Coastal Cooling on Hot Days in the Eastern United States

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Abstract

This project takes a climatological perspective in examining hot days with relatively cool temperatures within 60 km of the eastern United States coast. We aggregate these 'coastal cooling' days for eight regions, for both historical conditions and future projections. Our results reveal distinct regional distributions of coastal-cooling distance and intensity, with larger distances and intensities for the northernmost regions as well as Texas. Projections for 2075-2099 suggest a modest weakening of coastal cooling in both distance and intensity, the causes of which are the subject of ongoing investigation.

Background and Purpose

Extreme heat is expected to increase substantially over the 21st century [*Horton et al.,* 2016]. The coastal counties of the eastern US contain 66 million people, or 20% of the US population [*Bamford,* 2013], meaning that health and economic effects are highly concentrated there. A potential mechanism for moderating this extreme heat along the coast is the sea breeze, which can occasionally penetrate far inland [*Orton et al.*, 2010]. Because sea breezes are a local, shallow, and transient phenomenon, however, they are difficult to study systematically. For example, regional variations in heat-wave generative mechanisms result in differences in winds that, in combination with local coastline shape, can have a strong effect on sea-breeze intensity and penetration distance [*Gilliam et al.,* 2004; *Arritt,* 1993].

Consequently, in this study we take an agnostic approach of considering coastal cooling *ipso facto*, as it is more easily observable and directly measures the desired societal impact. Previous high-resolution studies of extreme heat focused on larger regional averages, rather than on the behavior of temperatures within 10's of km of the coast [*Zobel et al.,* 2017; *Gao et al.,* 2012].

Data

- Interpolated historical station data:
  - Parameter Regression on Independent Slopes Model [PRISM] output at daily, 4-km resolution for 1981-2015 [*Daly et al.,* 2008]
- Model projections:
  - Output from 15 GCMs (RCP8.5, 2075-2099) statistically downscaled to 6 km in the Localized Constructed Analogs [LOCA] project [*Pierce et al.,* 2014]

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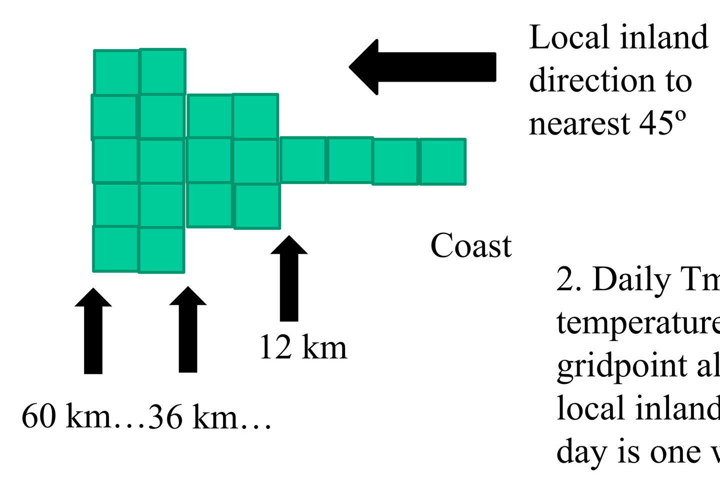
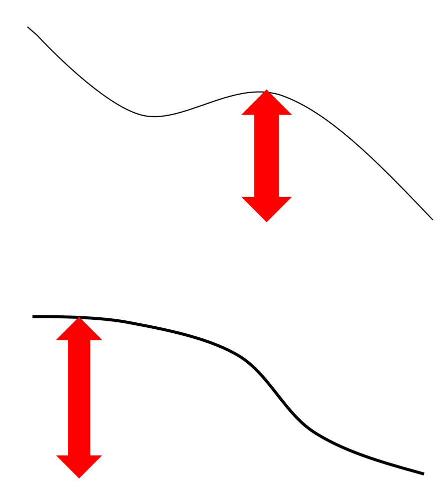
Coastal-Cooling Definition

Generic East Coast scenario



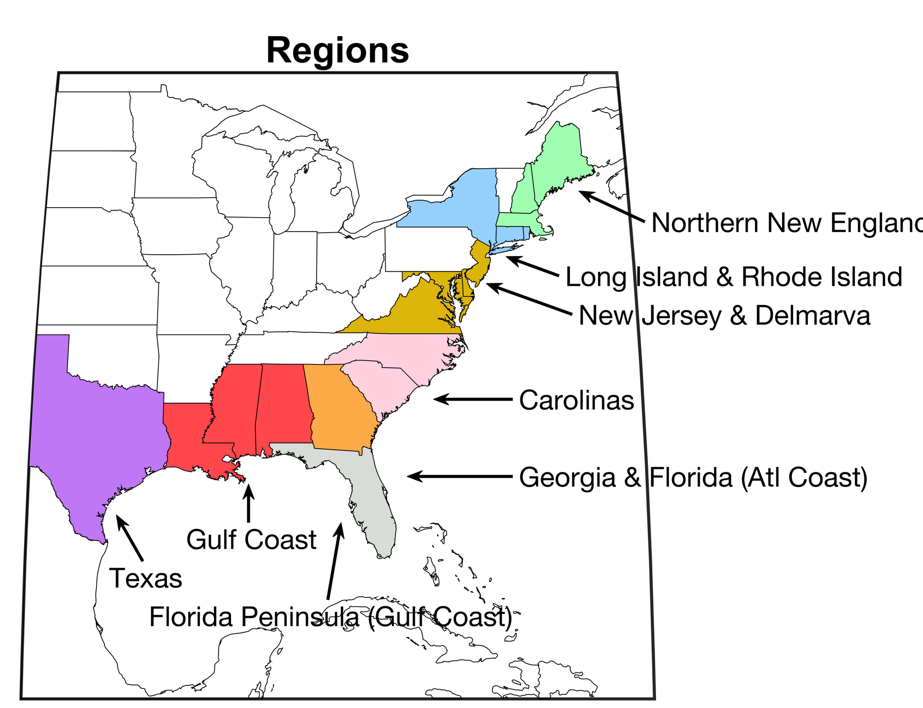


1. For each of the 8 regions (see below), JJA days with regional-average Tmax>p95 are classified as regional hot days.

2. Daily Tmax is used to construct temperature profiles from each coastal gridpoint along a 60-km line normal to the local inland direction. A coastal-cooling day is one where daily Tmax at the coast is >0.5 C cooler than in the coastal plain 60 km inland.

3. The horizontal placement of the red arrows marks the location of the coastal-cooling distance for the given sample temperature profile, and their vertical extent marks the coastal-cooling intensity. As an empirical condition, we consider the first instance of a gradient of <0.05 C per km as the limit of the inland extent of the coastal cooling.

Regions



Regions studied. Note that the state of Florida is divided into three regions according to the orientation of the local coastline.

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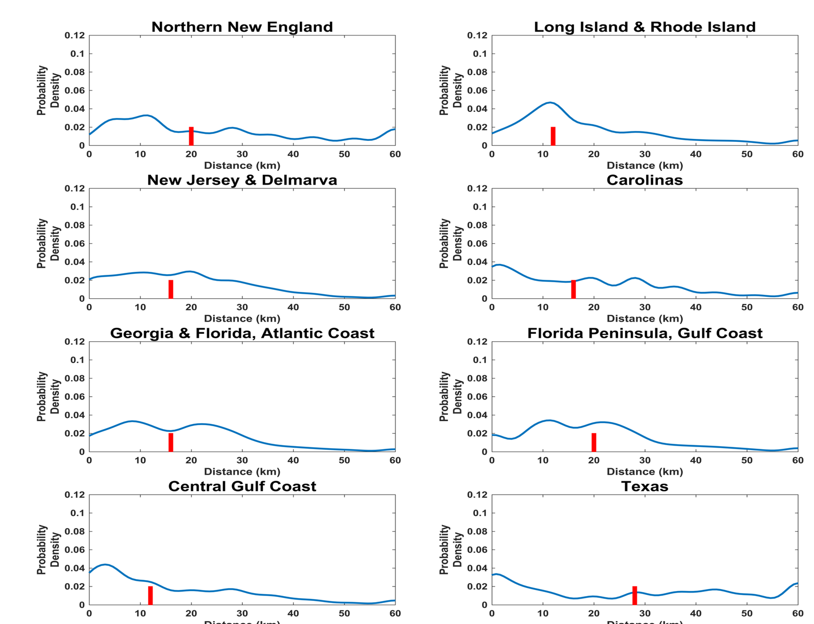
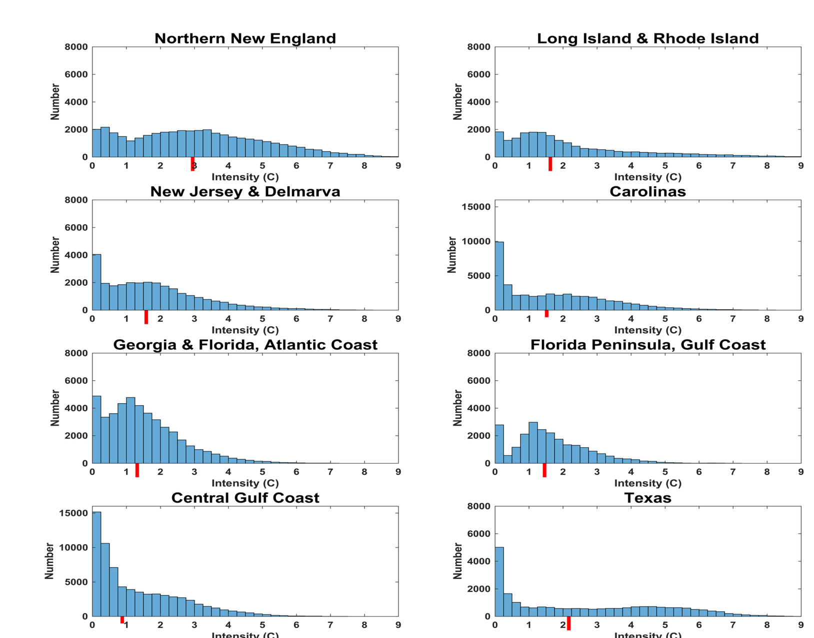
Historical Climatology

Having defined coastal-cooling occurrence, distance, and intensity at each gridpoint, we construct regional averages of each of these quantities over the approximately 10,000 gridpoint-days (~100 gridpoints * ~100 days/gridpoint). We take the resulting averages to be reasonably robust representations of the climatologies over physically meaningful sections of coastline.

Distance

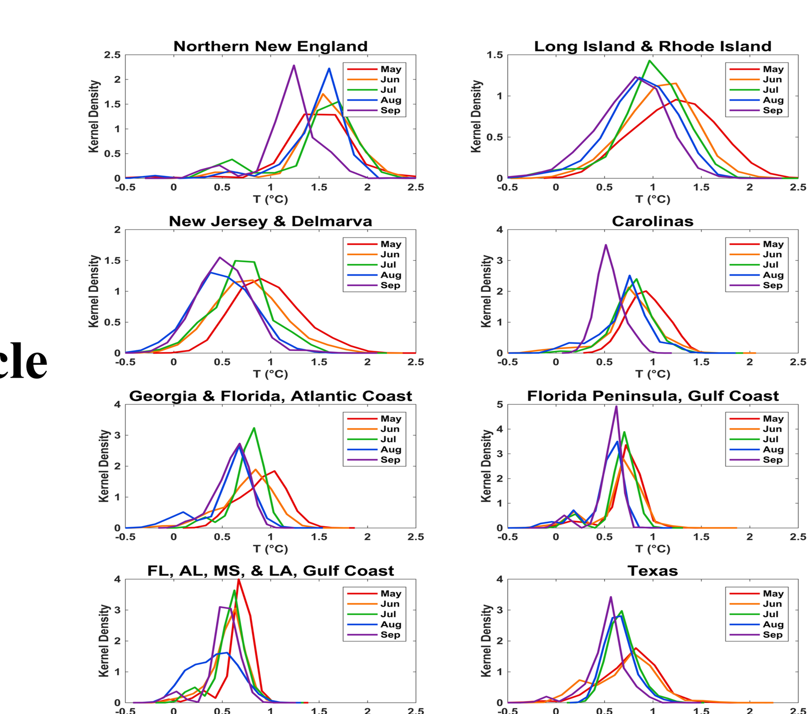


Intensity



Regional distributions of distance (top) and intensity (bottom) from the PRISM dataset. Red lines indicate the median value.

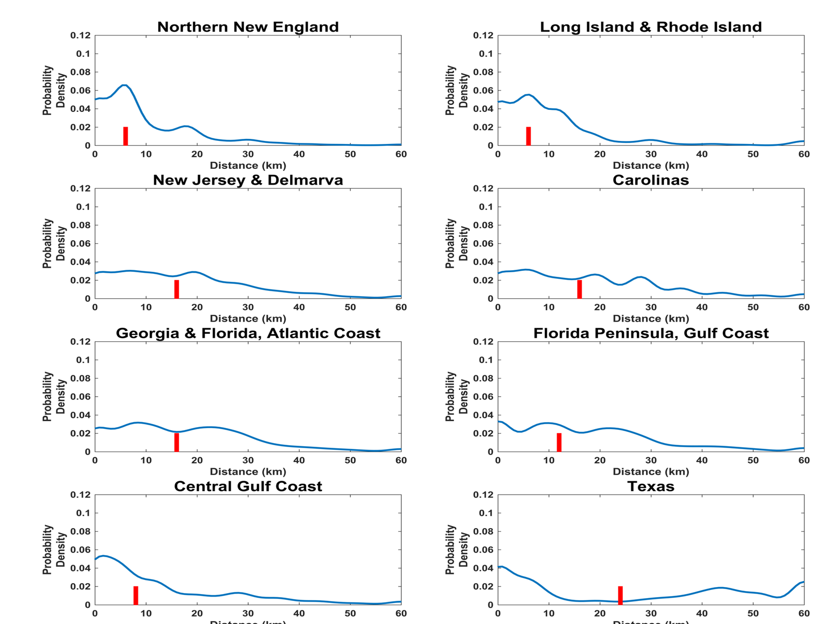
Seasonal Cycle of Intensity

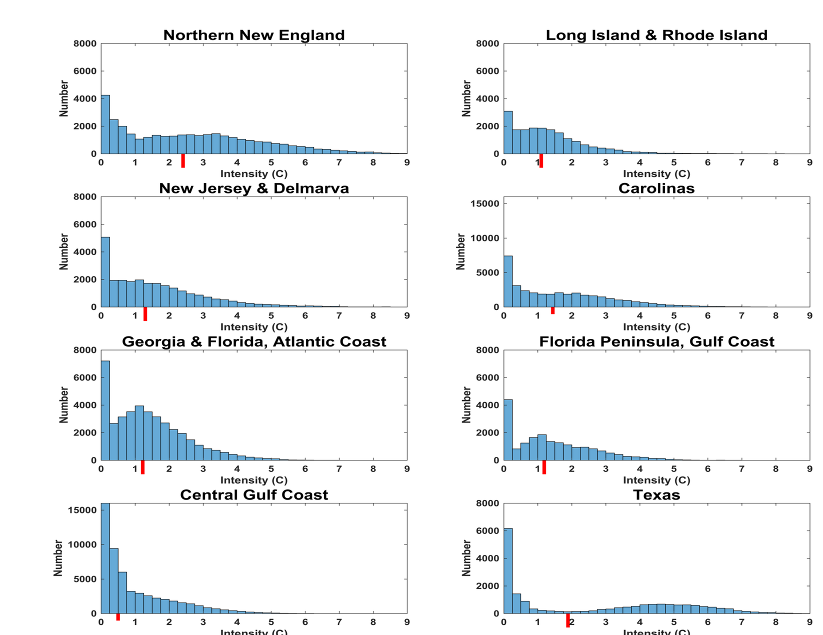


The seasonal distribution of intensities for each region obtained by fixing the inland distance at 12 km.

Projections

For projections, we employ LOCA statistically downscaled GCM products for 15 models. These are at 6-km resolution, but the methodology is otherwise identical to that used for the PRISM historical data. Heat-wave thresholds are defined relative to the future period in order to focus on local changes rather than large-scale mean warming.





Analogous distributions for 2075-99 in the GCM mean.

Conclusions and Future Work

We find that significant coastal cooling typically occurs within 10-20 km of the coast, but can in rare cases extend to at least 60 km inland. Intensities are on the order of 1 K but often reach 3-5 K in many regions, with occasional extremes of 6+ K in New England and Texas. We find that coastal cooling in the northern parts of the United States with cool SSTs exhibits a strong seasonal cycle that appears to be a direct function of the land-sea temperature gradient, as reported elsewhere [*Zhao et al.,* 2011]. However, dynamical effects play a considerable role in modulating coastal cooling, particularly in Texas, where JJA mean low-level onshore wind is near 6 m/s (not shown).

Late-21st-century projections from the 15-model mean suggest reductions in both distance and intensity, concentrated in the regions that presently have the most coastal cooling. This makes an informative contrast with projections for the central California coast [*Lebassi-Habetzion et al.,* 2011], where increasing land-sea contrast has led to decreases in coastal temperature via invigorated sea breezes. We posit land-sea contrasts in the Northeast US may be muted due to reductions in the magnitude of the seasonal cycle of SSTs or to annual-average SSTs outpacing inland temperatures, as has been the case in recent decades [*Thomas et al.,* 2017]. It may also be that large-scale dynamical changes, such as in terms of mid-level winds, oppose any land-sea contrast enhancement effects.