# Time-Invariant and Time-Varying Downscaling Approaches for the Assessment of Extreme Temperature Rise During 21st Century

**Subbarao Pichuka and Rajib Maity**

Department of Civil Engineering Indian Institute of Technology, Kharagpur, West Bengal, India.

## Introduction

- Many Global Climate Models (GCMs) used in Coupled Model Intercomparison Project phase-5 (CMIP5) projected rising trend in the global temperature during the 21st century. The IPCC Fifth Assessment Report (AR5) reveals that there is an average of 0.85°C rise in global temperature during 1800-2012 (IPCC, 2013).

- The application of GCM projections are found poor when the spatial resolution becomes finer and not useful for simulating the local climate. Hence, to improve the accuracy at local scale, the downscaling technique is adopted.

- The downscaling is a technique to improve the low resolution large scale data (GCM data) to the local scale finer resolution. The downscaled data can be used for many local scale impact assessments.

- Future temperature rise within Indian cities in the 21st century is assessed in this study through time-varying and time-invariant downscaling approaches. The relationship between causal and target variables is assumed to be time-invariant in most of the statistical downscaling approaches (Wilby et al. 2002; Sachindra and Perera, 2016). Such relationship is debatable in the context of climate change.

- The historical timeseries of urban temperature may exhibit non-stationarity due to rapid increase in the recent past as compared to historical period. The daily maximum ($T_{max}$) and minimum ($T_{min}$) temperature values of each month are considered for the analysis.

- Recent literature confirms the relationship between the causal variables and the target variable is time-varying i.e. non-stationary (Rashid et al. 2016; Merkenschlager et al. 2017). Merkenschlager et al., (2017) found that the results are improved when compared to the stationary based models by incorporating the non-stationary behavior of causal-target variables with in the statistical downscaling.

- The $T_{max}$ and $T_{min}$ are downscaled using time-varying (Time Varying Downscaling Model i.e. TVDM) approach and the outputs are compared with the time-invariant (Statistical Downscaling Model i.e. SDSM) approach

## Objective

To check whether the time-varying downscaling approach is better than time-invariant downscaling approach and also to assess the impact of climate change in the Indian temperature during the 21st century.

### Authors Contact Details

Subbarao Pichuka, PhD student, Department of Civil Engineering, Indian Institute of Technology, Kharagpur, West Bengal, India.
E-mail: srpichuka@gmail.com

Dr. Rajib Maity, Associate Professor, Department of Civil Engineering, Indian Institute of Technology, Kharagpur, West Bengal, India.
E-mail: rajib@civil.iitkgp.ac.in , rajibmaity@gmail.com
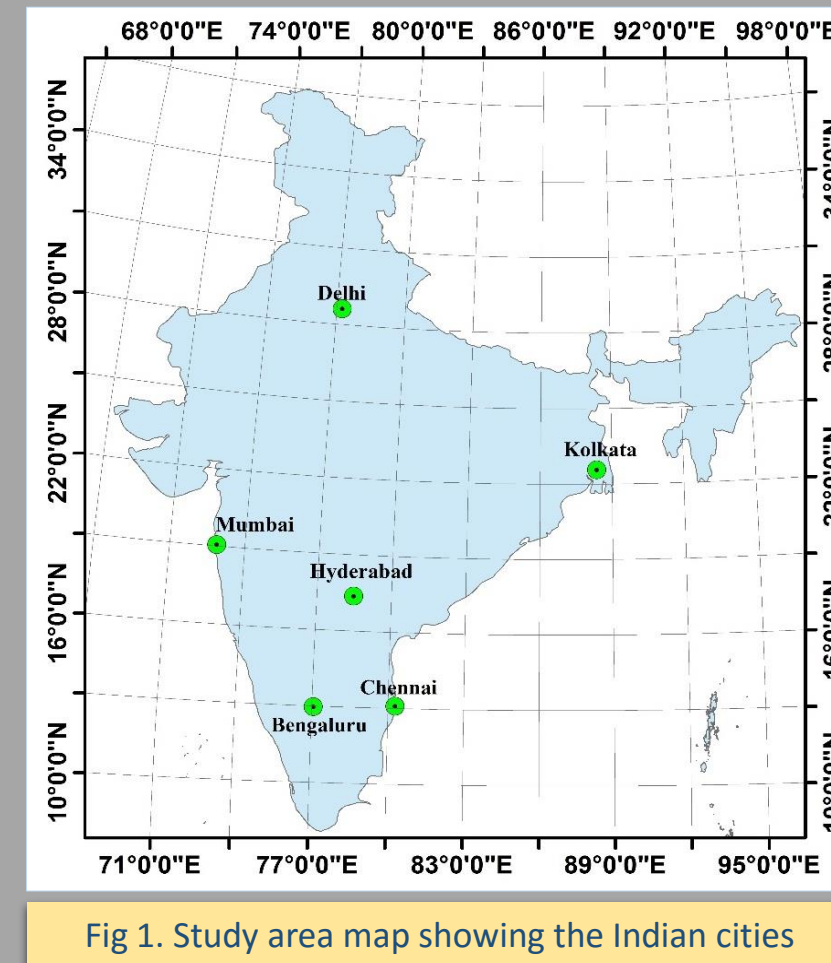
## Study Area and Data



Fig 1. Study area map showing the Indian cities

### Data Used

#### GCM data

| GCM | CanESM2 | HadCM3 |
|---|---|---|
| Spatial resolution (lat.×lon.) | 2.81°×2.81° | 2.5°×3.75° |
| Data availability | 1951-2100 | 1951-2035 |
| Scenarios used | RCP4.5 and RCP8.5 | RCP4.5 |

#### Observed data

Observed gridded maximum and minimum temperature data is obtained from India Meteorological Department (IMD), Pune
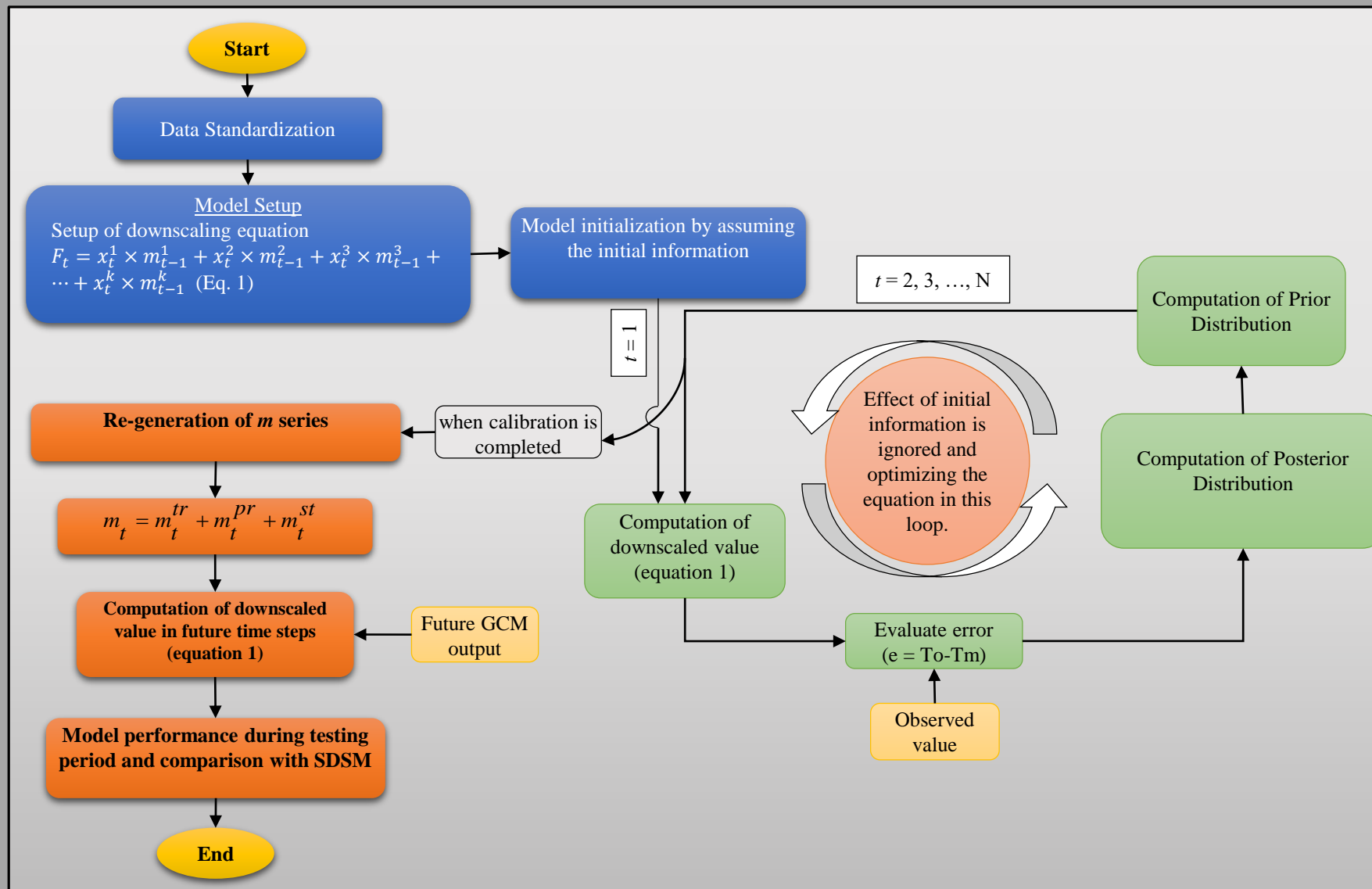
## Methodology



Fig 2. Time Varying Downscaling Model (Pichuka and Maity, 2018)
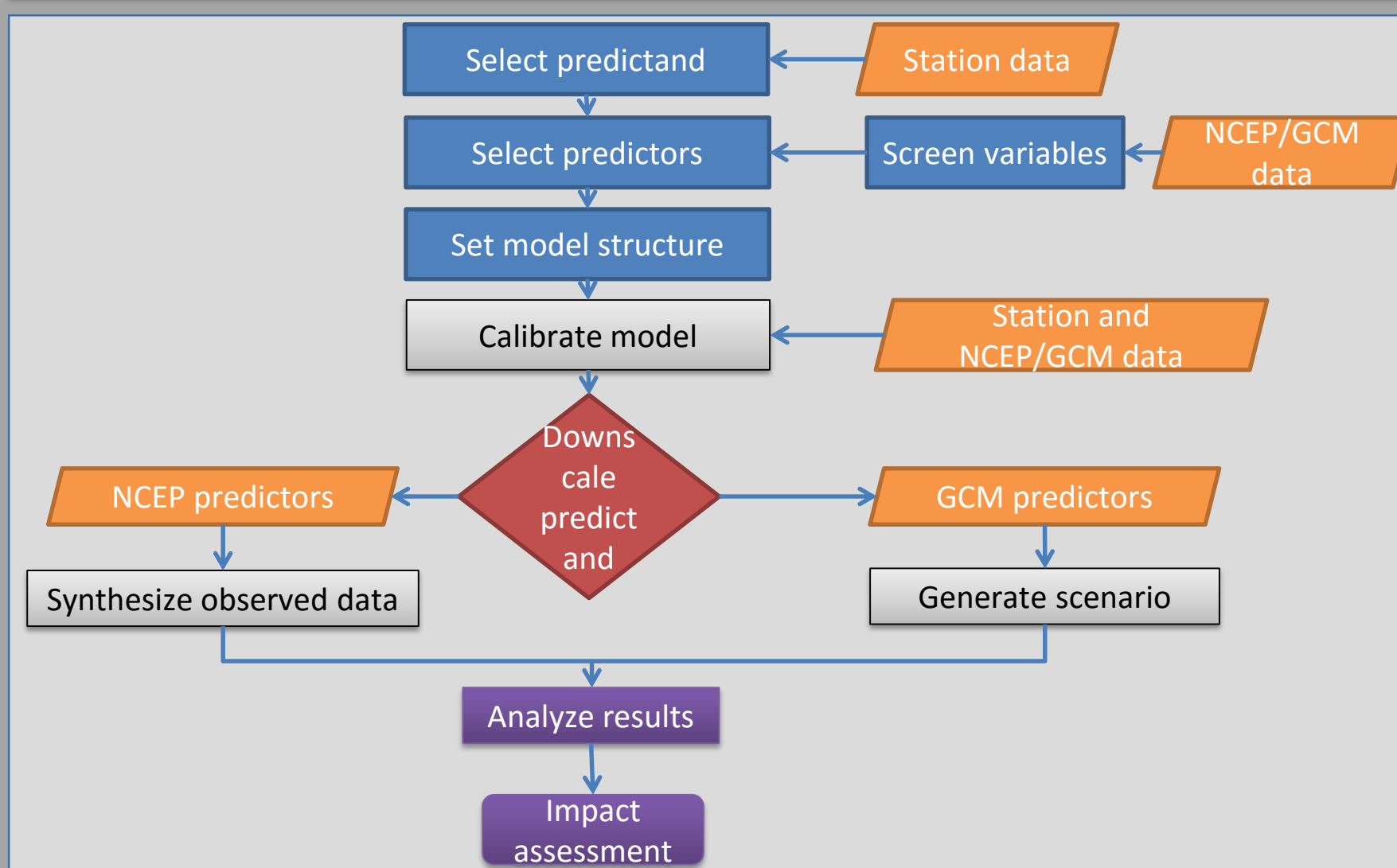


Fig 3. Statistical Downscaling Model (Wilby et al., 2002)
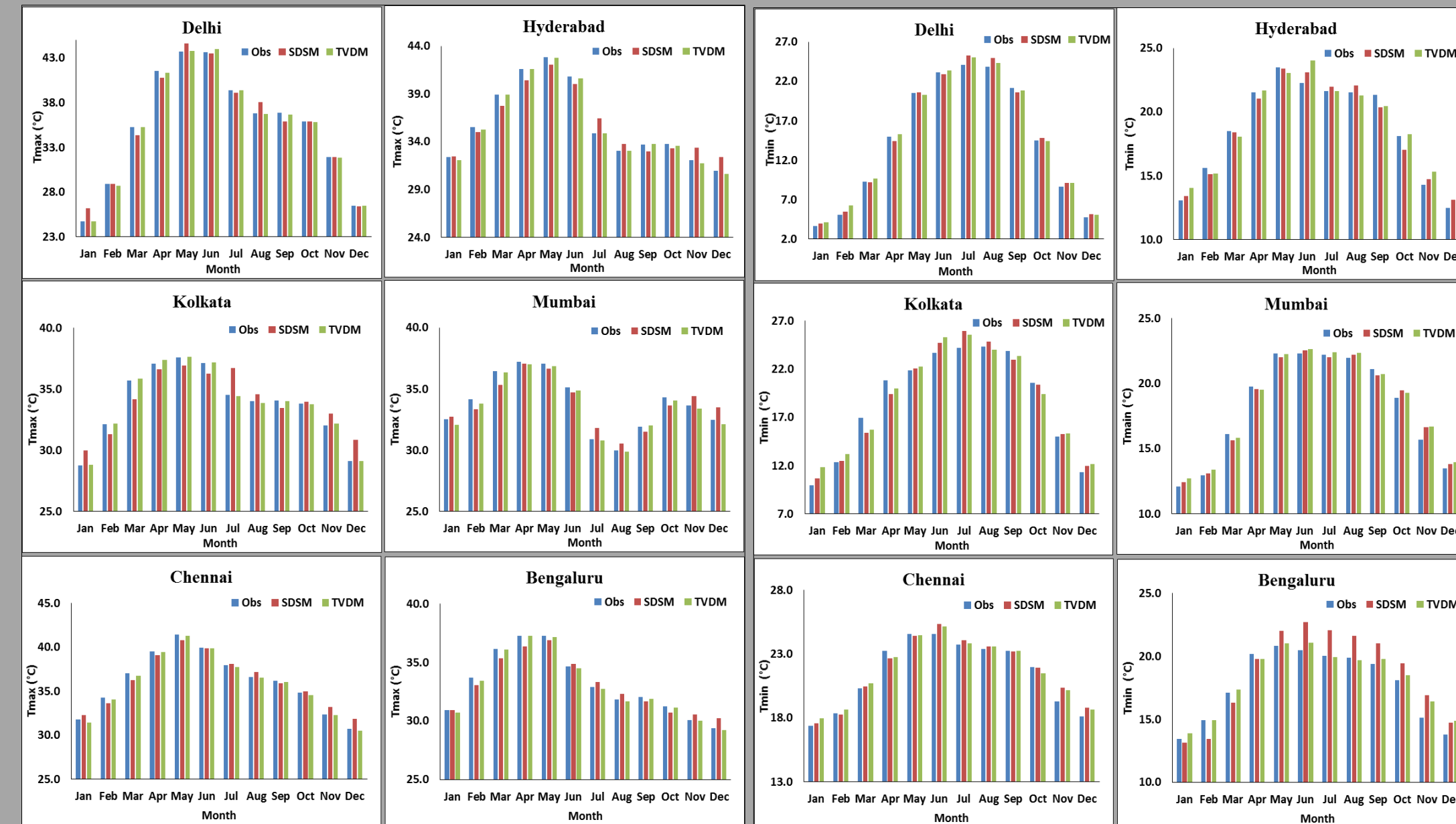
## Results and Discussions



Fig 4. Match between observed vs. Downscaled (TVDM and SDSM) temperatures during baseline (1971-2000) period
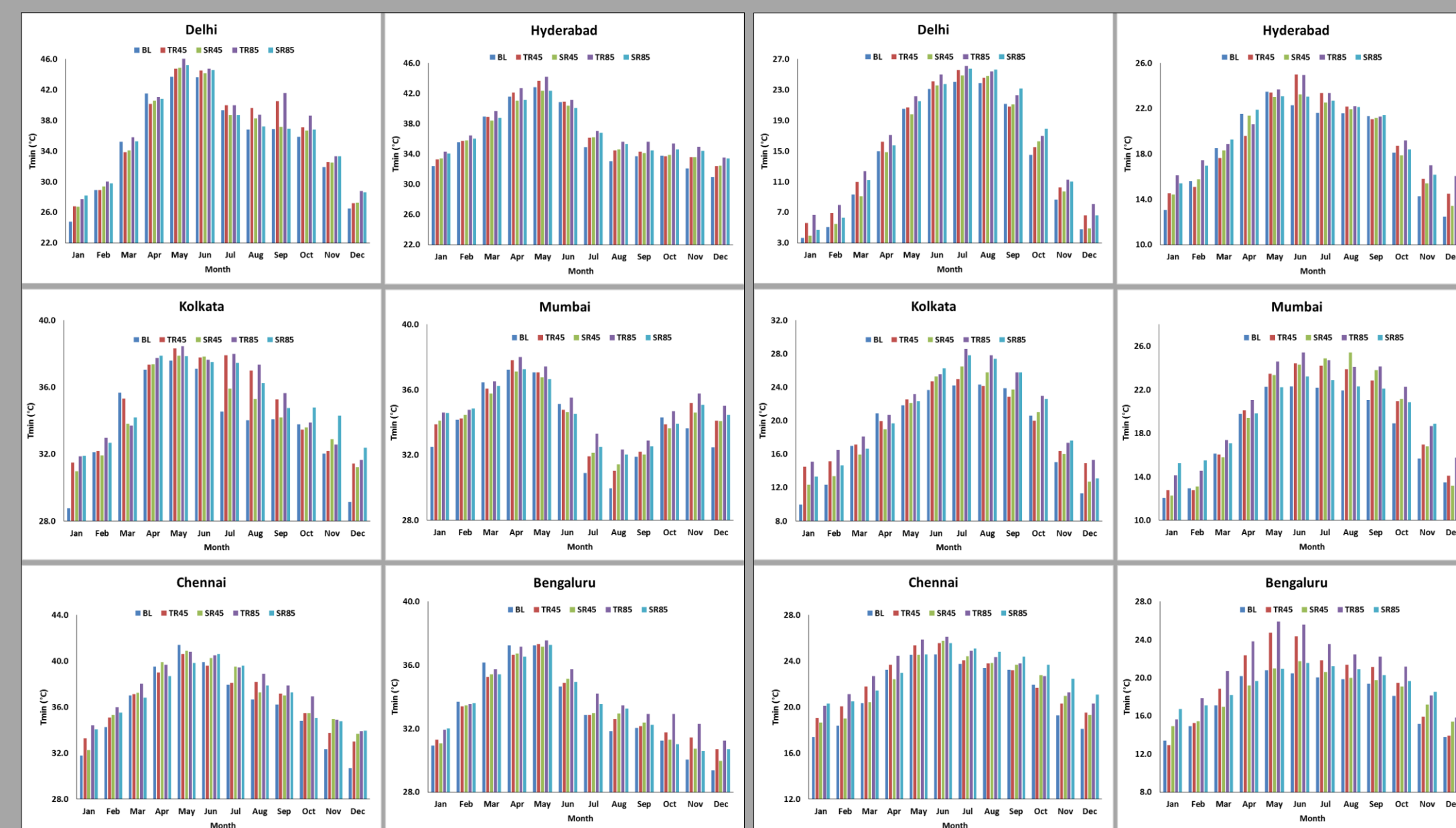


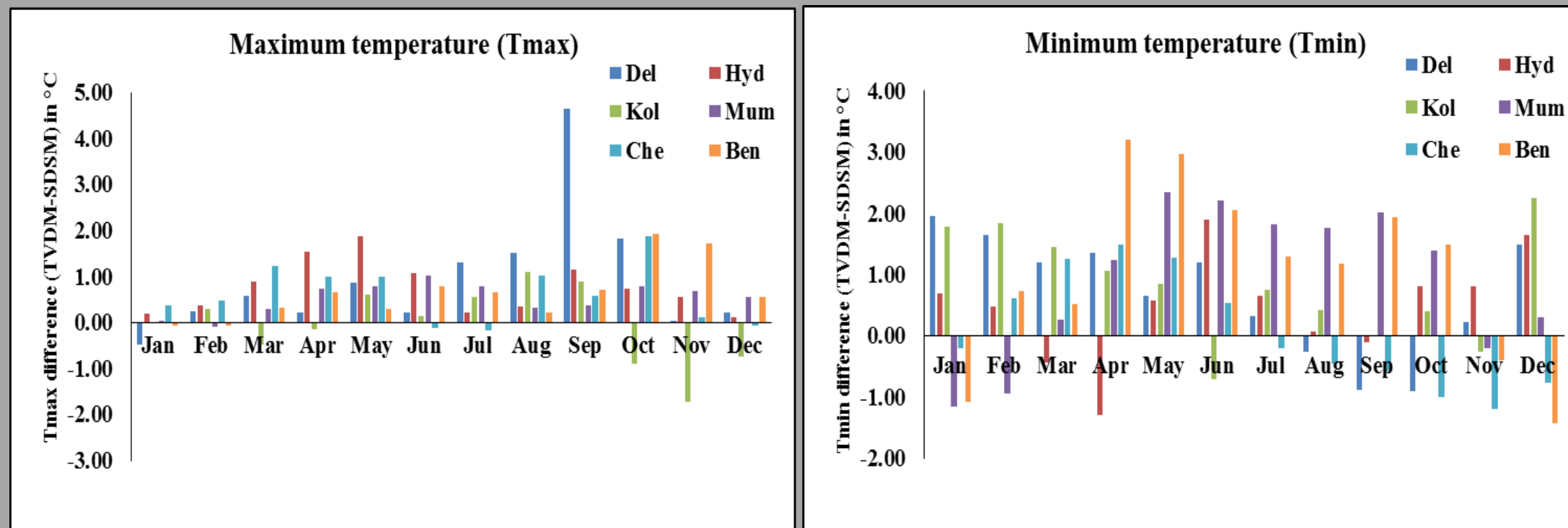Fig 5. Temperature change during epoch-3 (2071-2100) with respect to baseline period



Fig 6. Difference between TVDM and SDSM downscaled $T_{max}$ and $T_{min}$ using CanESM2 outputs during epoch-3.

## Conclusions

- Epoch-wise analyses, using TVDM and SDSM, proved that the magnitude of $T_{max}$ and $T_{min}$ will increase in all epochs (as compared to the baseline period). The highest positive difference (projected Temperature – baseline Temperature) was noticed in the third epoch (2071-2100) for all the cities as per RCP4.5 and RCP8.5 scenarios.

- It can be concluded that $T_{max}$ during the monsoon months is decreased as per RCP4.5 scenario in the south Indian cities (Chennai, Hyderabad and Bengaluru) during the first epoch (2006-2035) and it is consistent from both the GCMs. However, it is found to be increase in the North (Delhi); East (Kolkata) and West (Mumbai); Indian cities.

- The $T_{max}$ will be increased drastically (on an average 3 °C) by the end of 21st century (epoch3) as per TVDM considering RCP8.5 scenario and it is expected to increase up to 2 °C as per SDSM for the said case. The rise of $T_{min}$ is expected to be ~2.5 °C across all the cities during the third epoch (2071-2100) as per TVDM. It implies that there will be more hot days by the end of 21st century.

- The magnitudes of $T_{min}$ during the winter (November through February) season are expected to be rising at a higher rate as compared to the summer (April through June) and monsoon (July through September) months. It implies that there will be warmer nights (more in number) during epoch3 (2071-2100).

- The comparison results reveal that SDSM (time-invariant model) show less increase as compared to the TVDM (time-varying model) during the future period. On an average, the difference (TVDM-SDSM) of $T_{max}$ in future period (epoch3) is almost double in RCP8.5 scenario as compared to RCP4.5. The performance of the TVDM is superior to the existing SDSM during historical (development and testing) period as the downscaled temperature is closer to the observations. Therefore, it can be concluded that the temperature obtained using time-varying (TVDM) approach is more dependable than the time-invariant (SDSM) approach.

## References

Merkenschlager C, Hertig E, Jacobeit J (2017) Non-stationarities in the relationships of heavy precipitation events in the Mediterranean area and the large-scale circulation in the second half of the 20th century. Global and Planetary Change 151:108–121. doi: 10.1016/j.gloplacha.2016.09.009.

Pichuka S, Maity R (2018) Development of a time-varying downscaling model considering non-stationarity using a Bayesian approach. International Journal of Climatology. doi: 10.1002/joc.5491.

Sachindra DA, Perera BJC (2016) Statistical Downscaling of General Circulation Model Outputs to Precipitation Accounting for Non-Stationarities in Predictor-Predictand Relationships. PLOSone 11:1–21. doi: 10.1371/journal.pone.0168701.

Wilby RL, Dawson CW, Barrow EM (2002) SDSM — a decision support tool for the assessment of regional climate change impacts. Environmental Modelling & Software 17:145–157. doi: 10.1016/S1364-8152(01)00060-3.