS*, Shamekh et al 2023, *PNAS*

How can AI help? 3. Improved projections

Step-change improvements in extremes
→ critical for inundation and flood projections

Rasp et al., 2018 PNAS; Shamekh et al .PNAS 2023