Actionable Climate Information for Cities: Challenges and Opportunities

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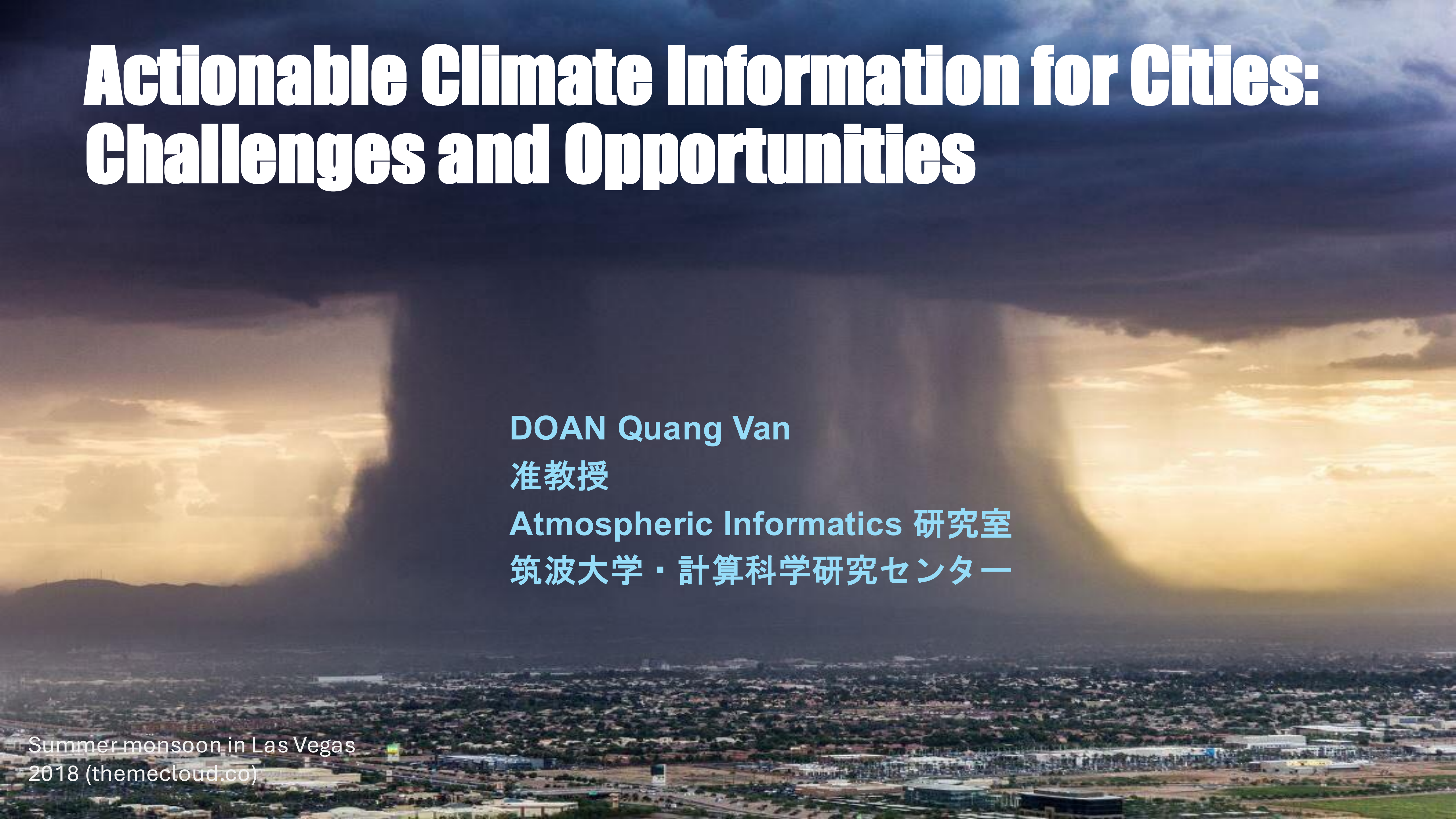
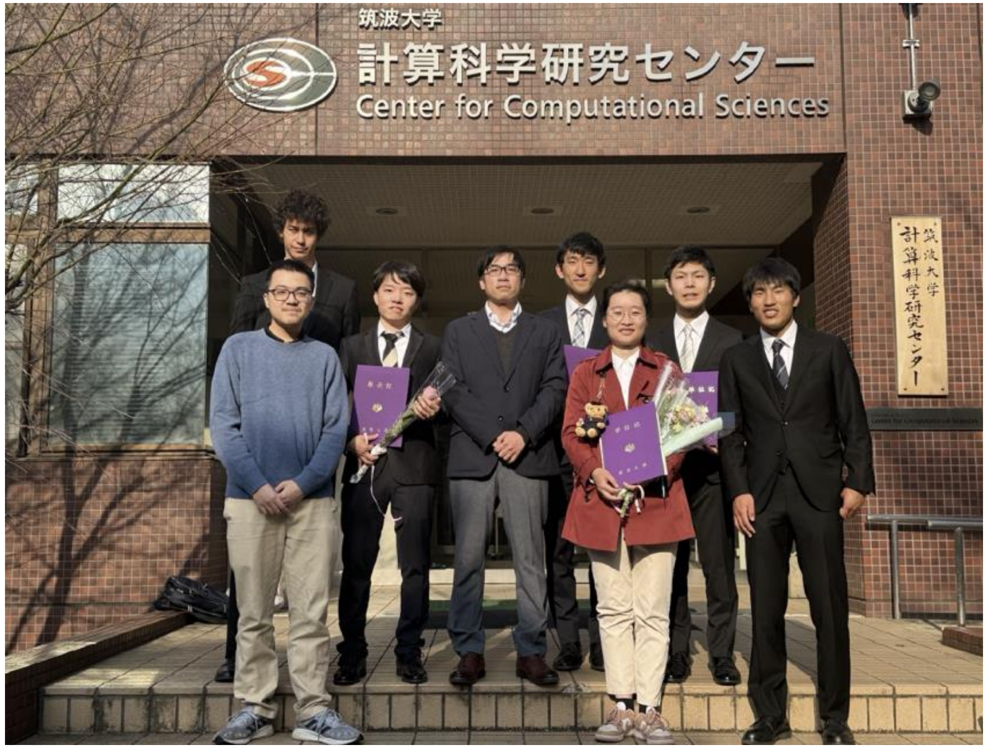


Summer monsoon in Las Vegas
2018 (themecloud.co)

Atmospheric Informatics (AI) Lab: Who we are?



AI-Lab (March 2025)

研究員: １ 人
事務補佐: 1人
博士課程: 1人
修士課程: 5人
学部生: 2人

人工知能
データマイニング
複雑ネットワーク (Graph theory)
=> 大気科学への応用・開発

数値計算
陸面過程、都市キャノピーモデル
領域気候モデル, WRF, HRLDAS

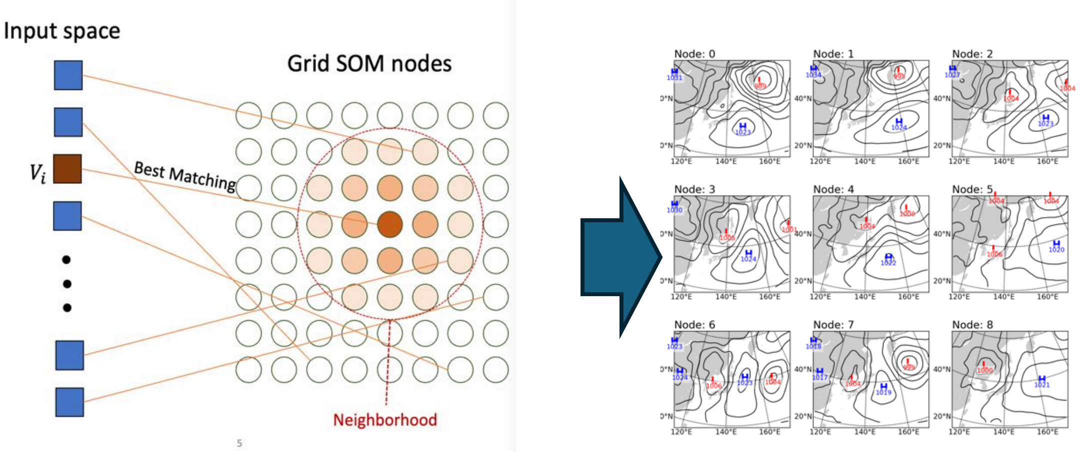
極端気象・気候
Compound and cascading

都市環境, 都市気候物理プロセス
Urban resilience, urban digital twins

人工知能/データマイニング、複雑ネットワーク

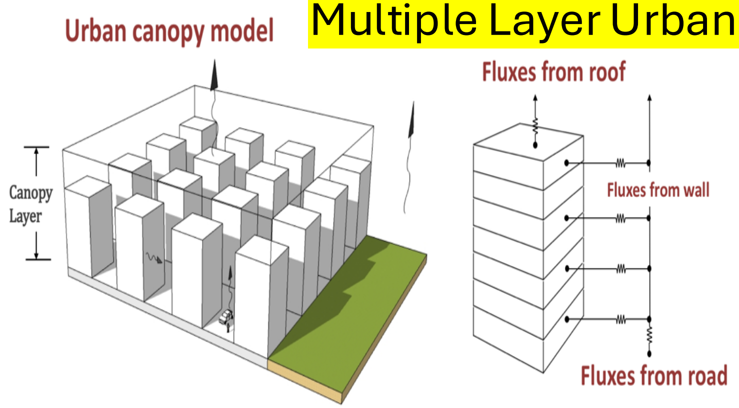
数値計算
陸面過程、都市キャノピーモデル領域気候モデル

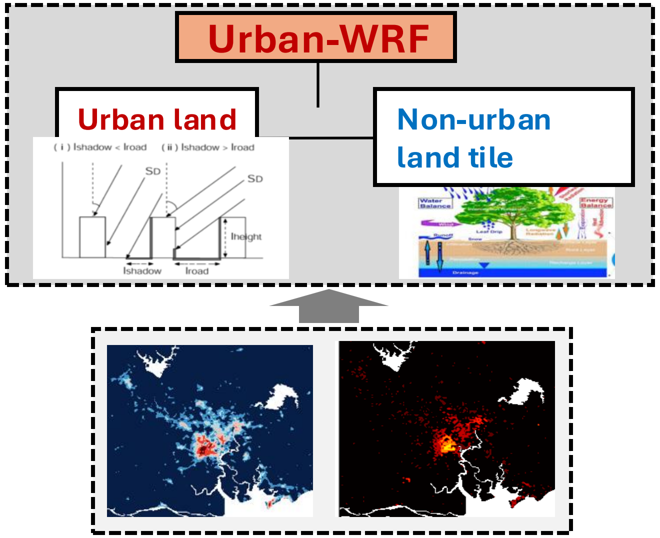
Development & Application



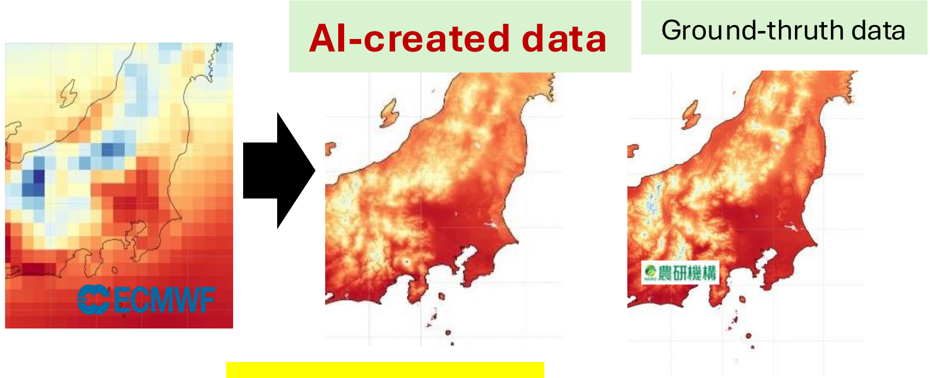
Structural Self Organizing Map for Weather Typing

Multiple Layer Urban Canopy Model

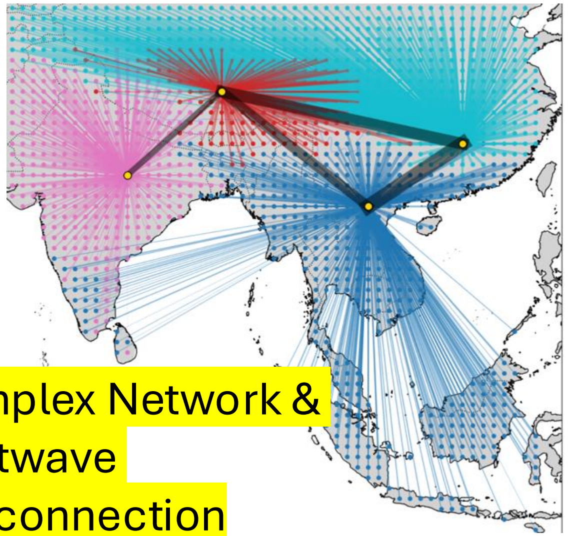




Urban Specific WRF model



AI Downscaling



Complex Network & Heatwave Teleconnection

国際協力

代表, **WRCP My Climate Risk Japan Hub**

代表, **CORDEX SEA urban climate sub-group**

メンバー, **ERB-RCC** (Flagship Pilot project on urban climate downscaling)

メンバー, **CORDEX Task Force on Machine Learning**

主任著者, 第２章**IPCC特別報告書「Climate Change and Cities」**

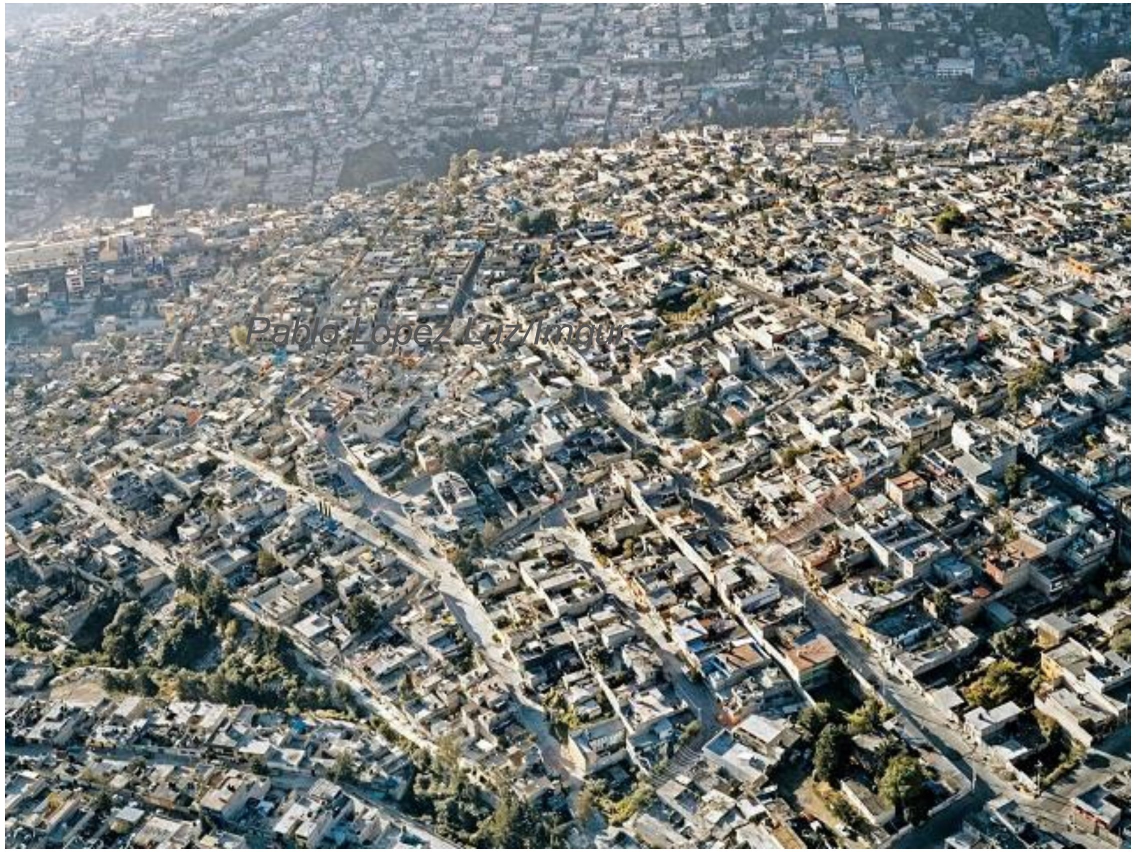
IPCC Special Report LAM1 at Osaka (2025)

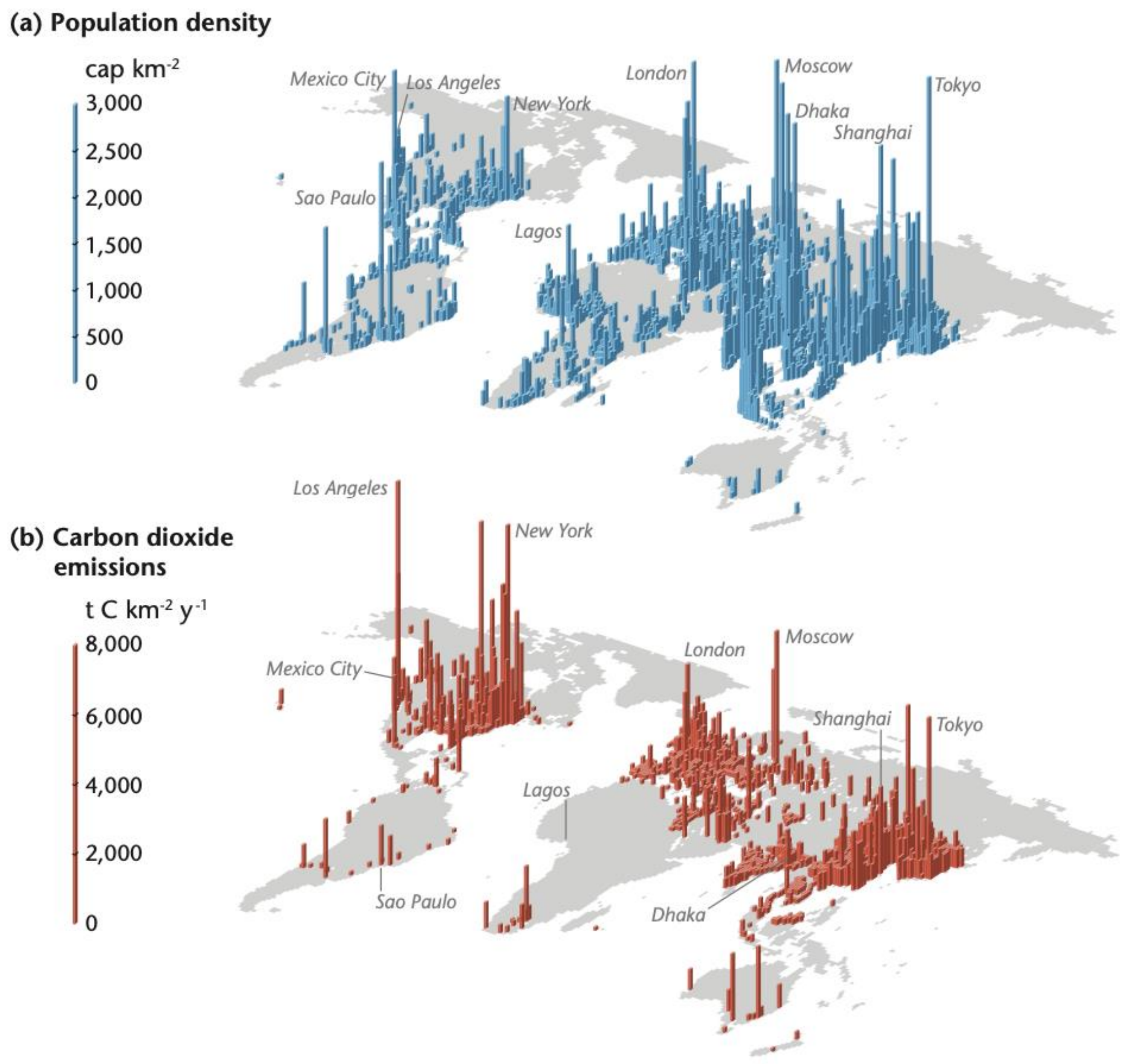
Actionable climate information for cities:

Concept, technique overview

Why cities matter?

都市、なぜ？





Credit to Oke (2017)

Cities occupy less than **1%** of global land
Home more than **50 %** of global population
Genarete more than **80 %** of global GDP
Account for **70 %** of global C02 emissions

Cities is the focus of upcomming IPCC Special Report on Climate Change and Cities

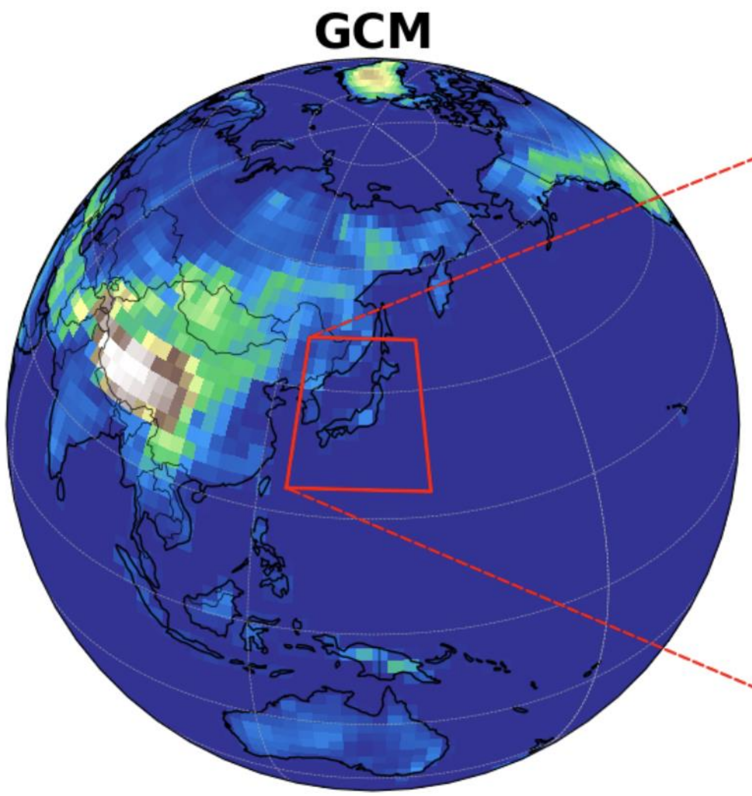
IPCC Scoping Meeting (16 – 19 April, Riga, Latvia)

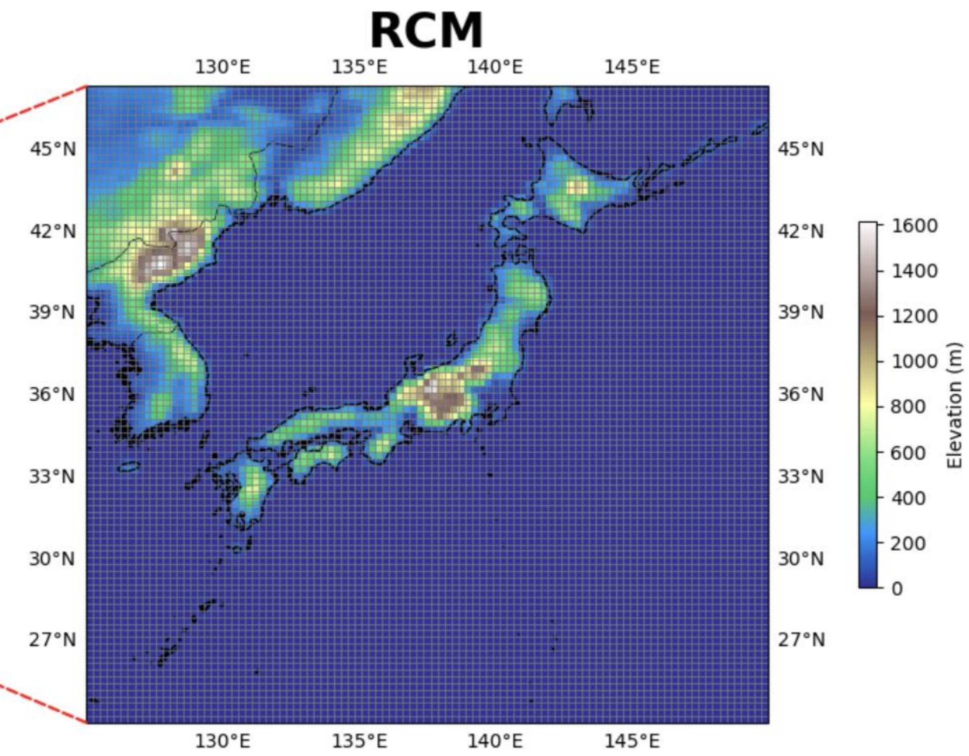
Climate downscaling is more than refining GCM resolution

There are many approaches to obtain high-res climate information

力学的気候ダウンスケーリング（Dynamical climate downscaling）

Explicit Representation of local conditions (orography, land use change, urbanization).

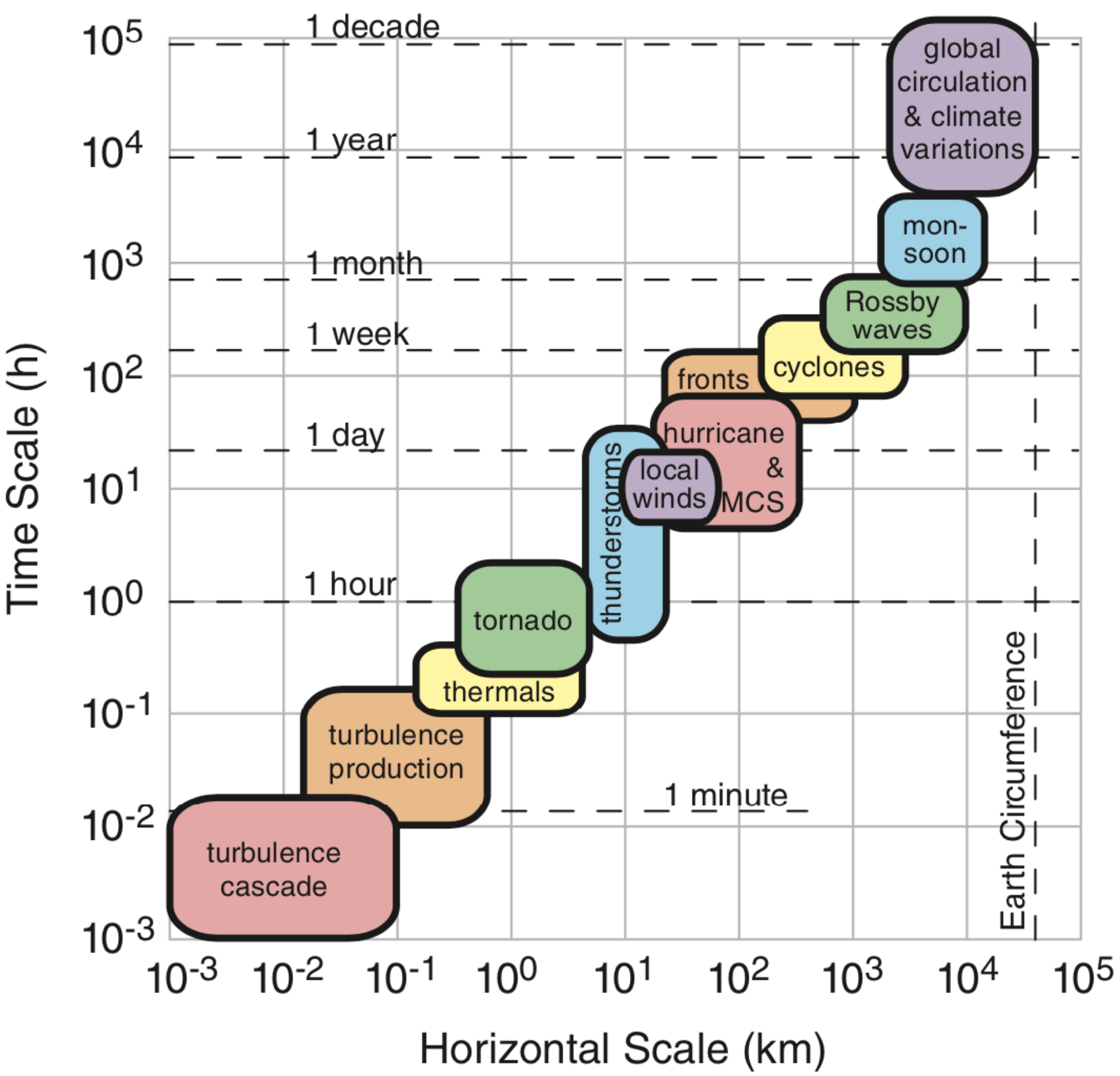




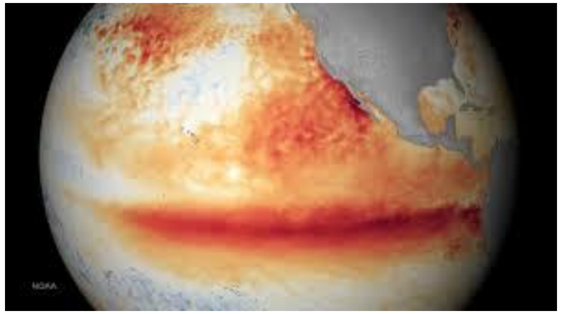
~100 km resolution

Unable to explicitly represent "sub-grid" phenomena

km resolution -> able to represent localized circulation like convective process



A log-log plot of time duration vs. horizontal size of many weather phenomena. (Stull, 2017)



NOAA

NASA

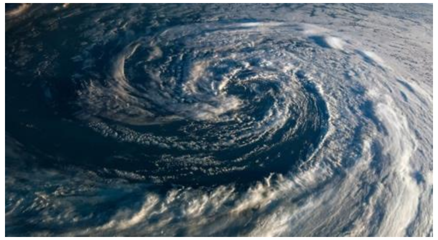
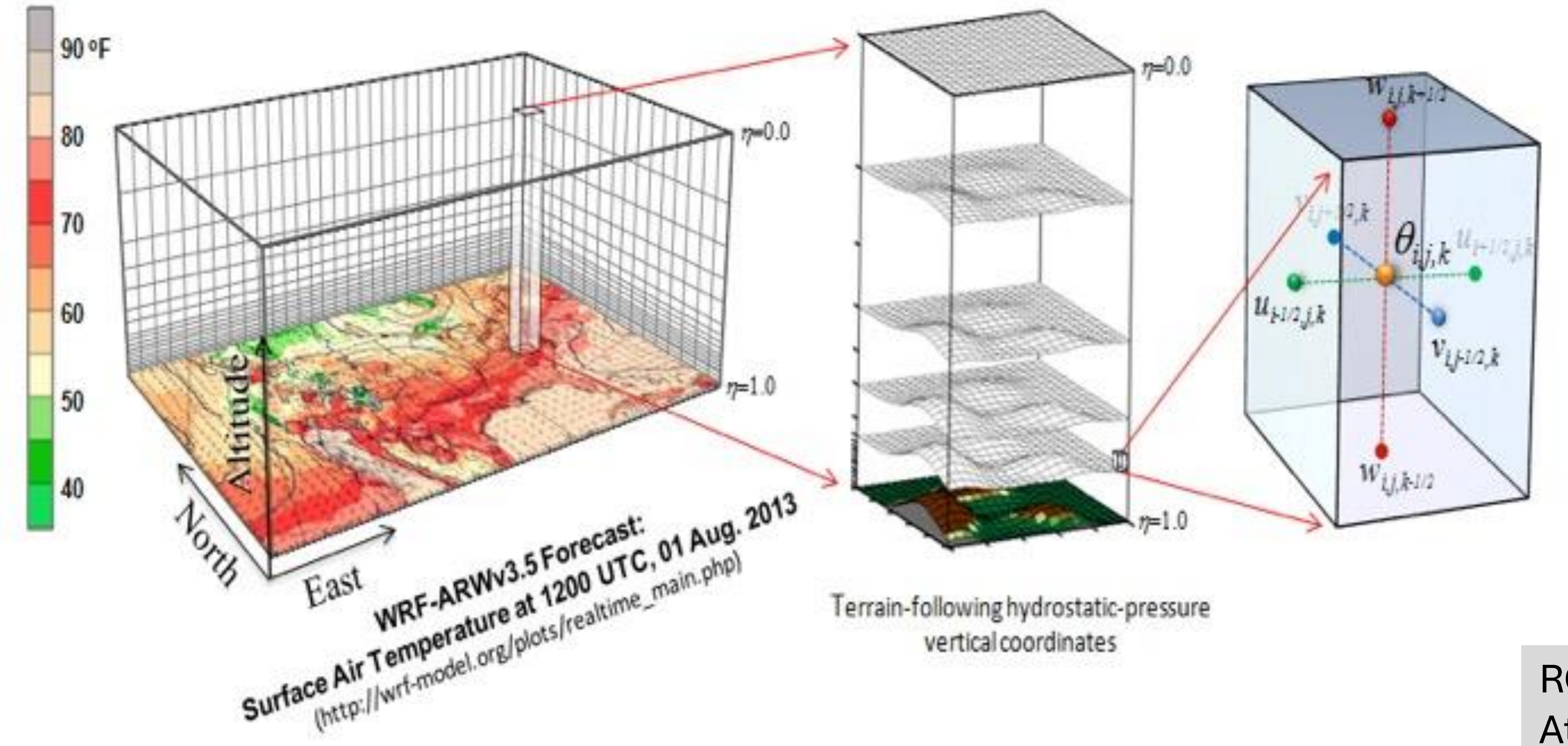


Image by Kyle Cutler/Wikimedia

Image: Forbes

Image: CNN

Weather Research and Forecasting model



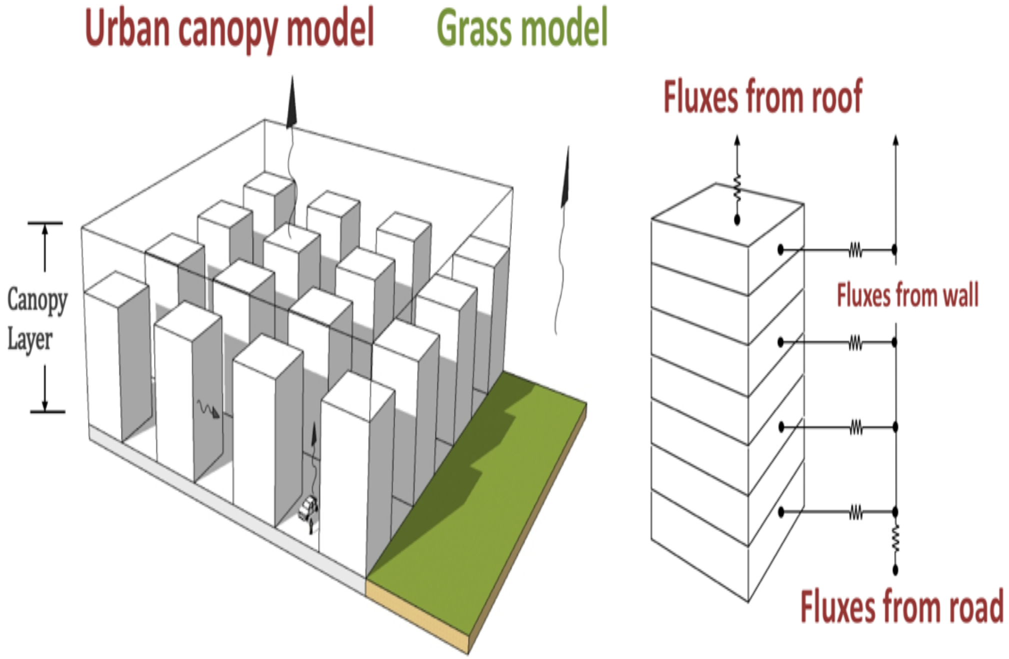
Weather Research and Forecasting (WRF) model
source: BioEarth, WSU

RCM needs
Atmospheric Initial Conditions
Top, and surface boudanry conditions
Lateral boudanry conditions

都市効果モデリング

From realistic urban form to a table of parameter values

https://architizer.com/blog/inspiration/industry/rendering-to-reality-mahanakhon/



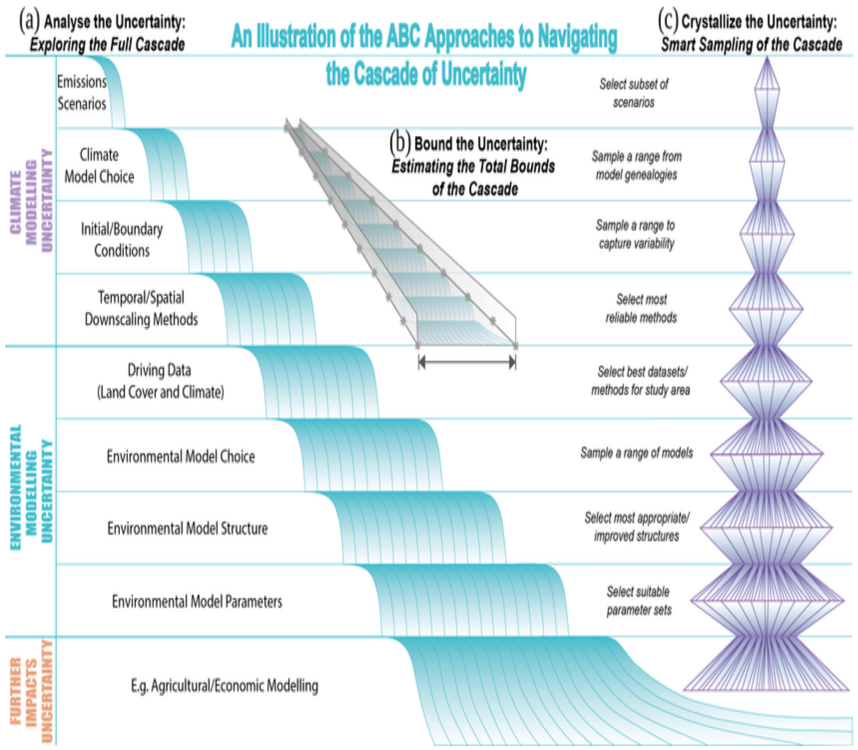
Parameters	Units	Compact H rise	Compact M rise	Compact L rise	Open H rise	Open L Rise	Large L Rise	Sparsely Built
Urban fraction	%	100	95	90	65	65	85	30
Roof heat capacity	J/m^3K	1.95E6	2.4E6	2.219E6	1.95E6	2.219E6	2.4E6	8.916E6
Roof thermal conductivity	W/mK	1.1538	0.937	0.649	1.1538	0.649	0.937	0.1615
Roof albedo	%	13	18	15	13	13	18	13
Roof emissivity	%	91	91	91	91	91	91	91
Roof width	M	15	17.5	9	32	105	28.8	10
Ground heat capacity	J/m^3K	3.84E6	4.14E6	4.425E6	4.88E6	5.07E6	4.20E6	5.833E6
Ground thermal conductivity	W/mK	0.4004	0.4004	0.4004	0.4004	0.4004	0.4004	0.4004
Ground albedo	%	15	15	16	17	18	16	19
Ground emissivity	%	95	95	95	95	95	95	95
Wall heat capacity	J/m^3K	1.698E6	4.266E6	3.945E6	2.5E6	3.94E6	2.4E6	15.8E6
Wall thermal conductivity	W/mK	1.1538	0.937	0.649	1.1538	0.649	0.9375	0.1615
Wall albedo	%	25	20	20	25	25	25	25
Wall emissivity	%	90	90	90	90	90	90	90
Road width	m	15	12.7	5.7	37.5	12.4	32.5	10
Building height	m	25	17.5	6.5	25	6.5	6.5	6.5
Building area fraction (BAF)	%	50	40	40	20	20	20	16
COP of AC system		3	3	3	3	3	3	3
Target temperature of AC system	K	297	297	297	297	297	297	298
Heat generated by equipment	W/m^2	36	30	25	20	15	36	10

気候ダウンスケーリングの不確実性（Uncertainties ）

- **Aleatoric** (statistical) uncertainty refers to the notion of **randomness => reduced by ensemble approach**
- **Epistemic** uncertainty refers to uncertainty caused by a **lack of knowledge => reduced by additional information and knowledge**

Uncertainty is cascading

(Smith et al., 2018, J of Extreme Events)



Solutions

Ensemble approach: Quantify **probabilities** and **uncertainty** by sampling many plausible futures.

However *"Average of imperfection cannot become perfection"*

Storylining approach: Explore **specific, plausible trajectories** or events without assigning a prior probabilities.

擬似温暖化手法

Pseudo Global Warming Dynamical Downscaling

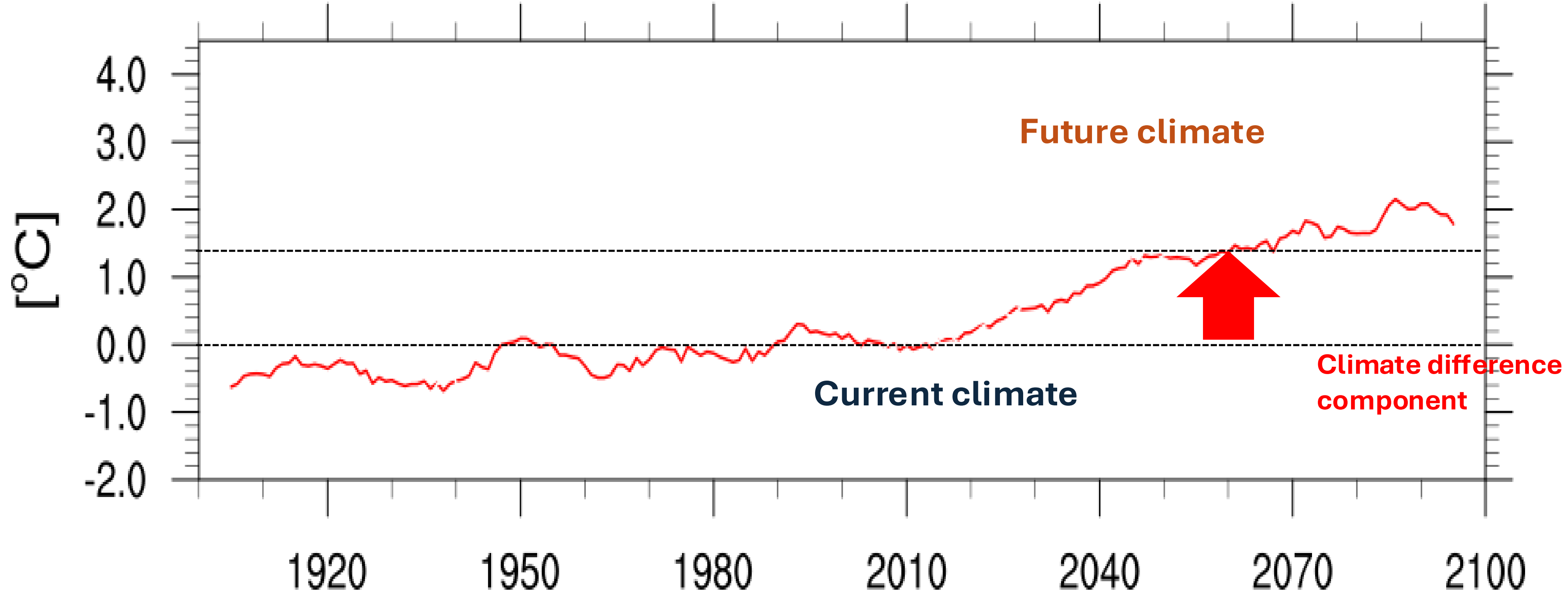
Pseudo Global Warming downscaling (PGW-DS) as **climate change storylining** approach:

Explore ***specific, plausible trajectories*** *or events without assigning a prior probabilities*.

PGW Downscaling

PGW DS is Dynamical Downscaling

Impose the warming signal predicted by GCM by assuming no change in large scale circulations

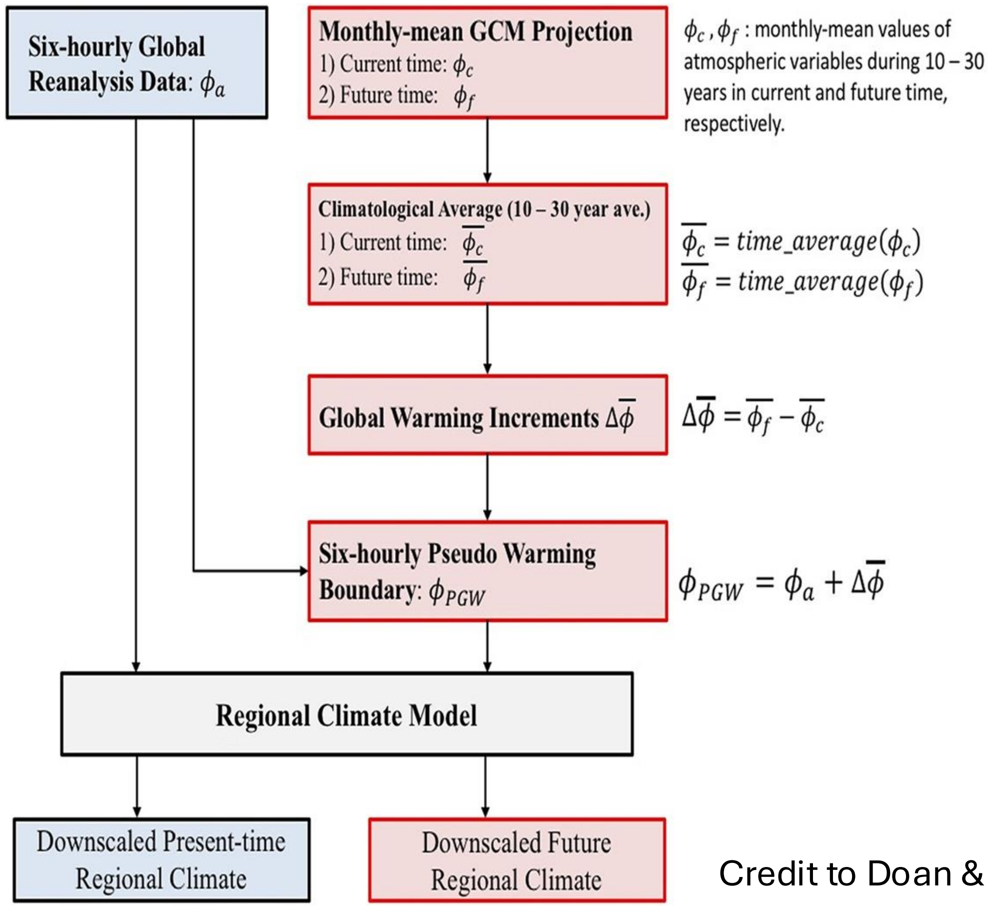


Key Characteristics

- **Maintains historical weather variability**, enabling detailed analysis of specific events (e.g., typhoons, heavy rainfall).
- **Avoids GCM biases** in circulation patterns since it uses reanalysis-based dynamics.
- Ideal for **impact studies** (e.g., hydrology, urban planning, disaster risk).

GitHub

https://github.com/doan-van/Pseudo-Global-Warming-Downscaling



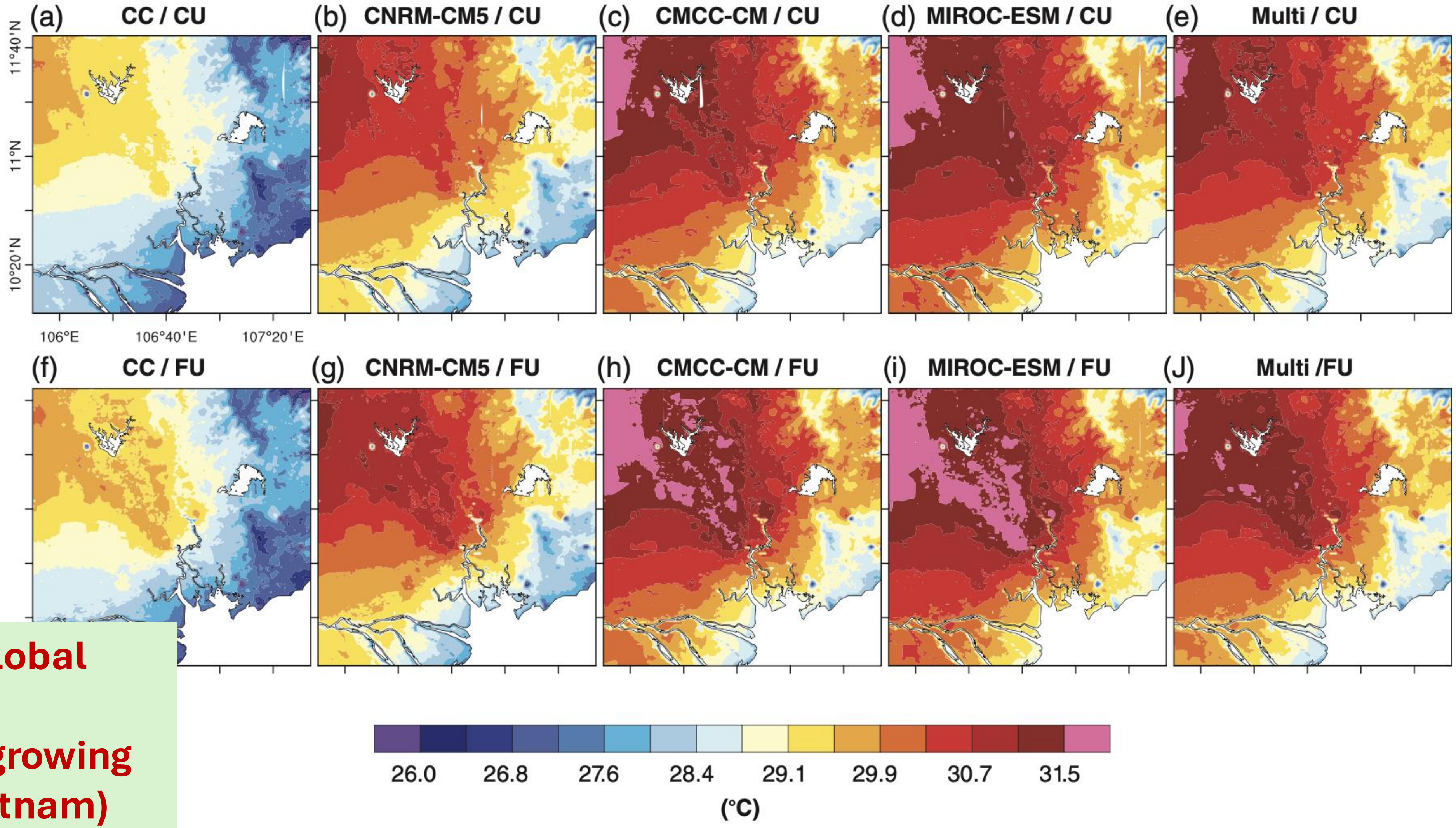
Credit to Doan & Kusaka (IJoC, 2018)

PGW DS Can Do	PGW DS Cannot Do
Downscale specific historical events into the future	Simulate future event frequency or emergence
Preserve synoptic-scale variability	Project shifts in climate variability patterns
Evaluate local impacts under warming	Capture full Earth system feedbacks
Provide high-resolution future analogs	Simulate time-evolving trends over decades

PGW DS is particularly useful for answering **event-focused, high-resolution, and impact-relevant scientific questions**.

応用例

Showcasing sucessful examples of using PGW-DS to investigate how and why local climate and extreme events respond to global warming



Coupled effects of Global Warming and Local Urbanization in fast-growing Ho Chi Minh City (Vietnam)

FIGURE 12 Spatial distribution of mean April T2 from the CC experiments and the FC downscaling experiments under the RCP8.5 scenario. CU and FU indicate current and future urban land surface conditions, respectively. "Multi" denotes inter-experimental averages of the FC experiments

Doan and Kusaka, IJOC 2018

JGR Atmospheres

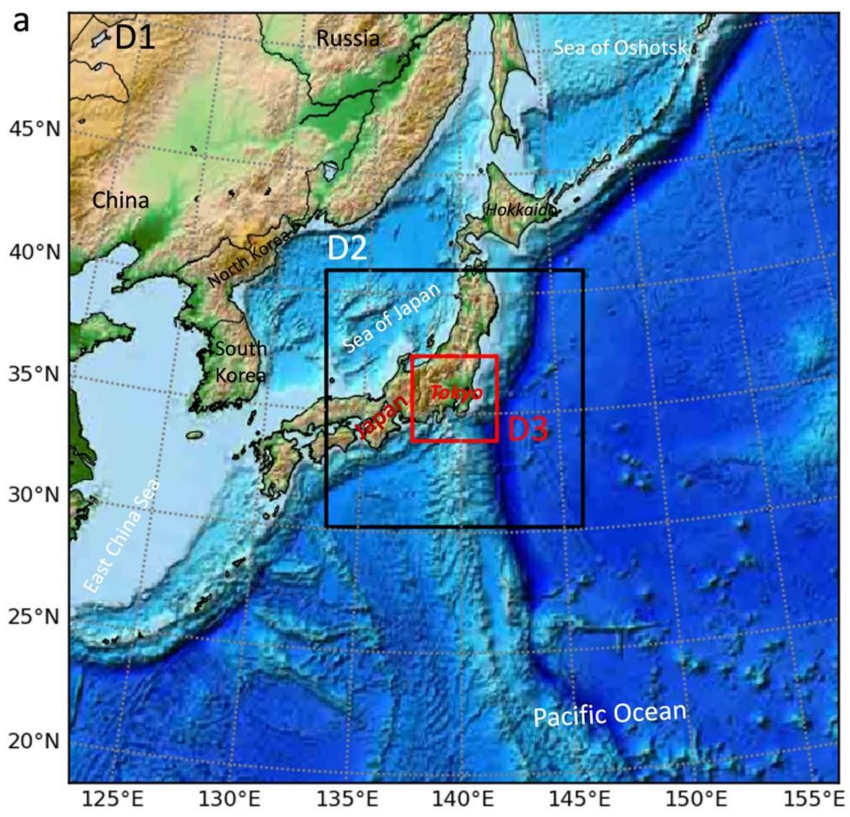
Research Article | Open Access

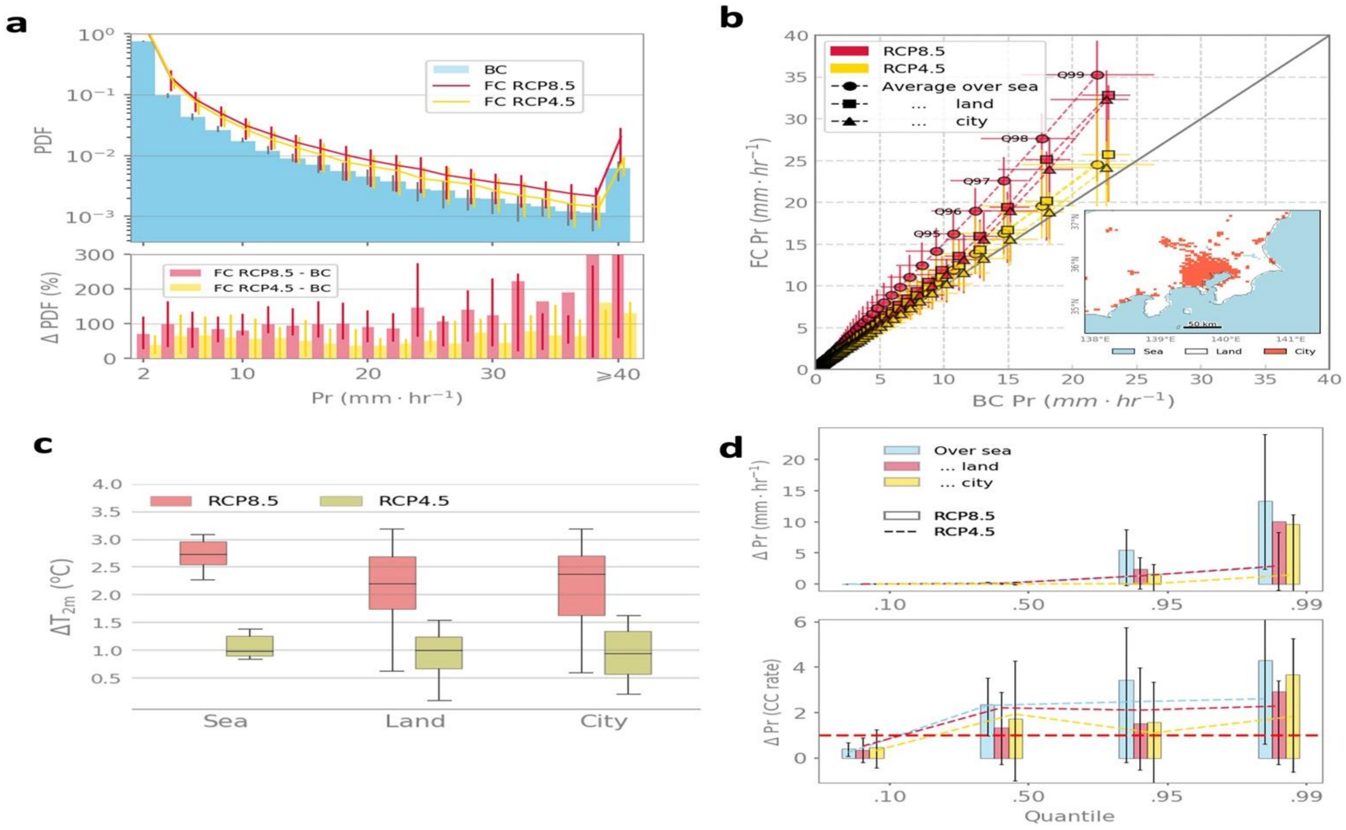
Identifying a New Normal in Extreme Precipitation at a City Scale Under Warmer Climate Regimes: A Case Study of the Tokyo Metropolitan Area, Japan

Quang-Van Doan, Fei Chen, Hiroyuki Kusaka, Jie Wang, Mizuo Kajino, Tetsuya Takemi

"Extreme gets more extreme"

Assymetric pattern in precipitation change with global warming revealed by PGW-DS





ENVIRONMENTAL RESEARCH
LETTERS

LETTER • OPEN ACCESS

Climate change effects on the worst-case storm surge: a case study of Typhoon Haiyan

Izuru Takayabu, Kenshi Hibino, Hidetaka Sasaki, Hideo Shiogama, Nobuhito Mori, Yoko Shibutani and Tetsuya Takemi

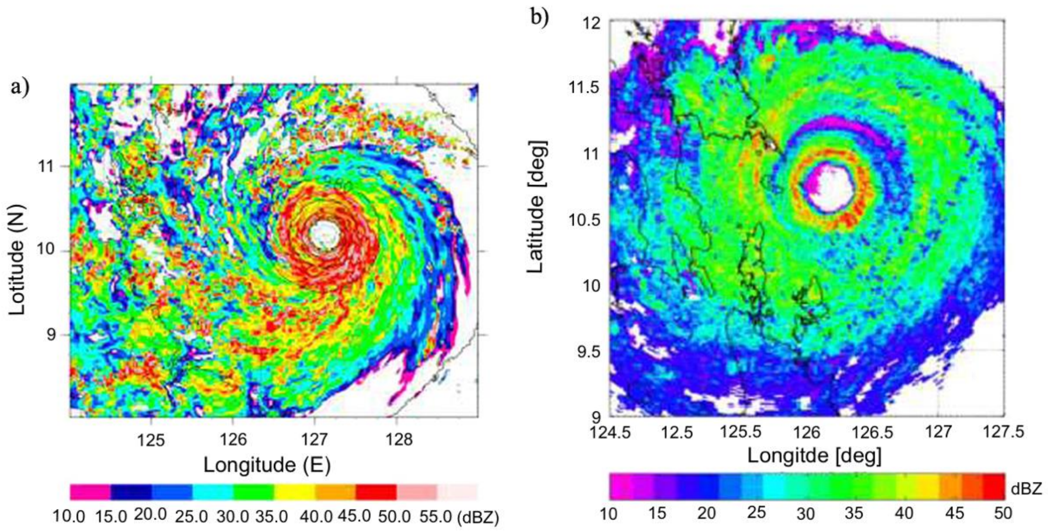
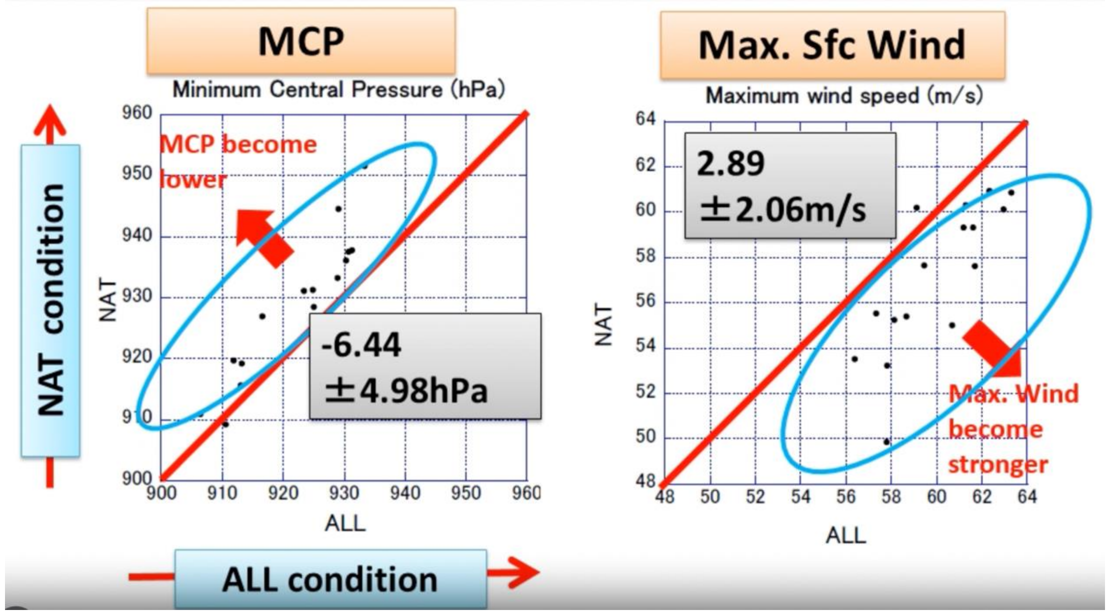


Figure 4. (a) Radar reflectivity at z = 2 km in the m02 (1001) experiment with the 1 km WRF model (dBZ) (1100 UTC on 8 November 2013). (b) Radar reflectivity data for Guiuan station (dBZ), elevation angle 1° (2016 UTC on 7 November 2013).

Typhoon Haiyan (Yolanda)

- Here the simulation results of Typhoon Haiyan is shown.
- Also an inundation is assessed by using SuWAT model.

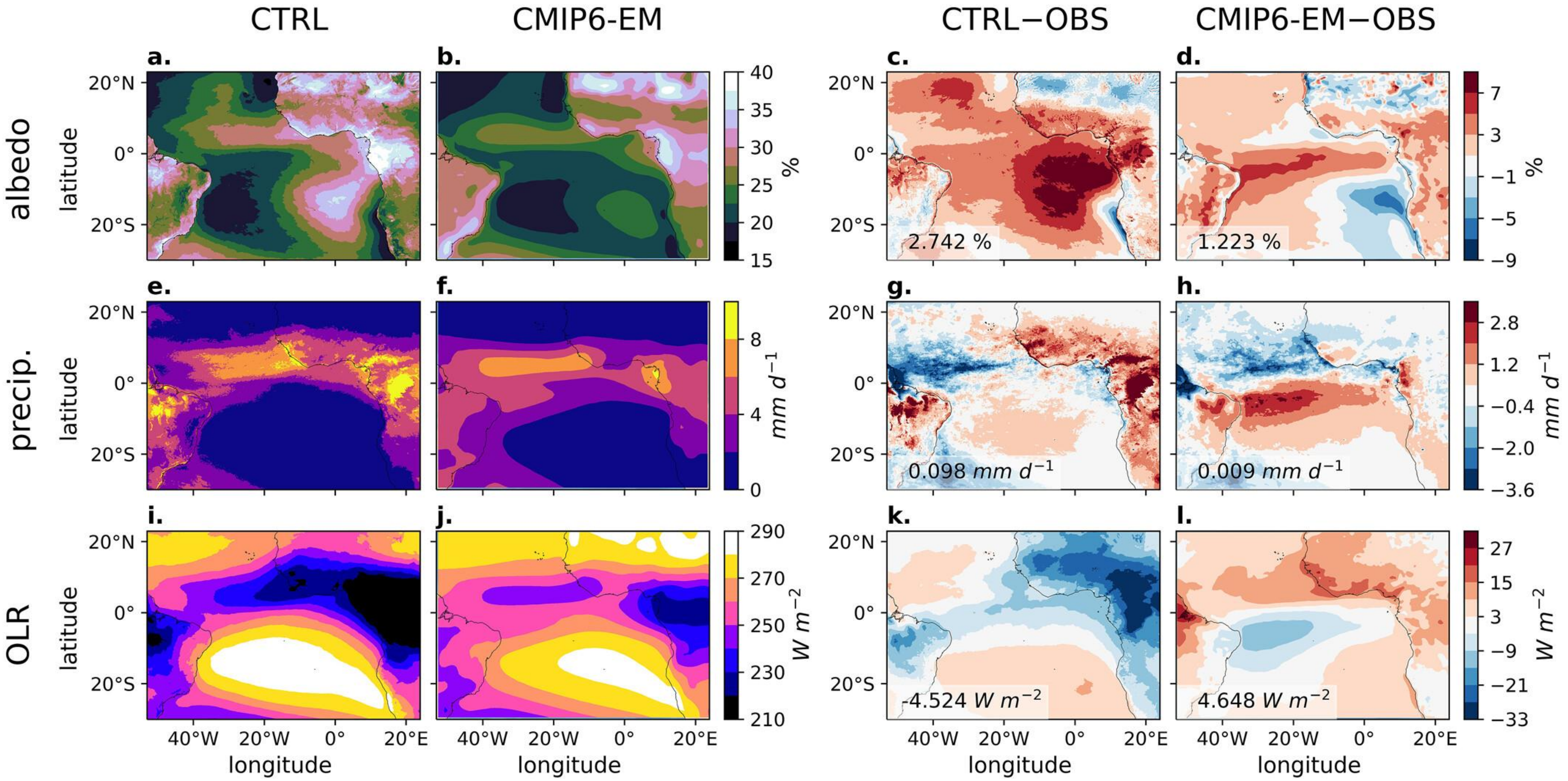


JGR Atmospheres

Research Article | Open Access

Application of the Pseudo-Global Warming Approach in a Kilometer-Resolution Climate Simulation of the Tropics

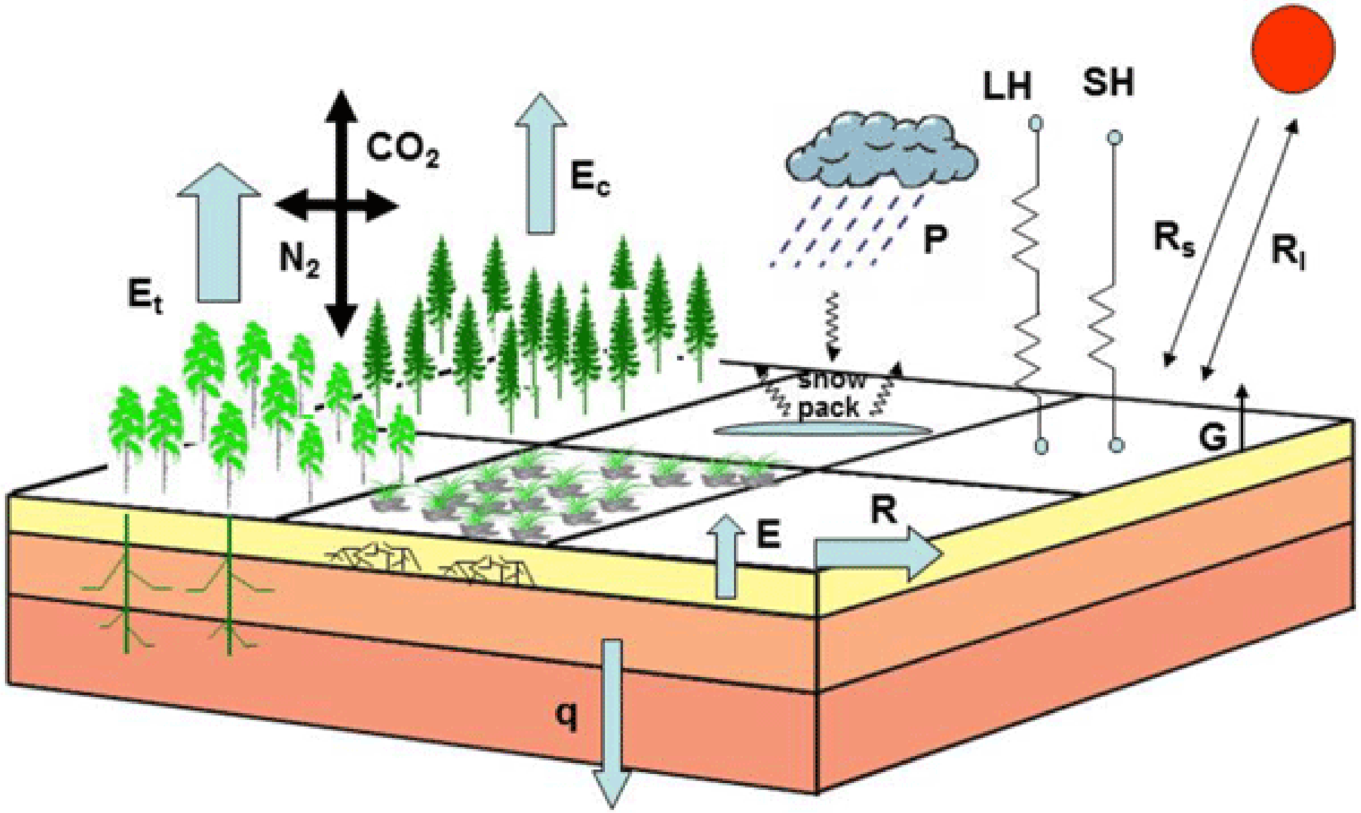
Christoph Heim, David Leutwyler, Christoph Schär



Atmospheric Informatics Labが開発したダウンスケーリング手法

A novel downscaling method:

Land surface physics-based downscaling (LSP-DS)

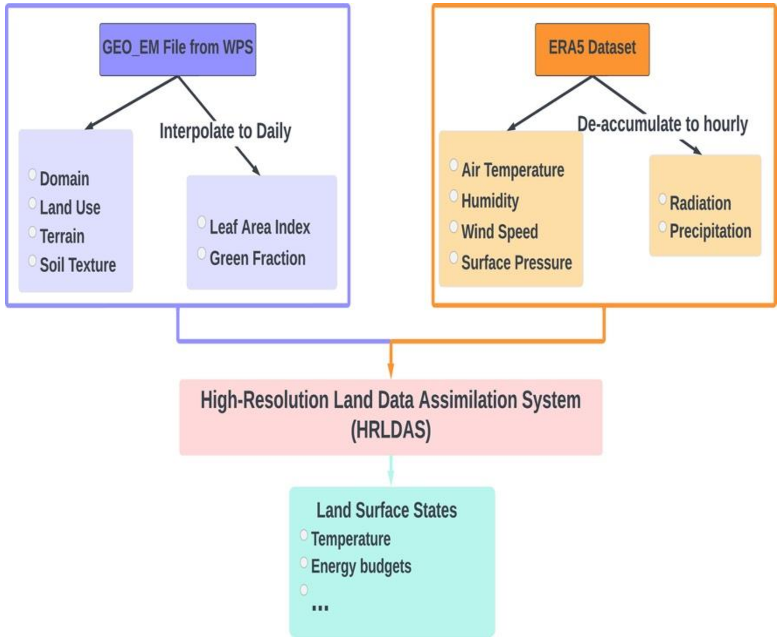


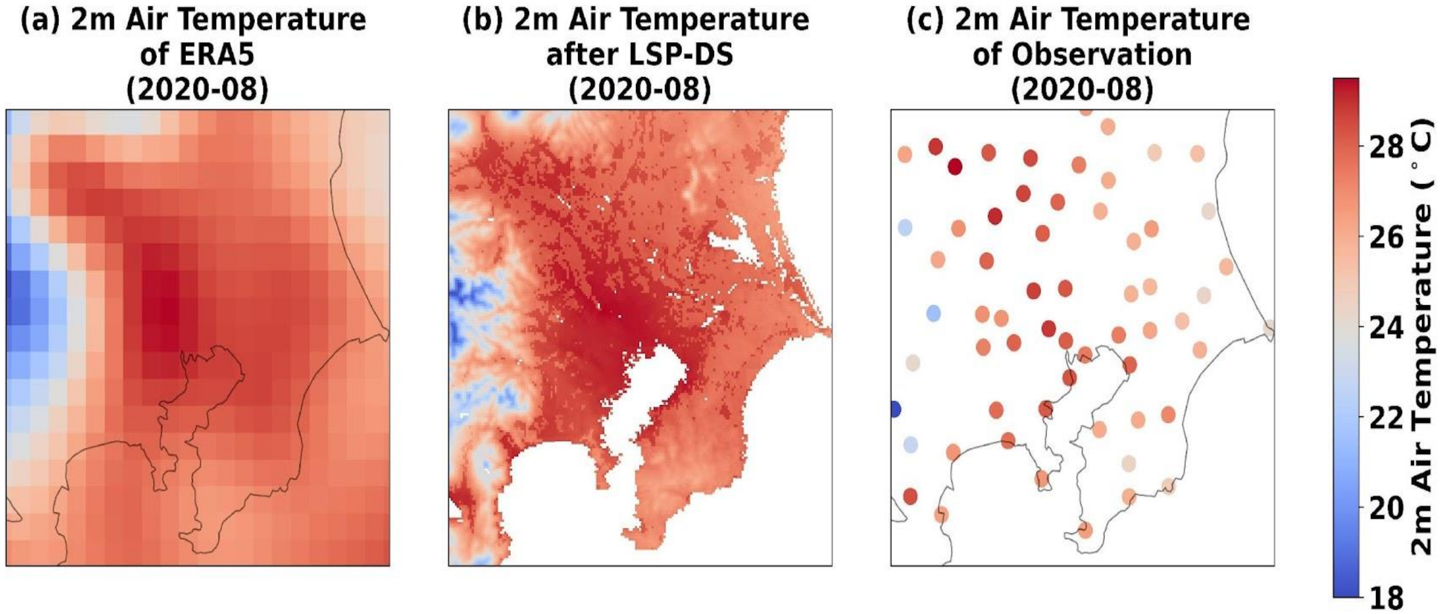
https://acp.copernicus.org/articles/15/5987/2015/acp-15-5987-2015.html#&gid=1&pid=1

Seeking for the *middle way* (中道-Trung Đạo) between two “extremes”: computational costly dynamical downscaling and physics-law-free statistical approach?

LSP-DS based on land surface physics process (using NCAR’s Noah-MP model).

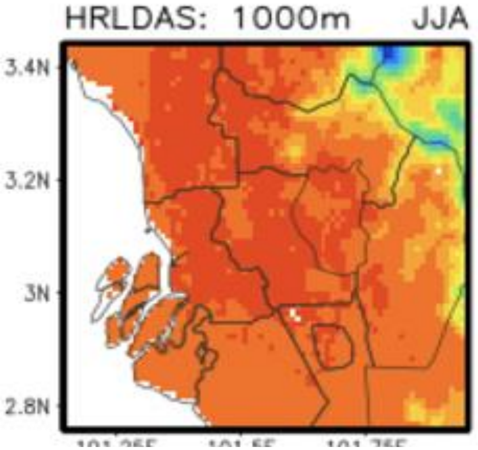
LSP-DS showed its *effectiveness and computational efficiency* to explain the *compounding effect* of urban heat island and heatwave effects (**Xue and Doan et al., 2024a, 2024b**)



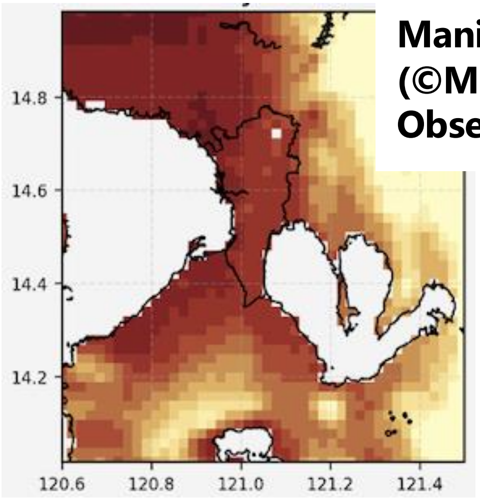


LSP-DS as a new possibility (standard) for climate downscaling

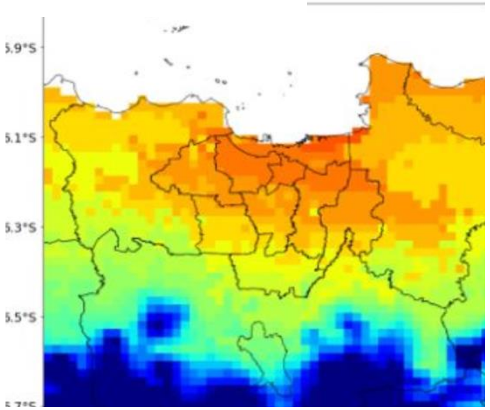
A/Prof Doan (AI-Lab) in LSP-DS workshop in Kuala Lumpur (May 2024)



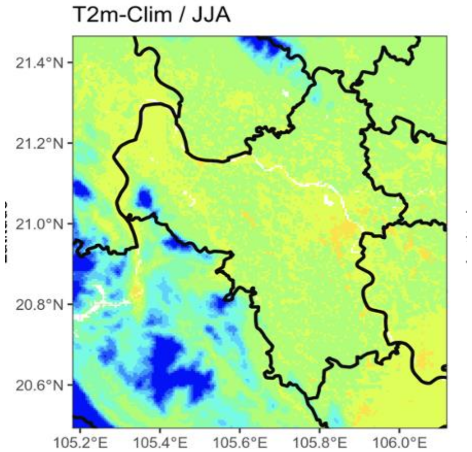
Kuala Lumpur LSP-DS (©U Malaysia)



Manila LSP-DS (©Manila Observatory)



Jakarta LSP-DS (©BMKG)



Hanoi LSP-DS (©U of Sci and Tech Hanoi)