Climate Team: Background, Approach, and Progress

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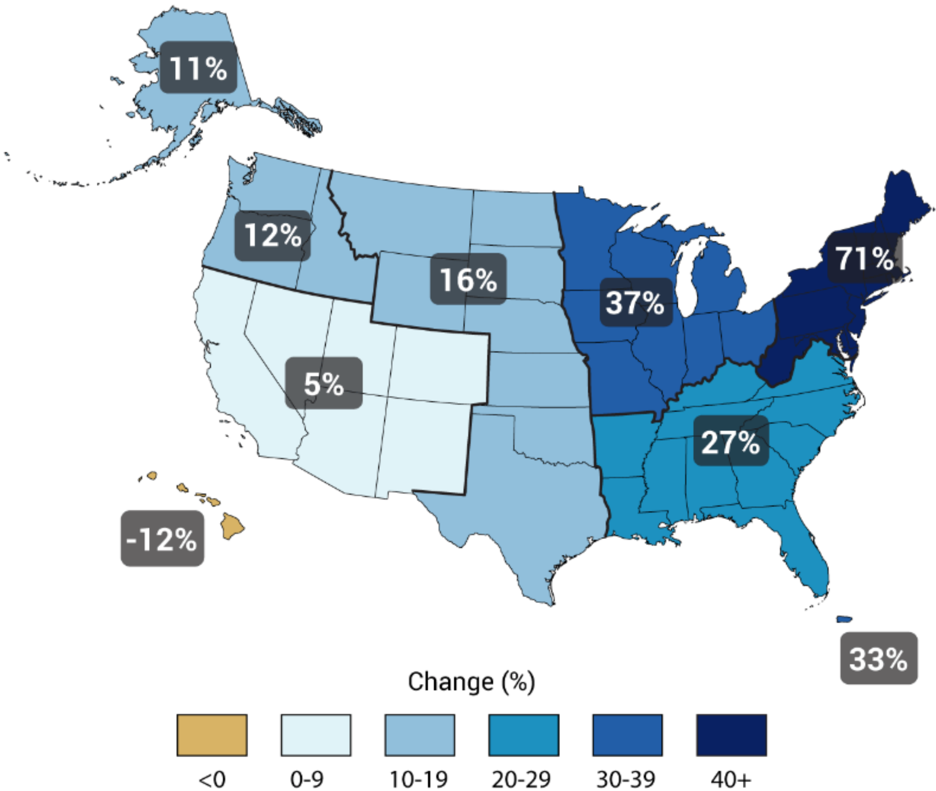
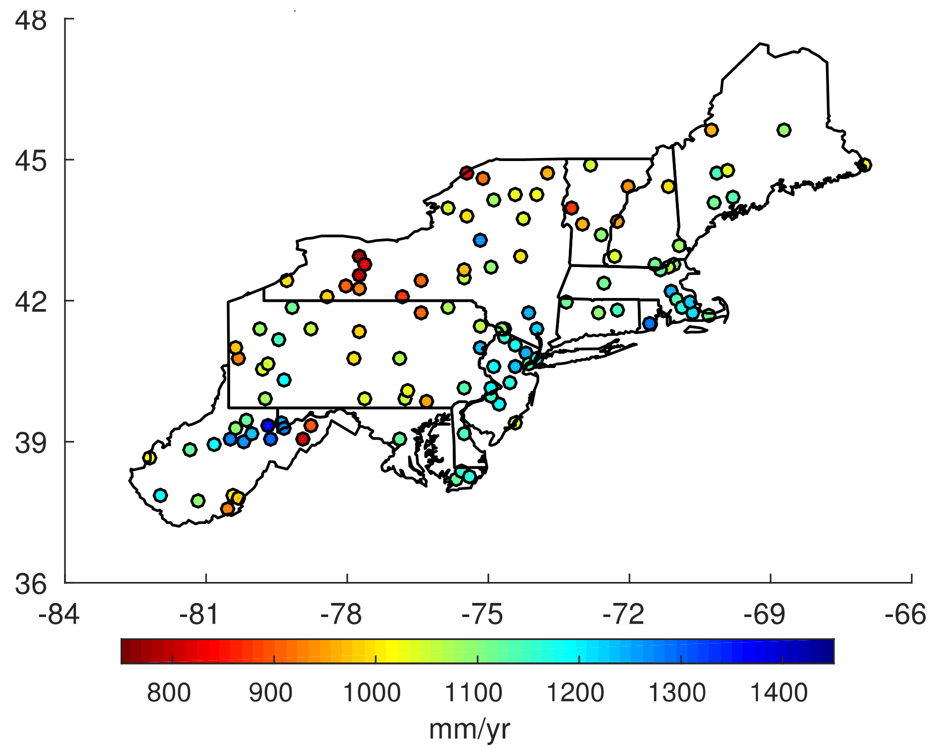
Northeast Extreme Precipitation Events Have Increased Dramatically 1960-Present

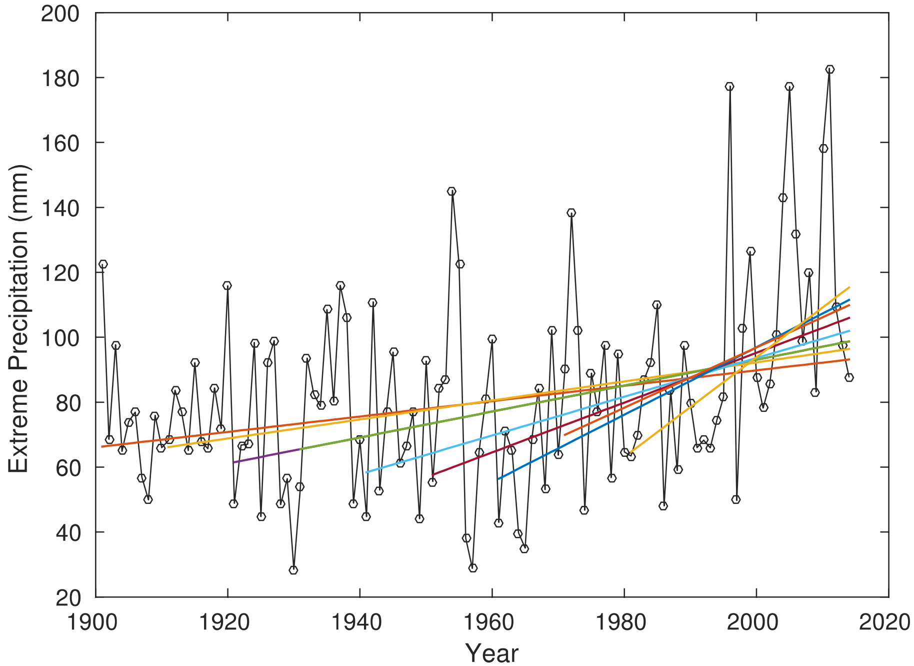


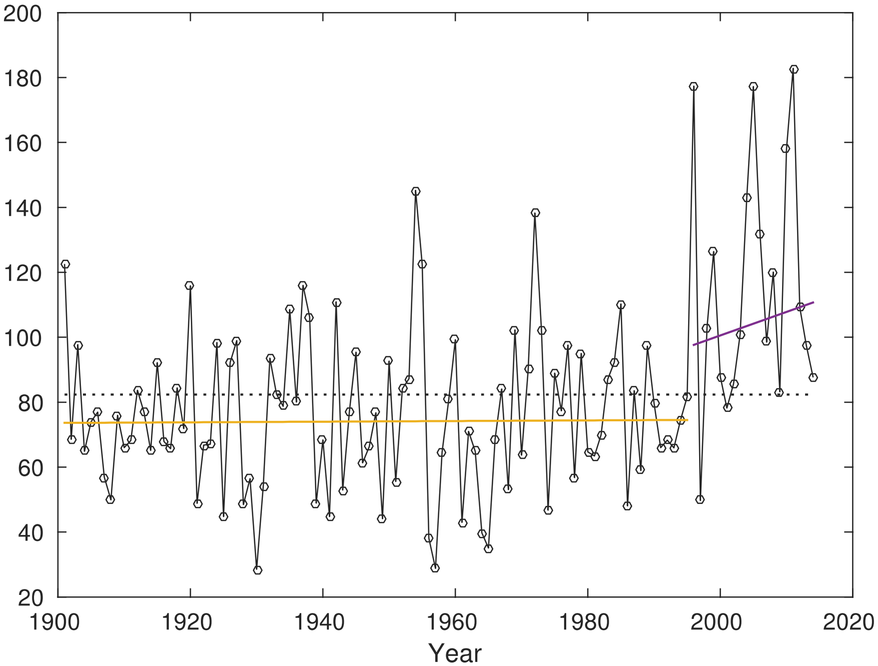


USGCRP, 2014; Huang et al., 2017

Trends Sensitive to Start Year, Changepoint Analysis Better Characterizes Time Series

- Trends generally increasing with later start year: 2.4 mm decade^{-1} (1901-2014) to 14.7 mm decade^{-1} (1979-2014)
- Extreme precipitation increase 1958-2012 using NCA methodology: 69%
- Change in extreme best characterized as a shift in 1996: 53%

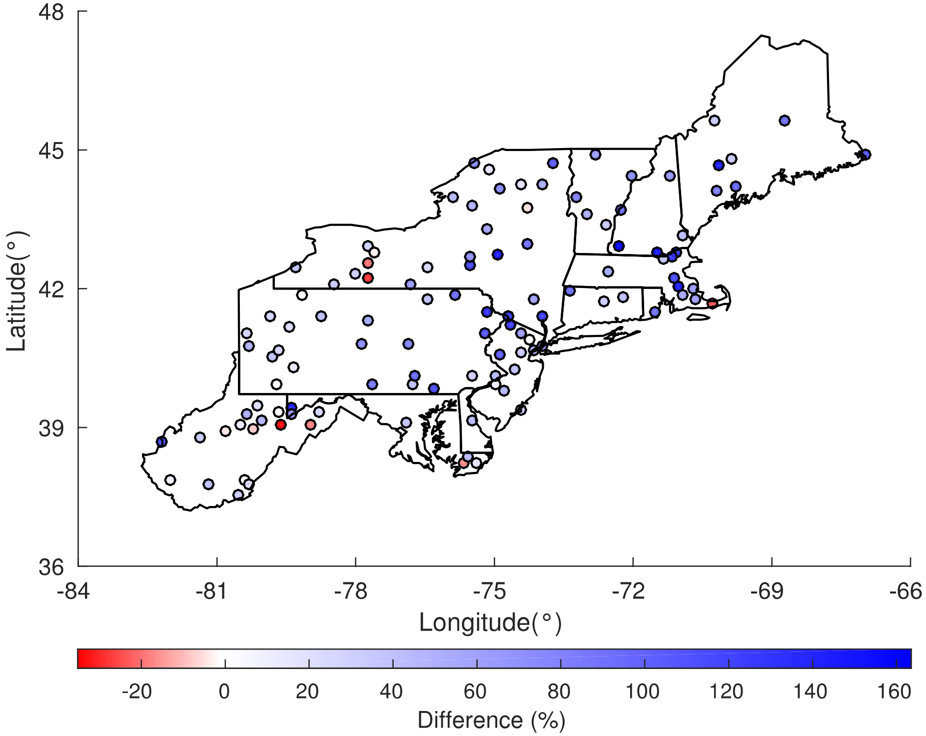




Huang et al., 2017

Extreme Precipitation: Difference between 1996-2014 and 1901-1995

- Annual extreme precipitation (%) was higher in 105 stations (91%) after 1996, with 56 stations exceeding a 50% increase
- Decreases east of Lake Erie (western New York and Pennsylvania) and northeast West Virginia
- Qualitatively consistent with trend analysis



Huang et al., 2017

Large Spring and Winter Trends; Shift Driven by Spring and Fall

- Trends are particularly large over 1979–2014 across all seasons
- Seasonal contributions to the annual extreme precipitation shift in 1996 dominated by increases in spring (83% higher) and fall extreme precipitation (85% higher)
- Winter and summer extreme precipitation are 45% and 27% higher, respectively, after 1996
- Fall extreme precipitation contains a changepoint in 1995

	Units	1901–2014	1915–2011	1979–2014
Spring				
Mean	mm yr^{-1}	18.1	17.7	25.1
Trend	mm $decade^{-1}$	0.8#	1.2#	4.1
Trend	% $decade^{-1}$	6.4	10.2	23.2
Summer				
Mean	mm yr^{-1}	22.9	23.0	25.0
Trend	mm $decade^{-1}$	0.2	0.1	2.5
Trend	% $decade^{-1}$	0.9	0.6	12.4
Fall				
Mean	mm yr^{-1}	21	21.8	26.7
Trend	mm $decade^{-1}$	0.6	0.8	3.5
Trend	% $decade^{-1}$	3.4	4.8	17.1
Winter				
Mean	mm yr^{-1}	15.1	15.0	17.3
Trend	mm $decade^{-1}$	0.5#	0.9#	3.8#
Trend	% $decade^{-1}$	4.3	8.3	35.3

Huang et al., 2017

Climate Team Goals

1. Determine how the frequency, intensity, and spatial scale of extreme weather events will change this century
2. Identify what local climate feedbacks will evolve through altered surface reflectance and moisture fluxes
3. Incorporate climate scenarios into the Integrated Assessment Model
4. Increase the size of the Vermont STEM workforce by integrating students and teachers into research

Global Climate Models (GCMs)

- GCMs solve the primitive equations (conservation of momentum, mass, and energy) to predict fluid flow on a spherical surface
- Global spatial coverage, but coarse resolution and contain significant inaccuracies at local scale
- Basis of Intergovernmental Panel on Climate Change Fifth Assessment Report (IPCC AR5)

Regional Climate Models (RCMs)

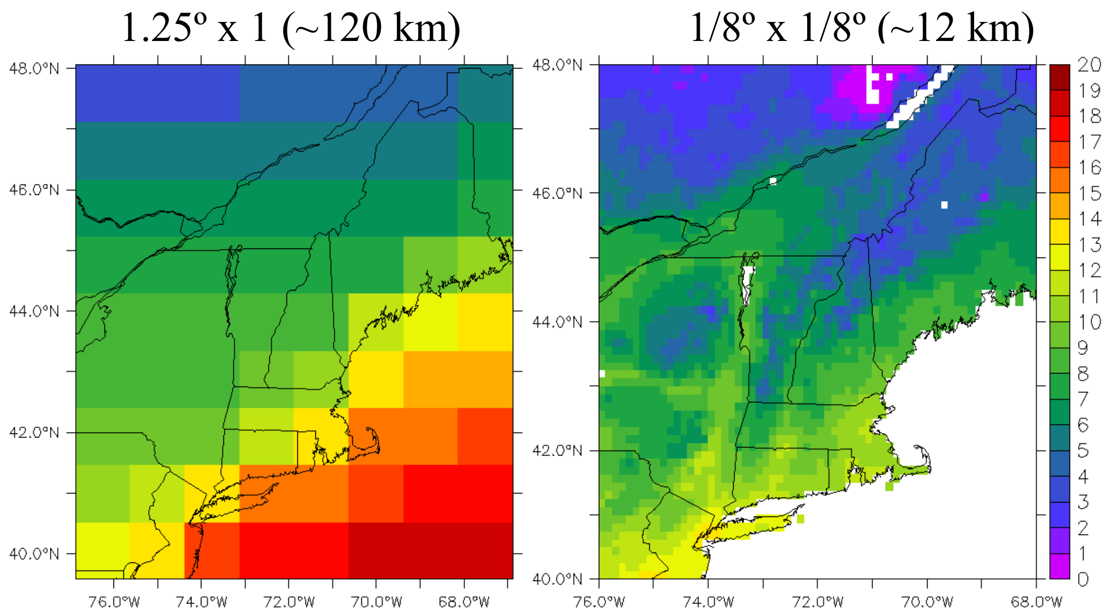
- RCMs are weather forecast models adapted to run at longer temporal scales or GCMs adapted to run at finer spatial scales
- High resolution, but limited spatial coverage, bounded by a large-scale atmospheric forcing generally provided by a GCM or reanalysis and can contain significant inaccuracies from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

BREE Climate Team Approach

1a. Deploy, calibrate, and evaluate a regional climate model (Weather Research and Forecasting Model; WRF)
1b. Refine WRF to better capture extreme events
2a. Use WRF forced with future GCM data to determine feedbacks
3a. Work with Integration Team to include WRF climate scenarios in the IAM
4a. Contribute to summer intern program, which provides research training experiences to undergraduates

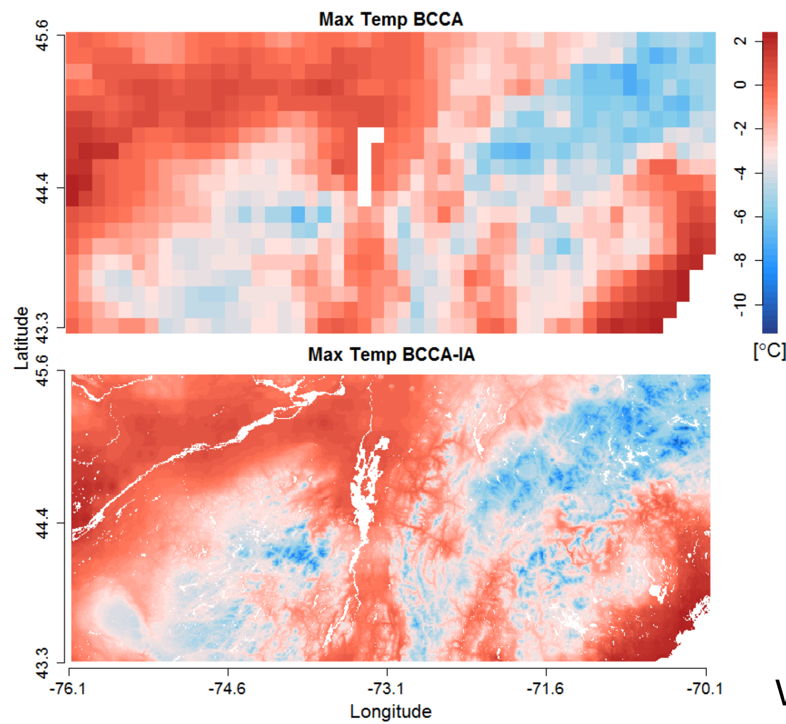
Deploy, Calibrate, and Evaluate a Regional Climate Model (WRF)

- Team
  - PI Leads: Jonathan Winter, Brian Beckage, Janel Hanrahan
  - Students: Huanping Huang (Dartmouth), Maike Holthuijzen (UVM)
- Key Activities
  - Deploy, calibrate, and evaluate WRF forced with reanalysis (WRF-REA)
  - Setup and evaluate WRF forced with historical GCM data (WRF-HIS)
  - Create downscaled climate projections using WRF forced with future GCM data (WRF-FUT)
- Facilities
  - Discovery (Dartmouth)
  - Cheyenne (NCAR)



Refine WRF to Better Capture Extreme Events

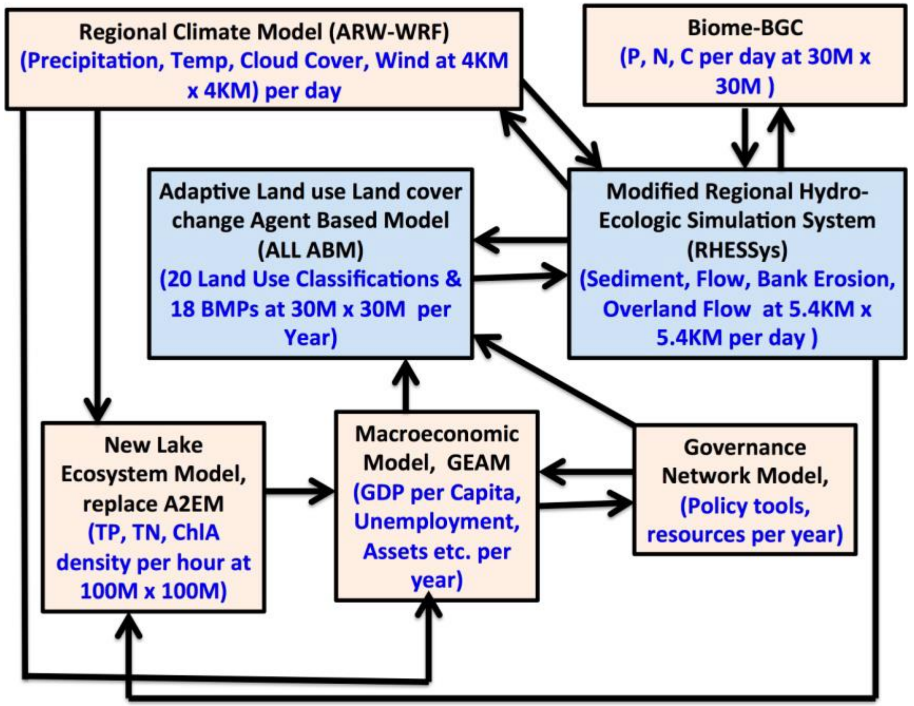
- Team
  - PI Leads: Brian Beckage, Jonathan Winter, Janel Hanrahan
  - Students: Maike Holthuijzen, Huanping Huang
- Key Activities
  - Apply bias correction to WRF simulations
  - Employ Extreme Value Theory (EVT)
- Facilities
  - Babbage (UVM)
  - Cheyenne (NCAR)



Winter et al., 2016

Include WRF Climate Scenarios in the IAM

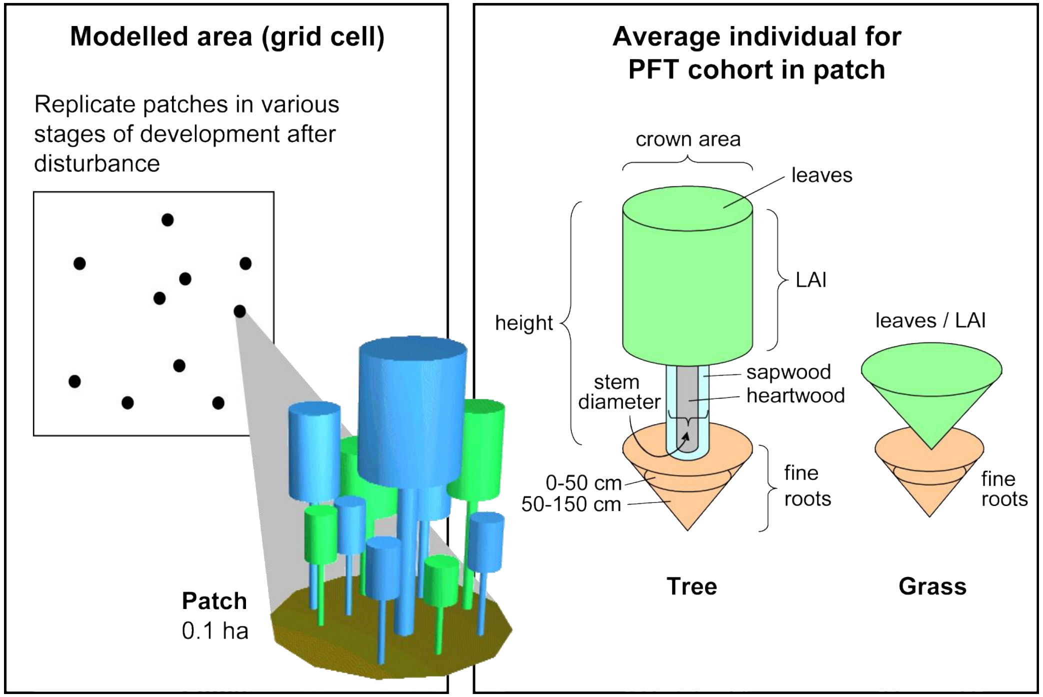
- Team
  - PI Leads: Patrick Clemins, Asim Zia, Brian Beckage, Jonathan Winter
  - Students: IAM Student/Postdoc, Maike Holthuijzen
- Key Activities
  - Climate scenario integration with IAM component models
  - Support climate projections for downstream applications
- Facilities
  - Babbage (UVM)
  - Leibnitz (UVM, raccfs)
  - Cheyenne (NCAR)



Zia et al., 2016

Identify Local Climate Feedbacks using WRF Projections

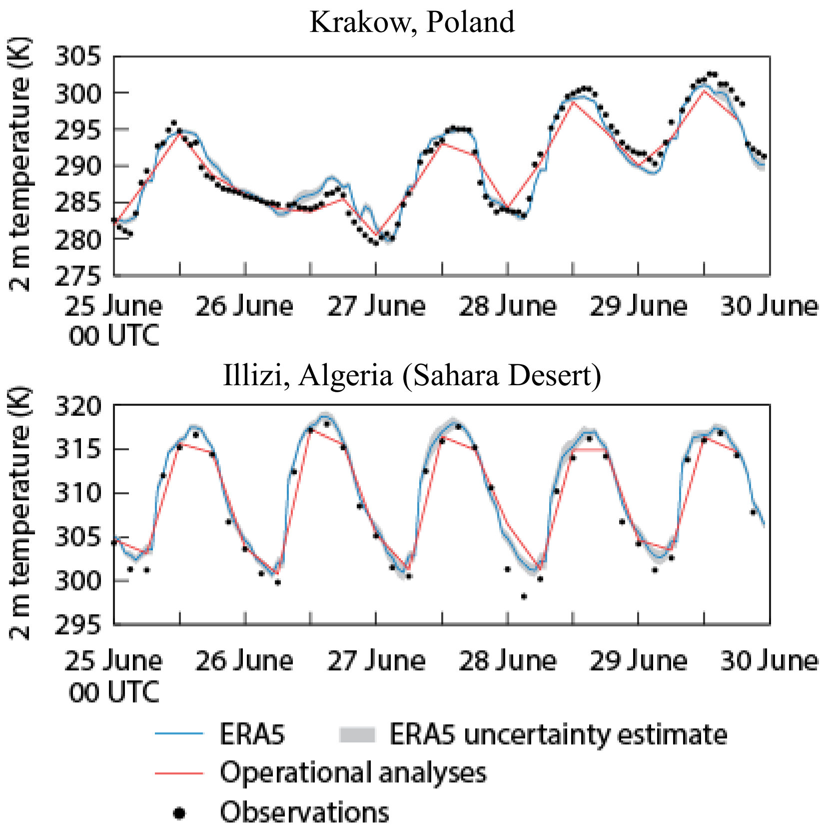
- Team
  - PI Leads: Brian Beckage, Patrick Clemins, Jonathan Winter
  - Students: Maike Holthuijzen, Huanping Huang
- Key Activities
  - Implement a dedicated forest model to add specificity to forested land use change in IAM and WRF simulations
  - Evaluate local climate feedbacks due to projected albedo and vegetation change
- Facilities
  - Cheyenne (NCAR)
  - Babbage (UVM)



Smith et al., 2014

ERA5 Regional Precipitation Analysis

- Team
  - PI Leads: Arne Bomblies, Lesley-Ann Dupigny-Giroux, Alan Betts
  - Students: Caitlin Crossett
- Key Activities
  - ECMWF Reanalysis 5: in production, 1979-present (by 2018 have 40yrs), 2010-2016 available this summer, 0.25 x 0.25 spatial resolution, hourly temporal resolution
- Facilities
  - Leibnitz (raccfs)
  - Workstations



ECMWF, 2016

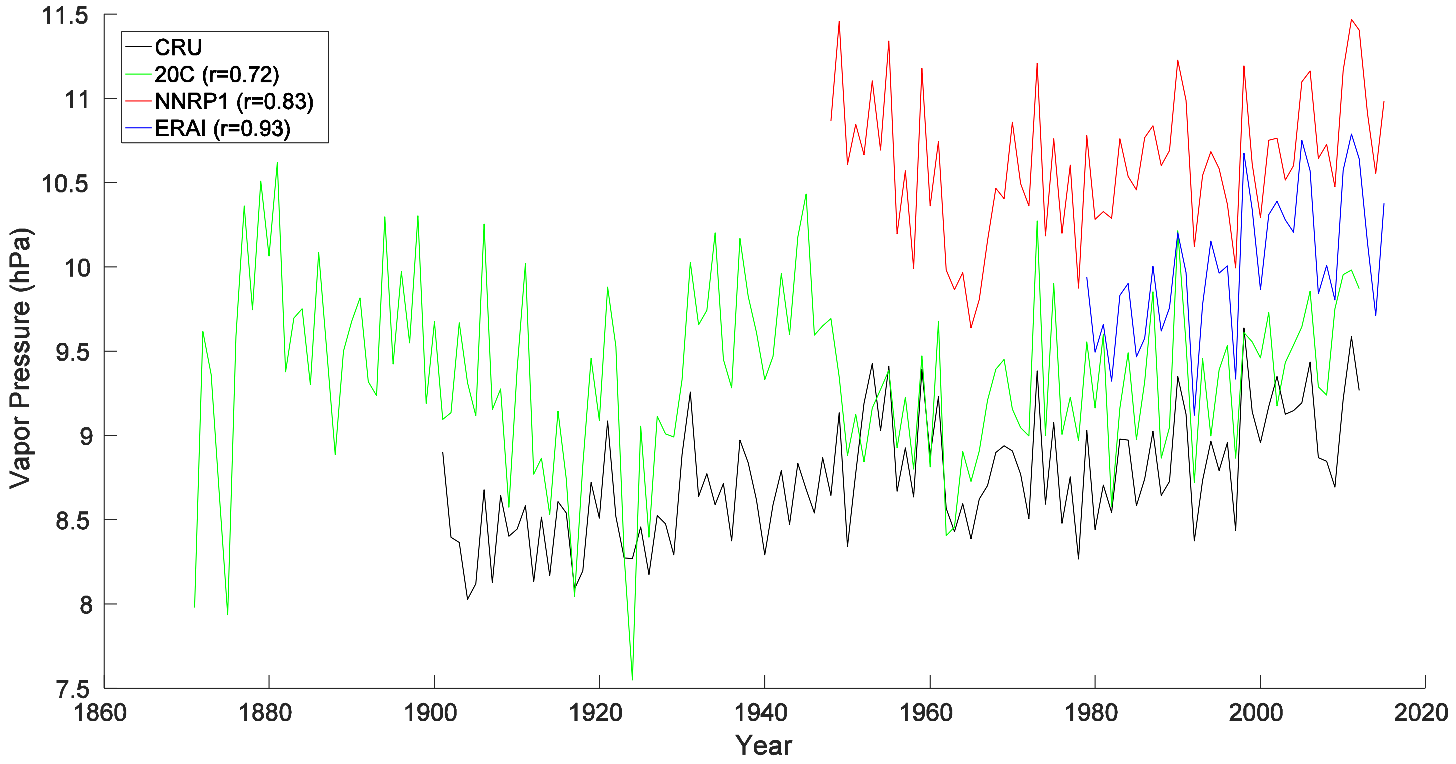
BREE Climate Team Progress

1a. Deploy, calibrate, and evaluate a regional climate model (Weather Research and Forecasting Model; WRF)

4a. Contribute to summer intern program, which provides research training experiences to undergraduates

Deploy, Calibrate, and Evaluate a Regional Climate Model (WRF)

- Select reanalysis dataset to use for WRF-REA (e.g. ERA, NCEP/NCAR, NARR); Obtain/reformat reanalysis data
  - ERA-I, NCEP-NCAR R1, NCEP-DOE R2, NOAA 20C, and NARR evaluated
  - ERA-I selected based on humidity, precipitation, and temperature against CRU gridded observations; temporal/spatial attributes

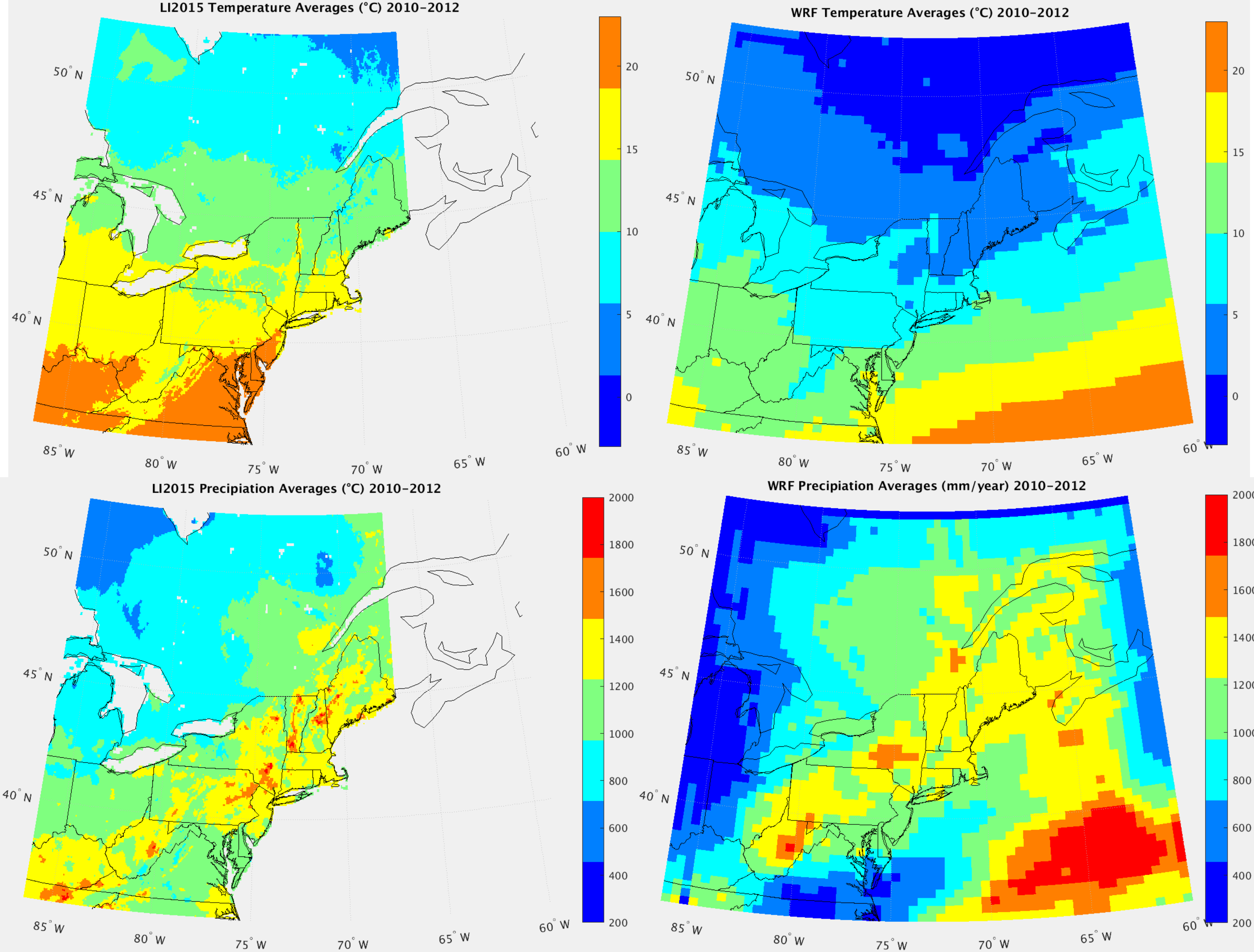


Deploy, Calibrate, and Evaluate a Regional Climate Model (WRF)

- Start calibration of WRF forced with reanalysis (WRF-REA) e.g., adjust domain size, resolution, number of nests, and land surface and convective parameterizations
- Continue calibration of WRF-REA

Contribute to Summer Undergraduate Intern Program

- Team
  - PI Leads: Janel Hanrahan, Tania Bacchus, Brian Beckage, Jonathan Winter, Patrick Clemins
  - Students: Maike Holthuijzen, Huanping Huang
- Key Activities
  - Develop realistic, manuscript relevant, conference presentable summer research projects
  - Create cross-campus interactions
  - Intern class 2017: Johnson State College – Harris Eidelman, Ilán Nieves Gómez; Lyndon State College - Ben Frechette, Kevin Ziegler


LI2015 Temperature Averages (°C) 2010-2012
WRF Temperature Averages (°C) 2010-2012
LI2015 Precipiation Averages (°C) 2010-2012
WRF Precipitation Averages (mm/year) 2010-2012
50° N
45° N
40° N
85° W
80° W
75° W
70° W
65° W
60° W
0
5
10
15
20
200
400
600
800
1000
1200
1400
1600
1800
2000