Threats to North American forests from southern pine beetle with warming winters

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Motivation

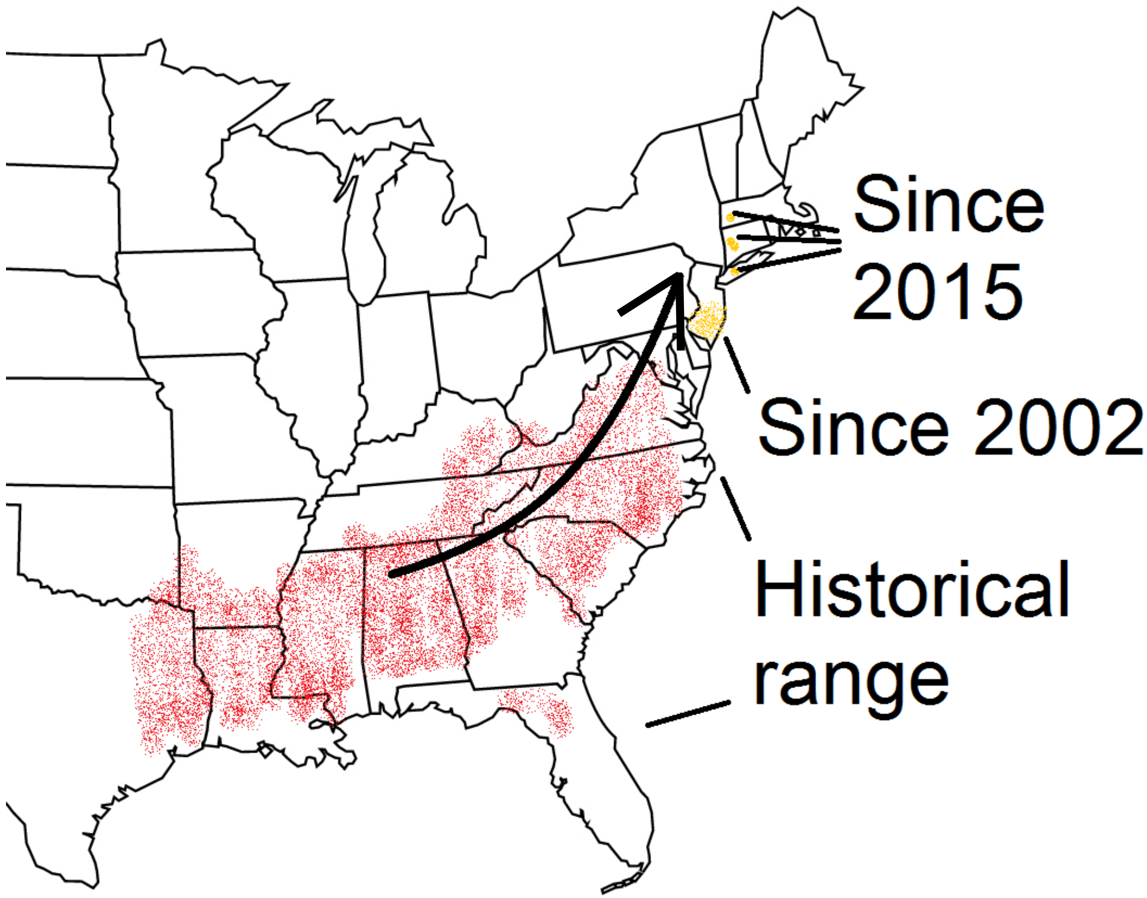
- Much of the impact of climate change will be felt through changing extremes
  - More extreme heat, **less extreme cold**
- Ecosystem responses can be highly complex
- Threshold-type responses to changing extremes provide an opportunity to project impacts

Background

- **Major forest pest in the southeastern U.S.**

- **Timber losses of US$1.7 billion over 1990-2004 (Pye et al. 2008)**
- **Presence and outbreaks strongly linked to cold extremes (Beal 1933, Ungerer et al. 1999)**
- **In lab experiments, temperatures of -14°C to -20°C are lethal (Lombardero et al. 2000)**

SPB expansion with warmer winters



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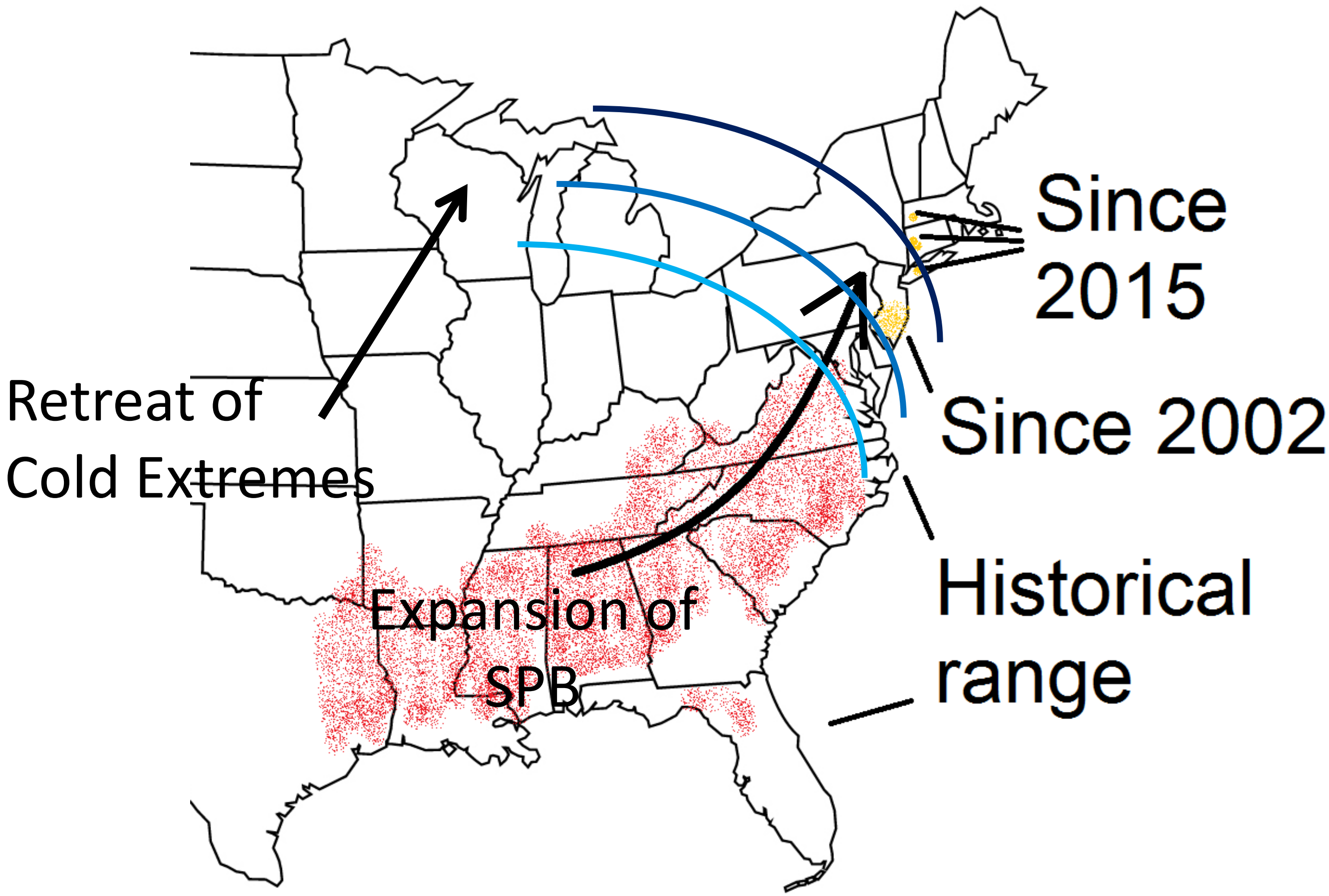
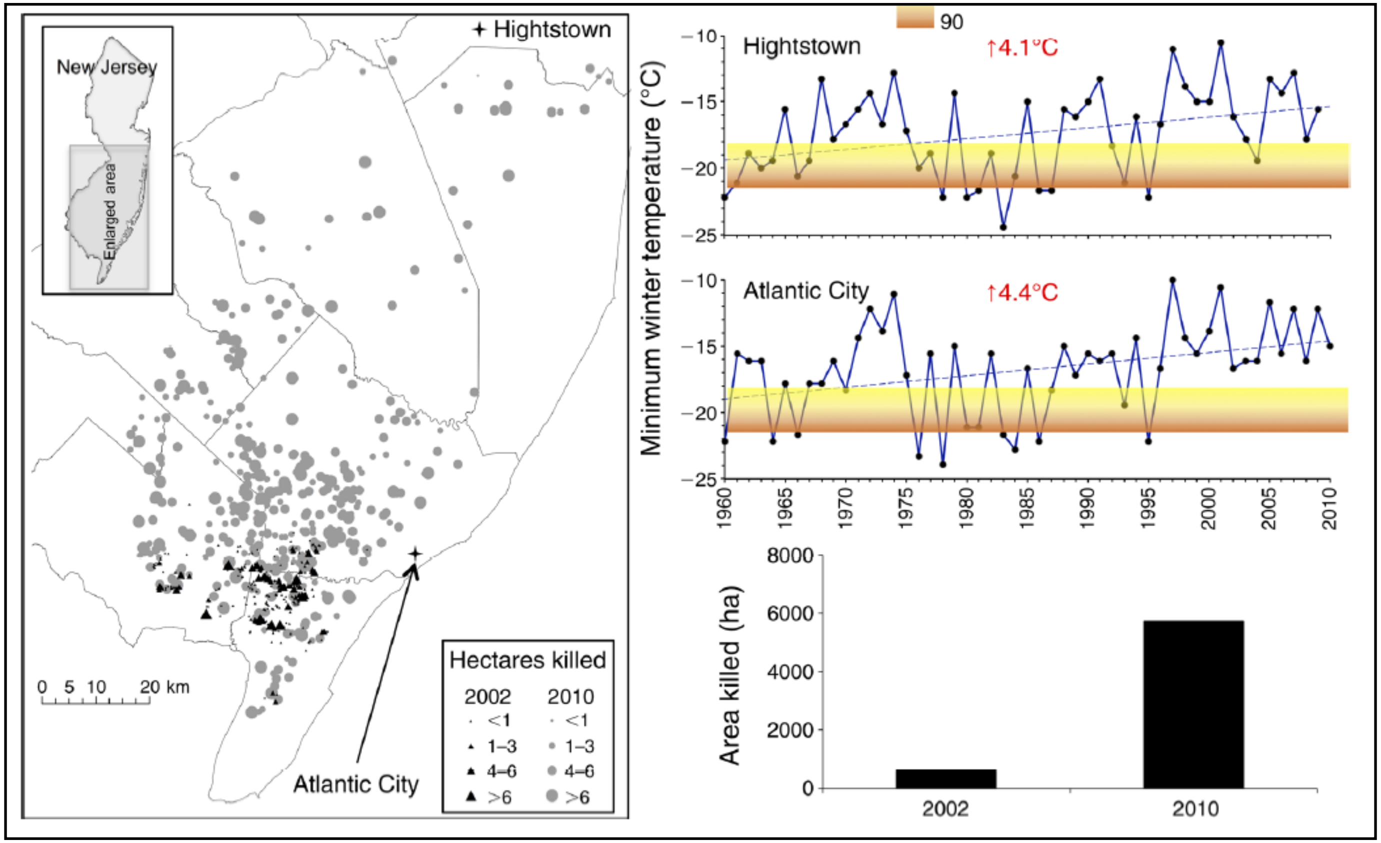


Recent History



(Weed *et al.* 2013)

Study objectives:

Use spatial relationship between SPB and cold extreme incidence to determine a 'range predicting temperature'

Use GCM output to project northward expansion of SPB suitable climate under continued climate change

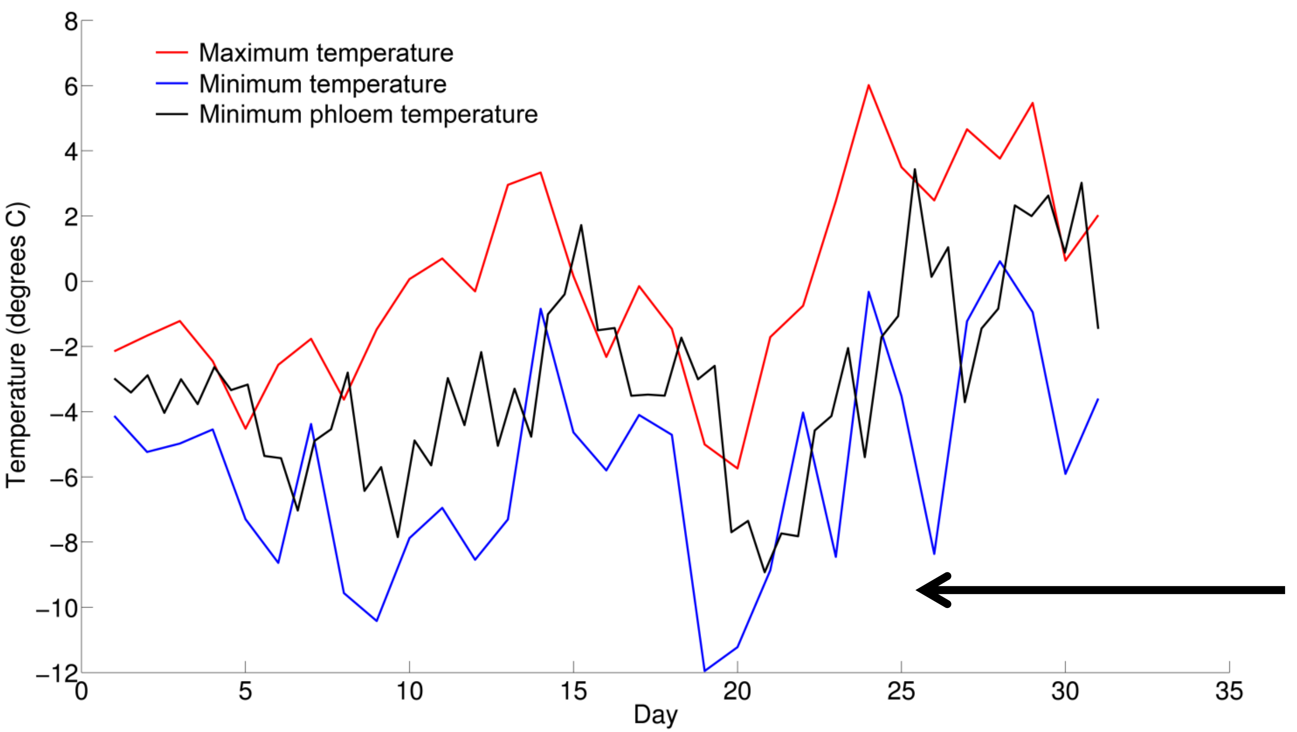
Provide a timeline to aid in adaptation planning

Overwintering

- Winter minimum temperatures most likely to occur when SPB is overwintering in the phloem
- Woody tissue has thermal inertia, lowering exposure of SPB to extreme cold
- We therefore simulated phloem temperatures based on air temperatures for our analysis (Tran *et al.*, 2007)

Phloem temperature model

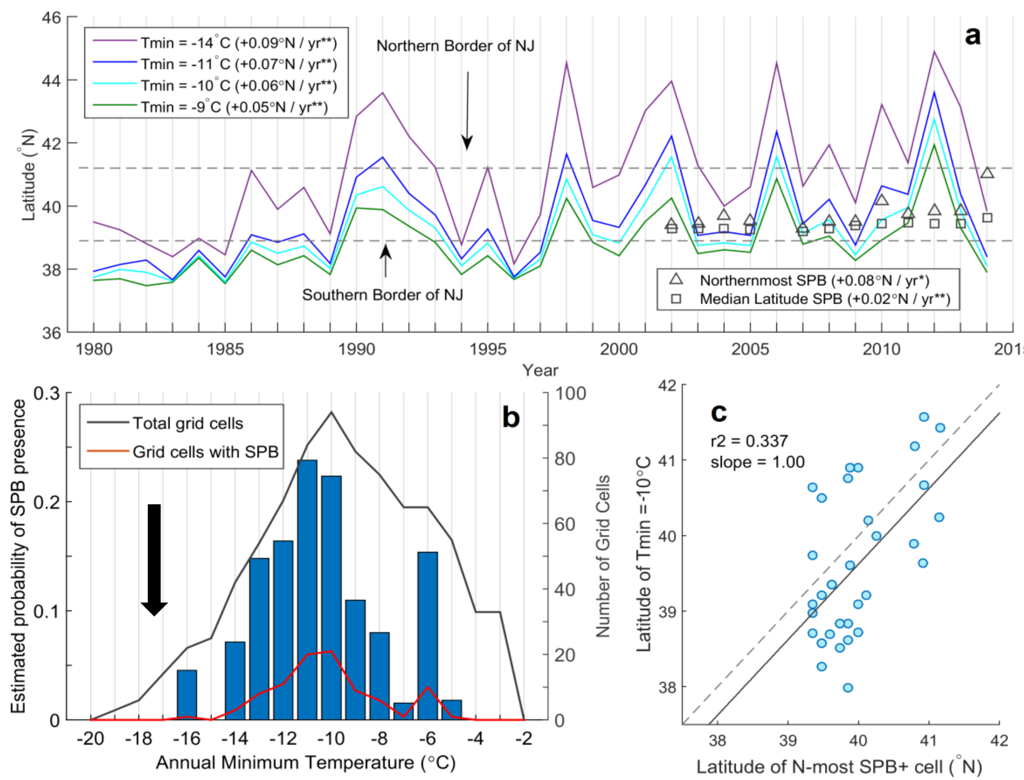
Example: January 1981 NARR air temperature data with modeled phloem temperature



Simulated thermal inertia buffers cold extremes

Evidence for a range-predicting temperature

Using phloem temperatures modeled based on bias-corrected NARR air temperatures, with SPB aerial survey data



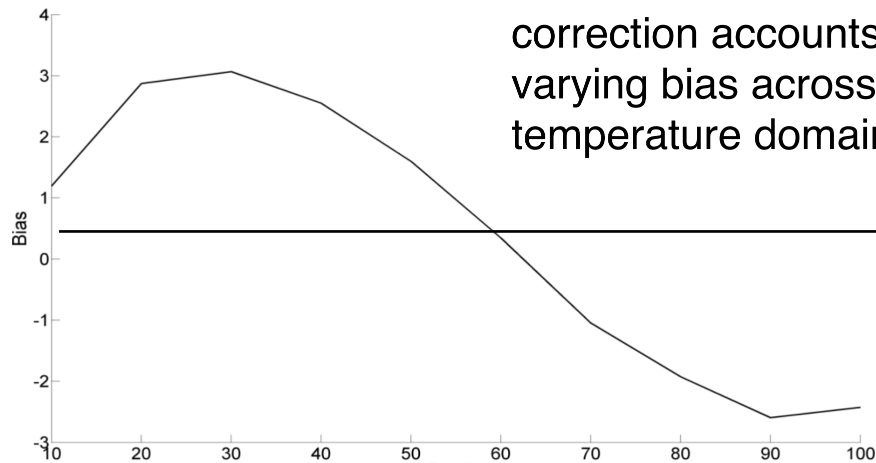
Minimum phloem temperature of -16ºC pose a lethal limit to SPB

But -10ºC best tracks the expansion of SPB

Year of emergence projections

- Daily temperature output from 27 CMIP5 general circulation models (GCMs) under RCP 4.5 and 8.5, bias corrected against NCEP reanalysis

Quantile-based bias correction accounts for varying bias across temperature domain

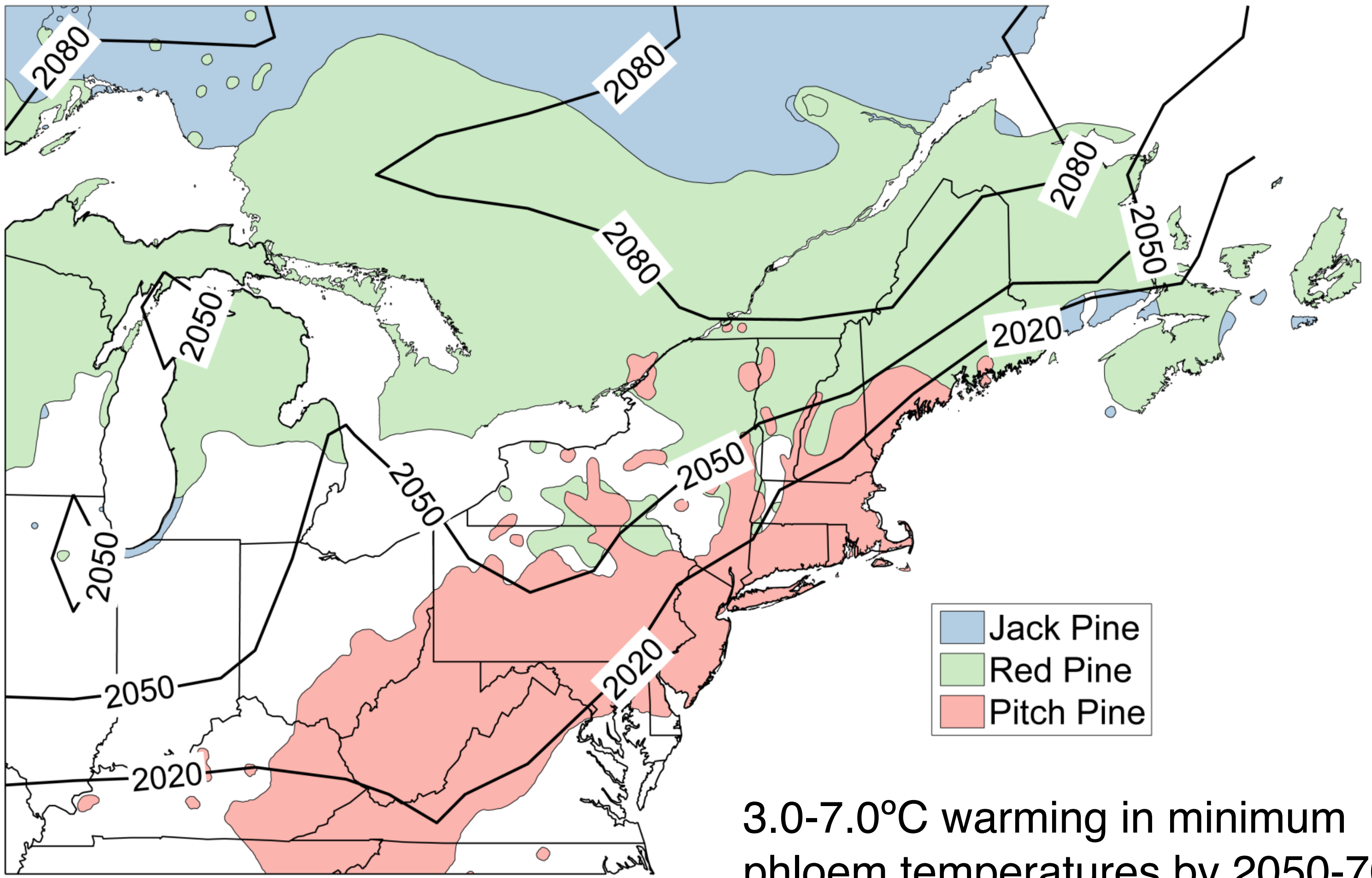


Temperature Decile

- Phloem temperatures modeled based on GCM output
- Year of emergence of SPB-suitable climate map computed for each GCM using annual minimum phloem temperature, then averaged across models

Projected year of emergence of SPB-suitable climates

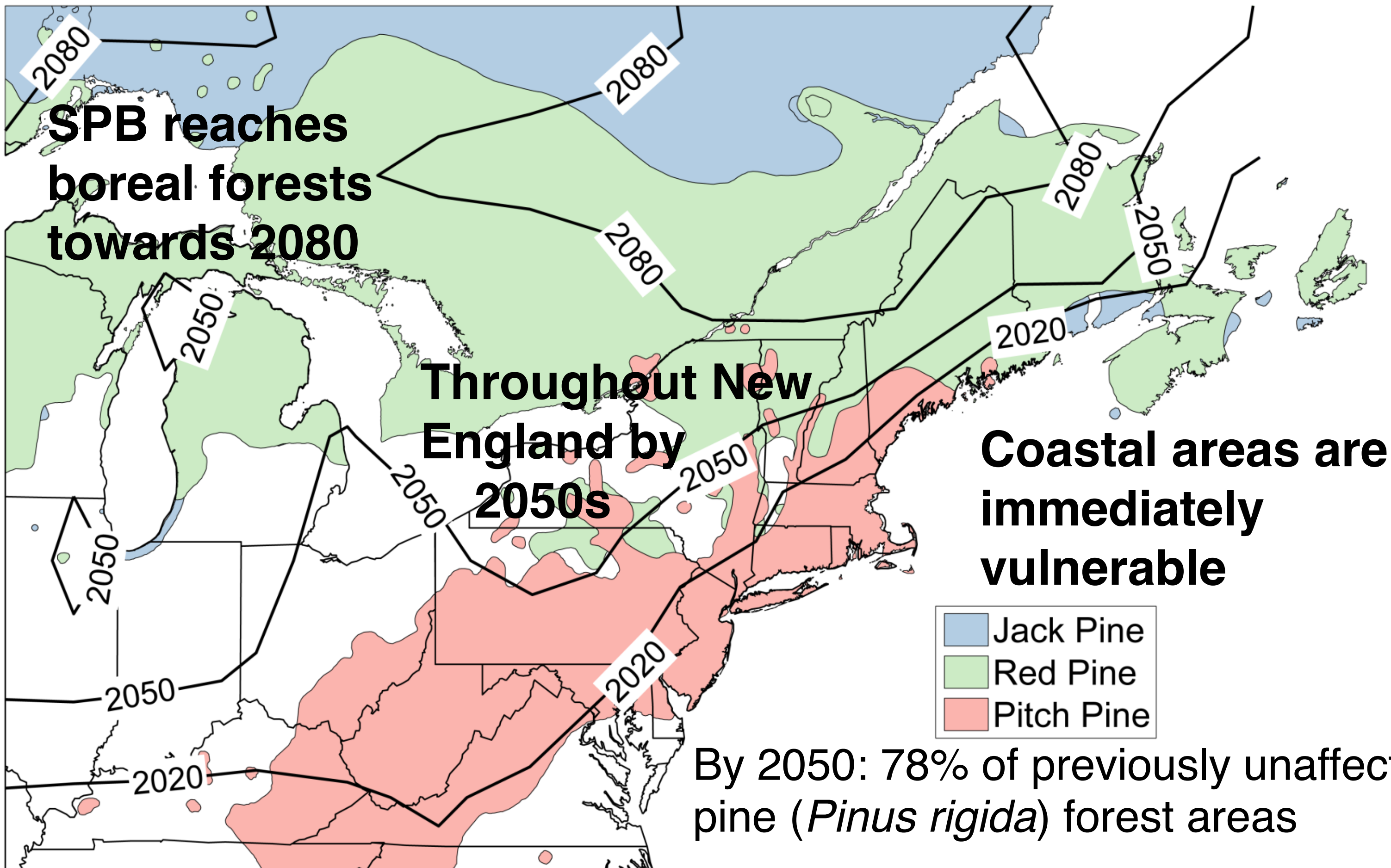
Multi-run mean (162 runs)



3.0-7.0°C warming in minimum phloem temperatures by 2050-70

Projected year of emergence of SPB-suitable climates

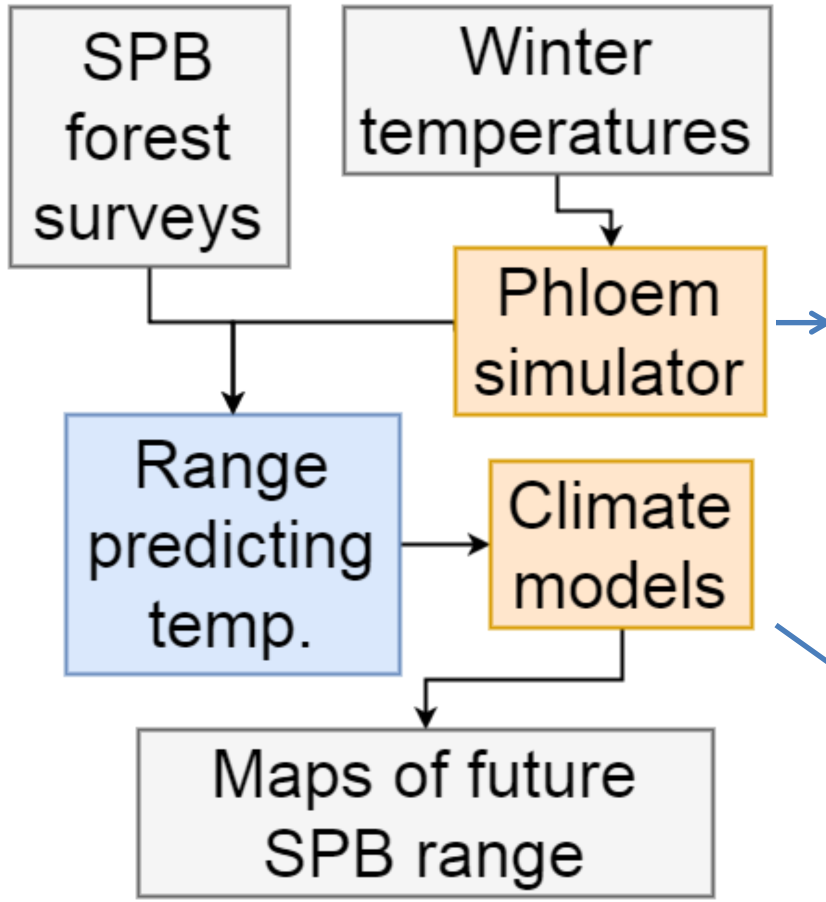
Multi-run mean (162 runs)



By 2050: 78% of previously unaffected pitch pine (*Pinus rigida*) forest areas

By 2080: 71% of red pine (*P. resinosa*) and 48% of jack pine (*P. banksiana*) forest areas

Sources of uncertainty



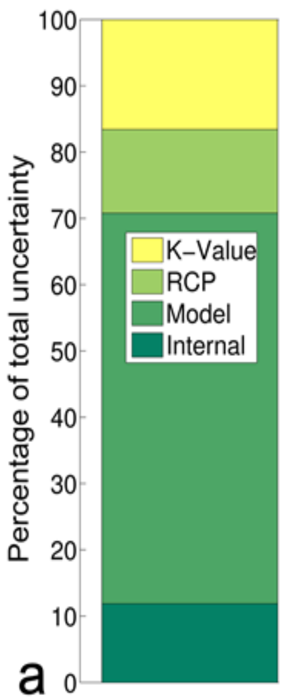
3 thermal buffering constant values (*K*-values) for plausible tree diameter classes

27 CMIP5 GCMs

2 plausible emissions scenarios (RCP 4.5 and 8.5)

+ uncertainty due to internal variability (chaotic behaviour of climate system), which is theoretically irreducible

Uncertainty estimation



- Year of emergences ranges 43 years
  - among 162 runs (27 GCMs, 3 *K*-values, 2 RCPs)
- 13% is fully irreducible internal variability
- Up to 83% is effectively irreducible for near-term management decision-making
  - Highlights the importance of working with uncertainty

Potential Impacts

- Disruption of local ecosystem services (biogeochemical and hydrological regulation) (Mikkelson et al. 2013)
- Threats to native biodiversity (iconic or endangered species and communities) (e.g. Wagner et al. 2003)
- Shifts in forest structure (transient mortality, longer-term changes in diversity) (Harrington et al. 2000)
- Lost income from forestry and tourism
- Global carbon regulation (if SPB flourishes in Canadian boreal forest) (Kurz et al. 2008)

Limitations and caveats

- Uncertain whether SPB will thrive in northern pine species
  - However SPB is highly polyphagous, and is affecting new northern pine species (Thatcher et al. 1980, Belanger et al. 1993)

- Our model does not consider population dynamics and outbreak severity/risk
  - Life-cycle and phenology may be interrupted
  - However new predation/disease is expected
  - Where SPB exists, it becomes a problem, **especially with drought**

- Local winter temperature extremes may change in ways different than GCMs suggest
  - Snow cover feedbacks, jet-stream dynamics and cold outbreaks

Conclusions

- SPB poses a threat to forests of eastern North America in coming decades
- Undesirable impacts are likely
- But there are management options and lessons from the U.S. South to reduce impacts