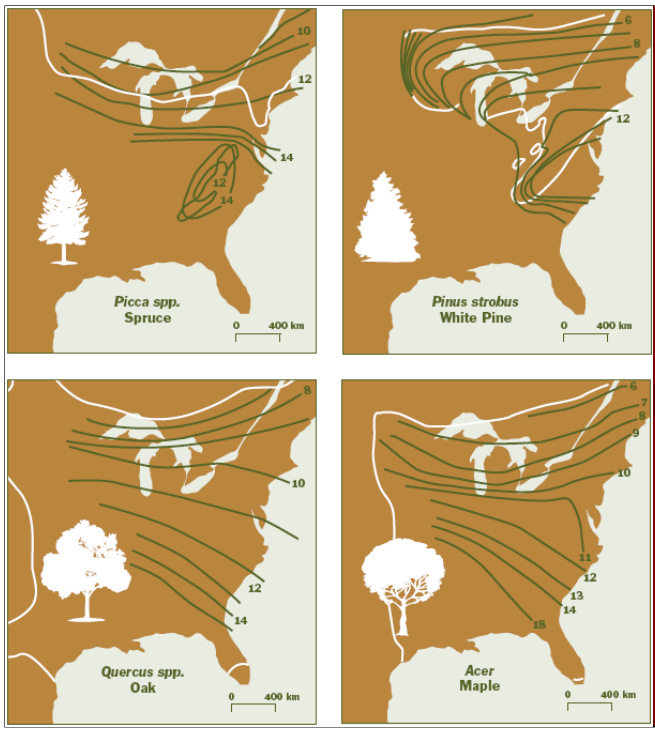


- During the Holocene, which began 10-12k yrs ago, the avg. global temperatures increased by about 2 deg C.
- This warming is at the low end of IPCC, 2007 projections for 2100 !!!

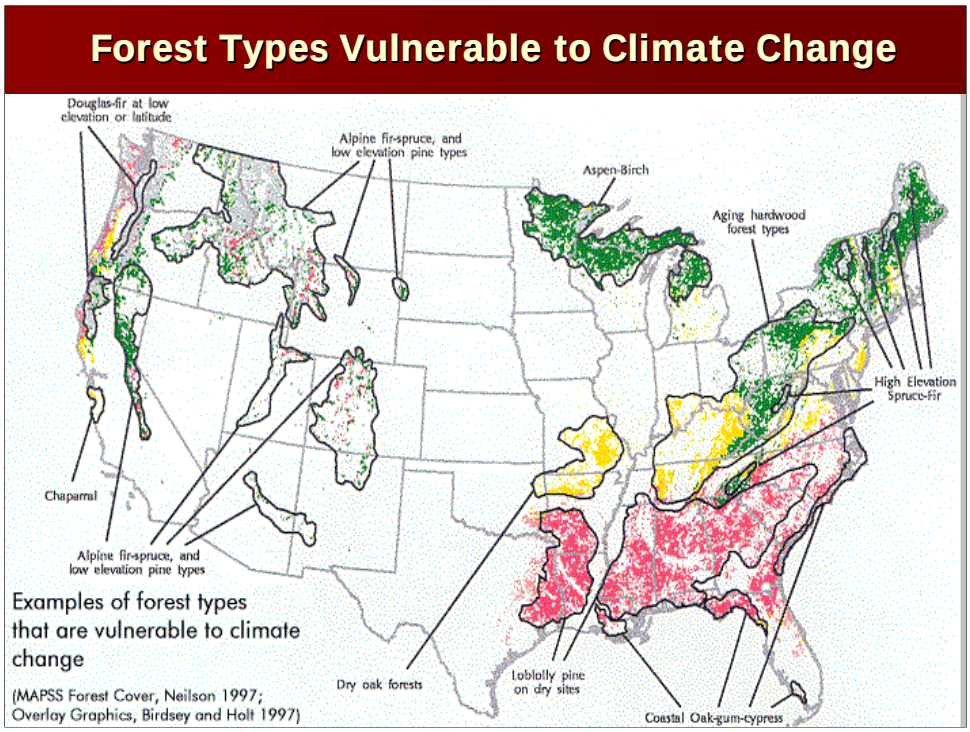
How's present-day vegetation going change with such rapid climate change + human-landuse disturbance ?!?

Source: Davis, 1981.

One important point to note is that during the Holocene, whole ecosystems did not move due to changing climate - it was individual species that responded...we take the same approach in our model too.

Map shows four species migrating northward and upward during the Holocene…where the earth 2 deg C increase in about 12 K years.

The lines in the maps above mark the boundaries of the species ranges in units of millennia (e.g., 12 indicates the range boundary of the species 12,000 years ago). The changes in the species ranges are in response to climate changes of roughly the same magnitude as that projected over the 21st Century due to climate change.



This shows forests vulnerable to climate change...as you can see a large chunk is in the east…

Our approach to modelling was based on individual tree species in keeping with the changes that happened since the Holocene…

Types of Vegetation Models

Dynamic Models	Empirical/Stats Models
■ GAP models - simulates stand/plot-level forest dynamics - can model growth and mortality (Zelig, Jabowa, Foret etc.) ■ Dynamic process based models (DGVMs) – can model plant functional types with biogeography, biogeochemistry & disturbance components (MC1, Biome4 etc.)	■ Climate Equilibrium models (species presence/absence prediction models based on climate envelopes) ■ "Species Abundance" prediction models: tree-based ensemble regression techniques using climate + soils + elevation + land-use predictors

Different types of veg. models

Forest Inventory and Analysis

- **FOREST INVENTORY (US Forest Service)**
  - 37 states east of 100th meridian
  - 134 tree taxa
  - 103,488 plots, ~1 plot per 2400 ha of forest
  - 2,938,518 tree records
- **PROCESS**
  - Extract latest FIA plot data by State
  - Calculate Importance Value (IV) based on number of stems & basal area (understory + overstory)
  - Aggregate points to 20 x 20 km grids
- **OUTPUT**
  - Importance Value (IV) for 134 tree species, by 20 km cell

Available online: Prasad and Iverson 2003

We used FIA to derive abundances in the form of Importance Values (IV)

Environmental Predictor Variables

Climate

AVGT	Mean annual temperature (deg. C)
JANT	Mean January temperature (deg. C)
JULT	Mean July temperature (deg. C)
TMAYSEPT	Mean May-September temperature
PMAYSEPT	or precipitation
PPT	Annual precipitation (mm)
JANJULDif	Difference temp Jan/Jul

GCMs: (Hadley-Hi & Lo; PCM-Hi & Lo; GFDL Hi & Lo;)

Elevation

ELV_CV	Elevation coefficient of variation
ELV_MAX	Maximum elevation (m)
ELV_MEAN	Average elevation (m)
ELV_MIN	Minimum elevation (m)
ELV_RANGE	Range of elevation (m)

Soil Class

ALFISOL	Alfisol (%)
ARIDISOL	Aridisol (%)
ENTISOL	Entisol (%)
HISTOSOL	Histosol (%)
INCEPTSOL	Inceptisol (%)
MOLLISOL	Mollisol (%)
SPODOSOL	Spodosol (%)
ULTISOL	Ultisol (%)
VERTISOL	Vertisol (%)

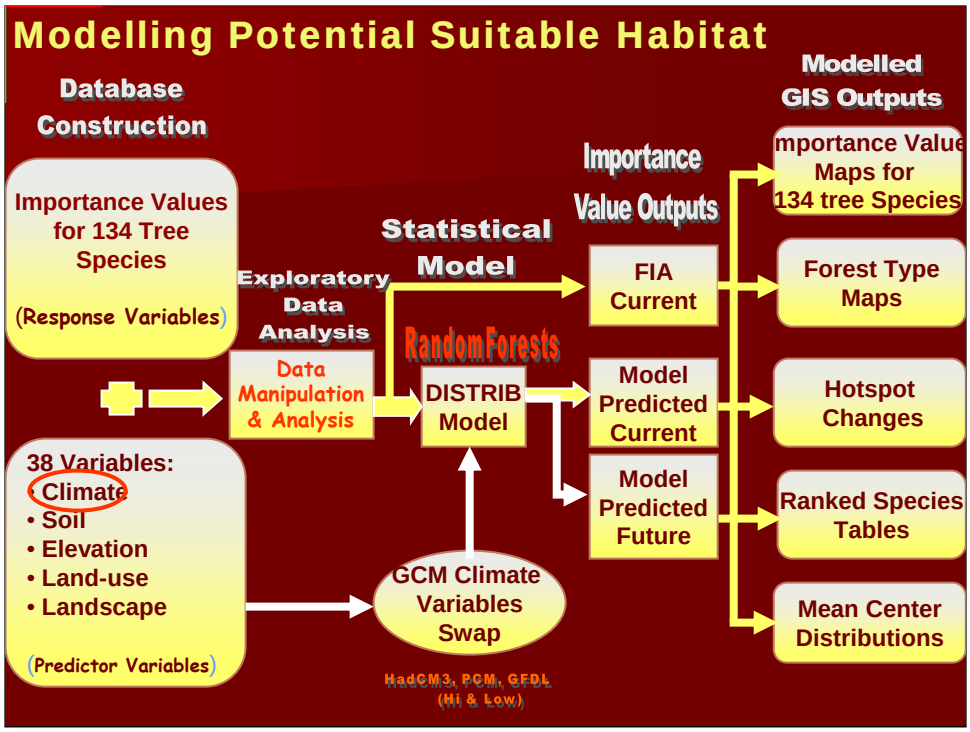
Soil Property

BD	Soil bulk density (g/cm3)
CLAY	Percent clay (< 0.002 mm size)
KFFACT	Soil erodibility factor, rock fragments free
NO10	Percent soil passing sieve No. 10 (coarse)
NO200	Percent soil passing sieve No. 200 (fine)
OM	Organic matter content (% by weight)
ORD	Potential soil productivity, (m3 of timber/ha)
PERM	Soil permeability rate (cm/hour)
PH	Soil pH
ROCKDEP	Depth to bedrock (cm)
ROCKFRAG	Percent weight of rock fragments 8-25 cm
SLOPE	Soil slope (percent) of a soil component
TAWC	Total available water capacity (cm, to 152 cm)

Land Use and Fragmentation

AGRICULT	Cropland (%)
FOREST	Forest land (%)
FRAG	Fragmentation Index (Riitters et al. 2002)
NONFOREST	Non-forest land (%)

We used a total of 37 predictors….gleaned from various sources…we used 3 climate change models for future climate ….



This schematic shows our modelling scheme. So for each species we had the current distribution according to FIA

Then we had the model predicted output...The DISRIB model was based on RandomForests statistical technique …In order to find out how our model would predict under changed climate, we...swapped current climate with future climates and reran the model.

Tree-based ensemble

(the "Tri-mod approach")

- Regression Tree Analysis (RTA or CART)
  - (help understand relationships, map drivers)
- Bagging Trees (BT)
  - combines 30 trees using bootstrap sampling and averages the results
  - (use 30 trees to assess variability among individual tree models = a measure of model reliability)
- Random Forest (RF)
  - combines 1000 trees like in BT, but each with a randomized subset of predictors
  - (best for prediction without overfitting)

However, using a single tree for prediction is not a good idea – so we used an ensemble technique…what we call the tri-mod approach

Assessment of Model Reliability

- Not all species models are equal – need to know about "model confidence" for each species:
- factors used in model reliability score:
  - R^2 equivalent of the Random Forest model
  - Fuzzy Kappa statistic comparing prediction to actual data
  - An assessment of predictor stability and consistency using the 30 Bagged trees

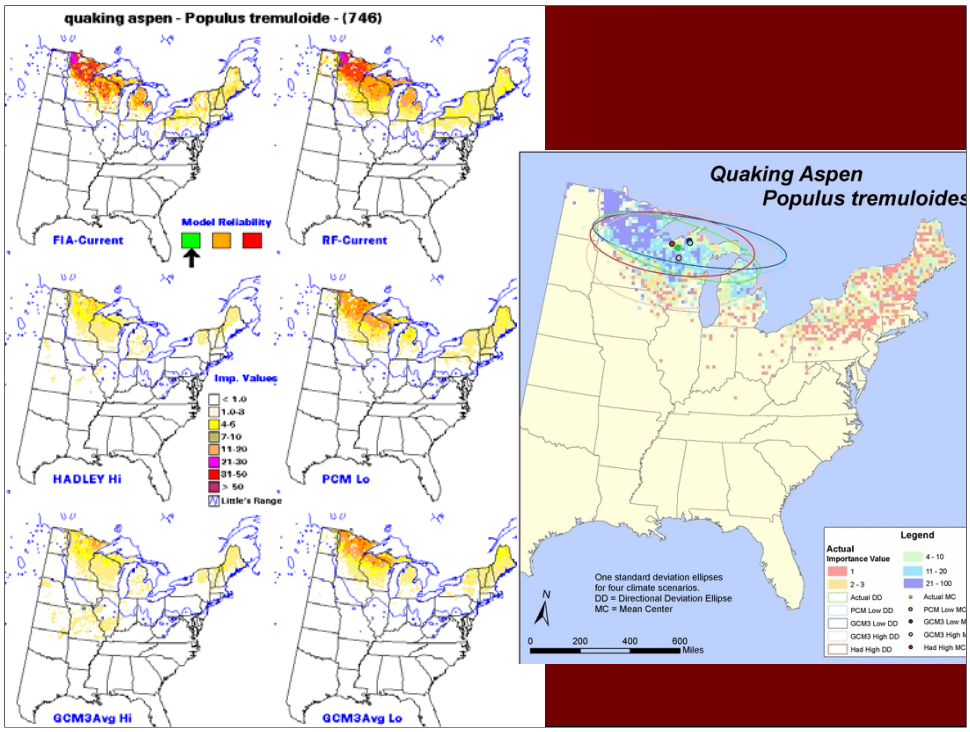
By using this tri-mod approach we ware able to assess the reliability of the model for each species…

Important!

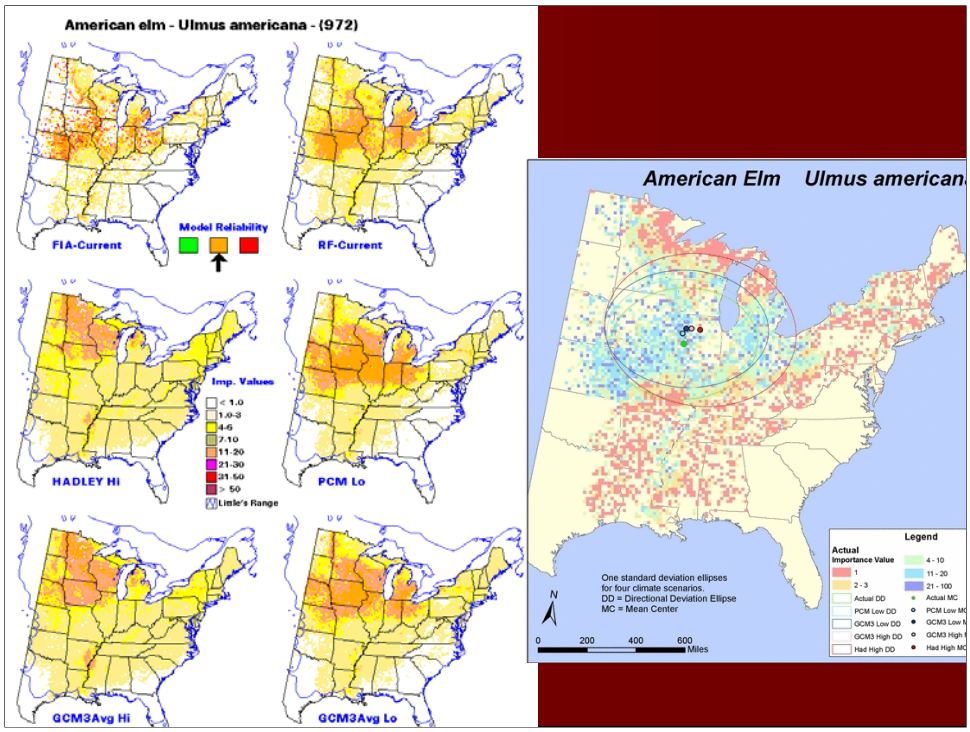
- With these models, we are predicting potential suitable habitat by year 2100. We are NOT predicting where the species will be at that time, as great lag times are involved in tree species migrations.
- The model does not account for future biotic interactions (competition, herbivory, mutualism etc.) or other human (land-use change, fire) or natural (ice, wind) disturbances - as these are extremely difficult to quantify accurately for future scenarios.

Make sure that you note these before interpreting the atlas!

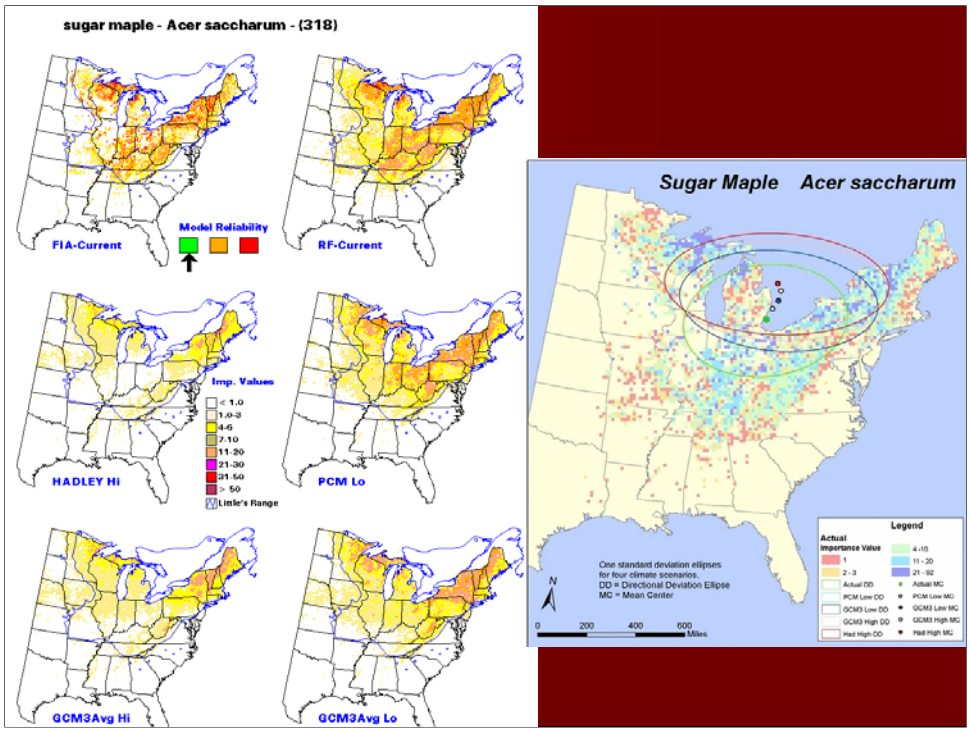
The tree atlas our flagship product has been online for several months now…the bird atlas went online sometime back. I encourage you to take a look and give us feedback.



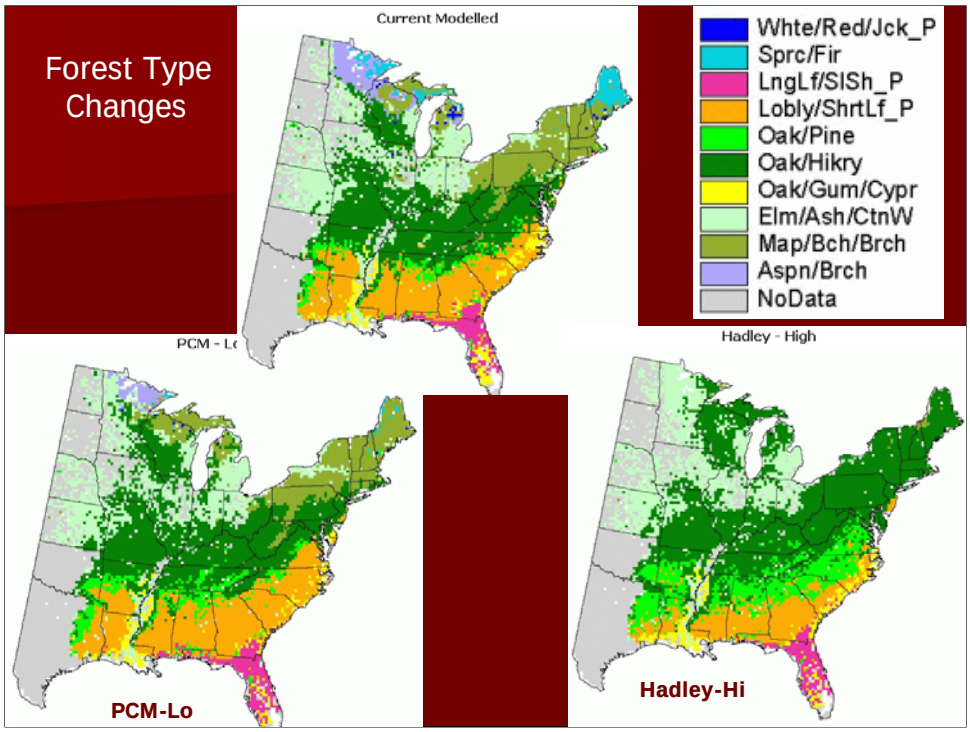
Note that Hadley Hi is the harshest and PCM Lo is the mildest of the scenarios.



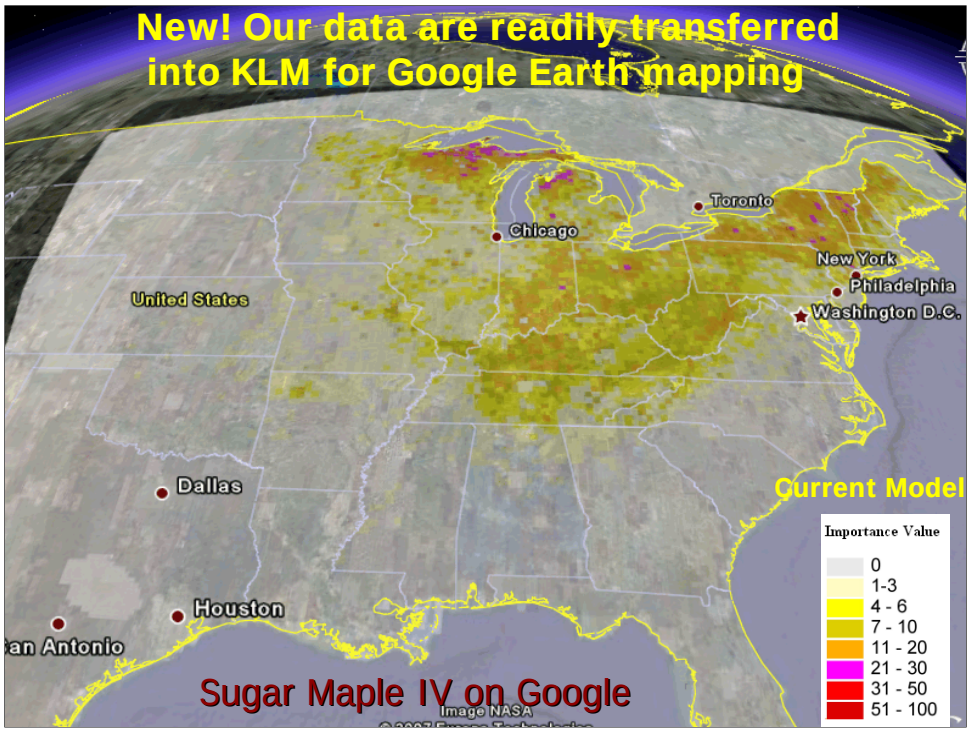
Notice the model reliability – it is medium….so there is more uncertainity..even though the tables told us that Am. Elm decreased



Note that Hadley Hi is the harshest and PCM Lo is the mildest of the scenarios.



We can assemble the IVs of species assemblages and see how Forest Types change.



I recently linked our climate change maps onto to Google Earth…we are quite excited as it broadens the scope of our work quite a bit especially with ancillary data avaliable in GE….

Strengths of our modelling approach

- FIA samples are statistically sound and non-biased
- Analysis and prediction based more on core of distribution via IVs, not the error-prone range edges or just presence/absence maps
- Extremely robust non-parametric statistical tools using “tri-mod” ensemble approach
- The reliability of individual species models can be evaluated
- RF is resistant to over-fitting & stable predicting into novel environments
- Can use different variables to describe distribution drivers in different parts of its geographic setting
- Models “realized” niche - therefore integrates over historic disturbances and climatic phenomena.
- Provides risk assessments for individual species due to climate change (change in area-weighted IV)
- Can produce ranked lists of species that may be in greatest risk (e.g., Hoosier National Forest)
- Can be readily adapted to Google Earth platform

Some strengths

Take-Home Message for Managers/Foresters

- With climate change predictions, plan for the worst case scenario (Hadley-Hi) but encourage lower emissions.
- Pay attention to the reliability of each species model – and regardless, there still will be errors!
- Less common species are more prone to error.
- Edge boundaries are 'fuzzy', both now and in future – core areas are more indicative
- Use these models as guidelines for regional trends – they are not appropriate for stand level management without the regional context

IF you abide by these caveats, and you live in the Eastern US, you can use our atlas to:

- Learn which species are in, or could potentially be in, your location
- Learn which environmental factors are driving species' suitable habitat, e.g., which are most susceptible to climate drivers
- Learn what species are most and least likely to have their habitats move, and how far
- Learn which species could incur the most risk under climate change
- Learn which species could become newly suitable for your location (from the south)

What you can do with our outputs.