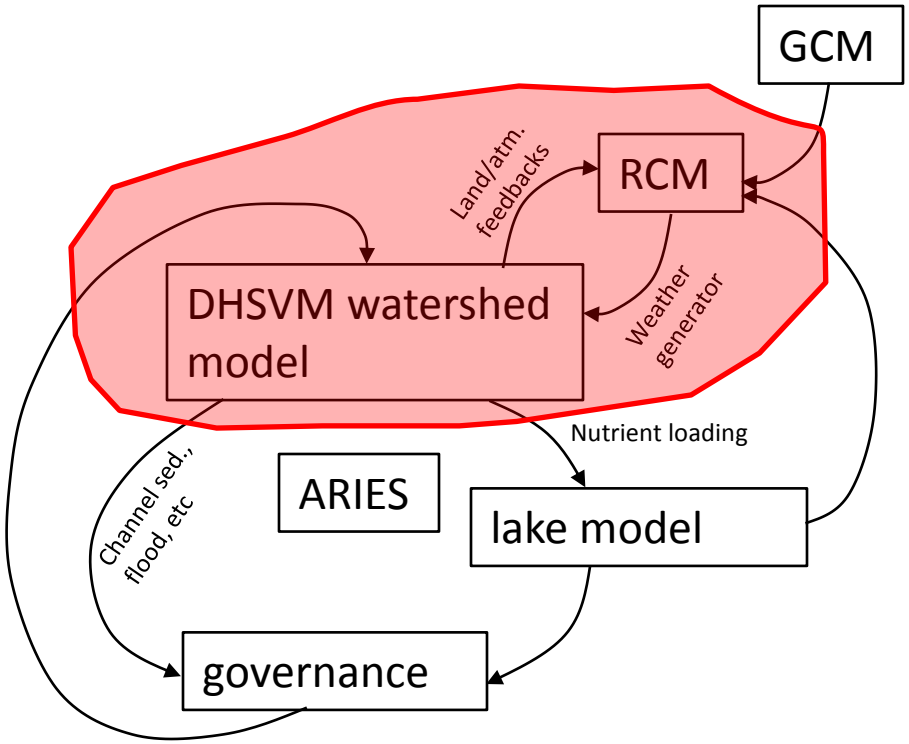
“Question 2”: Watershed component

Which alternative stable states can emerge in the watershed and lake resulting from non-linear dynamics of climate drivers, lake basin processes, social behavior, and policy decisions?



We are taking a SYSTEMS APPROACH to impacts and adaptation studies.

We seek to understand:

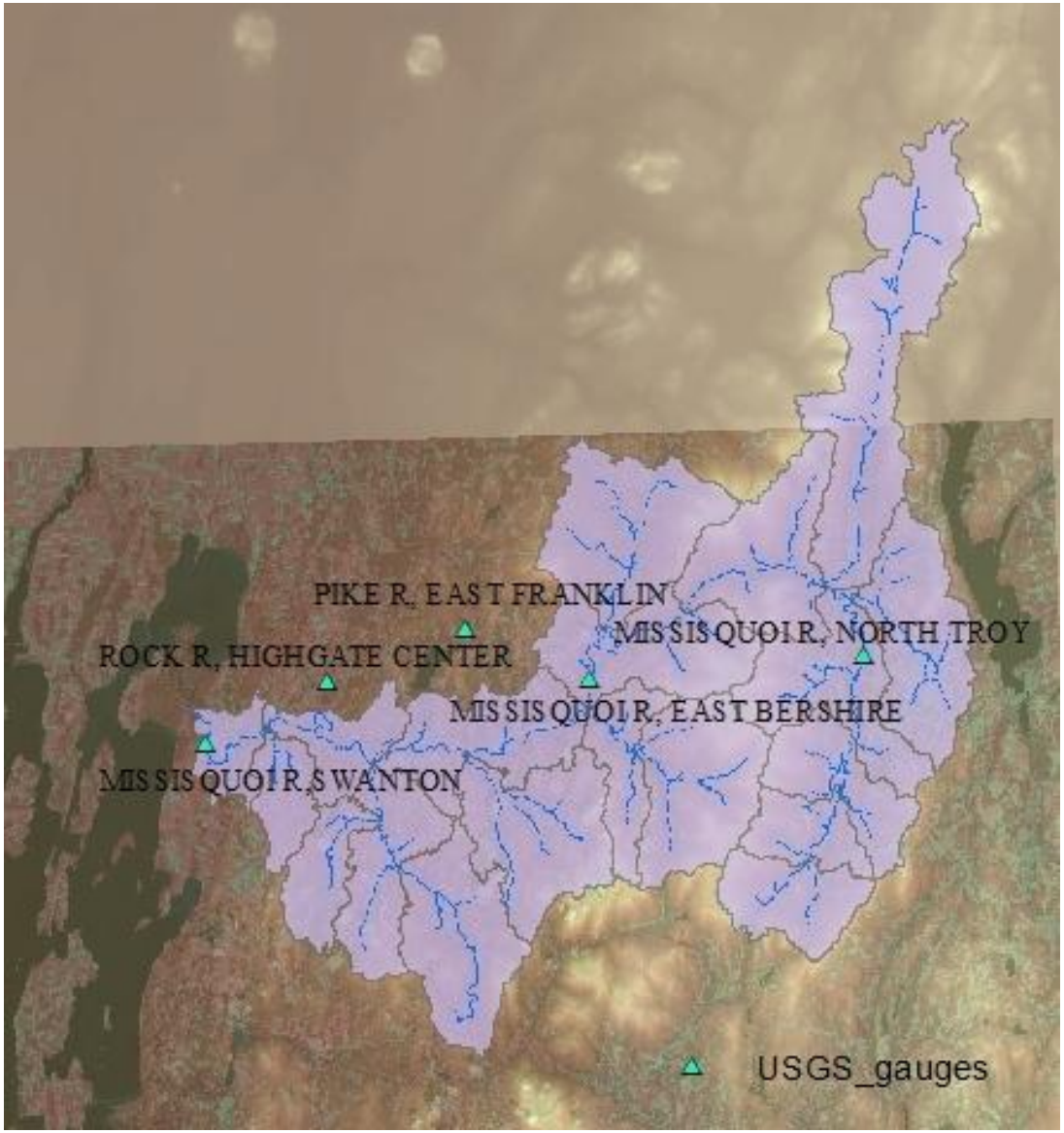
1. The watershed/lake system as a complex adaptive system
2. The expected impact of precipitation change on:
    1. Sediment and non-point phosphorus mobilization
    2. Flooding/scouring of channels and floodplains
    3. Natural vegetation and farming practices
    4. Infrastructure

    } Watershed model
3. The expected impact of temperature change on:
    1. Natural vegetation
    2. Frozen ground
    3. Snow/rain ratio

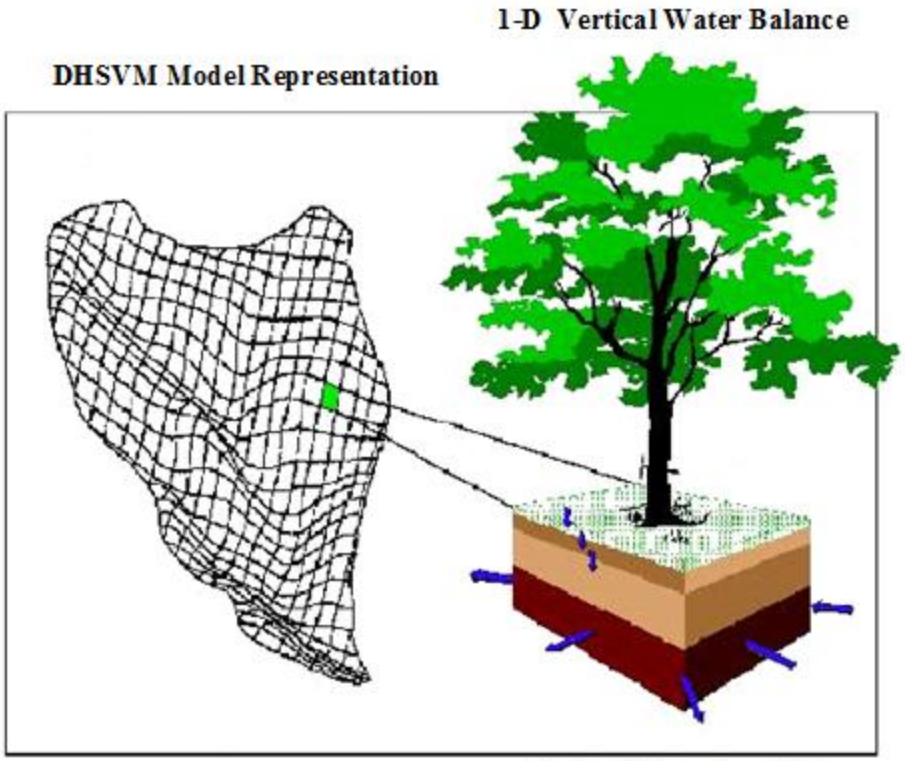
    } Regional Climate Model
4. System resilience to future changes under a variety of scenarios
    1. What variables dominate? (e.g. land use, governance, etc)
    2. What alternative stable states may the watershed take on? (agricultural/ urban, forest succession, healthy channels/impacted,etc)

Geographic scope: **Winooski** and Missisquoi watersheds

Geographic scope: Winooski and **Missisquoi** watersheds



Distributed hydrology-soil-vegetation model (DHSVM)



- Physically based hydrologic model that represents the effects of
  - Topography
  - Soil
  - Vegetation
- Solves the energy and water balance at each grid cell at each timestep

Hydrological modeling:

- Ibrahim Mohammed, PhD (EPSCoR postdoc)

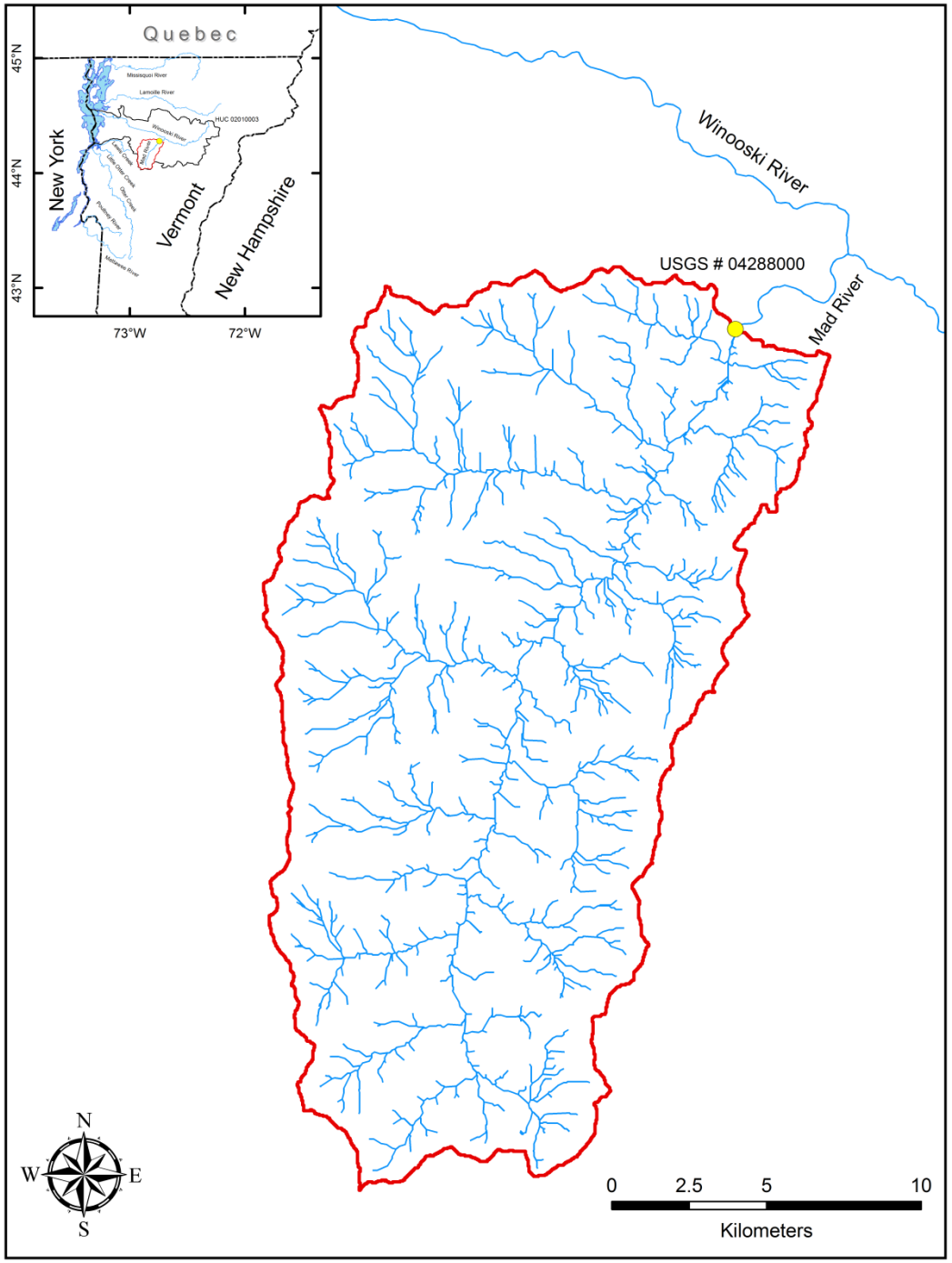
  Dr Mohammed is mentored by Beverley Wemple and Arne Bomblies
  Watershed model development using Rhessys with DHSVM routing

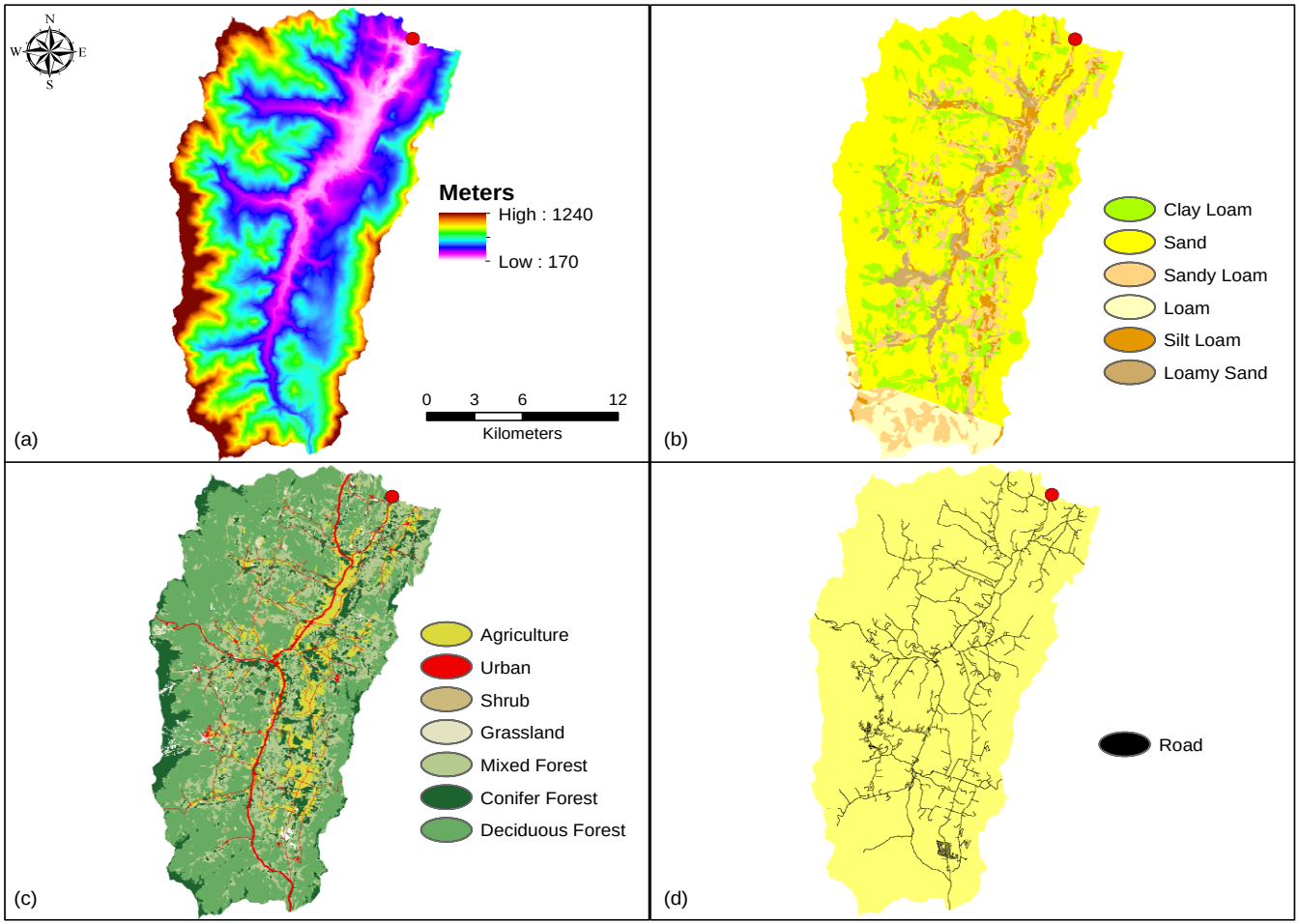
- Jody Stryker (EPSCoR GRA)

  Ms Stryker is mentored by Beverley Wemple and Arne Bomblies
  Development of models to simulate sediment transport from land surface and stream banks

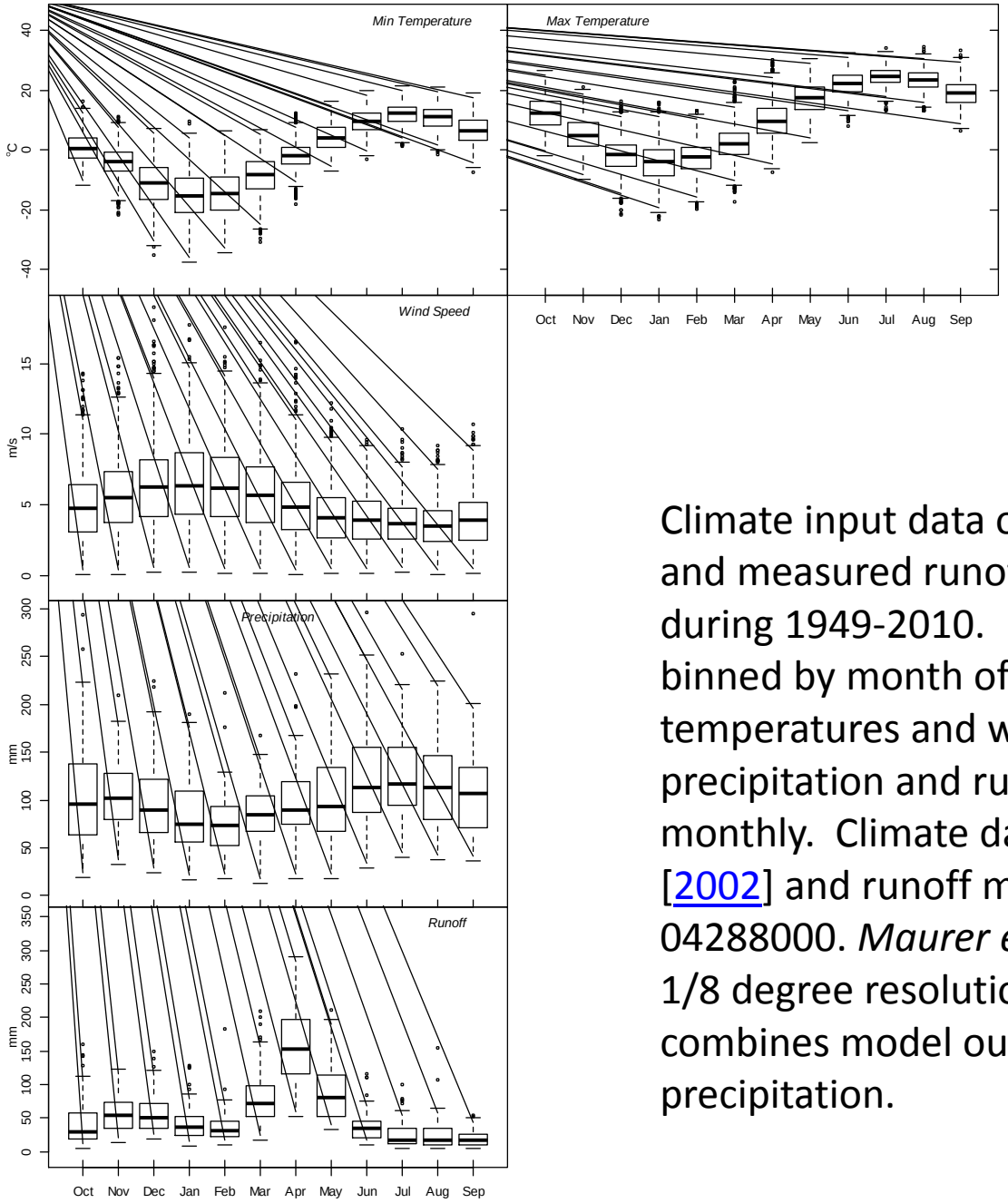
Hydrological modeling:

Begin with Mad River watershed

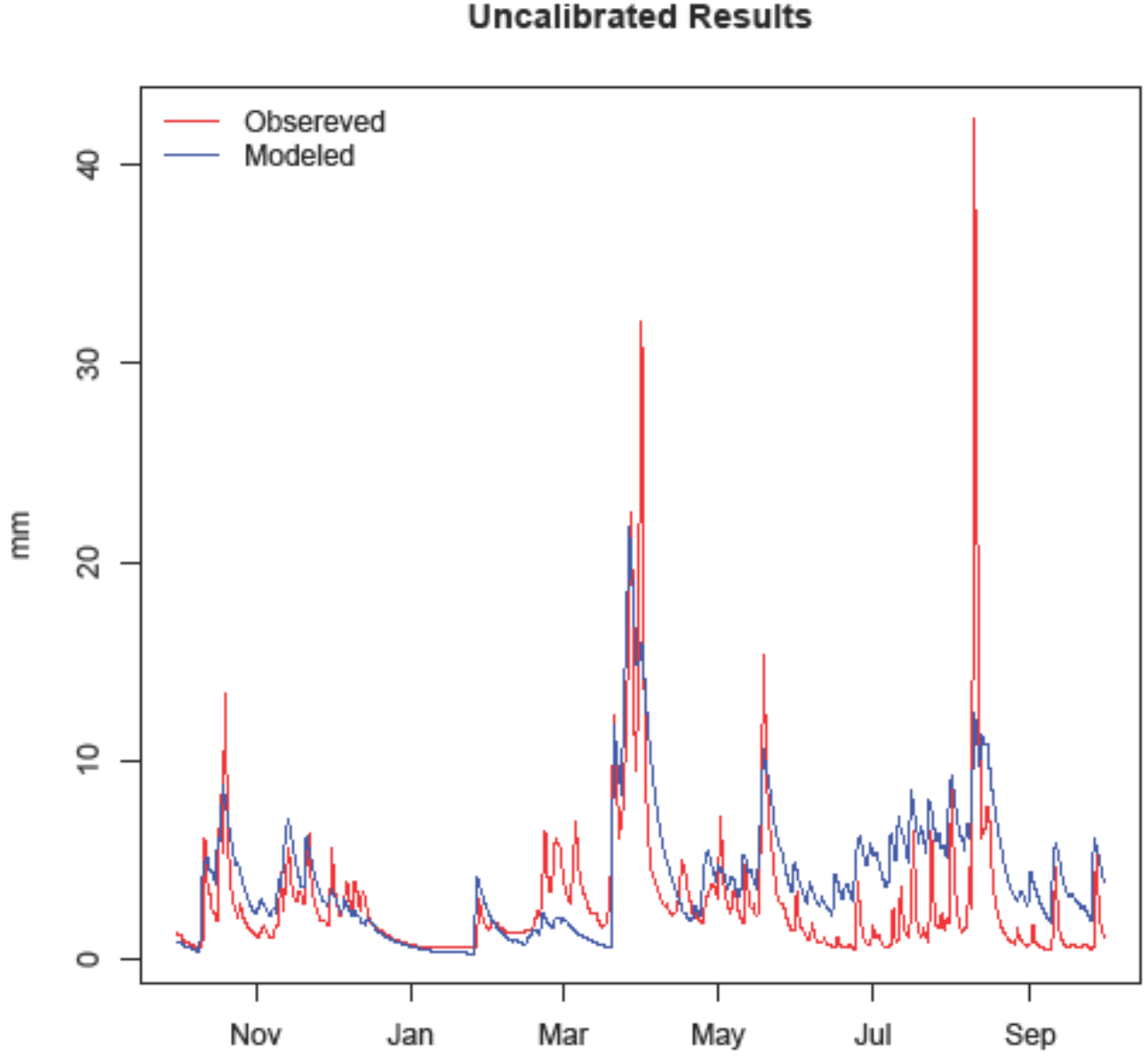




Spatial input data. a) Digital Elevation Model (DEM) (30 meter grid size), b) Soil Texture, c) Land Cover, and d) Roads. Soil Texture data are from SSURGO 2.2 dataset, Land Cover data are from the NLCD 2006 dataset, and Roads data are from the Vermont E9-1-1 GIS dataset.



Climate input data over the study watershed and measured runoff at the watershed outlet during 1949-2010. Boxplots of daily records binned by month of minimum, maximum air temperatures and wind speed. Boxplots of precipitation and runoff amounts summed monthly. Climate data from *Maurer et al*. [2002] and runoff measured at USGS gauge # 04288000. *Maurer et al* describes a dataset at 1/8 degree resolution at 3-hr time step, which combines model output and observed precipitation.


Uncalibrated Results
Obsereved
Modeled
mm
0
10
20
30
40
Nov
Jan
Mar
May
Jul
Sep

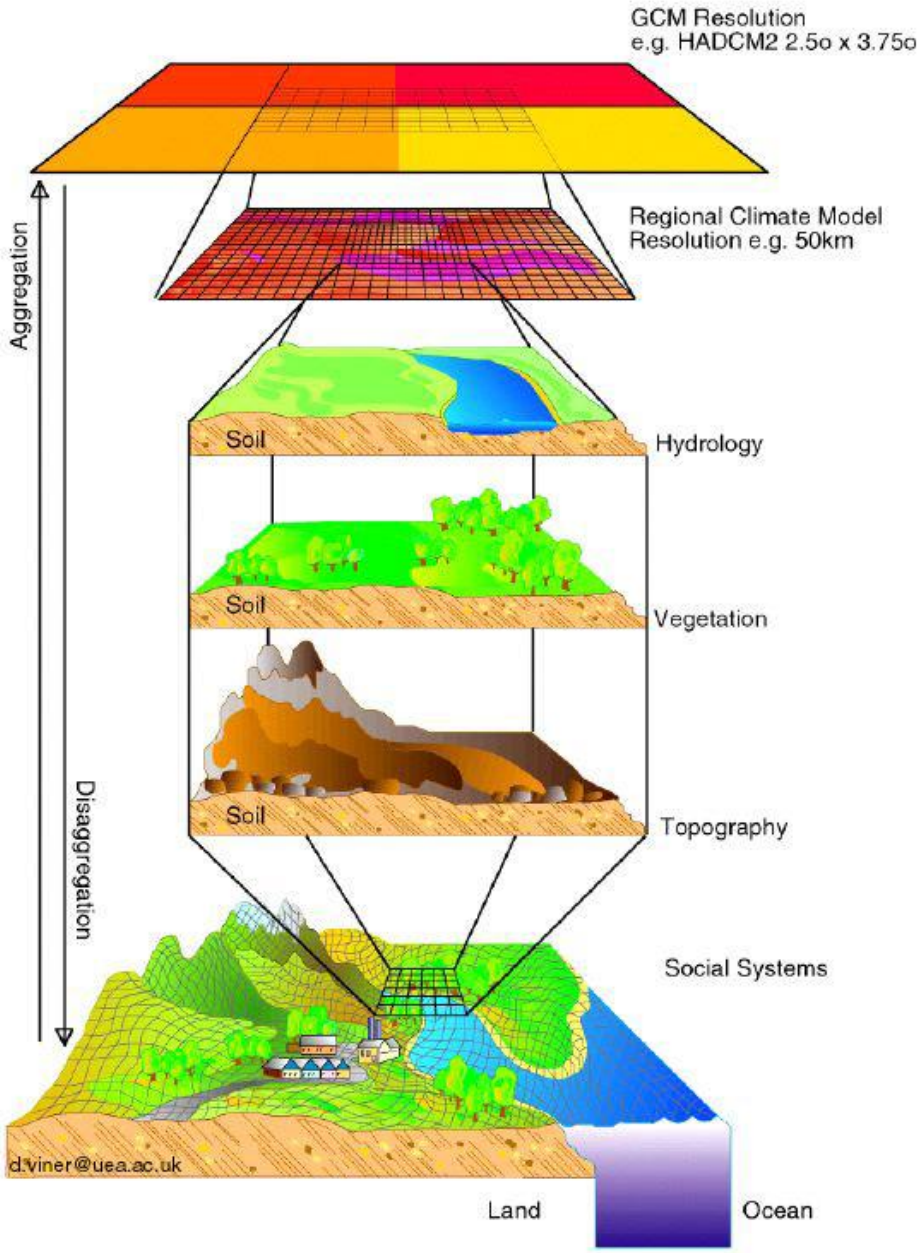
Climate downscaling

Dynamic (regional climate models)

- •Computationally expensive
- •Captures local processes and feedbacks

Statistical

- •Simpler
- •Assumes stationary transfer function



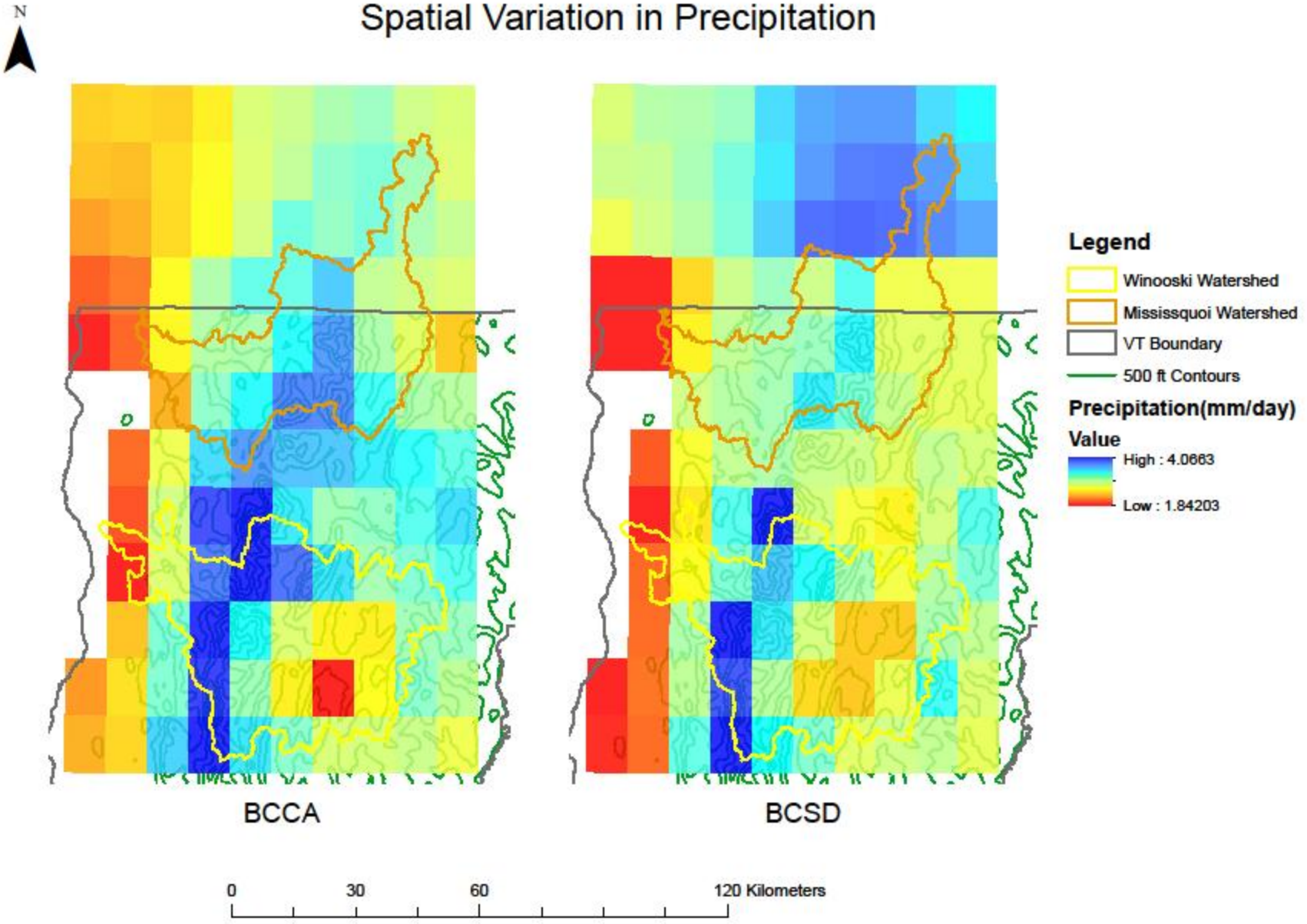
Statistical downscaling approaches:

- **Delta method**
  - **Simply applies temperature and precipitation factors predicted by GCM to all observations.**

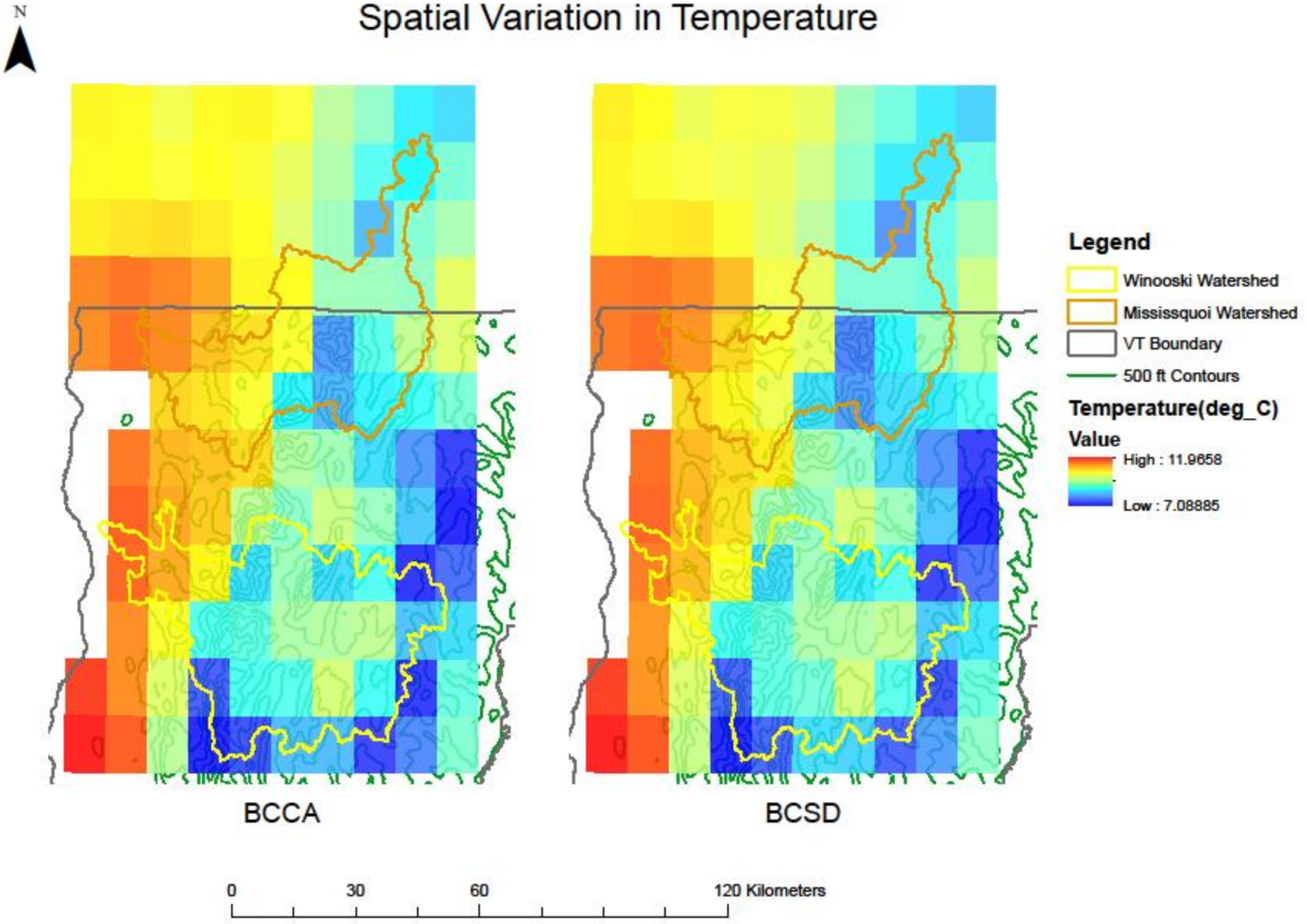
- **BCCA (Bias Correct, constructed analogues)**
  - **Outperforms the others <- we decided on this approach**
  - **Depends on modeling of "observations" in a coarse resolution analogue**

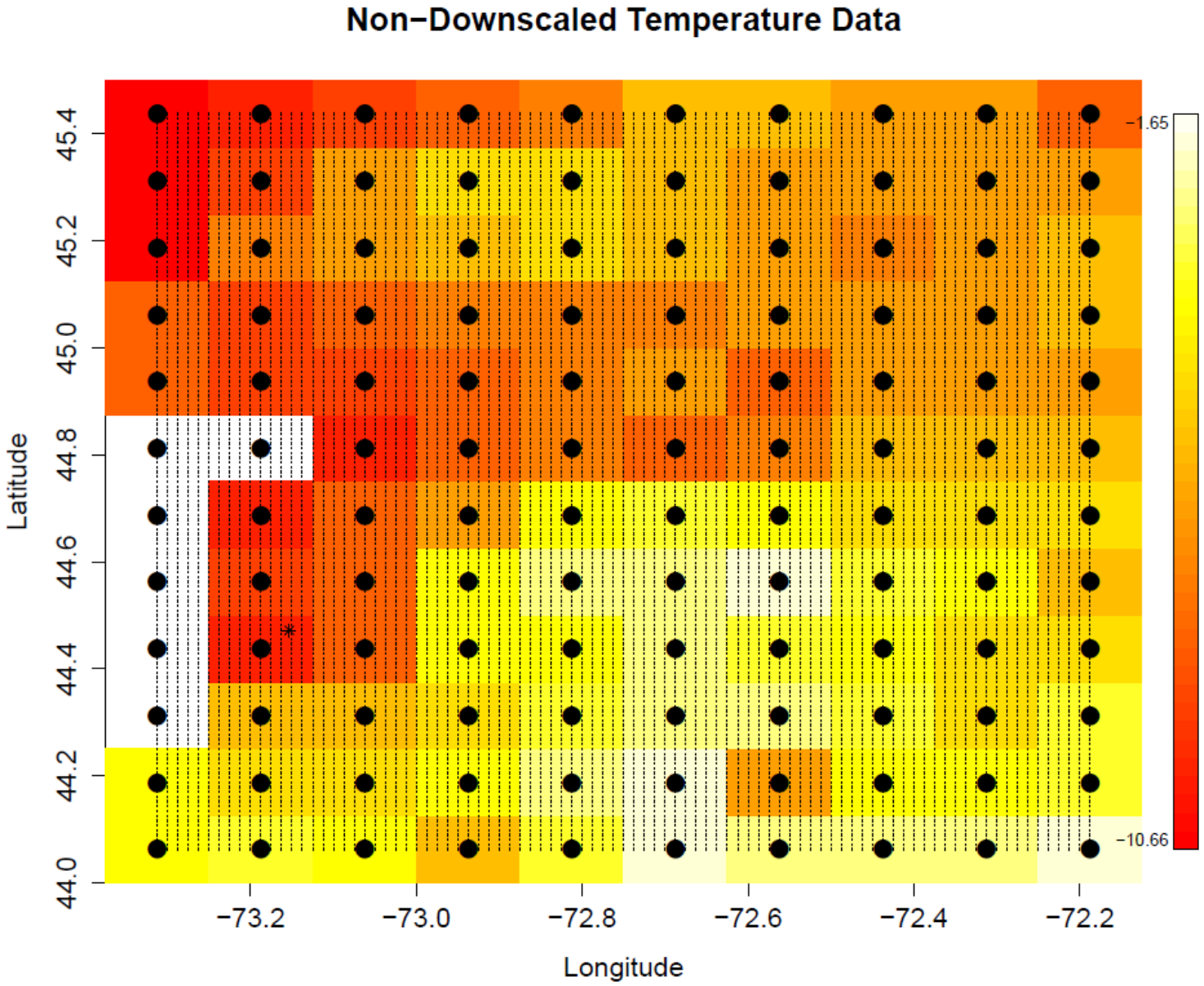
- **BCSD (Bias Corrected, Spatial Disagregation)**
  - **Aggregate observations to GCM scale (100s of km)**
  - **Calculate precip and temp factors relative to coarse-scale climatology**
  - **Interpolate factors to 1/8 degree grid**
  - **Apply to fine-scale grid**

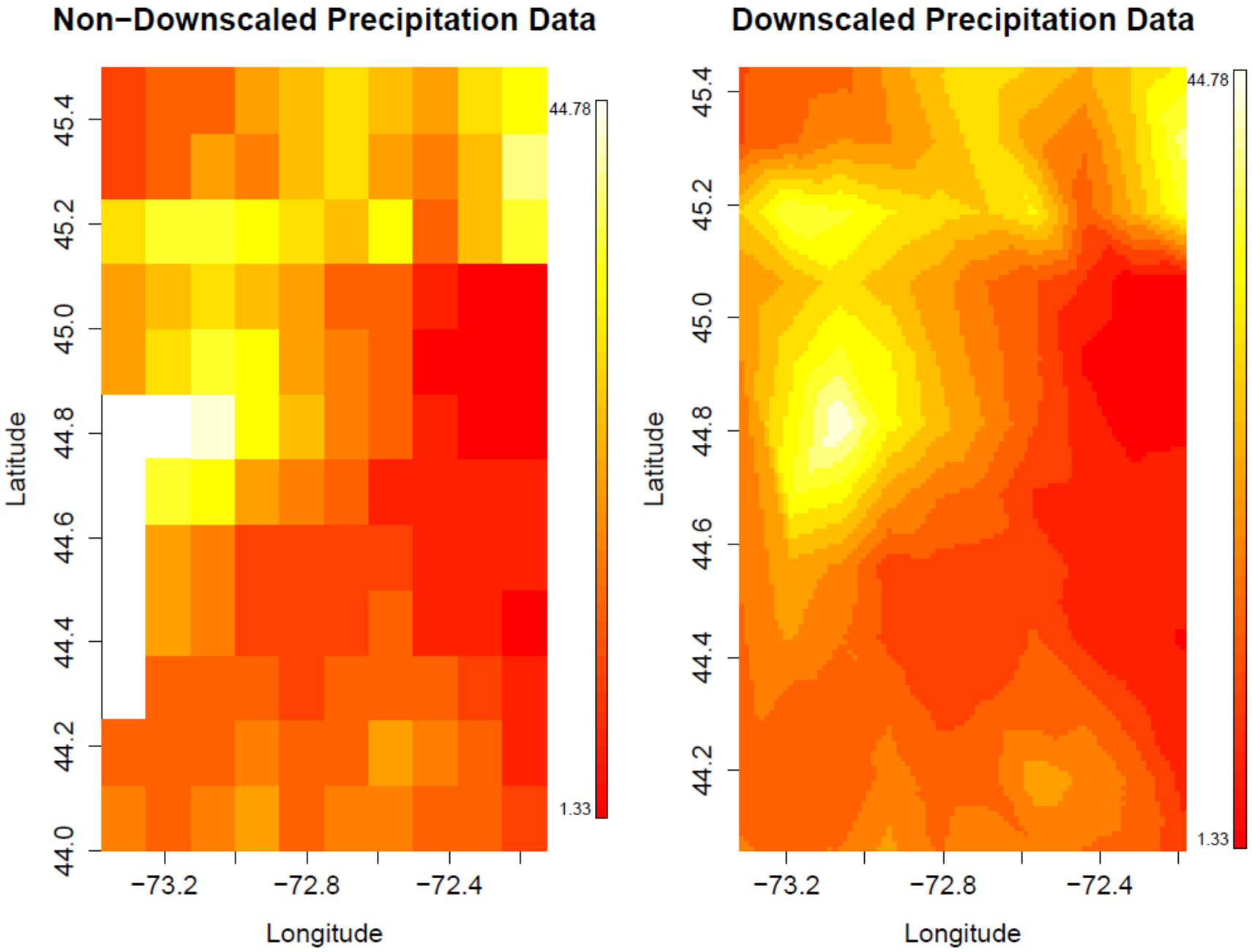
Spatial Variation in Precipitation

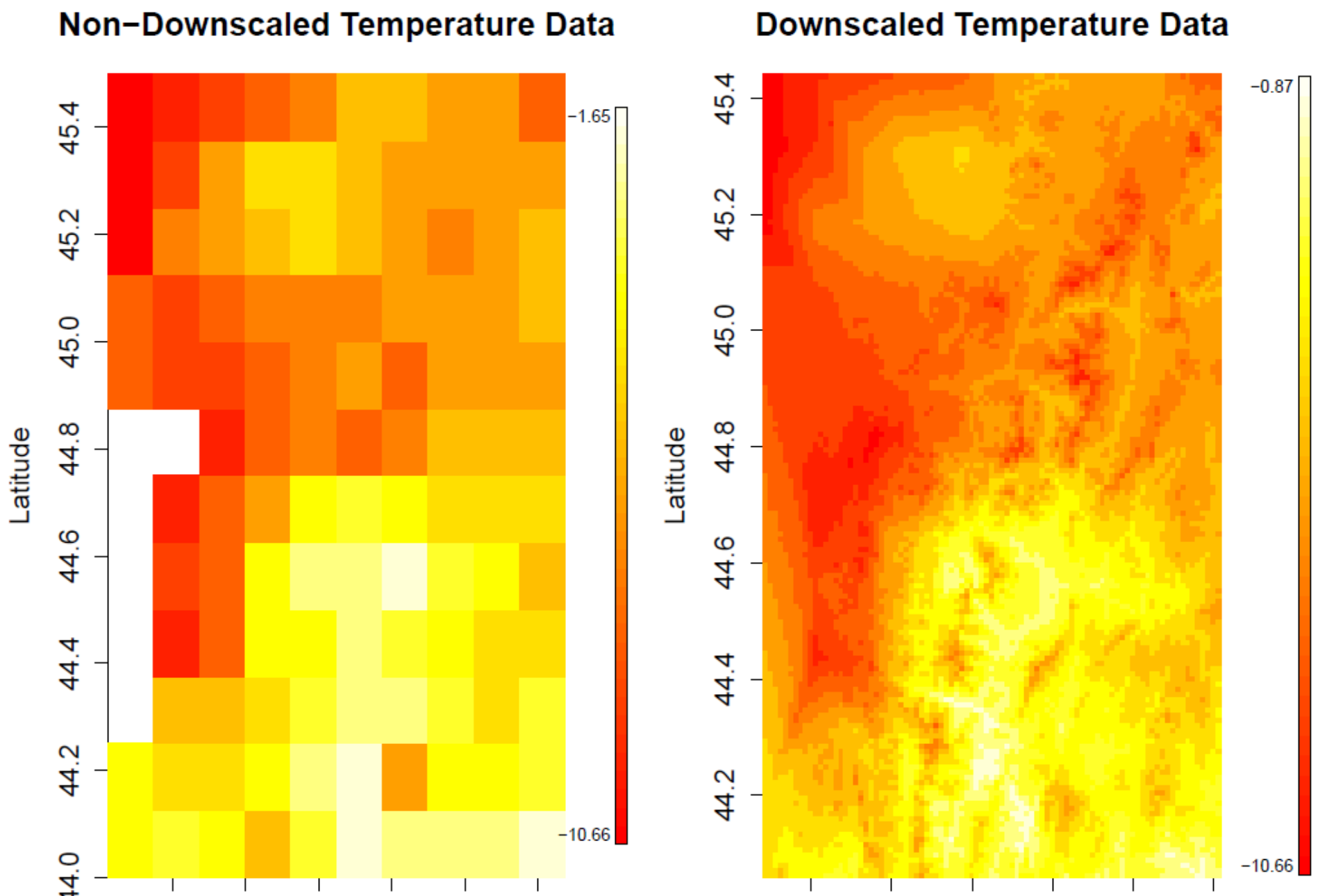


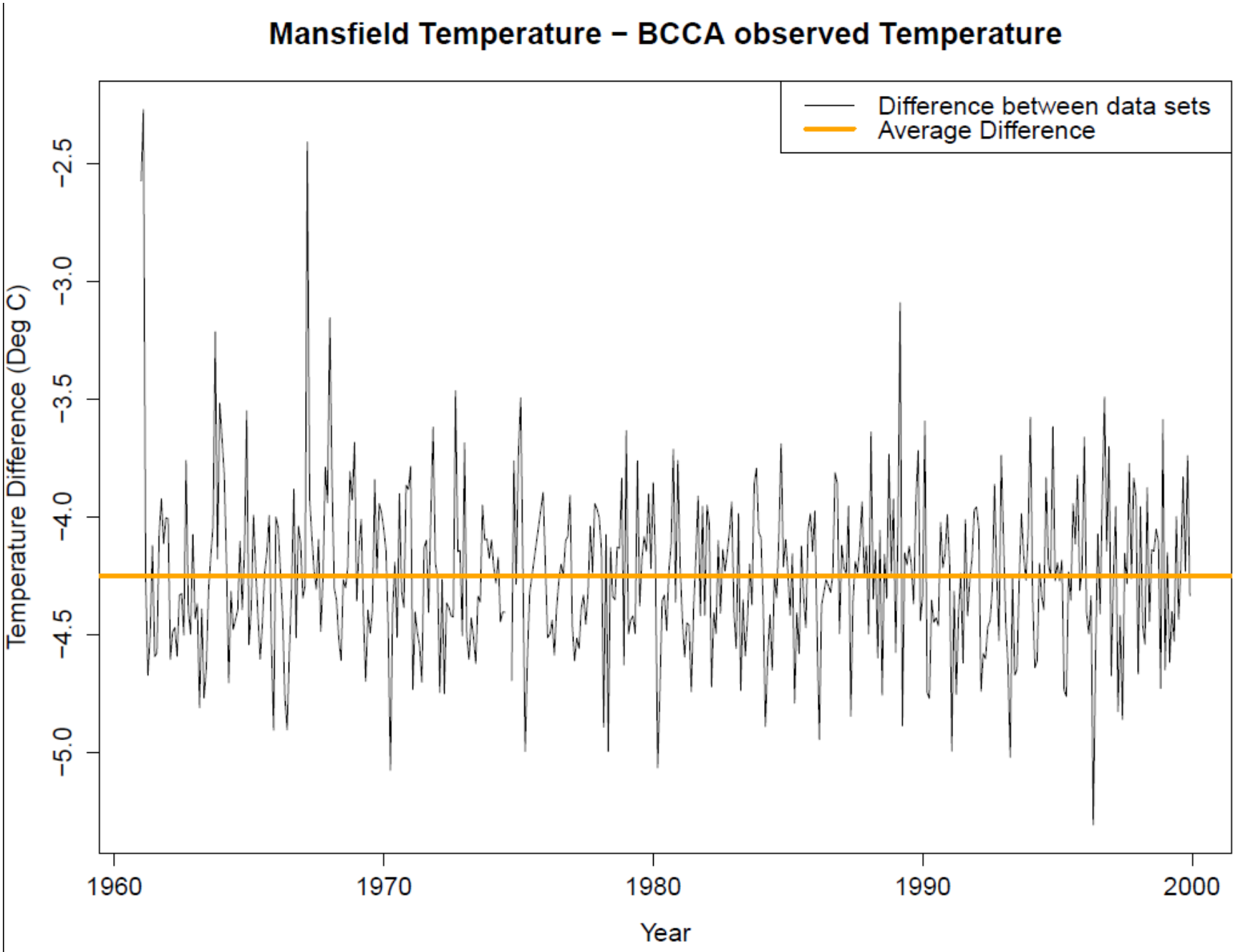
Spatial Variation in Temperature

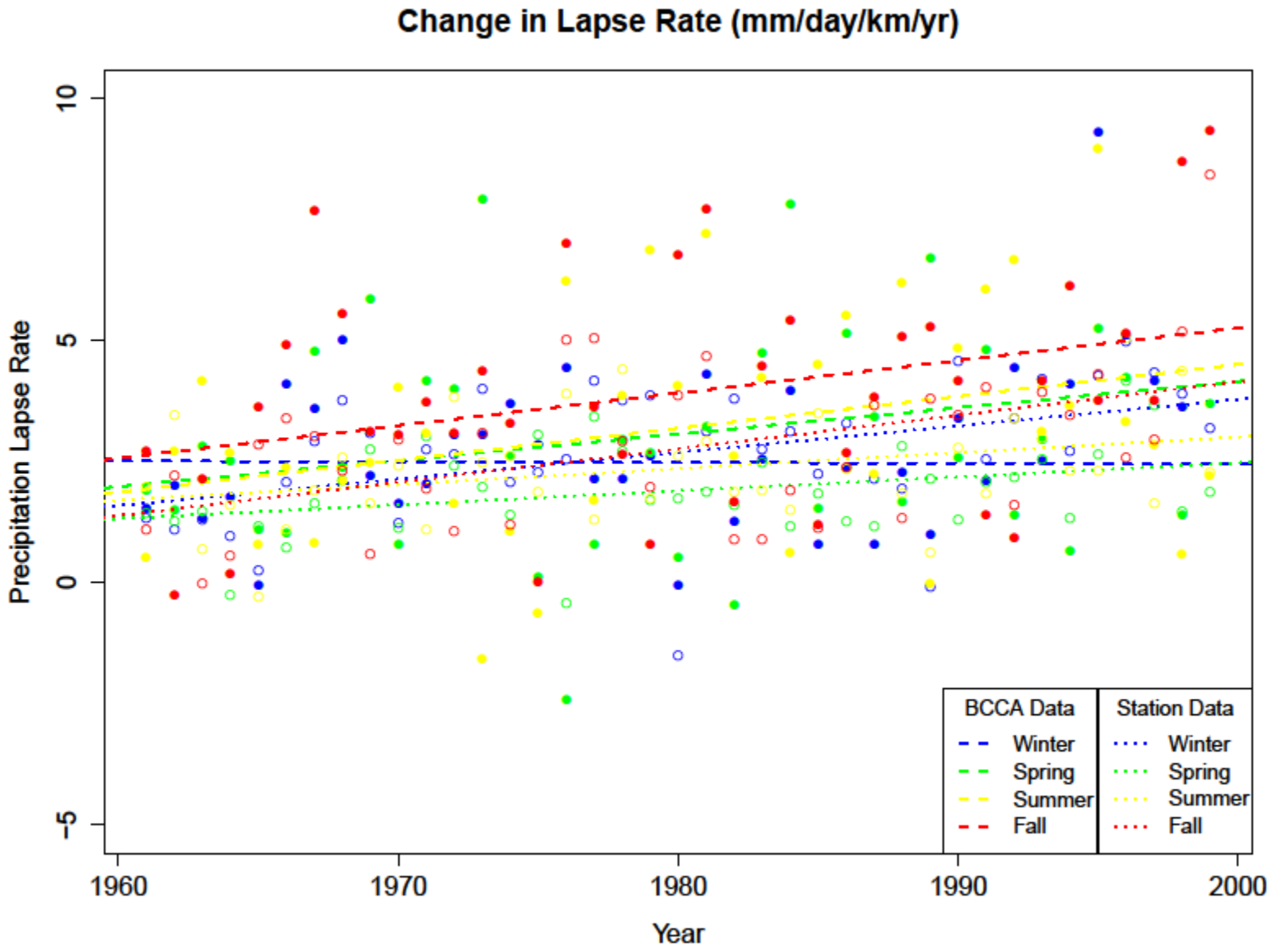


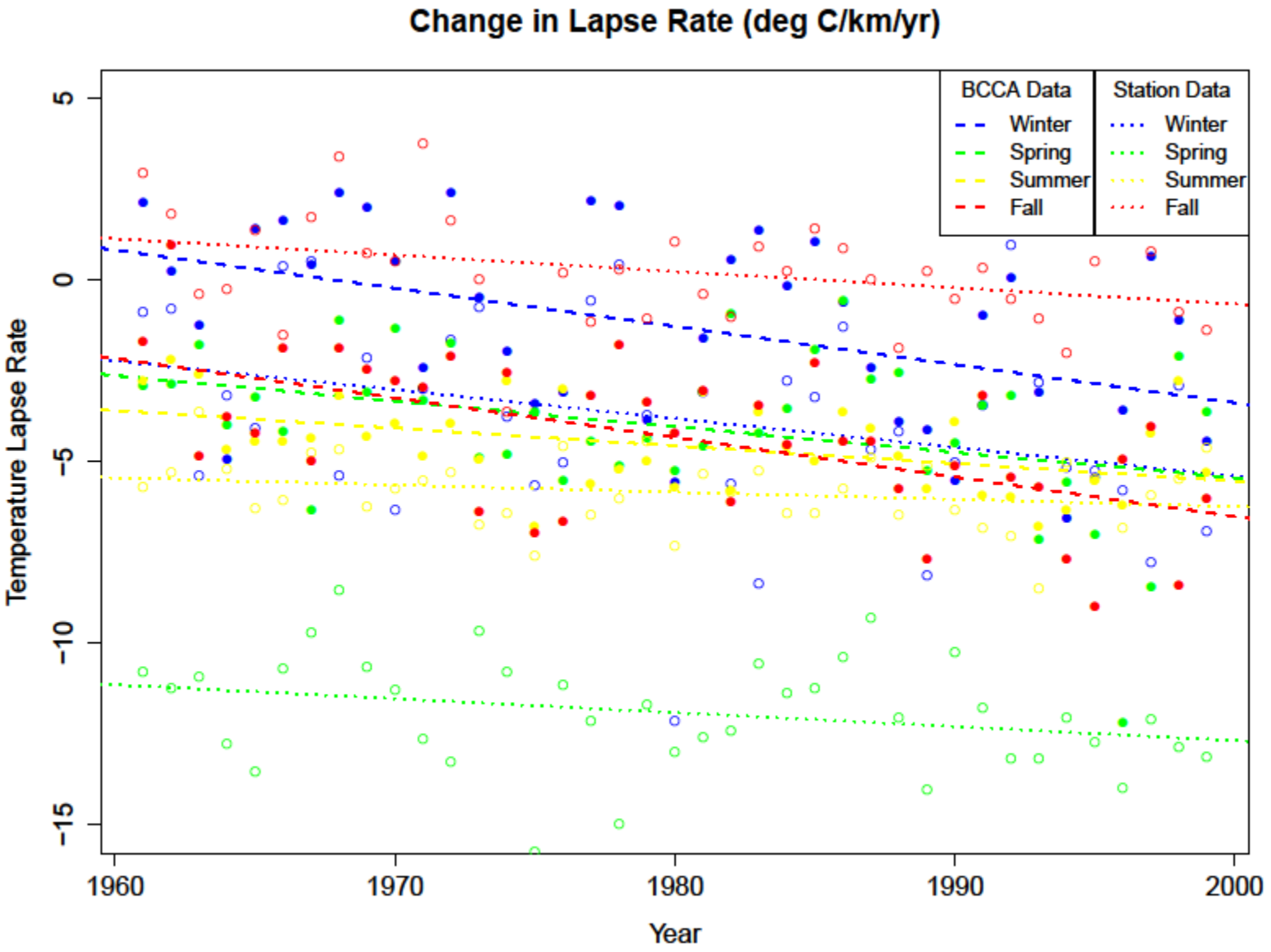

Non−Downscaled Temperature Data
Latitude
45.4
45.2
45.0
44.8
44.6
44.4
44.2
44.0
−73.2
−73.0
−72.8
−72.6
−72.4
−72.2
Longitude
−1.65
−10.66

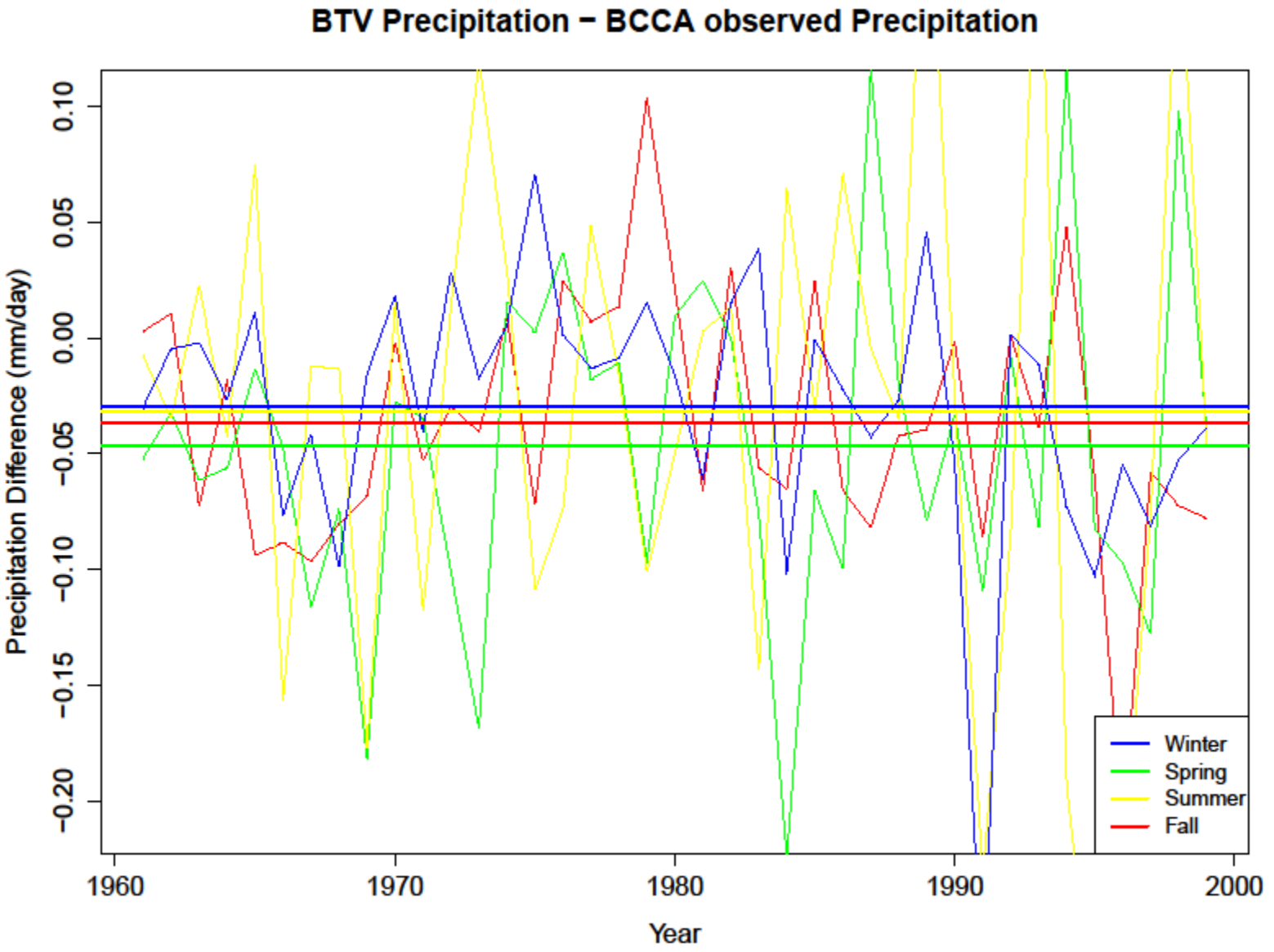

Non−Downscaled Precipitation Data
Latitude
45.4
45.2
45.0
44.8
44.6
44.4
44.2
44.0
−73.2
−72.8
−72.4
Longitude
44.78
1.33
Downscaled Precipitation Data
Latitude
45.4
45.2
45.0
44.8
44.6
44.4
44.2
−73.2
−72.8
−72.4
Longitude
44.78
1.33

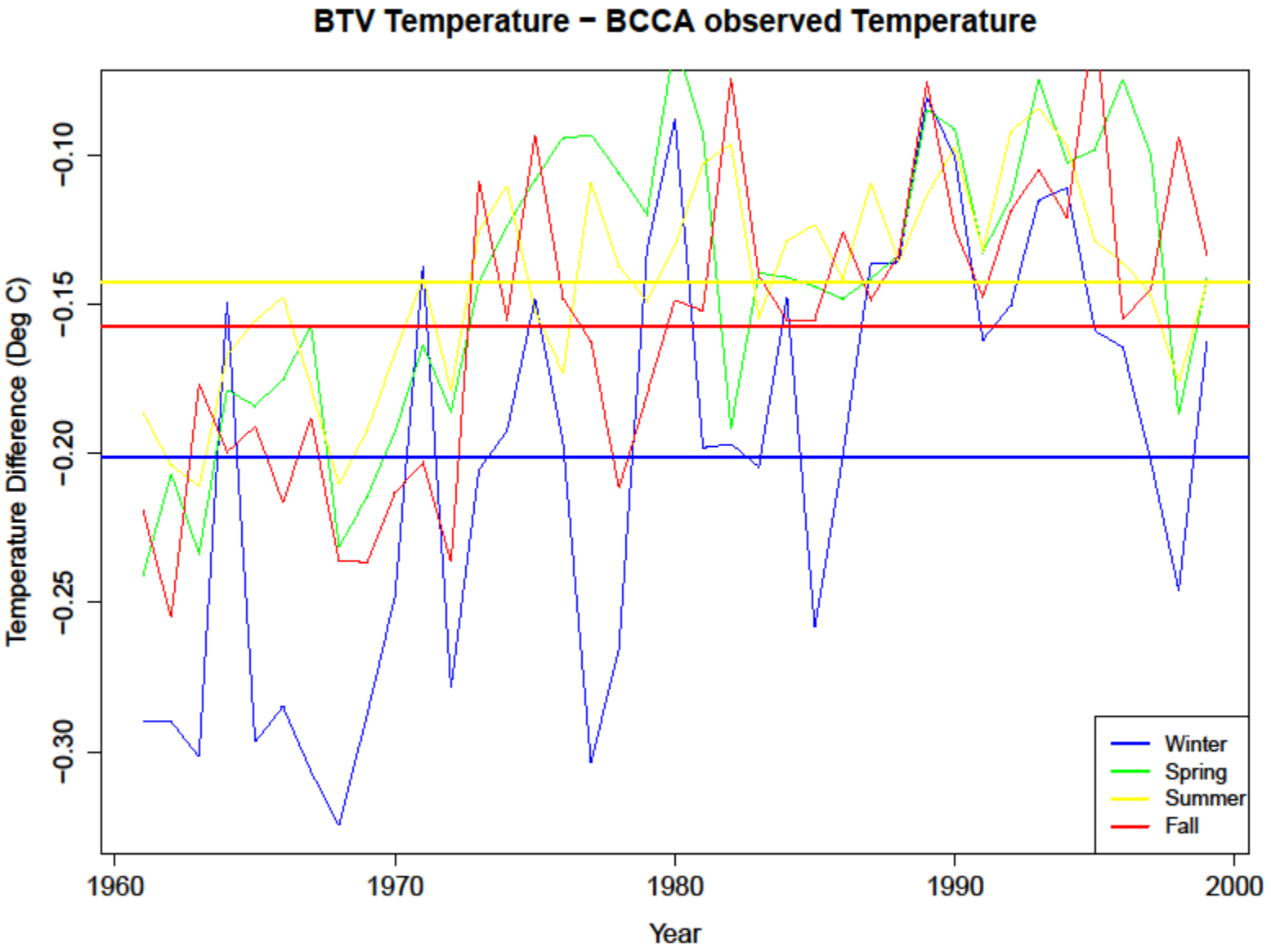

Non−Downscaled Temperature Data
Latitude
45.4
45.2
45.0
44.8
44.6
44.4
44.2
44.0
−1.65
−10.66
Downscaled Temperature Data
Latitude
45.4
45.2
45.0
44.8
44.6
44.4
44.2
−0.87
−10.66


Mansfield Temperature − BCCA observed Temperature
Difference between data sets
Average Difference
Temperature Difference (Deg C)
−2.5
−3.0
−3.5
−4.0
−4.5
−5.0
1960
1970
1980
1990
2000
Year


Change in Lapse Rate (mm/day/km/yr)
Precipitation Lapse Rate
10
5
0
−5
1960
1970
1980
1990
2000
Year
BCCA Data
Winter
Spring
Summer
Fall
Station Data
Winter
Spring
Summer
Fall


Change in Lapse Rate (deg C/km/yr)
BCCA Data
Winter
Spring
Summer
Fall
Station Data
Winter
Spring
Summer
Fall
Temperature Lapse Rate
5
0
−5
−10
−15
1960
1970
1980
1990
2000
Year


BTV Precipitation − BCCA observed Precipitation
Precipitation Difference (mm/day)
0.10
0.05
0.00
−0.05
−0.10
−0.15
−0.20
1960
1970
1980
1990
2000
Year
Winter
Spring
Summer
Fall


BTV Temperature − BCCA observed Temperature
Temperature Difference (Deg C)
−0.10
−0.15
−0.20
−0.25
−0.30
1960
1970
1980
1990
2000
Year
Winter
Spring
Summer
Fall