Vermont EPSCoR

Experimental Program to Stimulate Competitive Research

Climate change projections for the Lake Champlain basin

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Associate Professor
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Regional climate change

1. Project changes in climate for our study region
   - Delta method applied to GCM simulations

2. Statistically downscale coarse resolution GCM simulations to fine spatial scales needed for hydrological, ecological, and social models:
   -Utilize station data and high resolution topography

3. **Dynamical downscaling of GCM simulations using a regional climate model**

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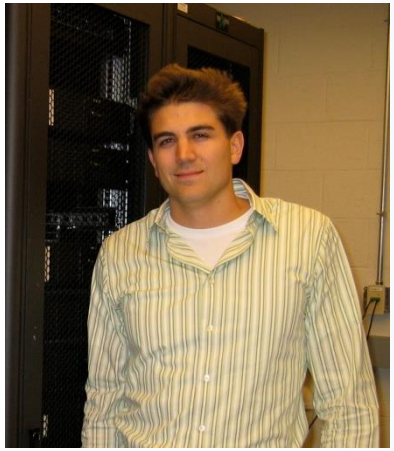

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Climate Projection Methodologies

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Columbia University Center for
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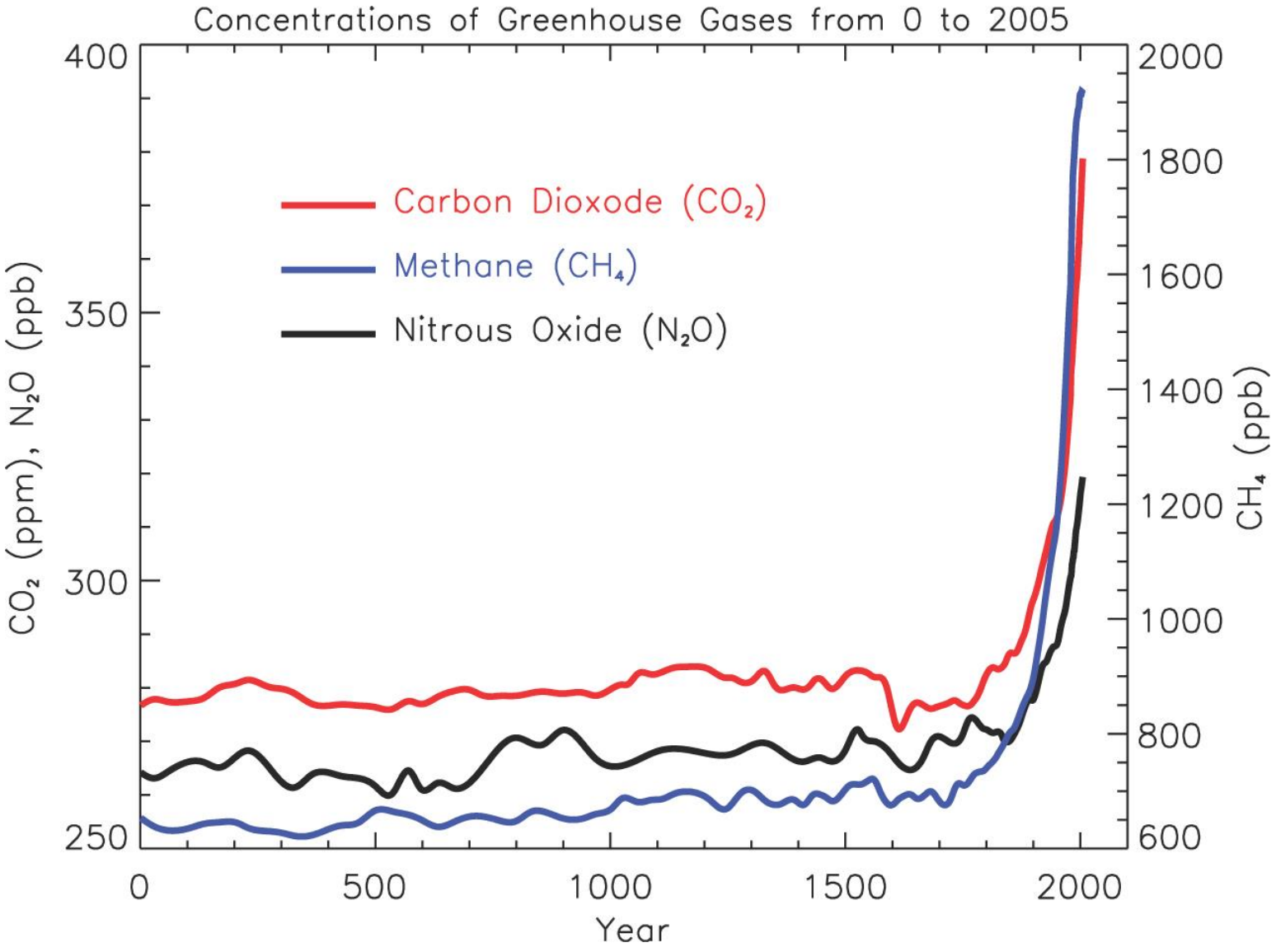
Source: The Nature Conservancy, weather.com, NASA Earth Observatory



Source: IPCC Fourth Assessment Report

Heat-Trapping Gas Passes Milestone, Raising Fears

Chris Stewart/Associated Press

The average carbon dioxide reading surpassed 400 parts per million at the research facility atop the Mauna Loa volcano on the island of Hawaii for the 24 hours that ended at 8 p.m. on Thursday.

Source: NY Times, May 10, 2013

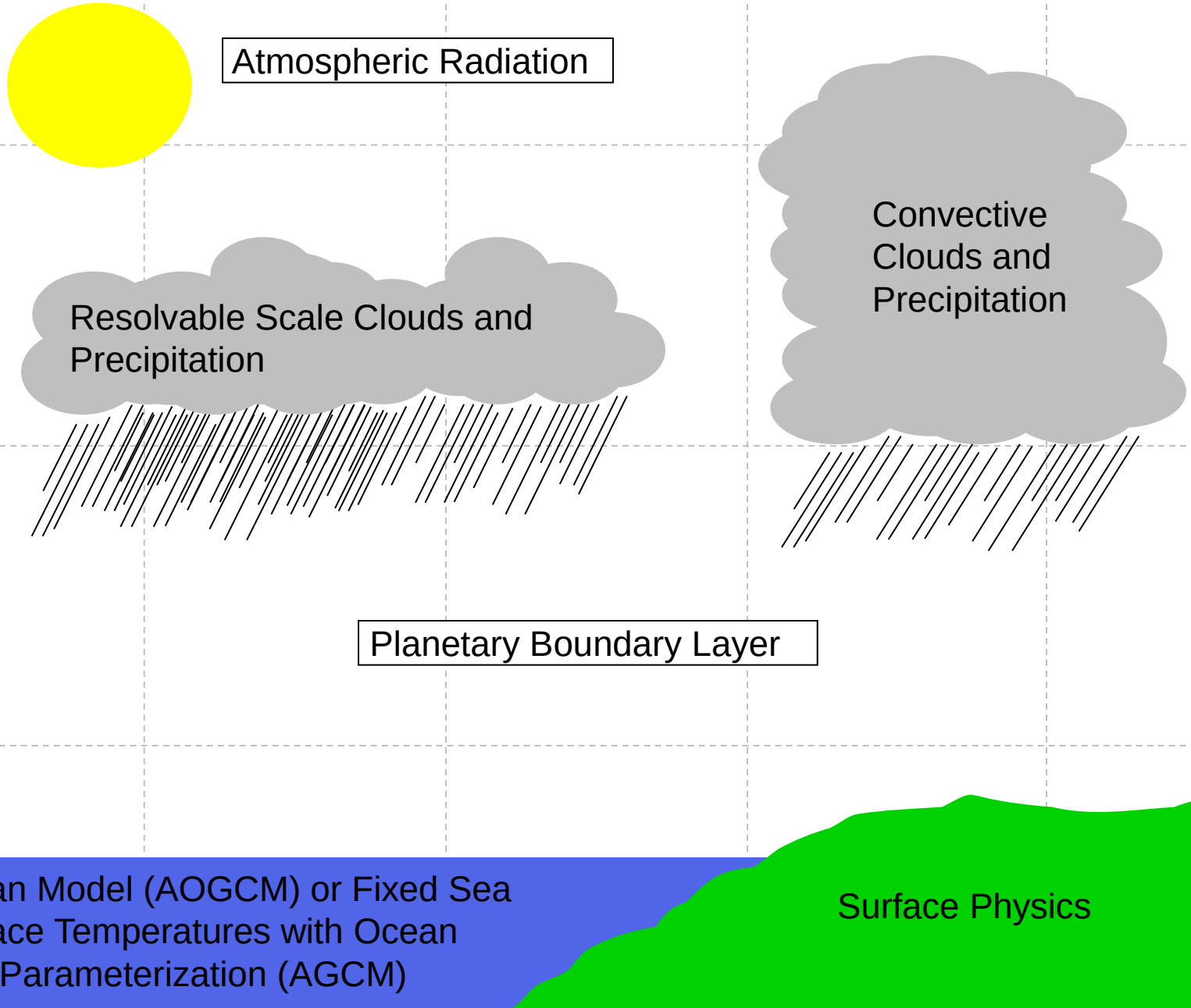
Climate Change, Water Resources, Ecosystems, and Society

- How well can we simulate climate using numerical models?
- What is the local response of precipitation and temperature to climate change?
- How will evolving temperature and precipitation impact runoff, soil moisture, forests, agriculture, nutrient loading, infrastructure, society?
- What are the key uncertainties in predicting climate change impacts?

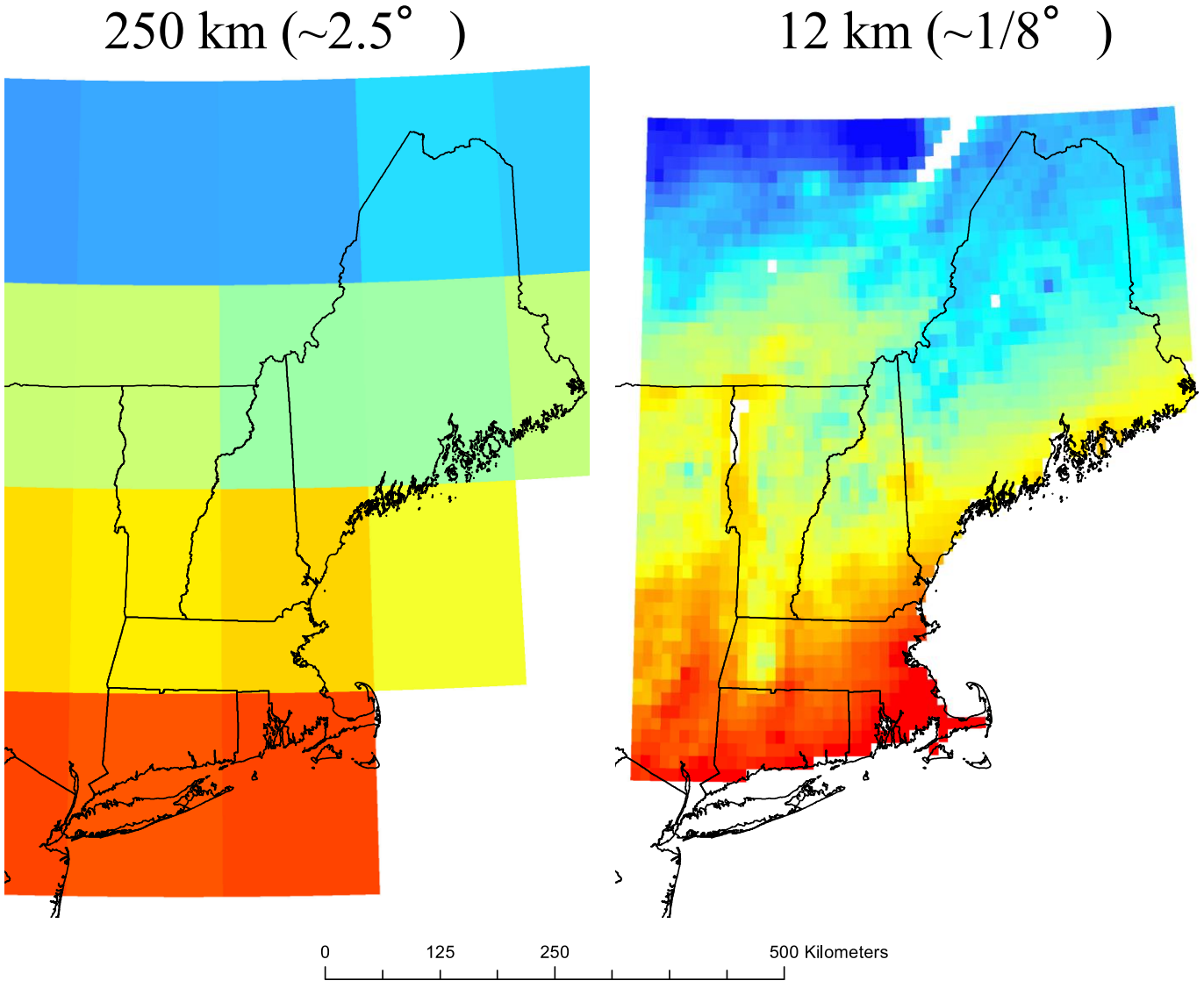
Source: Lake Champlain Basin Program

Global Climate Models (GCMs)

- GCMs solve the primitive equations (conservation of momentum, mass, and energy) to predict fluid flow on a spherical surface
- Can be atmospheric (AGCM), oceanic (OGCM) or coupled atmospheric-oceanic general circulation models (AOGCM)
- AOGCMs are the core of full climate models
- Global spatial coverage
- Contain significant inaccuracies
- Coarse resolution


Atmospheric Radiation
Resolvable Scale Clouds and Precipitation
Convective Clouds and Precipitation
Planetary Boundary Layer
Ocean Model (AOGCM) or Fixed Sea Surface Temperatures with Ocean Flux Parameterization (AGCM)
Surface Physics

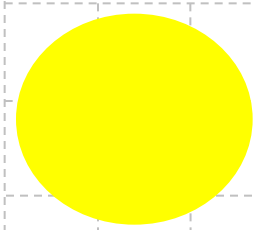
Downscaling GCMs



Regional Climate Models (RCMs)

- RCMs are weather forecast models adapted to run at longer temporal scales or GCMs adapted to run at finer spatial scales
- High resolution
- Limited spatial coverage, bounded by a large-scale atmospheric forcing generally provided by a GCM or reanalysis
- Contain significant inaccuracies produced both by the large-scale forcing and the RCM itself

Boundary Conditions - NCEP-DOE Reanalysis 2, ECHAM5, CCSM3

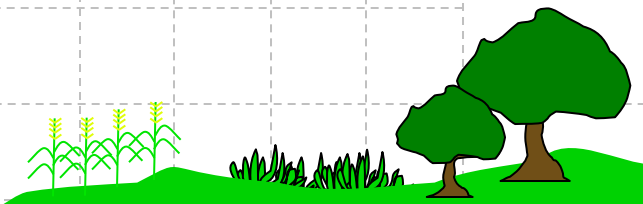


Atmospheric Radiation- Kiehl (1996)

Resolvable Scale Clouds and Precipitation – SUBEX (Pal, 2000)

Convective Clouds and Precipitation - Grell (1993), AS74, FC80 Closure

Planetary Boundary Layer- Holtslag (1990)



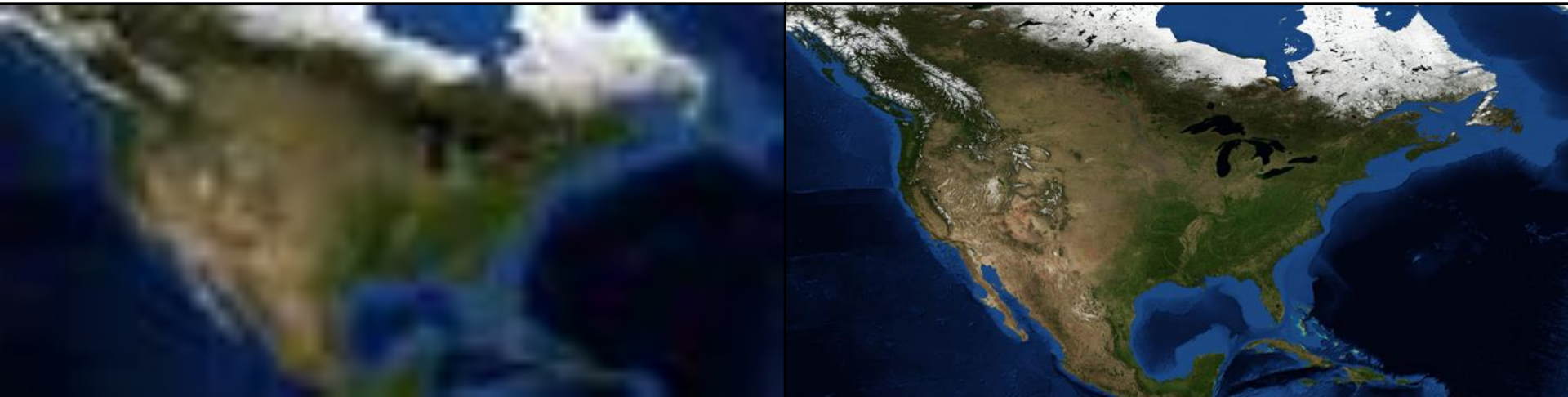
Sea Surface Temperatures - NOAA, EH5OM GCM

Ocean Flux Parameterization - Zeng (1998)

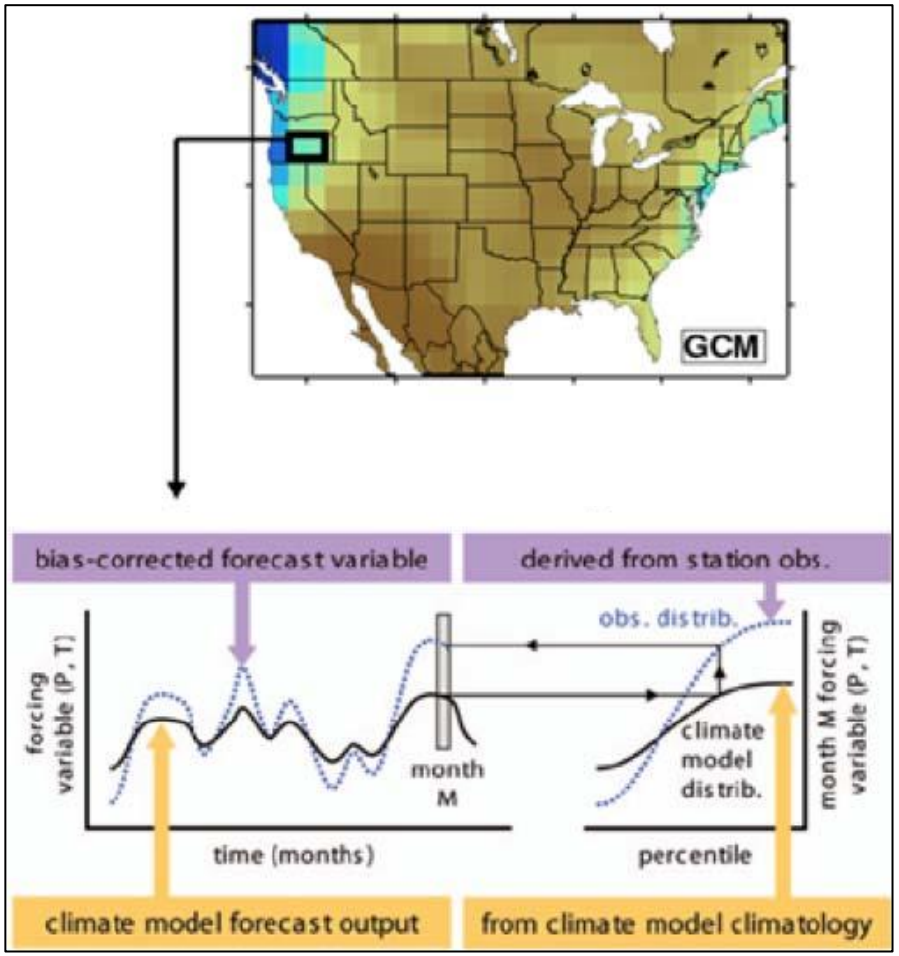
Surface Physics - IBIS (Foley, 1996; Winter, 2009), BATS1e (Dickinson, 1993)

Statistically Downscaled GCMs

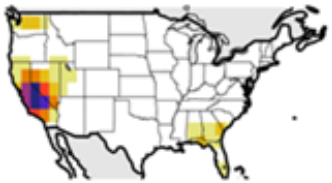
- Bias correct and downscale GCM data based on interpolated station observations
- Multiple methods and target observational datasets
- High resolution
- Removes some inaccuracies of GCMs
- Limited spatial coverage
- Climate projections constrained by observational record or extrapolations of observational record



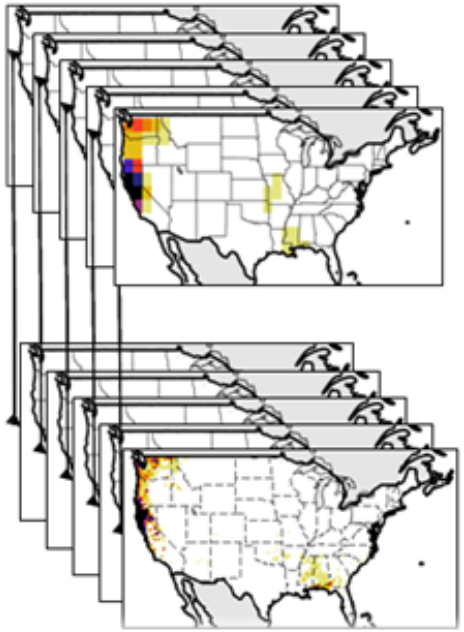
Bias Correction using Constructed Analogs (BCCA)



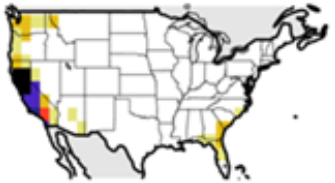
Given daily GCM anomaly

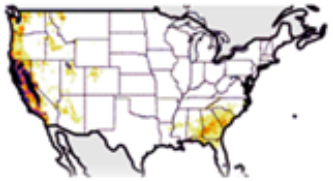


Library of previously observed anomaly patterns:



Coarse resolution analogue:





Wood et al., 2006; Hidalgo et al., 2008

Source: http://visibleearth.nasa.gov

Projected Climate Change in our Study Region using the Delta Method

Justin Guilbert

PhD Student

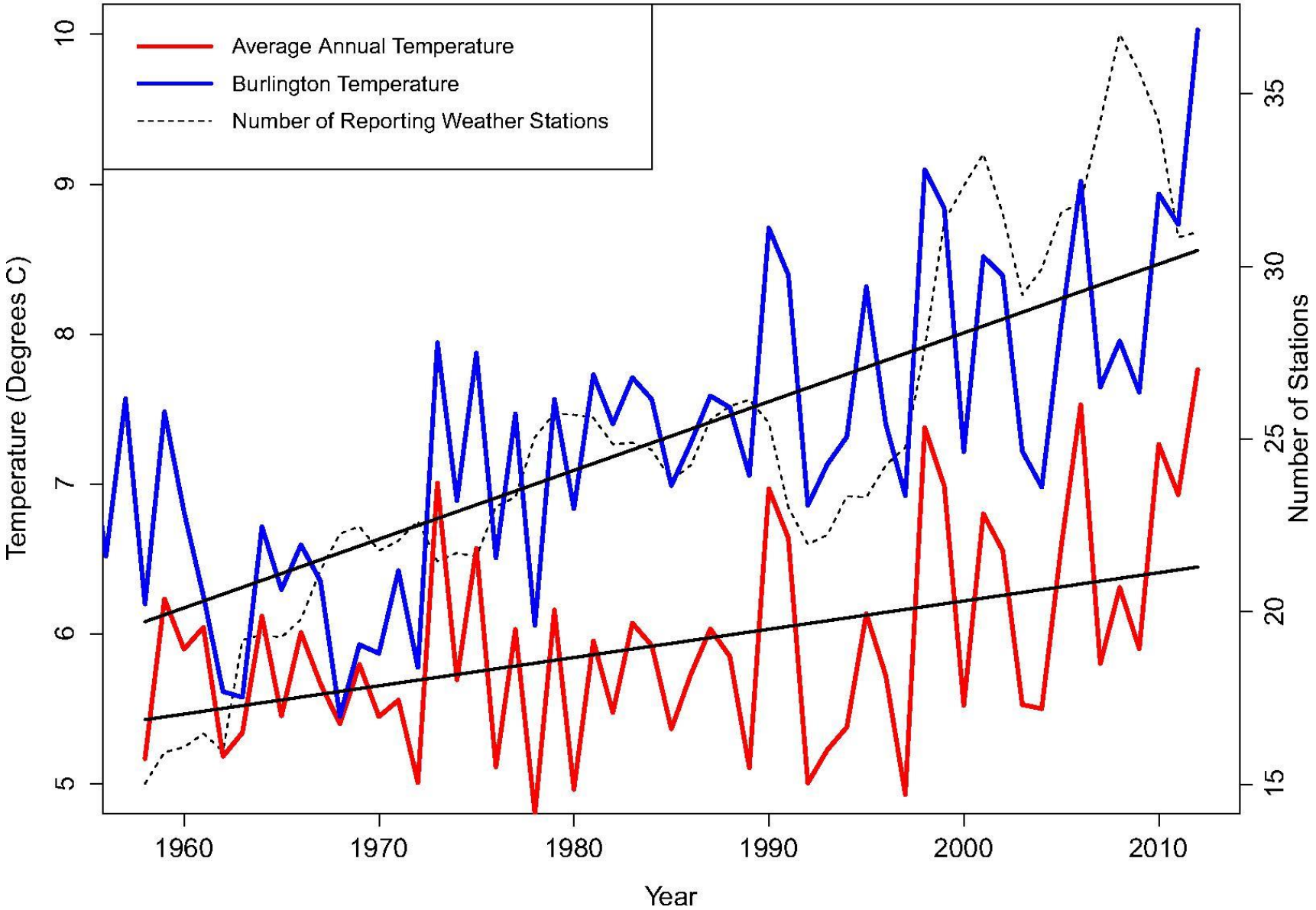
Annual EPSCoR Meeting

Goals

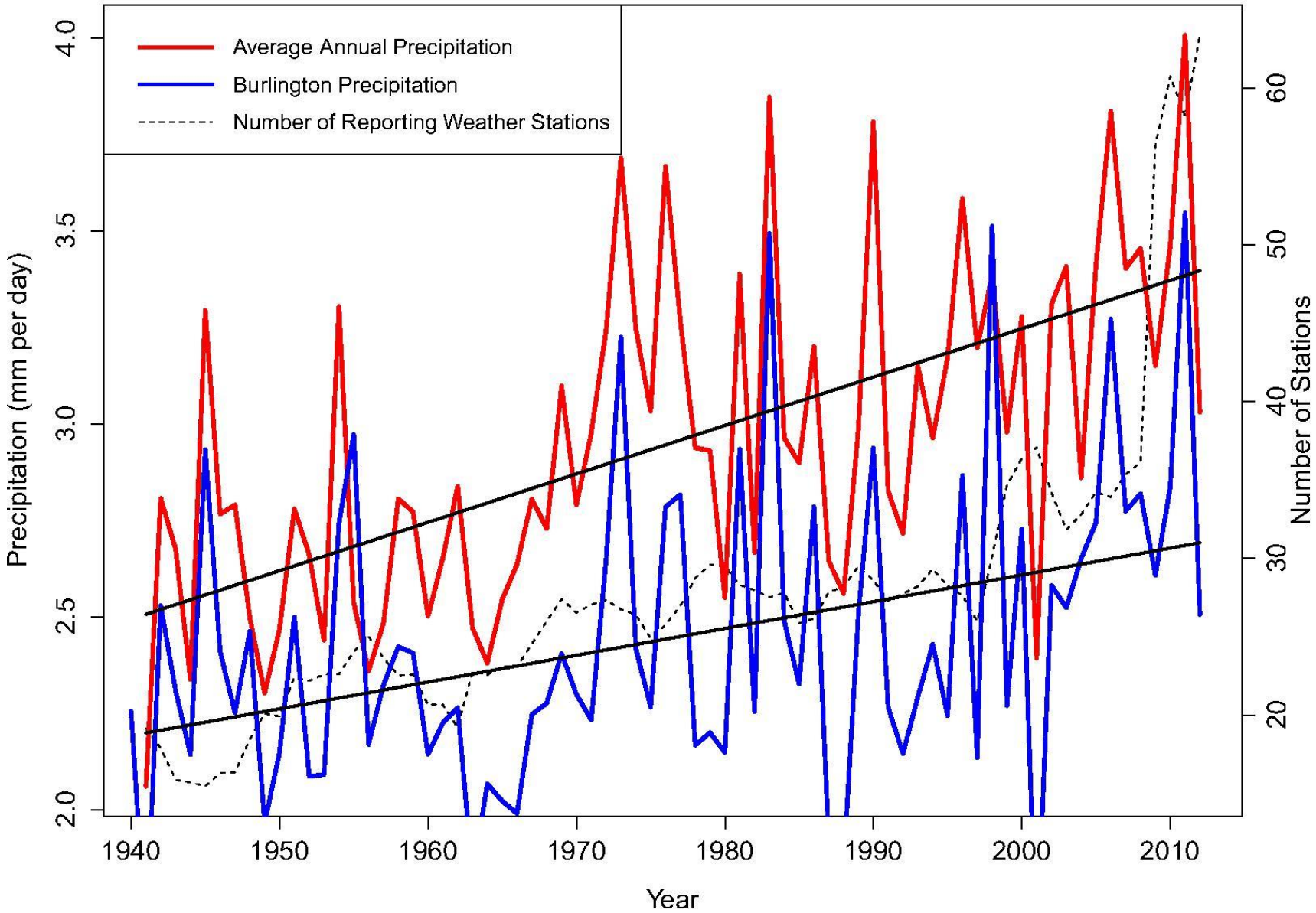
- Using the BCCA 1/8th degree product and 1/8th degree PRISM(observation based) data:
  - Project of future temperature and precipitation
  - Ranges of uncertainty in projections
  - Develop metrics for snowfall, length of growing season, and moisture balance using climate projections

Historical Data

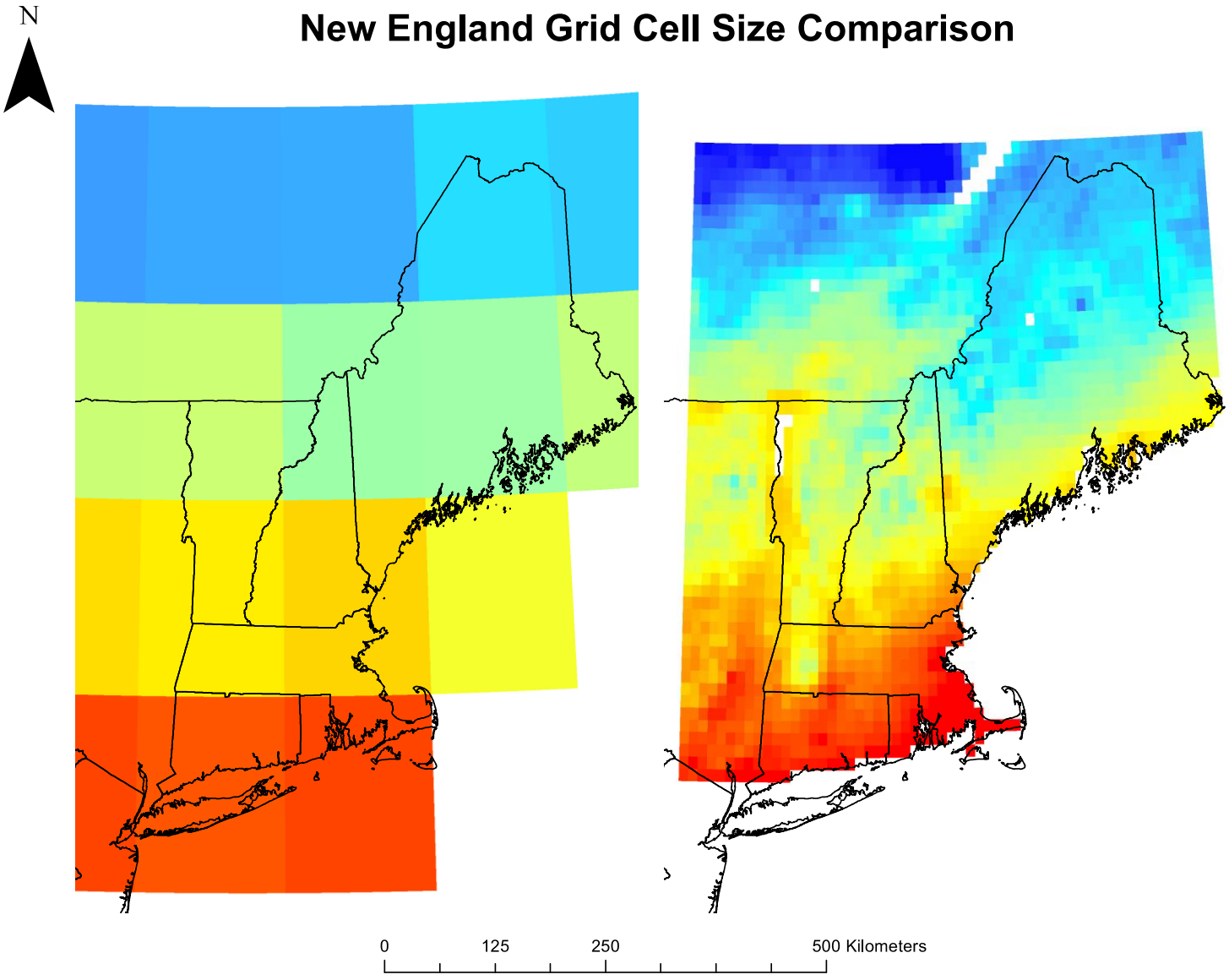
Temperature



Historical Data



250 km → 12 km


N
New England Grid Cell Size Comparison
0
125
250
500 Kilometers

Sources of Uncertainty

1. Different Storylines
   - A2, A1B, and B1 storylines
2. Different GCMs
   - cccma_cgcm3_1 ~ Canadian Centre for Climate Modelling and Analysis
   - ipsl_cm4 ~ Institut Pierre Simon Laplace, France.
   - mri_cgcm2_3_2a ~Meteorological Research Institute, Japan Meteorological Agency, Japan

Delta Method Calculations

- Temperature:

Delta = BCCA Future Projection – BCCA Baseline Simulation

Future Projection = PRISM Baseline + Delta

- Precipitation:

Delta Factor = BCCA Future Projection / BCCA Baseline Simulation

Future Projection = PRISM Baseline x Delta Factor

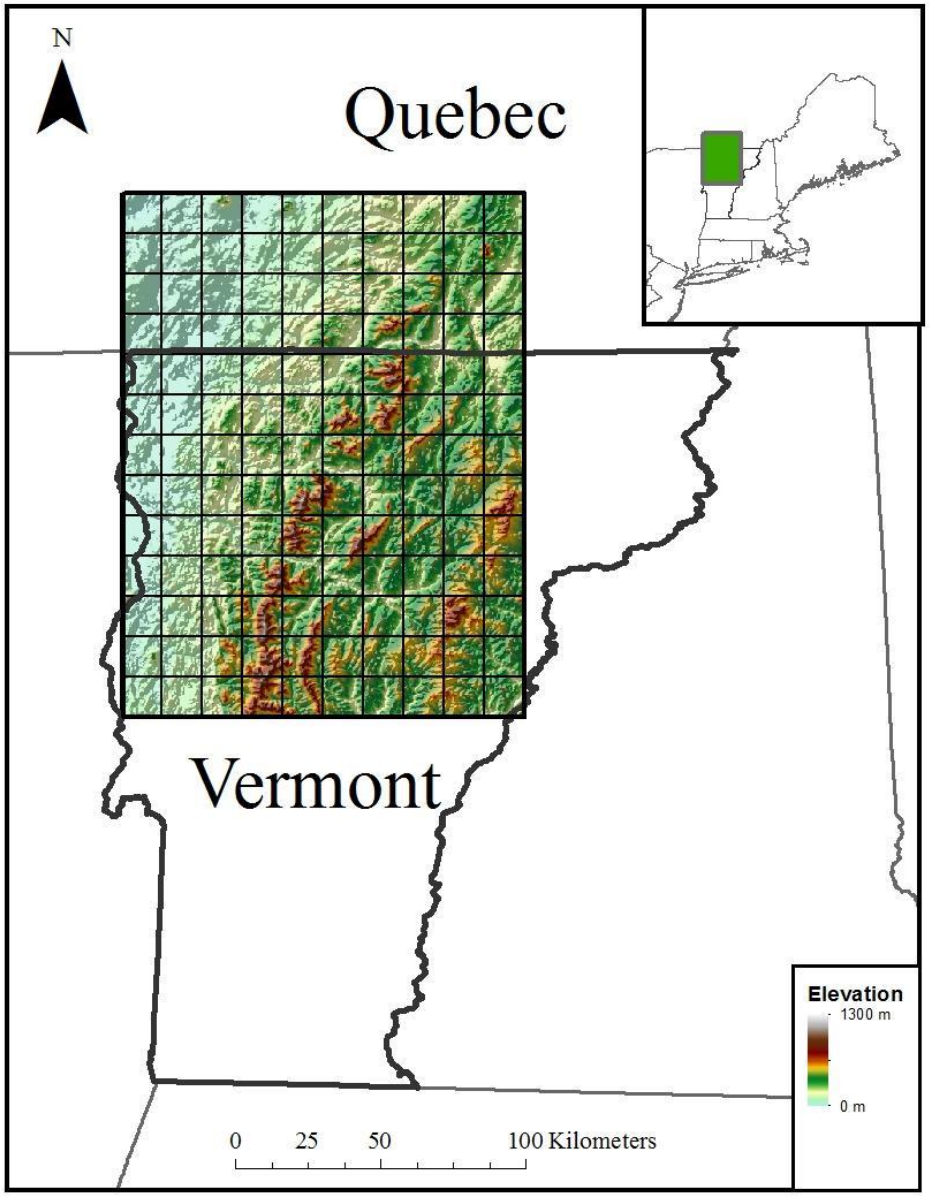
Why use the Delta Method

- Pros
  - Eliminate the biases associated with using GCM data
  - Straight forward
  - Computationally inexpensive
- Cons
  - Limited by quality of PRISM data
  - Daily and inter-annual variability are held constant

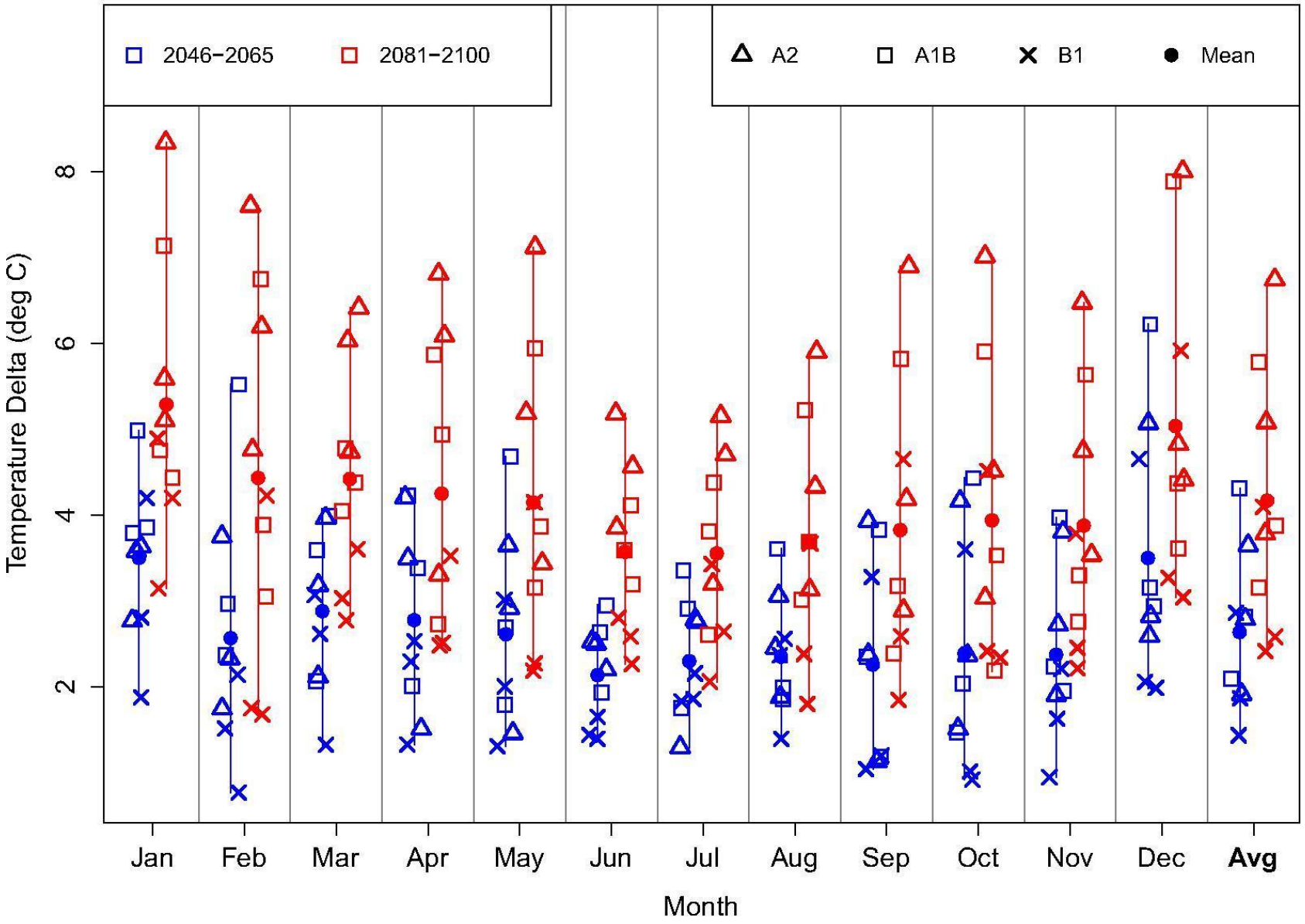
BCCA Cells

Study Region:

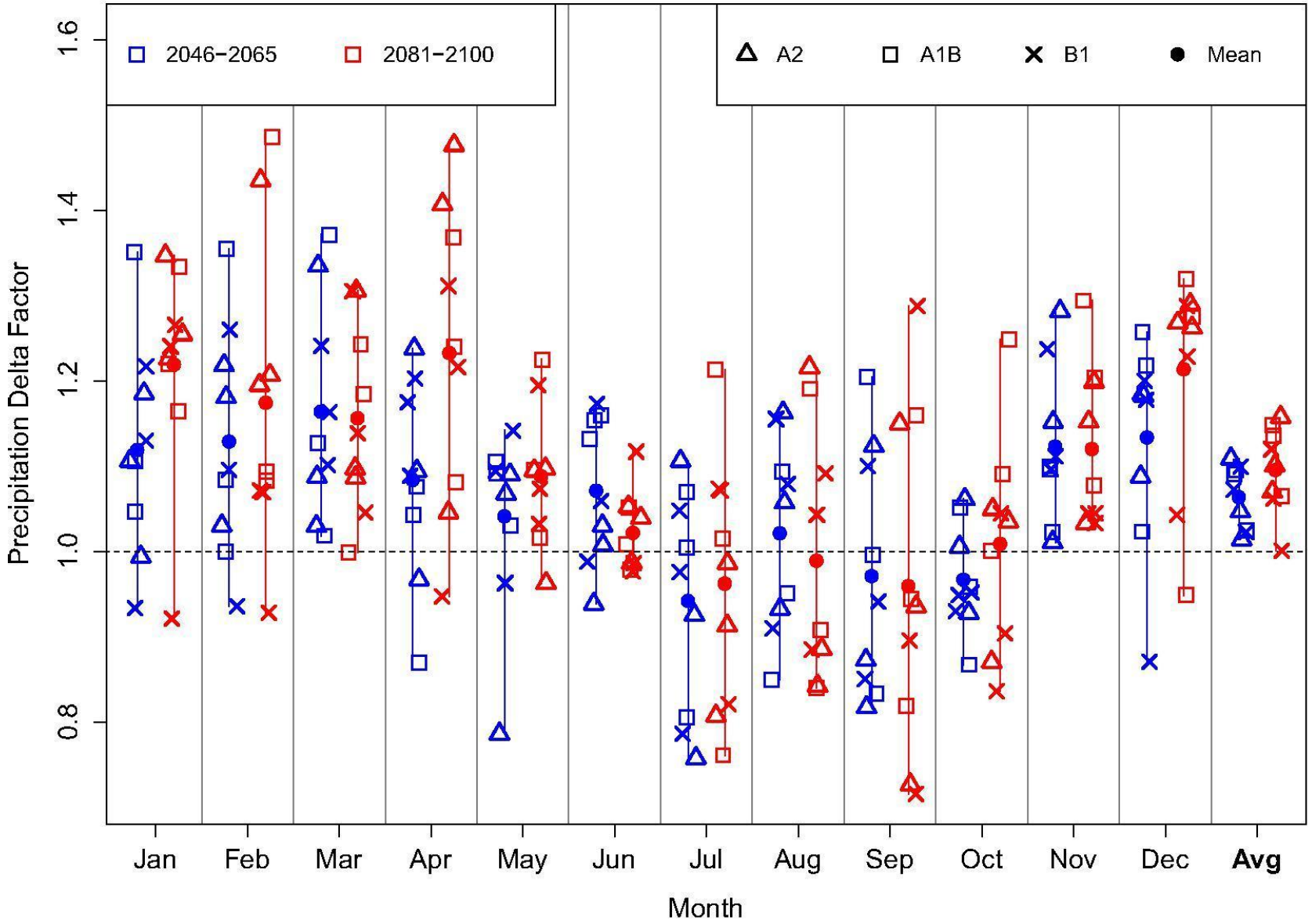
- 130 cells
- 12 km by 12 km cells
- Encompasses Winooski and Mississquoi watersheds



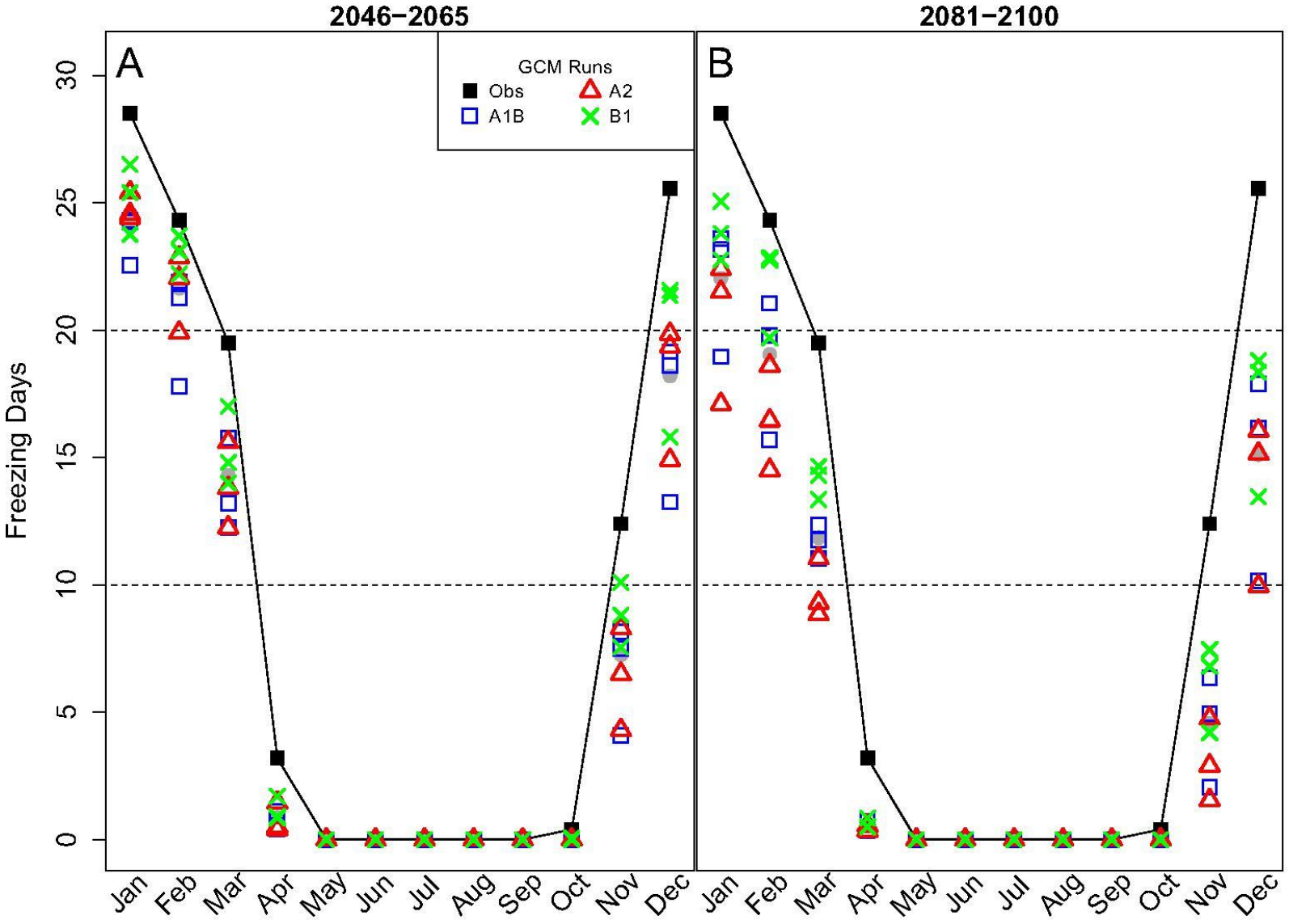
Temperature Change



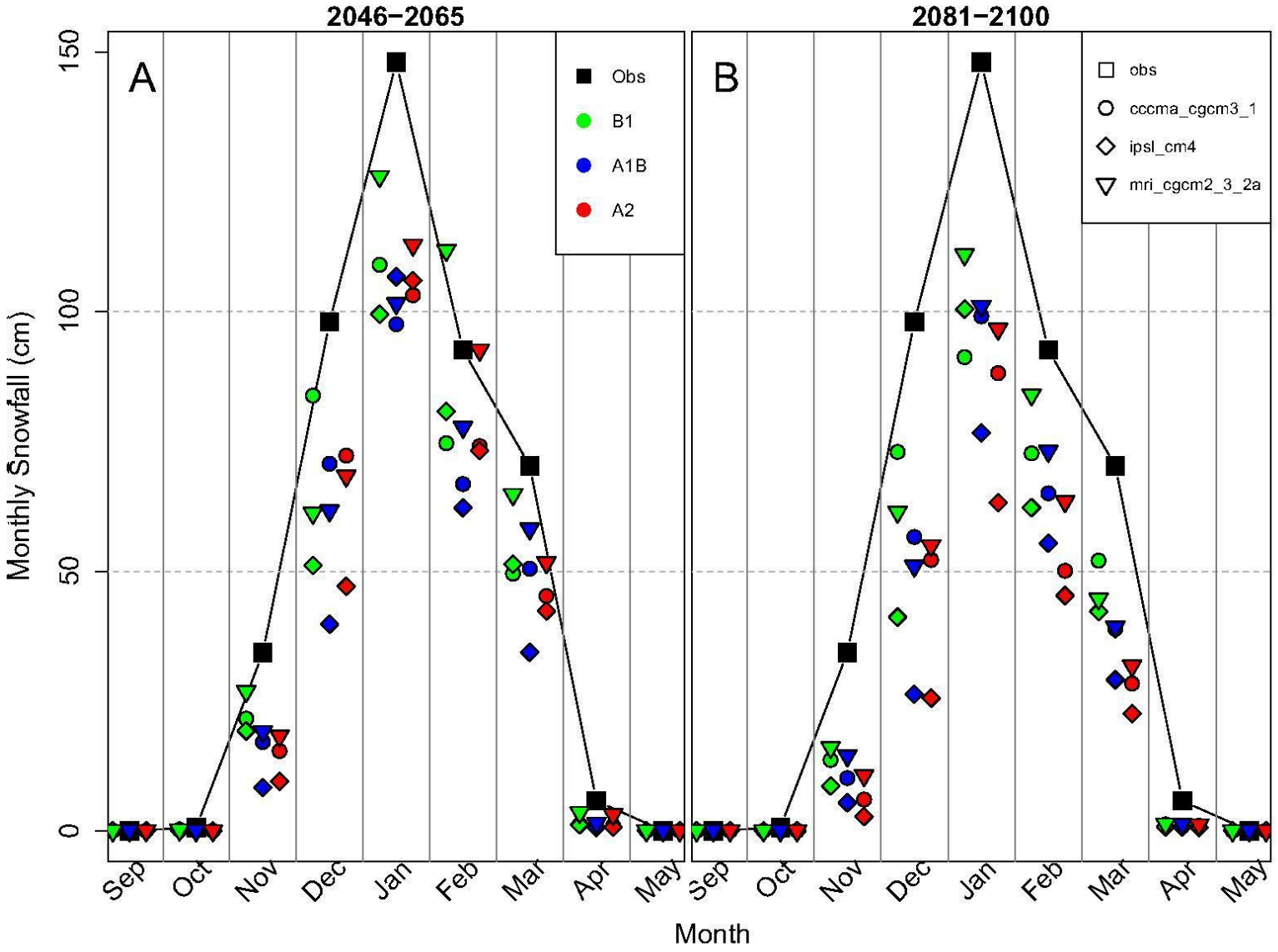
Precipitation Delta Factors



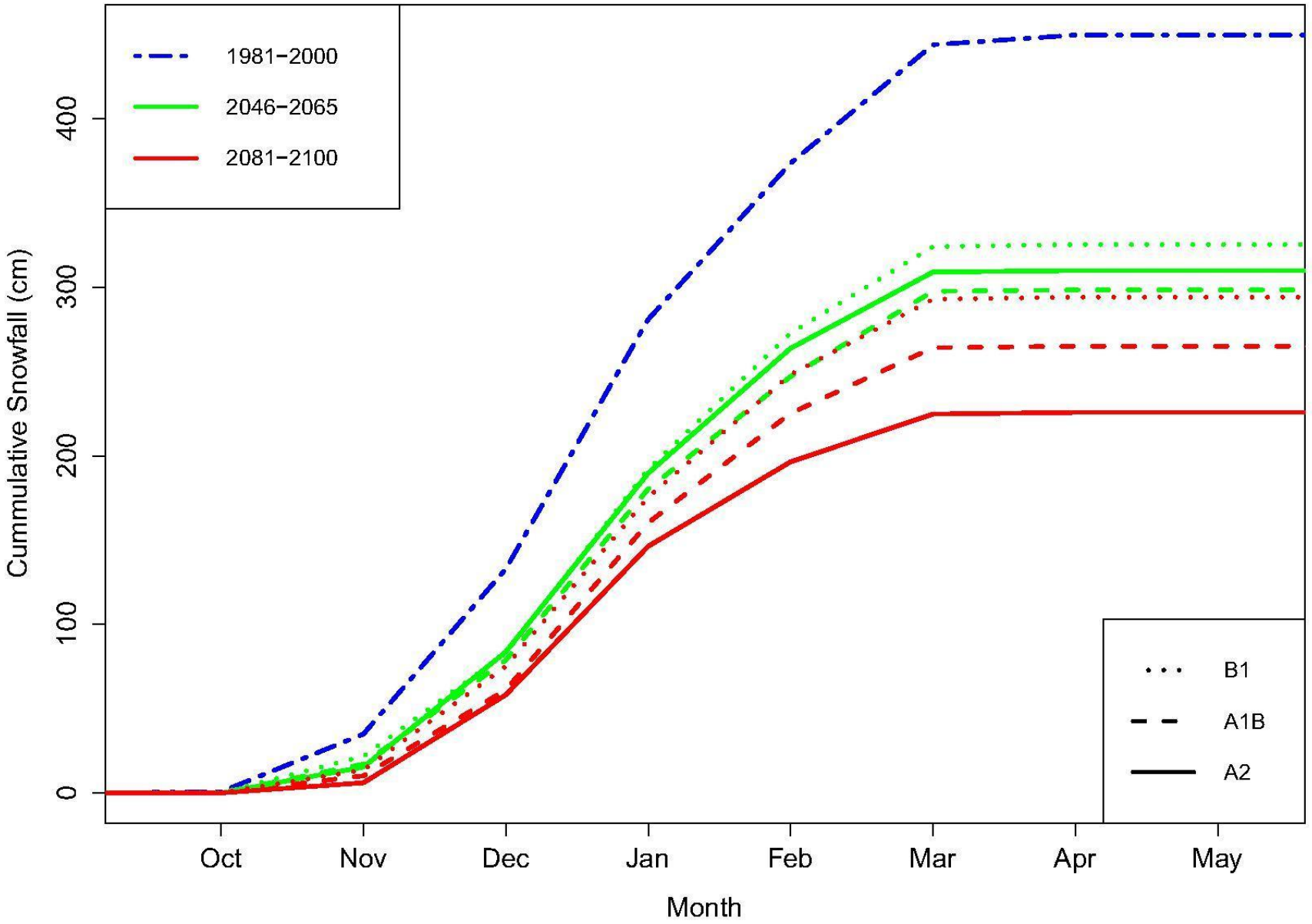
Days Below Freezing



Snowfall by Month

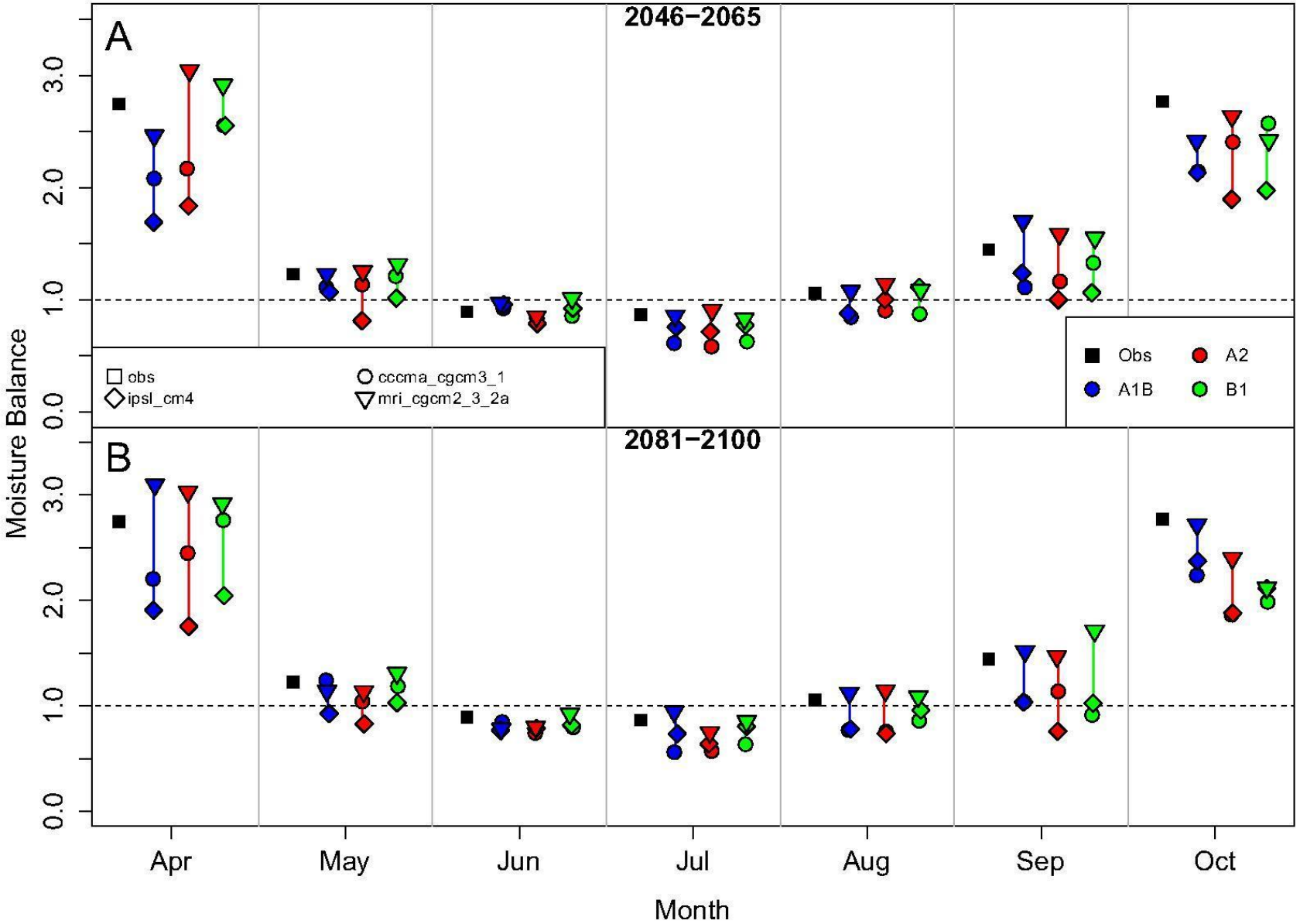


Cumulative Snowfall



Moisture Balance

(ratio of precipitation to potential evapotranspiration)



Downscaling climate simulations to 1 km spatial resolution

Gabriela Bucini
RACC Postdoctoral associate

EPSCoR annual meeting
May 16, 2013

Overview

Goal: produce high-resolution climate projections for our study region

Application: inputs to regional hydrological, ecological and social models

Challenge: impacts models run at finer resolution than global climate models,

necessitates producing high-resolution climate projections

Our approach

Approach: add information by taking advantage of fine-resolution topography

This requires identifying a relationship between climate variables and elevation

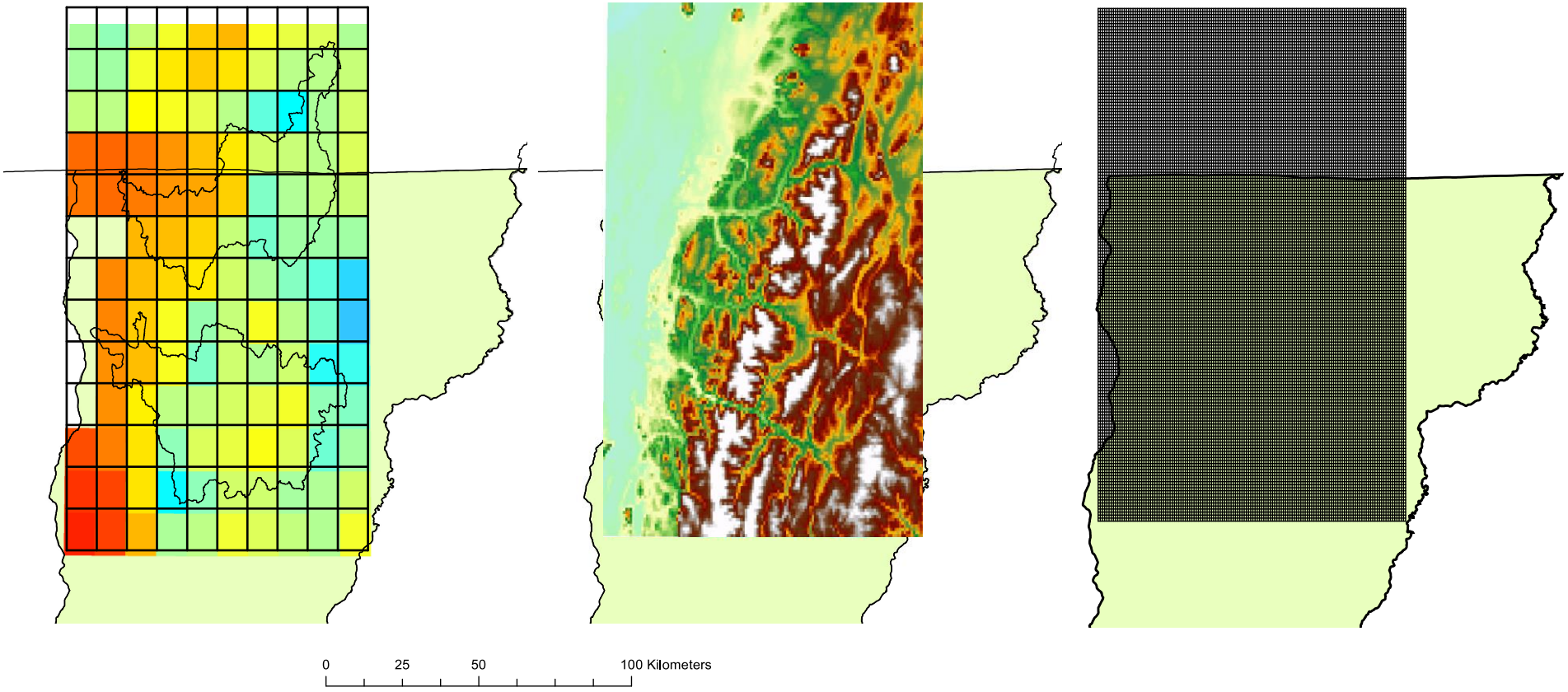
12 km to 1 km

grid cell size comparison

BCCA GRID

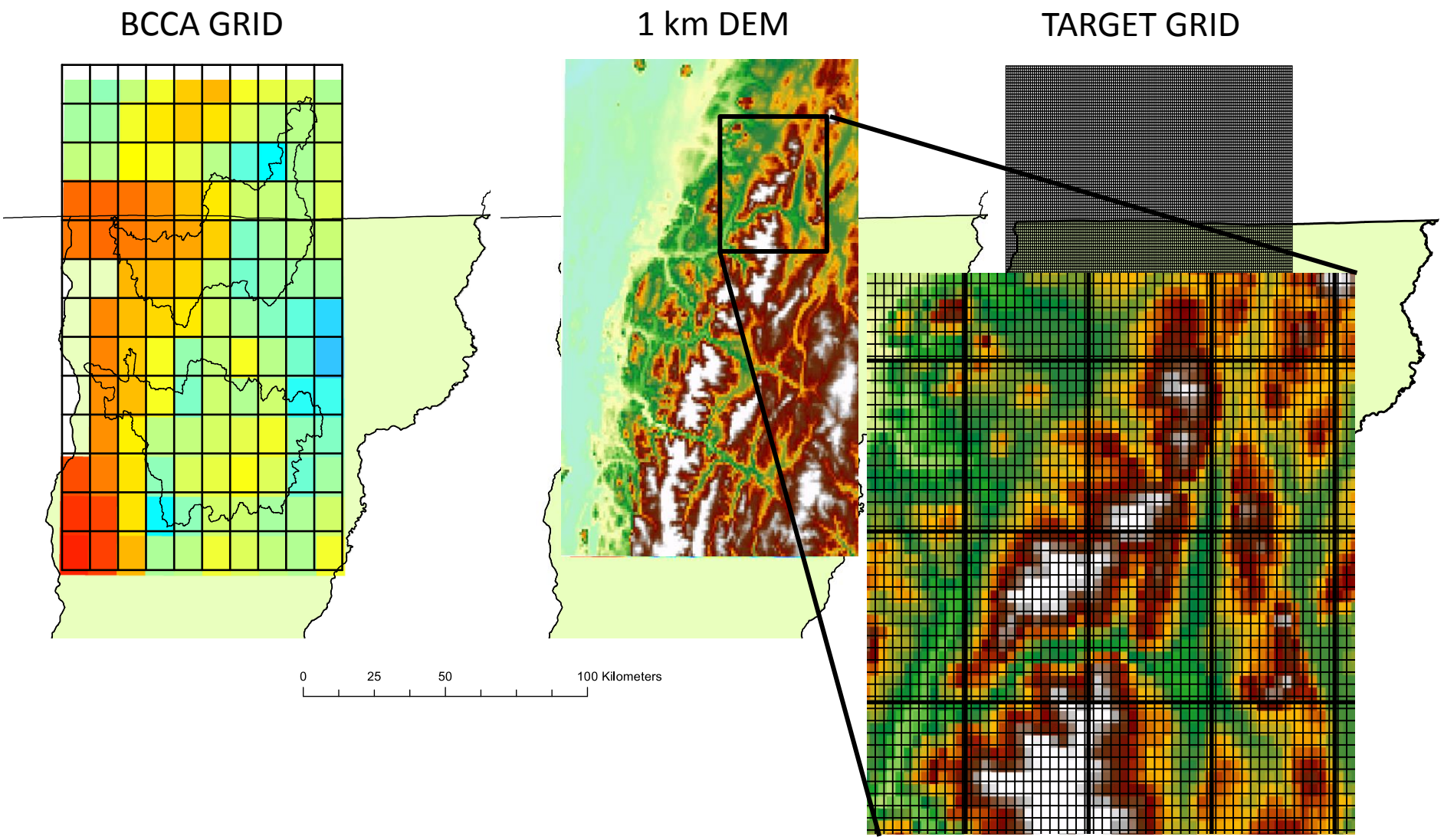
1 km DEM

TARGET GRID



12 km to 1 km

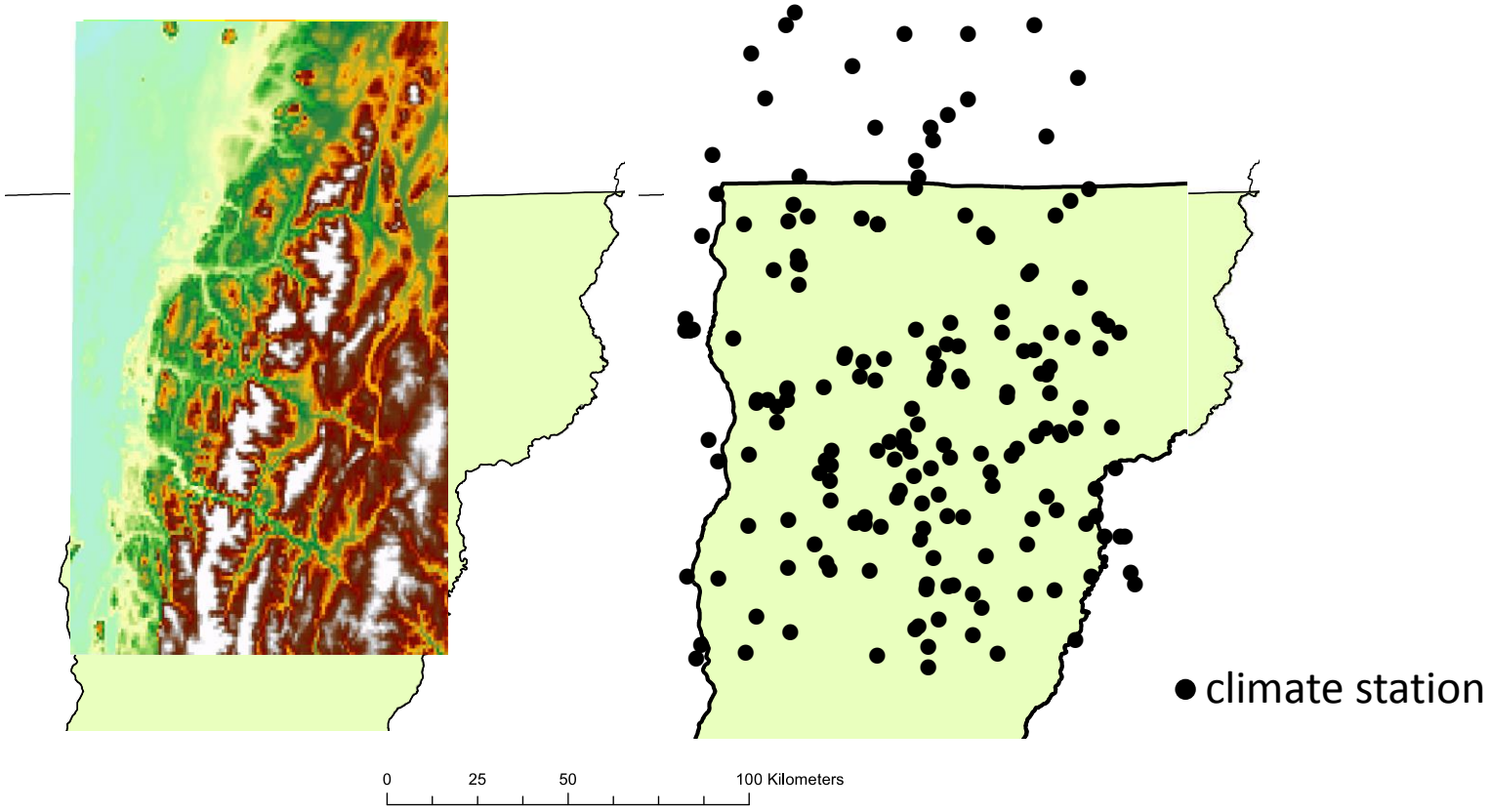
grid cell size comparison



LAPSE RATES

Precipitation = f_P(elevation)

Temperature = f_T(elevation)



Lapse rates can…

be constant
within and across years

OR

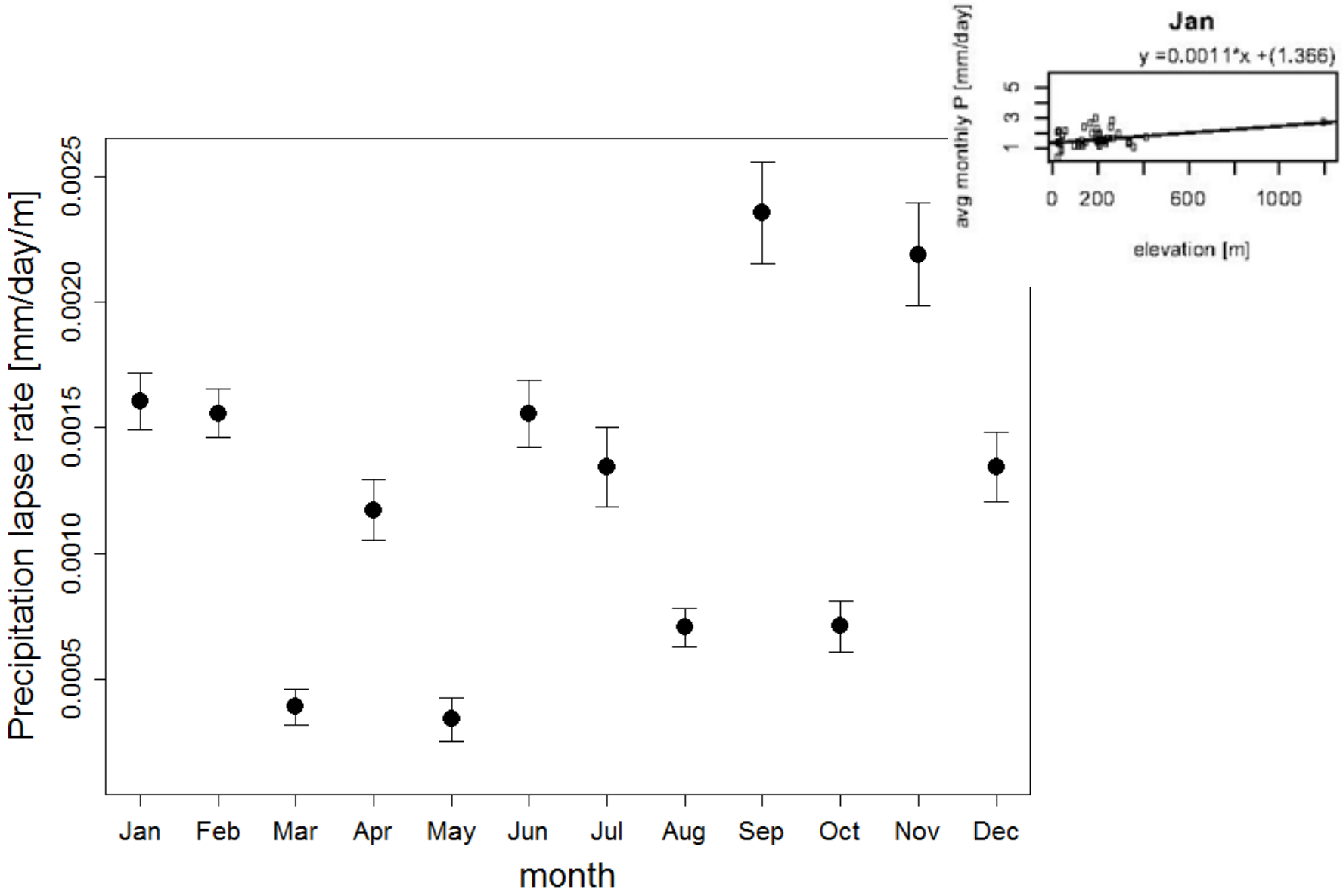
change
within and across years

Are lapse rates (f_P and f_T) stationary through time?

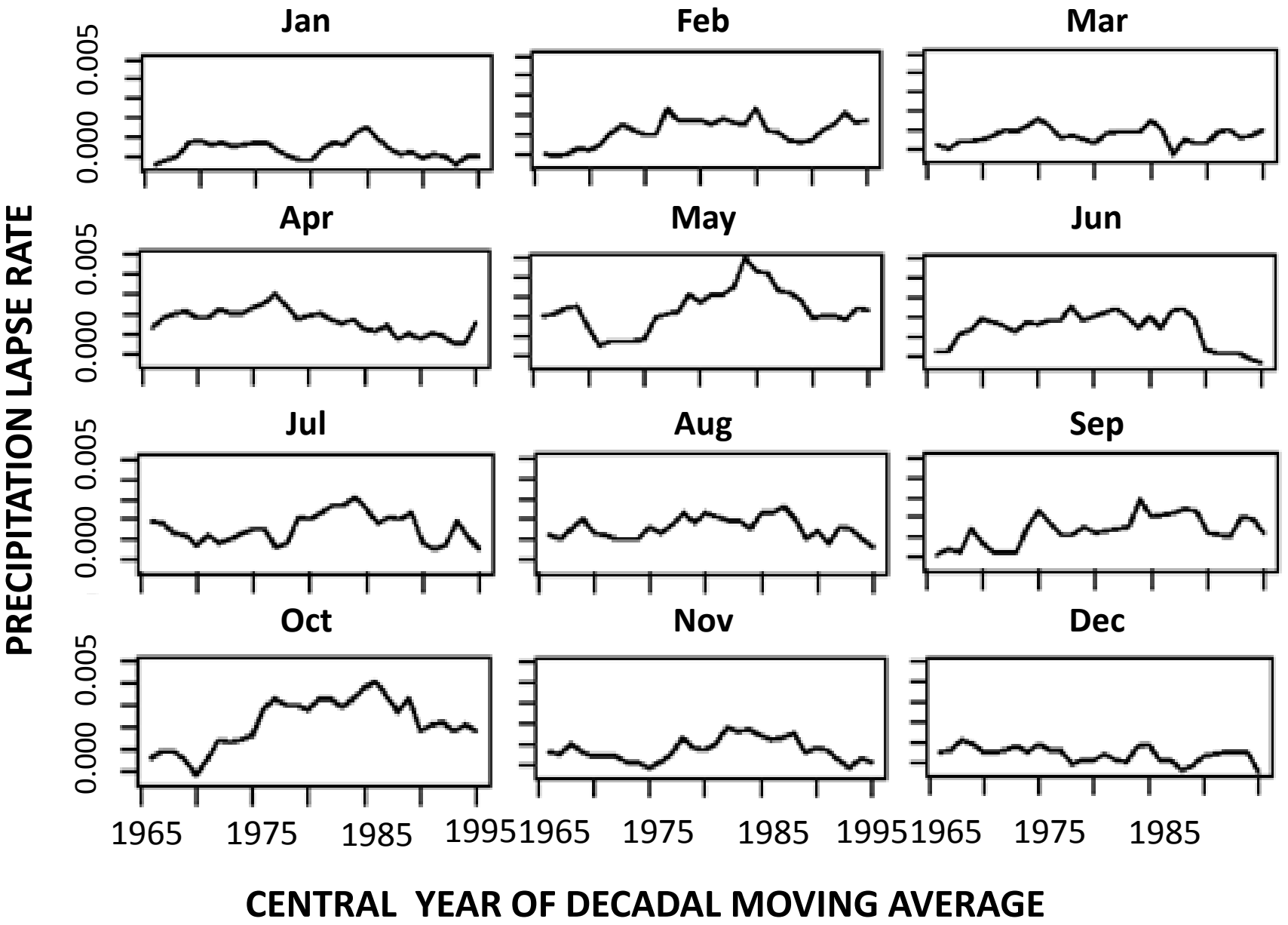
IF YES → We can apply the observed relationships to future climate

IF NO → We need to determine how lapse rates change through time

Lapse rate change across months



Lapse rates change across decades



Observed lapse rates change with time

How will they change in the future?

We do not have future station measurements so we need to rely on modeled climate data for our predictions.

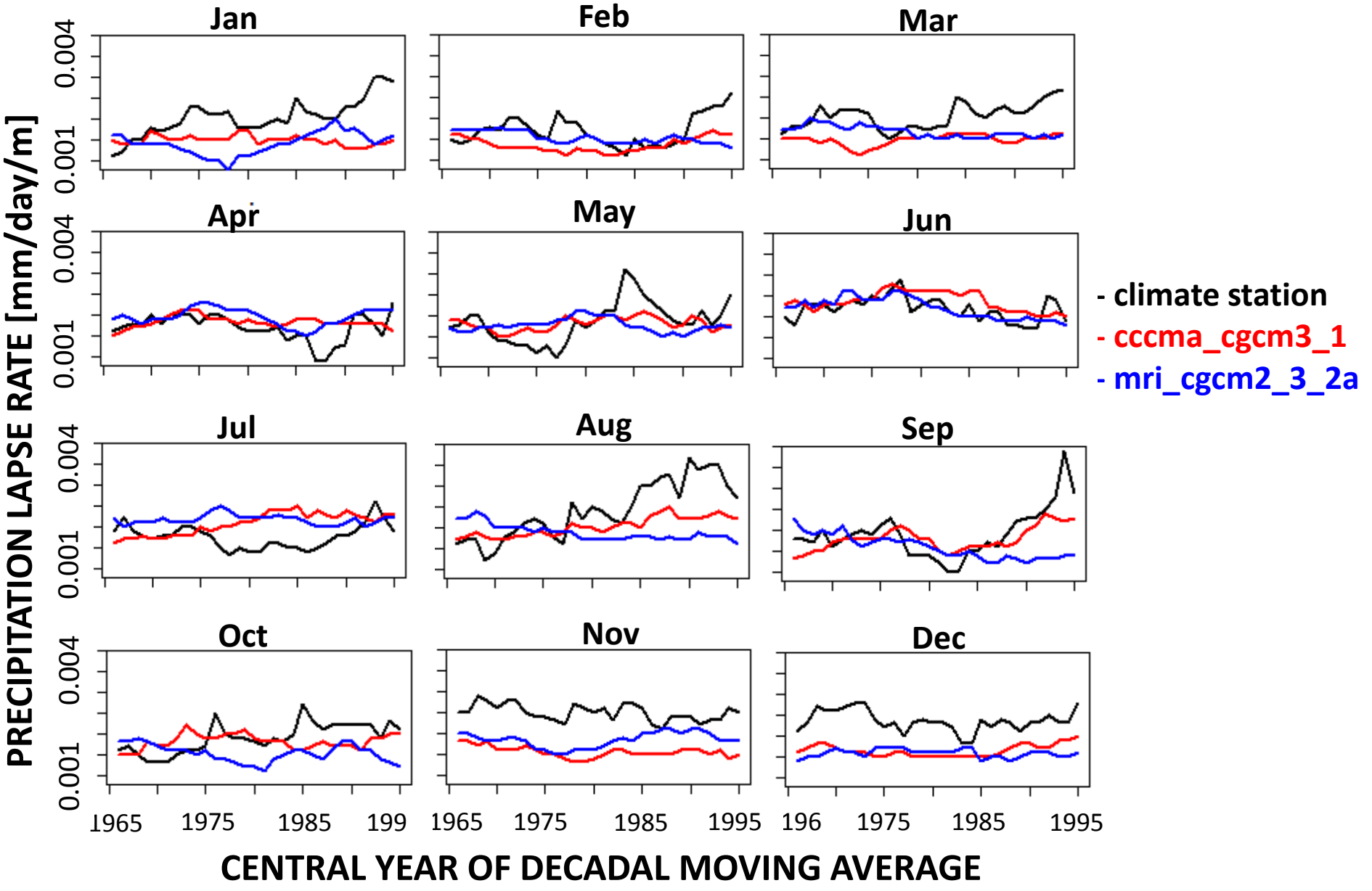
Do modeled lapse rates behave in the same way as the station lapse rates?

Are lapse rates calculated from BCCA and station data the same?

IF YES → We can apply BCCA lapse rates to future projections

IF NO → We need to determine how station and BCCA lapse rates are related.

Observed and BCCA lapse rates are dissimilar



Summary

1. Lapse rates are NON-STATIONARY
   - within a year
   - across years
2. Lapse rates are DISSIMILAR between STATION observations and BCCA

Precipitation = f_P(elevation, time, data set)

Temperature = f_T(elevation, time, data set)

Future work

1. Construct competing statistical models for lapse rate correction for temperature and precipitation
2. Select best model using station data
3. Apply best model for downscaling BCCA data to 1 km grid


Thank you
mmmaria

Future directions

1. Submit manuscript on climate change projections (Delta method): Summer 2013.

2. Complete statistical downscaling of climate change projections: Fall 2013.
   -Submit manuscript: Winter 2013

3. Dynamical downscaling using regional climate models: Begin using NCAR WRF RCM in Fall 2013.

Questions?