Climatekit: Unified Climate Indices for Temperature, Precipitation, and Drought in R

by Charles Coverdale

Abstract The climatekit package computes the standard suite of climate indices from daily weather observations behind a single R interface. Thirty functions cover temperature (frost days, ice days, summer days, growing and heating degree days, tropical nights, diurnal range, growing-season length, warm-spell duration), precipitation (wet and dry spells, heavy-precipitation days, one-day and five-day maxima, precipitation intensity), drought (Standardised Precipitation Index, Standardised Precipitation-Evapotranspiration Index, potential evapotranspiration via the Hargreaves method), agroclimatology (Huglin, Winkler, Branas, frost dates), and thermal comfort (wind chill, heat index, humidex, fire danger). Definitions follow the Expert Team on Sector-specific Climate Indices recommendations where applicable. Every function returns a tidy data frame with a period, a value, an index name, and a unit, so outputs compose directly. The package is pure computation, has no API calls, and is available on CRAN.

1 Introduction

The **climatekit** package consolidates thirty climate indices behind a single consistent interface. Each function takes daily vectors (temperature, precipitation, humidity) with an accompanying date vector and returns a data frame with four columns: `period` (the reporting period, typically annual or monthly), `value` (the index value), `index` (a character name), and `unit`. Users can feed any output directly into plotting, tabulation, or further aggregation without reshaping.

Climate-index analysis is a routine operation across applied climate work: national meteorological services publish annual index tables, regional climate assessments benchmark stations against one another, agricultural and viticultural research tracks growing-season indices, insurance underwriters use drought indices in parametric products, and public-health authorities monitor heat-index exceedances. Until now, the R ecosystem has exposed parts of this analysis piecemeal, with separate packages for drought indices (**SPEI**), for standard climate-change indices (**climdex.pcic**, archived), and for various agricultural indices. **climatekit** unifies the set.

The package has no network access, no external data dependency, and no runtime requirements beyond **cli** and base R. Users pair it with a data-acquisition package (**readnoaa** for NOAA's Global Historical Climatology Network, or direct downloads from a national met service) and pass the resulting daily series straight in.

2 Background

Climate-index standardisation dates to Frich et al. (2002), who proposed twenty-seven indices targeted at climate-change detection, and continued through the joint CCl/WCRP/JCOMM Expert Team on Climate Change Detection and Indices (ETCCDI), now the Expert Team on Sector-specific Climate Indices (ET-SCI). Zhang et al. (2011) synthesised the ET-SCI core set, which informs most modern national climate assessments. Applied analyses of the ETCCDI indices on observed station records (Alexander et al., 2006) and on gridded reconstructions (Donat et al., 2013) document robust multi-decadal trends. Sillmann et al. (2013) evaluate the same indices across CMIP5 climate-model output, establishing the index suite as the bridge between observational and model-based climate-change attribution.

Temperature indices. The core definitions are threshold counts (frost days where $T_{\min} < 0°C$; tropical nights where $T_{\min} \geq 20$; summer days where $T_{\max} \geq 25$; ice days where $T_{\max} < 0$) and degree-day accumulations (growing degree days above a base, heating degree days below a reference, cooling degree days above a reference). Diurnal range, growing-season length, and warm-spell duration round out the temperature family.

Precipitation indices. Consecutive dry and wet days summarise spell length. Total accumulation, heavy-precipitation exceedances, and one- and five-day maxima summarise intensity. The simple daily intensity index (SDII) is the average daily total on wet days. The ETCCDI-standard thresholds for heavy-precipitation counts are the 95th (R95p) and 99th (R99p) percentiles of the wet-day distribution at each station; `ck_heavy_precip()` accepts an explicit threshold argument so users can supply either a fixed value or a station-specific percentile computed from the data.

Drought indices. McKee et al. (1993) introduced the Standardised Precipitation Index (SPI), which fits a gamma distribution to precipitation accumulated over a chosen window (three, six, twelve months) and standardises to a standard normal. Values below minus one indicate moderate drought; below minus two, extreme drought. Vicente-Serrano et al. (2010) extended this to the Standardised Precipitation-Evapotranspiration Index (SPEI), which incorporates potential evapotranspiration via a climatic water balance. Stagge et al. (2015) compare candidate distributions for both indices and find that the gamma family (for SPI) and the generalised logistic (for SPEI) perform best in normality-of-residuals tests; **climatekit** uses these defaults. Potential evapotranspiration is computed by the Hargreaves and Samani (1985) method from temperature extremes and extra-terrestrial radiation.

Agroclimatic indices. The Huglin heliothermal index (Huglin, 1978) accumulates heat summed between a base temperature and a latitude-adjusted day length; it is the primary viticultural suitability index in temperate Europe. The Winkler index (Winkler et al., 1974) is a similar cumulative heat metric used widely in California. Branas, Bernon, and Levadoux's index is the French viticultural analogue. First-frost and last-frost dates set the frost-free growing window.

Thermal comfort. The US National Weather Service's heat index (Rothfusz, 1990) converts temperature and humidity into an apparent-temperature equivalent; Canadian humidex (Masterton and Richardson, 1979) does the same with a different functional form. Wind chill (Osczevski and Bluestein, 2005) is the cold-weather counterpart. Fire-weather indices combine temperature, humidity, wind, and precipitation history.

3 Package design

climatekit is pure R with no compiled code. Runtime imports are **cli**, `stats`, and `tools`. R 4.1.0 or later is required. The test suite contains over a hundred tests covering every exported function and every index definition.

Every index function returns a data frame with four columns: `period`, `value`, `index`, and `unit`. The `period` is a `Date` keyed to the start of the reporting window (year or month); the `value` is numeric; `index` and `unit` are character strings. This invariant means output from any function composes directly into a larger panel via `rbind()`, and plotting code is shared across index families. Every index function takes one or two daily numeric vectors plus a `dates` vector of matching length.

`ck_compute()` dispatches to any index by name, letting users select the index programmatically from a configuration file or argument. `ck_available()` lists the indices that can be computed given a supplied set of inputs; `ck_metadata()` returns each index's definition, unit, reference, and typical use.

4 Temperature indices

Four threshold-exceedance counters cover the core temperature indices. Cold extremes are counted by `ck_frost_days()` (minimum below 0°C) and `ck_ice_days()` (daytime maximum below zero). Hot extremes are counted by `ck_summer_days()` (maximum at or above 25) and `ck_tropical_nights()` (minimum at or above 20). Three degree-day accumulators report cumulative heat above or below a reference temperature. Agricultural work uses `ck_growing_degree_days()` to sum degree-days above a user-specified base. Energy-demand applications use the heating and cooling counterparts, `ck_heating_degree_days()` and `ck_cooling_degree_days()`. Figure 4 in the case study below shows these indices applied to seventy-five years of real NOAA data from the New York Central Park station.

5 Precipitation and drought indices

`ck_total_precip()`, `ck_dry_days()`, and `ck_wet_days()` summarise accumulation and spell counts. `ck_heavy_precip()` and `ck_very_heavy_precip()` count exceedances of user-specified thresholds. `ck_max_1day_precip()` and `ck_max_5day_precip()` return rolling maxima. `ck_precip_intensity()` returns the simple daily intensity index.

Figure 1 shows two precipitation indices on the Central Park station's daily record from 1950 to 2024: annual total precipitation (blue) and the count of heavy-precipitation days with daily total above 10 mm (red, scaled by 50 for visual comparability). Both trend upward over the seventy-five-year window: the annual total rises by about 45 mm per decade and the heavy-precipitation day count by 1.15 days per decade, consistent with the expected intensification of the hydrological cycle under continental-US warming documented in Alexander et al. (2006) and Donat et al. (2013).

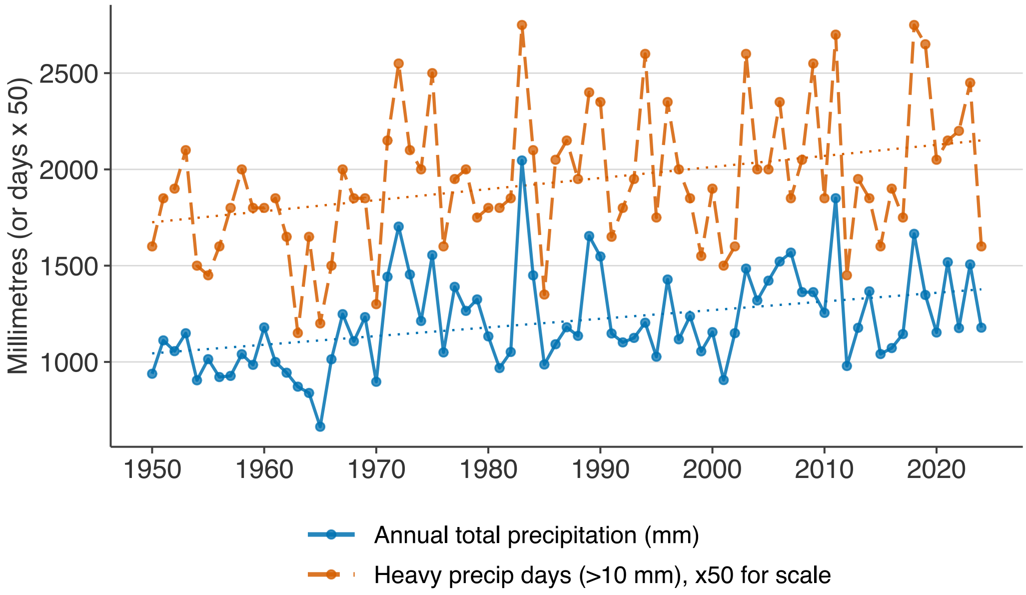

Figure 1: Annual precipitation indices for New York Central Park (GHCND station USW00094728), 1950 to 2024. Blue solid: annual total precipitation in millimetres, linear trend +45 mm per decade. Red dashed: count of days with daily total above 10 mm, scaled by 50 for visual comparability, linear trend +1.15 days per decade. Dotted lines are OLS trend fits. Both indices rise over the period.

6 Drought and pluvial episodes

`ck_spi()` and `ck_spei()` return the Standardised Precipitation Index and the Standardised Precipitation-Evapotranspiration Index. Both are unitless anomalies scaled to standard deviations: a value of -1 sits one standard deviation below the long-run mean for that calendar month, commonly interpreted as moderate drought, and values below -2 as severe drought. The index is computed by fitting a gamma distribution to rolling accumulated precipitation totals and transforming to standard normal deviates, separately for each calendar month to remove seasonality.

Figure 2 applies `ck_spi()` at a twelve-month scale to the 1950-to-2024 daily precipitation record at New York Central Park. The 1960s Northeast drought is visible as an extended run of deeply negative values between 1962 and 1966, the most severe drought episode in the station's recorded history. The 2001-02 drought is also clearly marked. The upper tail is populated by well-known wet years, including 1972, 1983-84, and 2011.

7 Agroclimatic and comfort indices

`ck_huglin()` returns the Huglin heliothermal index, accumulated from April through September (Northern Hemisphere) from daily maximum and mean temperatures weighted by a latitude correction. `ck_winkler()` returns the Winkler index. `ck_branas()` returns the Branas product index. `ck_first_frost()` and `ck_last_frost()` report frost dates each year. Figure 3 shows the Huglin index applied to ten years of a synthetic temperate site. Grey horizontal bands mark approximate viticultural classification ranges; the site plots within the Cool to Temperate range.

Four comfort functions cover hot and cold extremes. `ck_heat_index()` returns the US National Weather Service heat index (apparent temperature) from mean temperature and relative humidity. `ck_humidex()` returns the Canadian humidex from the same inputs. `ck_wind_chill()` returns wind chill from temperature and wind speed. `ck_fire_danger()` returns a linearised approximation of the Canadian Fire Weather Index (CFFWIS). Users requiring the full iterative CFFWIS should pair with the specialised **cffdrs** package.

8 A seventy-five-year case study

Figure 4 applies **climatekit** to real NOAA Global Historical Climatology Network Daily (GHCND) data from the New York Central Park station (USW00094728) from 1950 to 2024, a seventy-five-year

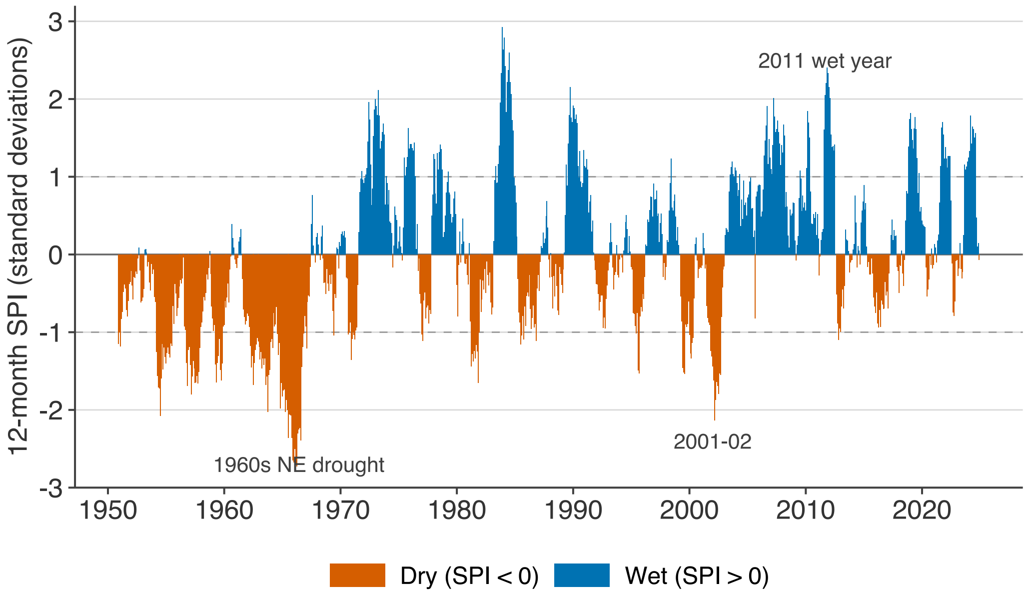

Figure 2: Twelve-month Standardised Precipitation Index for New York Central Park, 1950 to 2024. Computed with `ck_spi(scale = 12)` on the full GHCND USW00094728 daily precipitation record. Dashed horizontal lines at plus and minus one mark the moderate drought and moderate wet thresholds. The 1960s Northeast drought (1962 to 1966) and 2001 to 2002 drought are the two deepest dry episodes; 2011 is the wettest year in the sample.

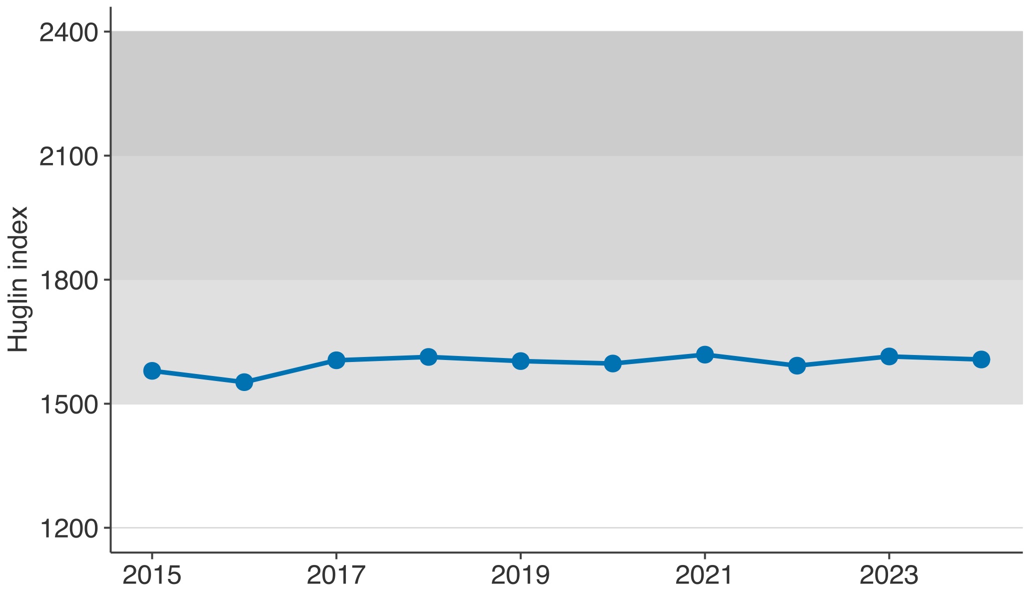

Figure 3: Huglin heliothermal index on a 10-year synthetic temperate site at latitude 51.5 degrees north. Shaded horizontal bands mark approximate viticultural suitability ranges: below 1500 is too cool, 1500 to 1800 is Cool, 1800 to 2100 is Temperate, 2100 to 2400 is Warm, above 2400 is Hot. The sample falls mostly in the Cool range.

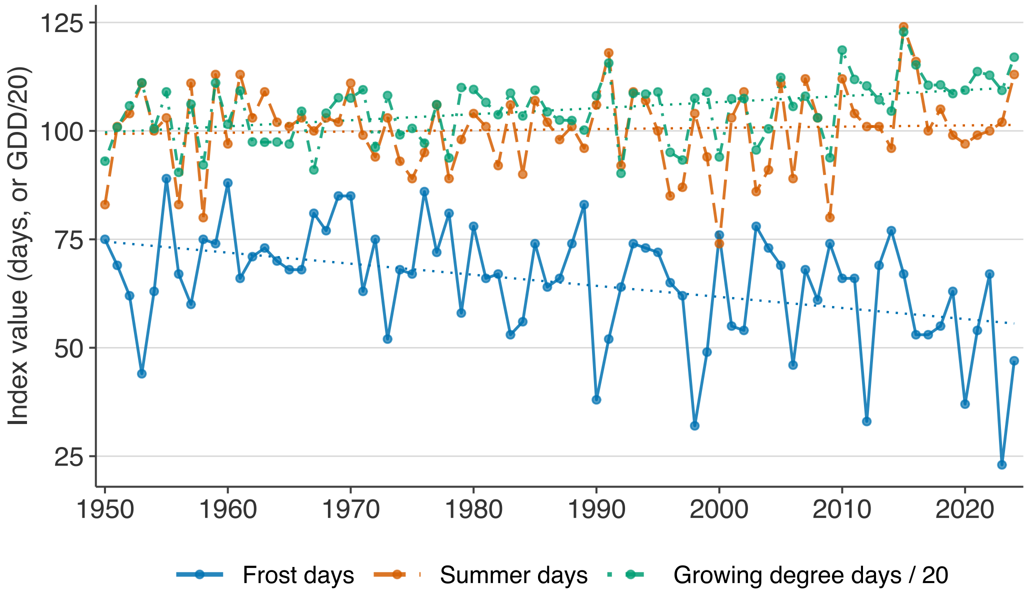

Figure 4: Three temperature indices for New York Central Park (GHCND station USW00094728), 1950 to 2024. Annual counts from raw daily T_{min}, T_{max}, and T_{mean}. Blue solid: frost days ($T_{\text{min}} < 0°\text{C}$), linear trend -2.6 days per decade. Red dashed: summer days ($T_{\text{max}} \geq 25°\text{C}$), trend $+0.3$ days per decade. Green dotdash: growing degree days above base 10°C, divided by 20 for visual scale, trend $+28$ GDD per decade. Dotted lines are OLS trend fits.

daily record with zero missing observations in T_{min}, T_{max}, and precipitation. Three temperature indices are computed directly from the raw daily vectors: frost days, summer days, and growing degree days at base 10. A linear trend fitted over the sample returns a decline of 2.6 frost days per decade, a rise of 28 growing-degree-days per decade, and a roughly stable summer-days count. The signs and magnitudes are consistent with the observed warming trends for the US Northeast documented in Alexander et al. (2006) and Donat et al. (2013). The full computation is three function calls on three vectors.

9 Replication

The canonical workflow is four lines.

```
library(climatekit)
frost_days <- ck_frost_days(tmin, dates, period = "annual")
spi3       <- ck_spi(precip, dates, scale = 3)
huglin     <- ck_huglin(tmin, tmax, dates, lat = 51.5)
```

Each call returns a tidy data frame that can be bound directly into a panel with other indices or plotted without reshaping.

10 Limitations

Five limitations apply.

1. **climatekit** computes indices from daily observations. Sub-daily (hourly) indices, including heat-wave indices based on night-time minimum temperatures and apparent-temperature exceedances, are not implemented.
2. Gridded-climate input is not natively supported. Users must reduce a gridded product to a per-cell time series before passing it in. For CMIP6 and similar model output, **terra**-based preprocessing is the natural partner.
3. The SPI and SPEI implementations use the gamma distribution as the parametric family. Users studying very arid regions may prefer the Pearson III family favoured by Vicente-Serrano et al. (2010); this is not currently exposed.

4. Quality control is the user's responsibility. Missing-value handling propagates `NA` through the aggregation functions.
5. Station homogenisation is not implemented. Detecting inhomogeneities (relocation, instrument change) in a daily record requires specialised techniques that are out of scope.

11 Appendix of index definitions

Selected formulas used by **climatekit**. Daily observations are indexed by t; aggregations run over a reporting window $\mathcal{T}$.

Frost days. $\mathrm{FD} = \sum_{t \in \mathcal{T}} \mathbf{1}\{T_{\mathrm{min},t} < 0°\mathrm{C}\}$.

Growing degree days (base b). $\mathrm{GDD}_b = \sum_{t \in \mathcal{T}} \max(T_{\mathrm{mean},t} - b, 0)$.

Huglin heliothermal index. For latitude ϕ and northern-hemisphere summation over 1 April to 30 September,

$$\mathrm{HI} = K(\phi) \sum_{t=\mathrm{Apr}}^{\mathrm{Sep}} \frac{(T_{\mathrm{mean},t} - 10) + (T_{\mathrm{max},t} - 10)}{2},$$

where $K(\phi)$ is Huglin's day-length correction.

Standardised Precipitation Index. For precipitation P_s summed over an s-month window, fit a two-parameter gamma distribution with shape α and scale β, compute the non-exceedance probability $F(P_s; \alpha, \beta)$, and transform to a standard normal: $\mathrm{SPI}_s = \Phi^{-1}(F(P_s; \alpha, \beta))$.

12 Conclusion

Climate-index computation is a daily activity in meteorological services, climate research, agricultural consultancies, and insurance underwriting, and the R ecosystem had not had a single unified implementation. **climatekit** consolidates thirty indices across temperature, precipitation, drought, agroclimatology, and thermal comfort behind a tidy-data-frame output format. The package is pure R, has no data dependencies, and returns output that composes directly into downstream analysis.

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The CCl/WCRP/JCOMM Expert Team on Climate Change Detection and Indices (ETCCDI) and its successor the Expert Team on Sector-specific Climate Indices (ET-SCI) developed and documented the index definitions on which this package is built. The National Oceanic and Atmospheric Administration publishes the Global Historical Climatology Network Daily (GHCND) dataset used in the case study. The author thanks the R Core Team and CRAN maintainers for the infrastructure that supports open-source statistical software.

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