Application of an Integrated Modeling System for Climate and Air Quality Change Studies at Regional to Local Scales

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Illinois State Water Survey (1895)
2003-2006

University of Illinois at Urbana-Champaign

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Objective

To quantify, and understand the uncertainties of, the individual and combined impacts of global climate and emission changes on U.S. air quality, from the present to 2050 and 2100.

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Hypothesis

U.S. air quality is determined by complex interactions over a range of spatial and temporal scales from

1) chemical processes and emissions on local to regional scales

2) long-range transport of global pollutants and precursors

3) global and regional climate changes and variability

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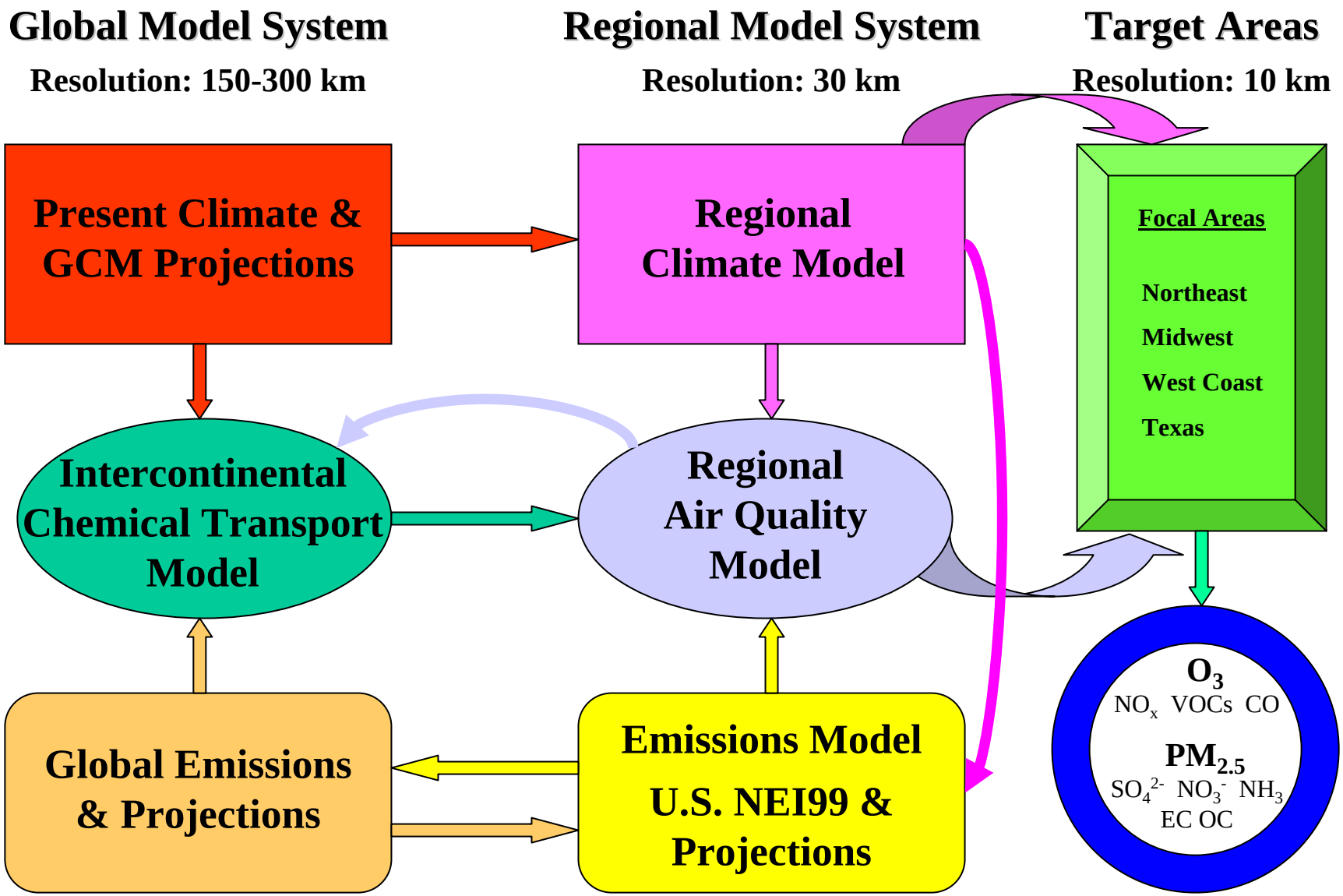
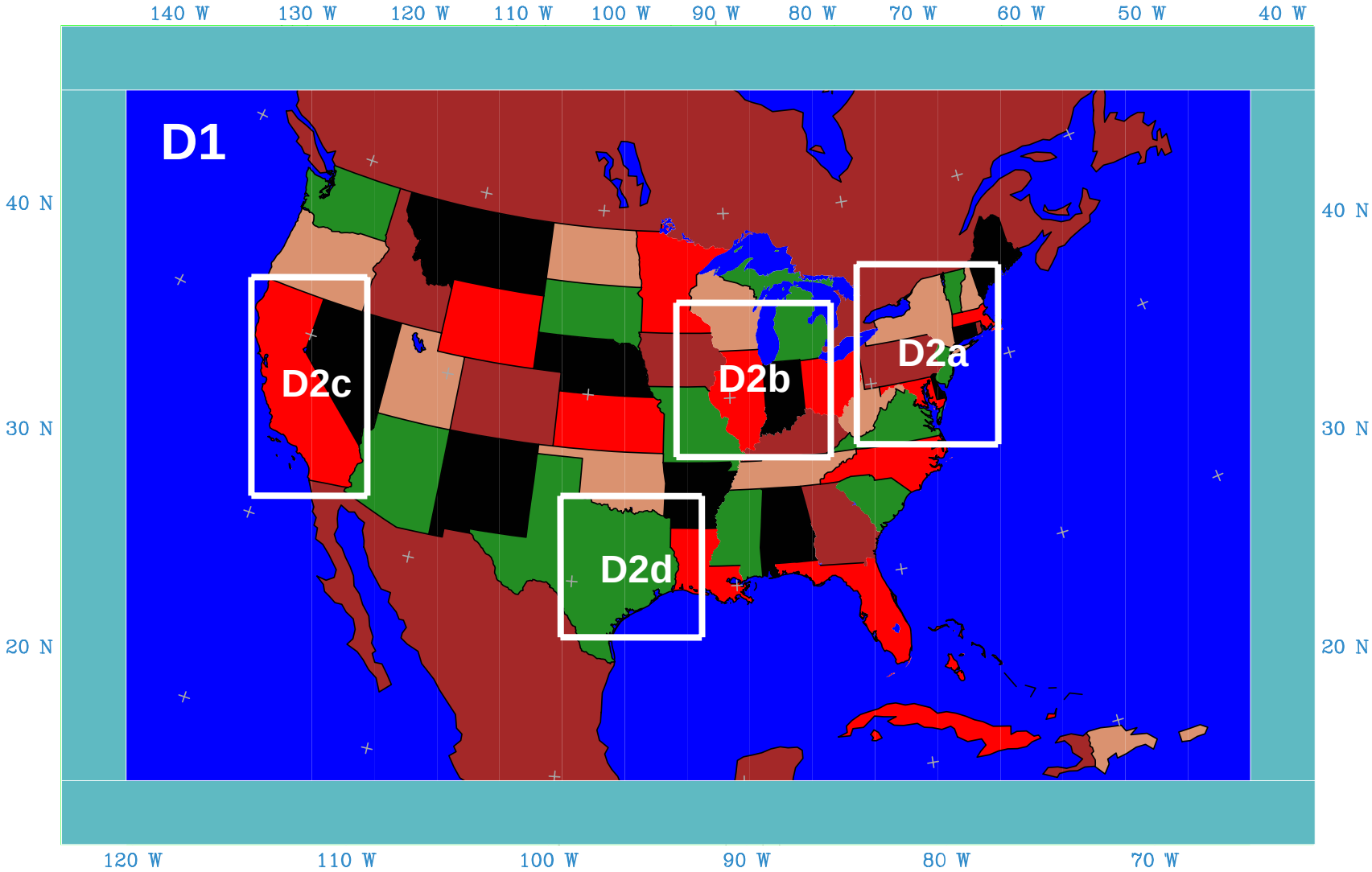


The nested global-regional modeling system: its components and their interactions



Regional computational domain design. The global models provide the regional models with lateral boundary conditions in the buffer zones (shaded outer edges). The climate model uses a grid spacing of 30-km over domain D1, while the air quality model uses 90-km in D1 and 30-km in subdomains D2a-d.

Uncertainty

- Biases in the climate and chemistry arising from the driving global models and the incomplete physics of the regional models
- Different climate sensitivities of the driving global models and the regional models
- Inconsistencies in the coupled global-regional modeling system
- Pollutant emissions error
- Natural variability

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Global Climate Models

- **LOW** climate sensitivity:

  Parallel Climate Model (**PCM**) of the National Center for Atmospheric Research/U.S. Department of Energy

- **HIGH** climate sensitivity:

  Hadley Centre third generation climate model (**HAD**)

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Future Projections

- PCM simulations for 2050 and 2100
  - A1Fi : high emissions scenario
  - B1: low emissions scenario
- HAD simulations for 2100
  - A2: intermediate high emissions scenario
  - B2: intermediate low emissions scenario

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Climate Model Results

The following examples show

- the difference between GCMs in simulating the present climate and projecting future changes
- the effect of the RCM downscaling on regional climate simulations and projections

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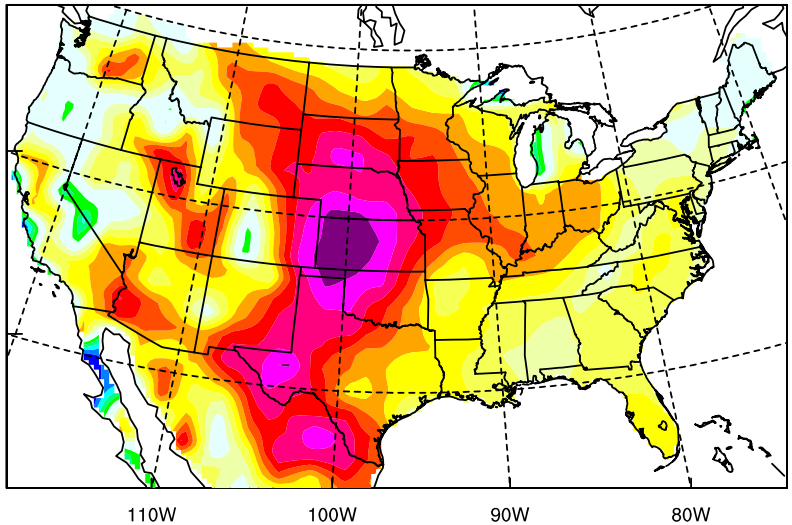
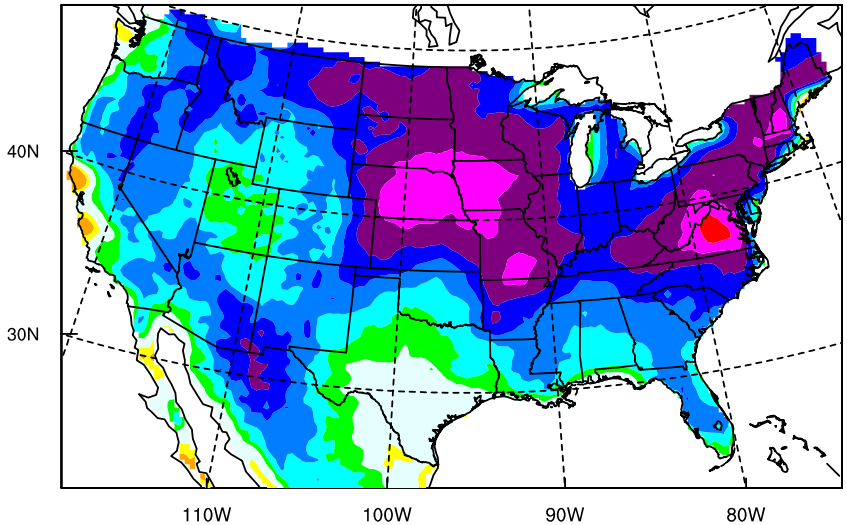
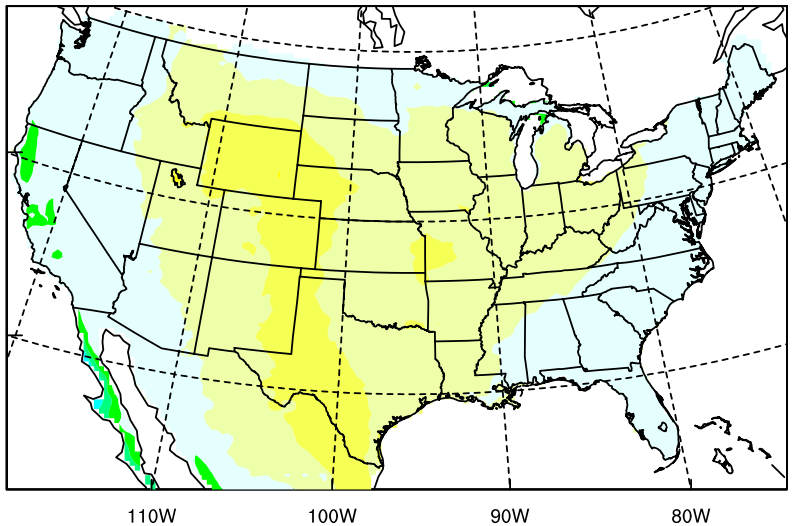
HAD-PCM JJA TA Present (2000) Climate



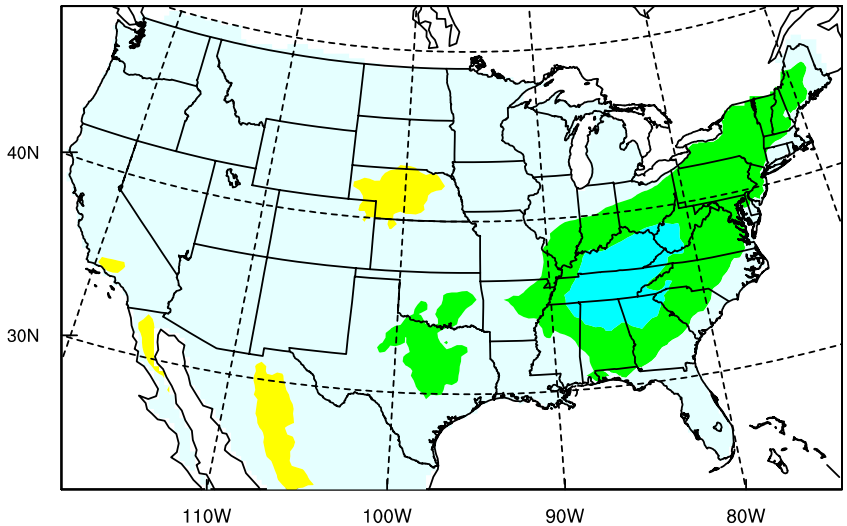
HGR-HAD JJA TA Future (2100) A2 Change



HGR-PGR JJA TA Present (2000) Climate



PGR-PCM JJA TA Future (2100) B1 Change



Summary for Climate Simulations

- GCMs produce substantial regional climate biases and inter-model differences
- RCM downscaling reduces GCM climate biases and inter-model differences
- RCM downscaling projects smaller warming trends, particularly in the central U.S.

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Air Quality Model Results

The following examples show

- the AQM ozone projections for 2100 under different emissions scenarios and incorporating climate changes
- the effect of the RCM climate sensitivity on AQM simulations and projections

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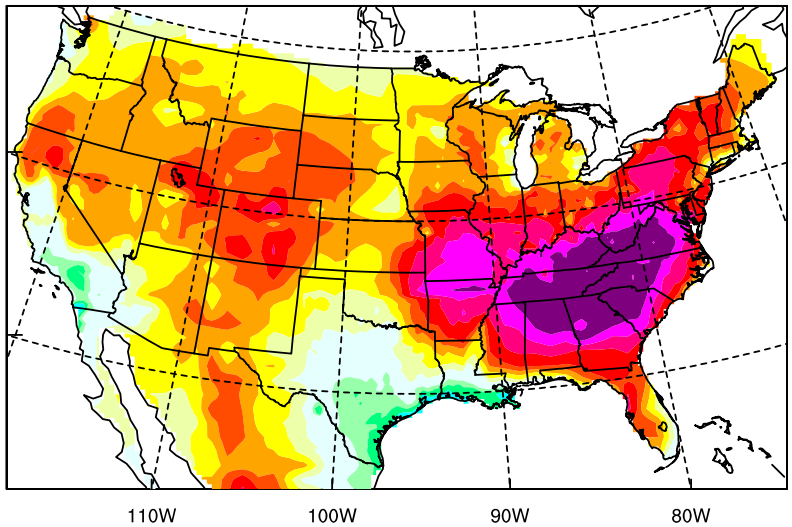
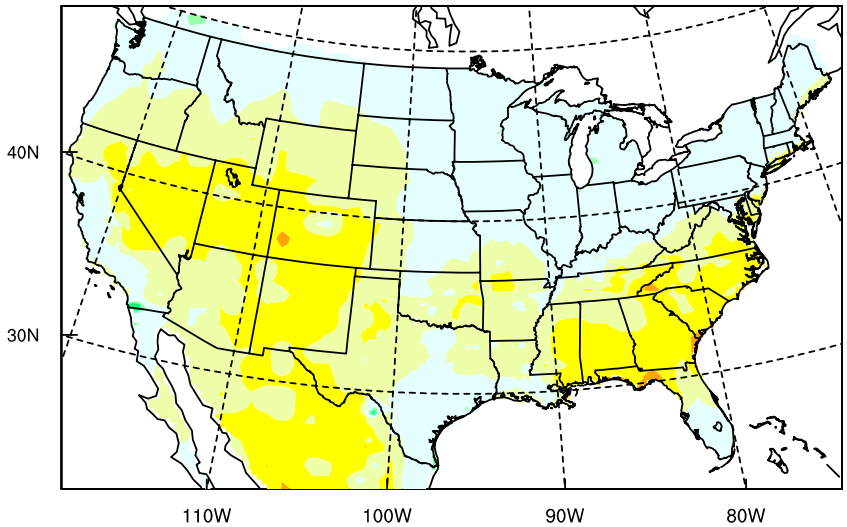
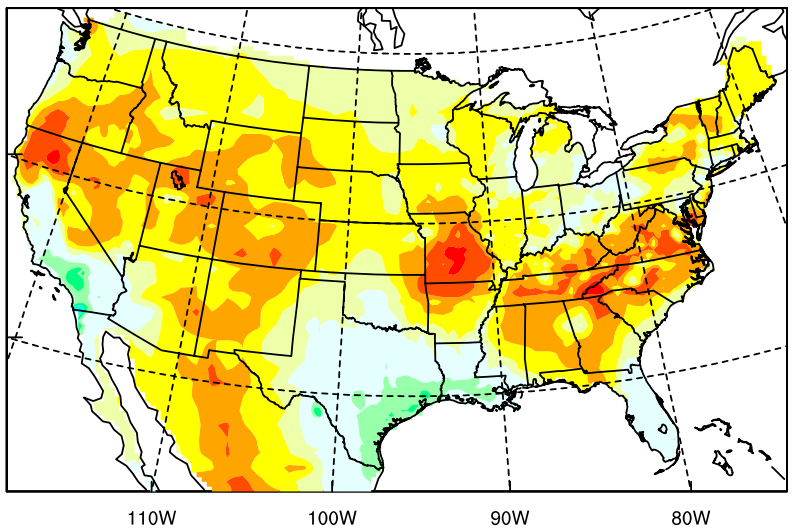
AQM/PKF JJA Ozone Future (2100) A1Fi Change



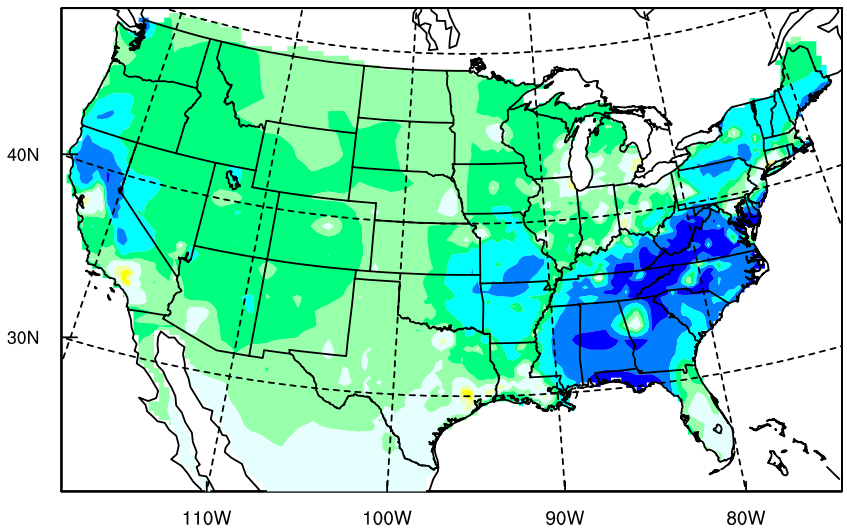
AQM/HGR JJA Ozone Future (2100) A2 Change

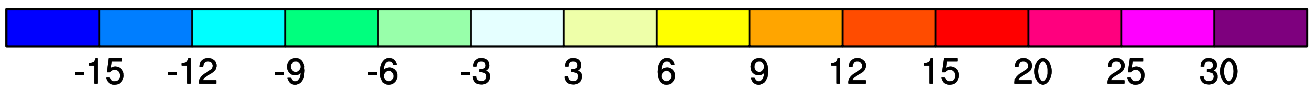


AQM/PGR JJA Ozone Future (2100) A1Fi Change



AQM/PGR JJA Ozone Future (2100) B1 Change





Summary for AQ Simulations

- Ozone concentration depends sensitively on temperature as expected, but this sensitivity is regionally variable
- This sensitivity is particularly high in the Southeast U.S. where the difference between high and low emissions scenarios is pronounced
- If the high emissions scenarios are realized in the future, the Southeast U.S. may have a difficult time meeting the NAAQS O_3 standard as a result of substantial O_3 increase due to the *projected* warmer climate and more biogenic VOC emissions

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Overall Regional Uncertainty

The following examples show

- the spread among models of Midwest temperature and ozone biases and future projections under various emissions scenarios
- the sensitivity of ozone temperature-dependence to regional emission changes

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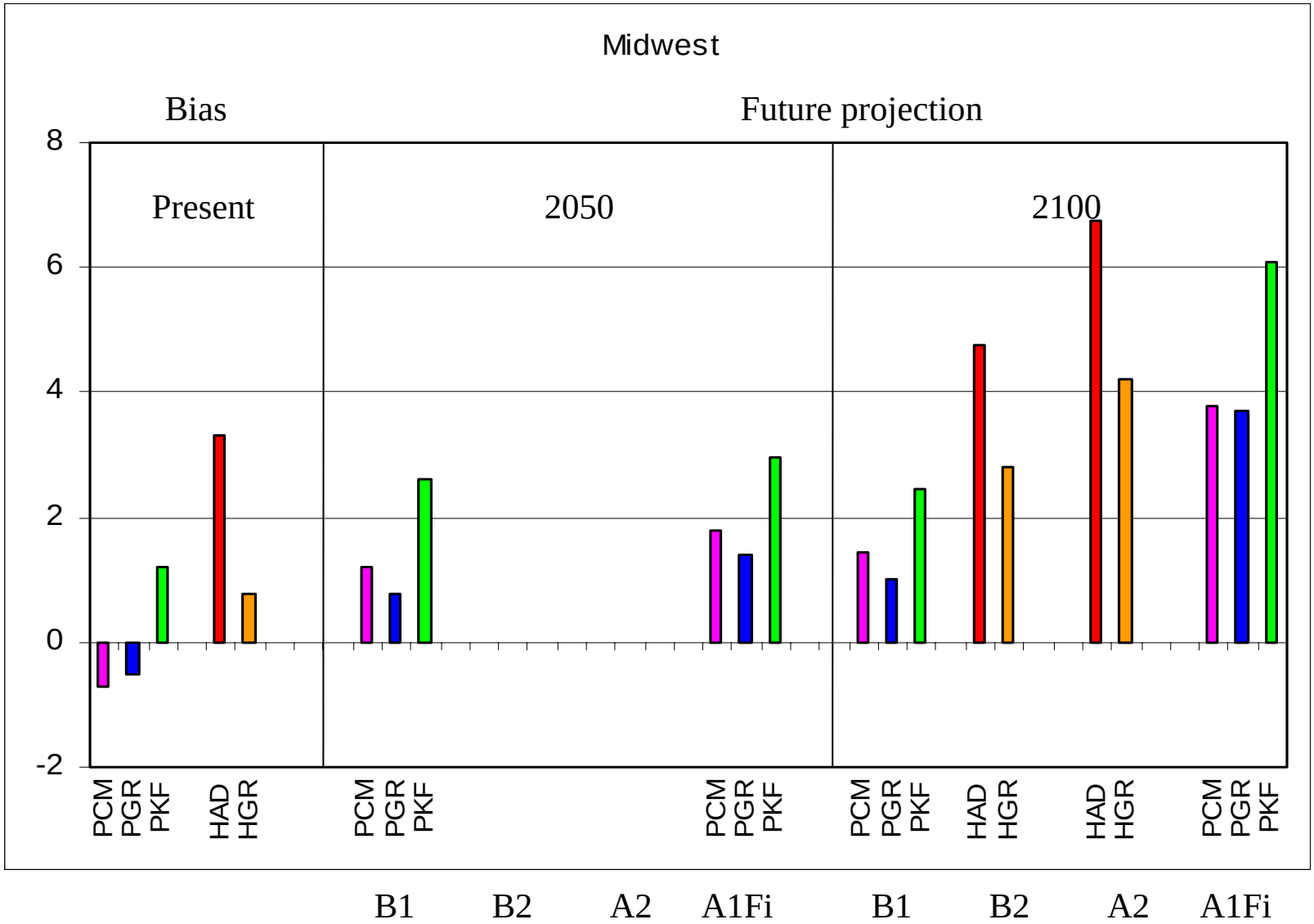
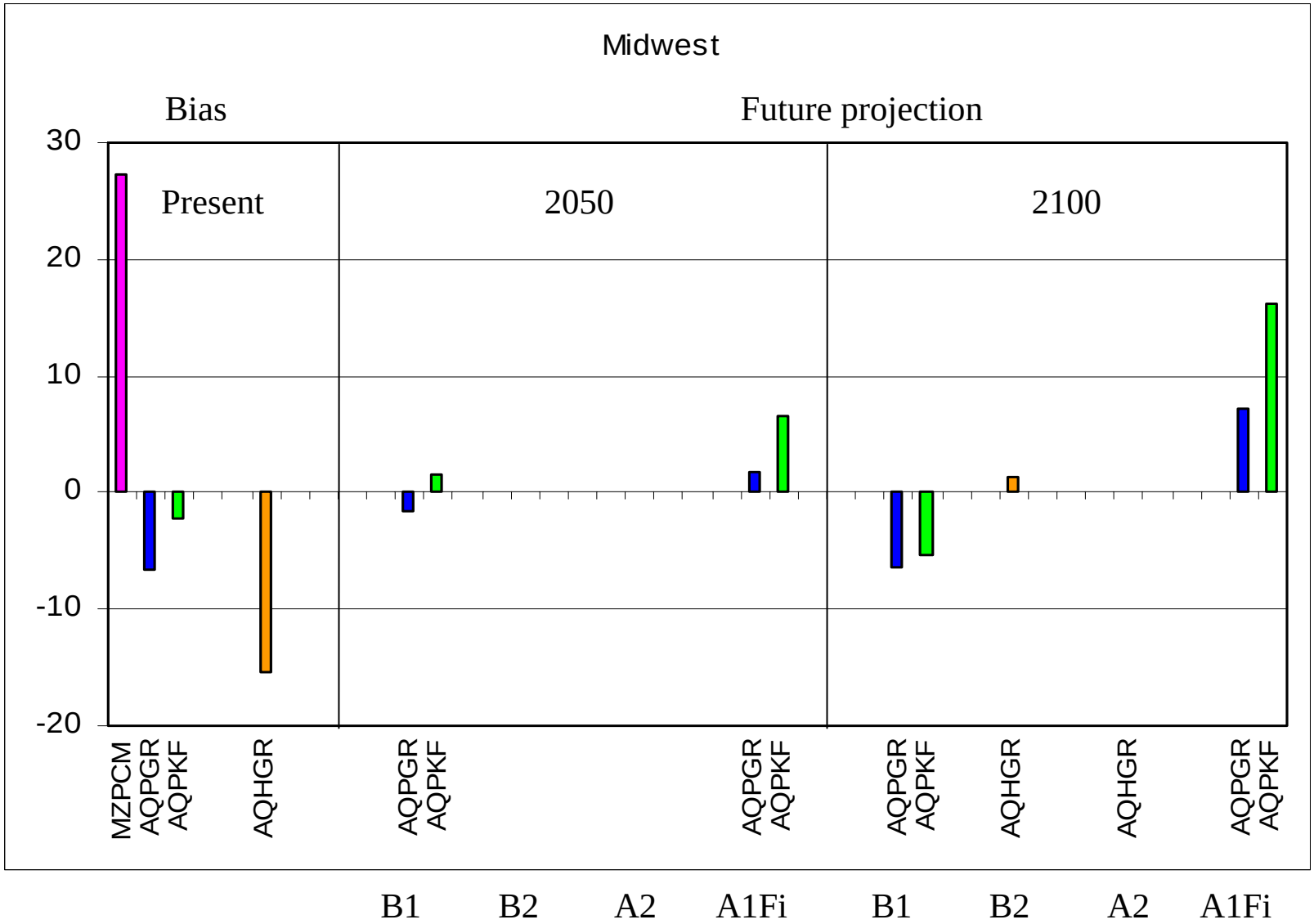
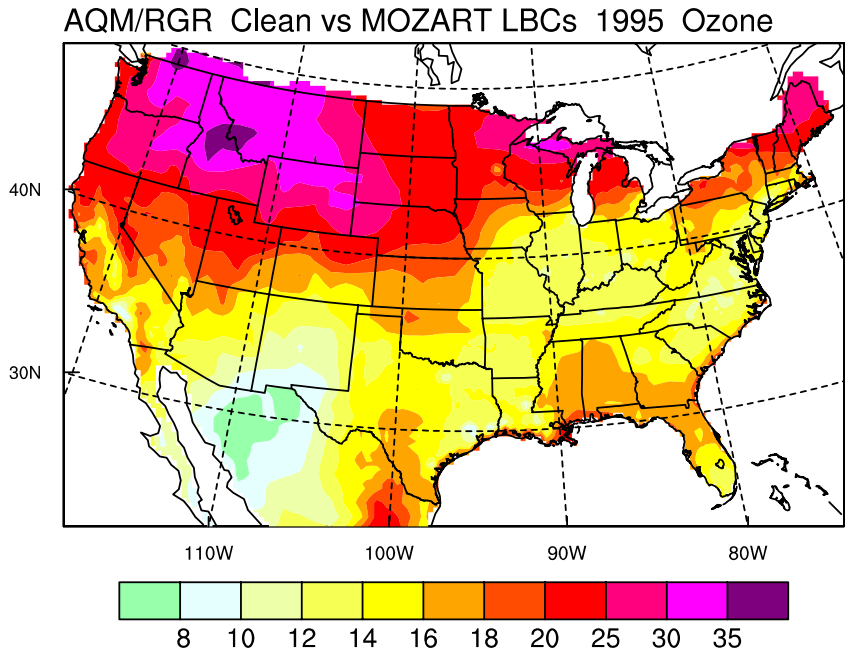


U.S. Midwest regional temperature biases and future projections by GCMs (PCM, HAD) and their downscaling RCMs (GR, KF)



U.S. Midwest regional ozone biases and future projections by GCMs (PCM, HAD) and their downscaling RCMs (GR, KF)

Long-Range Transport Impact on Local-Regional AQ



The chemical LBCs predicted by MOZART cause AQM to produce overall more O_3 than assuming clean air boundaries. The effect is especially large in northwest U.S., where 20-35 ppb more O_3 may result from the long-range transport.

Long-range transport can exacerbate local and regional air quality problems by elevating the background and loading during episodes.

Conclusions

- The regional model downscaling can significantly reduce biases of the driving global models in simulating the present climate/air quality patterns and that this improvement has important consequences for future projections of regional climate/air quality changes.
- For both the present and future climate simulations, the regional model results are sensitive to the planetary forcings imposed by outputs from different global models as well as to its own physical process representations, especially different cumulus parameterizations, with strong regional dependence.

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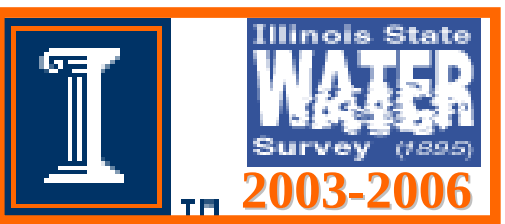
Conclusions

- Due to these sensitivities, there are large uncertainties involved in application of model projections of future climate/air quality changes for decision making at regional to local scales.
- Given significant uncertainties in estimating/projecting surface emissions and important contributions from long-range pollutant transport, decision making on U.S. air quality regulation is challenging.



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