# GenHack 2025 – Week 2: Visualization & Communication

# Urban Heat Island Analysis

## Berlin, Germany

**Team 19 UrbanCoolers**

November 24, 2025
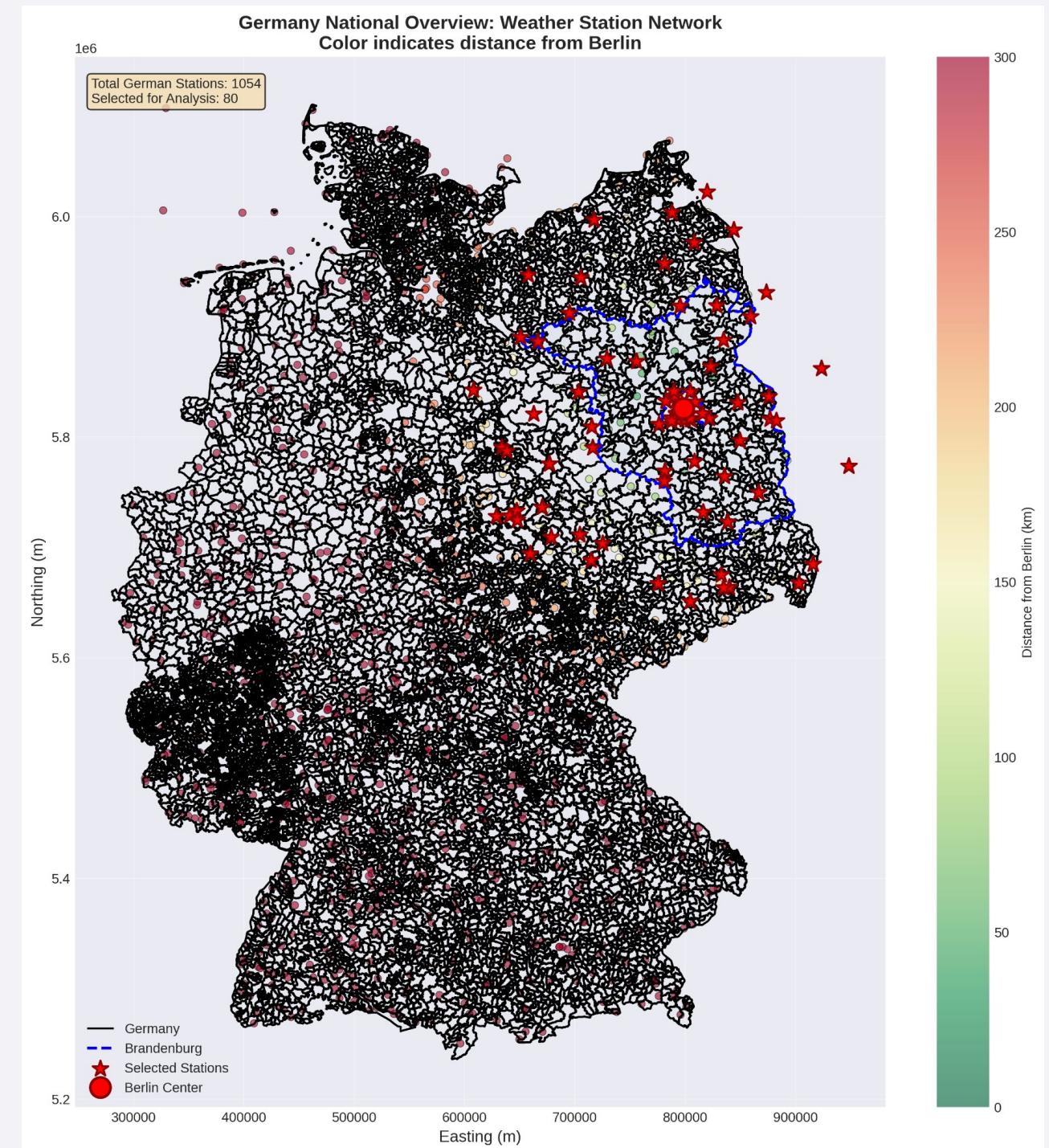
# Berlin Urban Heat Island Analysis
## Quantifying the City's Thermal Signature

**Research Question:** *How does urbanization in Berlin affect local climate patterns, and how well do current climate models capture these effects?*

## Study Area:

- Berlin: 893 km², 3.7M inhabitants

- Brandenburg: 29,697 km², 2.5M inhabitants
- Data Period: 2020-2023

# Comprehensive Data Approach:

## Three Data Sources:

| 80 Weather Stations | ERA5 Reanalysis | Sentinel-2 NDVI |
|---|---|---|
| (Urban/Suburban/Rural gradient) | (9km resolution, 2020-2023) | (80m resolution, 16 quarters) |
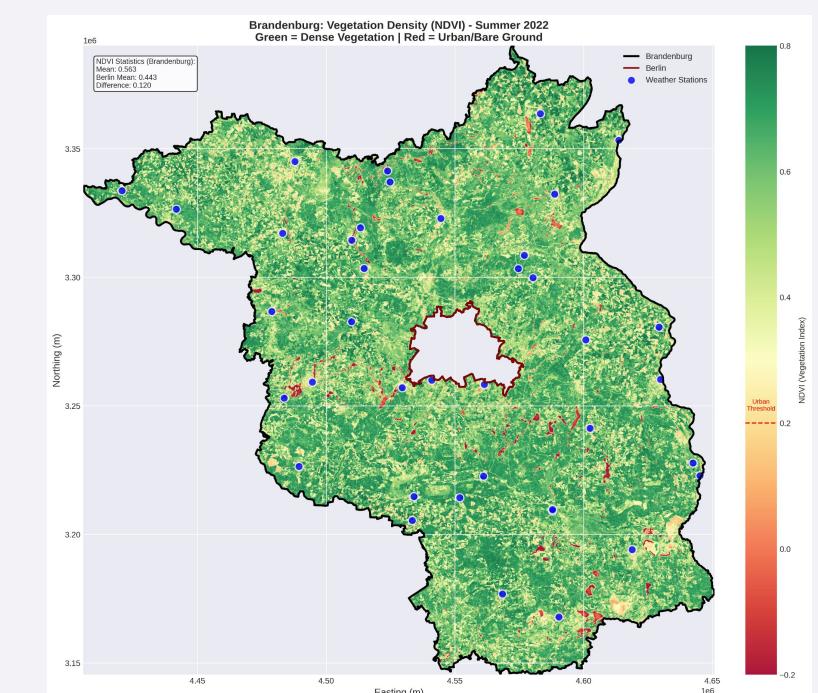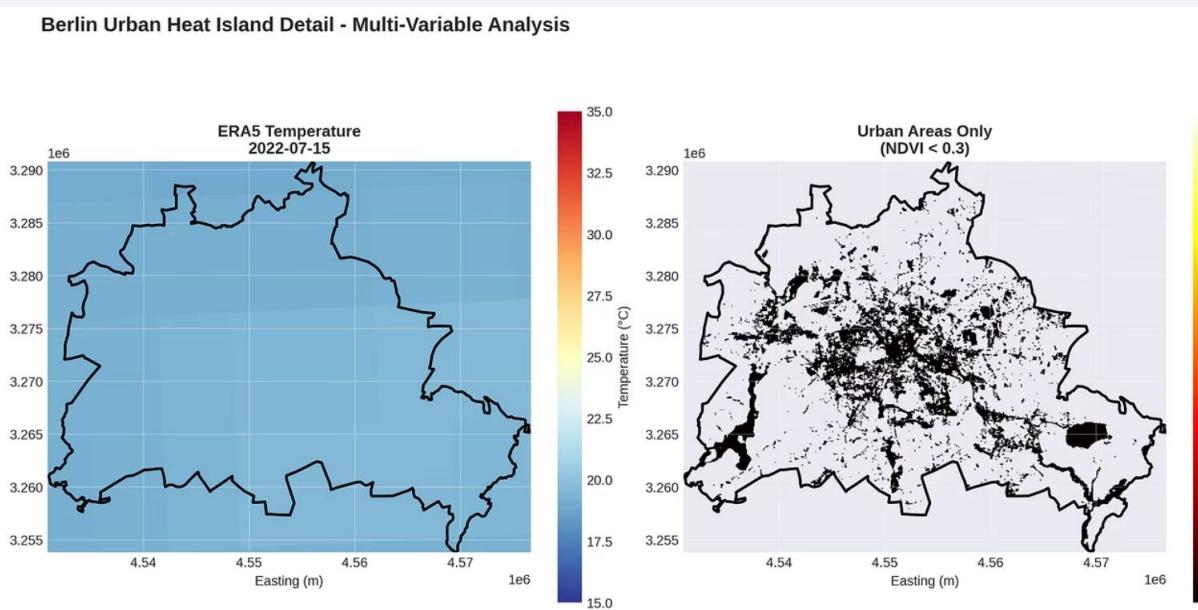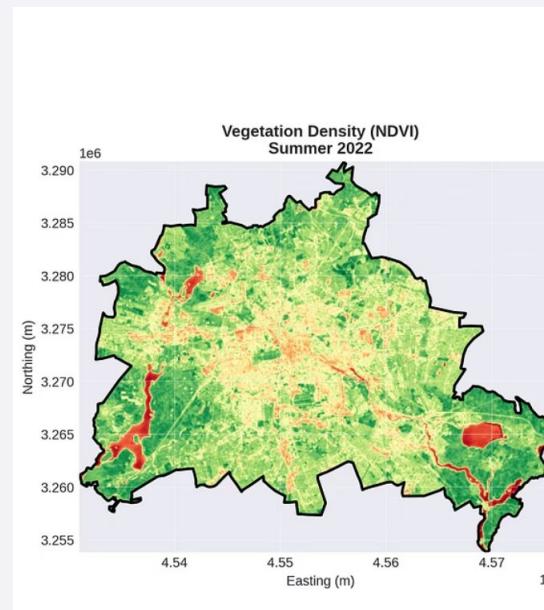
## Station Classification:

**Urban (8):** <10km from center

**Suburban (14):** 10-30km from center
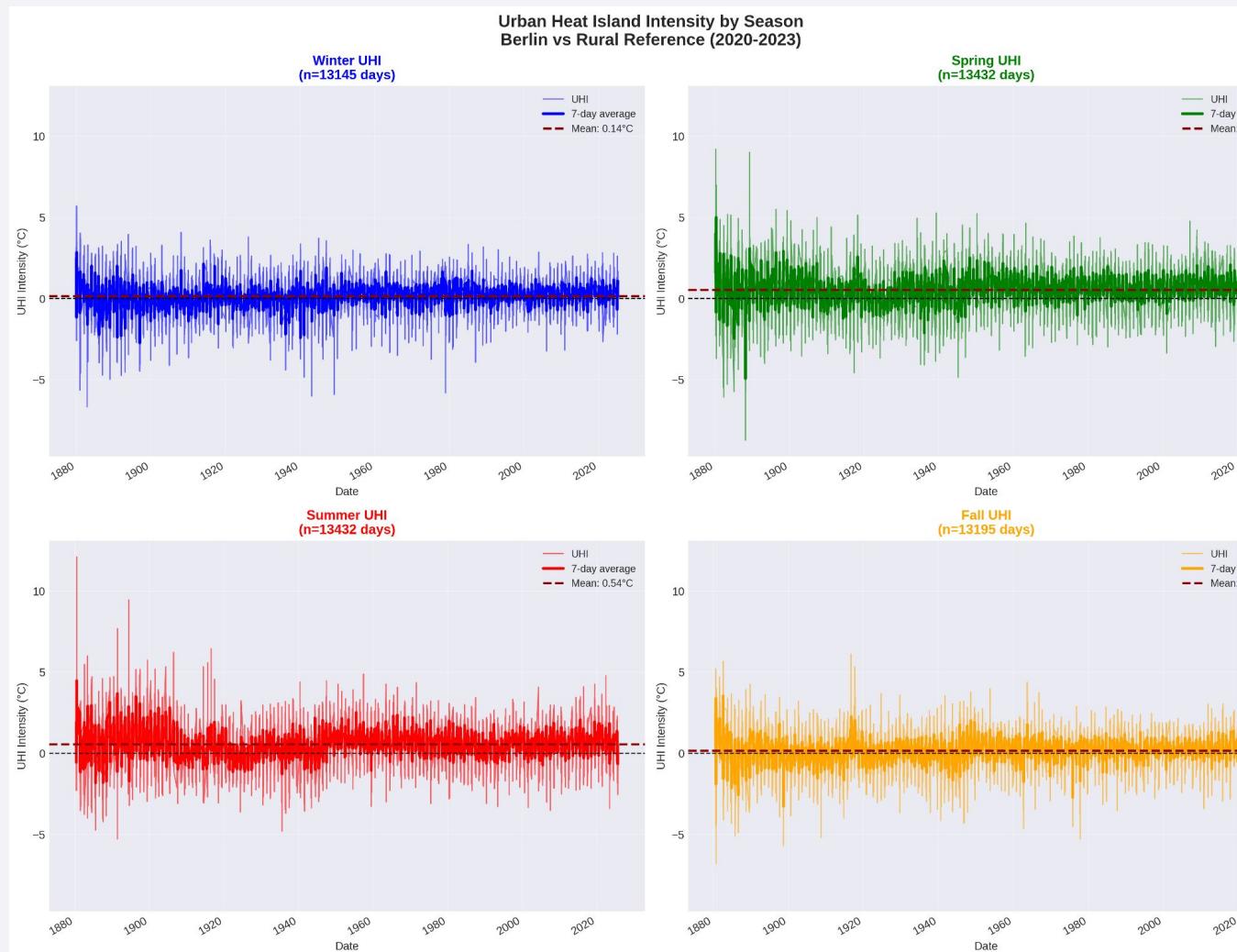
**Rural (58):** 30-200km from center



Berlin Urban Heat Island Detail - Multi-Variable Analysis



Brandenburg: Vegetation Density (NDVI) - Summer 2022
Green = Dense Vegetation | Red = Urban/Bare Ground

# Quantitative Evidence:

# Mean UHI Intensity: $+0.34\degree$C

- Berlin consistently warmer than surrounding countryside

- Peak intensity: **+12.10°C** (extreme summer event)



**Key Insight:** UHI 4x stronger in summer when heat matters most

## Seasonal Variation:

Summer: **+0.54°C** ⬆️

Winter: **+0.14°C** ⬇️

Spring: **+0.53°C**,

Fall: **+0.15°C**

# Clear Urban-Rural Gradient:

## Temperature Decreases with Distance:
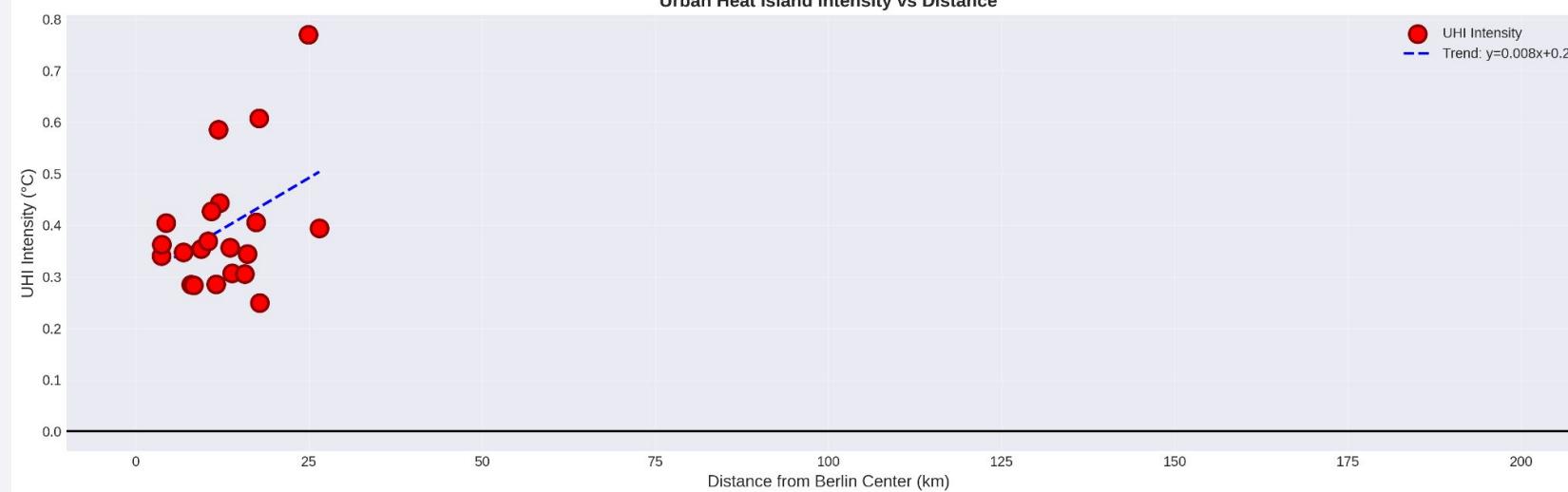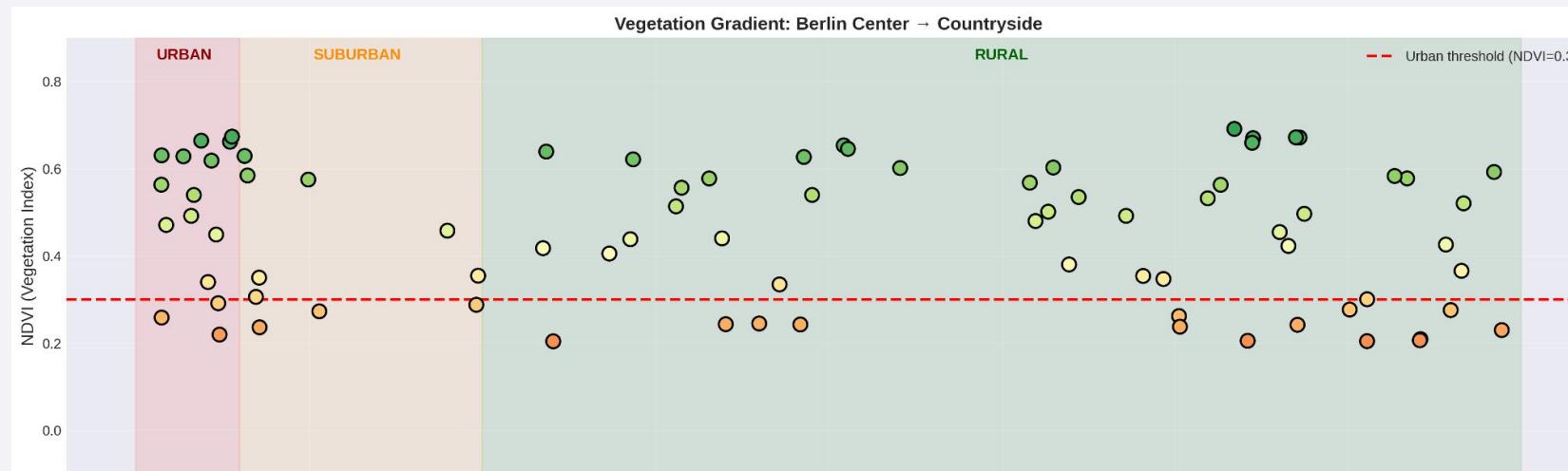
**Strongest effects within 15km of city center**

**Smooth transition from urban to rural climate**

**Entire urban area affected, not just city core**



## Multi-Scale Evidence:

- Regional scale shows Berlin as "heat island"
- City scale reveals internal variations
- Station network captures local patterns



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# Quantifying the Green Deficit:

**NDVI Analysis:**

## 0.450
**Berlin**

(mixed urban-suburban)
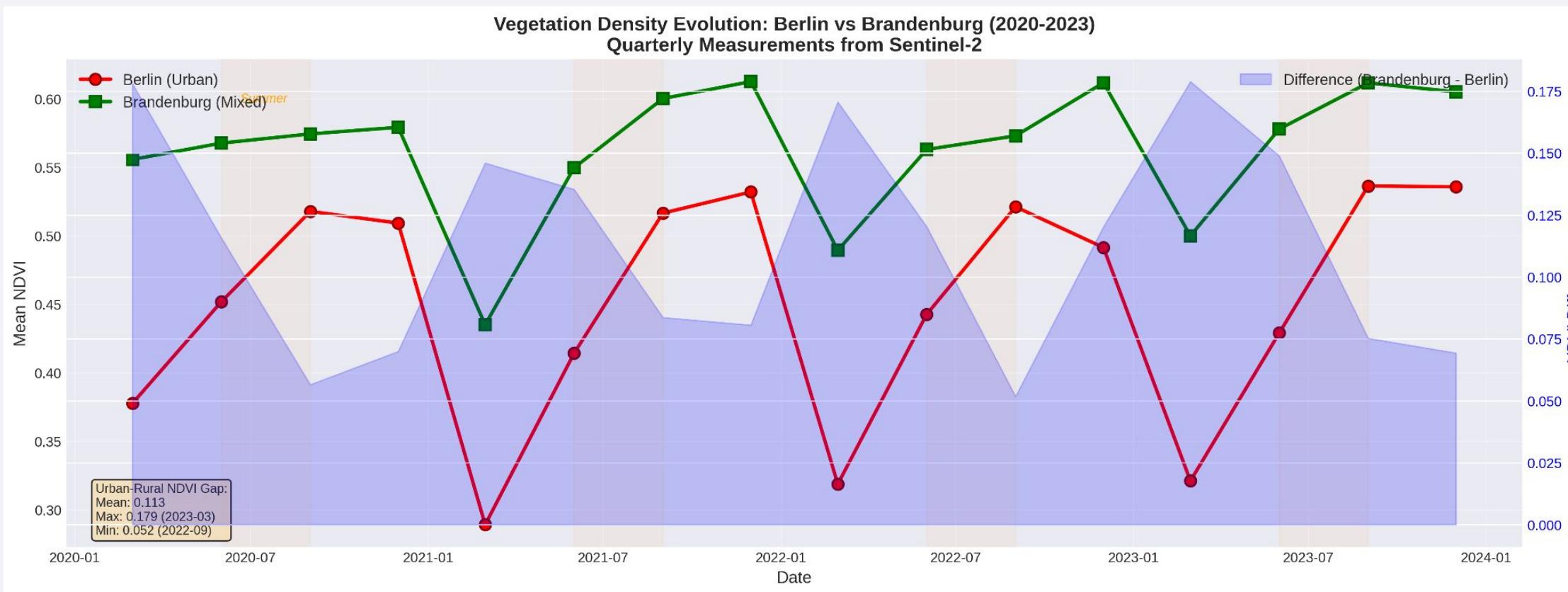
## 0.563
**Brandenburg**

(rural-vegetated)

## 0.113
**Urban–Rural Gap**



Vegetation Density Evolution: Berlin vs Brandenburg (2020-2023)
Quarterly Measurements from Sentinel-2

- Berlin (Urban)
- Brandenburg (Mixed)
- Difference (Brandenburg - Berlin)

Urban-Rural NDVI Gap:
Mean: 0.113
Max: 0.179 (2023-03)
Min: 0.052 (2022-09)

### Interpretation:

Berlin has **20% less vegetation** than surroundings

- Clear seasonal cycle in both regions

- Persistent vegetation gap year-round

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# ERA5 Model Performance: Systematic Assessment

## Overall Performance:
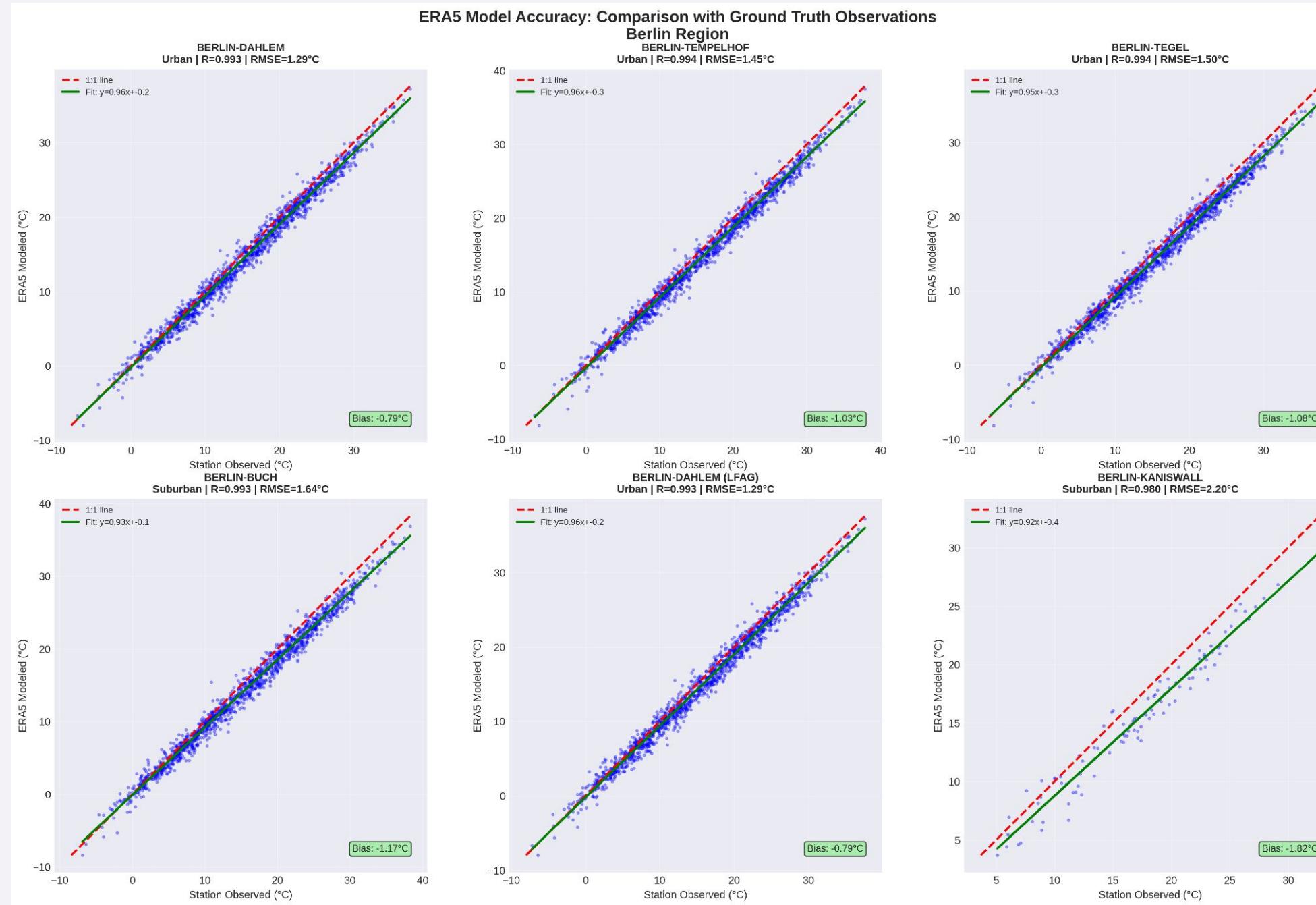
| Correlation: 0.993 ✅ | Bias: −0.97°C ❄️ (cold bias) | RMSE: 1.50°C ✅ |
|---|---|---|
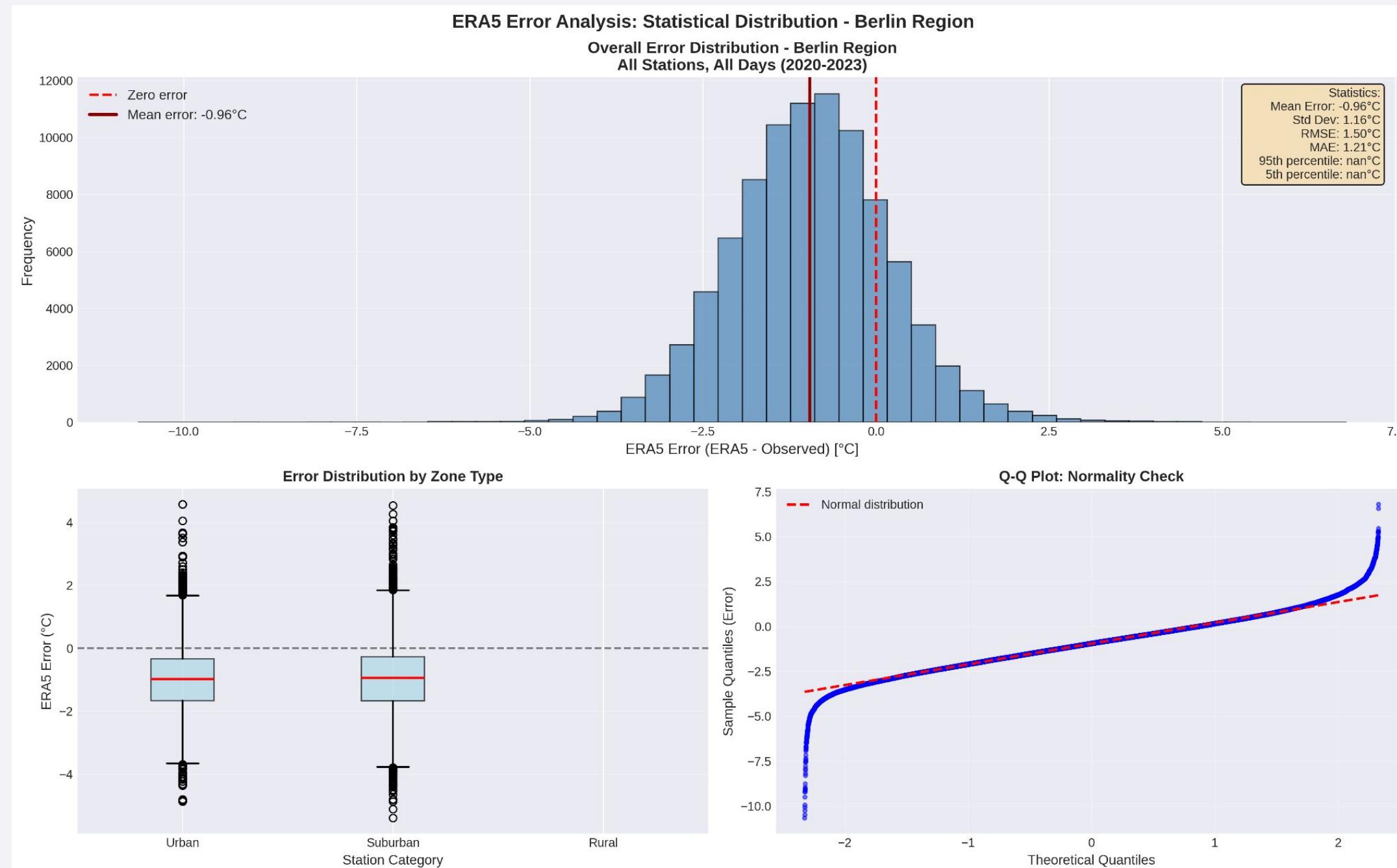
## By Zone Type:

| Zone | Bias | RMSE | Correlation |
|---|---|---|---|
| Urban | -0.98°C | 1.41°C | 0.994 |
| Suburban | -1.03°C | 1.49°C | 0.992 |
| Rural | -0.95°C | 1.51°C | 0.993 |

# ERA5 Model Performance: Systematic Assessment



ERA5 Model Accuracy: Comparison with Ground Truth Observations
Berlin Region

# ERA5 Model Performance: Error analysis



ERA5 Error Analysis: Statistical Distribution - Berlin Region
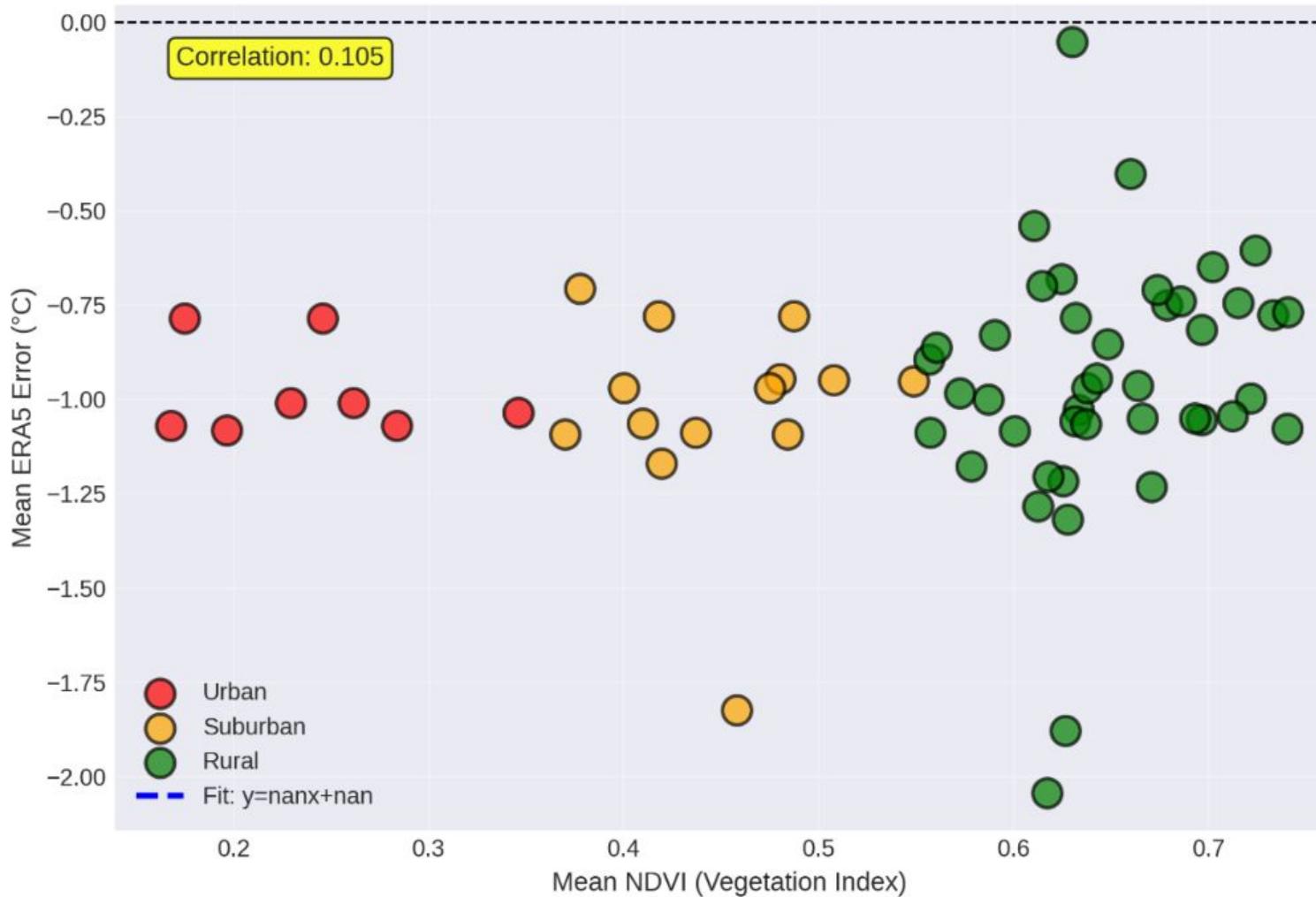
- Normally distributed errors around negative mean

- Systematic Cold Bias
- Good Precision, Poor Accuracy
- **Manageable Error Magnitude:** The typical error is around 1.2°C (MAE), The RMSE of 1.5°C suggests that while most errors are small, there is a tail of larger errors that should be investigated. -> OUTLIERS
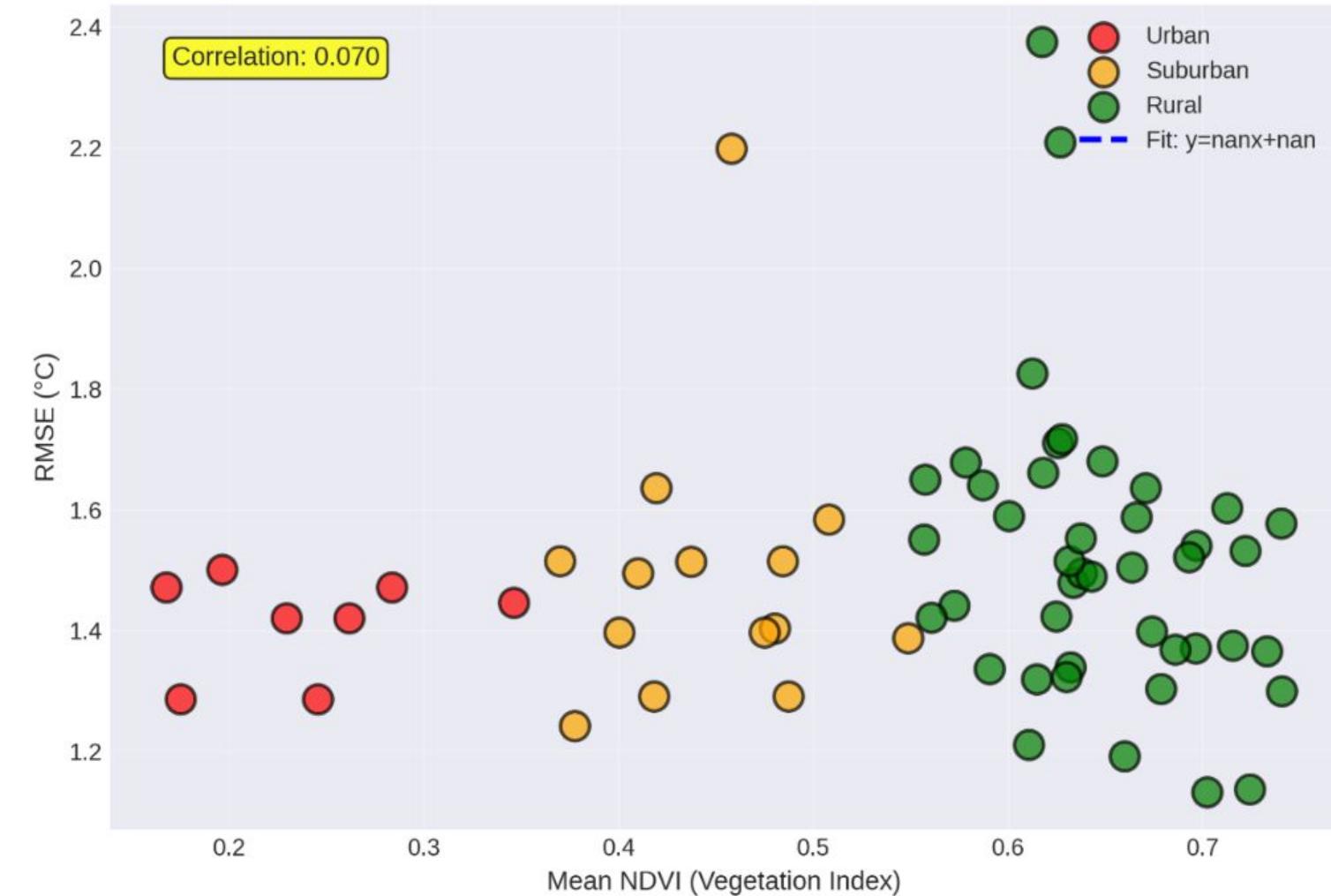
# ERA5 Model Performance: Correlation NDVI – Error



Correlation Analysis: Vegetation Density vs ERA5 Accuracy - Berlin Region

**No strong correlation between NDVI and ERA5 bias**

# Three Main Conclusions:



KEY FINDINGS - URBAN HEAT ISLAND ANALYSIS (BERLIN, GERMANY)

1. TEMPERATURE PATTERNS:
   • Berlin shows a measurable Urban Heat Island effect compared to rural Brandenburg
   • Mean UHI intensity: +0.34°C (Berlin warmer than rural reference)
   • Peak UHI observed: +12.10°C during summer heat waves
   • Seasonal variation: UHI strongest in summer (0.54°C), weakest in winter (0.14°C)

2. VEGETATION PATTERNS:
   • Clear urban-rural NDVI gradient: Berlin (NDVI=0.450) vs Brandenburg (NDVI=0.563)
   • NDVI gap of 0.113 indicates substantially less vegetation in Berlin urban core
   • Seasonal NDVI cycle observed: peak in spring/summer, minimum in winter
   • Green spaces in Berlin show local cooling effects (visible in high-resolution NDVI maps)

3. ERA5 MODEL PERFORMANCE:
   • ERA5 reanalysis at 9km resolution partially captures regional temperature patterns
   • Model shows systematic biases in urban areas due to coarse spatial resolution
   • Urban Heat Island effects are underestimated by ERA5 (grid cells average urban + suburban areas)
   • Better agreement with observations in rural, homogeneous areas with high NDVI

4. SPATIAL SCALE INSIGHTS:
   • Multi-scale analysis reveals importance of resolution: 80m NDVI vs 9km ERA5 vs point stations
   • Reprojecting ERA5 onto NDVI grid highlights spatial discrepancies
   • Station observations show local variations not captured by gridded products
   • Berlin city (892 km²) fits within ~2-3 ERA5 grid cells, explaining limited urban representation

5. IMPLICATIONS:
   • Urban climate monitoring requires high-resolution data to capture local heat islands
   • Vegetation plays crucial role in urban temperature regulation
   • Current reanalysis products insufficient for city-scale climate impact assessments
   • Need for downscaling techniques and urban-aware temperature corrections

DATA COVERAGE: 80 stations | 1461 days (2020-2023) | 16 NDVI quarters

## URBAN HEAT ISLAND ANALYSIS - SUMMARY DASHBOARD
## Berlin & Brandenburg Region (2020-2023)

**+0.34°C**

*Mean Urban Heat Island Intensity*

Peak: +12.10°C

**0.113**

*Urban-Rural NDVI Gap*

Berlin: 0.450
Brandenburg: 0.563

**80**

*Selected Weather Stations*

Rural: 58
Suburban: 14
Urban: 8

### Urban Heat Island Time Series (2020-2023)

Study Area:
Berlin-Brandenburg