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Applications of statistical techniques in climate physics

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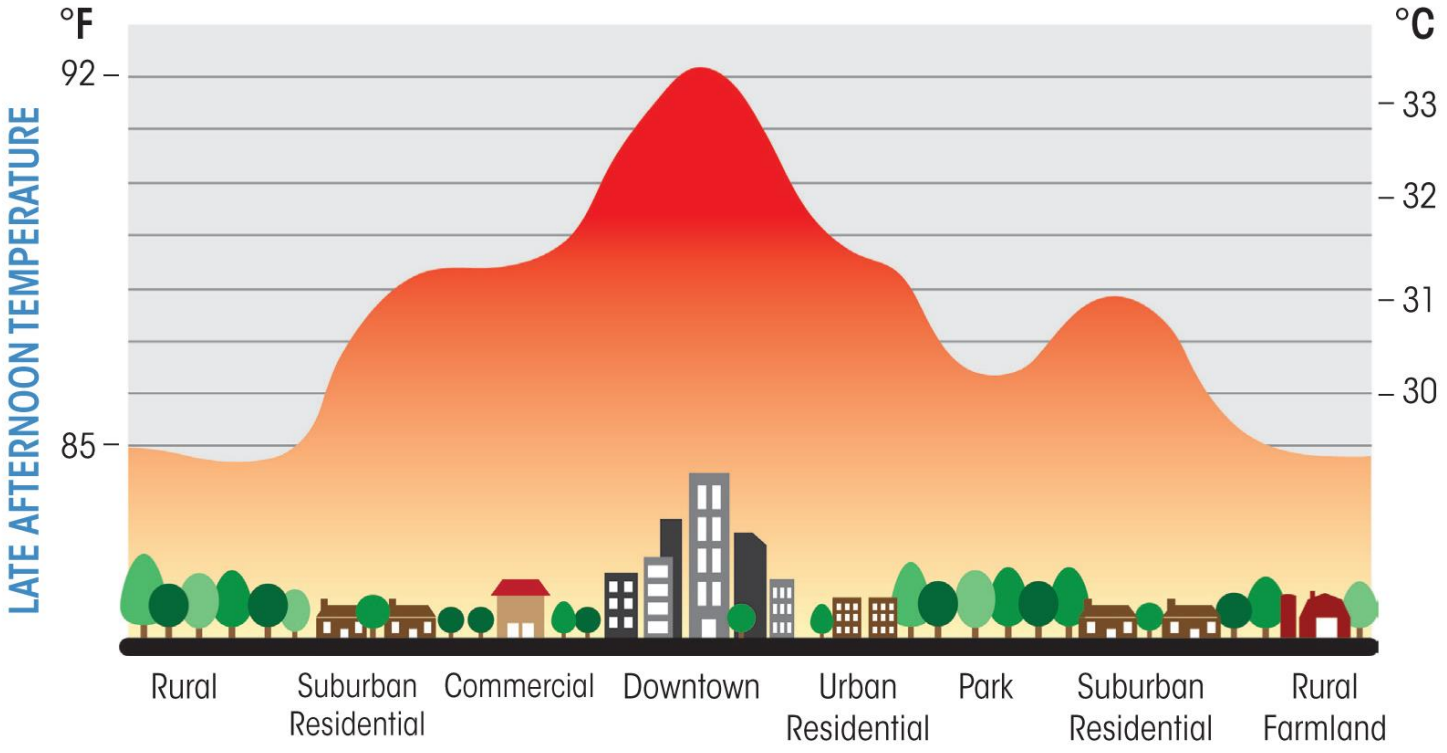
Project Introduction

Introduction and Aims



S. Babu, "Urban Heat Island Effect: All you need to know," *Eco-intelligent*^{TM}, Apr. 13, 2017. https://eco-intelligent.com/2017/04/13/the-urban-heat-island-effect/

Problematic:

The Urban Heat Island (UHI) effect not only affects the city itself, but also the surrounding environment.

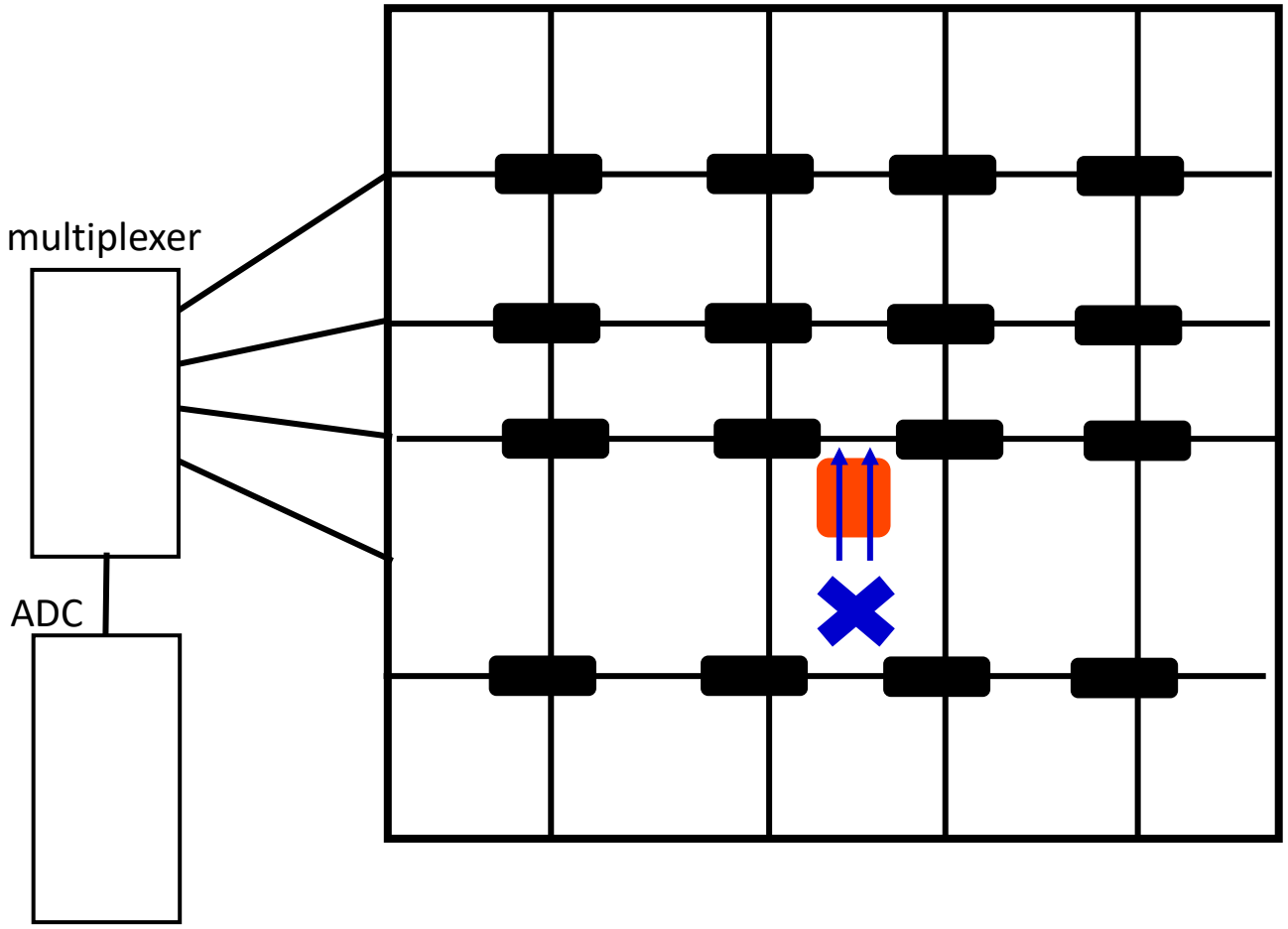
Aims:

Investigate how UHI affect the surrounding temperature by building a physical apparatus that allows us to mechanically simulate the spread of heat from UHI. Maybe there is a bigger effect than we imagined.

Apparatus design

The apparatus is an insulated box with a matrix of thermistors, a heating element, and an axial fan blowing weak uniform wind.

The thermistor data is recorded via an ADC.



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Where maths come in handy

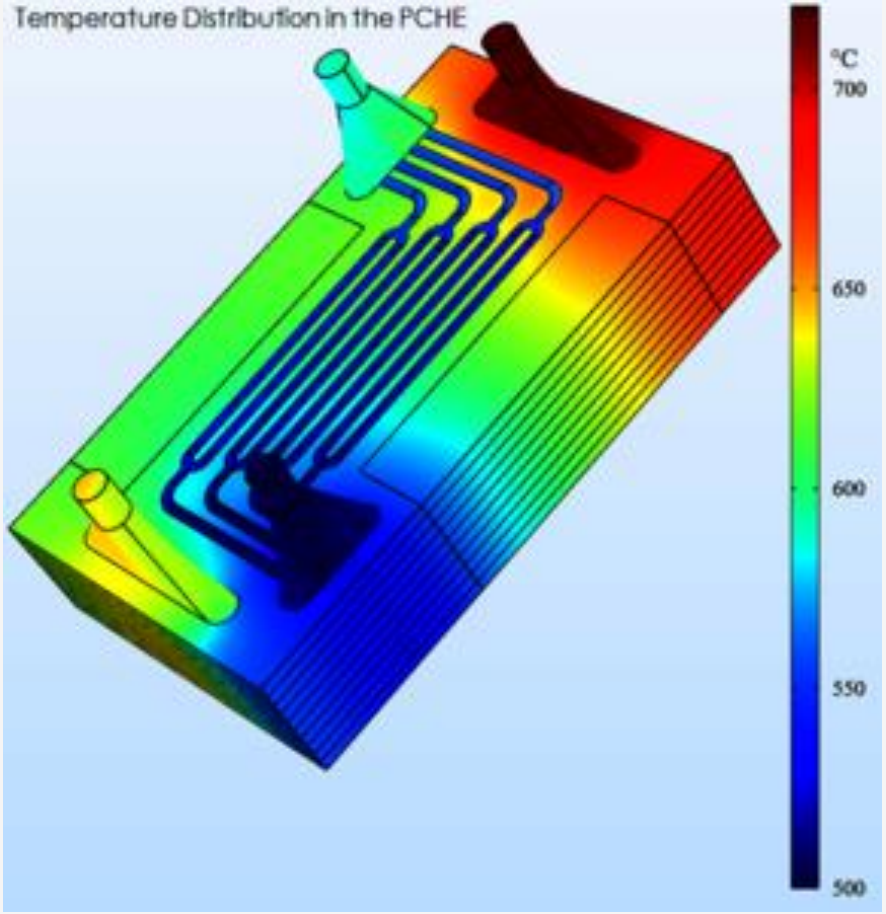
Simulation for heat losses: design choices

Challenge:

We know what properties of materials we need for the apparatus, but what parameters do we need specifically to allow the appropriate heat loss?

(Potential) resolution:

Perform numerical simulations. We have many pre-existing ones, but for our specific use case, what are some specific techniques that would be important?



"Thermal and Flow Simulation of a High Temperature Printed Circuit Heat Exchanger," *www.comsol.fr*. https://www.comsol.fr/paper/thermal-and-flow-simulation-of-a-high-temperature-printed-circuit-heat-exchanger-81551 (accessed Jun. 21, 2024).

Interpolation of thermistor data

Challenge:

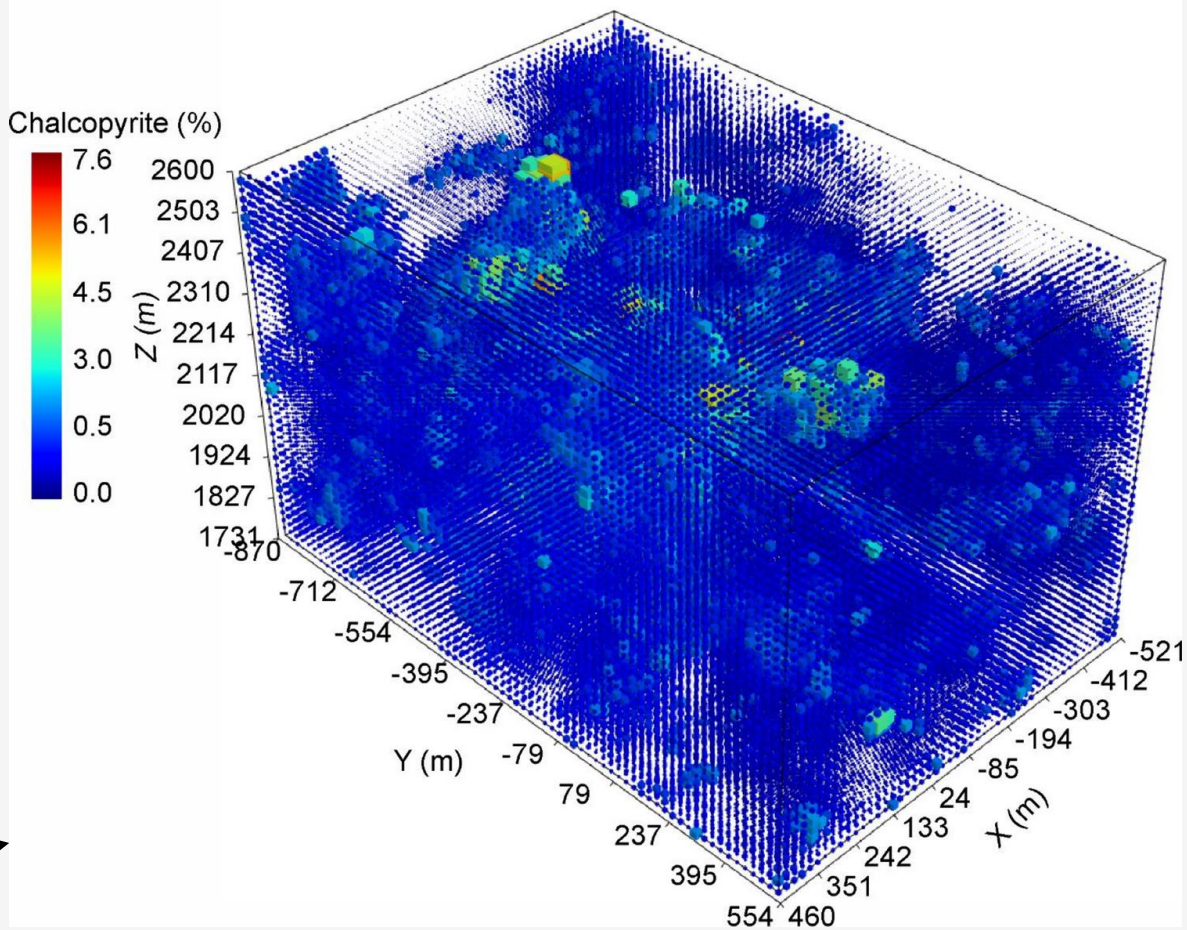
Low resolution data due to necessary experimental considerations.

(Potential) resolution:

Interpolate with various different interpolation models:

- RBFNs,
- CNNS,
- Kriging,
- etc.

Geological data but the idea is the same



G. T. Nwaila, S. E. Zhang, J. E. Bourdeau, H. E. Frimmel, and Y. Ghorbani, "Spatial Interpolation Using Machine Learning: From Patterns and Regularities to Block Models," *Natural resources research*, vol. 33, no. 1, pp. 129–161, Nov. 2023, doi: https://doi.org/10.1007/s11053-023-10280-7.

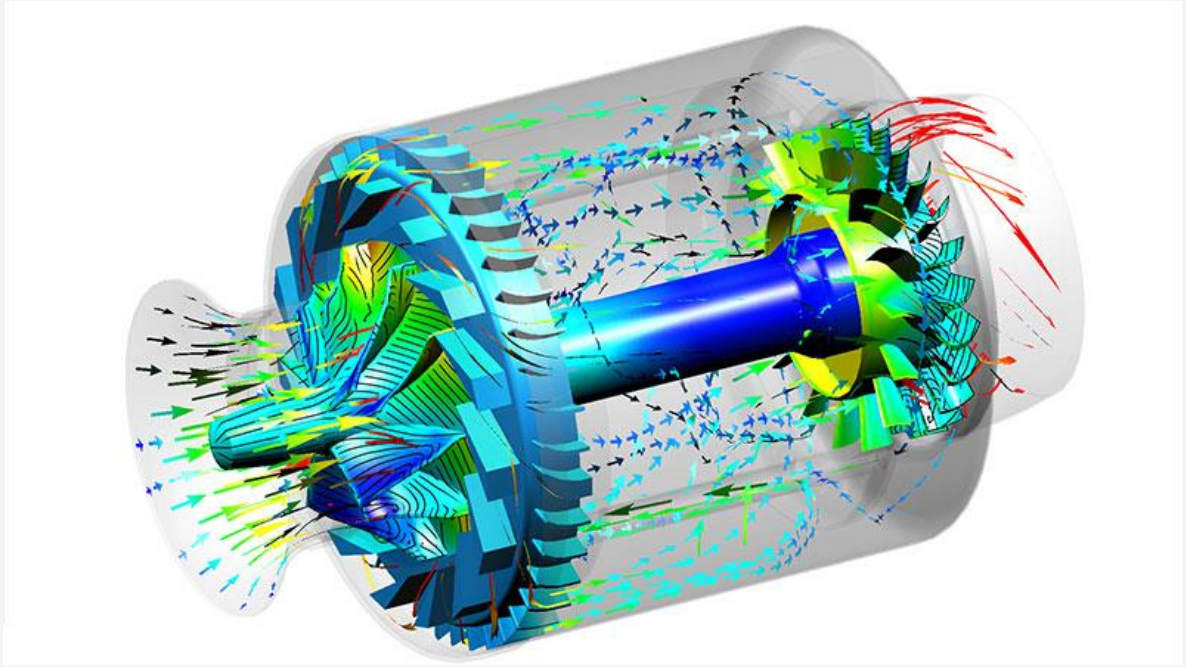
Comparison with simulations

Challenge:

It is always helpful to have some simulation data on hand (sample for interpolation, compare models, etc).

(Potential) resolution:

Perform experiment numerically on simulations. But this is quite challenging for many physicists once it gets too advanced.



"Numerical Simulations – Quandela." https://www.quandela.com/numerical-simulations/ (accessed Jun. 21, 2024).

Comparison with real life data

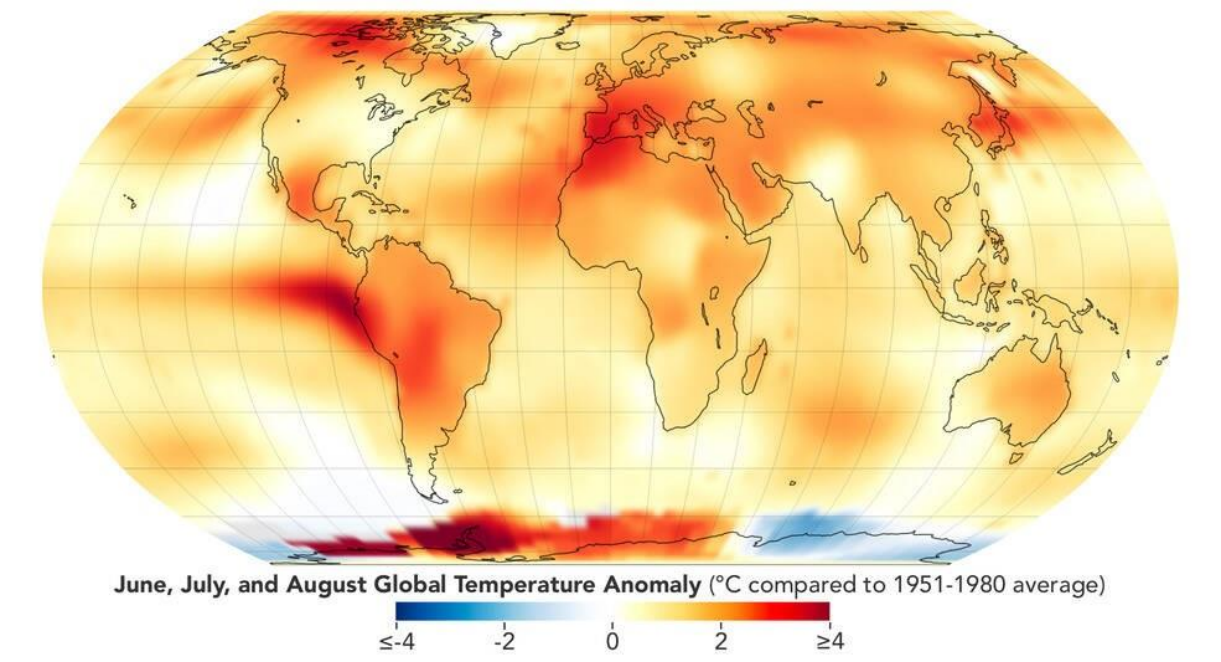
Challenge:

How do we know our experiment actually works?

(Potential) resolution:

Compare with real data of the atmosphere, see if our distribution matches what we can measure in real life. To this end, we need statistical inference:

- Bayesian
- Frequentist
- Other more suitable methods



"NASA, NOAA to Announce 2023 Global Temperatures, Climate Conditions - NASA." https://www.nasa.gov/news-release/nasa-noaa-to-announce-2023-global-temperatures-climate-conditions/

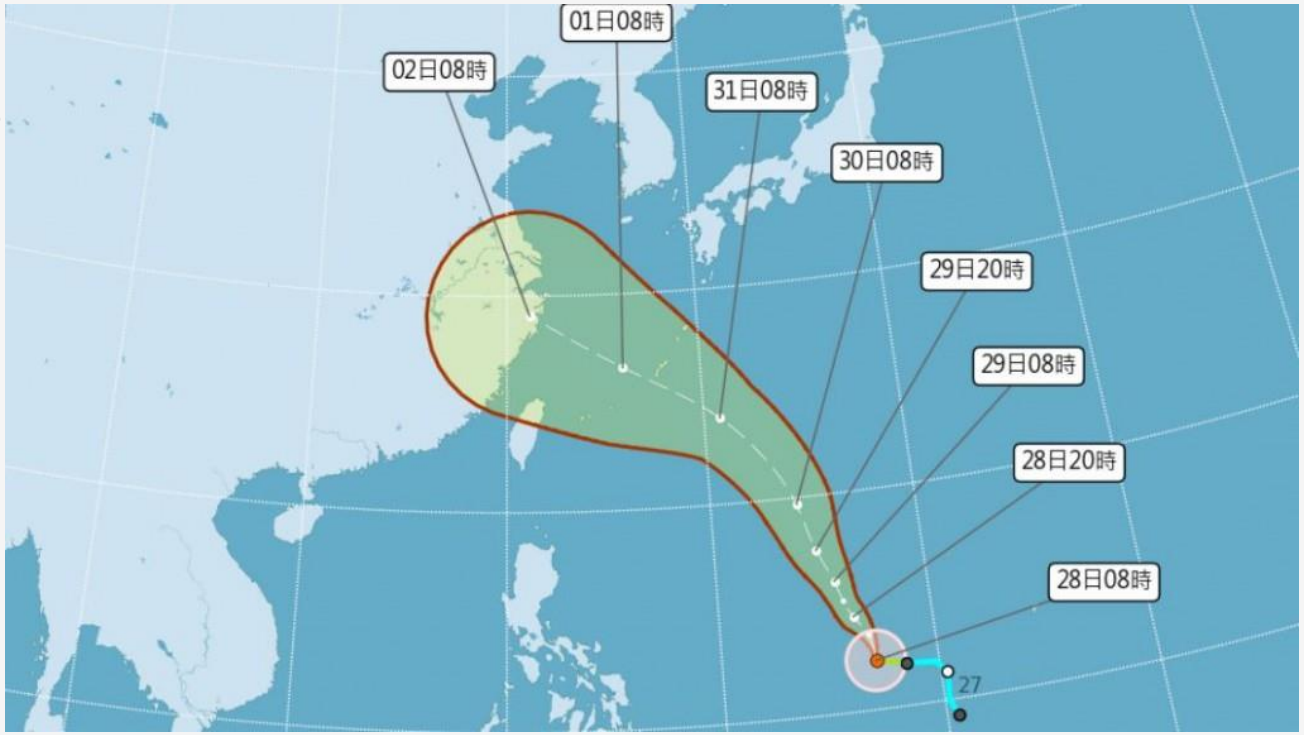
“Cone of uncertainty”

Challenge:

The simulation deviates further from reality the longer we run it for, when does it start to deviate too much?

(Potential) resolution:

Many of the methods are common to physicists (cone of uncertainty for hurricane predictions), however care is needed for the 3d spatial temperature distributions.



“Tropical Storm Khanun forms, north Taiwan in cone of uncertainty | Taiwan News | Jul. 28, 2023 11:23,” *taiwannews.com.tw*, Jul. 28, 2023. https://www.taiwannews.com.tw/news/4956373 (accessed Jun. 20, 2024).

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Thanks for listening