A numerical study of the mechanical and thermodynamic effects of urbanization on the climate of Las Vegas by dynamical downscaling

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Objectives

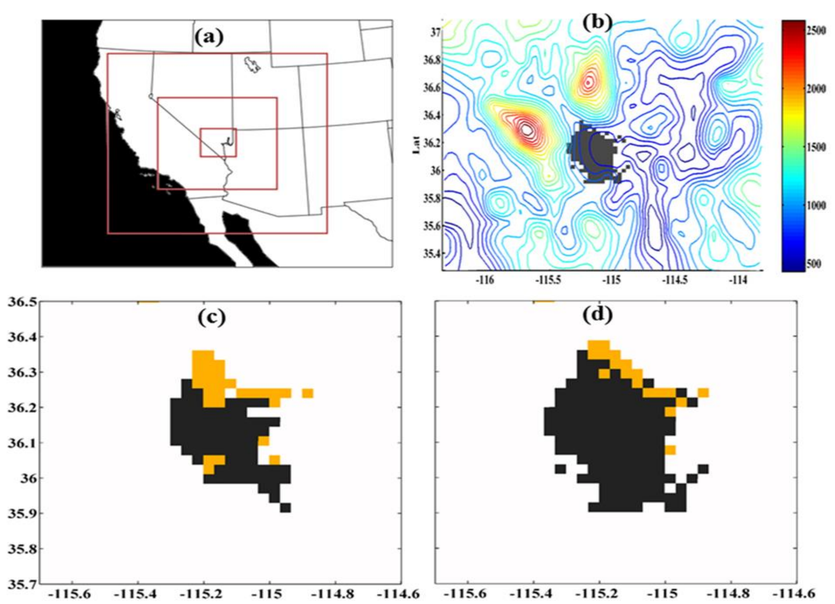
- Using dynamical downscaling and high resolution regional climate model to study the effect of urbanization of Las Vegas on local temperature and wind
- Study the change of surface energy balance due to land use change
- Quantify the interaction between thermodynamic and mechanical effects of urbanization on local climate

Model overview

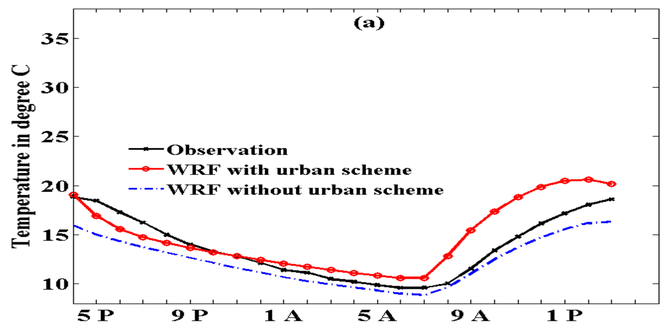
- The Weather Research and Forecasting model (WRF) 3.3.1 (Skamarock et al. 2008)
- Equations: Nonhydrostatic with a full suite of physical parameterization schemes
- Noah land surface model (Chen and Dudhia 2001)
- Urban canopy model (Kusaka et al. 2001, 2004)

Experimental set up

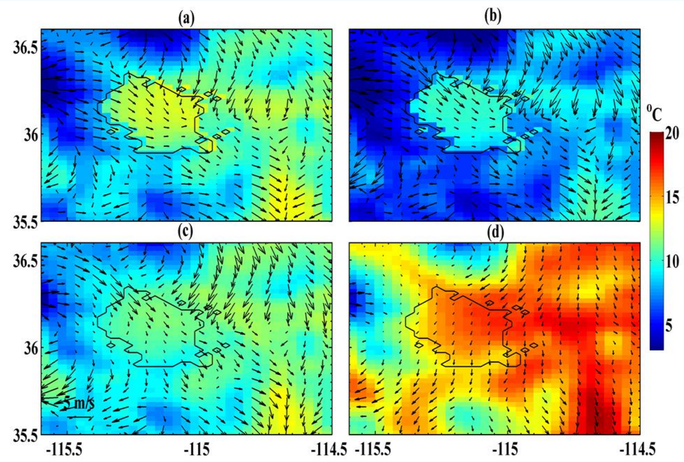
- Three layers of nesting centered at downtown Las Vegas with resolutions 48,12,3 km
- Lateral BC for summer and winter 2006 from NCEP analysis
- Surface BC over Las Vegas are constructed from NLCD2006 and NLCD1992 data, plus a 1900 case with no urban land
- Total of six 4-month simulations for the combinations of 3 land use maps and 2 seasons



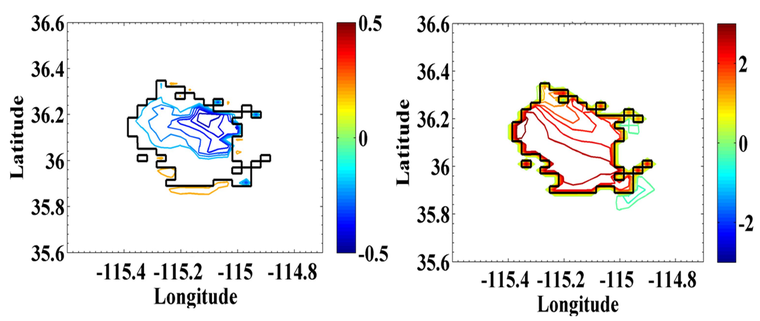
Model Validation



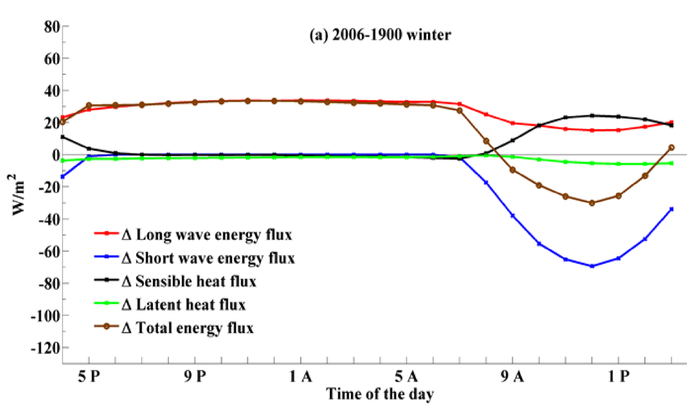
Climatology (winter 2006): 10 m wind vector and 2 m temperature



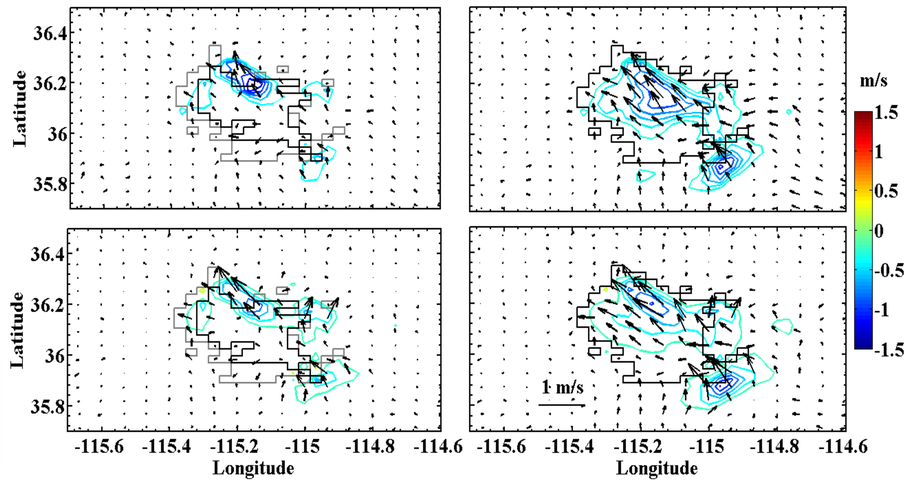
Change in 2m temperature for winter (2006 – 1900)



Surface Energy balance for winter

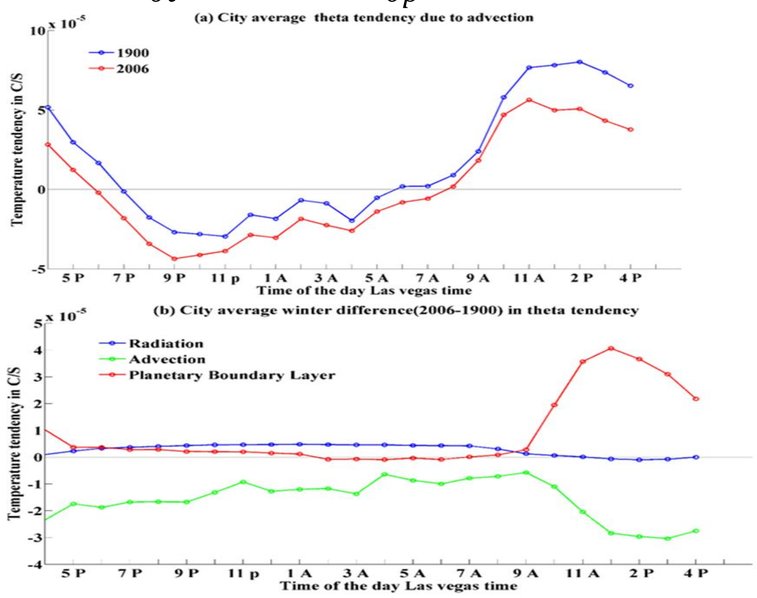


Change in 10 m wind (2006-1900)



Potential temperature advection for winter

$$\frac{\partial \theta}{\partial t} = -\boldsymbol{V} \bullet \nabla\theta - \frac{\partial}{\partial p}(\overline{\omega'\theta'}) + Q$$



Summary

- Urbanization leads to a strong nighttime warming but also a weak daytime cooling over Las Vegas.
- The decrease in surface albedo and increase in the effective emissivity due to urbanization play a major role in shaping the influence of urbanization on local climate.
- Urbanization leads to a reduction of surface wind speed over Las Vegas which has a secondary effect on temperature.
- In nighttime, the increase in urban-rural temperature gradient is strong enough to compensate the reduced wind speed such that the ventilation effect by wind still increases along with the enhancement of urban heat island.

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