

Evaluation of ICON-2I with TERRA-URB across Winter and Summer Seasons

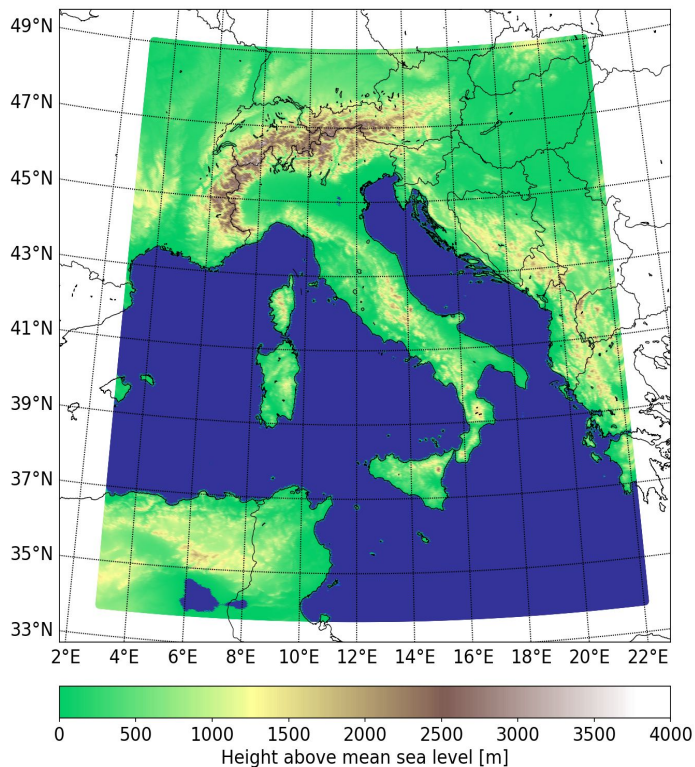
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¹ ARPAE, ² DWD, ³ CMCC

COSMO General Meeting, September 14th-19th 2026, Rome

Introduction

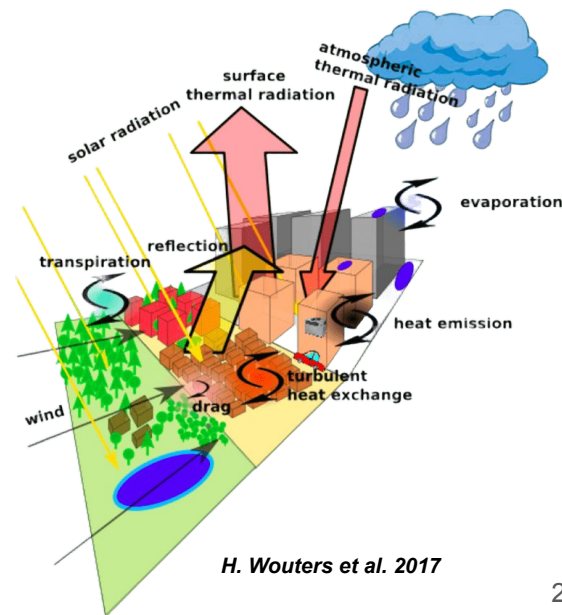
ICON-2I: main operational model at ARPAE



- 2 km grid step
- BC from IFS

- continuous DA based on Kenda
- **No urban parametrization**

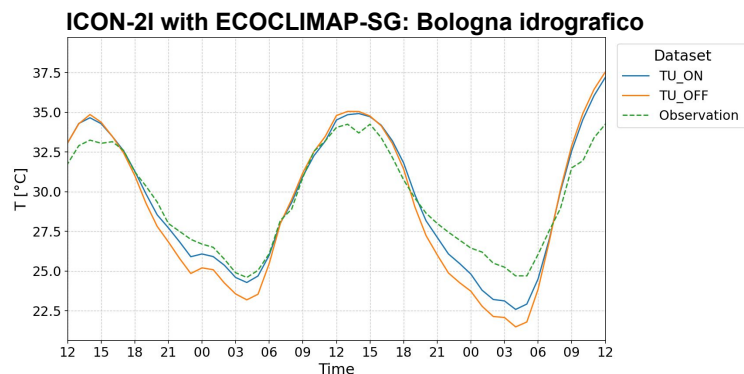
TERRA_URB



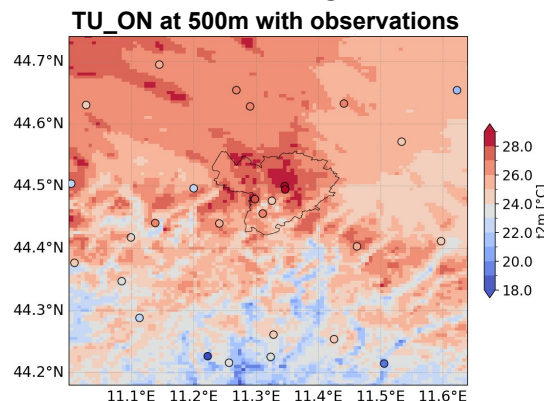
Objective

TERRA_URB has shown significant improvements in capturing the Urban Heat Island (UHI) effect (COSMO Priority Project CITTA')

In the last year at ARPAE multiple urban analysis under different configurations



"First tests with Zonda for ECOCLIMAP-SG in ICON", COSMO GM 2025 - Basel



"Hectometric-scale urban simulations with ICON in Emilia-Romagna", ICCARUS 2026 - DWD, Offenbach am Main

Evaluate the performance of TERRA_URB with ICON-2I over the full operational domain

Simulation setup

- ICON-2I operational configuration
- Land cover dataset: GLOBCOVER 2009
- **TERRA_URB old configuration:**
- Runs at 00 UTC and 12 UTC
- + 72h
- Operational KENDA (no TERRA_URB)

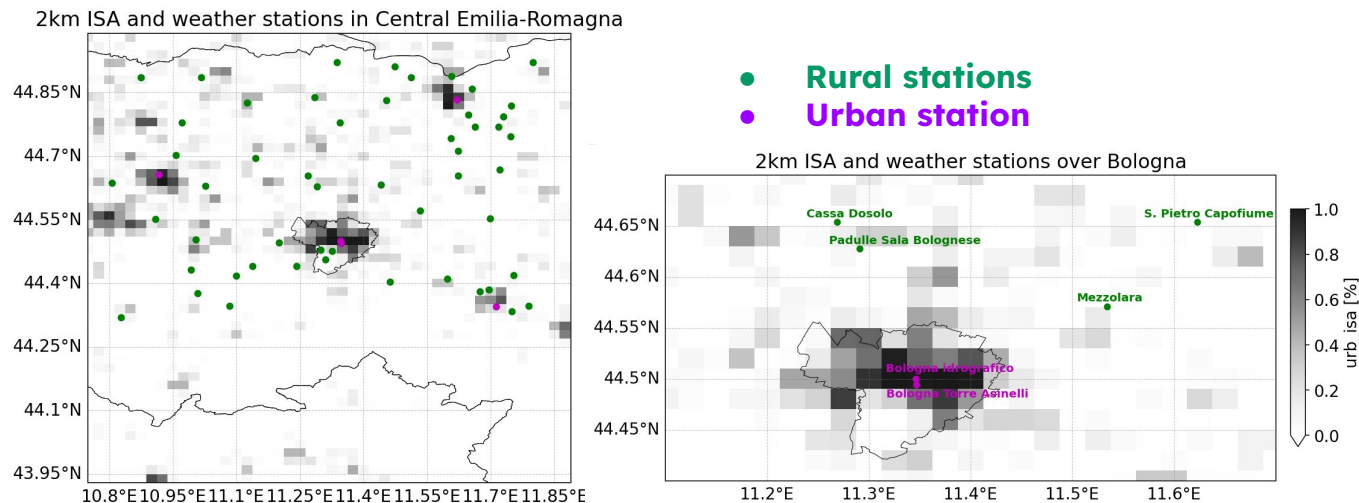
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Simulation period:

- 01/12/2024 - 31/01/2025: **winter** period, many nights characterized by strong UHI
- 20/05/2026 - 19/07/2026: **summer** period, multiple HWs

First step: **T2M analysis** across the Emilia-Romagna region, targeting both **Bologna** and smaller urban areas

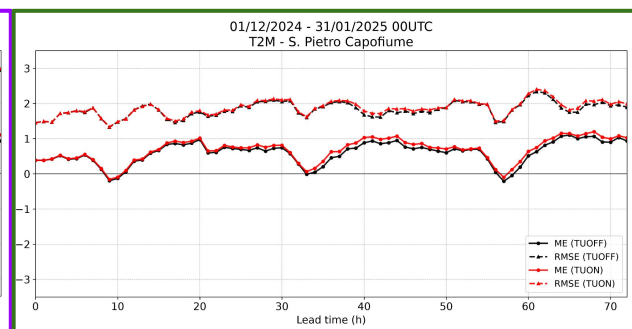
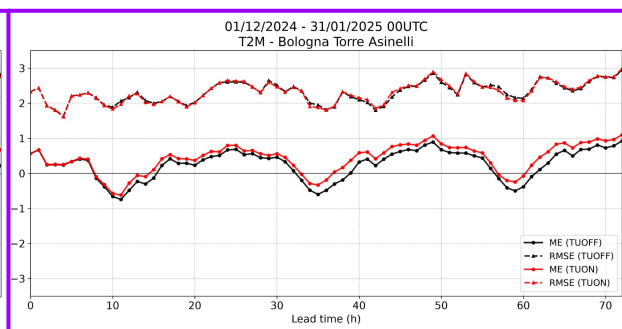
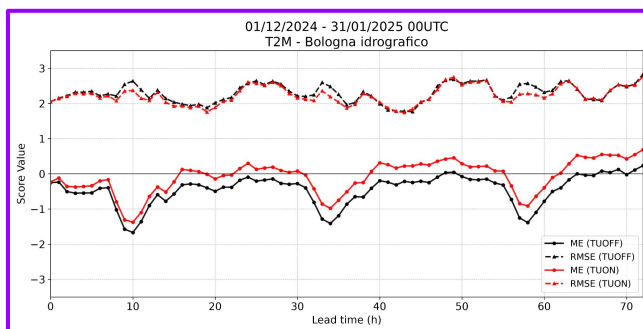
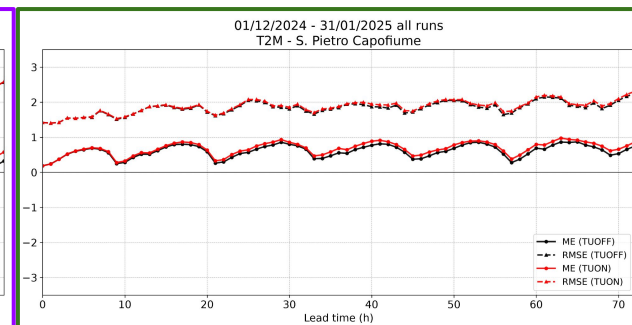
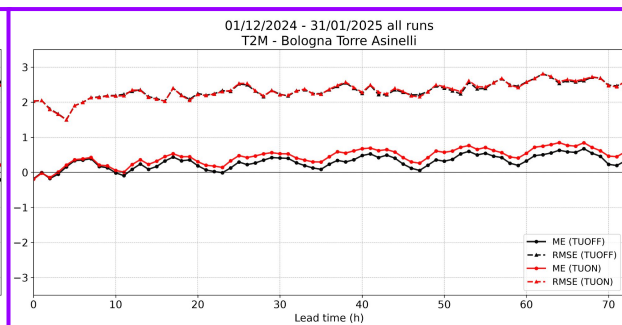
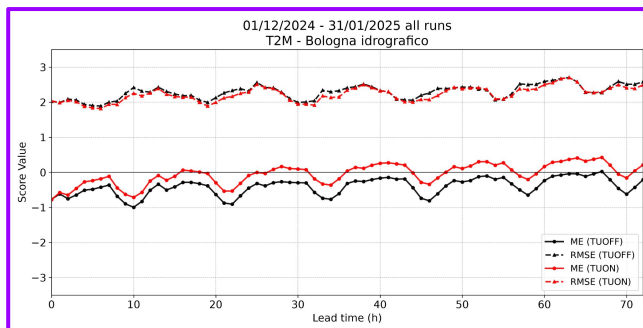
Observations: **local ARPAE weather stations** → urban observations



Vertical level choice: Obs. height < lowest model level → value at 2m

Obs. height ≥ lowest model level → interpolation between model levels

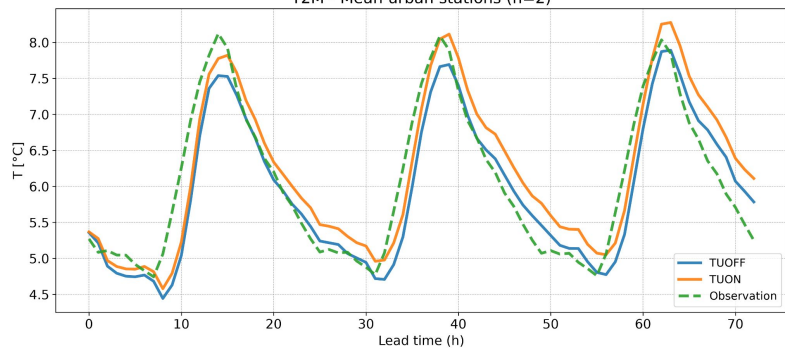
Bologna: winter period



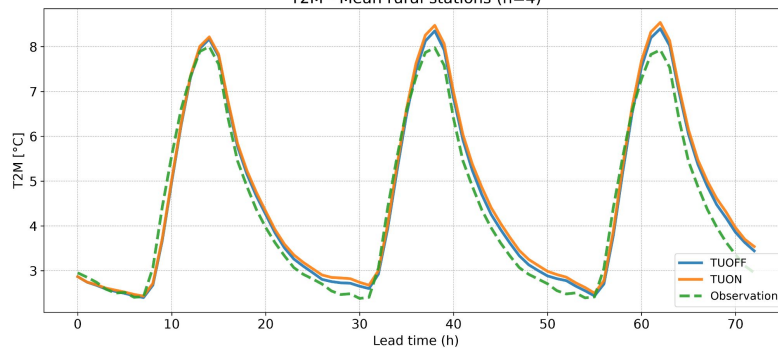
- Urban effect present both during daytime and night time
- Very slight decrease of RMSE around 10 UTC
- General improvement in ME

- Almost no urban effect
- Slight, constant overestimation throughout the day

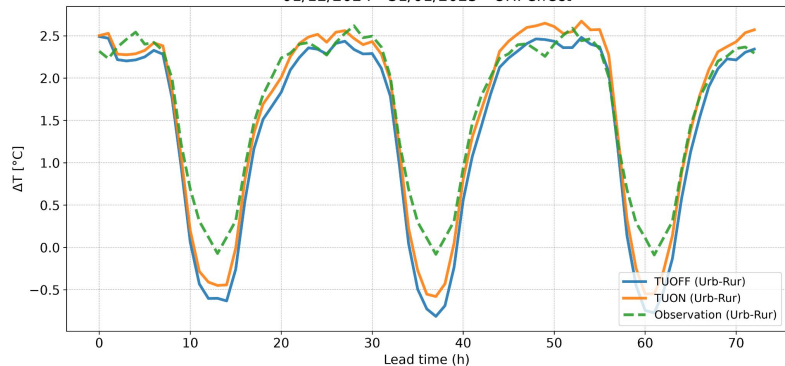
01/12/2024 - 31/01/2025 - Time series
T2M - Mean urban stations (n=2)



01/12/2024 - 31/01/2025 - Time series
T2M - Mean rural stations (n=4)

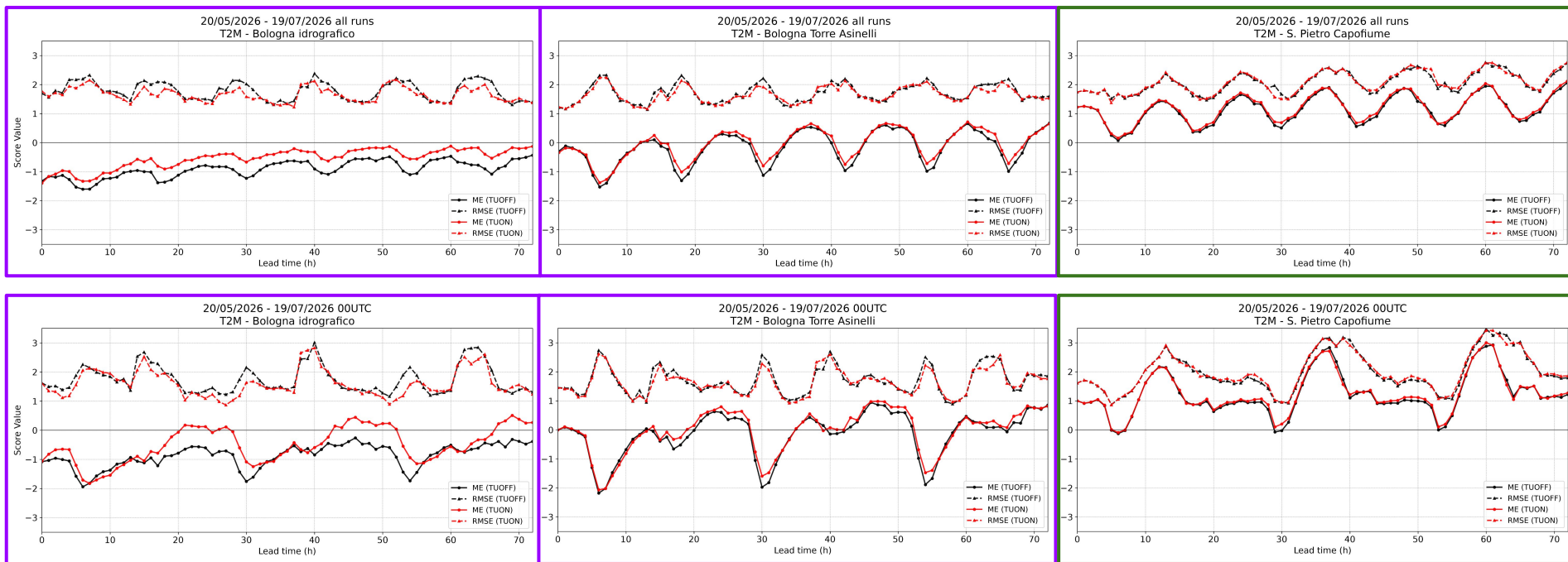


01/12/2024 - 31/01/2025 - UHI effect



- TERRA_URB effect is low during the first few hours
- Then, urban temperatures in TUON are higher across the whole diurnal cycle
- Daytime slight negative UHI:
 - Simulated in the model, but not in observations
 - Mainly due to the model overestimating T2M in rural areas

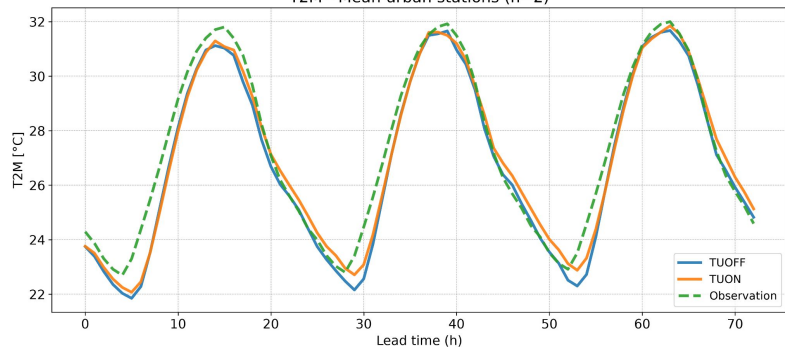
Bologna: summer period



- Urban effect occurs mainly during nighttime, as expected
- Improvement in scores due to TERRA_URB is slightly better compared to the winter season
- Smaller impact observed at Torre Asinelli station
- Diurnal bias is stronger during the summer season with maximum at 12 UTC

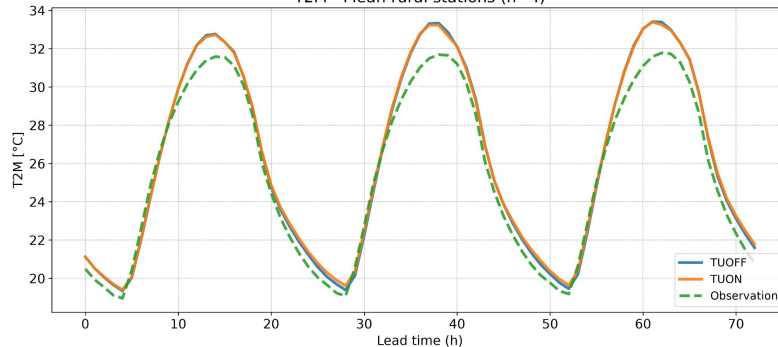
20/05/2026 - 19/07/2026 - Time series

T2M - Mean urban stations (n=2)

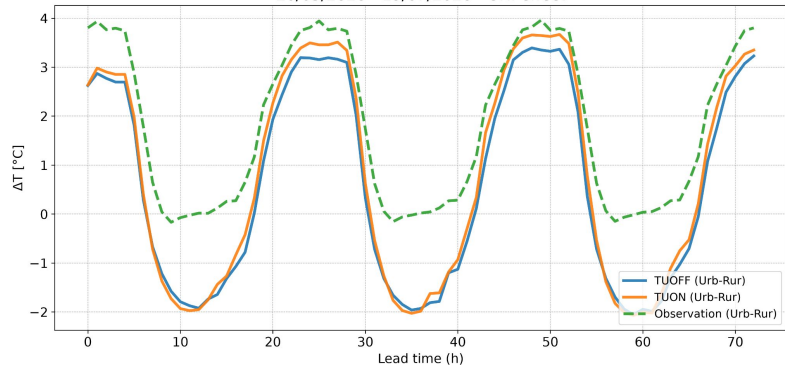


20/05/2026 - 19/07/2026 - Time series

T2M - Mean rural stations (n=4)



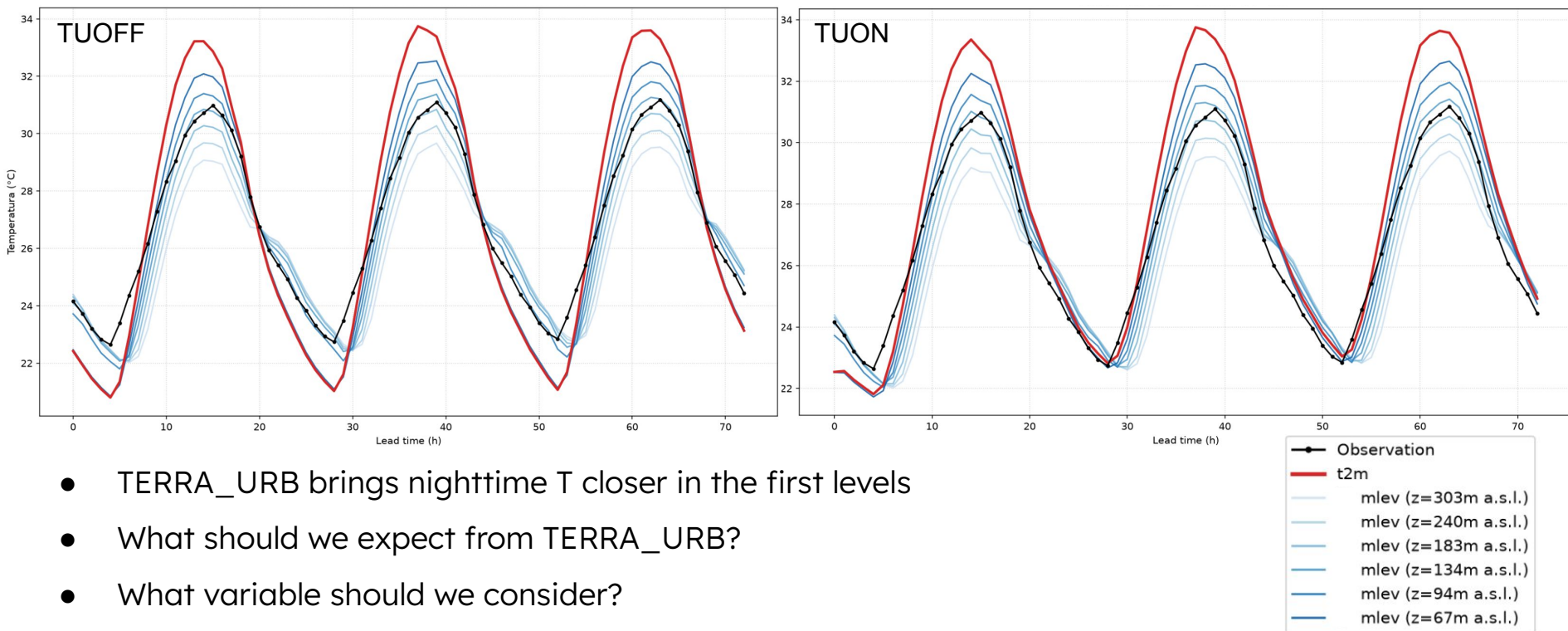
20/05/2026 - 19/07/2026 - UHI effect



- Big overestimation of T2M over rural by both configurations
- TERRA_URB improves nighttime temperature, though a slight mean underestimation persists
- Delayed morning warming: ICON delays the temperature rise after the nighttime minimum compared to observations

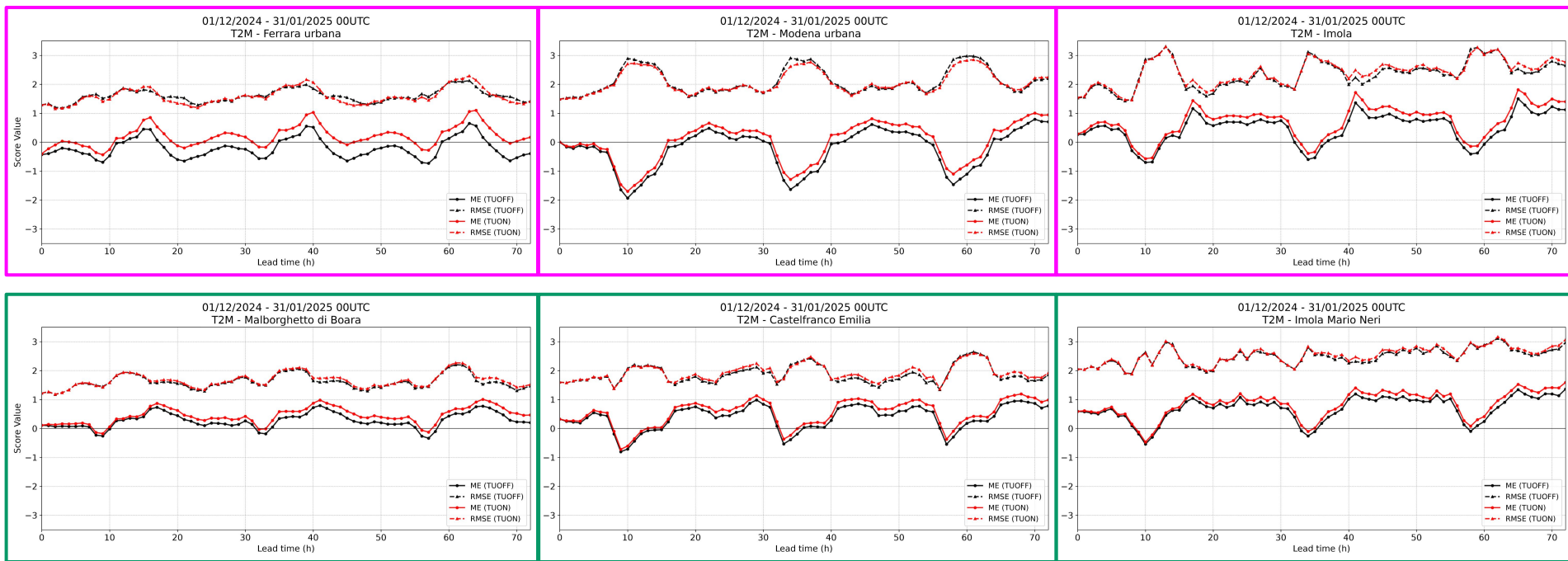
Issue with mlev-interpolation approach

T(z) time series vs observations — Bologna Torre Asinelli (148.0m a.s.l.)
2026-05-20 — 2026-07-19



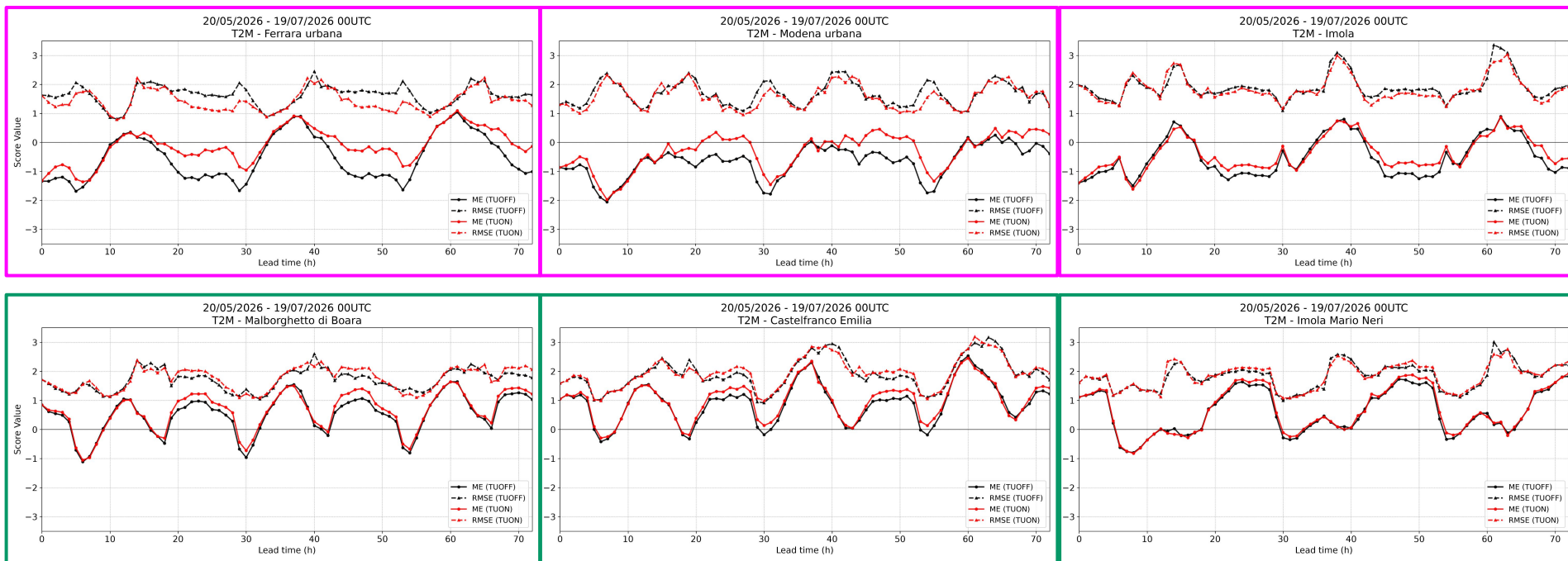
- TERRA_URB brings nighttime T closer in the first levels
- What should we expect from TERRA_URB?
- What variable should we consider?

Impact on smaller cities: winter



- Improvement in Mean Error (ME), especially when compared to the rural bias
- A slight urban effect is observed at 3 specific rural stations due to neighbourhood cells with ISA>0

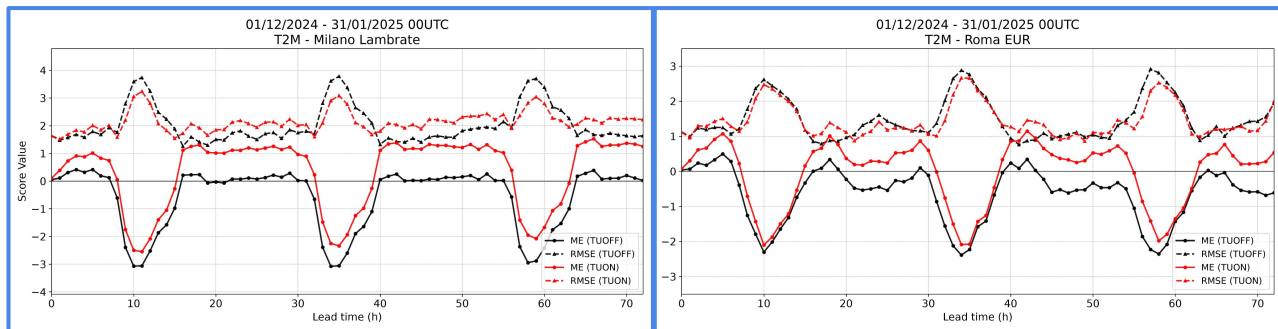
Impact on smaller cities: summer



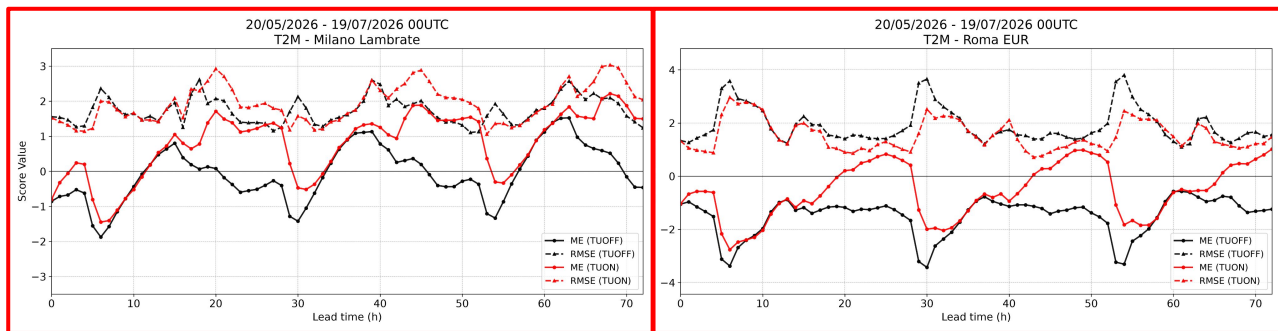
- Nighttime improvement quite important in both RMSE and ME
- Little increase in RMSE values

Milan and Rome: first results

Winter



Summer



- Mean TERRA_URB quite big compared to previous cities
- More weather stations available and must be considered
- Rural areas investigation to understand biases

Over Bologna:

- **Winter:** **small improvement** by TERRA_URB with an impact is small but persistent throughout the diurnal cycle
- **Summer:** Nighttime impact is stronger, leading to **improvement in RMSE and ME**, though temperatures remain slightly underestimated
- Daytime UHI: False negative UHI observed, driven by the **overestimation of max T2M** in rural areas
- **Timing:** Delayed morning warming is evident when using the model-level interpolation approach

Over smaller cities:

- Significant TERRA_URB impact observed
- Consistent improvement in overall scores

- Expand the analysis to other Italian cities and evaluate additional variables (Relative Humidity)
- FFV2 evaluation (SYNOP stations), precipitation verification and focus on Turin (collaboration with ARPAP & CIMA)
- Investigate the daytime T2m overestimation in Po Valley rural areas
- Continue testing TERRA_URB at the hectometric scale and comparison with different models (collaboration with the University of Bologna - presentation: Nagaraju et al.)

Thank you for your attention

lmattavelli@arpae.it

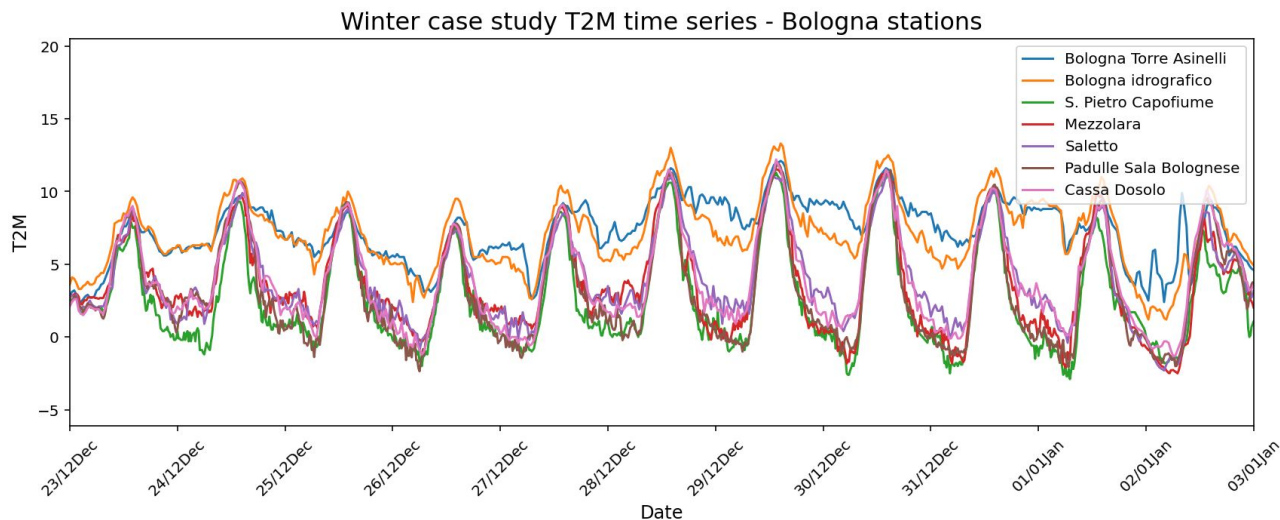
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Case study: UHI 23/12-01/01

23/12/2024 - 01/01/2025: 10 days of clear sky and low winds

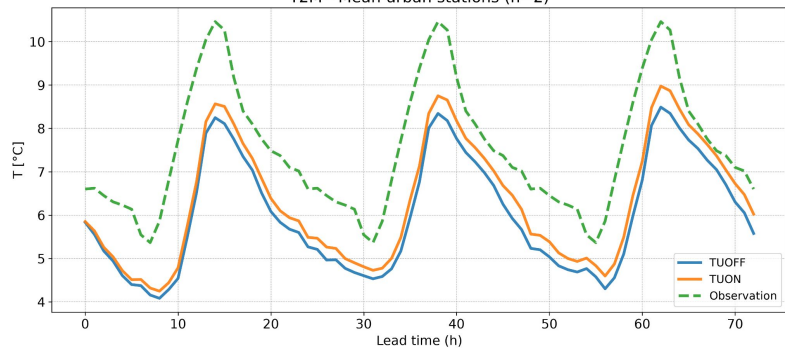
Observed persistent:

- slightly higher temperatures in the city center during daytime
- big night-time UHI effect

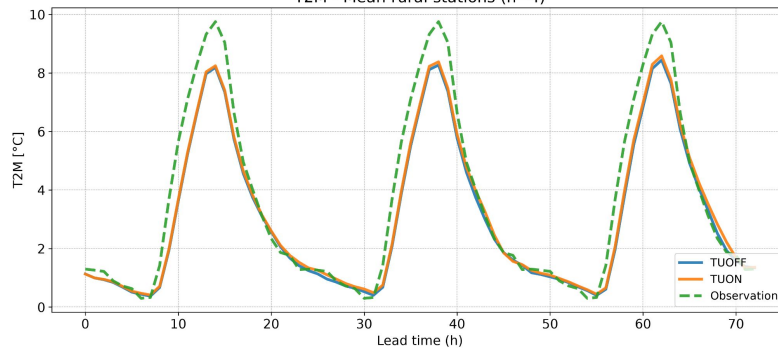


Case study: UHI 23/12-01/01 - 00 UTC runs

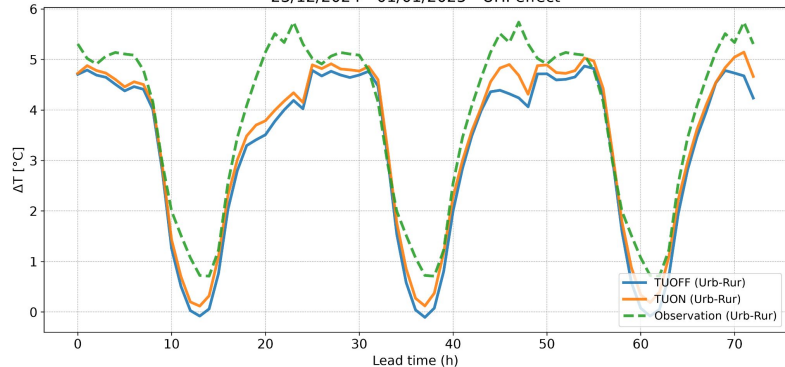
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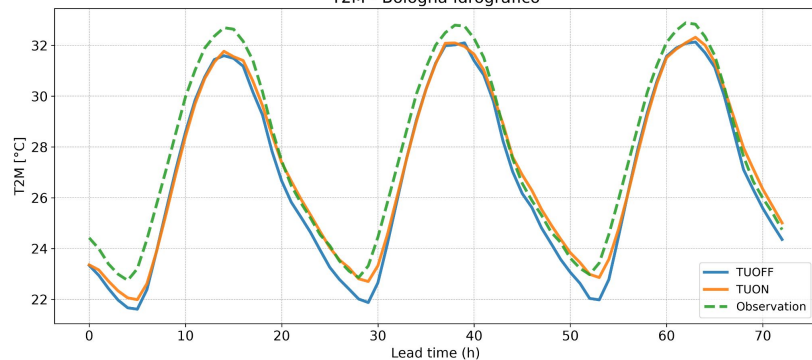
23/12/2024 - 01/01/2025 - UHI effect



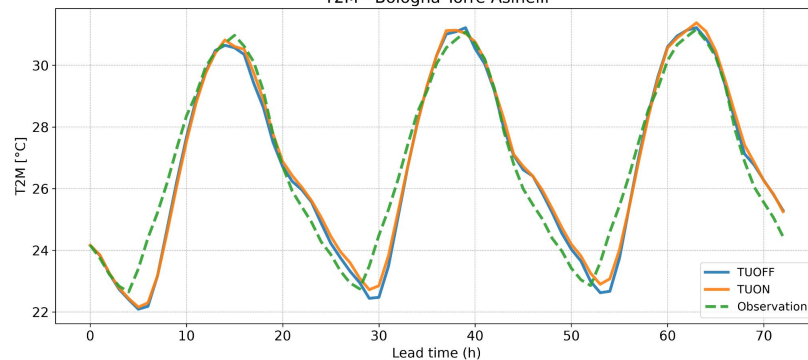
- Bias of almost 2°C on T in the city center
- Underestimation of daytime T2M in the rural areas
- TERRA_URB effect too little over this period

Time series for specific urban stations- 00 UTC runs

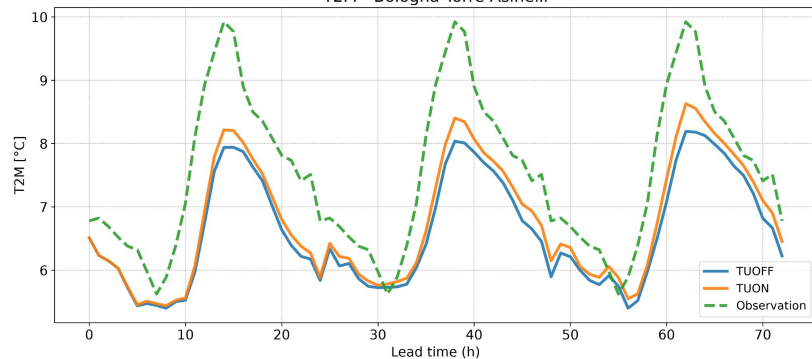
20/05/2026 - 19/07/2026 - Time series
T2M - Bologna idrografico



20/05/2026 - 19/07/2026 - Time series
T2M - Bologna Torre Asinelli



23/12/2024 - 01/01/2025 - Time series
T2M - Bologna Torre Asinelli



23/12/2024 - 01/01/2025 - Time series
T2M - Bologna idrografico

