Operational AI Downscaling System and Its Performance in Predicting Extreme Temperatures in Japan during Summer 2025

4th June 2026, UEF2026

Fuki KUDO and Jumpei FUJINO
Weathernews Inc.

Agenda

- **Introduction**
- WNI's AI Downscaling Forecast
- Extreme temperatures in Japan during summer 2025
- Case Study 1: 5 August in the Kanto region
- Case Study 2: 30 July in the Kansai region
- Summary and Future Work

Self Introduction

Fuki KUDO

Forecast system development manager
In charge of developing the multi-model ensemble system and AI downscaling forecast.

WNI Forecast Center
Weathernews Inc.

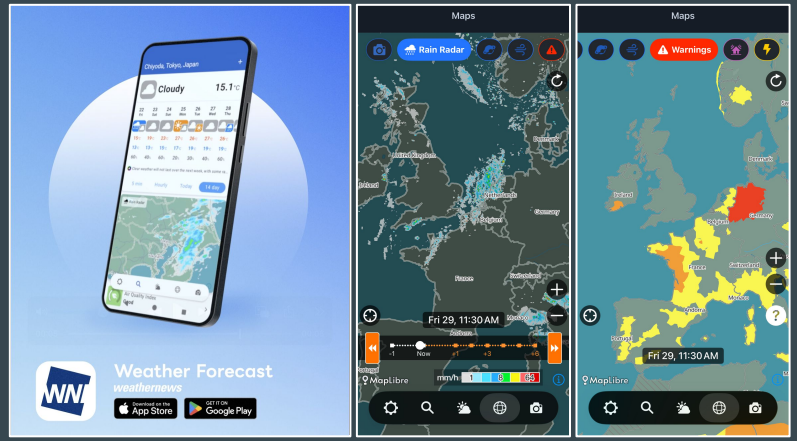
Jumpei Fujino

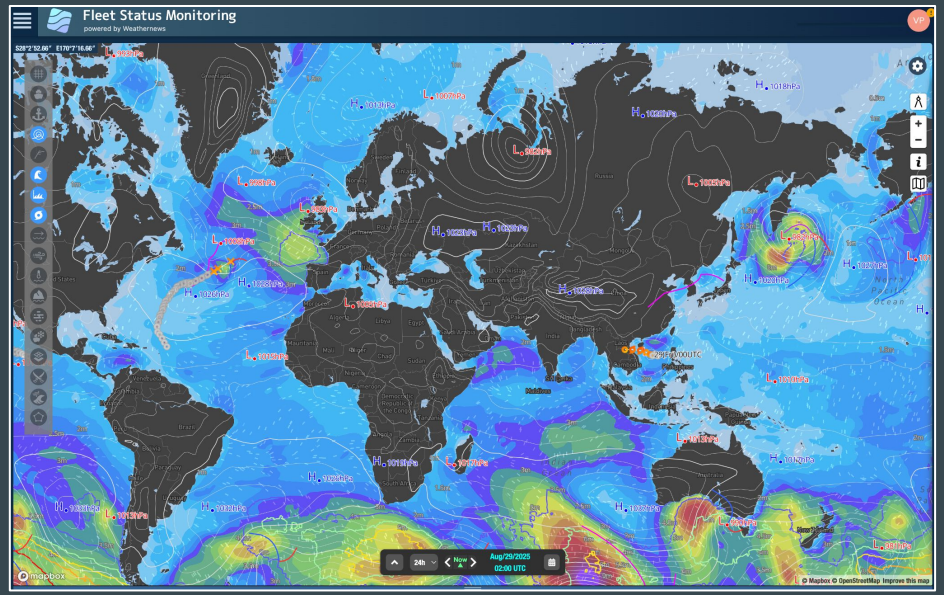
Developer specialized in statistics
In charge of developing probabilistic forecast and AI weather prediction models.

WNI Forecast Center
Weathernews Inc.

Weathernews Inc. (WNI)

- Headquarters in Chiba, Japan
- Founded in 1986
- Consolidated sales : about 160 M USD as of May 31st, 2025
- Number of employees: 1,095 as of May 27th, 2026
- **Our clients: shipping, aviation, railway, road management, energy, broadcasting, general consumers, etc.**



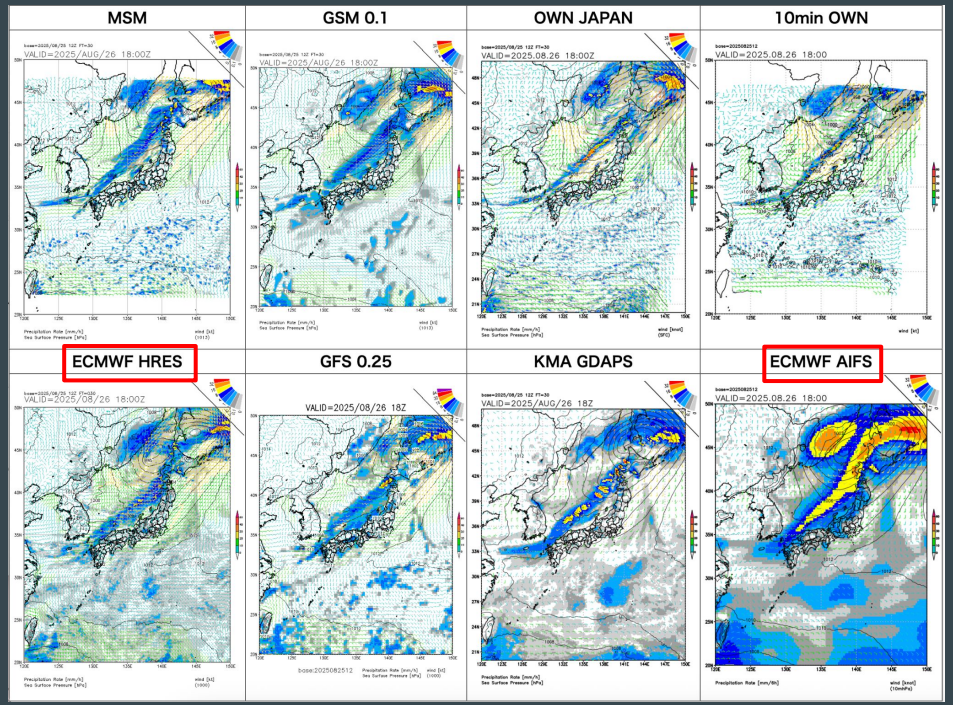


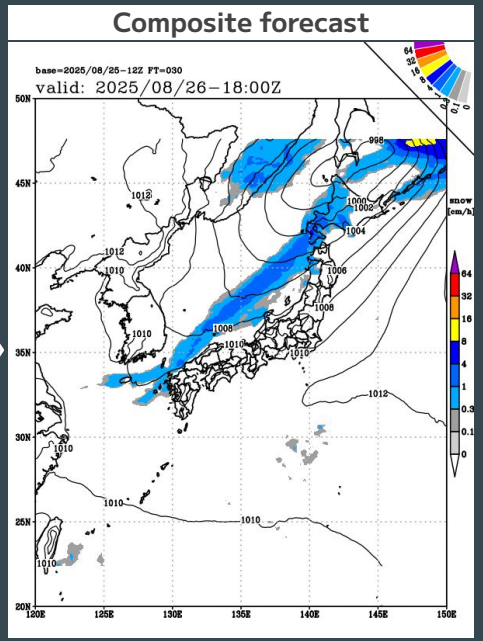
Ocean weather forecast, voyage route recommendation, vessel performance monitoring and forecast for shipping industry

Mobile weather app
50 M downloads
Launched a Global Mode from 28th May 2026.

Usage of ECMWF data in Weathernews

Our core forecasting system: creating accurate forecast by combining weather predictions gathered from around the world (Multi-Model Ensemble)





AIFS is a candidate for integration into this system in the future.

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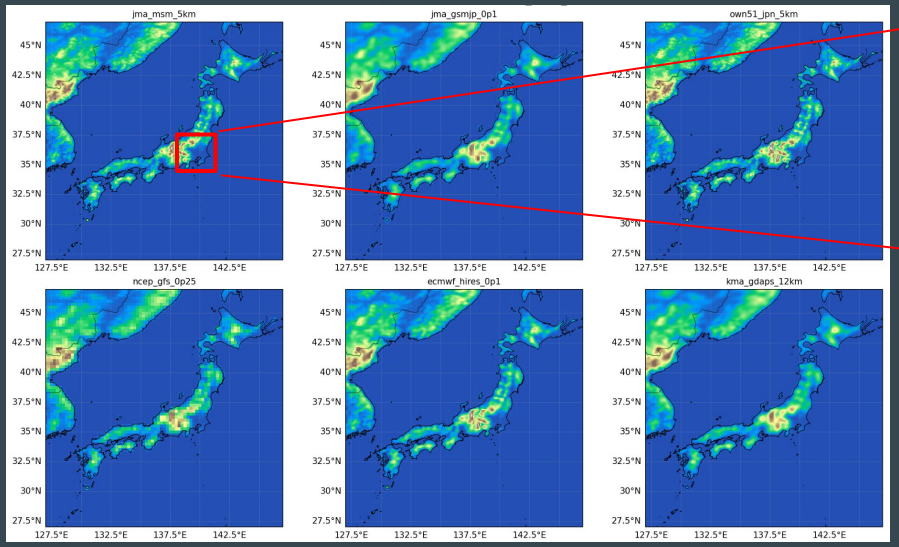
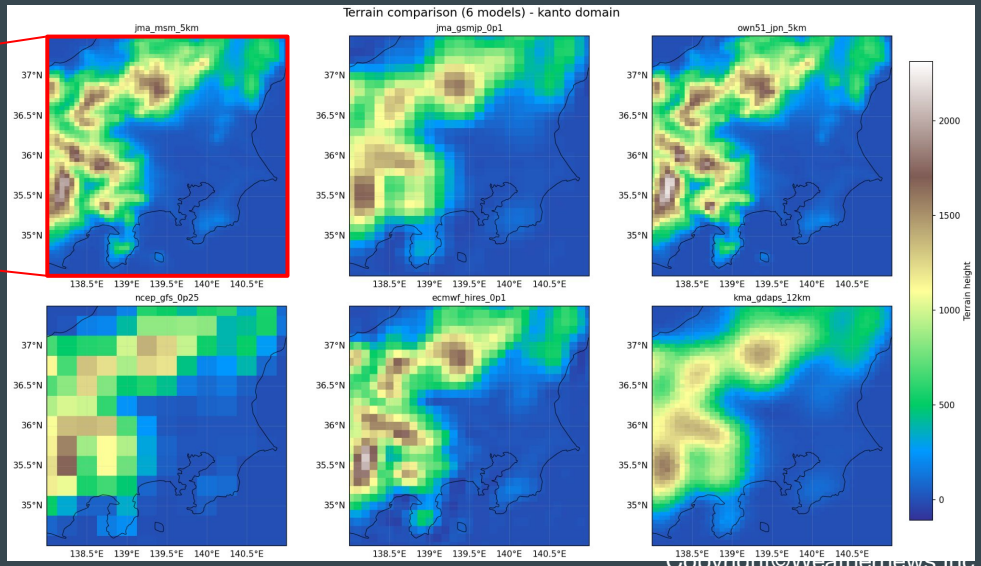
Motivation for downscaling

- Statistical preprocessing is required to unify the spatial and temporal resolutions when combining multi-models.
- Especially, Japan has intricate coastlines and mountains.
- A constant temperature lapse rate correction is insufficient for accurately predicting temperature distribution, especially in complex coastal areas.

Elevation in each NWP within our multi-model ensemble

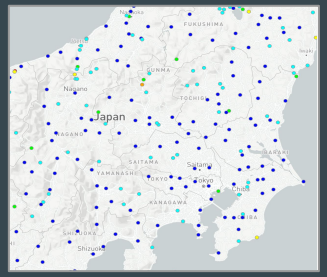




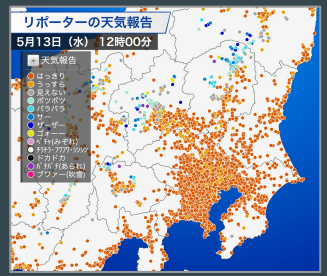
Our unique analysis - The Ground Truth for AI downscaling

- WNI original 1 km analysis
  - incorporates data from...
    - JMA Automatic Weather Station (AMeDAS) observation
    - Observation from corporate clients
    - Wx Reports submitted by mobile app. users. (*precipitation and wx categories only)
  - Updated every 10 minutes

Observation
- AMeDAS
- corporate clients

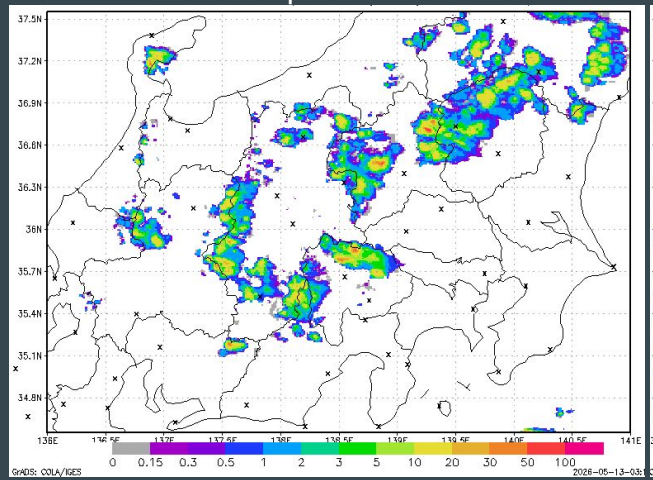


Wx Reports by app. users

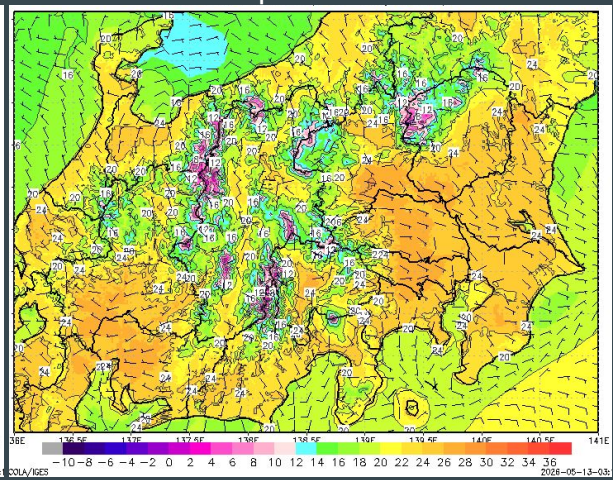


WNI 1 km analysis

Precipitation

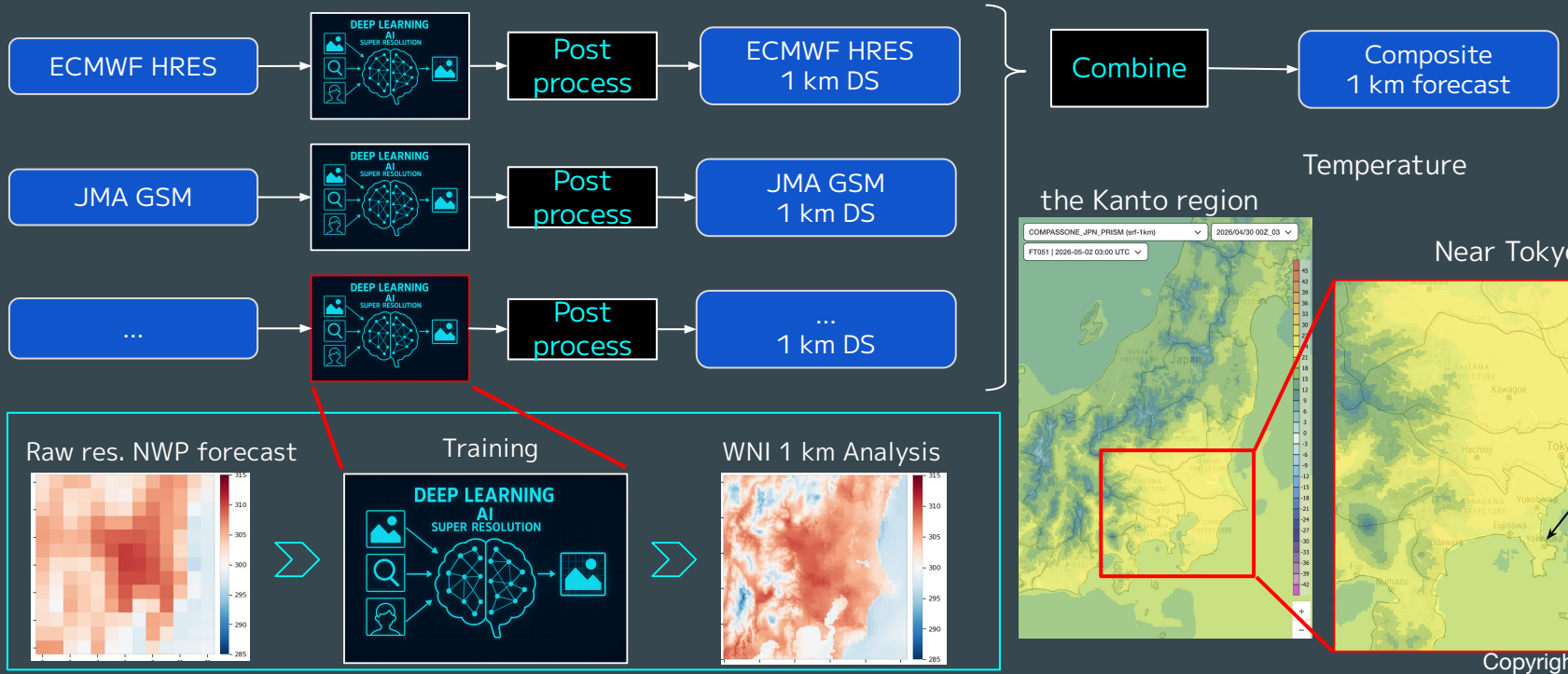


Temperature



AI downscaling methods

- For each model's temperature in the multi-model ensemble:
  - Trains CNN-based model
    - input data: Raw resolution NWP forecast
    - supervised data : WNI 1 km analysis



Temperature

the Kanto region

Near Tokyo Bay

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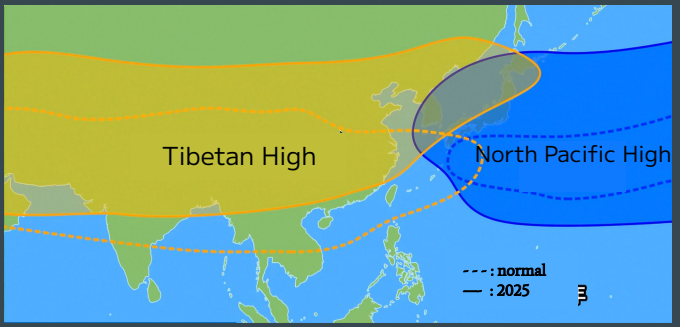
Extreme temperatures in Japan during summer 2025

- Record-breaking heat: Japan set national temperature records twice in 2025
- Synoptic-scale driver: "Double High" (North Pacific High and Tibetan High)
- Meso-scale driver: Fohen-type downslope winds / Heat accumulation in small basins

Question: How well did AI downscaling predict these extreme heat events?



Schematic of "Double High" in summer 2025

Daily Max Temperature of AMeDAS during summer 2025 (Total N of Stations: 915)

Date	N of Stations: ≥40℃	N of Stations: ≥35℃	Hottest Station	Daily Max Temp of Hottest Station
30 Jul	**4**	**276**	**Kaibara, Hyogo**	**41.2℃***
31 Jul	1	213	Takahashi, Okayama	40.4℃
1 Aug	1	234	Kuwana, Mie	40.4℃
2 Aug	3	284	Isesaki, Gunma	40.1℃
4 Aug	1	250	Komatsu, Ishikawa	40.3℃
5 Aug	**14**	**289**	**Isesaki, Gunma**	**41.8℃ ****
6 Aug	1	255	Shizuoka, Shizuoka	41.4℃
30 Aug	4	231	Kuwana, Mie	40.5℃
31 Aug	1	217	Nagoya, Aichi	40.0℃

*: Record high temperature in Japan

Data to be Compared

Forecasts

- **ECMWF HRES**
  - ECMWF physical deterministic model (-9 km spatial resolution)
- **ECMWF HRES 1 km corrected**
  - Corrected by constant lapse rate(0.0055℃/m) and using the same elevation as WNI 1 km Analysis.
- ECMWF HRES 1 km AI DS
  - AI downscaling output of ECMWF HRES (hourly temperature at 2m).

Observation & Analysis

- **AMeDAS**
- **WNI 1 km Analysis**

Data to be Compared

Comparison Target

- For forecast: Using Day 1 forecast(issue time = 00z)
- Focusing on the maximum temperature during 09 - 15 JST
  - **AMeDAS :**
    - Daily max temperature recorded during 09 - 15 JST.
  - **WNI 1 km Analysis :**
    - Max 2m temperature (2T) during 09 - 15 JST (10-min interval)
  - **ECMWF HRES & ECMWF HRES 1 km corrected :**
    - Max 2m temperature in the previous 6 hours (mx2T6h) at 15 JST
  - **ECMWF HRES 1 km AI DS :**
    - Max 2m temperature (2T) during 09 - 15 JST (1-hour interval)

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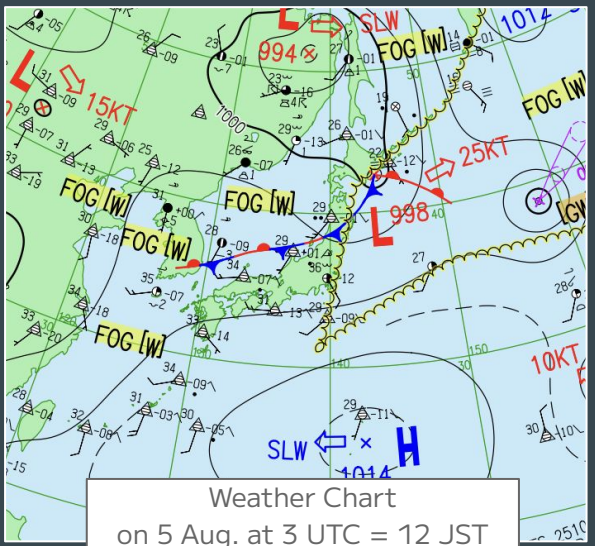
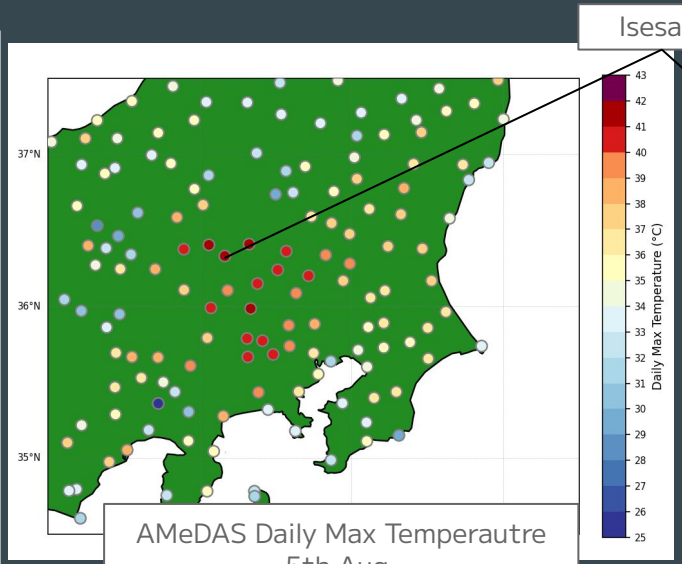
Case Study 1: 5 August in the Kanto Region

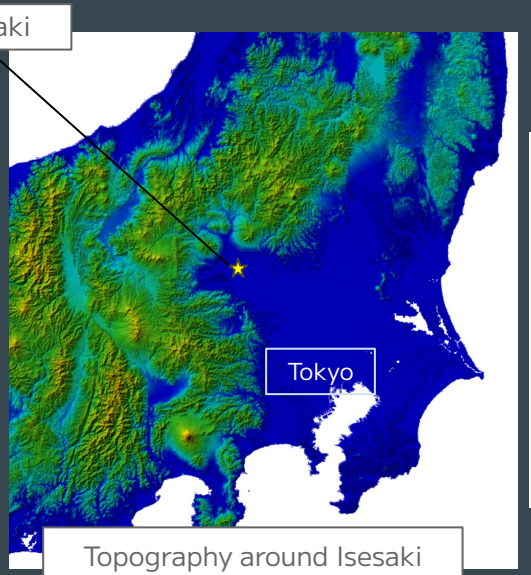
- What happened:
  - A record high temperature of 41.8℃ was recorded in Isesaki.
  - 14 AMeDAS stations recorded temperatures exceeding 40℃.
- Causes: Foehn-type downslope winds and strong solar heating



Weather Chart
on 5 Aug. at 3 UTC = 12 JST
made by JMA



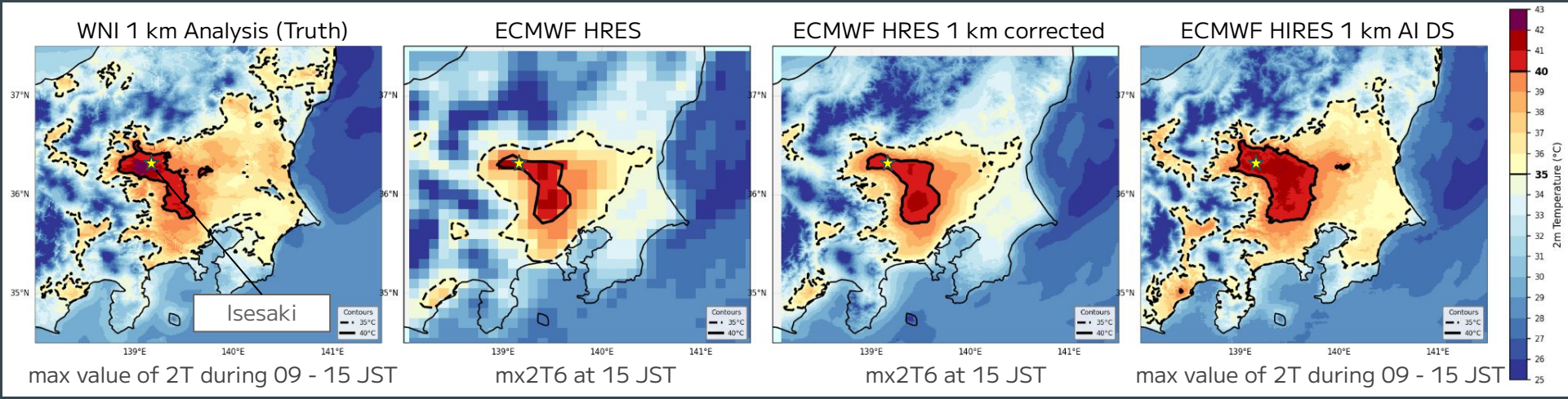
AMeDAS Daily Max Temperautre
5th Aug.



Topography around Isesaki

Case Study 1: 5 August Map-Based Comparison

- ECMWF HRES & ECMWF HRES 1 km corrected
  - Over-40℃ area: Well captured
  - Over-35℃ area: Underestimated
- ECMWF HRES 1 km AI DS
  - Over-40℃ area: Slightly overestimated
  - Over-35℃ area: Well captured



max value of 2T during 09 - 15 JST | mx2T6 at 15 JST | mx2T6 at 15 JST | max value of 2T during 09 - 15 JST

Case Study 1: 5 August Confusion Matrix Comparison

- At both thresholds (≥35℃ and ≥40℃), AI DS significantly improved the number of True Positives (values in the green boxes).
- Equitable Threat Score for ≥35℃ : 0.23 (HRES) → 0.57 (HRES 1 km DS).

Confusion Matrix (vs. AMeDAS daily max temperature during 09 - 15 JST)
5th Aug. 2025

HRES (mx2T6 at 15 JST)

	Fcst ≥ 35℃	Fcst < 35℃
Obs ≥ 35℃	58	189
Obs < 35℃	3	466

	Fcst ≥ 40℃	Fcst < 40℃
Obs ≥ 40℃	2	9
Obs < 40℃	1	704

HRES 1 km AI DS (max value of 2T during 09 - 15 JST)

	Fcst ≥ 35℃	Fcst < 35℃
Obs ≥ 35℃	153	94
Obs < 35℃	19	450

	Fcst ≥ 40℃	Fcst < 40℃
Obs ≥ 40℃	7	4
Obs < 40℃	3	702

716 AMeDAS stations observed the daily max temperature during 09 -15 JST

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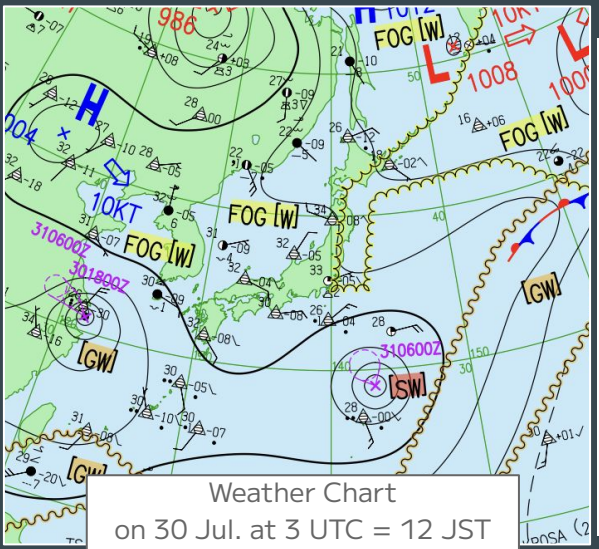
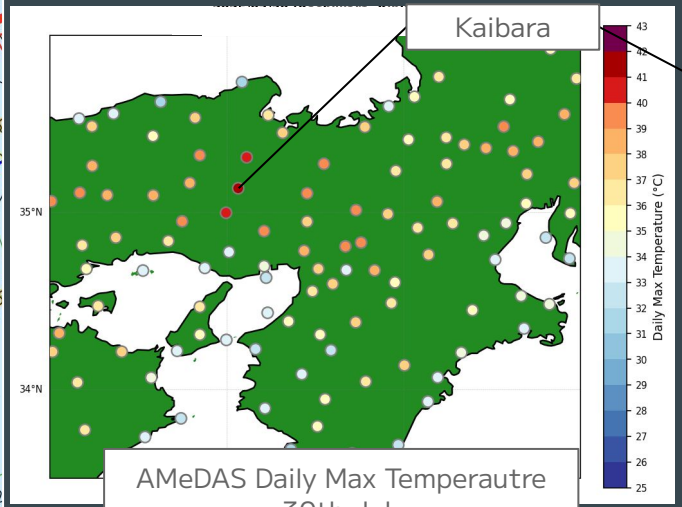
Case Study 2: 30 July in the Kansai Region

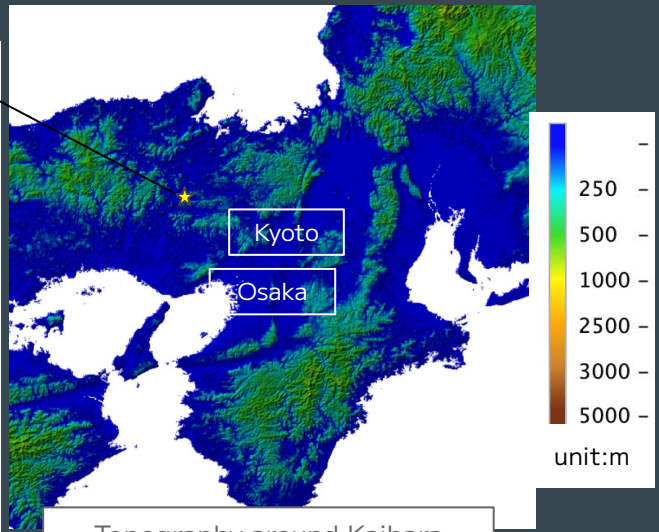
- What happened:
  - 4 stations recorded temperatures exceeding 40℃.
  - Kaibara reached 41.2℃. This remained the national record high until 5 August.
- Causes:
  - Heat accumulation in a small inland basin.
  - Unlike most record-breaking heat events in Japan, this case was not Foehn-driven.



Weather Chart
on 30 Jul. at 3 UTC = 12 JST
made by JMA



AMeDAS Daily Max Temperautre
30th Jul.

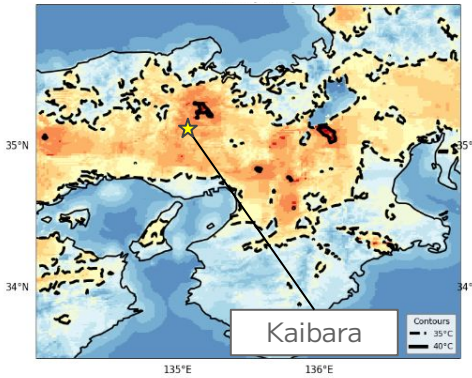


Topography around Kaibara

Case Study 2: 30 July Map-Based Comparison

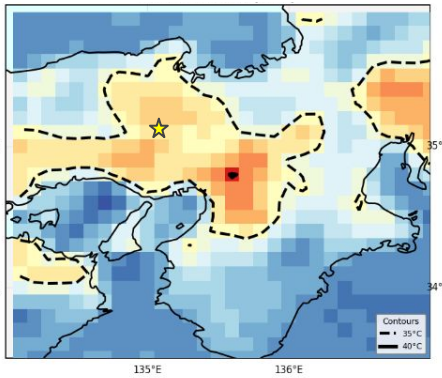
- WNI 1 km Analysis
  - This event was highly localized and transient, and even the 10-minute interval analysis failed to capture the 41.2℃ observed at Kaibara.
- ECMWF HRES & ECMWF HRES 1 km corrected
  - The HRES model placed the over-40℃ area away from Kaibara.
- ECMWF HRES 1 km AI DS
  - The model captured the high temperatures in the basin near Kaibara, but overall it produced a warm bias.

WNI 1 km Analysis (Truth)



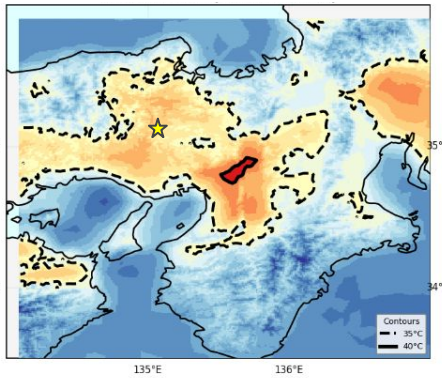
max value of 2T during 09 - 15 JST

ECMWF HRES



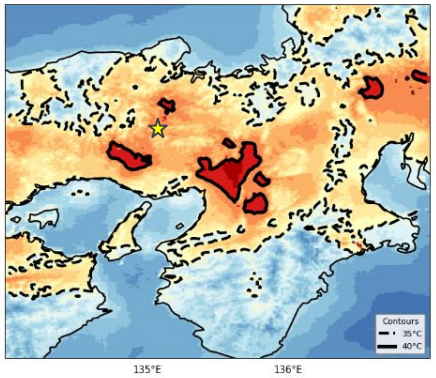
mx2T6 at 15 JST

ECMWF HRES 1 km corrected

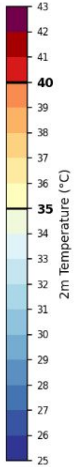


mx2T6 at 15 JST

ECMWF HRES 1 km AI DS

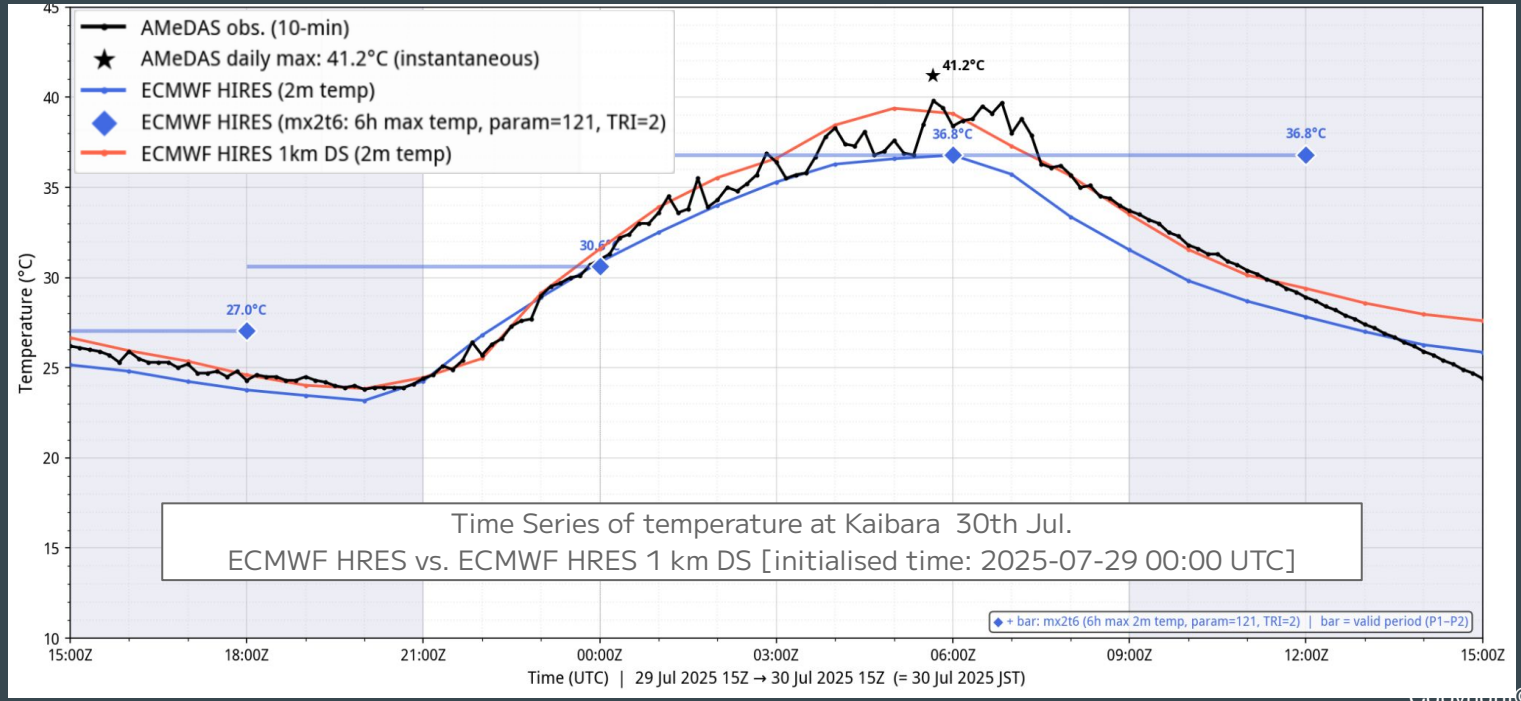


max value of 2T during 09 - 15 JST



Case Study 2: 30 July Time-Series Comparison

- The 41.2℃ recorded at Kaibara was a very short-lived peak; all temperatures observed at 10-minute intervals remained below 40℃.
- This raises questions about whether such small-scale extreme temperatures can, or should, be forecast.



Time Series of temperature at Kaibara 30th Jul.
ECMWF HRES vs. ECMWF HRES 1 km DS [initialised time: 2025-07-29 00:00 UTC]

Case Study 2: 30 July Confusion Matrix Comparison

- 1 km DS improved the number of True Positives for extreme heat, but showed marginal improvement for the ≥40℃ threshold.
- Equitable Threat Score for ≥35℃ : 0.31 (HRES) → 0.73 (HRES 1 km DS).

Confusion Matrix (vs. AMeDAS daily max temperature during 09 - 15 JST)
30th Jul. 2025

HRES (mx2T6 at 15 JST)

	Fcst ≥ 35℃	Fcst < 35℃
Obs ≥ 35℃	72	149
Obs < 35℃	10	545

	Fcst ≥ 40℃	Fcst < 40℃
Obs ≥ 40℃	0	3
Obs < 40℃	0	773

HRES 1 km AI DS (max value of 2T during 09 - 15 JST)

	Fcst ≥ 35℃	Fcst < 35℃
Obs ≥ 35℃	199	22
Obs < 35℃	50	505

	Fcst ≥ 40℃	Fcst < 40℃
Obs ≥ 40℃	1	2
Obs < 40℃	6	767

776 AMeDAS stations observed the daily max temperature during 09 -15 JST

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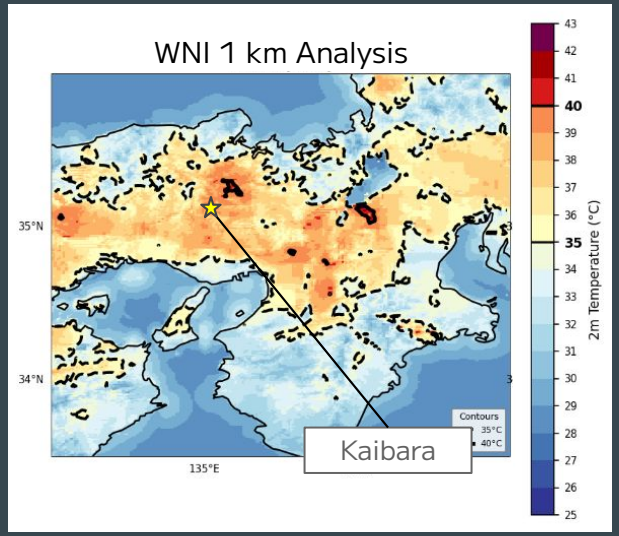
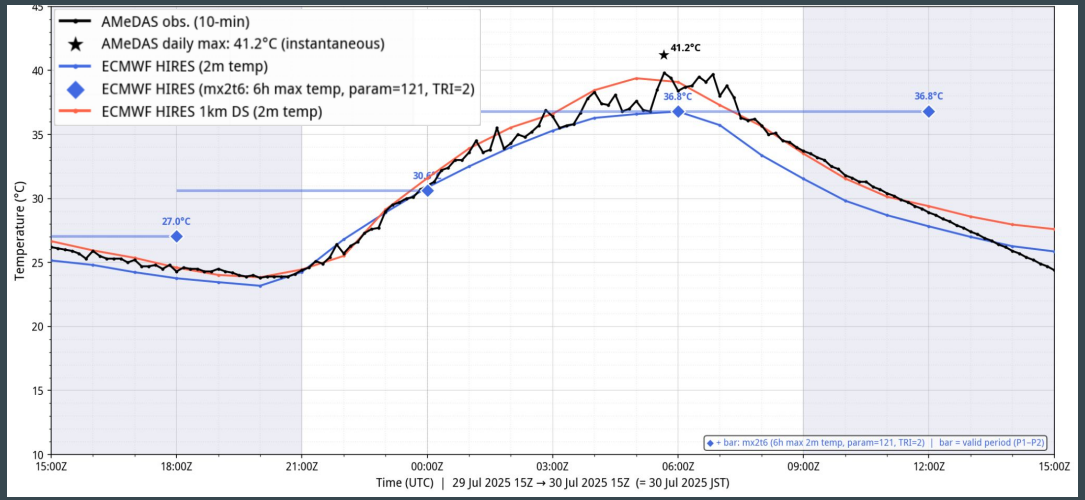
Summary

- We introduced the WNI AI Downscaling system for Multi-Model Ensemble
- We compared three ECMWF HRES-related forecasts (original, corrected by constant lapse rate, and AI Downscaling) in extreme heat cases in Japan.
- **The AI Downscaling forecast generally captured extreme heat events better than the original model**.
- For the ~50-km-scale extreme heat event caused by Foehn-type downslope winds (case study 1), HRES forecast the extreme heat area well.
- The AI Downscaling output captured the area exceeding 35℃ better than both the original forecast and the constant lapse rate correction.
- **For the extreme heat event in a small basin (case study 2), AI downscaling struggled to capture the peak temperatures.**

Future Work 1: Better analysis fields

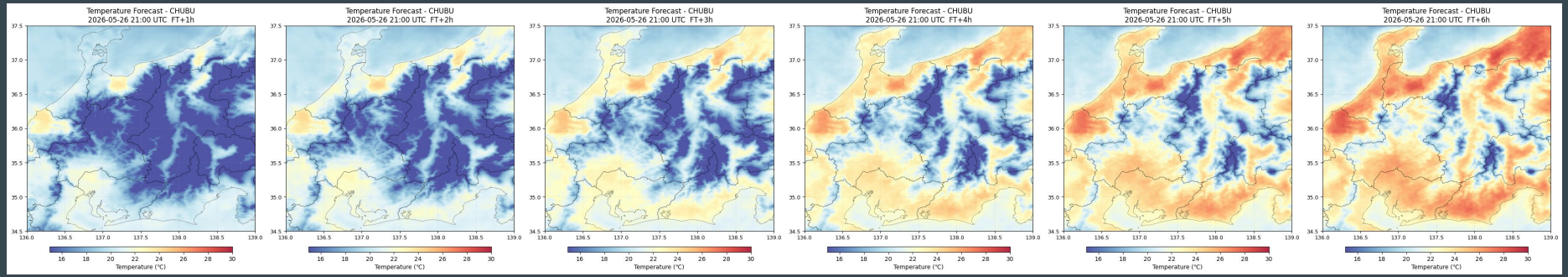
- To generate better AI forecasts, it is important to improve the quality of analysis fields used as training data.
- Case study 2 (the Kaibara case) suggests that analysis fields for daily maximum temperature may be needed.





Future Work 2: AI Nowcasting

- We are currently developing a LAM (Limited Area Model)-based nowcasting system using the Anemoi framework.
- We adopt an hybrid approach that simultaneously performs spatial downscaling of the external model and predicts the temporal evolution of the analysis fields.



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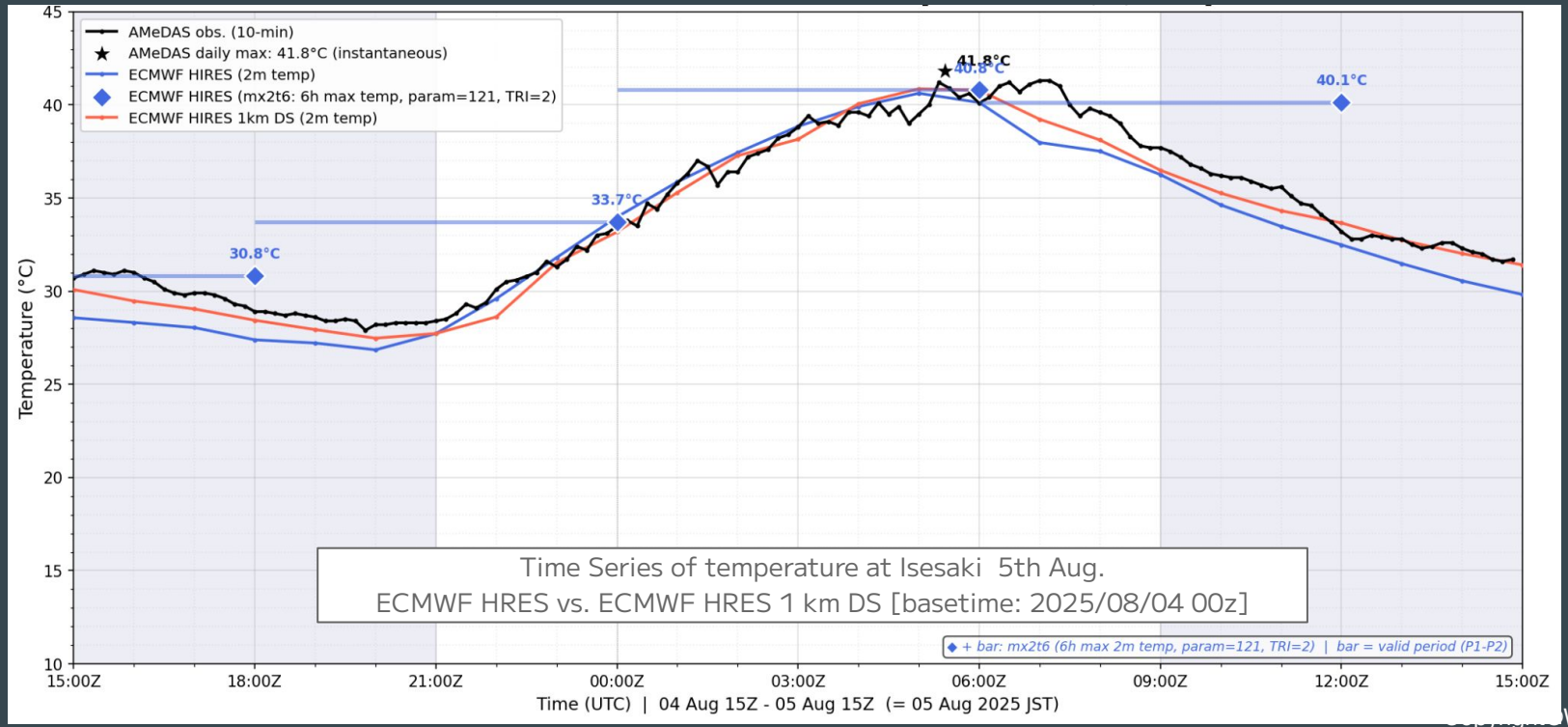
Thank you for your attention.

weathernews

Appendix

Case Study 1: 5 August Comparison with AMeDAS

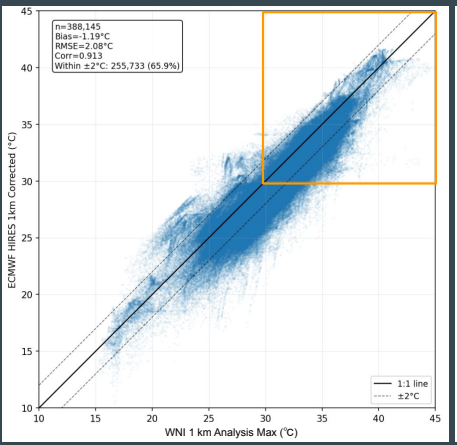
- At Isesaki, both ECMWF HRES and ECMWF HRES 1 km DS forecasted temperature over 40℃



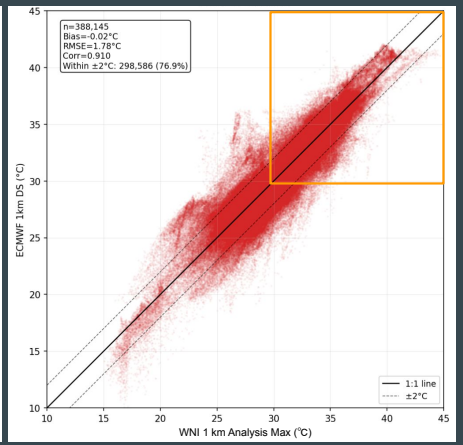
Case Study 1: 5 August Comparison with Analysis

- Comparing Scatter Plots (vs. WNI 1 km Analysis) for all land-grid samples in Japan:
  - ECMWF HRES 1 km corrected shows a negative bias; 1 km DS significantly improves this.
  - ECMWF HRES 1 km DS achieves a higher ratio of samples within ±2℃ (approx. 10% improvement).

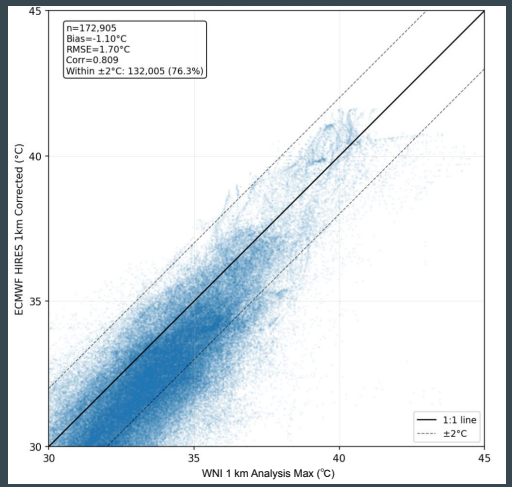
ECMWF HRES 1 km corrected
(mx2T6 at 15 JST)



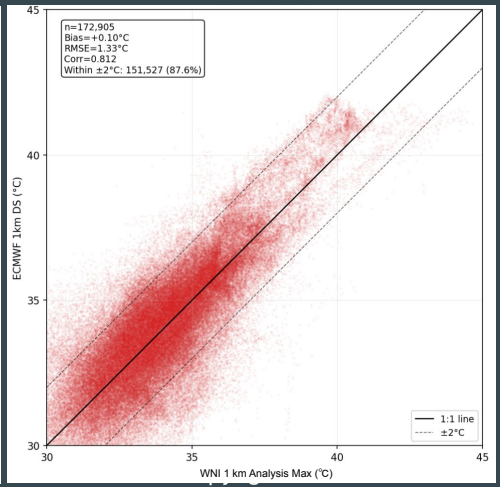
ECMWF HRES 1 km DS
(max value of 2T during 09 - 15 JST)



ECMWF HRES 1 km corrected
(mx2T6 at 15 JST)



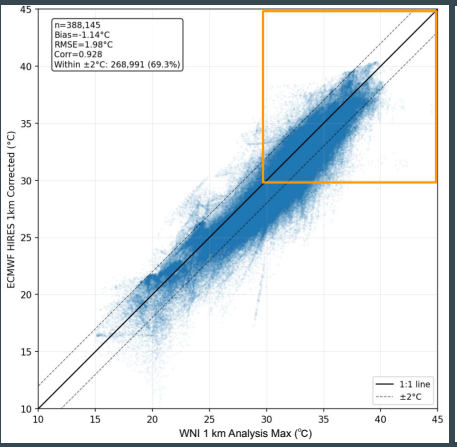
ECMWF HRES 1 km DS
(max value of 2T during 09 - 15 JST)



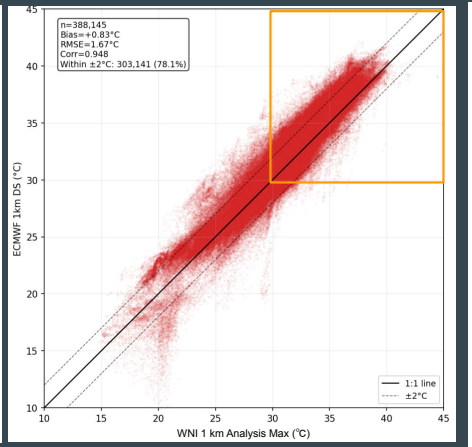
Case Study 2: 30 July Comparison with Analysis

- Comparing Scatter Plots (vs. WNI 1 km Analysis) for all land-grid samples in Japan:
  - Totally, 1 km DS is better accuracy than constant rapse late correction.
  - Focusing on samples over 30℃, 1 km DS tends to overestimate (positive bias).

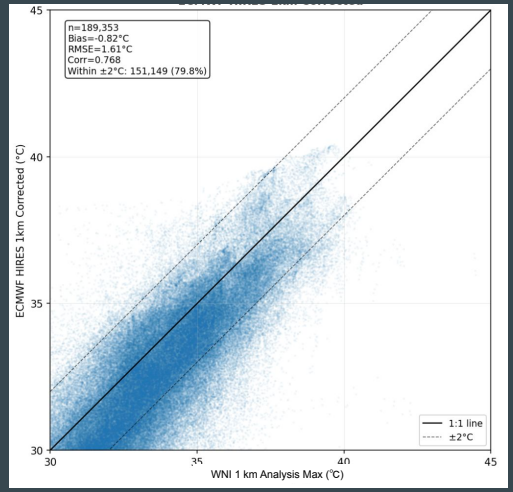
ECMWF HRES 1 km corrected
(mx2T6 at 15 JST)



ECMWF HRES 1 km DS
(max value of 2T during 09 - 15 JST)



ECMWF HRES 1 km corrected
(mx2T6 at 15 JST)



ECMWF HRES 1 km DS
(max value of 2T during 09 - 15 JST)