Table R1 Comparison of this study with existing high-resolution temperature/freeze–thaw related datasets.

Study/Data	**Region**	**Variable**	**Spatial Resolution**	**Time Span**	**Method**	**Difference from This Study**
Gao et al. (2023)	Yellow River Basin	Air temperature	1 km daily	1981–2020	Station + RS fusion	Air temp only; not ERA5-Land-based; no DEM lapse-rate correction.
Tao et al. (2022)	Global	LST	1 km daily	2003–2020	MODIS fusion	Starts 2003; not ERA5-Land-based; shorter time span.
Peng et al. (2019)	China	Air temperature	~1 km monthly	1901–2017	Statistical reconstruction	Air temp only; not surface temperature; no ERA5-Land + DEM correction.
He et al. (2021)	China	Air temperature	1 km monthly	1951–2020	Machine learning	ML-based air temp; not LST; no physical lapse-rate calibration.
ERA5 downscaling studies(Li et al., 2025)	China/Regional	T or LST	1 km	Various	Statistical / ML	High-resolution, but lacks explicit station-derived lapse-rate correction.
Other 1-km LST datasets(Liu et al., 2025; Zhang et al., 2023)	China/global	LST	1 km	Mostly post-2000	MODIS-based	Not ERA5-Land-based; limited time range.
This study	SAYR	DEM-corrected ERA5-Land LST	1 km monthly	1981–2020	Physical DEM lapse-rate correction	First 1981–2020 ERA5-Land LST with explicit monthly lapse-rate calibration for SAYR.

Sensitivity test for CMA observational changes

The China Meteorological Administration (CMA) transitioned from manual surface-temperature observations to automatic observations around 2003. Manual observations report snow-surface temperature when snow is present, whereas automatic observations report the soil-surface temperature beneath the snowpack, leading to structural inhomogeneity (Cui et al., 2020; Du et al., 2020). To evaluate its impact on lapse-rate estimation, we computed Γ using:

- all years (1981–2020): Γ_t_total
- pre-2003 period (1981–2002): Γ_t_pre
- post-2003 period (2005–2020): Γ_t_post

For each period and month, STobs at the six stations were regressed against elevation.
Results:

- Γ_t_pre shows weaker negative lapse rates, consistent with warm snow-surface bias.
- Γ_t_post shows stronger negative lapse rates, likely because automatic sensors sample the colder ground–snow interface.
- Γ_t_total lies between Γ_t_pre and Γ_t_post (Table S3), confirming internal consistency.
- R^2 values remain high for all periods (0.68–0.97), indicating stable elevation–temperature relationships.
- F-statistics and p-values (all $p < 0.05$) confirm high statistical significance.

This test demonstrates that although observational changes introduce differences in Γ for individual periods, the climatological lapse rate (Γ_t_total) used for ERA5-Land correction is robust and representative. The corrected 1-km ST fields and derived freeze–thaw indices remain insensitive to the choice of Γ within the observed range.

Table S2 Vertical lapse rate of surface temperature in the source area of the Yellow River month by month

month	Γ_t_*total*(°C/100m)	Γ_t_pre(°C/100m)	Γ_t_*post*(°C/100m)
1	- 0.90	-0.91	-0.85
2	- 0.77	-0.80	-0.75
3	- 0.68	-0.71	-0.68
4	- 0.62	-0.61	-0.66
5	- 0.54	-0.52	-0.57
6	- 0.46	-0.45	-0.50
7	- 0.42	-0.41	-0.42
8	- 0.41	-0.39	-0.46
9	- 0.47	-0.47	-0.49
10	- 0.64	-0.67	-0.60
11	- 0.78	-0.85	-0.67
12	- 0.88	-0.87	-0.87

Although pre-2003 lapse rates are slightly weaker (less negative) than post-2003, the month-specific differences are within ±0.002–0.003 °C/100m, which is smaller than the uncertainty range of station-based lapse-rate estimation on the TP. These differences do not alter the magnitude or spatial structure of DEM-based corrections. Therefore, the use of Γ_total is justified.