SimulateDailyDrought.r Documentation

Overview

The `SimulateDailyDrought.r` script performs a two-stage transformation of daily weather data to simulate drought conditions under climate change scenarios. It combines monthly climate change projections (delta shifts) with seasonal precipitation redistribution to model drought impacts.

Purpose

This script is designed to:

1. Apply monthly delta shifts representing climate change projections to precipitation and temperature data
2. Simulate drought conditions by reducing spring/summer precipitation and redistributing it to fall/winter
3. Generate both daily transformed weather data and comprehensive metadata documenting the transformation process

Two-Stage Transformation Process

Stage 1: Delta Shifts (Climate Change Projections)

- **Precipitation**: Applies monthly percentage changes to days with precipitation > 0
- **Temperature**: Applies monthly temperature offsets to all days
- Represents gradual climate change impacts over time

Stage 2: Drought Simulation

- **Reduces** spring/summer (March-August) precipitation by a specified drought factor
- **Redistributes** the reduced precipitation to fall/winter (September-February) days that have precipitation
- Distribution is proportional to existing fall/winter precipitation amounts
- Maintains mass balance within each seasonal year

Function Parameters

drought_simulation_with_shifts()

Parameter	Type	Default	Description
`input_file`	character	"short.csv"	Path to input CSV file with daily weather data
`output_file`	character	"dailyWeatherScenario.csv"	Path to output CSV file
`delta_file`	character	"MonthlyDeltaShifts.csv"	Path to monthly delta shifts CSV
`drought_factor`	numeric	0.75	Proportion of spring/summer precipitation to retain (0-1)

Drought Factor Interpretation:

- `0.75` = Retain 75% of spring/summer precipitation (reduce by 25%)
- `0.50` = Retain 50% of spring/summer precipitation (reduce by 50%)
- `1.00` = No reduction (no drought simulation applied)

Input File Formats

Main Input File (e.g., short.csv)

Required Columns (case-insensitive):

- `date` - Date in YYYY-MM-DD format or other parseable formats
- `precipitation` or `precipitation` - Daily precipitation values
- `air_temperature` or `temperature` - Daily temperature values in °C

Example:

```csv
date,precipitation,air_temperature
1991-01-01,0.67,-1.74
1991-01-02,5.36,1.1
1991-01-03,1.39,1.92
```

Delta Shifts File (e.g., MonthlyDeltaShifts.csv)

Required Columns (case-insensitive):

- `Month` - Integer 1-12 representing calendar months
- `PPctChange` - Precipitation percent change (e.g., 10 for +10%, -15 for -15%)
- `Toffset` - Temperature offset in °C (e.g., 2.5 for +2.5°C increase)

Example:

```csv
Month,PPctChange,Toffset
1,5,1.5
2,5,1.5
3,10,2.0
```

Must contain exactly 12 rows (one for each month).

Output Files

1. dailyWeatherScenario.csv

Daily transformed weather data with the following columns:

Column	Description
Date	Date of observation
OriginalPrecipitation	Original precipitation from input file
DeltaShiftPrecipitation	Precipitation after applying monthly delta shifts (Stage 1)
OriginalTemperature	Original temperature from input file
DeltaShiftTemperature	Temperature after applying monthly delta shifts (Stage 1)
ScenarioPrecipitation	Final precipitation after drought simulation (Stage 2)

Note: Scaling factors are calculated internally but not included in the CSV output.

2. dailyWeatherScenario.json

Comprehensive metadata file documenting the entire transformation process.

JSON Structure

```json
```

```
{
  "scenario_info": {
    "scenario_type": "Drought",
    "scenario_name": "Drought Simulation with Delta Shifts",
    "date_created": "2025-01-15 14:30:00 UTC",
    "drought_reduction_factor": 0.75
  },
  "input_files": {
    "input_file": "short.csv",
    "delta_shifts_source": "MonthlyDeltaShifts.csv"
  },
  "output_files": {
    "csv_file": "dailyWeatherScenario.csv",
    "metadata_file": "dailyWeatherScenario.json"
  },
  "monthly_delta_shifts_applied": {
        "Month_1": {

"PPctChange":  5,
"Toffset":
1.5..  },
  },
  "summary_statistics": {
    "total_records_processed": 10958,
    "date_range_start": "1991-01-01",
    "date_range_end": "2020-12-31",
    "years_processed_min": 1991,
    "years_processed_max": 2020
  },
  "delta_shifts_results": {
    "original_total_precipitation": 15234.56,
    "delta_shifted_total_precipitation": 16100.23,
    "precipitation_change_from_delta_shifts": 865.67,
    "precipitation_change_percent": 5.68,
    "original_mean_temperature": 8.45,
    "delta_shifted_mean_temperature": 10.12,
    "temperature_change_from_delta_shifts": 1.67
  },
  "drought_simulation_results": {
    "seasonal_breakdown": {
      "spring_summer_days": 5520,
      "spring_summer_precip_days": 2100,
      "fall_winter_days": 5438,
      "fall_winter_precip_days": 2300
    },
    "precipitation_totals": {
```

```
    "delta_shifted_total": 16100.23,
    "drought_delta_shifted_total": 16100.23,
    "mass_balance_difference": 0.0001,
    "mass_balance_preserved": true
   },
   "scaling_factor_statistics": {
    "spring_summer_scaling_factor": 0.75,
    "fall_winter_scaling_factor_min": 1.001,
    "fall_winter_scaling_factor_max": 1.458,
    "fall_winter_scaling_factor_mean": 1.089
   }
  },
  "drought_scaling_factors_by_year": [
   {
    "year": 1991,
    "fall_winter_factor": 1.089234
   },
   {
    "year": 1992,
    "fall_winter_factor": 1.103456
   },
   ...
  ]
}
```


JSON Metadata Fields Explained

scenario_info:

- Documents the scenario type (Drought), name, creation timestamp, and drought reduction factor used

input_files:

- Records the paths to input data and delta shifts files

output_files:

- Lists the generated output files

monthly_delta_shifts_applied:

- Shows the exact delta shifts applied for each month (1-12)

summary_statistics:

- Basic information about the data processed (record count, date range, years covered)

delta_shifts_results:

- Quantifies the impact of Stage 1 (delta shifts)
- Shows total precipitation and mean temperature before and after delta shifts
- Calculates absolute and percentage changes

drought_simulation_results:

- **seasonal_breakdown**: Number of days in each season and days with precipitation
- **precipitation_totals**: Verifies mass balance is preserved
- **scaling_factor_statistics**: Spring/summer factor (constant = drought_factor) and fall/winter factor statistics (variable by day)

drought_scaling_factors_by_year:

- Array of objects showing the mean fall/winter scaling factor for each year
- Fall/winter factors vary because they compensate for reduced spring/summer precipitation
- Spring/summer factor is constant (equal to drought_factor) and therefore not included

Methodology

Seasonal Definitions

- **Spring/Summer**: March through August (months 3-8)
- **Fall/Winter**: September through February (months 9-12, 1-2)
- **Season Year**: For January-February, assigned to previous calendar year for seasonal continuity

Delta Shifts Algorithm (Stage 1)

1. For each day, identify the calendar month
2. Look up the corresponding `PPctChange` and `Toffset` from the delta shifts file
3. **Precipitation adjustment**:
   - Only applied to days with precipitation > 0
   - New value = Original × (100 + PPctChange) / 100
4. **Temperature adjustment**:
   - Applied to all days
   - New value = Original + Toffset

Drought Simulation Algorithm (Stage 2)

1. Group data by season year and calculate seasonal totals using delta-shifted precipitation
2. For each season year:
   - Calculate amount to redistribute: `p2shift = springSummer_total × (1 - drought_factor)`
   - **Spring/Summer reduction**: Multiply all spring/summer precipitation by `drought_factor`

- **Fall/Winter redistribution**:
  - Identify all fall/winter days with precipitation > 0
  - Calculate each day's proportion of total fall/winter precipitation
  - Add to each day: `p2shift × day_proportion`

3. Calculate scaling factors for each day

Mass Balance Preservation

The script ensures that total precipitation is preserved:

- `sum(ScenarioPrecipitation) = sum(DeltaShiftPrecipitation)`

The redistribution is done proportionally, so days with more fall/winter precipitation receive proportionally more of the redistributed amount.

Usage Examples

Basic Usage (Default Parameters)

```r
source("SimulateDailyDrought.r")
result <- drought_simulation_with_shifts()
```

This will:

- Read from `short.csv`
- Apply delta shifts from `MonthlyDeltaShifts.csv`
- Use drought factor of 0.75 (25% reduction)
- Output to `dailyWeatherScenario.csv` and `dailyWeatherScenario.json`

Custom Parameters

```r
```

```r
# Severe drought scenario (50% spring/summer reduction)
result <- drought_simulation_with_shifts(
  input_file = "historical_weather.csv",
  output_file = "severe_drought_2050.csv",
  delta_file = "RCP85_2050_deltas.csv",
  drought_factor = 0.50
)

# Moderate drought scenario (25% spring/summer reduction)
result <- drought_simulation_with_shifts(
  input_file = "baseline_weather.csv",
  output_file = "moderate_drought.csv",
  delta_file = "RCP45_2040_deltas.csv",
  drought_factor = 0.75
)

# No drought, only climate change (delta shifts only)
result <- drought_simulation_with_shifts(
  input_file = "current_weather.csv",
  output_file = "climate_change_only.csv",
  delta_file = "future_deltas.csv",
  drought_factor = 1.00
)
```

Terminal Output

The script prints comprehensive statistics to the terminal during execution:

```
=== SIMULATE DAILY DROUGHT WITH DELTA SHIFTS ===
This function applies a two-stage transformation:
  Stage 1: Monthly delta shifts (climate change projections)
  Stage 2: Drought simulation (seasonal precipitation redistribution)

Reading input file: short.csv
Using columns: date , precipitation , and air_temperature
Reading monthly delta shifts from: MonthlyDeltaShifts.csv

Applying monthly delta shifts...
Delta shifts applied successfully.
Original total precipitation: 15234.5600
Delta-shifted total precipitation: 16100.2300
Original mean temperature: 8.4500
Delta-shifted mean temperature: 10.1200

Applying drought simulation to delta-shifted precipitation...
Drought simulation applied successfully.

=== SIMULATE DAILY DROUGHT WITH DELTA SHIFTS SUMMARY ===
Input file: short.csv
Delta shifts file: MonthlyDeltaShifts.csv
Output file: dailyWeatherScenario.csv
Drought reduction factor: 0.75
Total records processed: 10958
Date range: 1991-01-01 to 2020-12-31
Years processed: 1991 to 2020

=== DELTA SHIFTS APPLIED ===
Original total precipitation: 15234.5600
Delta-shifted total precipitation: 16100.2300
Precipitation change from delta shifts: 865.6700 ( 5.68 %)

Original mean temperature: 8.4500 °C
Delta-shifted mean temperature: 10.1200 °C
Temperature change from delta shifts: 1.6700 °C

=== DROUGHT SIMULATION RESULTS ===
Seasonal breakdown:
  Spring/summer days: 5520 (with precip: 2100 )
  Fall/winter days: 5438 (with precip: 2300 )

Precipitation after drought simulation:
  Delta-shifted total: 16100.2300
  Drought+delta-shifted total: 16100.2300
  Mass balance difference: 0.000100
```

```
  Mass balance preserved successfully.

Drought scaling factor statistics:
  Spring/summer scaling factor: 0.750
  Fall/winter scaling factors - Min: 1.001 Max: 1.458 Mean: 1.089

Output saved successfully to: dailyWeatherScenario.csv

Creating JSON metadata file...
Metadata JSON saved to: dailyWeatherScenario.json
```

Requirements

R Packages

The script automatically installs missing packages:

- **lubridate**: For flexible date parsing
- **jsonlite**: For JSON file creation

R Version

Compatible with R 3.5.0 or higher.

Error Handling

The script includes comprehensive error checking:

- **File existence**: Verifies input files exist before processing
- **Column validation**: Ensures required columns are present (case-insensitive)
- **Data validation**:
  - Checks for valid dates
  - Removes rows with invalid precipitation or temperature values
  - Warns about removed rows
- **Parameter validation**:
  - Drought factor must be between 0 and 1
  - Delta shifts file must have 12 months
- **Mass balance verification**: Checks that precipitation totals are preserved

Notes and Best Practices

1. **Column Names**: The script handles common typos (e.g., "precipitation") and is case-insensitive for all column matching

2. **Date Formats**: The flexible date parser can handle multiple formats, but YYYY-MM-DD is recommended
3. **Delta Shifts File**: Must contain exactly 12 rows (one per month). Missing months will cause an error
4. **Mass Balance**: The script verifies mass balance within 0.001 tolerance. Warnings are issued if exceeded
5. **Scaling Factors**:
    - Spring/summer scaling factor is constant (= drought_factor)
    - Fall/winter scaling factors vary by day and year depending on redistribution
    - Only fall/winter factors are included in the JSON output by year
6. **Season Year**: January and February are assigned to the previous calendar year for seasonal continuity
7. **Zero Precipitation Days**:
    - Delta shifts are only applied to days with precipitation > 0
    - Only fall/winter days with precipitation > 0 receive redistributed precipitation

Troubleshooting

Common Issues

Issue: "Could not find 'date' column"

- **Solution**: Ensure input file has a column named "date" (case-insensitive)

Issue: "Delta shifts file must contain 'Month', 'PPctChange', and 'Toffset' columns"

- **Solution**: Verify delta shifts file has correct column names (case-insensitive)

Issue: "No valid data remaining after removing invalid rows"

- **Solution**: Check input file for:
    - Valid date formats
    - Numeric precipitation values
    - Numeric temperature values

Issue: Mass balance error detected

- **Solution**: This is rare but may indicate:
    - Computational precision issues with very large datasets
    - Missing or NA values in the data

Contact and Support

For questions, issues, or enhancements, please refer to the project repository or documentation.

Version: 2.0

Last Updated: January 2025

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