SSP-Based Land Use Change Scenarios: A Critical Uncertainty in Future Regional Climate Change Projections

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Framework for Assessing Climate's Energy-Water-Land Nexus using Targeted Simulations

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Introduction

- In many instances, future regional climate simulations are produced assuming the current spatial distribution of different land covers will stay the same, even for long-term futures. This neglects the potential impacts of human land-use change (LUC) on regional climate.
- Does the inclusion of plausible [Shared Socioeconomic Pathway (SSP) consistent] future agricultural and urban LUC significantly modulate RCM projections?
- What is the magnitude of climate change produced by scenario-based anthropogenic LUC versus that forced by greenhouse gas (GHG) change?

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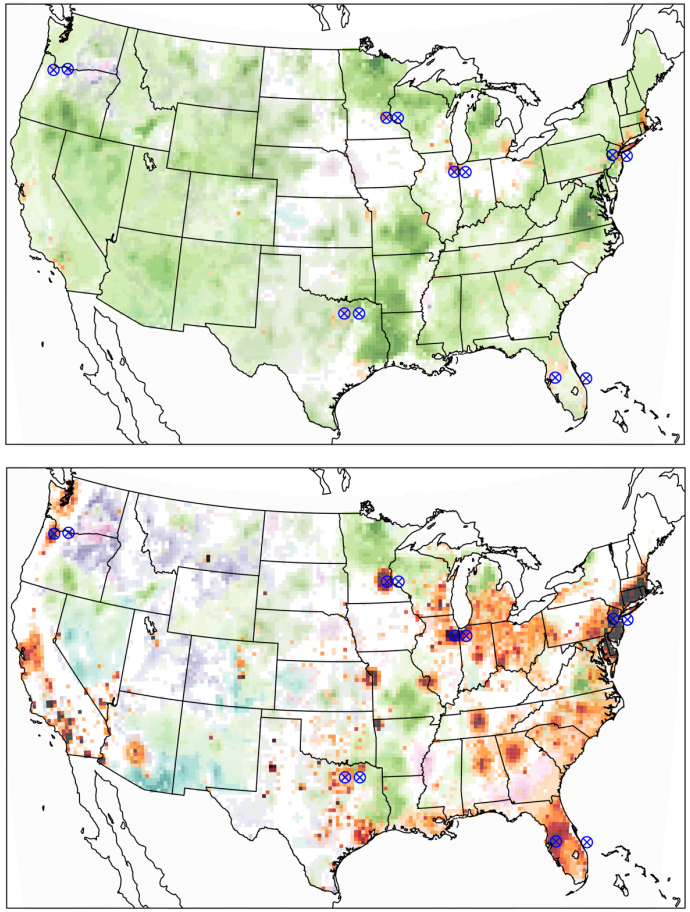
Methods

- WRF
  - 25km NA-CORDEX Configuration
  - NOAH LSM, USGS land-cover
  - Driving GCM: MPI-ESM-LR
  - Historical: 1980-2005
  - Future: 2075-2100
- Future scenarios
  - RCP8.5+SSP3
  - RCP8.5+SSP5
- Urban Land Use Model
  - Gao & O'Neill 2019
  - https://doi.org/10.1016/j.envsoft.2019.06.015
- Agricultural LU Model
  - Meiyappan et al. 2014
  - https://doi.org/10.1016/j.ecolmodel.2014.07.027

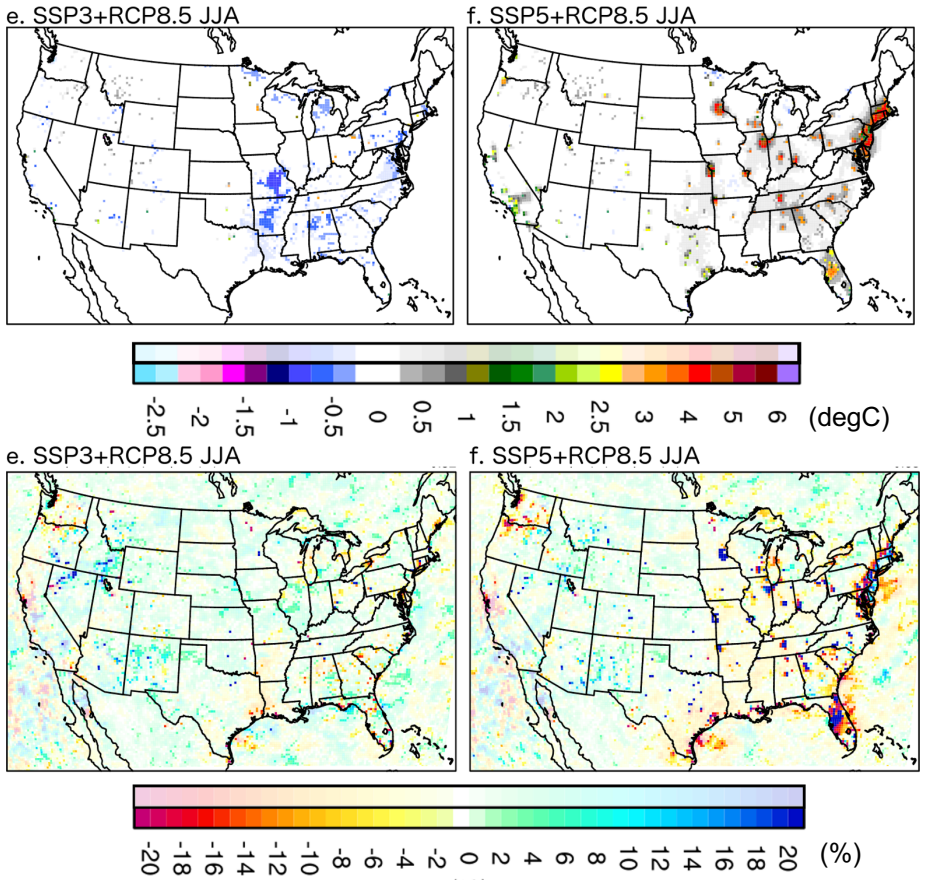


Absolute change in fractional land use from the historical period to the future in WRF under SSP3+RCP8.5 (top) and SSP5+RCP8.5 (bottom).

SSP3 = large crop change
SSP5 = large urban change

Key Results

- Additional warming over urban centers due to urbanization alone is on par with the warming due to GHG-forced climate change alone.
- Projections for mean temperature are up to 4-5℃ greater in JJA in urban centers.
    - In SSP5+RCP8.5 this additional warming is not limited to urban centers; projected temperature increases are up to 0.25-0.75 ℃ greater between them in the eastern half of the U.S. in JJA
- Crop expansion at the expense of forest yields cooling.
- Precipitation is enhanced over eastern U.S. urbanized areas in the warm-season, especially in SSP5+RCP8.5
    - Intensity of precipitation events increases, but also their length.
    - This has potential implications for projections of socio-environmental challenges like urban flooding.
- Precipitation is suppressed around the urbanized areas.
- Overall, this work suggests that for a more complete exploration of uncertainty in future regional climate projections, land-use changes that underlie the SSP+RCP framework should be considered and not just the GHG concentration scenarios.



Difference in JJA projections using SSP-based future LUC scenarios versus using the no-LUC future scenario. Top: temperature, bottom: precipitation. Differences that are not statistically significant follow the faded colorbars.

Research Needs/Future Opportunities

- CMIP6 ScenarioMIP simulations incorporate LUC scenarios that are consistent with the SSP+RCP future scenarios. Dynamically downscaled simulations from CMIP6 should potentially include the same LUC scenarios. Best practices for their inclusion need to be explored/developed.
- Explore the sensitivity of simulations to how LUC is incorporated and how LU is represented.
- How do different model configurations and resolutions modify results?
- LUC scenarios at higher resolutions may be necessary.
- Urban land-use model development for additional urban characteristics would increase realism.