Climate Projections Team: Background and Approach

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BREE
Basin Resilience to Extreme Events
in the Lake Champlain Basin

The University of Vermont

DARTMOUTH
1769

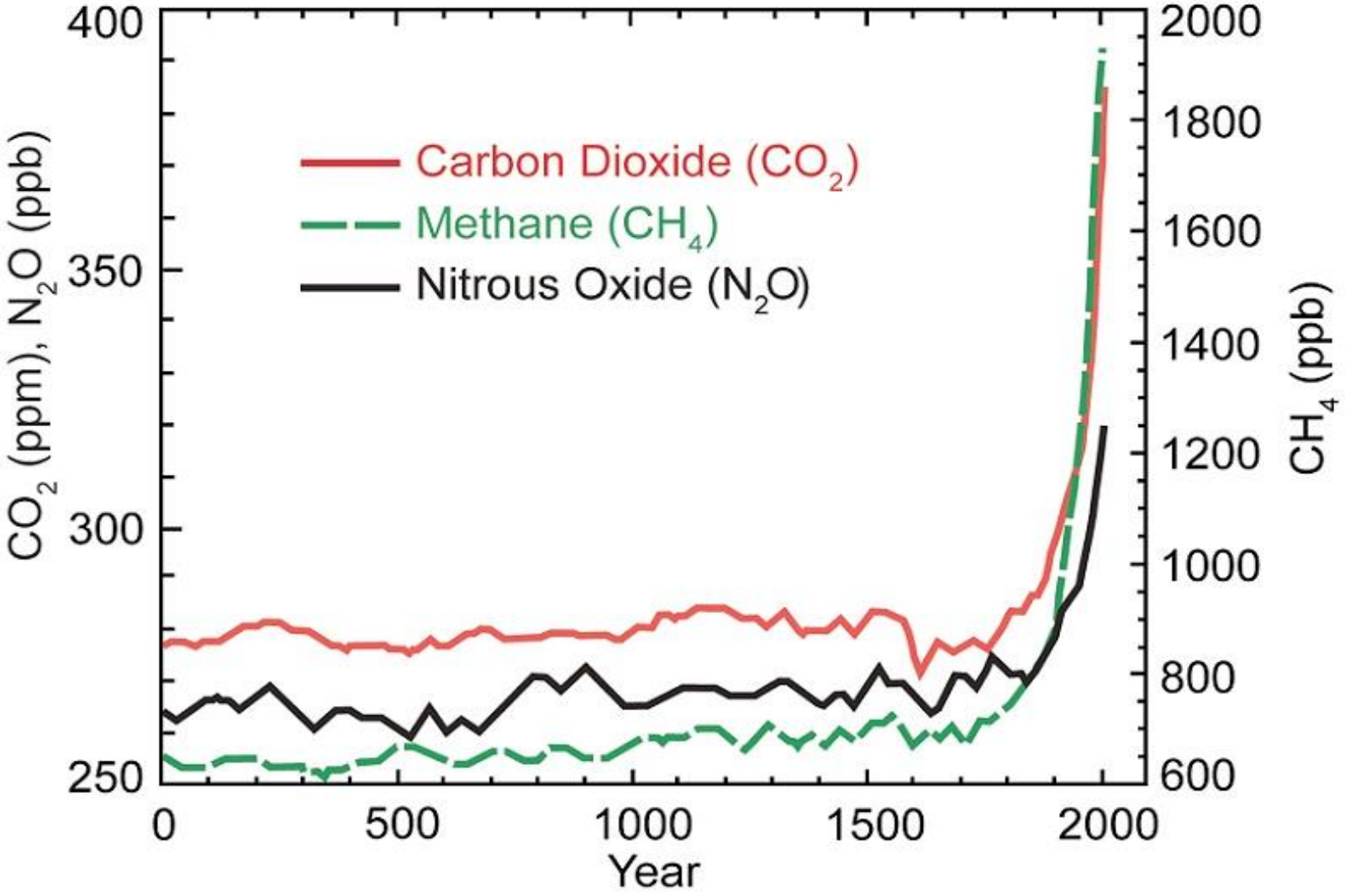
LYNDON
A vermont STATE COLLEGE

BREE Climate Team Overarching Research Question

How will the frequency, intensity, and spatial scale of extreme weather events change this century?

What local climate feedbacks will evolve through altered surface reflectance and moisture fluxes?

Greenhouse Gas Concentrations Are Increasing

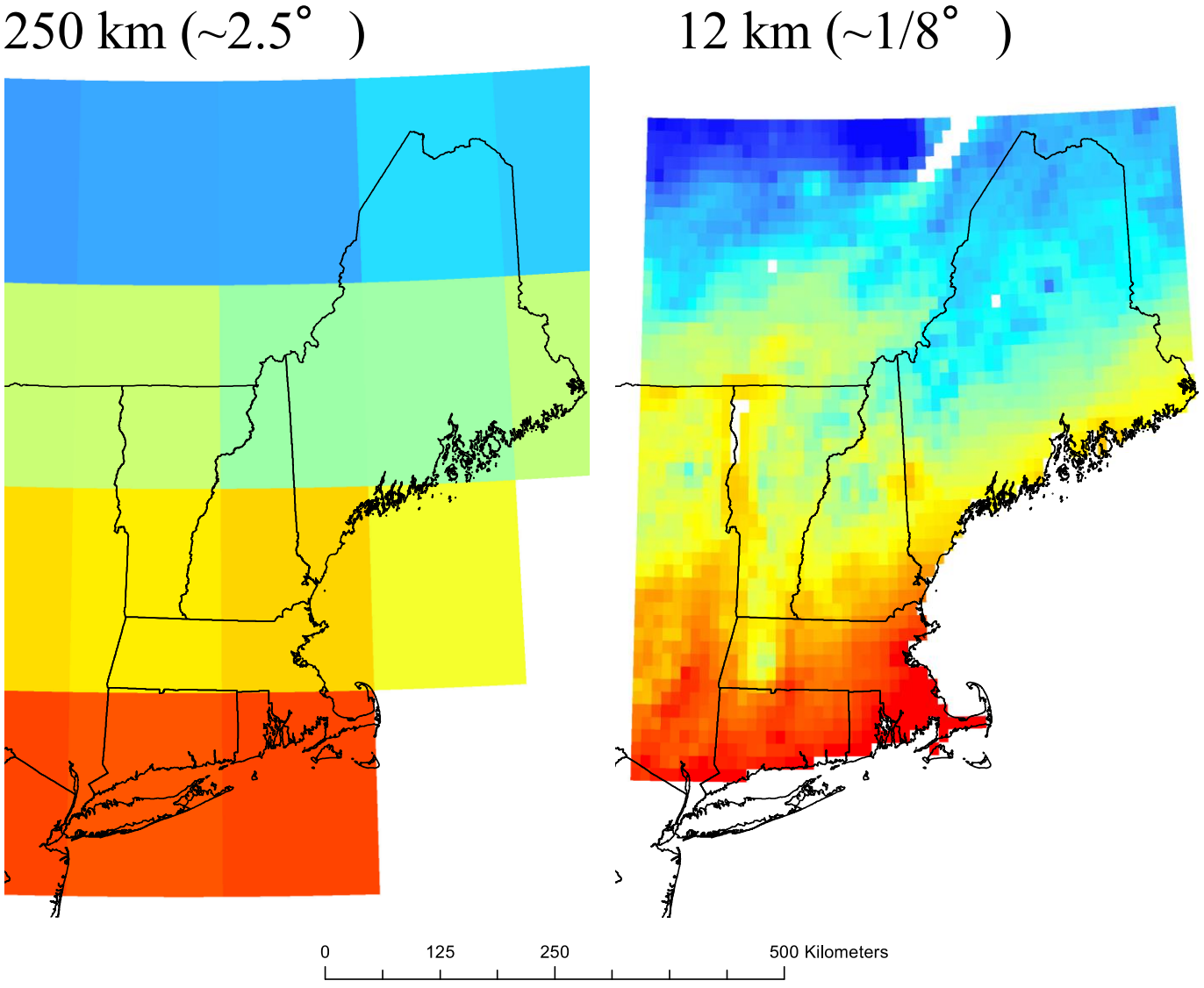


Source: USGCRP, 2009

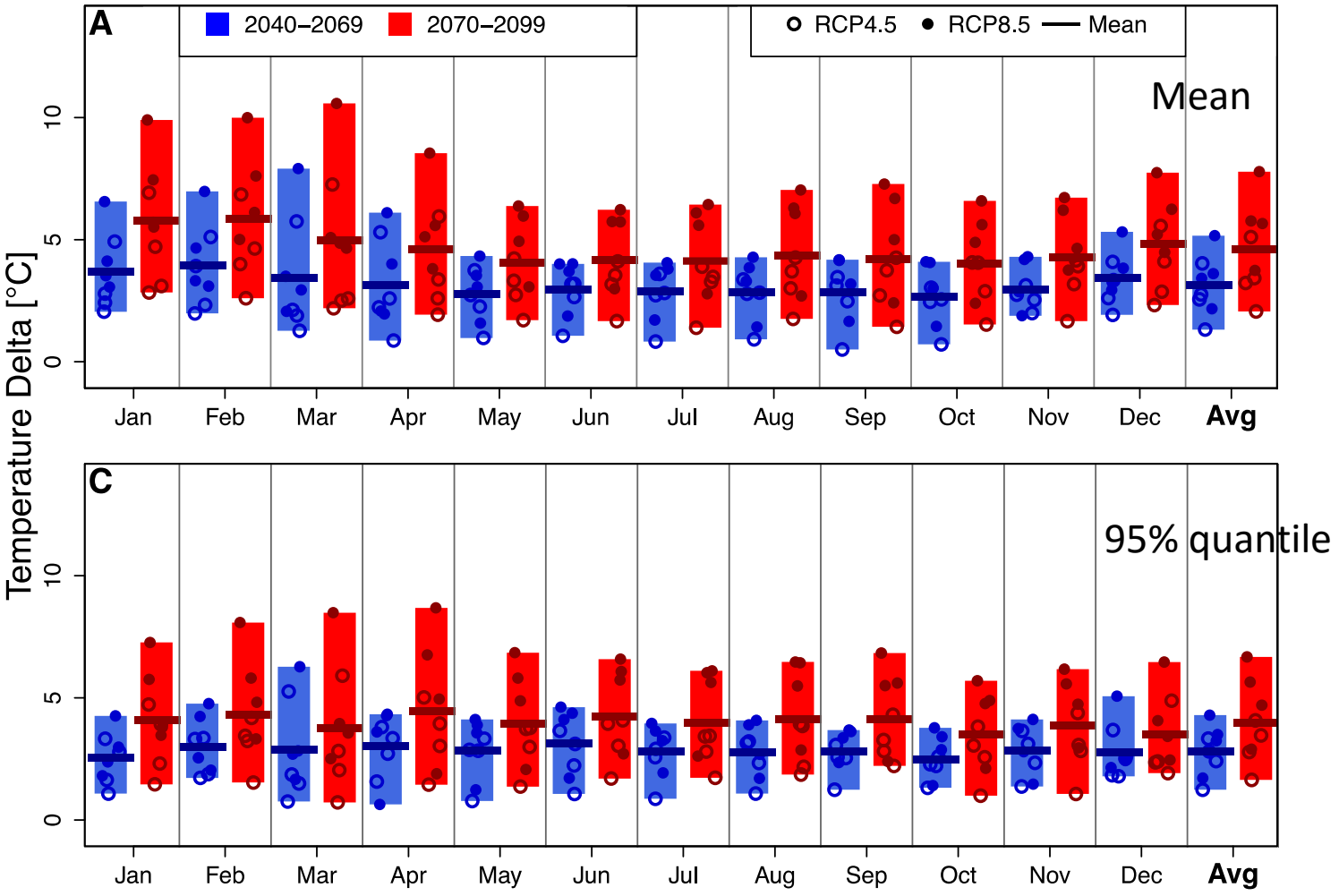
Global Climate Models (GCMs) Predict Temperature and Precipitation

- GCMs solve the primitive equations (conservation of momentum, mass, and energy) to simulate 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

Downscaling GCMs

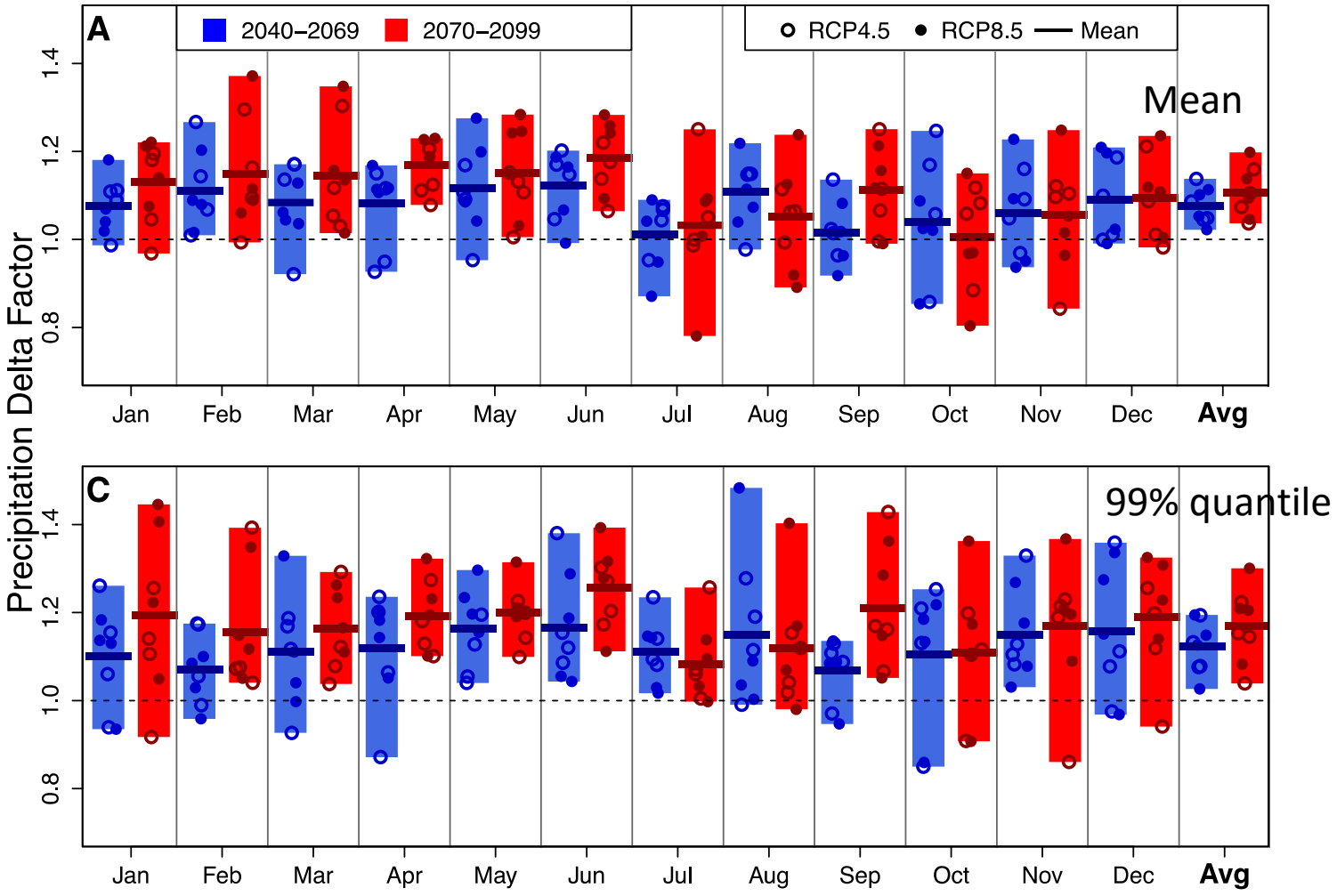


Temperature Will Increase



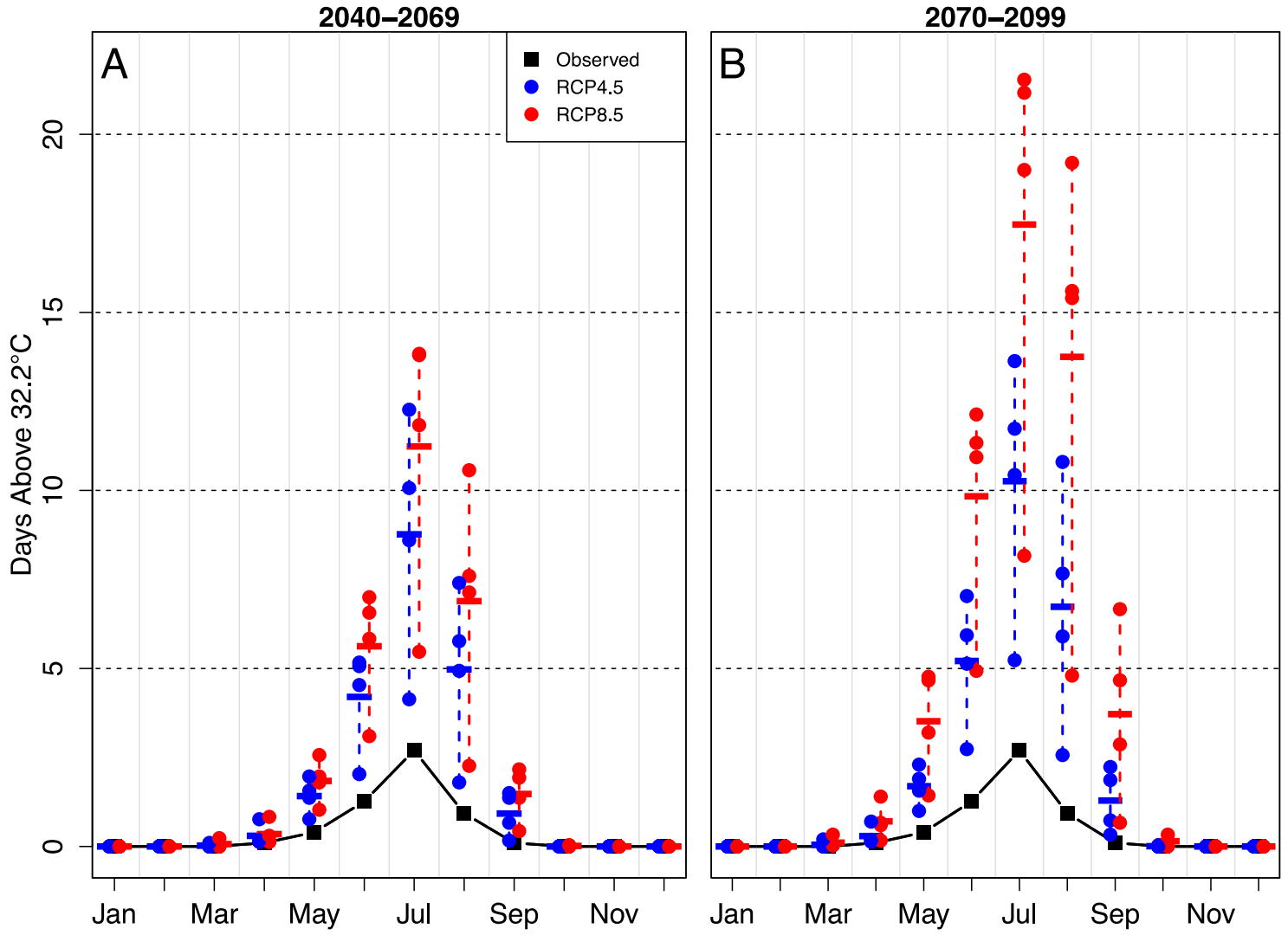
Source: Guilbert et al., 2014

Precipitation Is Likely to Increase



Source: Guilbert et al., 2014

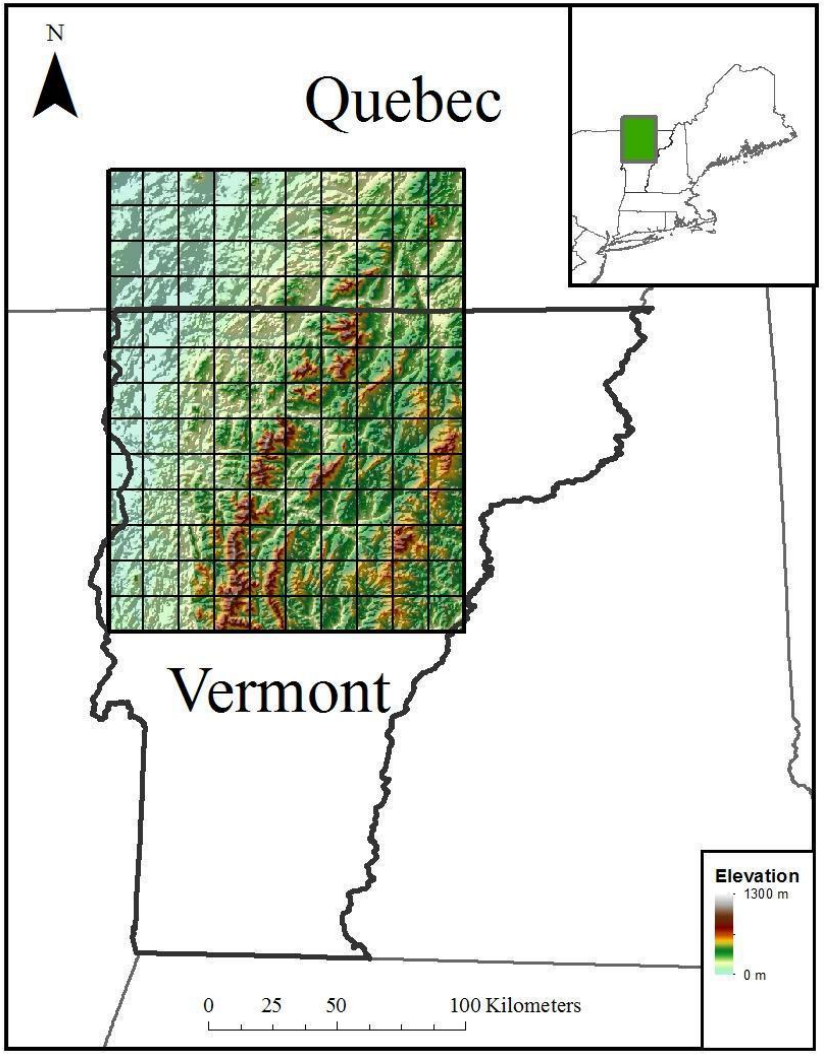
Hot Days (> 90 ° F) Will Increase



Source: Guilbert et al., 2014

Statistical Downscaling

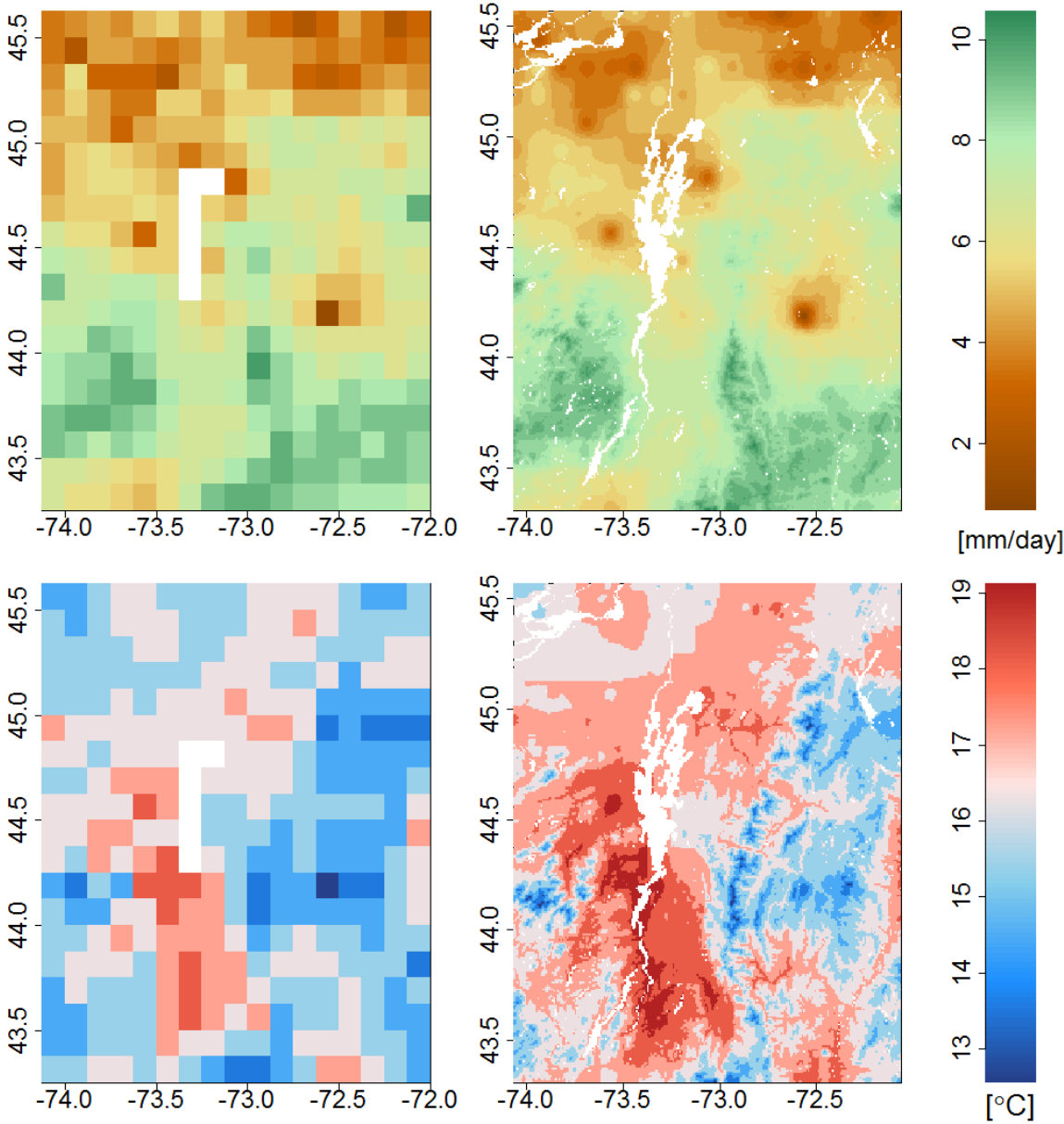
- Downscale intermediately downscaled products from 12 km to 1 km
  1. Derive observed temperature and precipitation elevation adjustments from station data
  2. Translate variables to a reference elevation using adjustments and intermediate resolution DEM
  3. Interpolate data to increase spatial resolution
  4. Create high resolution variables by modifying interpolated data using adjustments and high resolution DEM



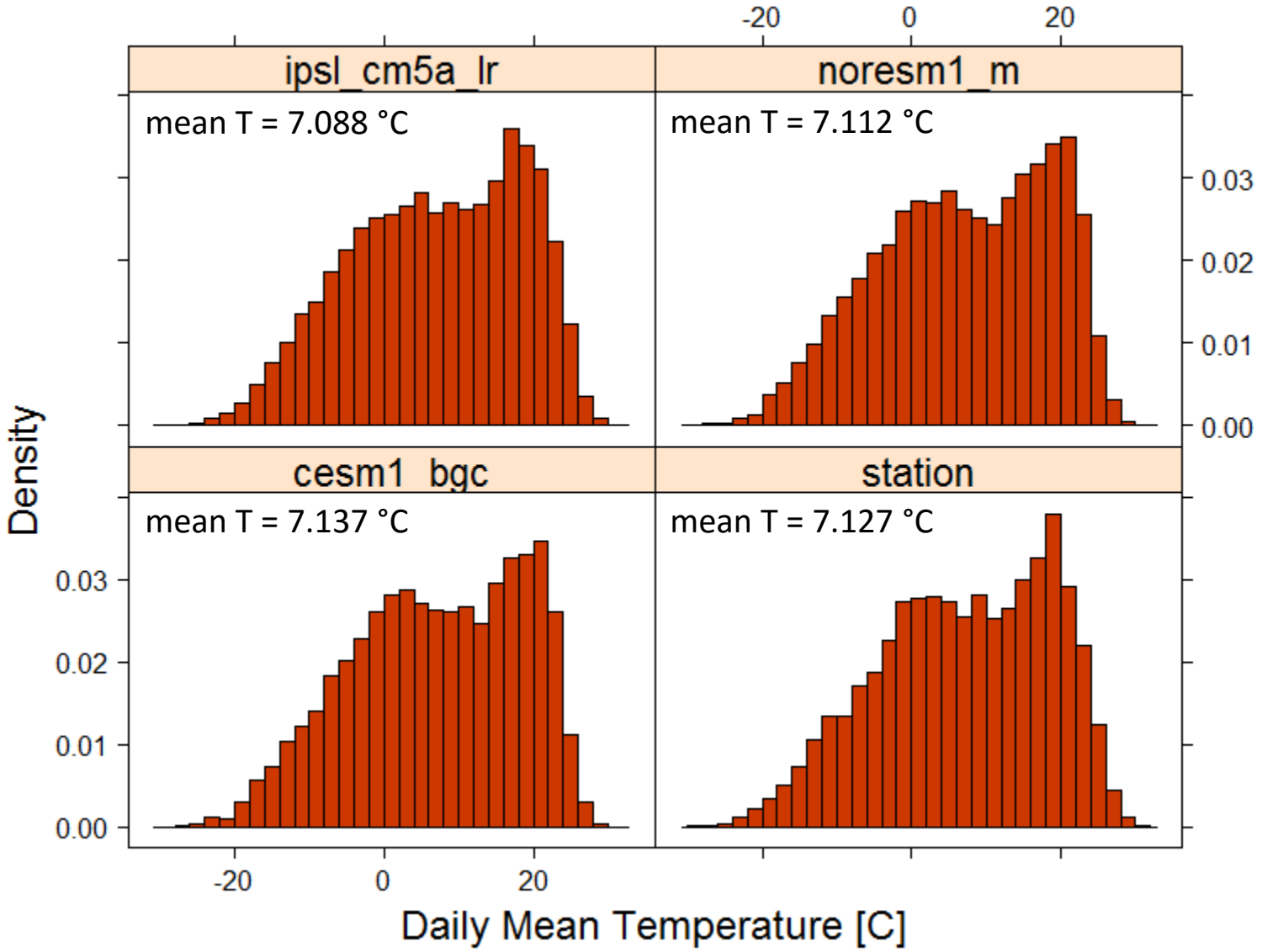
Source: Guilbert et al., 2014

Very High Resolution Output

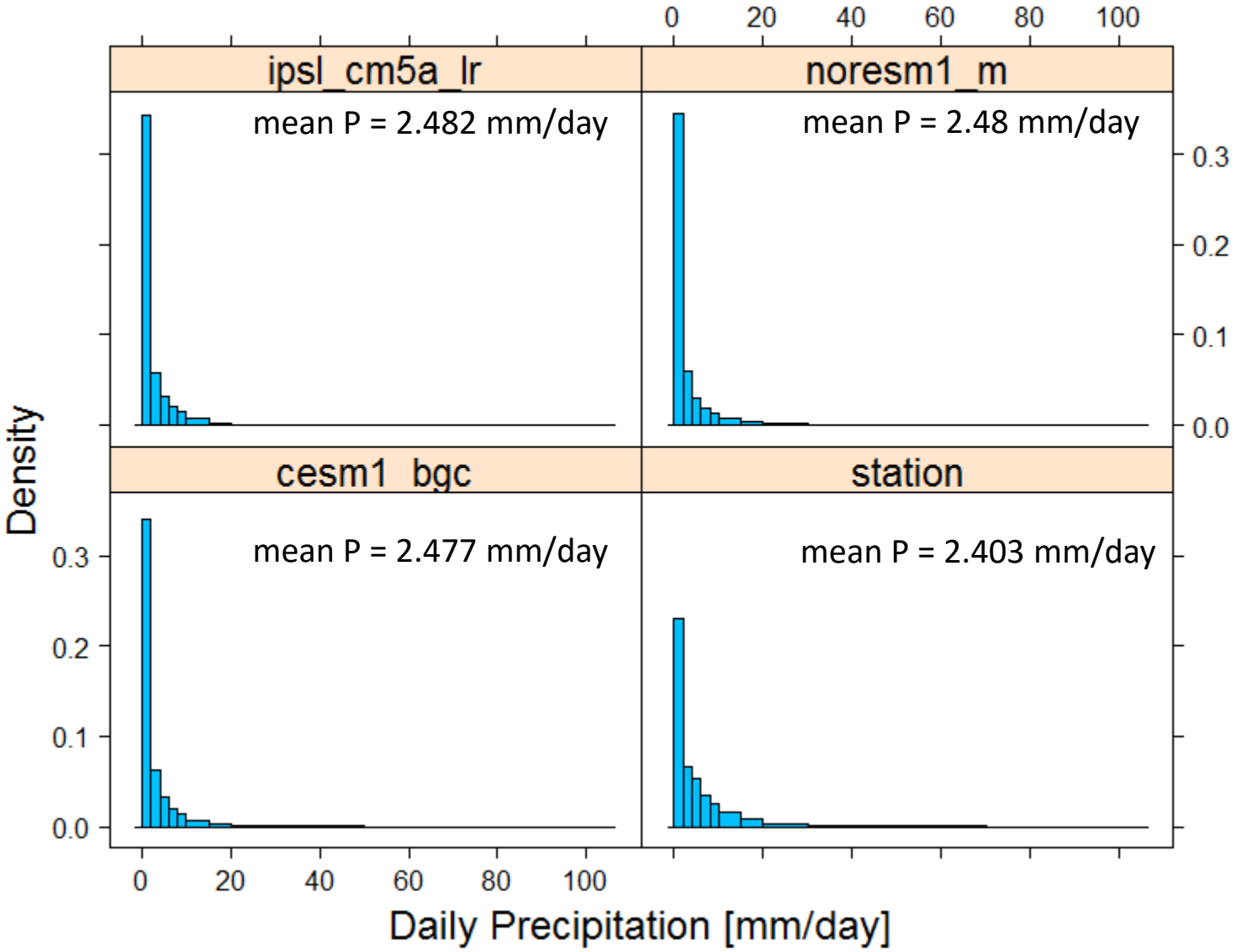
- Daily average precipitation (top) and temperature (bottom)
- May 24, 1970
- Beijing Climate Center Climate System Model
- Bias Corrected Constructed Analogues (Brekke et al., 2013)



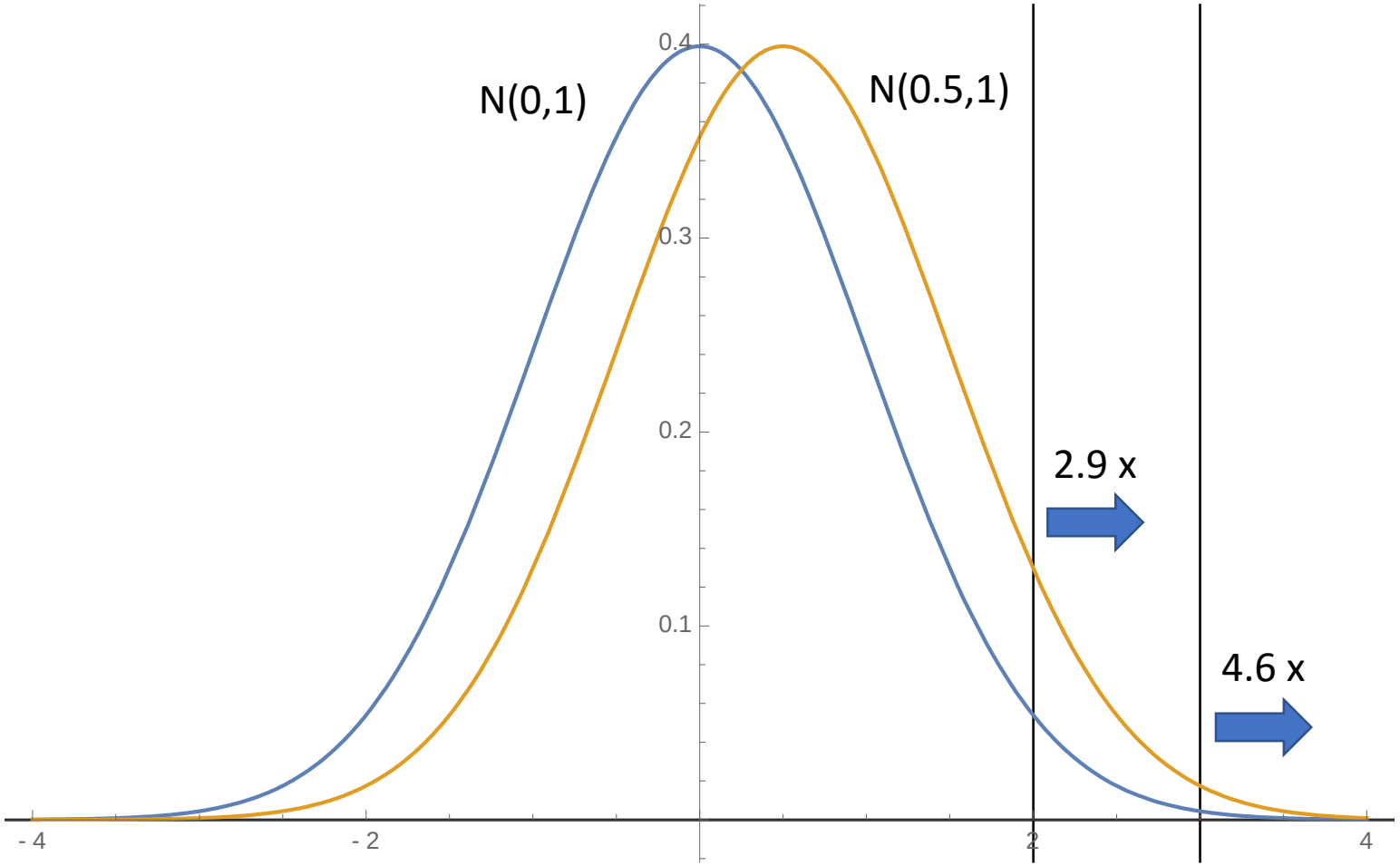
Very High Resolution Output: Burlington Temperature Histograms



Very High Resolution Output: Burlington Precipitation Histograms



Means vs Extremes



Regional Climate Models (RCMs)

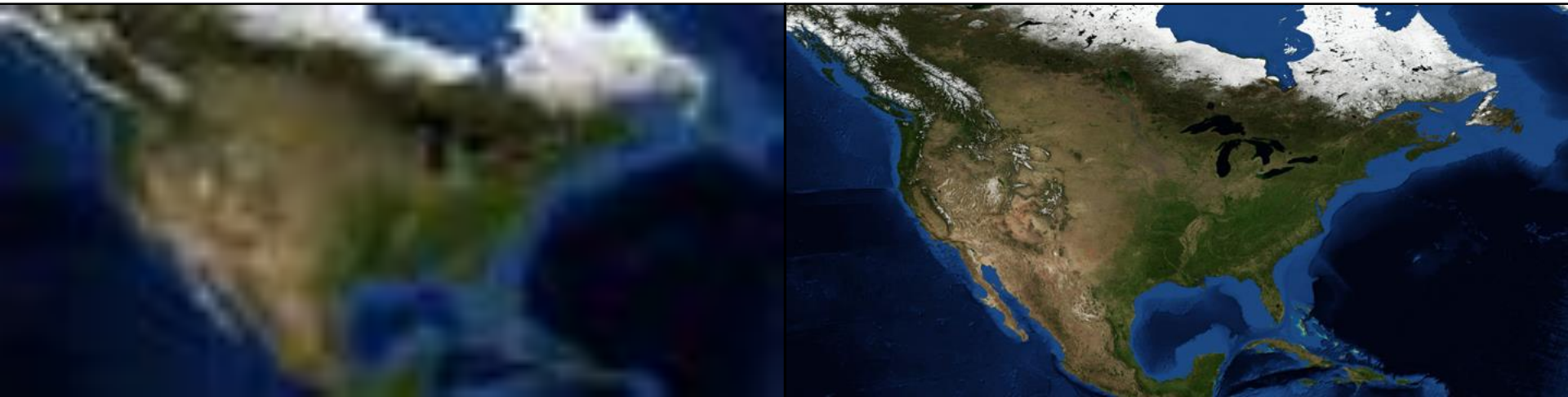
- RCMs are weather forecast models adapted to run at longer temporal scales or GCMs adapted to run at finer spatial scales
- High resolution: 2 to 4 km cells
- Limited spatial coverage, bounded by a large-scale atmospheric forcing generally provided by a GCM or reanalysis
- Can contain significant inaccuracies produced both by the large-scale forcing and the RCM itself

Methodology and Tasks

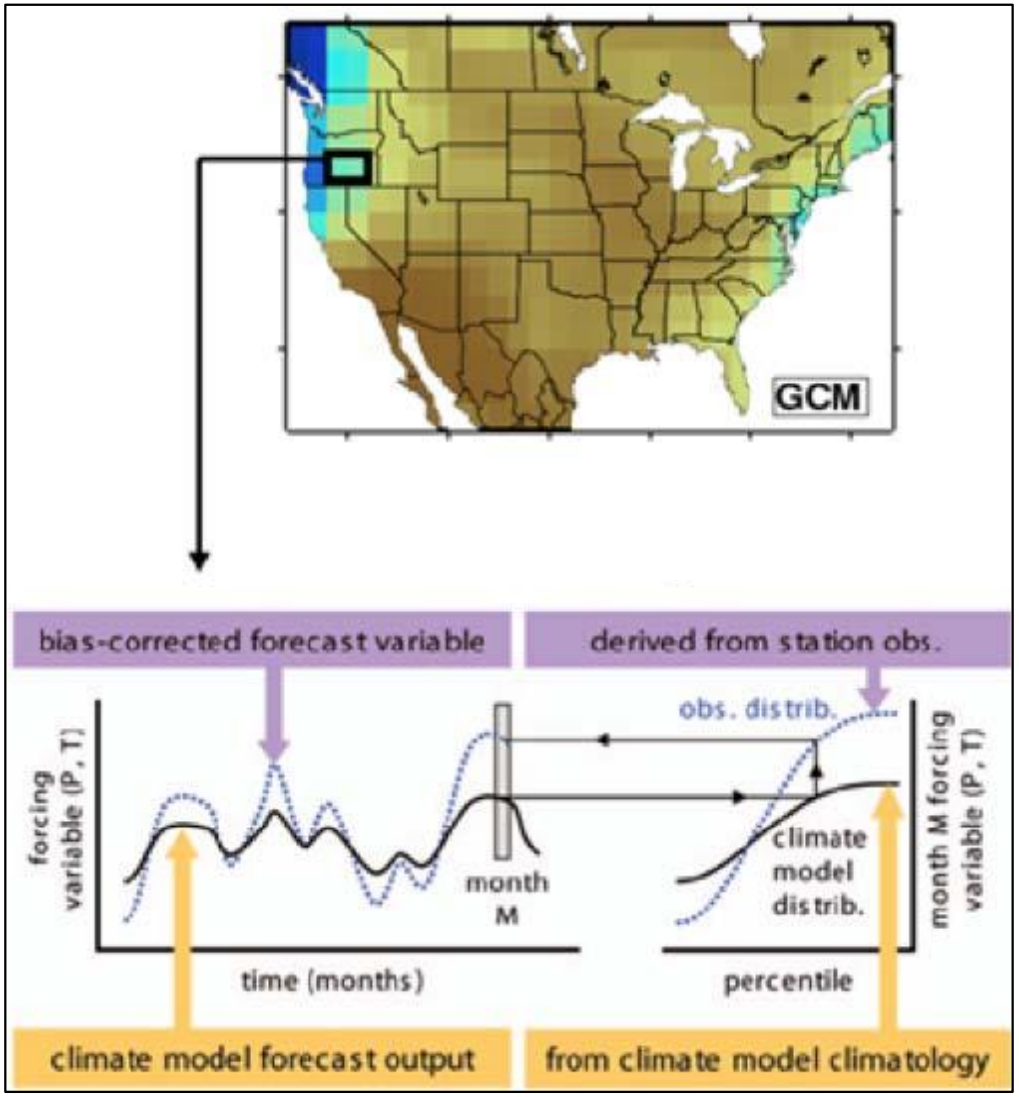
1. Calibrate the Weather Research and Forecasting (WRF) regional climate model and produce climate hindcasts driven by reanalysis and GCMs
2. Run WRF projections for end-of-century driven by GCMs
3. Bias correct and statistically process WRF simulations
4. Model extreme events using Extreme Value Theory
5. Assess albedo and land use change feedbacks on climate system

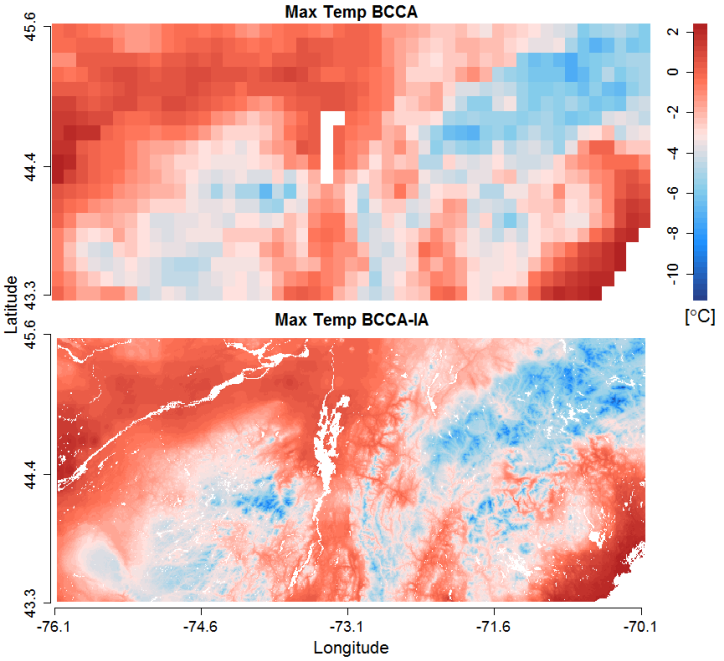
Statistical Processing and Analysis

- Bias correct and process RCM model runs incorporating station observations and reanalysis
- Reduce inaccuracies of RCM projections
- Incorporate historical information in model forecasts
- Increase spatial resolution: < 1km
- Climate projections constrained by observational record or extrapolations of observational record



Bias Correction and Spatial Disaggregation





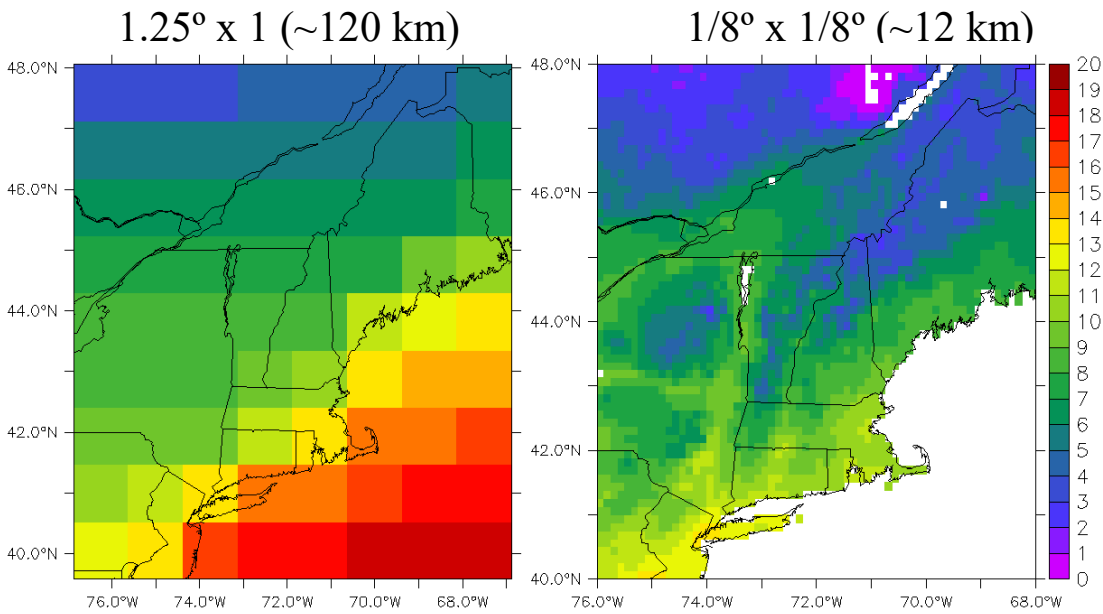
Statistically process WRF simulations

- Activities
  - Evaluate WRFs ability to capture historical extremes (T, P)
  - Apply bias correction and spatial disaggregation
  - Map WRF simulations to historical extremes using extreme value theory
  - Evaluate model ability to capture extremes
  - Apply statistical models/mappings to future WRF runs

Source: http://visibleearth.nasa.gov

Calibrate WRF and Generate Hindcasts

- Team
  - PI Leads: Jonathan Winter, Brian Beckage, Janel Hanrahan
  - Students: Huanping Huang (GRA #9), GRA #8
- Sample Activities
  - Deploy WRF over Lake Champlain Basin using nesting to achieve resolution and coverage required by downstream applications
  - Run WRF forced with reanalysis and GCMs
  - Evaluate ability of WRF to simulate temperature and precipitation, including extreme events
- Facilities
  - Discovery (Dartmouth)
  - Babbage (UVM)
  - Cheyenne (NCAR)

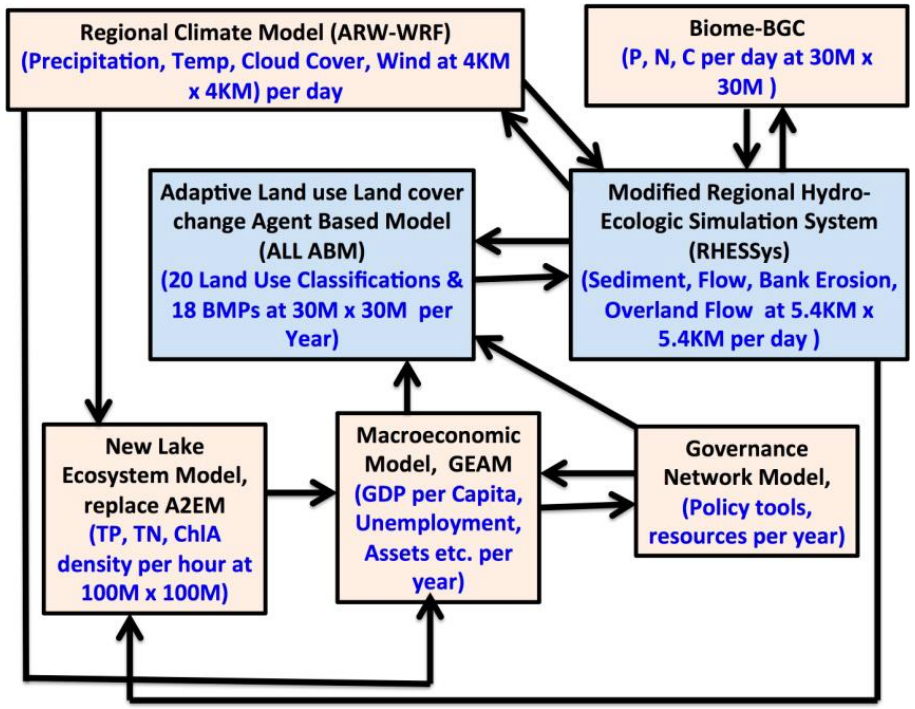


Run WRF Future Climate Projections

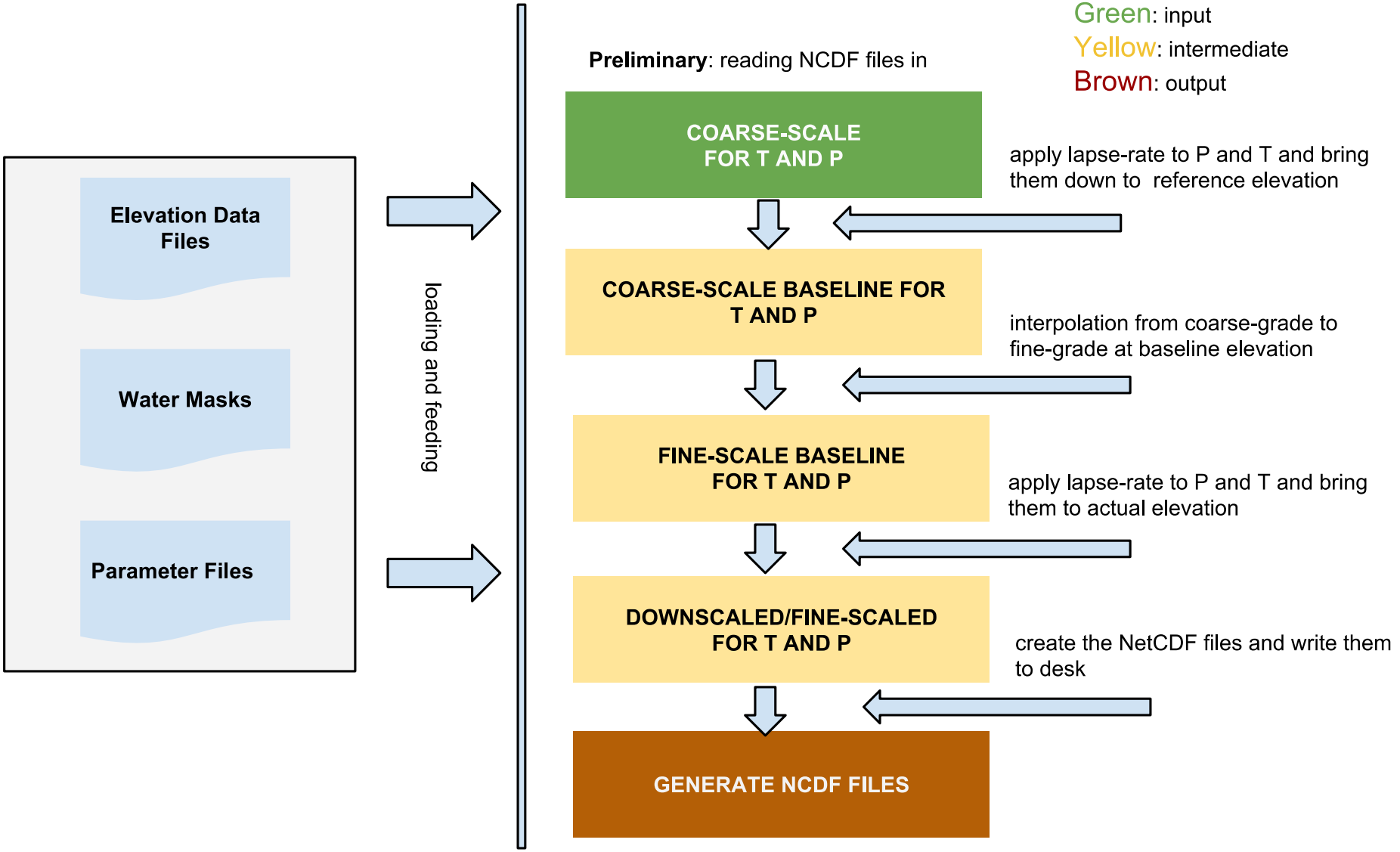
- Team
  - PI Leads: Jonathan Winter, Brian Beckage, Janel Hanrahan
  - Students: GRA #9, GRA #8
- Sample Activities
  - Evaluate GCM hindcasts over the Lake Champlain Basin, select set of best GCMs for boundary conditions
  - Run WRF for two future time slices (e.g., 2035-2064, 2080-2099)
  - Apply bias correction and statistical processing
  - Analyze value added of dynamical downscaling via WRF to simulation of extreme events
- Facilities
  - Cheyenne (NCAR)
  - Leibnitz (UVM)
  - Discovery (Dartmouth)

Feedbacks to Regional Climate and IAM Integration

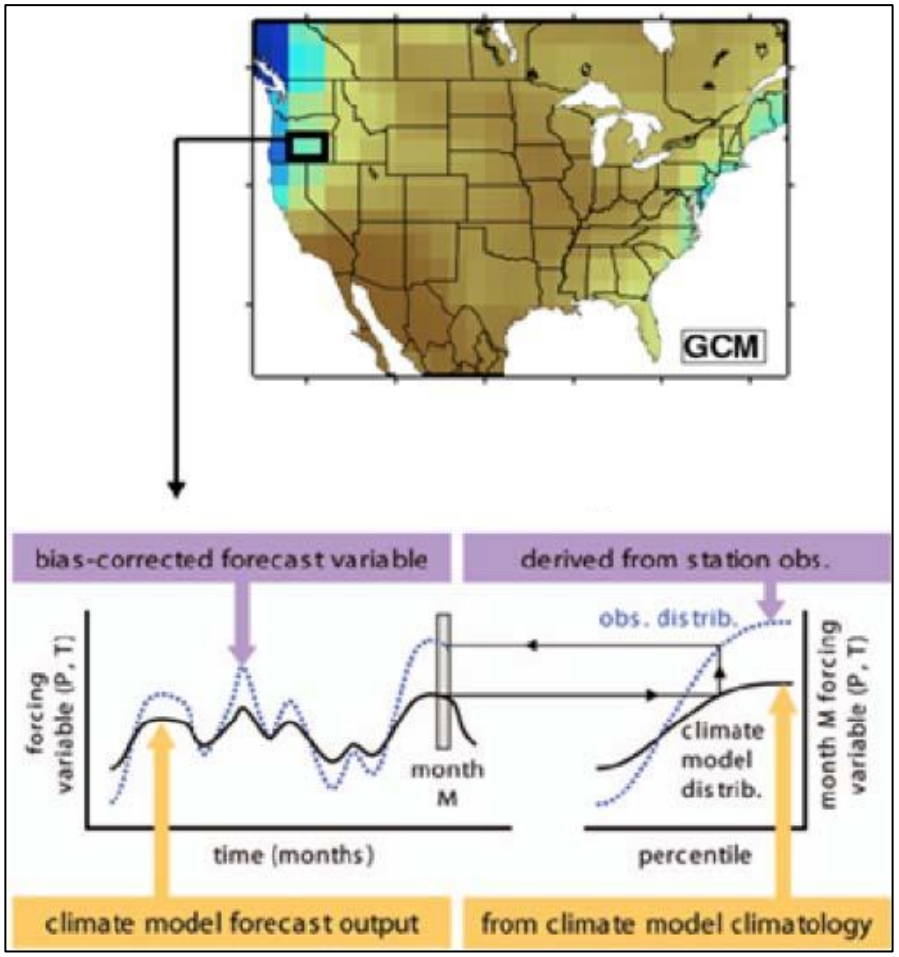
- Team
  - PI Leads: Brian Beckage, Jonathan Winter, Patrick Clemins
  - Students: GRA #8, GRA #9
- Sample Activities
  - Update forests across landscape (LPJ-GUESS) in response to regional climate
  - Incorporate updated urban landscape
  - Update WRF projections of regional climate in response to changed albedo and moisture fluxes
  - Support climate projections for downstream applications
  - IAM handles feedbacks between regional climate and other system components
- Facilities
  - Cheyenne (NCAR)
  - Babbage/Leibnitz (UVM)

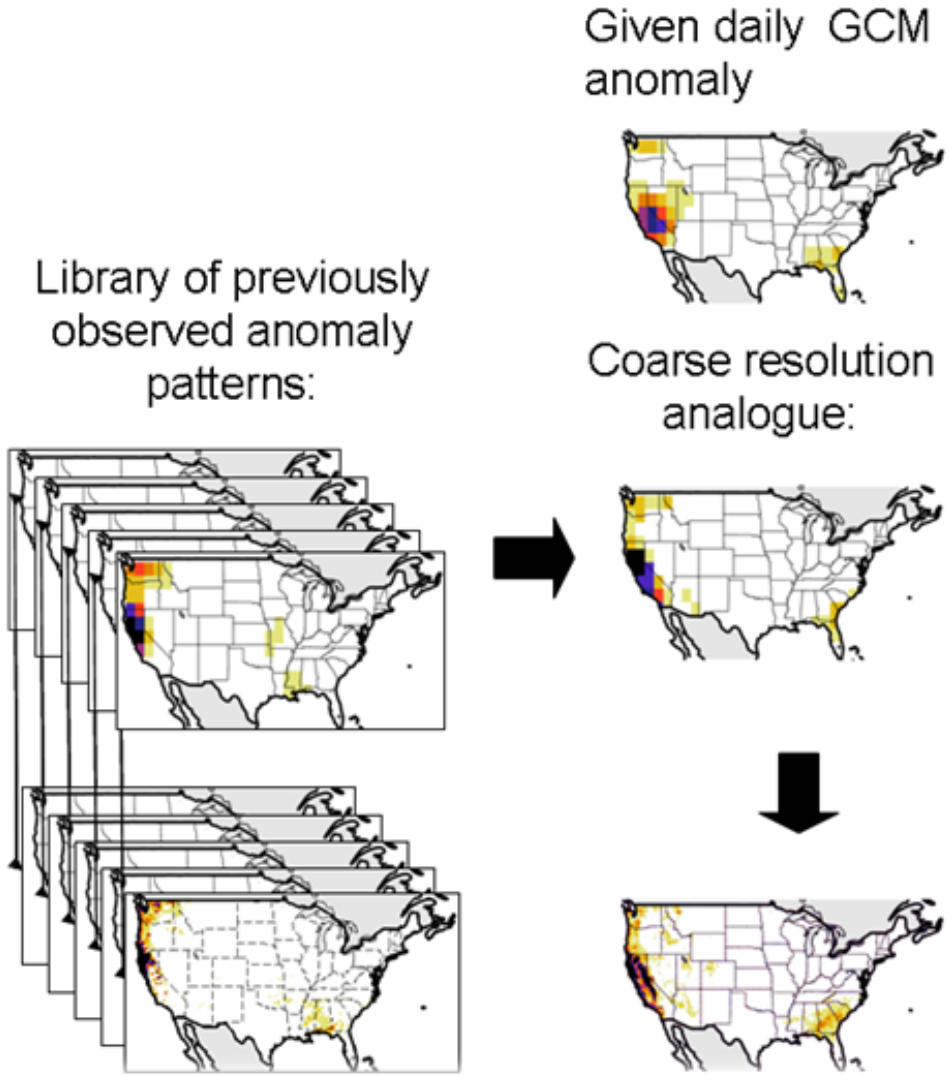


Pegasus Downscaling Workflow for Integration with IAM



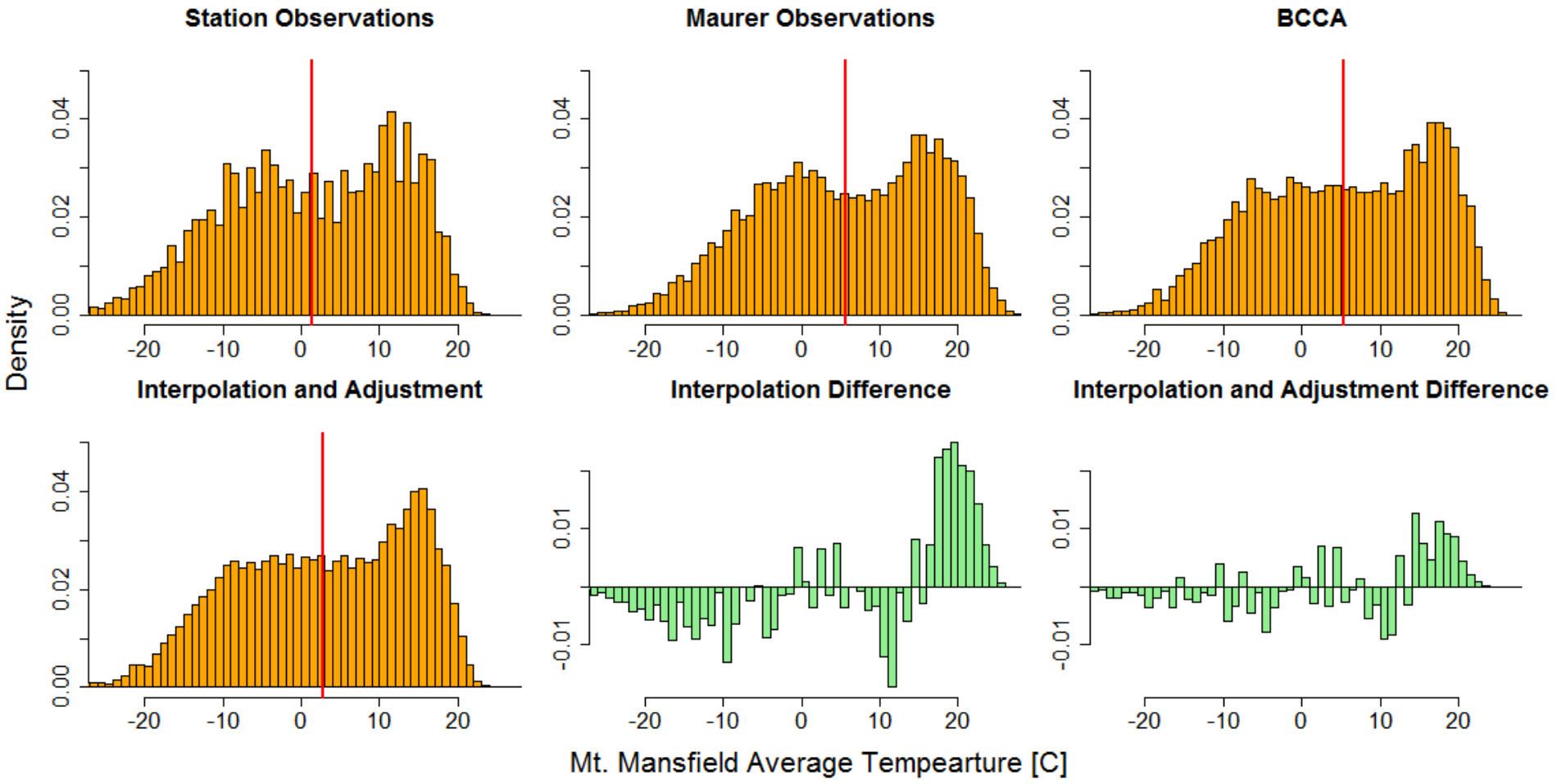
Bias Correction Using Constructed Analogs (BCCA)





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

Very High Resolution Output: Mt. Mansfield Temperature Histograms



Station: 1.3 °C; Interpolation: 5.4 °C; Interpolation and Adjustment: 2.8 °C