Urban Extremes and Cascading Hazards for Monsoon Systems: Opportunities using AI/ML and Digital Twin framework

Dev Niyogi, University of Texas at Austin

Also representing UNESCO- UT City CoLab (Endorsed by WWRP) and
WCRP Atmospheric Urban Digital Twins (AUDT) / Digital Earth Lighthouse Activity

William Stamps Farish Chair Professor
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https://texuslab.org/ https://utcitycolab.org/ https://Niyogi.dev
Email: happy1@utexas.edu
University of Texas at Austin

Urban Hazards in Monsoon Systems

- Urban Heat
- Urban Heavy Rain Events leading to Flooding
  - Monsoon Depressions
  - Tropical Cyclones

Urban Features can be a subgrid scale heterogeneity in operational models

Urban Feedback for solutions needs within city heterogeneity

AMS100

ABSTRACT

1C.1: National Network Research Program on Urban Climate for India

Monday, August 6, 2018 **10:15 AM - 10:30 AM**

City College of New York - SH - 95

BAMS

Integrated Urban Environmental System of Systems for Weather Ready Cities in India

Akshara Kaginalkar, Sachin D. Ghude, U. C. Mohanty, Pradeep Mujumdar, Sudheer Bhakare, Hemant Darbari, Arun K. Dwivedi, Pallavi Gavali, Srujan Gavhale, Sahidul Islam, Gouri Kadam, Sumita Kedia, Manoj Khare, Neelesh Kharkar, Santosh H. Kulkarni, Sri Sai Meher, A. K. Nath, Mohamed Niyaz, Sagar Pokale, Vineeth Krishnan Valappil, Sreyashi Debnath, Chinmay Jena, Raghu Nadimpalli, Madhusmita Swain, Saimy Davis, Shubha Avinash, C. Kishtawal, Prashant Gargava, S. D. Attri, and Dev Niyogi

science from national and international institutes. The urban collaboratory is a system of systems for simulating weather, hydrology, air quality, health, energy, transport, and economy and its interactions. Study and prediction of urban events involve multiscale observations and cross-sector models, heterogeneous data management, and enormous computing power. The consortia program (NSM_Urban) is part of "weather ready cities," under the aegis of India's National Supercomputing Mission. The ecosystem "Urban Environment Science to Society" (UES2S) builds on the integrated cyberinfrastructure with a science gateway for community research and end-user service with modeling and interoperable data. The collaboratory has urban computing, stakeholder participation, and a coordinated means to scaffold projects and ideas into operational tools. It discusses the design and the utilization of high-performance computing (HPC) as a science cloud platform

Authors

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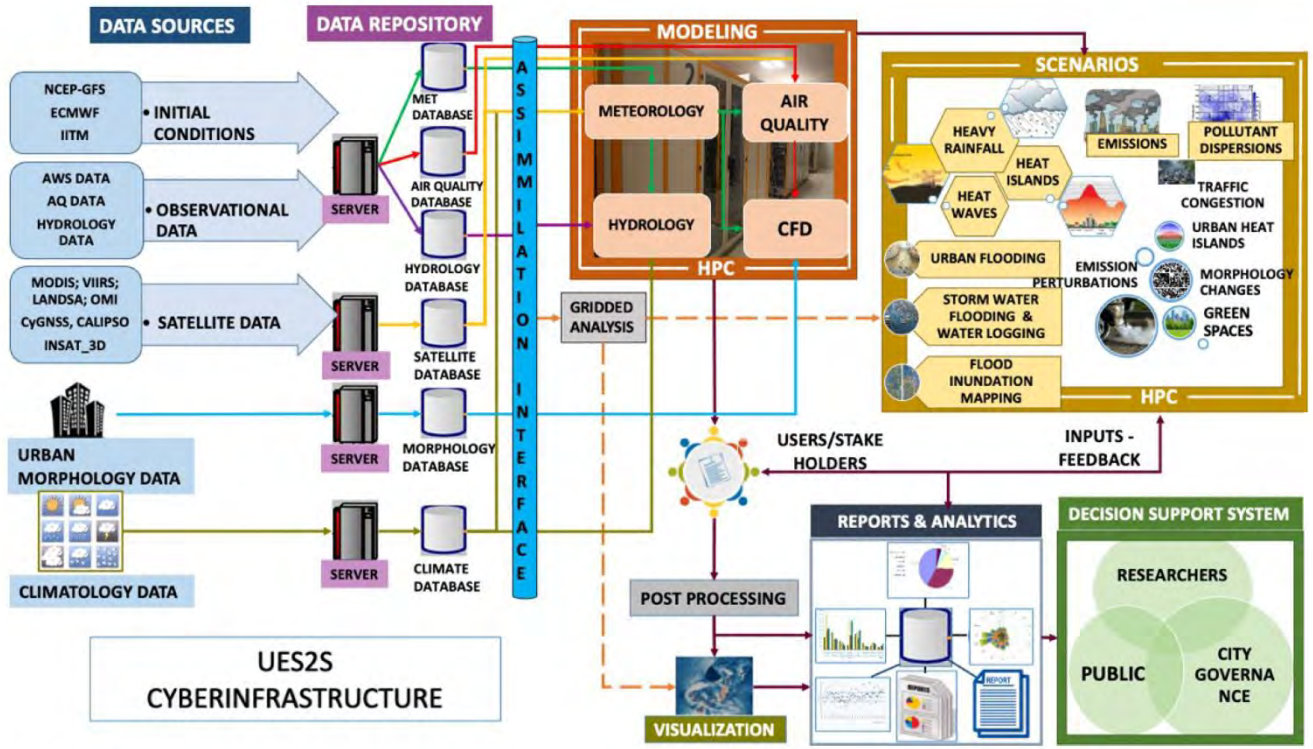
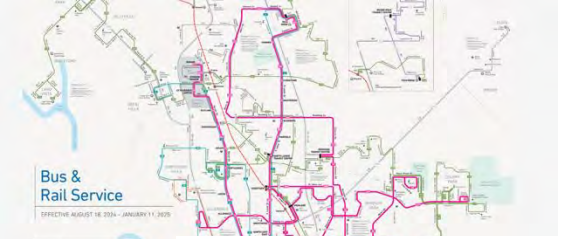


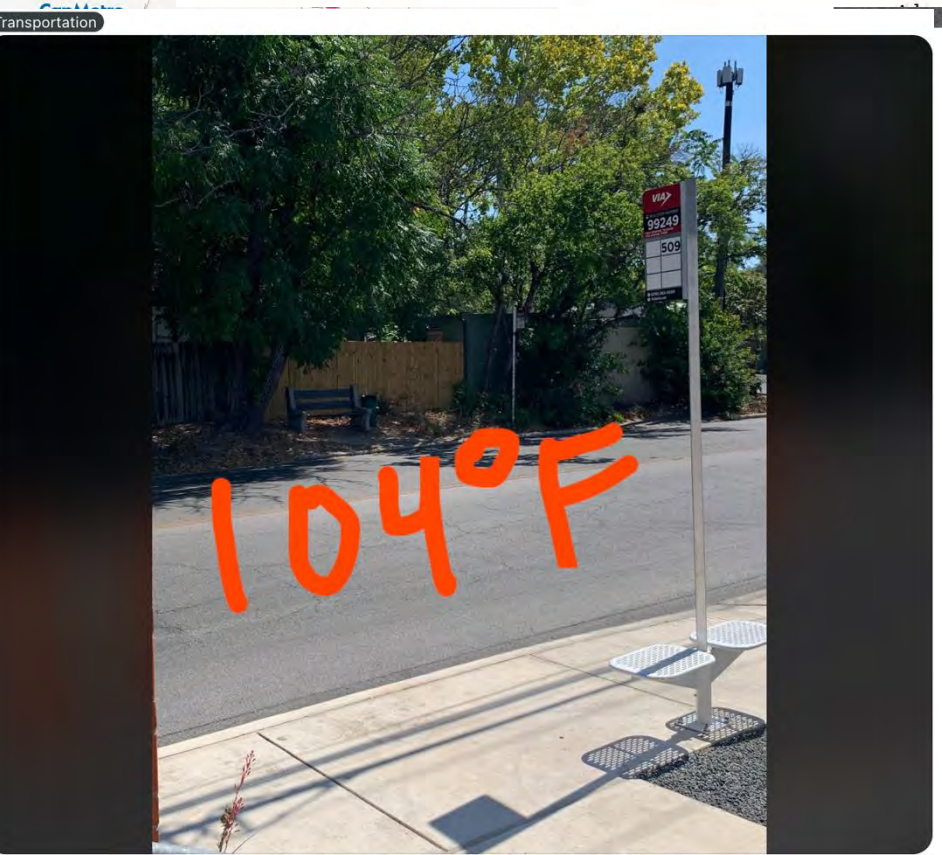
Fig. 5. UES2S system with data hub (blue), science gateway with modeling (red), urban intelligence with scenarios (brown), and DSS with visualization, analytics, and feedback data (mobile, crowd-sourcing) components (green and blue).



Home / India News / Indian cities brace for heatwaves but lack long-term planning, study finds

Indian cities brace for heatwaves but lack long-term planning, study finds

The study examined how nine major Indian cities-Bengaluru, Delhi, Faridabad, Gwalior, Kota, Ludhiana, Meerut, Mumbai, and Surat-are preparing for increasing heatwaves



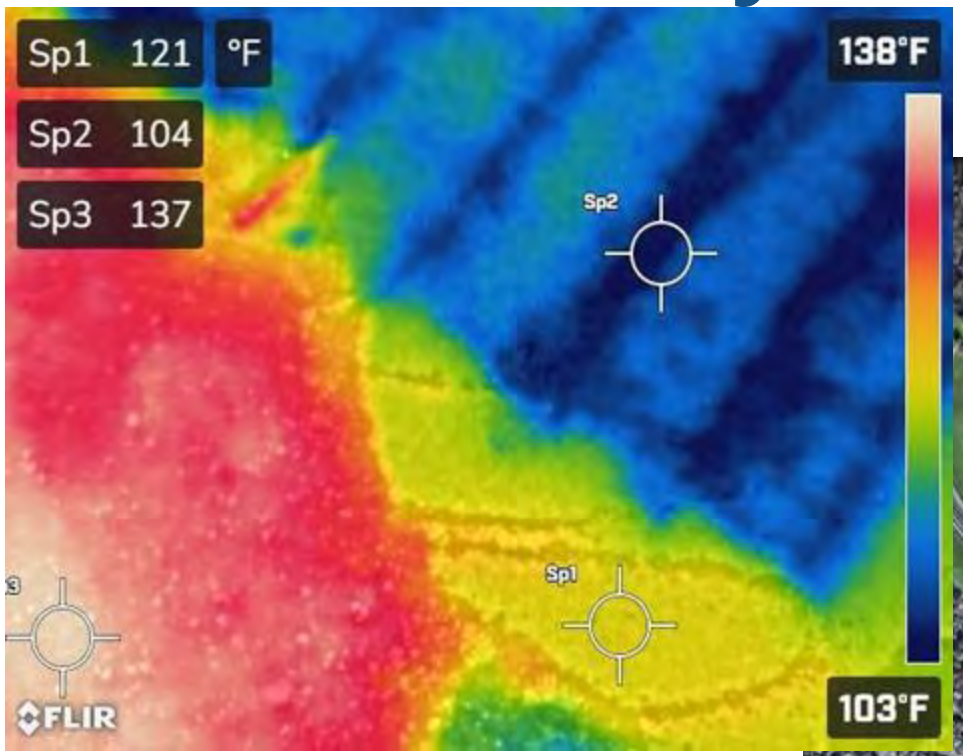
East Austin neighbor says CapMetro bus stop needs more shade coverings; officials say they're working on it

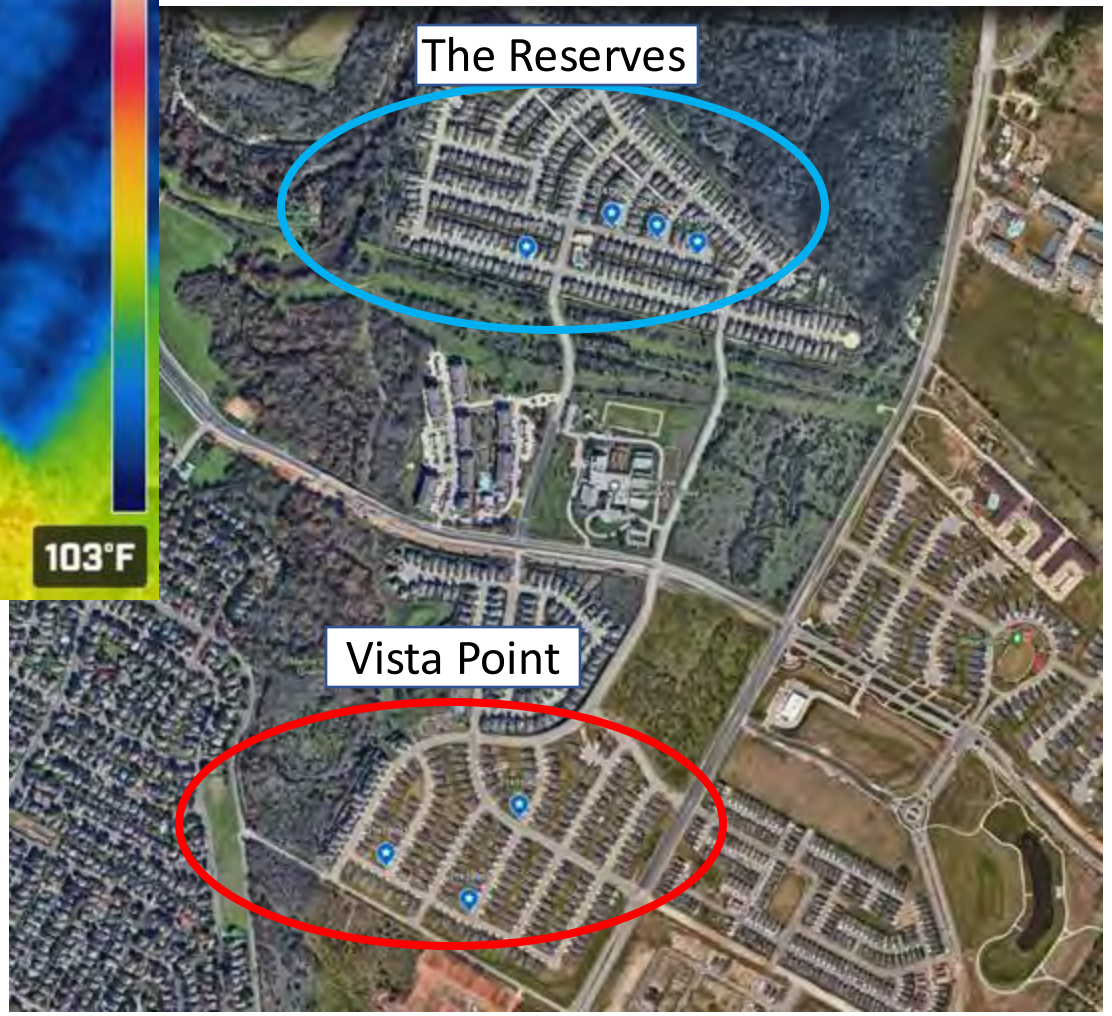
by: Candy Rodriguez
Posted: Jul 15, 2022 / 09:50 AM CDT
Updated: Jul 15, 2022 / 10:37 AM CDT

https://www.kxan.com/news/local/austin/east-austin-neighbor-says-capmetro-bus-stop-needs-more-shade-coverings-officials-say-theyre-working-on-it/

https://www.reddit.com/r/sanantonio/comments/w33994/the_bus_stops_in_this_city_are_sad_one_has_no/

Cool Pavement Priority





Hyperlocalization

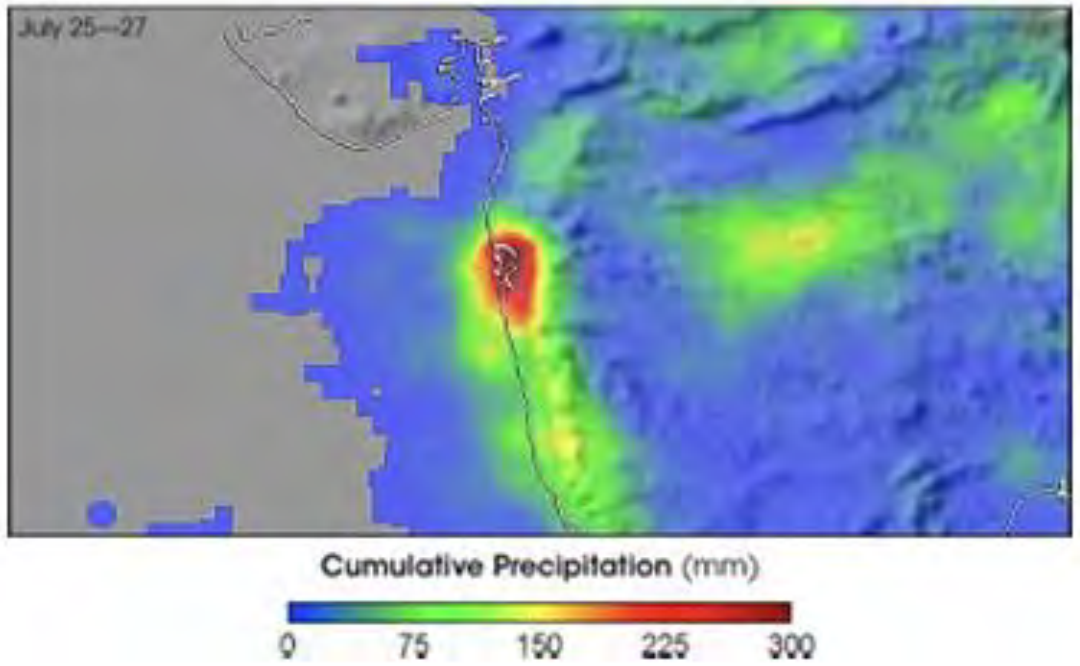
CIMBY – “Climate in My Backyard”

How?

Continued understanding of processes and scale interactions

- often sustained evidence
- “similar to pharma drug discovery”

(b)



QUARTERLY JOURNAL OF THE ROYAL METEOROLOGICAL SOCIETY
Q. J. R. Meteorol. Soc. **134**: 1897–1910 (2008)
Published online in Wiley InterScience
(www.interscience.wiley.com) DOI: 10.1002/qj.325

RMetS
Royal Meteorological Society

Analysis of the 26 July 2005 heavy rain event over Mumbai, India using the Weather Research and Forecasting (WRF) model

Anil Kumar,[a,b] J. Dudhia,[a] R. Rotunno,[a] Dev Niyogi[b]* and U. C. Mohanty[c]
[a]*National Center for Atmospheric Research, Boulder, Colorado, USA*
[b]*Purdue University, Department of Earth and Atmospheric Science, West Lafayette, Indiana, USA*
[c]*Indian Institute of Technology, Centre for Atmospheric Sciences, Delhi, India*

Urbanization signature in the observed heavy rainfall climatology over India

C. M. Kishtawal, Dev Niyogi ✉, Mukul Tewari, Roger A. Pielke Sr, J. Marshall Shepherd

First published: 20 November 2009 | https://doi.org/10.1002/joc.2044 | Citations: 276

Atmos. Chem. Phys., 8, 5975–5995, 2008
www.atmos-chem-phys.net/8/5975/2008/

Atmospheric Chemistry and Physics

Effect of explicit urban land surface representation on the simulation of the 26 July 2005 heavy rain event over Mumbai, India

M. Lei[1], D. Niyogi[1], C. Kishtawal[2], R. A. Pielke, Sr.[3], A. Beltrán-Przekurat[3], T. E. Nobis[3], and S. S. Vaidya[4]

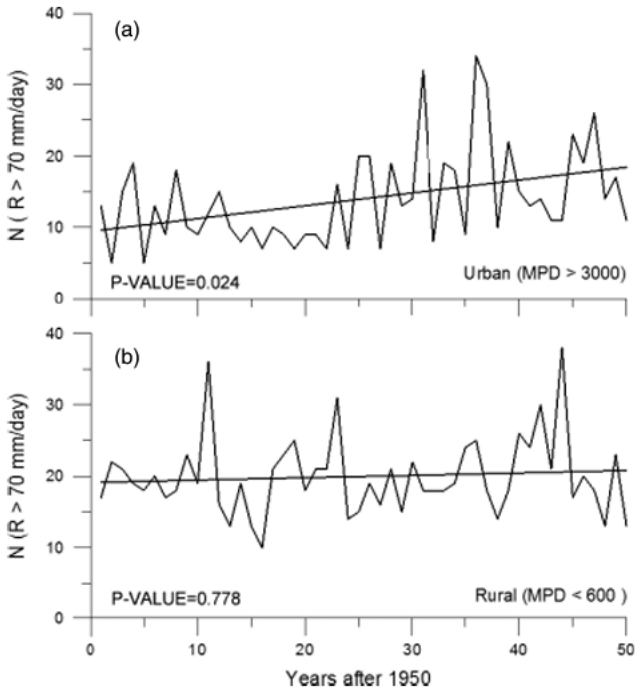
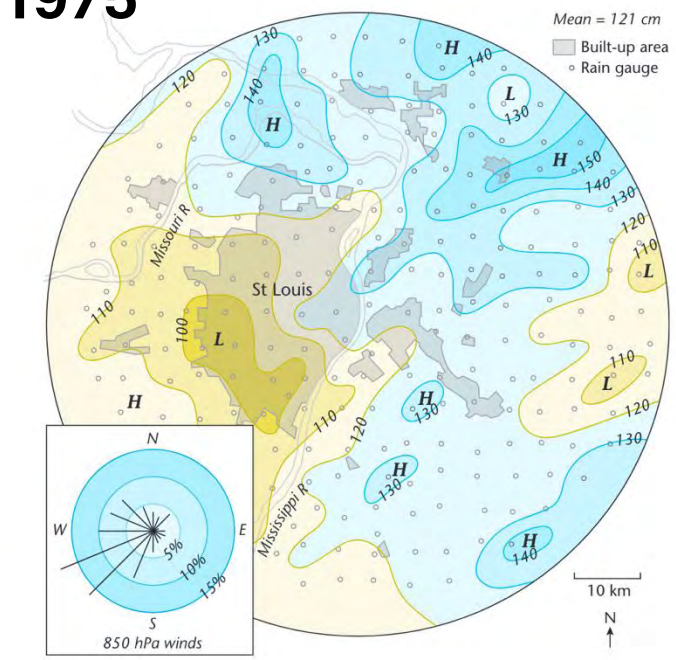


Figure 4. Upper panel shows the time series of the number of heavy rainfall (rain >70 mm/day) events over urban regions of study domain. Lower panel shows the same for the rural regions (number of rural events are normalized to equal the urban area). Lower/upper thresholds of MPD used to define a grid as urban/rural are indicated at the bottom of each figure.

Urban Precipitation and Urban Heat are interlinked

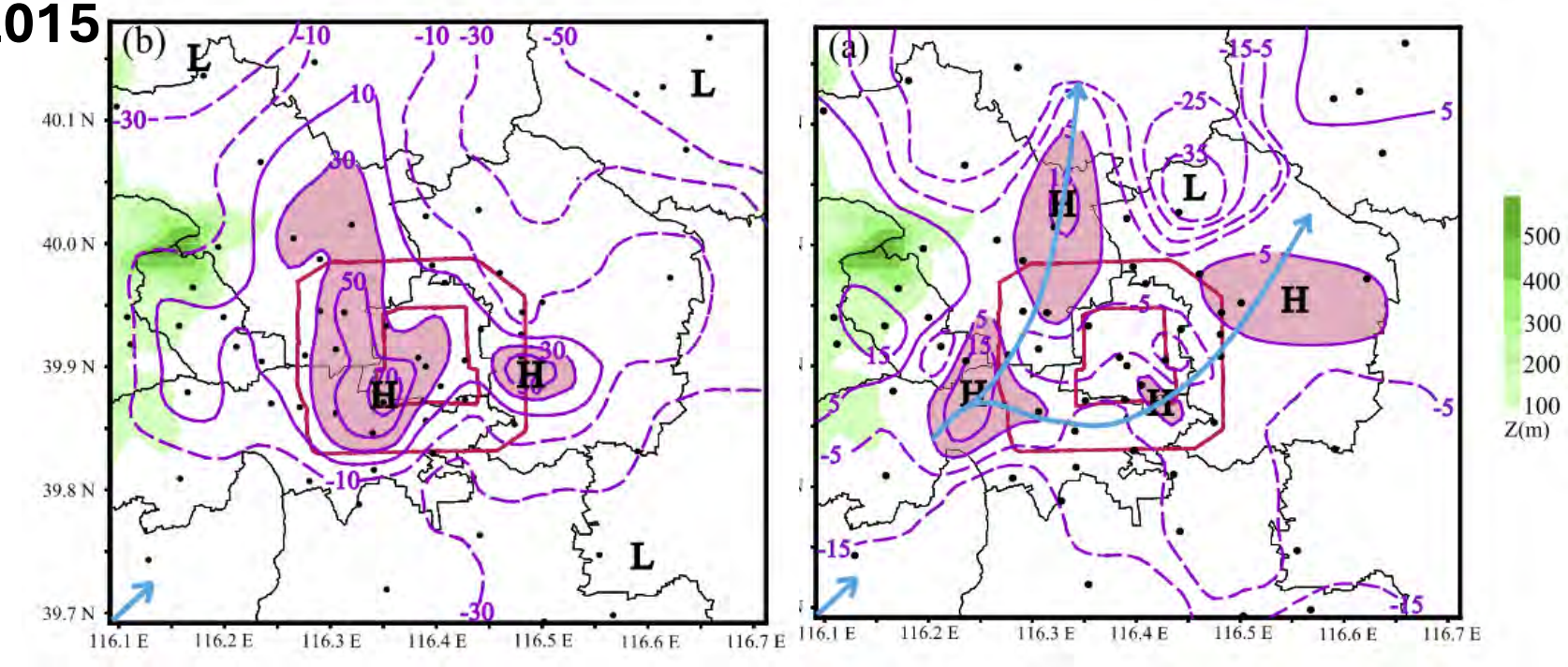
1975



Huff et al., 1971–1975 Summary of METROMEX Volume 1

Dou et al., 2015 *Journal of Applied Meteorology and Climatology*

2015



High UHI **Low UHI**

- Urban boundary layer (UBL) influence on convective precipitation has been studied for >50 years, but is under researched
- METROMEX (inland St. Louis): Urban modification *does* exist, combination of urban heat island (UHI), mechanical turbulence by buildings, and/or industrial aerosol production
- Beijing (inland): urban precipitation is modulated by UHI intensity

scientific reports

Article | Open access | Published: 13 May 2019

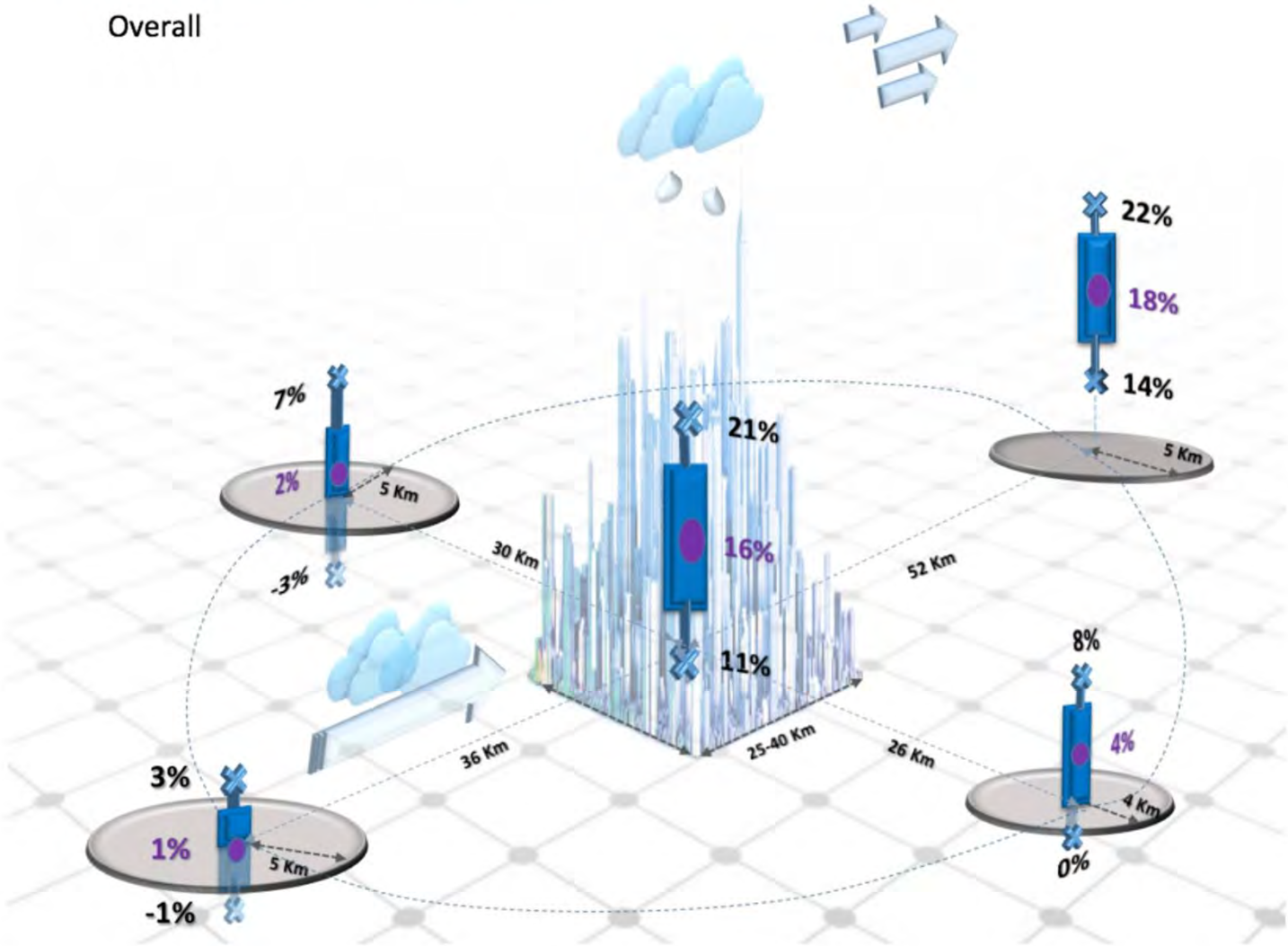
Meta-analysis of urbanization impact on rainfall modification

Jie Liu & Dev Niyogi ✉

Scientific Reports **9**, Article number: 7301 (2019) | Cite this article

Figure 2

From: Meta-analysis of urbanization impact on rainfall modification



Precipitation changes over urban areas and for surrounding landscape. The bars indicate the sample standard deviation for the precipitation change, and circles correspond to the mean change in precipitation location. On average, urban areas and the surrounding region experienced precipitation increases. The largest signal noted in a number of studies, was prominently in the downwind region of the city and experienced the highest rainfall change: 18% increase on average, (a range of 14 to 22% with one standard deviation). The distance over which these changes occurred (mostly increases in rainfall) is approximately 52 km downwind, and about 31 to 41 km upwind.

PNAS RESEARCH ARTICLE | EARTH, ATMOSPHERIC, AND PLANETARY SCIENCES OPEN ACCESS

Global scale assessment of urban precipitation anomalies

Xinxin Sui [a], Zong-Liang Yang [b], Marshall Shepherd[c], and Dev Niyogi [a,b,1]

Edited by Karen Seto, Yale University, New Haven, CT; received July 24, 2023; accepted June 7, 2024

September 9, 2024 121 (38) e2311496121

Significance

This research reports a global analysis of urban precipitation anomalies encompassing over one thousand cities worldwide. While earlier studies have focused on the impact of urbanization on precipitation for specific cities or isolated thunderstorm cases, our research breaks innovative ground by mapping global urban precipitation hotspots over the past 20 y. This study provides global evidence of noticeable urban precipitation anomalies, especially in hot and humid climates. Beyond the anticipated influence of local climate, our findings reveal that higher levels of urbanization enhance these urban precipitation anomalies. This research not only deepens our understanding of how cities shape precipitation but also establishes the groundwork for incorporating urbanization considerations into future precipitation projections.

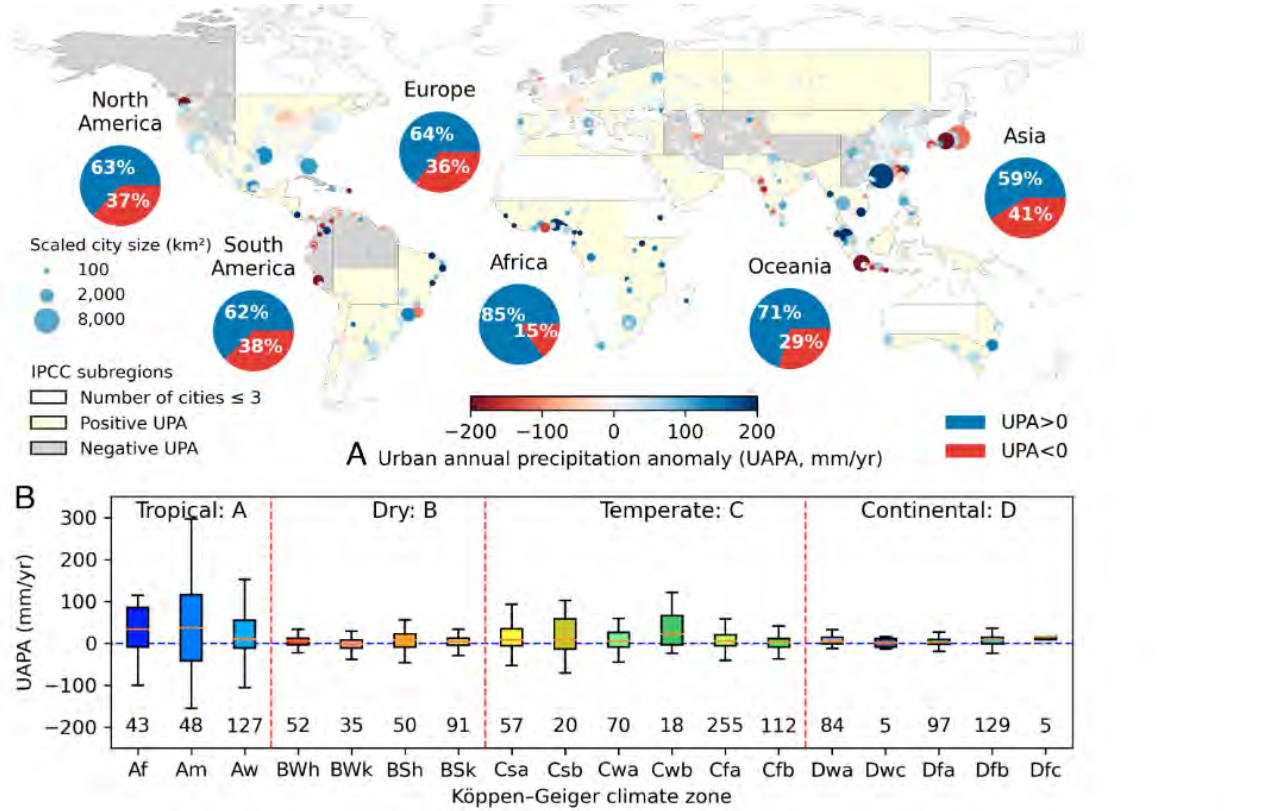


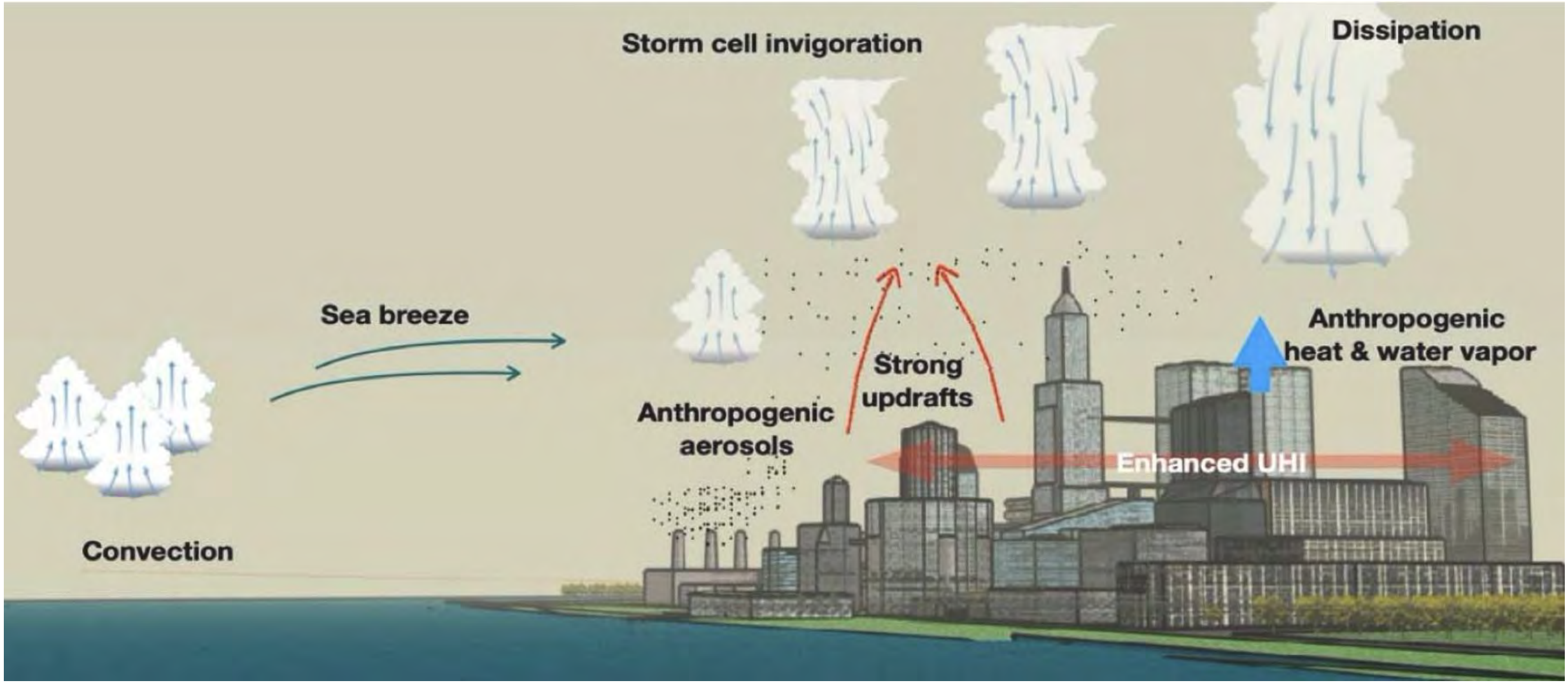
Fig. 1. Global urban annual precipitation anomalies. The urban annual precipitation anomalies according to continents and climate zones. (*A*) The color of the base map shows that the average of urban precipitation anomalies in the IPCC subregion is positive or negative. Each dot on the base map indicates one city, and the size and color of the dot describe the size and precipitation anomaly extent of the city. The pie charts show the percentage of cities with positive and negative (more or less precipitation over urban grids) urban precipitation anomalies in each continent (the pie charts for each IPCC subregion are shown in *SI Appendix*, Fig. S15). (*B*) The box plot for urban annual precipitation anomalies for cities in different climate zones. The numbers above the axis are the number of cities in that climate zone.

The Washington Post
Democracy Dies in Darkness

Why cities are getting more rainy

A study has found most cities receive significantly more rain than nearby rural regions, an effect that has become more pronounced over the past two decades.

Urban Precipitation Mechanisms



Source: González-Cruz et al., 2021 *Urban Climate*

Home > Natural Hazards > Article

First results from the Doppler Weather Radar observations over Mumbai urban region during the inter-seasonal phases of 2018 monsoon

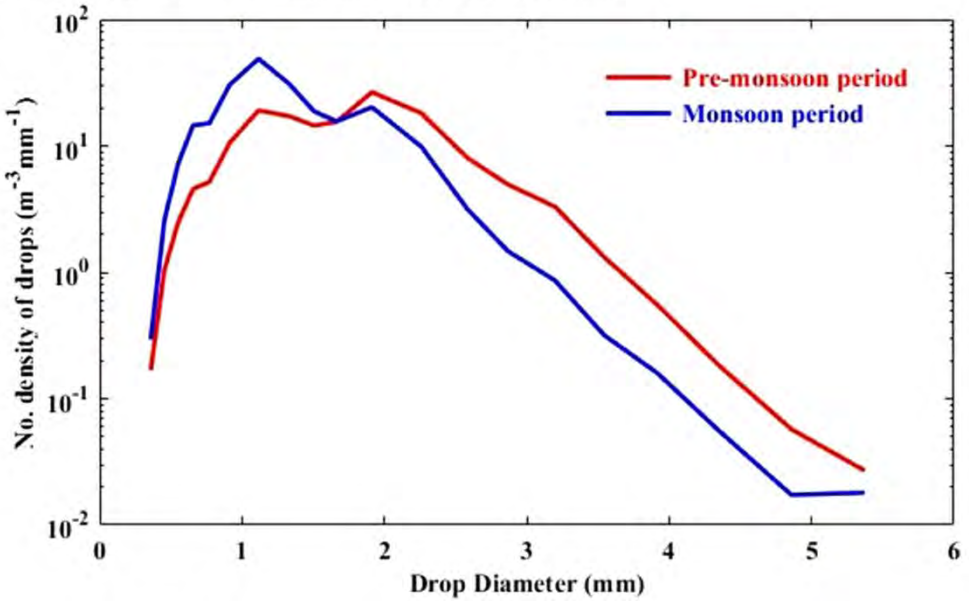
Original Paper | Published: 02 March 2021

Volume 107, pages 1413–1426, (2021) Cite this article

Download PDF

Kaustav Chakravarty, S. Gayathridevi, Jaan Mohmmad, K. S. Hosalikar, G. Pandithurai & Dev Niyogi

From: First results from the Doppler Weather Radar observations over Mumbai urban region during the inter-seasonal phases of 2018 monsoon



Inter-seasonal variability of raindrop size distribution over Mumbai

Indian Institute of Tropical Meteorology (IITM), Pune

PRESS RELEASE (14.9.2024)

India's first Urban Radar Network in Mumbai: Enhancing Rainfall Monitoring with City-Wide Coverage

Key Highlights

- **India's first Urban Radar Network in Mumbai is dedicated to Nation** on 14th September 2024
- Inaugurated by Dr. M. Ravichandran, Secretary MoES during the Stakeholders Workshop on "Severe Weather and Meteorological Services over Maharashtra", Mumbai

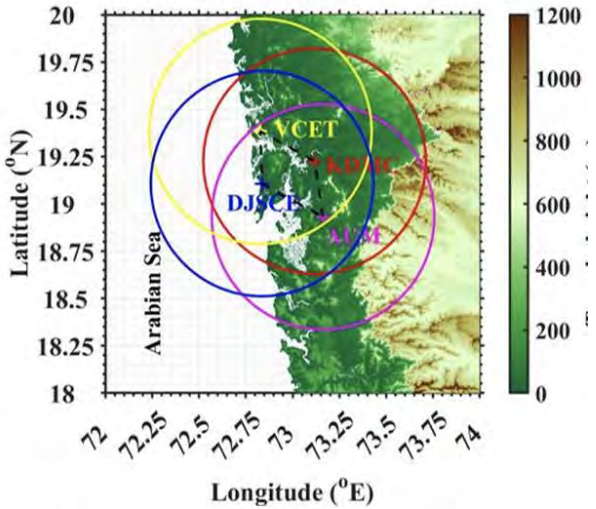


Fig.: Urban Radar Network over Mumbai comprising of four X-band polarimetric radars. Each circle indicate 60 km radar coverage. Radars are separated at distance of 30 km.

About 10 – 15 years from Research to Operational Setup

Br J Pharmacol. 2011 Mar; 162(6): 1239–1249.
doi: 10.1111/j.1476-5381.2010.01127.x
PMCID: PMC3058157
PMID: 21091654

Principles of early drug discovery

JP Hughes,[1] S Rees,[2] SB Kalindjian,[3] and KL Philpott[3]

Associated Data

▸ Supplementary Materials

Abstract

Go to: ▸

Developing a new drug from original idea to the launch of a finished product is a complex process which can take 12–15 years and cost in excess of $1 billion. The idea for a target can come from a variety of sources including academic and clinical research and from the commercial sector. It may take many years to build up a body of supporting evidence before selecting a target for a costly drug discovery programme. Once a target has been chosen, the pharmaceutical industry and more recently some academic centres have streamlined a number of early processes to identify molecules which possess suitable characteristics to make acceptable drugs. This review will look at key preclinical stages of the drug discovery process, from initial target identification and validation, through assay development, high throughput screening, hit identification, lead optimization and finally the selection of a candidate molecule for clinical development.

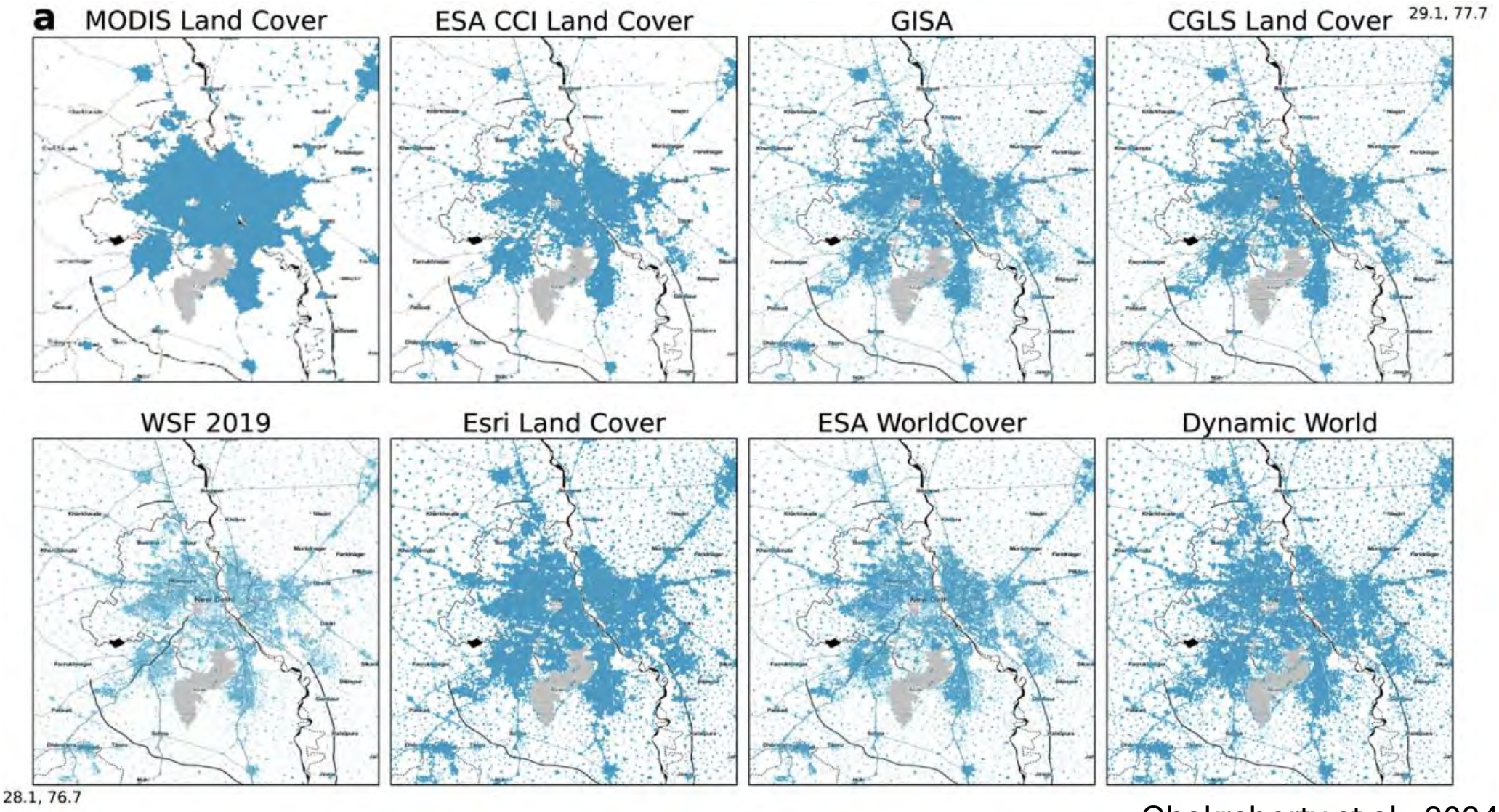
Keywords: drug discovery, high throughput screening, target identification, target validation, hit series, assay development, screening cascade, lead optimization

12- 15 years!

How can we Speed-up “Disruption” or R2O in Weather and Climate Services?

Different Urban Datasets Show Different Extent of Urbanization- Need Dynamic Urban Mapper and Parameter development

Delhi, India

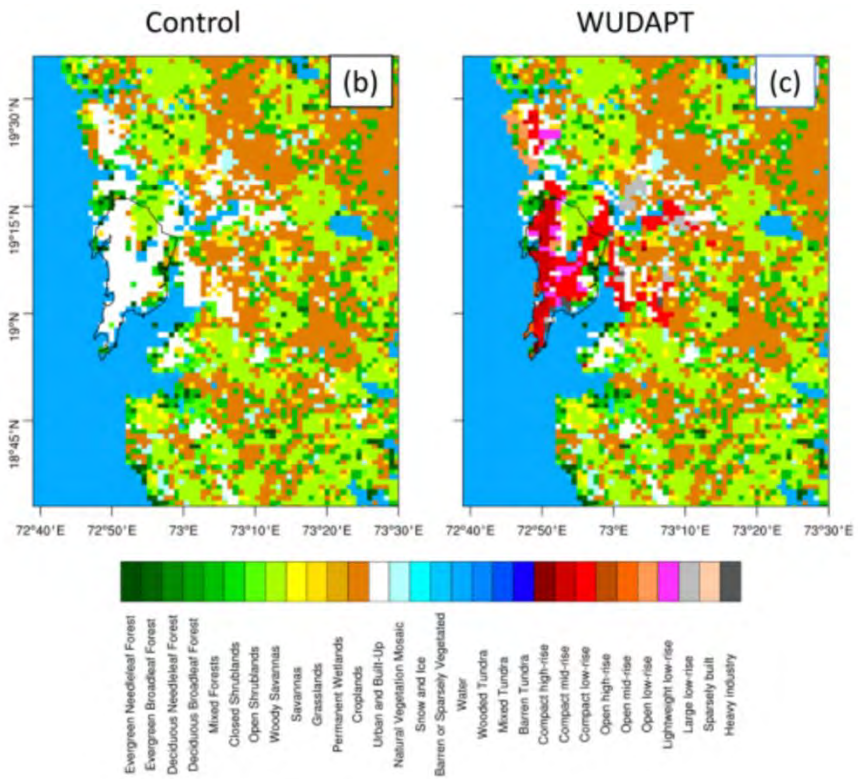


Chakraborty et al., 2024

Urban Climate
Volume 32, June 2020, 100616

Improved simulation of very heavy rainfall events by incorporating WUDAPT urban land use/land cover in WRF

Pratiman Patel [a], Subhankar Karmakar [a b], Subimal Ghosh [a c], Dev Niyogi [d]



World Urban Data Analysis Portal/ Tools

Urban Climate
Volume 28, June 2019, 100459

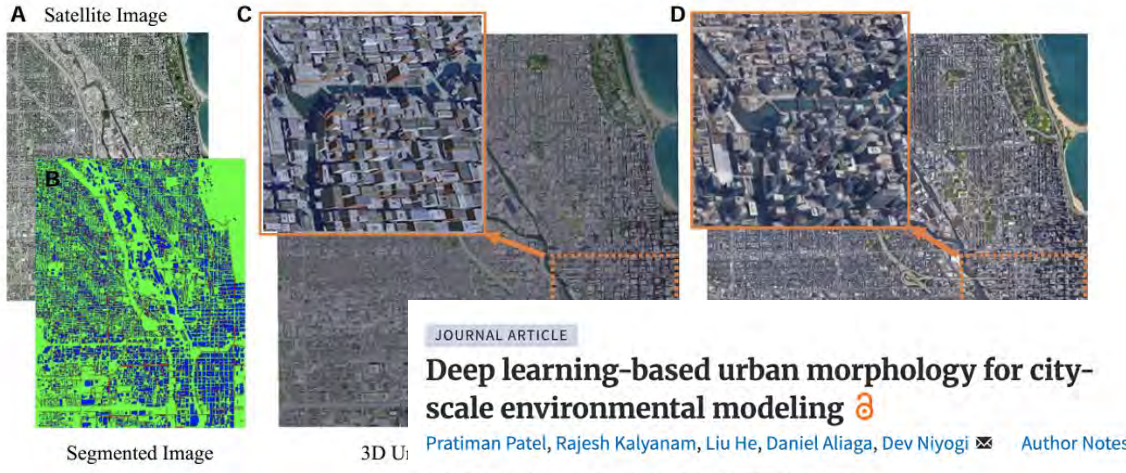
Pathway using WUDAPT's Digital Synthetic City tool towards generating urban canopy parameters for multi-scale urban atmospheric modeling

Home > Computational Urban Science > Article

Digitizing cities for urban weather: representing realistic cities for weather and climate simulations using computer graphics and artificial intelligence

Opinion paper | Open access | Published: 12 March 2024
Volume 4, article number 8, (2024) Cite this article

Computational Urban Science



JOURNAL ARTICLE

Deep learning-based urban morphology for city-scale environmental modeling

Pratiman Patel, Rajesh Kalyanam, Liu He, Daniel Aliaga, Dev Niyogi Author Notes

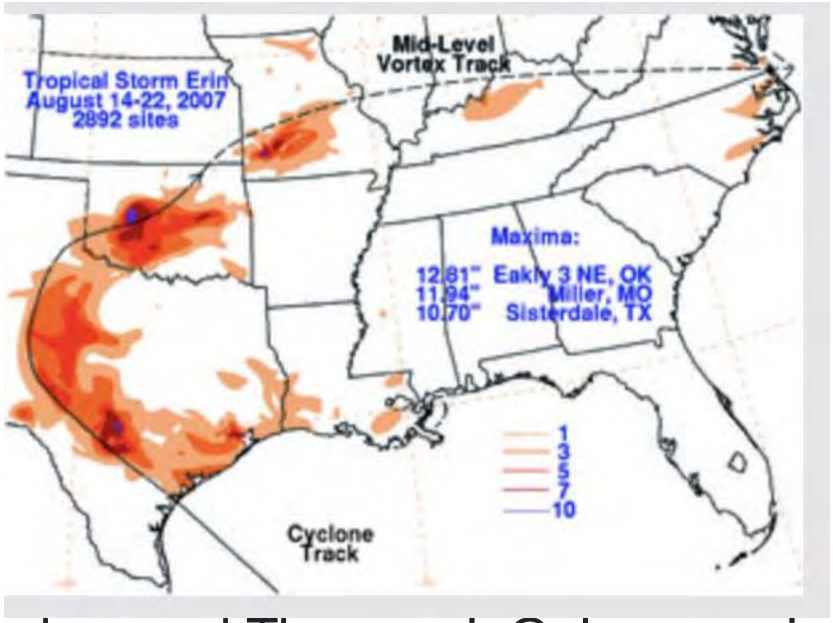
PNAS Nexus, Volume 2, Issue 3, March 2023, pgad027,
https://doi.org/10.1093/pnasnexus/pgad027

Another example/// Brown Ocean Effect

- Emanuel K, Callaghan J, Otto P (2008) A hypothesis for the redevelopment of warm-core cyclones over northern Australia. Mon Weather Rev 136:3863–3872. doi:10.1175/2008MWR2409.1

"It is here hypothesized that the intensification or reintensification of these systems, …possible by large vertical heat fluxes from a deep layer of very hot, sandy soil that has been wetted by the first rains of the approaching systems, significantly increasing its thermal diffusivity."

Chang, H.I., Niyogi, D., Kumar, A., Kishtawal, C.M., Dudhia, J., Chen, F., Mohanty, U.C. and Shepherd, M., 2009. Possible relation between land surface feedback and the post-landfall structure of monsoon depressions. *Geophysical Research Letters*, *36*(15).



- Evans, Clark, Russ S. Schumacher, and Thomas J. Galarneau Jr. "Sensitivity in the overland reintensification of Tropical Cyclone Erin (2007) to near-surface soil moisture characteristics." *Monthly Weather Review* 139, no. 12 (2011): 3848-3870.

- Hlywiak, J. and Nolan, D.S., 2021. The response of the near-surface tropical cyclone wind field to inland surface roughness length and soil moisture content during and after landfall. *Journal of the Atmospheric Sciences*, *78*(3), pp.983-1000.
- And several others…

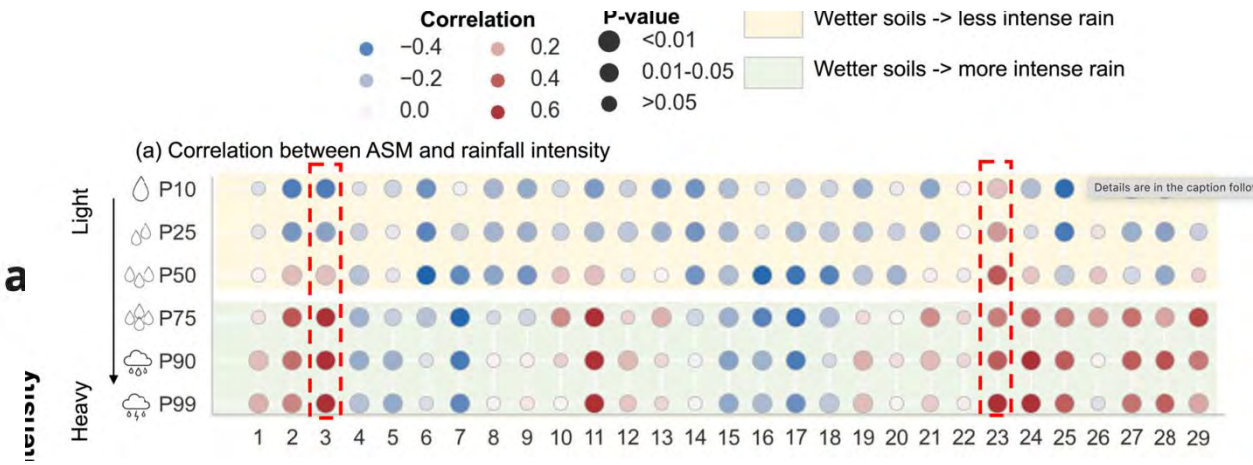
Geophysical Research Letters

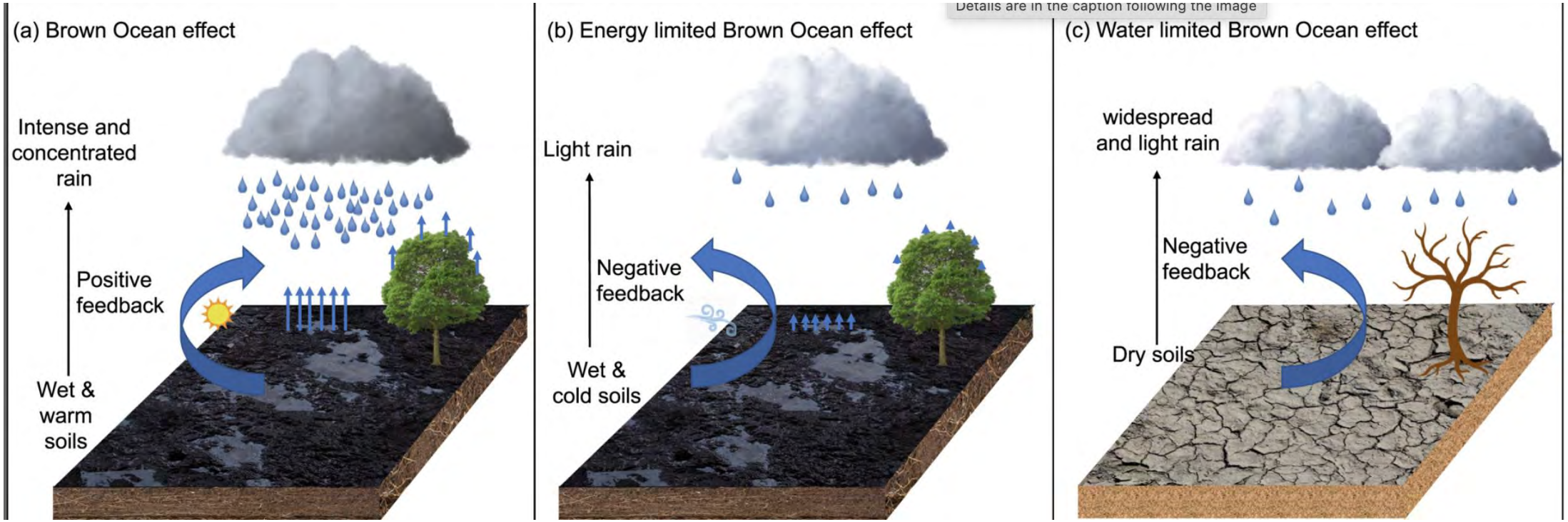
Research Letter | Open Access

Studying Brown Ocean Re-Intensification of Hurricane Florence Using CYGNSS and SMAP Soil Moisture Data and a Numerical Weather Model

Zhi Li, Alka Tiwari, Xinxin Sui, James Garrison, Frank Marks, Dev Niyogi

First published: 09 October 2023 | https://doi.org/10.1029/2023GL105102





JGR Atmospheres

RESEARCH ARTICLE
10.1029/2021JD035316

Modeling Large-Scale Heatwave by Incorporating Enhanced Urban Representation

Key Points:

- Sensitivity of weather research and forecasting model (WRF) heatwave simulation to surface parameterization and urban heterogeneity
- First results to show the use of local climate zones improves large-scale WRF simulation
- Urban representation can affect temperatures beyond the urban grids regionally

Pratiman Patel[1,2], Sajad Jamshidi[3], Raghu Nadimpalli[4], Daniel G. Aliaga[2], Gerald Mills[5], Fei Chen[6], Matthias Demuzere[7], and Dev Niyogi[8,9]

[1]Interdisciplinary Programme in Climate Studies, Indian Institute of Technology Bombay, Mumbai, India, [2]Department of Computer Science, Purdue University, West Lafayette, IN, USA, [3]Department of Agronomy, Purdue University, West Lafayette, IN, USA, [4]India Meteorological Department, New Delhi, India, [5]School of Geography, University College Dublin, Dublin, Ireland, [6]National Center for Atmospheric Research (NCAR), Boulder, CO, USA, [7]Department of Geography, Urban Climatology Group, Ruhr-University Bochum (RUB), Bochum, Germany, [8]Department of Geological Sciences, Jackson School of Geosciences, University of Texas at Austin, Austin, TX, USA, [9]Department of Civil, Architectural, and Environmental Engineering, Cockrell School of Engineering, University of Texas at Austin, Austin, TX, USA

Convergence of…

Summer Urban Heat

Landfalling Hurricanes

Urban Flooding

Geophysical Research Letters
Geophysical Research Letters homepage

Research Letter | Open Access

Impact of Urban Representation on Simulation of Hurricane Rainfall

Pratiman Patel, Kumar Ankur, Sajad Jamshidi, Alka Tiwari, Raghu Nadimpalli, N. K. R. Busireddy, Samira Safaee, Krishna K. Osuri, Subhankar Karmakar, Subimal Ghosh, Daniel Aliaga ... See all authors

First published: 09 November 2023 | https://doi.org/10.1029/2023GL104078

SECTIONS PDF TOOLS SHARE

Abstract

Taking the examples of Hurricane Florence (2018) over the Carolinas and Hurricane Harvey (2017) over the Texas Gulf Coast, the study attempts to understand the performance of slab, single-layer Urban Canopy Model (UCM), and Building Environment Parameterization (BEP) in simulating hurricane rainfall using the Weather Research and Forecasting (WRF) model. The WRF model simulations showed that for an intense, large-scale event such as a hurricane, the model quantitative precipitation forecast over the urban domain was sensitive to the model urban physics. The spatial and temporal

How can we Speed-up Disruption/ R2O in Urban Weather and Climate Services?

"CIMBY" - Climate In My Backyard

Why do we need this and how can AI-Good Systems help?

Dev Niyogi +

(+ = UT-City Climate CoLab and NSF&WCRP Atmospheric Urban Digital Twins (AUDT) Team)

William Stamps Farish Chair Professor

University of Texas Extreme Weather and Urban Sustainability (TExUS) Lab

UT-City Climate CoLab

https://texuslab.org/ https://utcitycolab.org/ https://Niyogi.DEV

Email: happy1@utexas.edu

University of Texas at Austin

6th NOAA AI Workshop (2024)

September 16-20, 2024: 6th NOAA AI Workshop on Leveraging Artificial Intelligence in Environmental Sciences

Sep 07, 2023

Project to Tackle Effects of Extreme Climate Unveiled by Doggett, UT and City of Austin

DOE/SC-0214

A Unified Data Infrastructure for Biological and Environmental Research

Report from the BER Advisory Committee

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BUSINESS • MEDIA

Scientists Are Using A.I. to Forecast Weather at the Paris Olympics

Scientists at the University of Texas at Austin are forecasting weather conditions at the summer games in Paris with the help of A.I. tools.

By Alexandra Tremayne-Pengelly • 07/30/24 3:09pm

UT-GLOBUS building height dataset

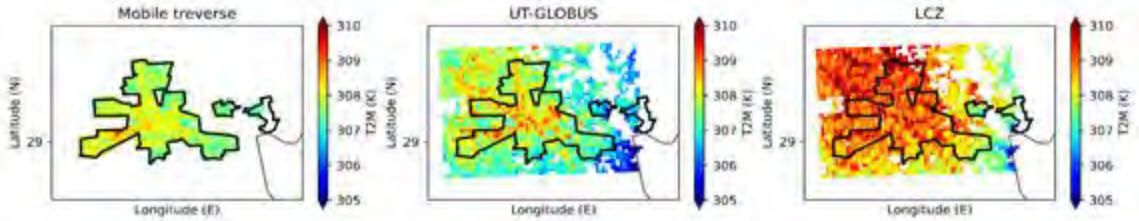
- Open, building heights urban canopy parameters for urban-WRF globally. More than 1000 cities globally.

Example Data availability for US cities

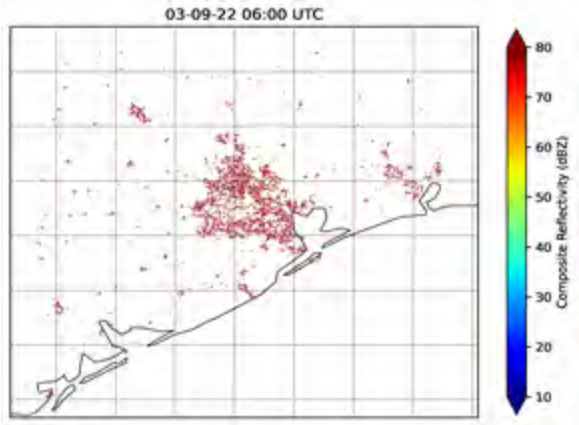
Paper: https://doi.org/10.1038/s41597-024-03719-w
Data: https://doi.org/10.5281/zenodo.11156602

Applications

1. Urban temperature simulations



2. Urban-thunderstorm interaction



3. Urban thermal comfort

https://arcg.is/DyKCW


E
N
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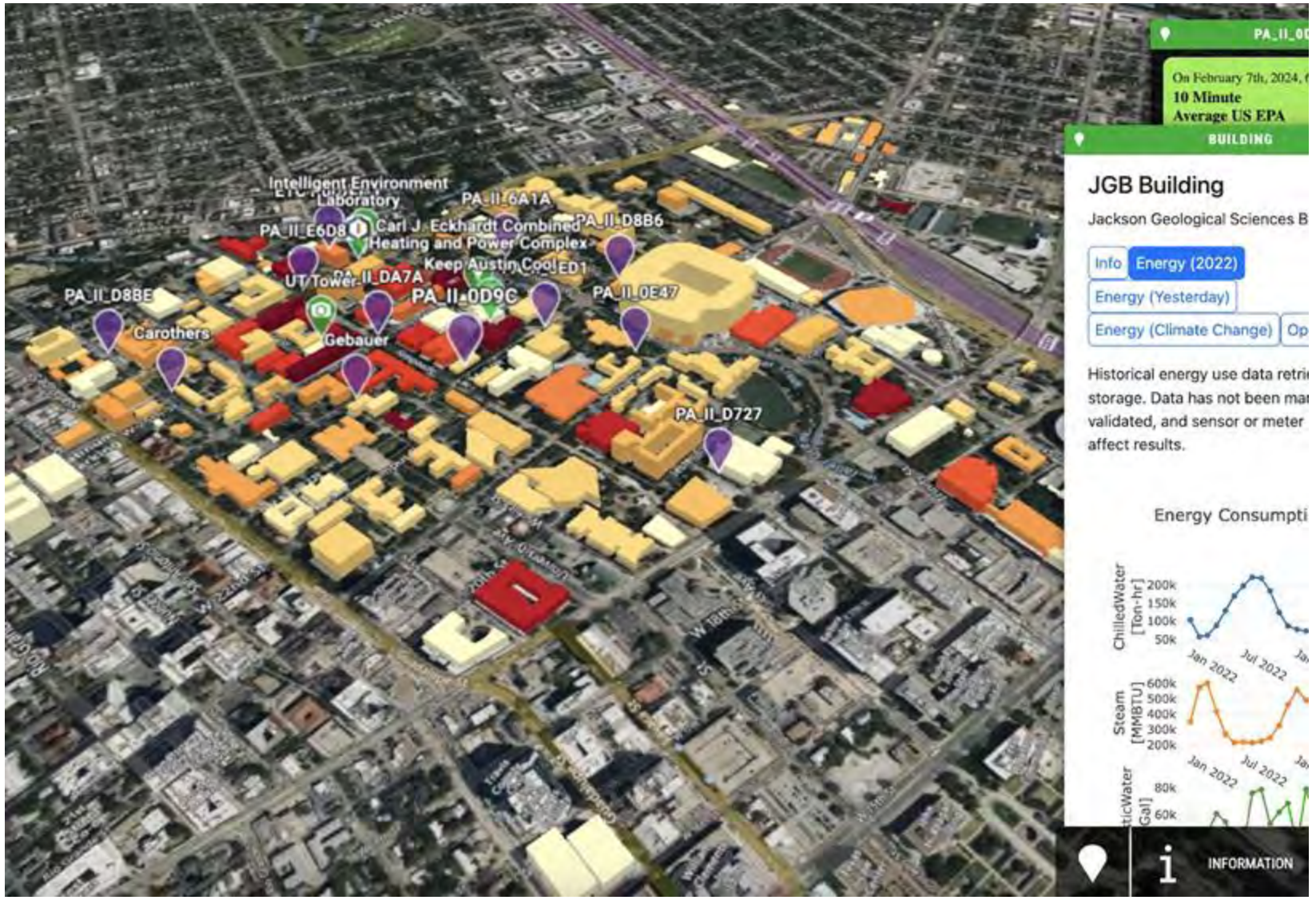
Atmospheric And Urban Digital Twins

- AUDTs are digital twins that capture the dynamic interplay between the urban scape and atmospheric elements.
- UTwin is a digital twin of the UT Austin campus.
- It provides historic and real-time energy use data, as well as energy demand forecasts



UTwin

NSF, DOE, Bentley Systems, WCRP Digital Earth Lighthouse Activity

THERMALSCAPE of Austin

tinyurl.com/colabthermalvr

UT-CITY CLIMATE COLAB

FIRE AND SMOKE, AIR QUALITY DIGITAL TWIN

Jiao, J., Lewis, R.H., Seong, K., Farahi, A., Navratil, P., Casebeer, N. and Niyogi, D., 2023. Fire and Smoke Digital Twin--A computational framework for modeling fire incident outcomes. arXiv preprint arXiv:2305.18313.

Paris 2024 Research Demonstration Project

Model Information

*Please provide any additional information on the parent models e.g., grid length, ensemble member number, if the initialisation time of the parent model is different to the model, whether the parent model configuration is exactly the same for multiple models (i.e., MESONH, AROME-500m, AROME-DBL).

Participant	Model	Resolution	Initialisation (UTC)	Approximate Time Available on Website (UTC)	Domain Size	Parent Models*	Land Cover Dataset	Turbulence and Convection Schemes
METEO-FRANCE CNRM/GMME	MESONH	100 m (Paris and suburbs) / 300 m (Ile-de-France)	00	13:30	300x300 (1.2km) 400x400 (300m) 300x300 (100m)	AROME France (1.3km)	Urban parameters: Open Street Map (100m) Vegetation: Ecoclimap Second Generation (300m)	Turbulence : 3D https://doi.org/10.3389/fear.2020.582056 No convection scheme **~ 07 August 2024 :** Added gray-zone shallow convection scheme in 300m domain (not enough mixing near the surface, too hot air temp. in countryside)
METEO-FRANCE CNRM/GMAP	AROME-500m	500 m	00	07:30	512x512	AROME France (1.3km)	- Land cover and urban parameters : Open Street Map (50m) - Vegetation : Ecoclimap second generation (300m)	
METEO-FRANCE	AROME-DBL	1.3 km	00	06:30	1440w1536	ARPEGE (~5km)	- Land cover and vegetation : Ecoclimap (1km)	

Participant	Model	Resolution	Initialisation (UTC)	Approximate Time Available on Website (UTC)	Domain Size	Parent Models*	Land Cover Dataset	Turbulence and Convection Schemes
Environment and Climate Change Canada (ECCC)	GEM	100 m	00 12 (not sent)	12:30	1024x1024 grid points (approx 100 km x 100 km)	Initialization with the Global Deterministic Prediction System analysis (GDPS-G1, 10km). Dynamical downscaling from 10km->2.5km->1km->250m->100m	Land cover: ESA CCI v1.6 (300m) Soil texture : SOILGRIDS Urban parameters: Open Street Map (100m) + MAPUCE	Turbulence: vertical 1D No deep convection scheme. Shallow convection: Kuo Transient scheme Microphysics: P3 (2–moment)
	WRF	100 m	12	09:30		???		
Deutscher Wetterdienst (DWD)	ICON	500 m	00	06:30	622580 grid points (resolution: ~500mx500m)	Boundary conditions for model: ICON-EU (~6.5 km) Model runs on 2.1km with 1km 2-way-nest, which contains 500m 2-way-nest.	Land cover and vegetation: GlobCover 2009 (300m) Urban parameters: Global default values Soil texture: FAO DSMW (10km) Albedo: MODIS climatology (5km) Orography: Aster	Turbulence: COSMO vertical diffusion and surface transfer schemes Convection: Tiedtke/Bechtold convection scheme, shallow convection only Microphysics: 1-moment scheme Land surface scheme: TERRA
TExUS lab, UT Austin	UT-MeteoGAN	1 km	00/06/12/18		30 km x 30 km	Google's Graphcast		AI/ML based downscaling and training

UT-MeteoGAN architecture

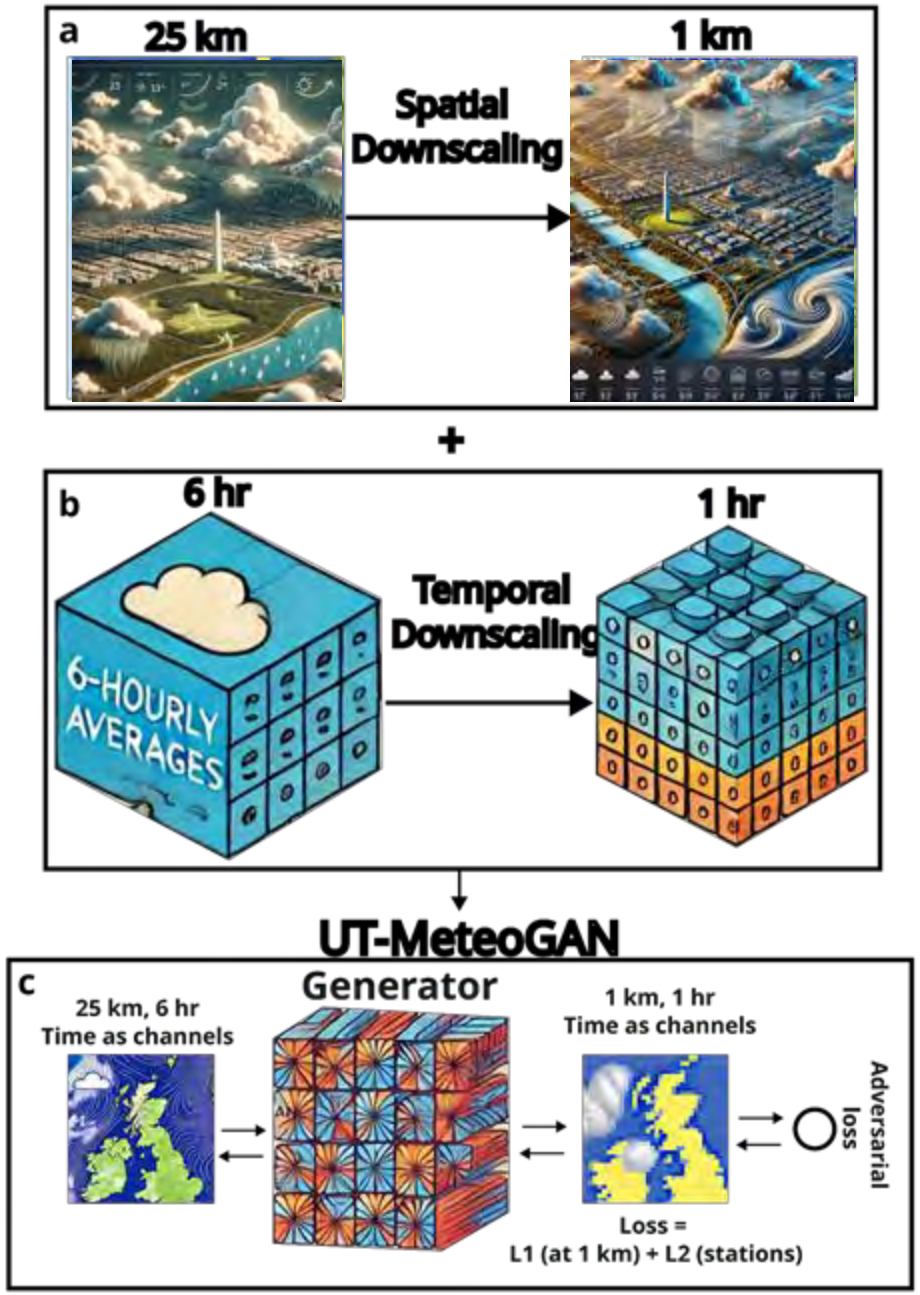
Input: Graphcast global 36 hr forecasts (25 km spatial resolution, 6 hourly averages)

Target: 1 km 1 hr NOAA AORC (https://registry.opendata.aws/noaa-nws-aorc/)

Model: SRGAN

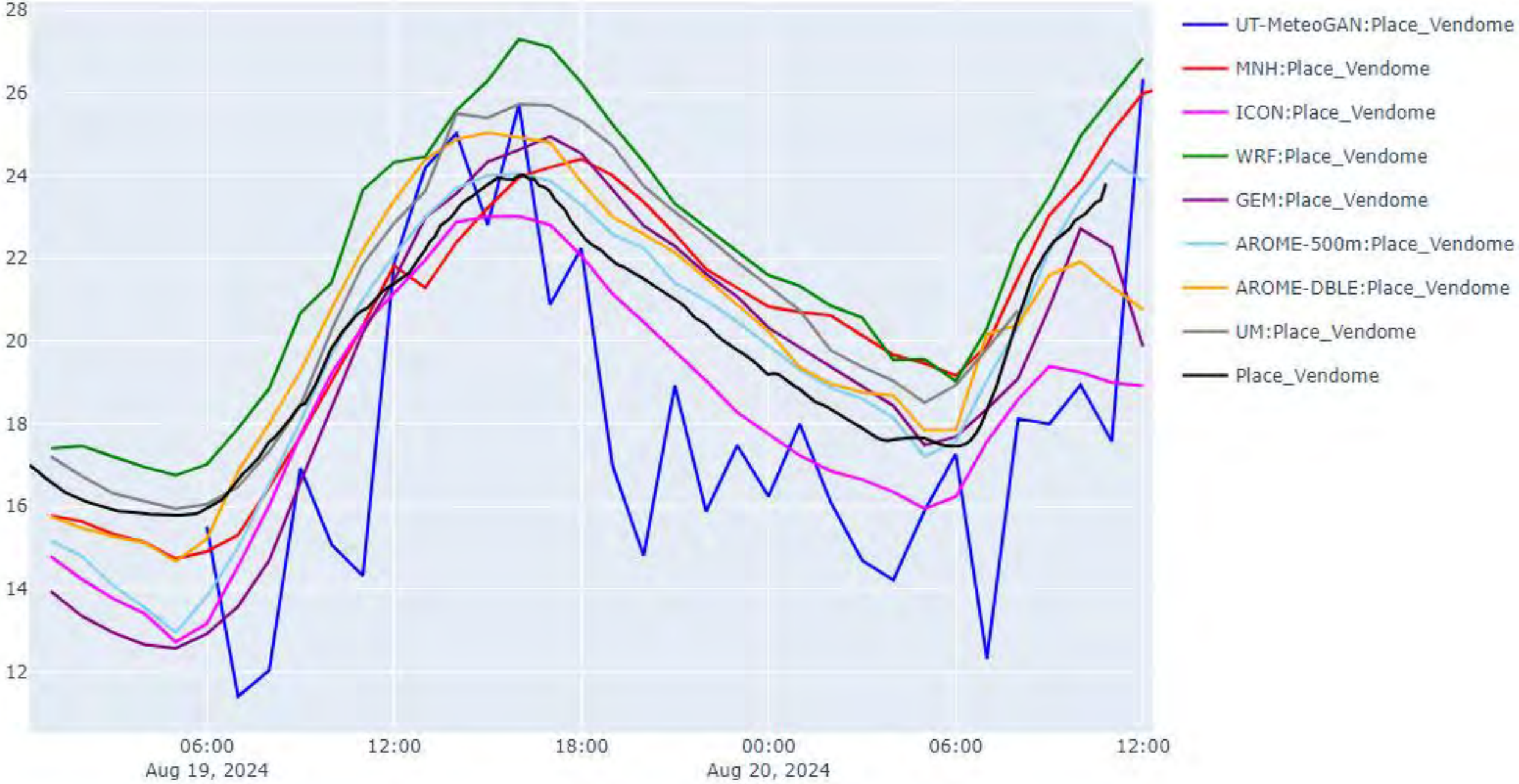
Variables: precipitation, surface air temperature, u and v surface winds

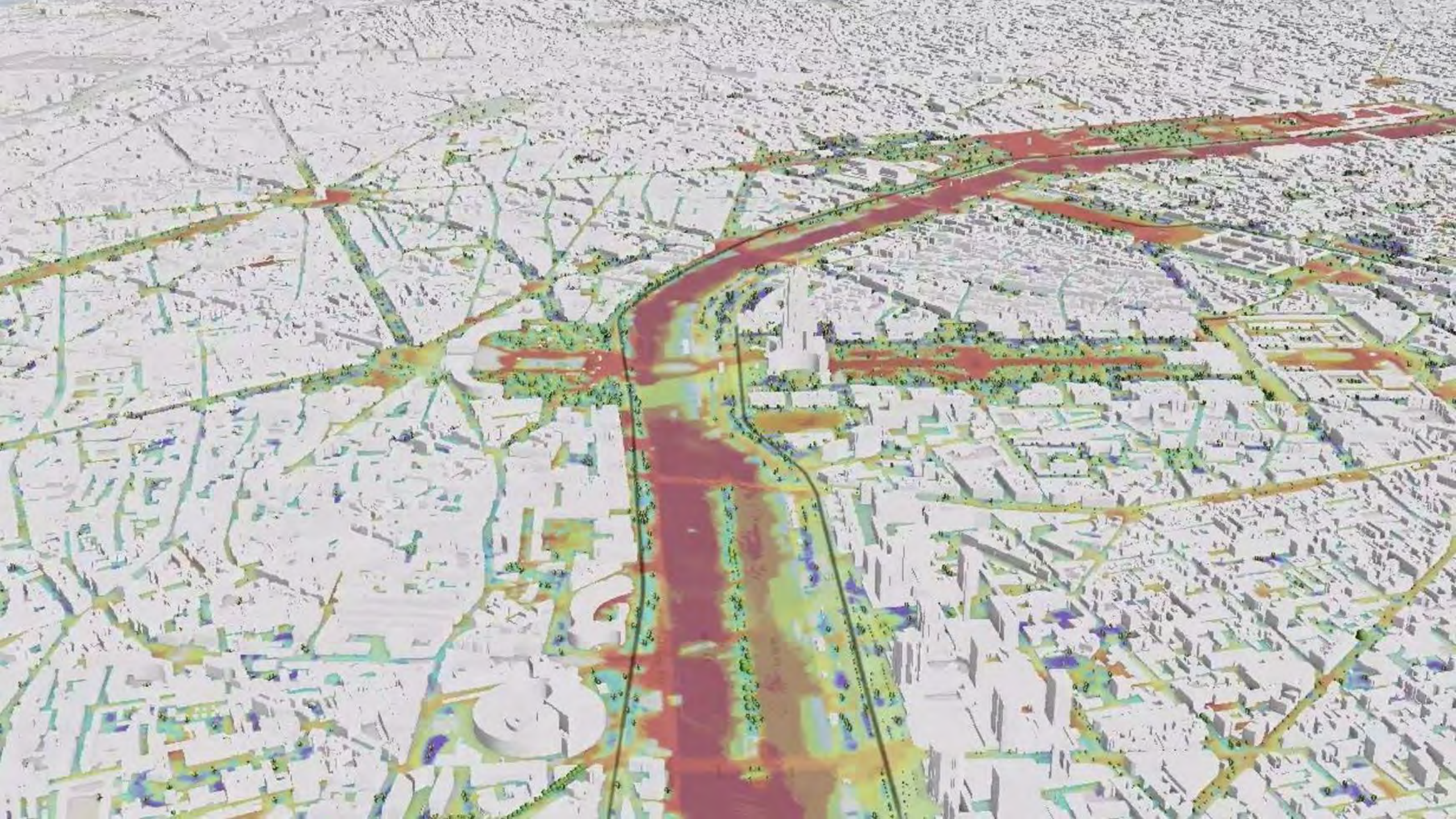
Trained over DC, transfer learning for Paris



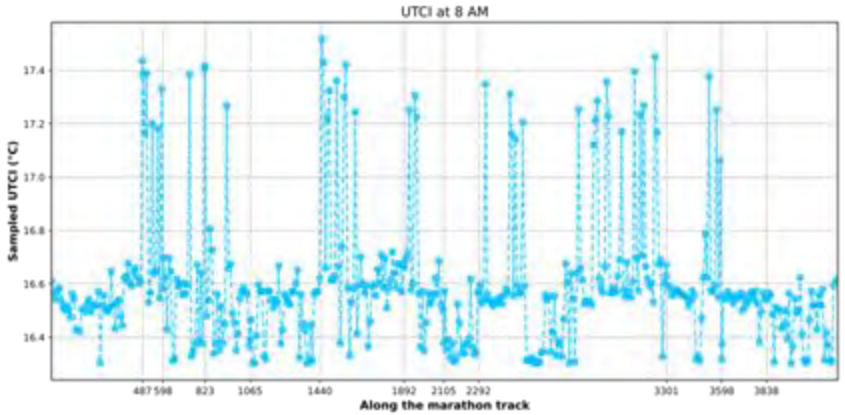
Fall, G., Kitzmiller, D., Pavlovic, S., Zhang, Z., Patrick, N., St. Laurent, M., Trypaluk, C., Wu, W. and Miller, D., 2023. The Office of Water Prediction's Analysis of Record for Calibration, version 1.1: Dataset description and precipitation evaluation. JAWRA Journal of the American Water Resources Association, 59(6), pp.1246-1272.

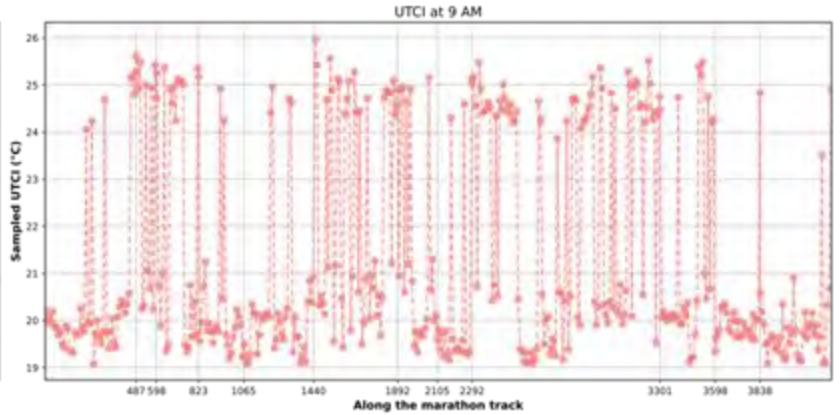
August 19th, 2024 Forecast

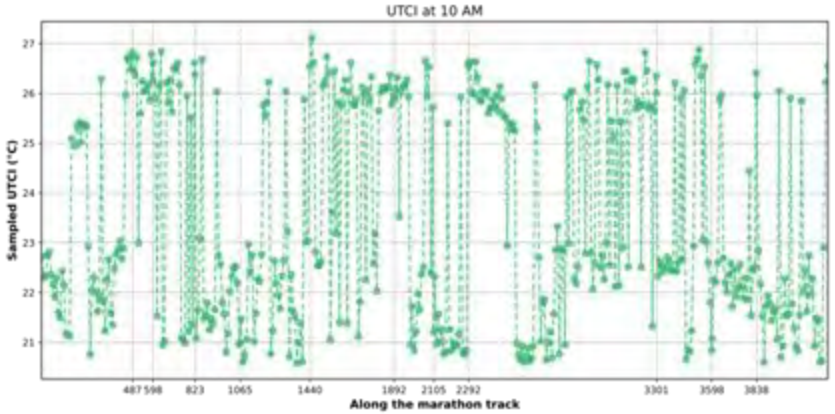


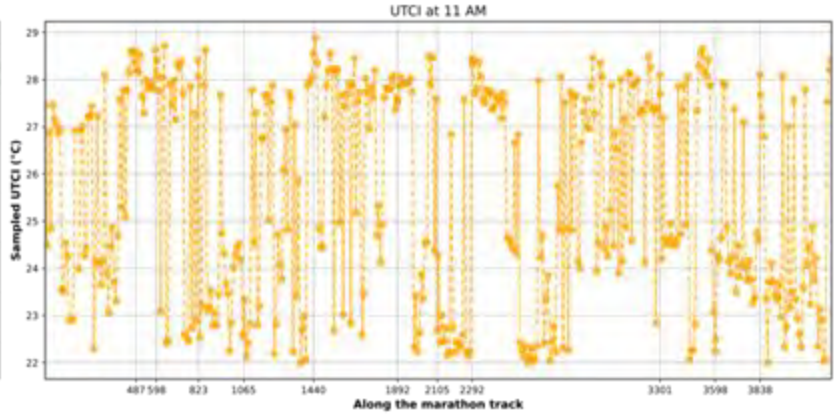


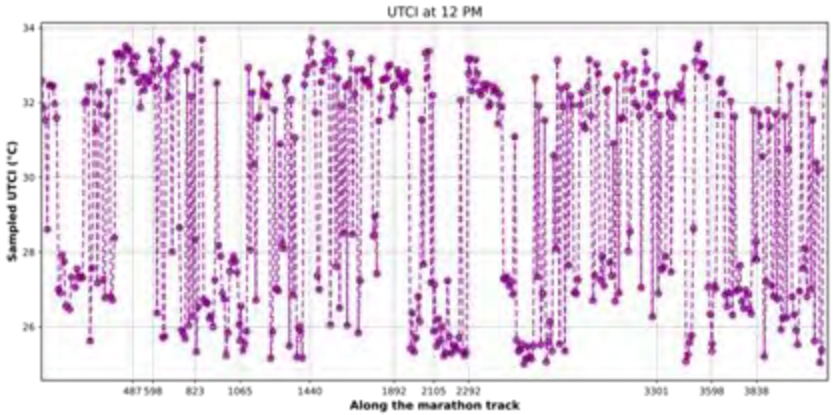
UTCI along the marathon track for different times











Thermal Comfort <u>for runners</u> considering the race start options for 8am, 9 am, 10am, 11 am, or 12 noon

Landmarks :

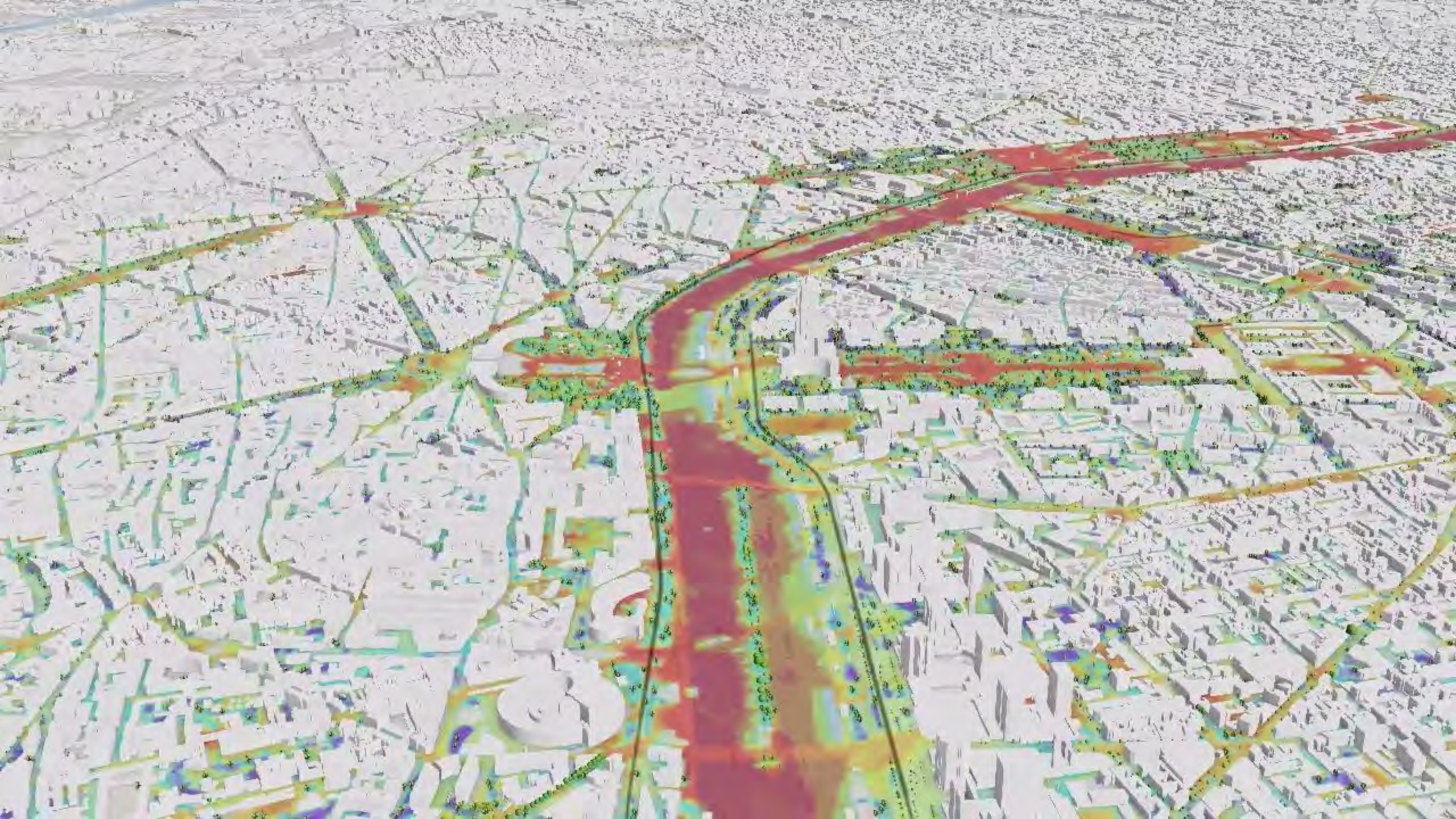
487 -- Palace du Corrousel 598 – Palace du Concorde 823 – Aquarium de Paris

1065 – Parc Saint-Perine 1440 – Pont de sevres 1892 – Foret domanale de Fausses-Reposes

2105 – UFR des Sciences Universite 2292 – Statue equestre de Louis XIV

2876 – Carrefour des Fonds de Morval 3301 – Pont de Billanciurt

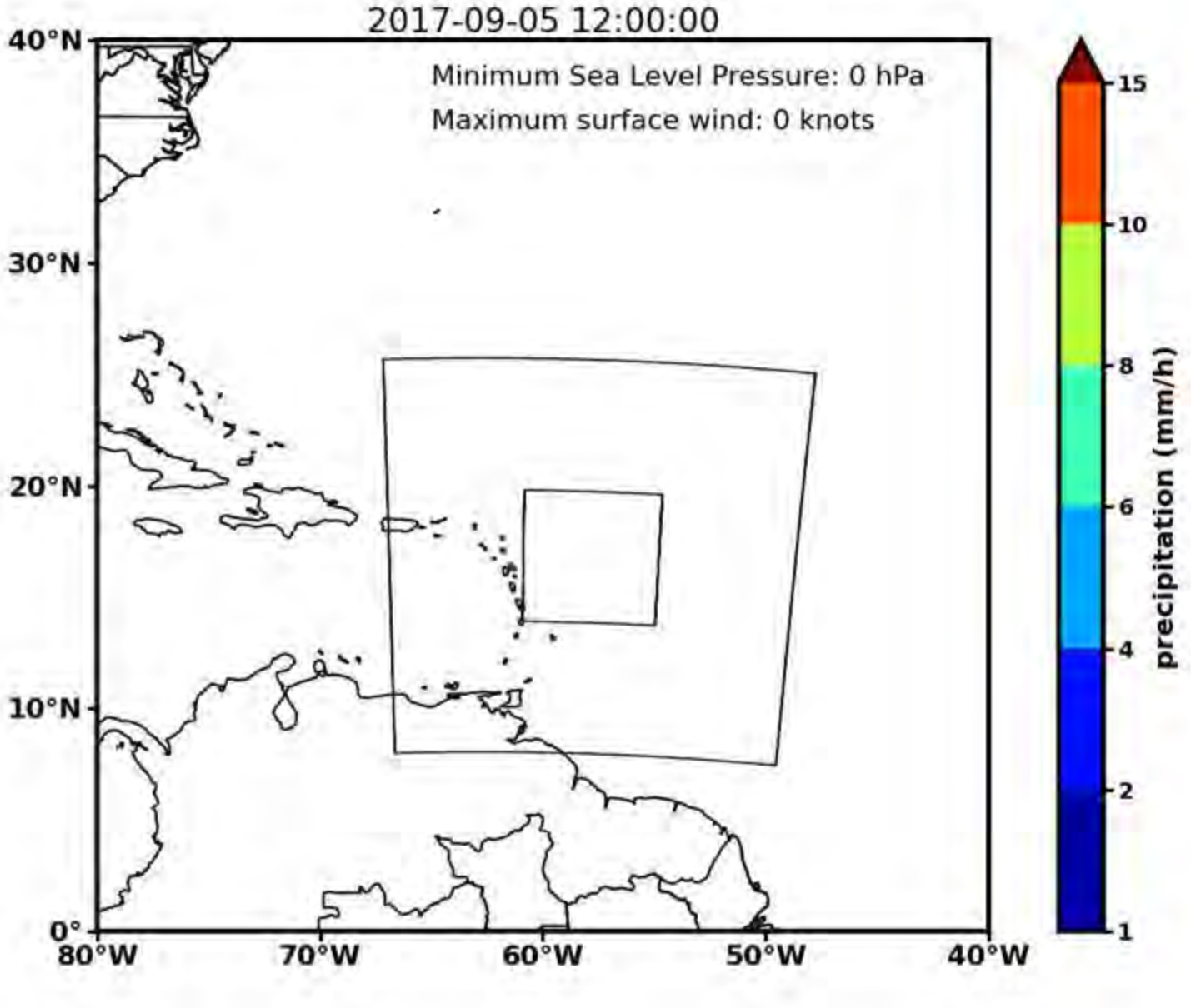
3598 – Parc Abdre Citroen 3838 – Eiffel tower



Other experimental Forecast for Heat + Hurricane studies
From UT Jackson School of Geosciences with TACC resources using Ongoing research Models HWRFxUT (with NOAA) and Graphcast-Operational Setup at UT

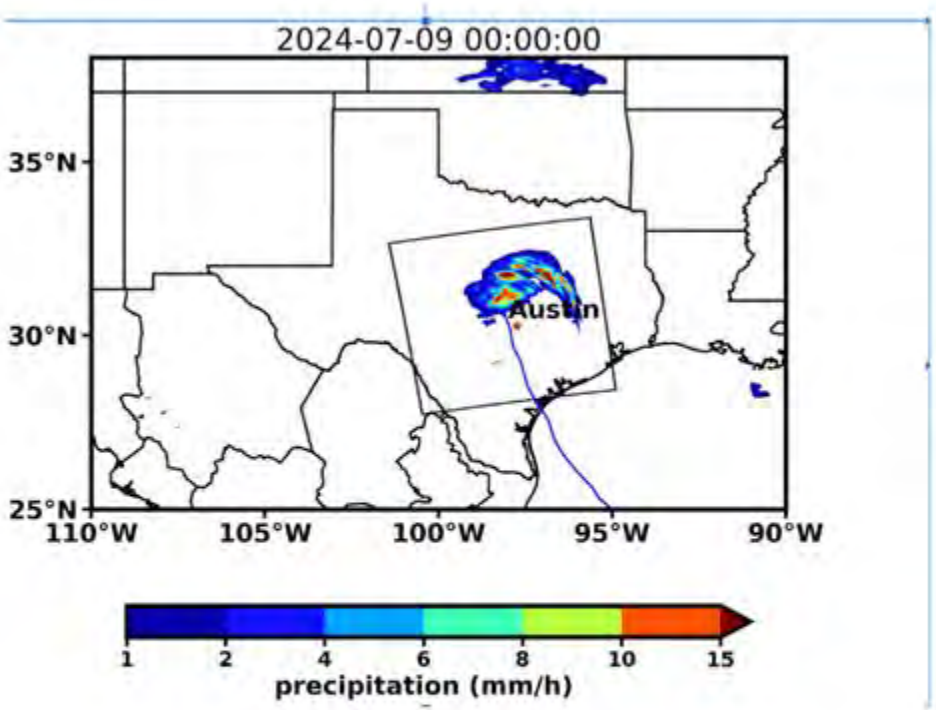
Working with NOAA-HRD testing the moving nests and physics based model capability in Monsoon Mission model IOLA/ HWRFx-UT

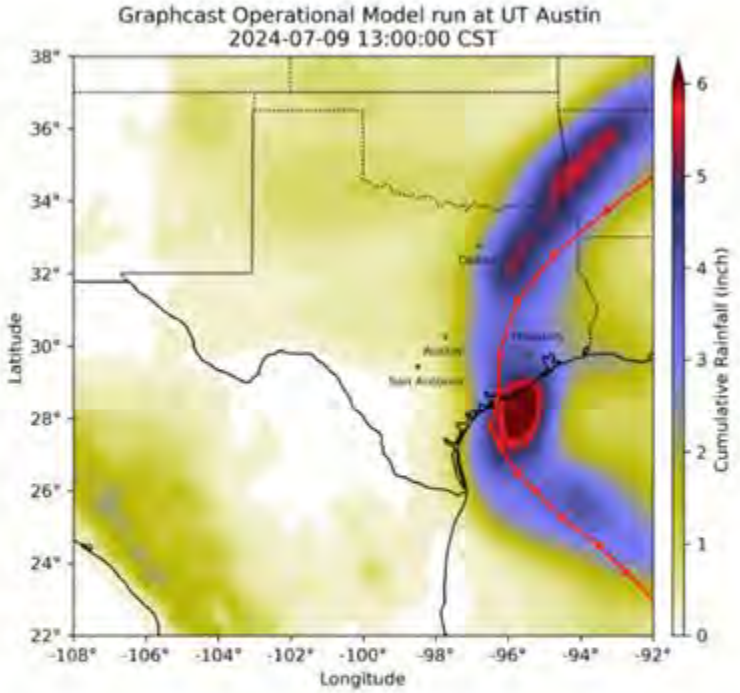
Simulations also for all recent Gulf Coast hurricanes Ida, Harvey, Michael, Idalia, Laura, (Beryl underway)



48 hour simulation of Hurricane Irma (2017)

Hurricane Beryl (2024)





PHYSICS/DYNAMICS – BASED MODEL (LEFT) vs AI-ML BASED MODEL (CENTER) NOAA/NHC Track

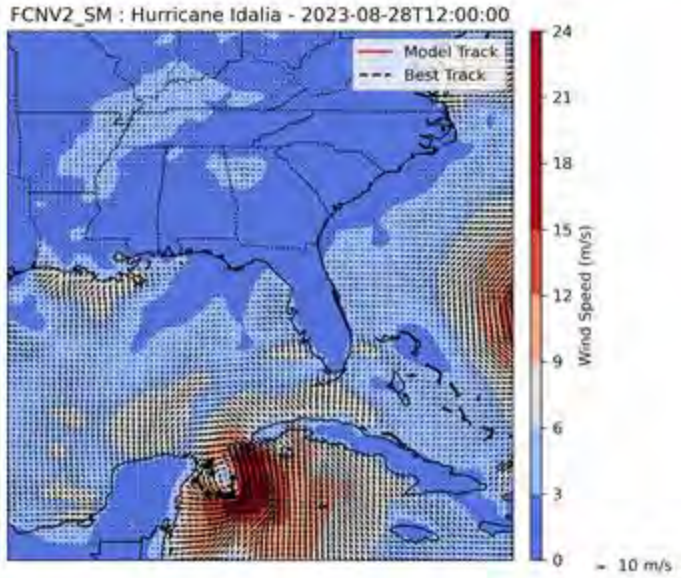
Heavy Rainfall over ATX, Storm center west of Austin

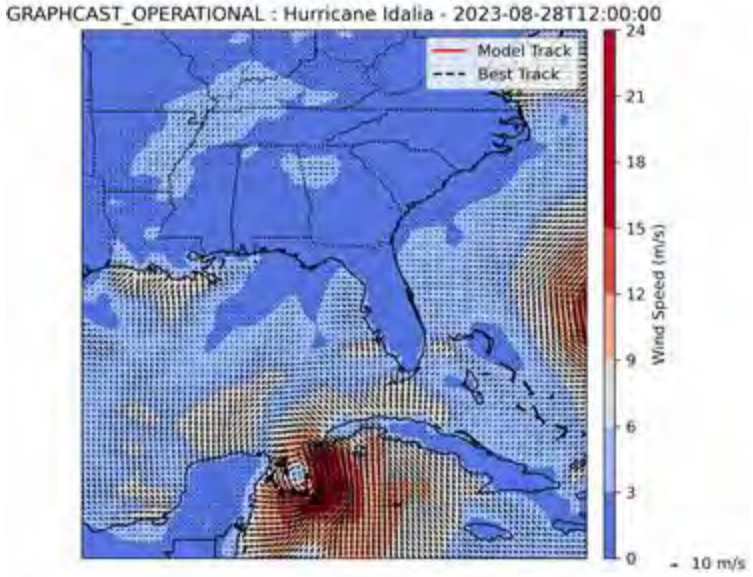
Rainfall and Storm Center significantly east of ATX

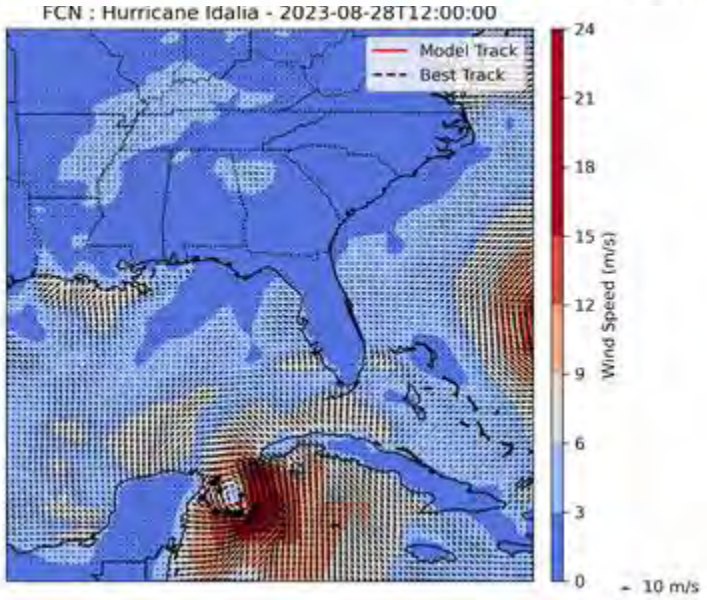
Hurricane tracks by AI models

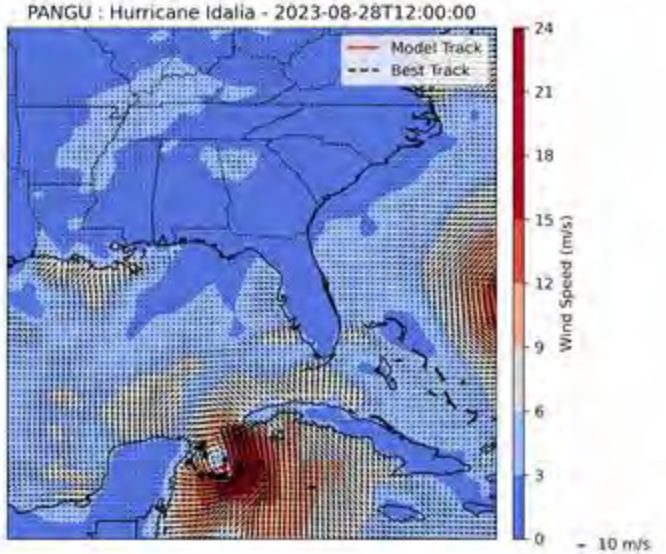
Hurricane Idalia 2023

The models are initiated ~48 hours before the landfall.









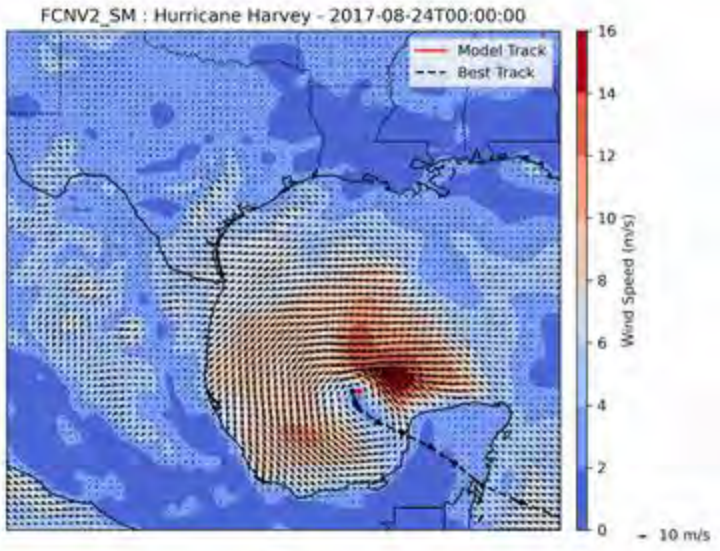
FCN- Fourcastnet,
FCNV2_SM- Fourcastnet V2
Graphcast Operational - Operational version of Graphcast

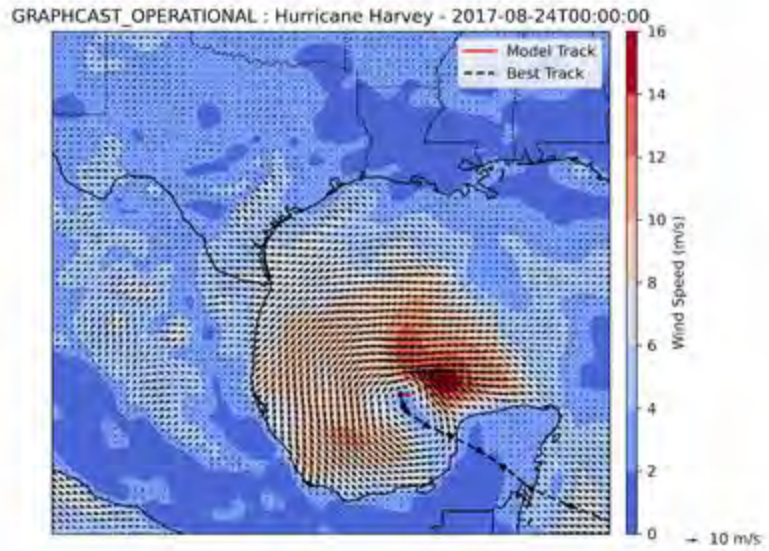
Initiated at
2023/08/28 12:00:00

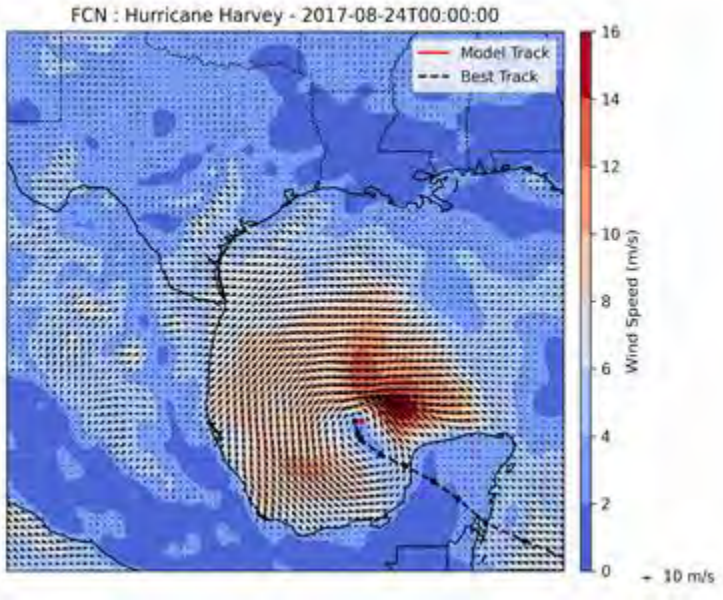
Hurricane tracks by AI models

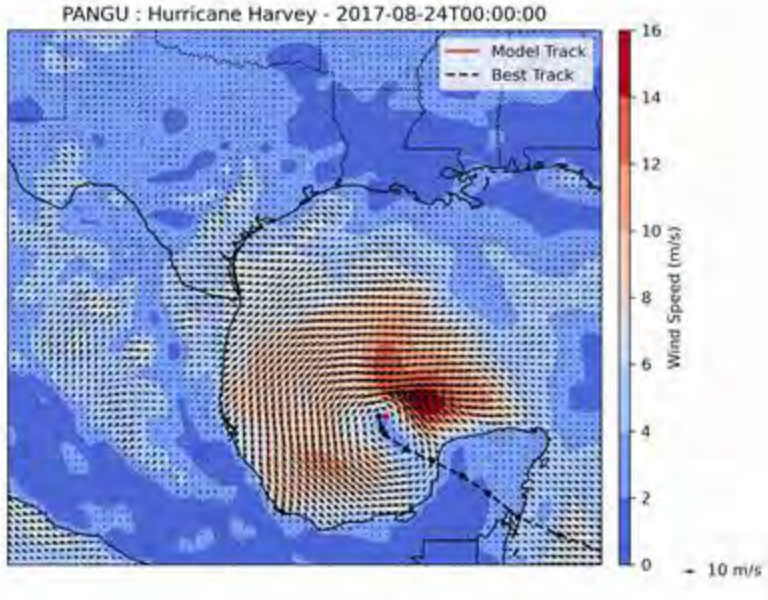
Hurricane Harvey 2017

The models are initiated ~48 hours before the landfall.







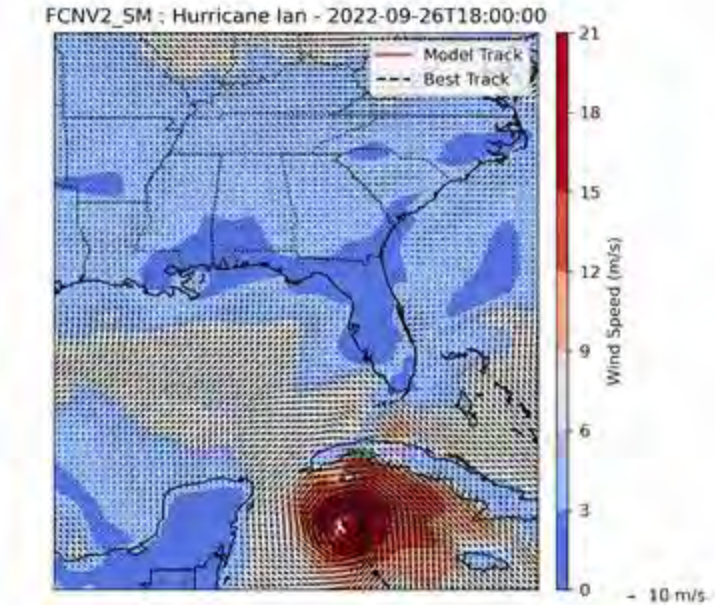


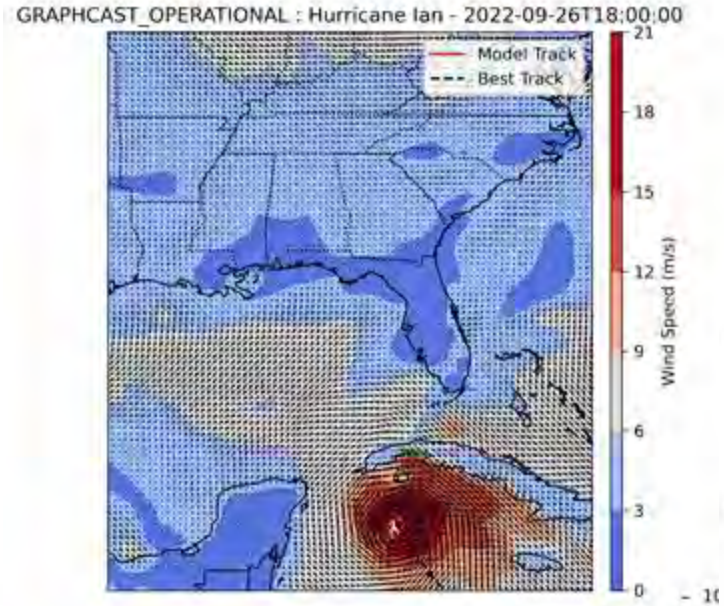
FCN- Fourcastnet,
FCNV2_SM- Fourcastnet V2
Graphcast Operational - Operational version of Graphcast
PANGU- Panguweather

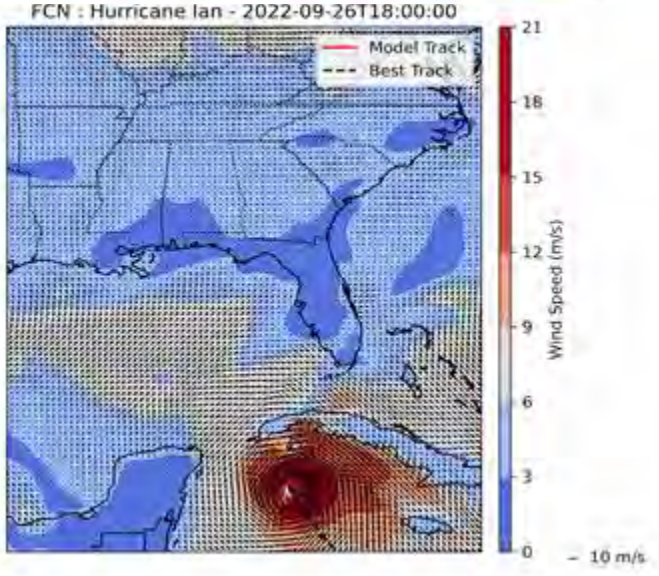
FCN - vision transformer architecture with Adaptive Fourier Neural Operator (AFNO) attention
FCNV2 - Spherical Fourier Neural Operator
Graphcast - Graph Neural Networks (GNNs)
Panguweather - 3D earth transformer

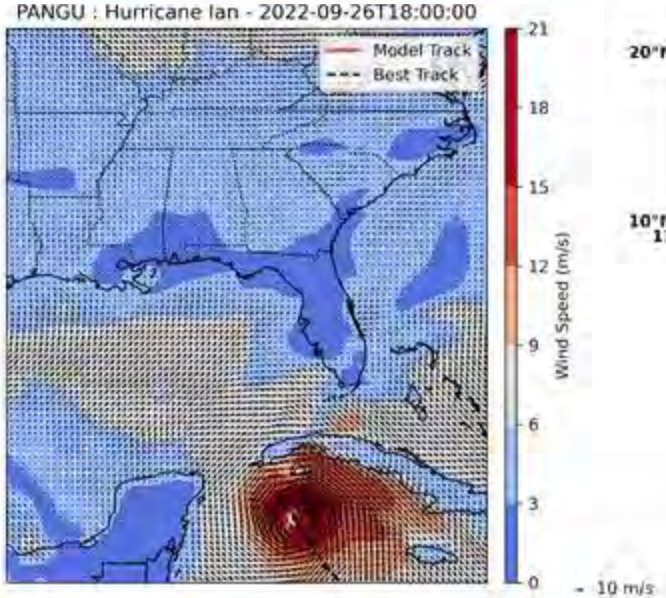
Initiated at
2017/08/24 00:00:00

Hurricane tracks by AI models



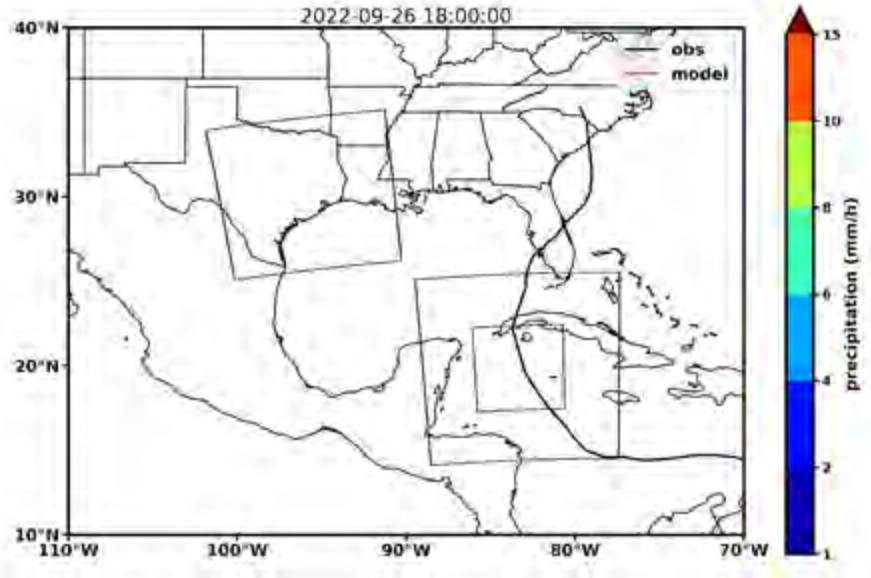






Hurricane Ian 2022
The models are initiated ~48 hours before the landfall.

FCN- Fourcastnet,
FCNV2_SM- Fourcastnet V2
Graphcast Operational - Operational version of Graphcast



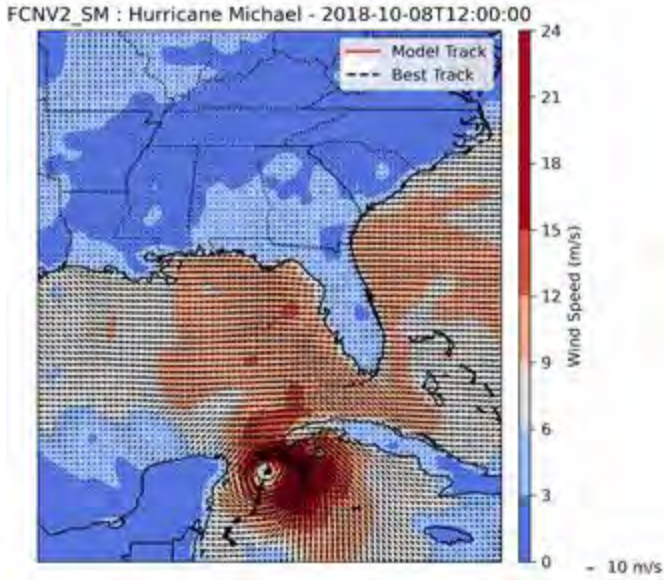
HWRFx model

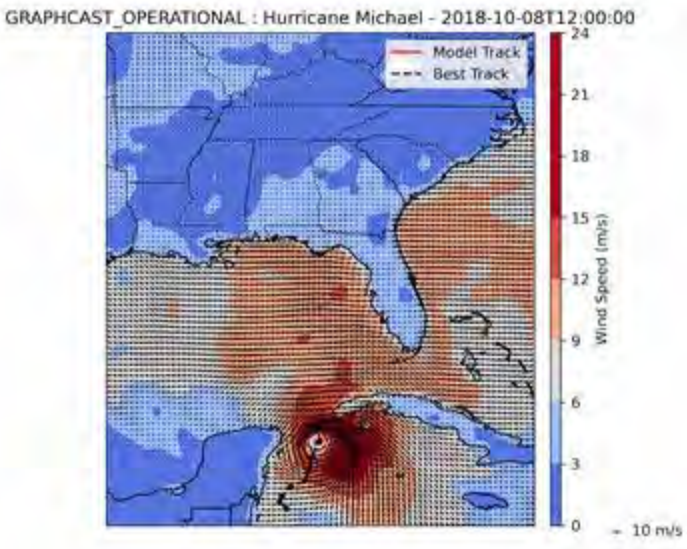
Initiated at
2022/09/26 18:00:00

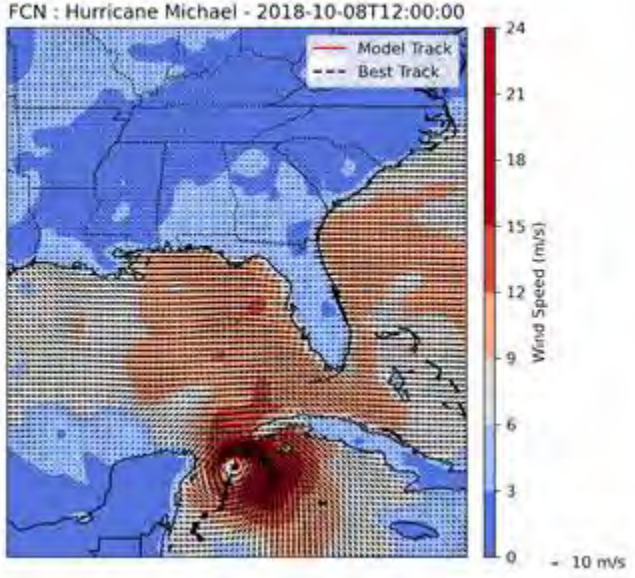
Hurricane tracks by AI models

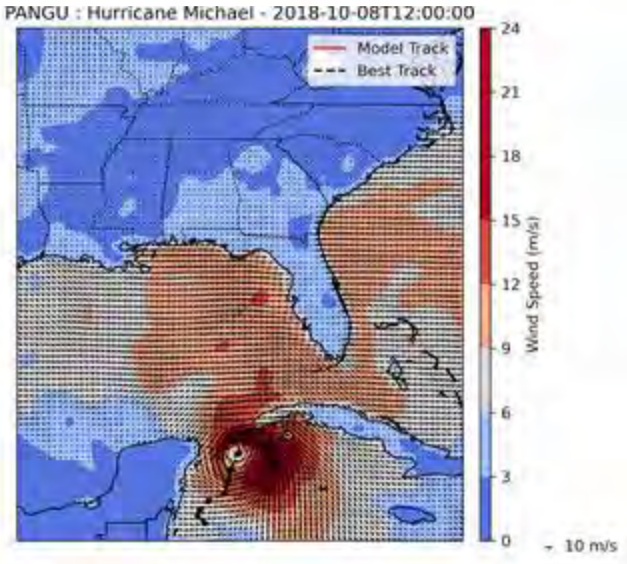
Hurricane Michael 2018
The models are initiated ~48 hours before the landfall.

FCN- Fourcastnet, FCNV2_SM- Fourcastnet V2
Graphcast Operational - Operational version of Graphcast
PANGU- Panguweather





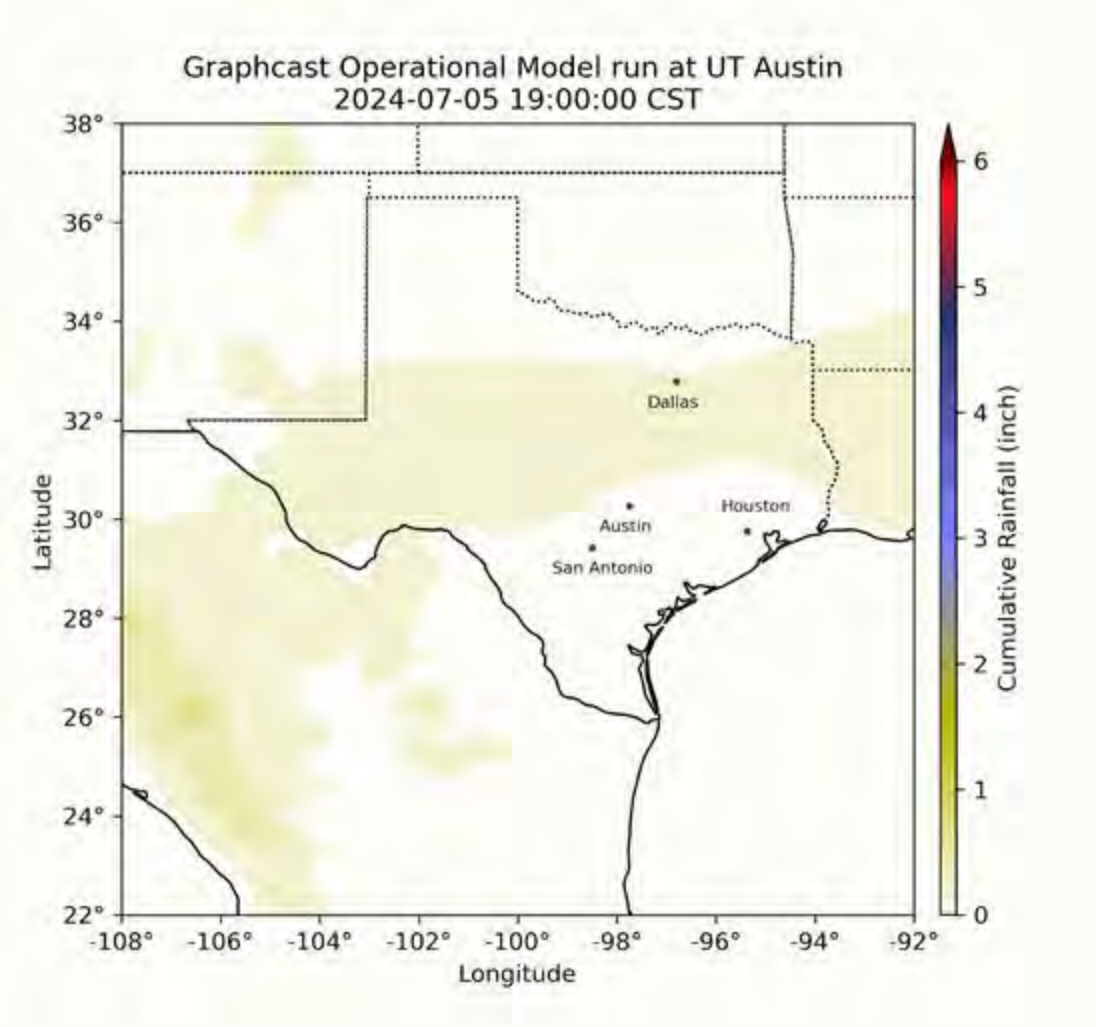




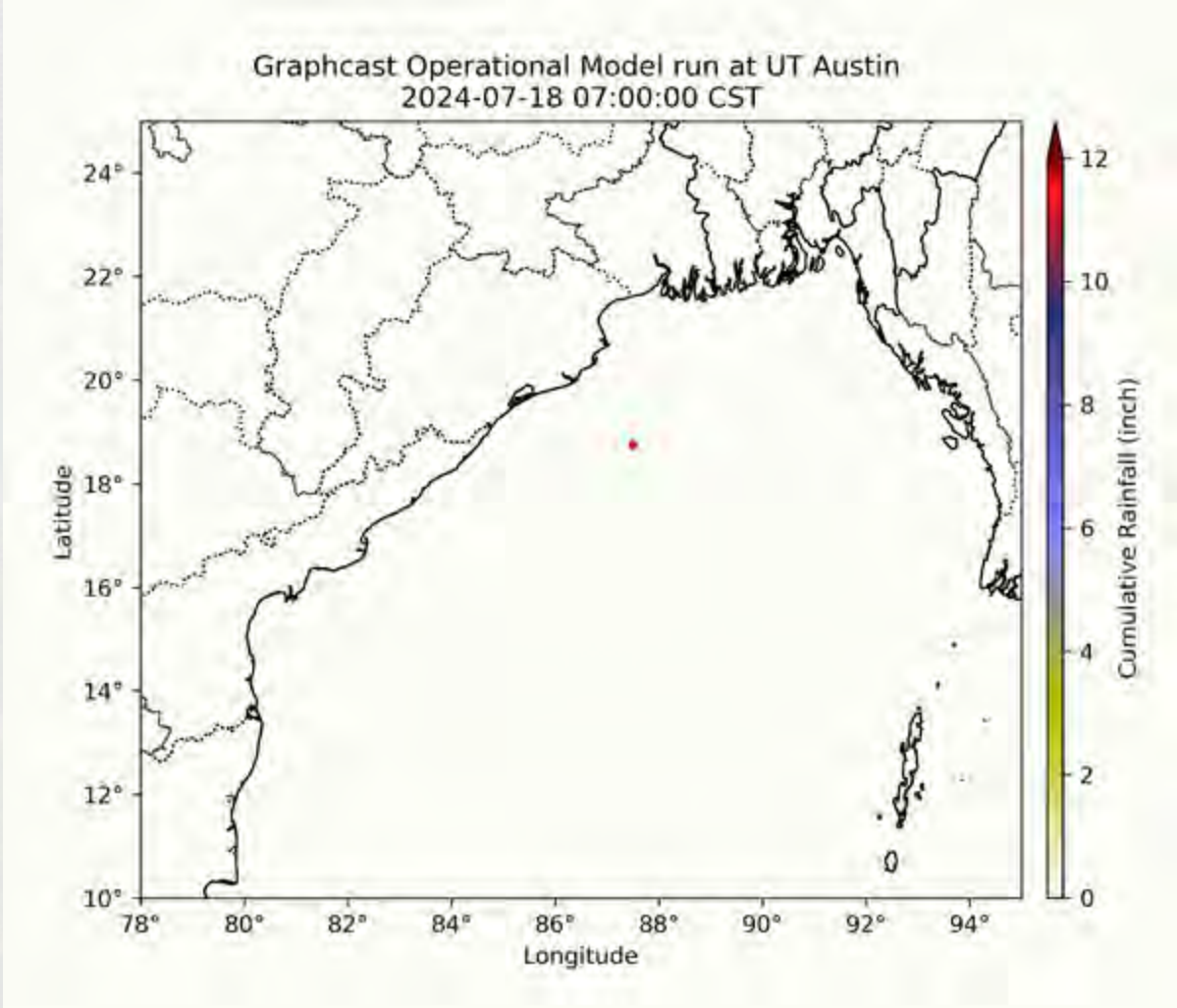
FCN - vision transformer architecture with Adaptive Fourier Neural Operator (AFNO) attention
FCNV2 - Spherical Fourier Neural Operator
Graphcast - Graph Neural Networks (GNNs)
Panguweather - 3D earth transformer

Initiated at
2018/10/08 12:00:00

Near Real Time Forecast



Hurricane Beryl



Depression BOB 02

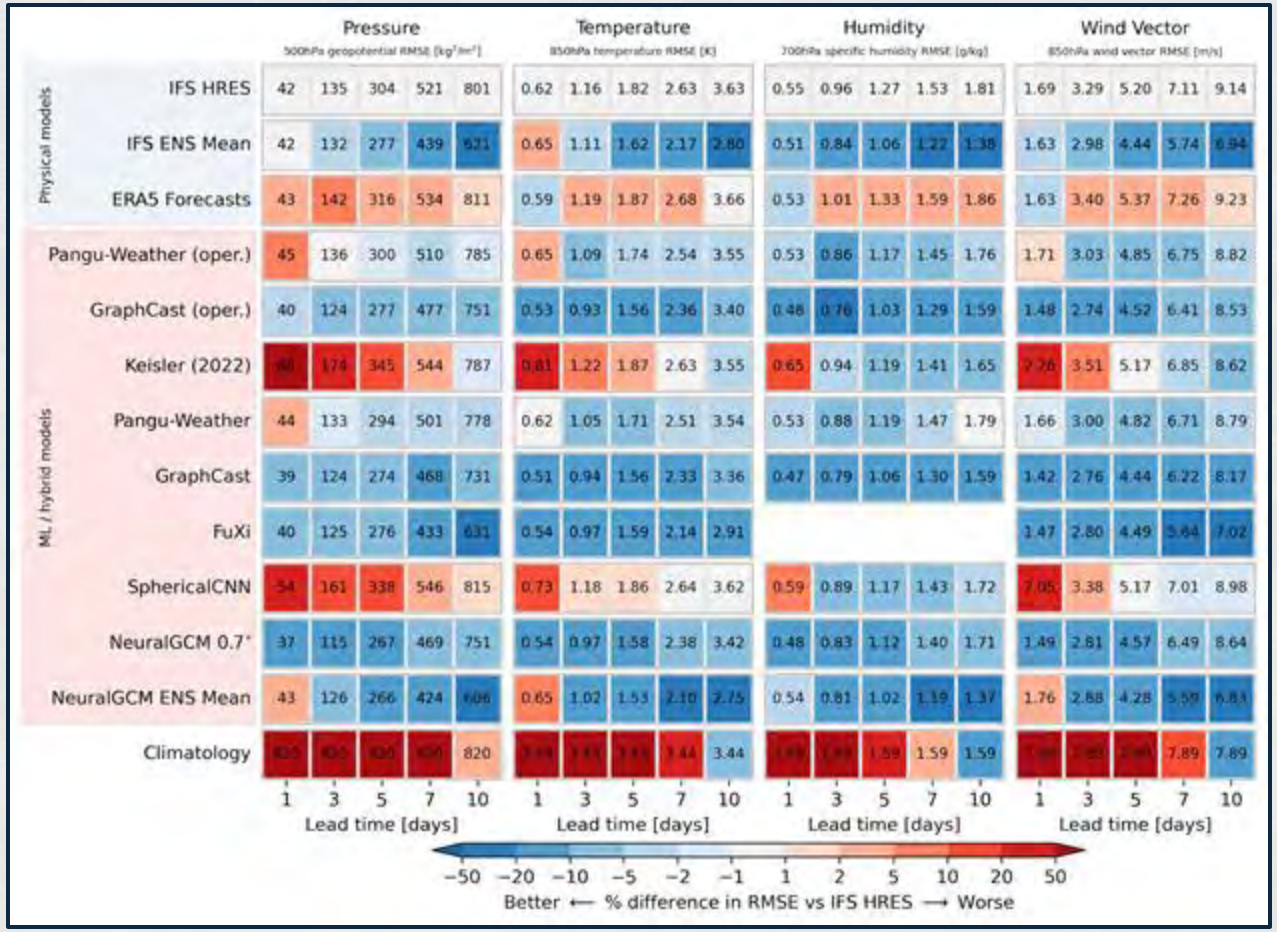
UT-HindCast: Google Graphcast based 45 year, global, hindcast Dataset from The University of Texas at Austin

Hindcast Generated from AI model (1979–2024)

- **Daily 15-day forecasts**, initialized at **00 UTC ERA5**.
- Produced at **0.25° x 0.25° resolution (global)**.
- Uses **Graphcast operational model**

Computational Performance

- **Texas Advanced Computing Center ’s NVIDIA H100 GPU**.
- **<4 minutes** to complete a **15-day forecast**.



Performance of AI models (Source: weatherbench 2)
1979- 2017 global data
(Models have different resolutions)

UT-HindCast: Google Graphcast based 45 year, global, hindcast Dataset from The University of Texas at Austin

Conversations/ tests underway

To host at the World Data Center for Climate (WDCC) @340TB data

and also

Document in WCRP /WMO Newsletter

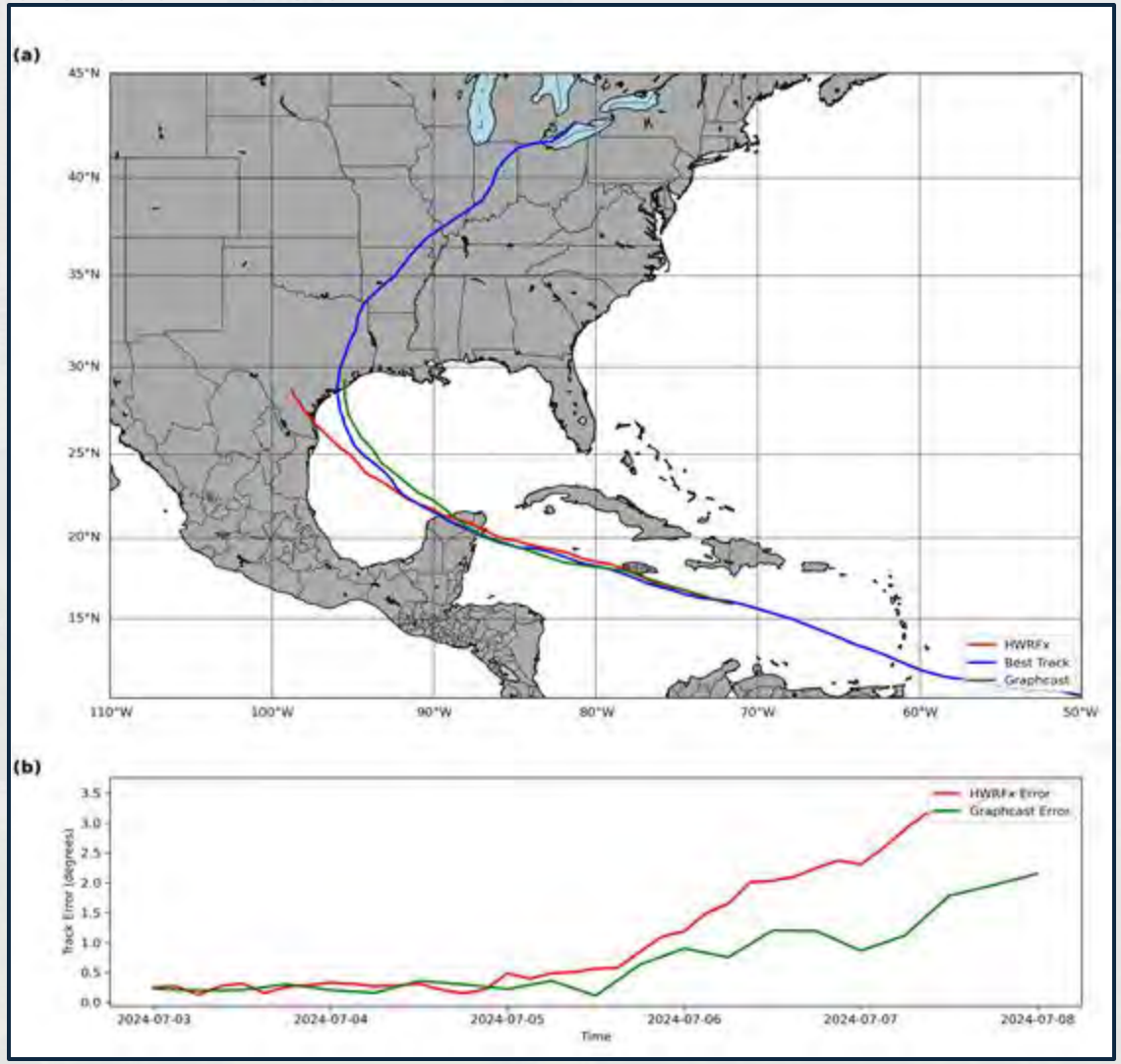
Peer reviewed publication under development

Surface Variables:

- Temperature
- Wind speed (u, v)
- Precipitation
- Mean sea-level pressure

Atmospheric Variables (13 vertical levels):

- Specific humidity
- Winds (u, v)
- Vertical wind
- Geopotential (height)
- Temperature



Comparison with HWRF model (Hurricane Beryl 2024) near real time runs with GFS

UT-HindCast: Google Graphcast based 45 year, global, hindcast Dataset from The University of Texas at Austin

Enhancing Extreme Weather Research (short and long term)

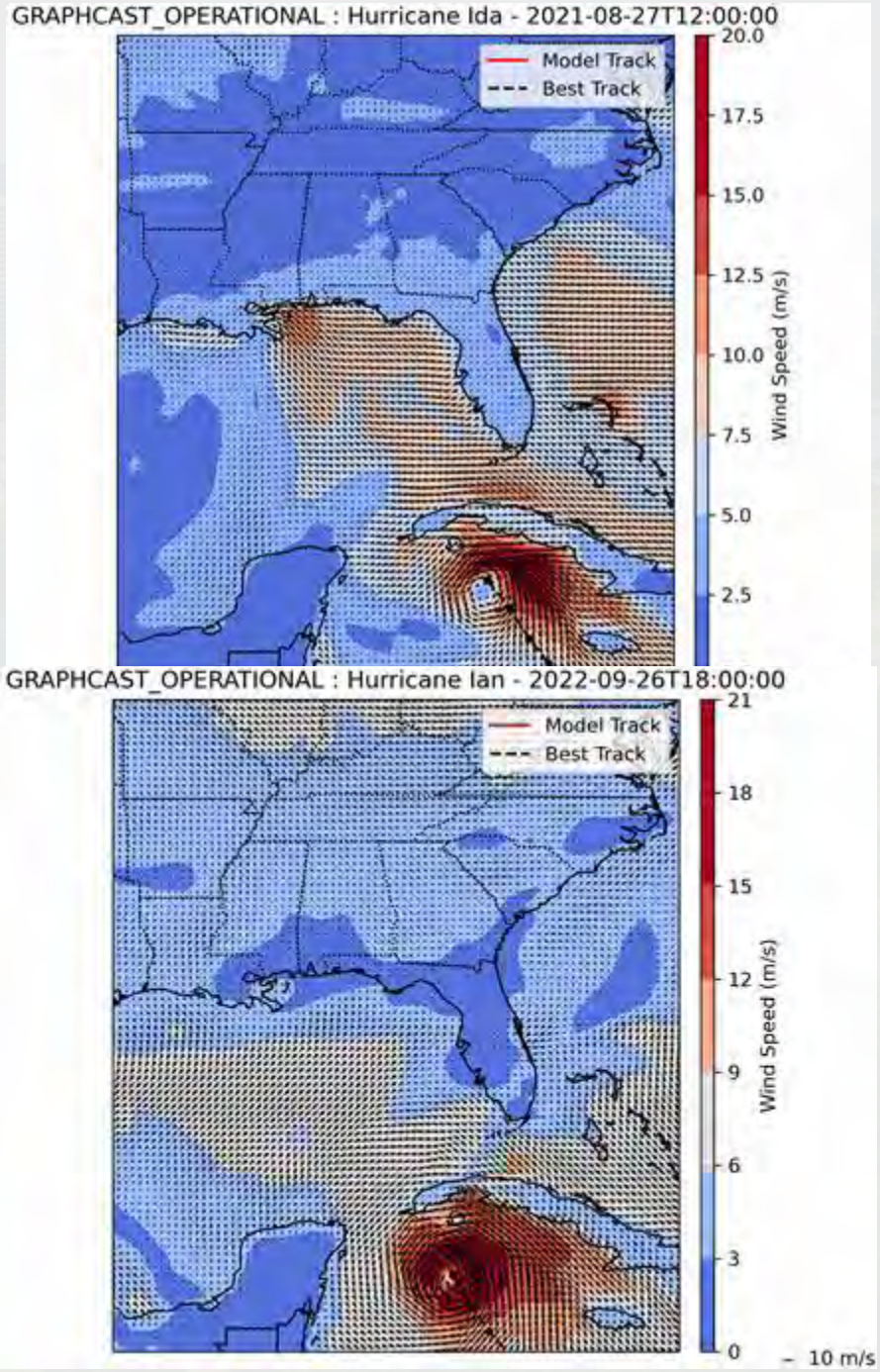
- Provides a **long-term dataset (45 years)** for **extremes and variability** studies.
- Allows **retrospective evaluation** of AI-based forecasting.

Benchmarking Against Traditional Models

- Help assess **Graphcast's performance** vs. numerical weather prediction (NWP) models.
- Enables **model improvements & uncertainty analysis**.

Supports Extreme Weather Prediction

- Helps study **hurricanes, heatwaves, and heavy rainfall events**.
- Can be leveraged for **real-time forecasting enhancements**.



Digital Twins (DT) for urban extremes/ cascading hazards

Select core physics and model development activities:

- Physics-based Numerical Weather Prediction / Hurricane Modeling
- AI/ML based models for Hurricanes (evaluation)
- Developing hybrid-models Testbed UT-DeepNWPv2
- AI/ML input to Physics based models (UT-GLOBUS) especially for coastal cities

- Atmospheric Urban DT (World Climate Research Program Digital Earth Lighthouse Activity)
- Experimental Paris Olympics Research Demonstration Project participation
- UT- NOAA MoA
- UT- NOAA - NITR/India partnership - IOLA (Indian Ocean - Land - Atmosphere Model) under Monsoon Mission

Towards hyperlocalization

- Continued understanding physics and processes
- Representing physics and processes in models
- Data Assimilation (to some extent)
- AI/ML based downscaling
- AI/ML based parameters for physics-based models
- (Building colabs for rapid dissemination and coproduction)

Other considerations

Hyperlocalization is necessary and useful but….

The AI ML models capability for local inland parameters of interest (winds, pressure, rains,..) is still matter of large uncertainty

AI ML models are surprisingly easy to use and develop – need for benchmarking; will likely need governance?

Earth systems models have evolved as community tools – the economic model is skipping scientific/community vetting and participation and could lead to sustained decline in discovery

Robust need to reassert the importance of physics-based models and approaches as the gold standard (despite all its current short comings)

" AI/ML based models are like cheap insurance. For most purposes it will work, but you are never sure if it will when you really need it. “: Personal perspective

Urban meteorology perspective

- Urbanization is the new global change
- Monitoring, modeling, development of model parameters are critical as we move towards sub km / hectometer scale modeling
- Many opportunities emerging
  - Need the measurements to model parameterizations development/testing plan
  - Improved physics, dynamical understanding
  - Need measurements to operational use which is still elusive for weather and feasible but expensive for climate models
  - Aerosols, Soil moisture have an impact as well– India will be starting a national soil moisture network as NISAR launch undertakes shortly.

  - More info: Email happy1@utexas.edu https://niyogi.DEV

UT-CITY CLIMATE
COLAB

The UT City & Climate CoLab is a collaborative initiative between the City and the University of Texas at Austin

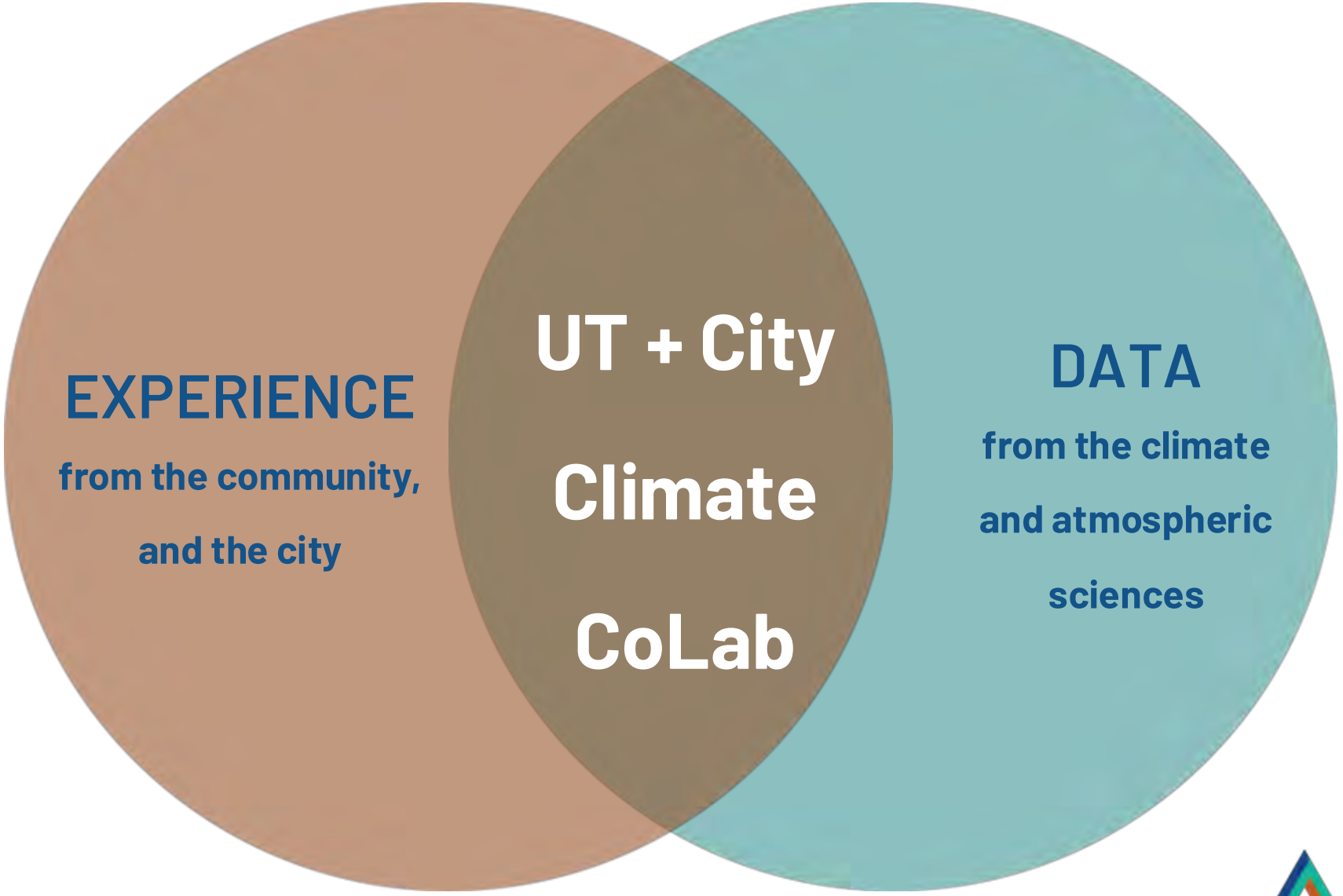
Focused on addressing weather and city climate extremes, data, and solutions.

Brings together researchers, policymakers, and community members to develop innovative solutions and strategies for building climate-resilient cities.

“Everyone has a story”.

Lived Experience + Localized Data → Useful and Usable Information

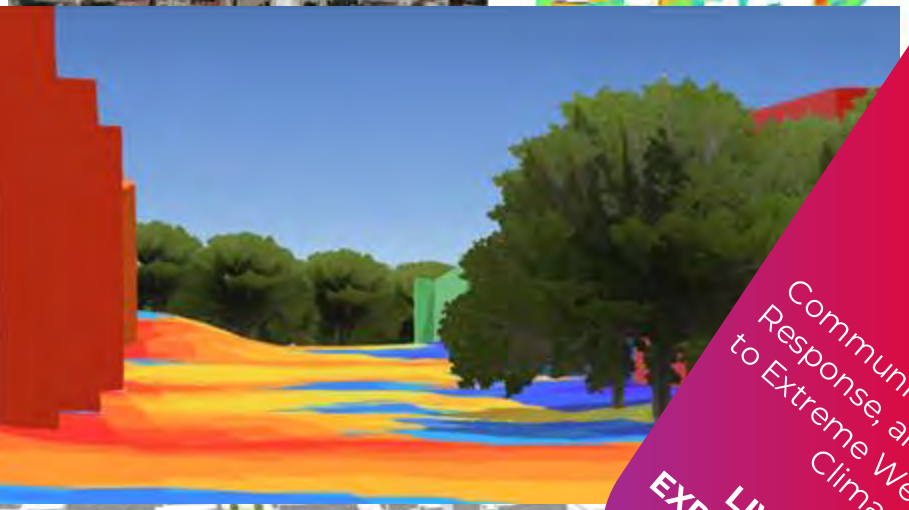
It is a framework that is tied into local city departments, communities, and UT Researchers



USEFUL TO USEABLE

UT-CITY CLIMATE COLAB

HEAT MAPPING



LOCAL DATA

Temperature, Precipitation, Air Quality, Satellite, Transportation, and Infrastructure

Academia, City, Community Partnership

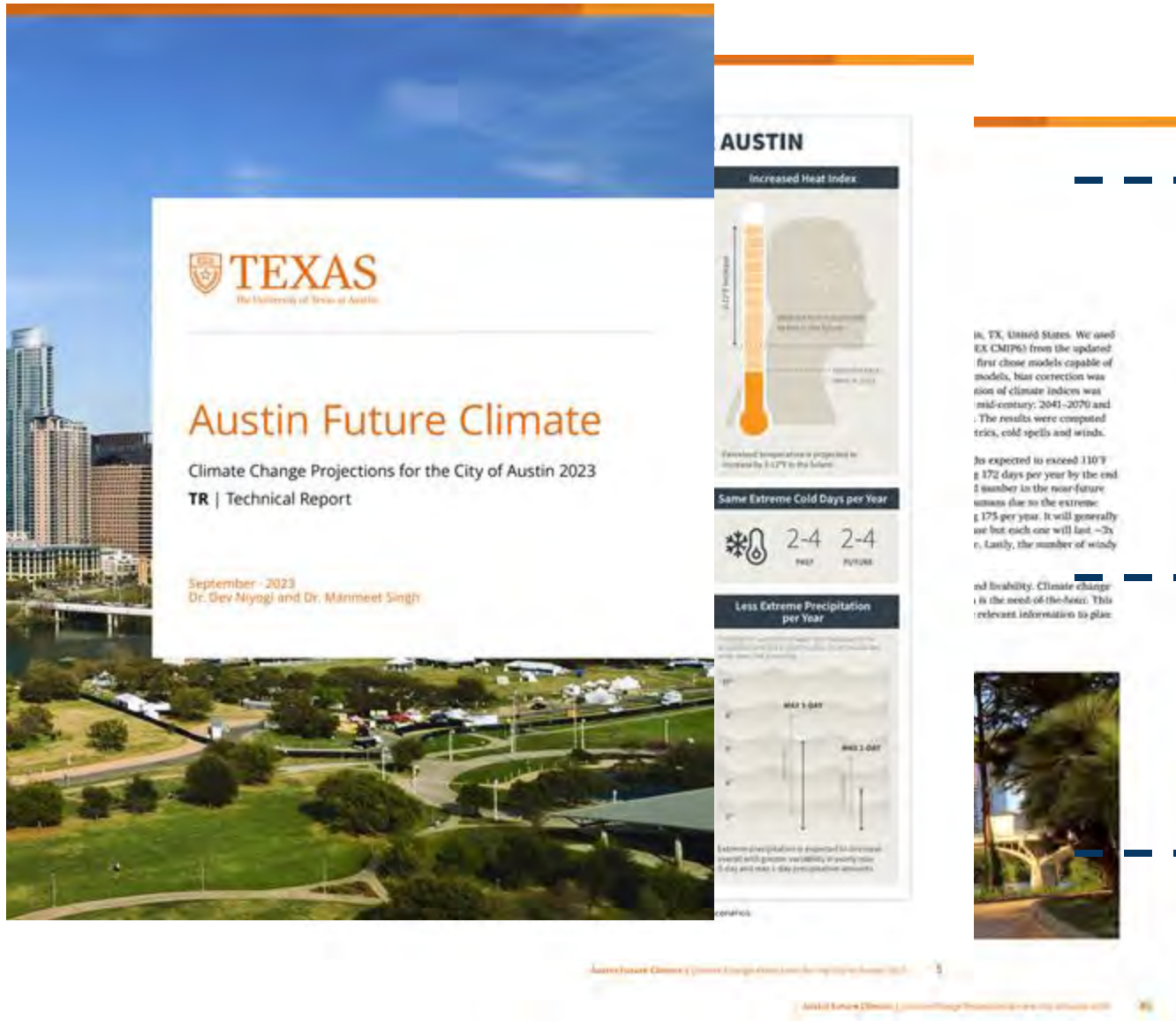
Community Feedbacks, Response, and Exposure to Extreme Weather and Climate

LIVED EXPERIENCES

Lived experiences combined with local data

INFORMED DECISIONS

AUSTIN'S FUTURE CLIMATE PROJECTIONS



Temperatures are projected to rise. The heat index, which is the temperature after factoring in humidity, can increase by 2–10°F in the future.

Both heatwaves and hot spells are expected to increase

Fewer frost days and freeze spells are projected.

UT-CITY CLIMATE COLAB