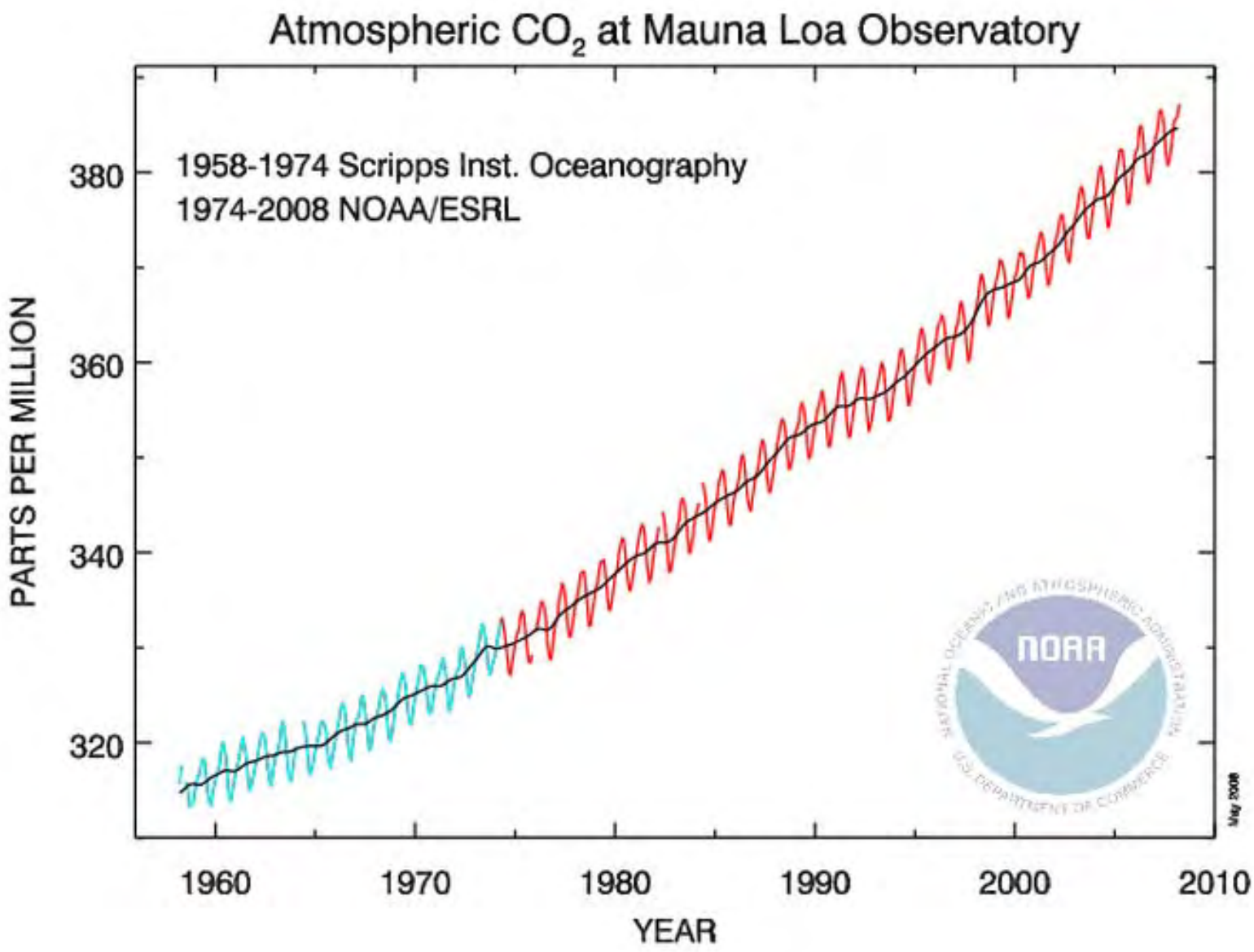
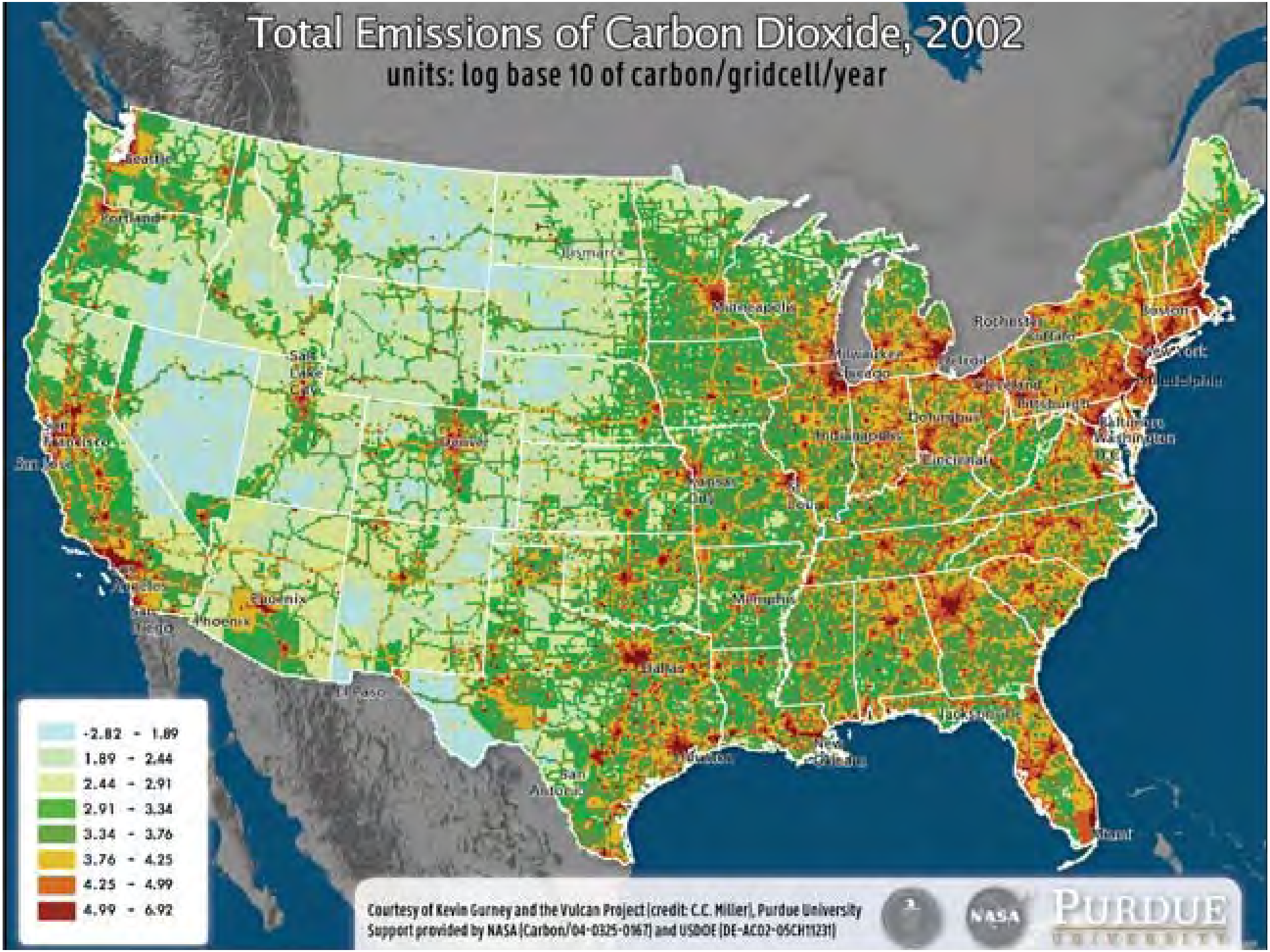
Climate change and trees in the eastern United States

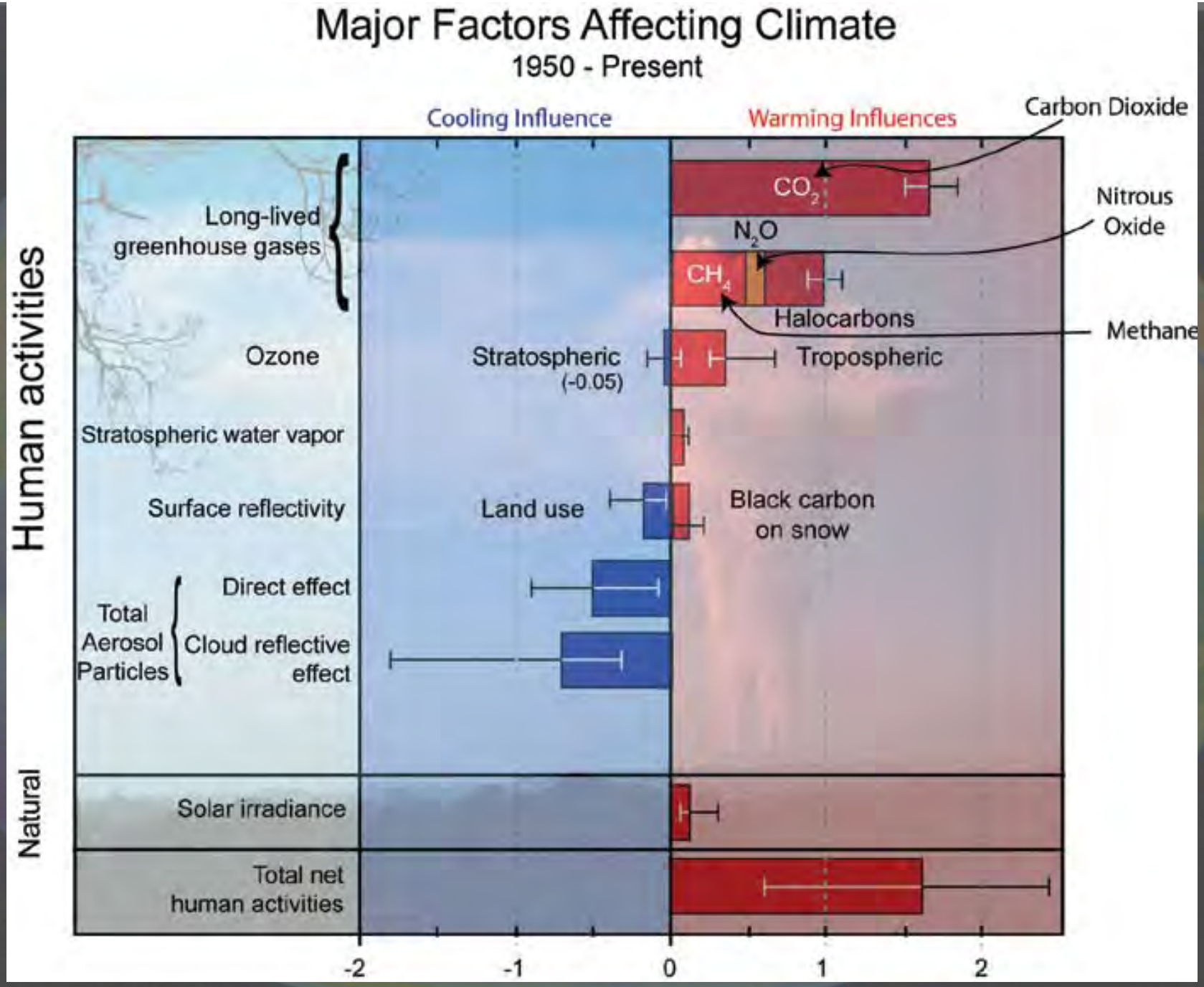
Sustainable Forest Management in the Context of Climate Change: Training and Tools for Strategy Development and Application

Louis Iverson, Anantha Prasad, Matthew Peters, Stephen Matthews
NRS-02, Delaware, OH

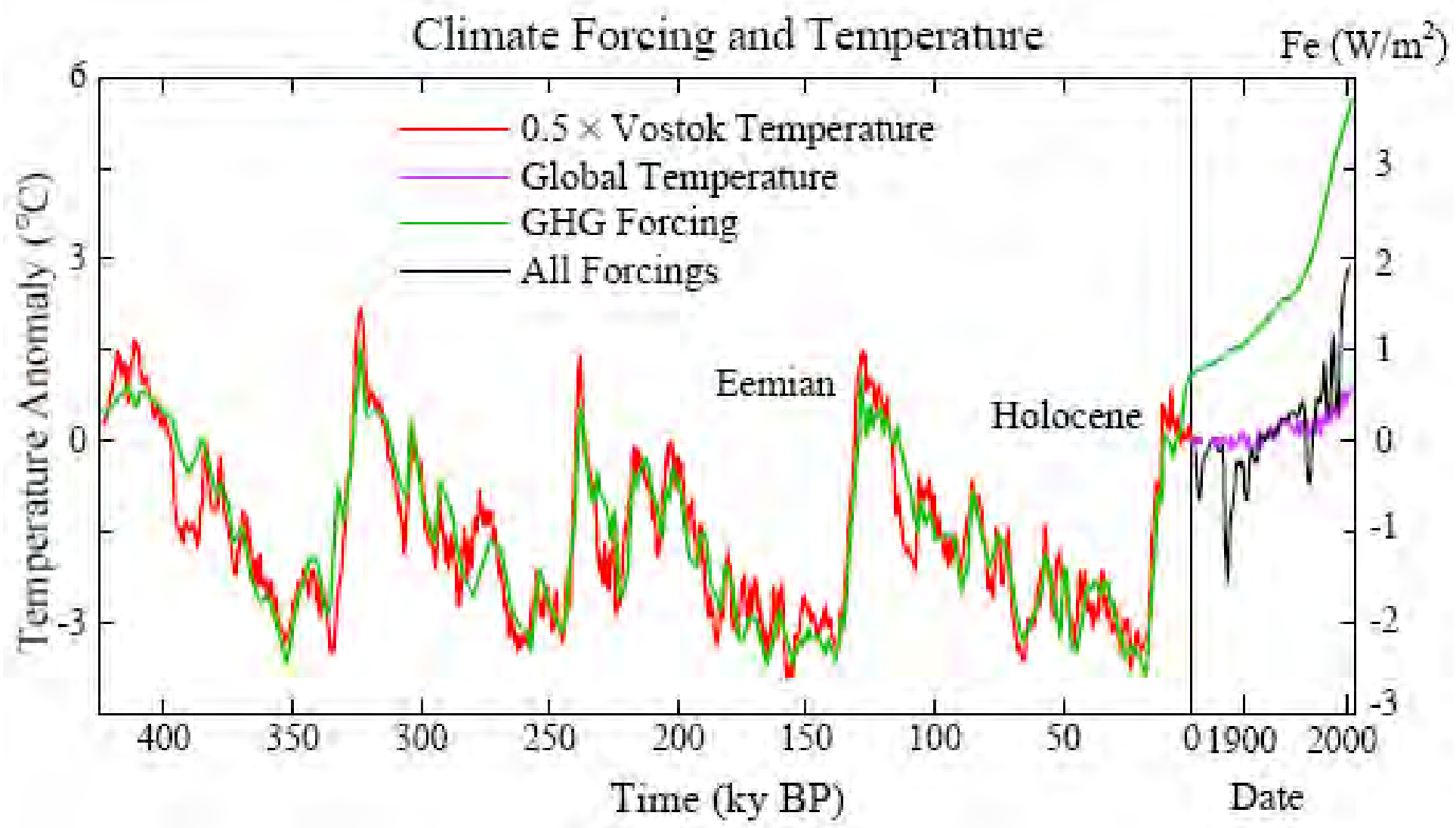
~2 ppm rise per year, now at 387 ppm =
100 ppm more than in 1860




Total Emissions of Carbon Dioxide, 2002
units: log base 10 of carbon/gridcell/year
-2.82 - 1.89
1.89 - 2.44
2.44 - 2.91
2.91 - 3.34
3.34 - 3.76
3.76 - 4.25
4.25 - 4.99
4.99 - 6.92
Courtesy of Kevin Gurney and the Vulcan Project (credit: C.C. Miller), Purdue University
Support provided by NASA (Carbon/04-0325-0167) and USDOE (DE-AC02-06CH11231)
NASA
PURDUE UNIVERSITY


Major Factors Affecting Climate
1950 - Present
Cooling Influence
Warming Influences
Carbon Dioxide
Nitrous Oxide
Methane
Human activities
Natural
Long-lived greenhouse gases
CO_2
N_2O
CH_4
Halocarbons
Ozone
Stratospheric (-0.05)
Tropospheric
Stratospheric water vapor
Surface reflectivity
Land use
Black carbon on snow
Total Aerosol Particles
Direct effect
Cloud reflective effect
Solar irradiance
Total net human activities
-2
-1
0
1
2

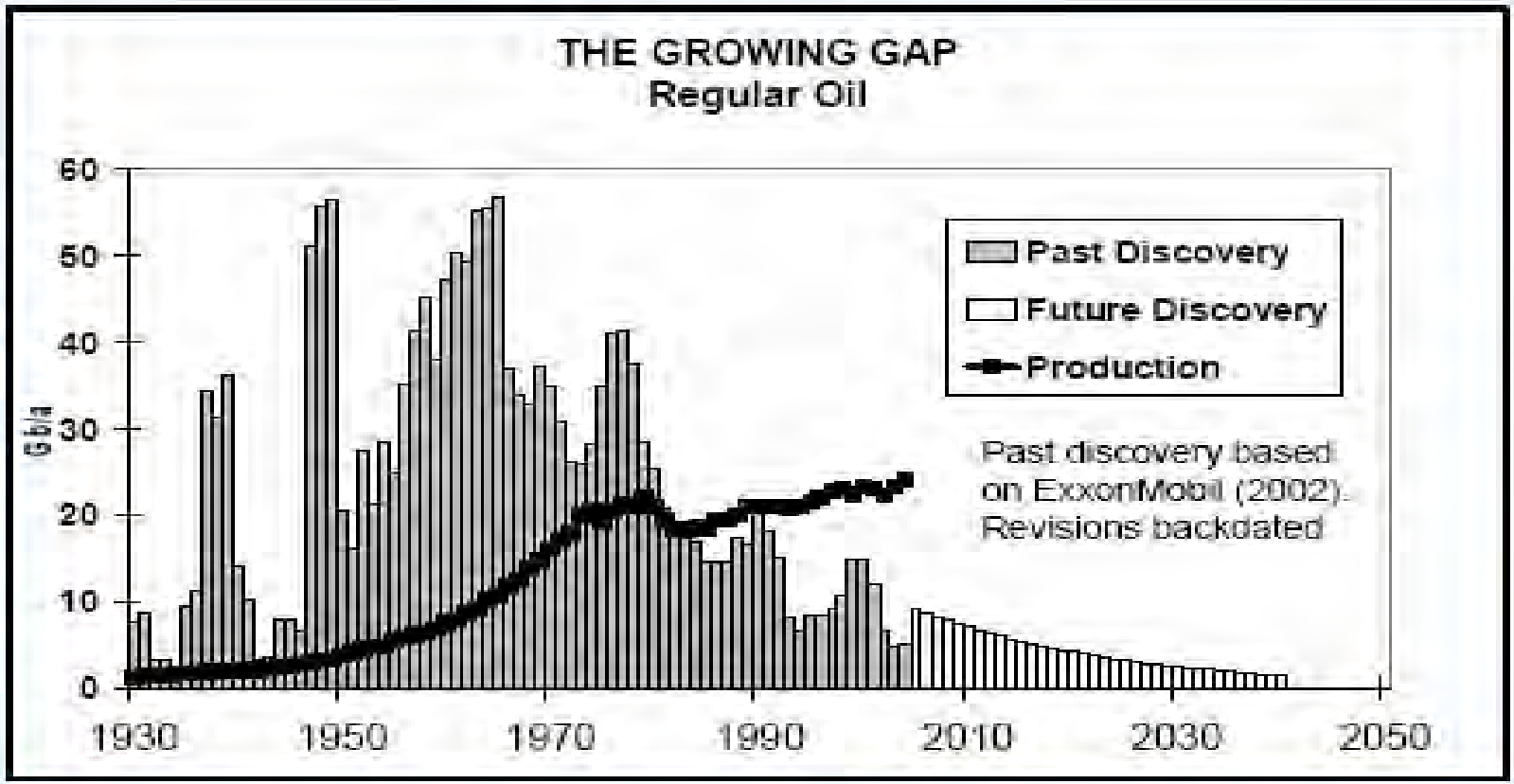
Hansen 2008


Climate Forcing and Temperature
Fe (W/m²)
0.5 × Vostok Temperature
Global Temperature
GHG Forcing
All Forcings
Eemian
Holocene
Temperature Anomaly (°C)
6
3
0
-3
3
2
1
0
-1
-2
-3
400
350
300
250
200
150
100
50
0
1900
2000
Time (ky BP)
Date

Hansen 2008

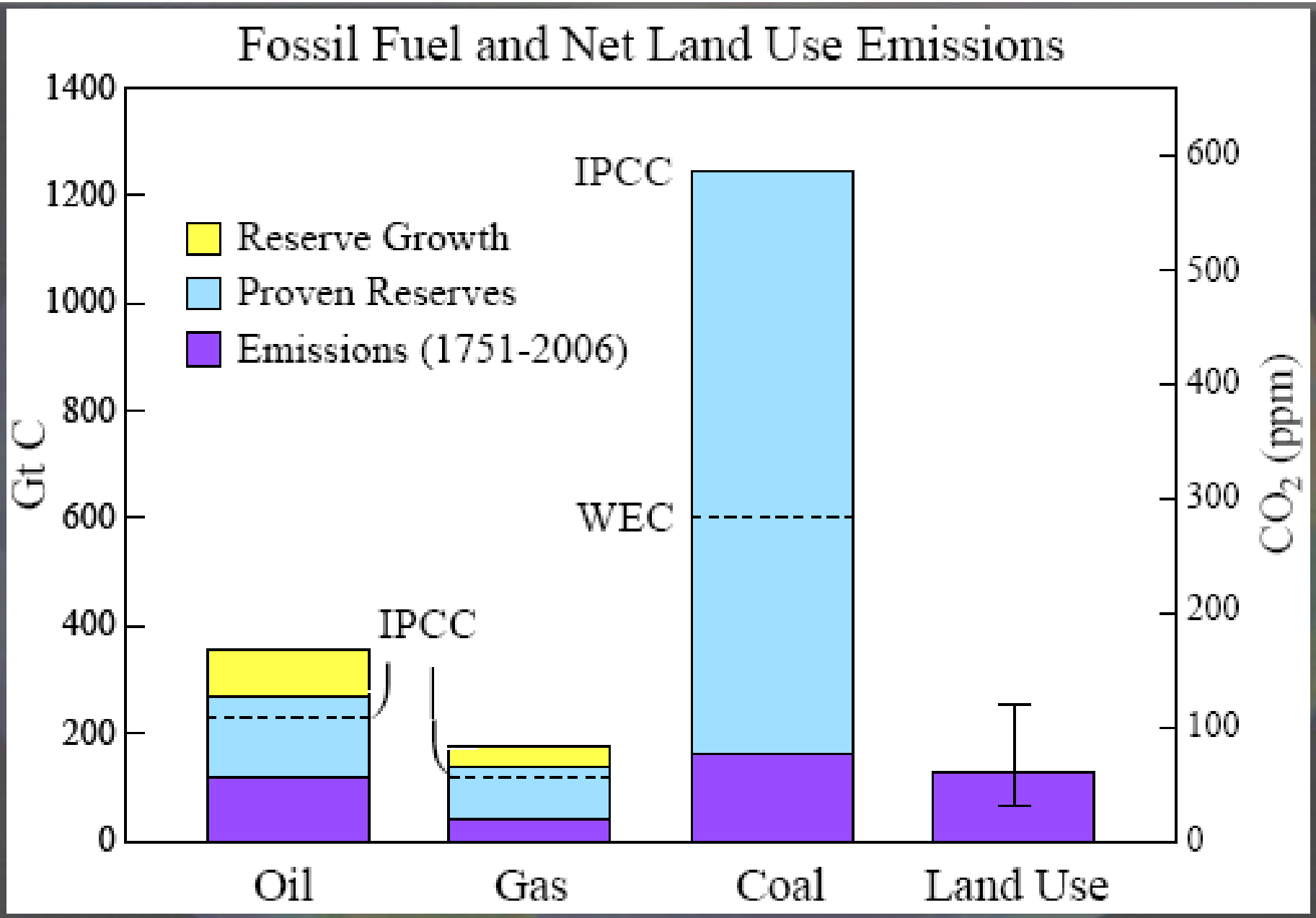
Energy

- Peak oil will be reached within a few years
- Oil-based economy will have to shift, hopefully NOT to coal unless clean coal technology is perfected



Today we burn 5 barrels of oil for every barrel of oil discovered.

Hall 2008



Still a lot of coal in the ground, but using that will have disastrous climate consequences

Hansen 2008

Outline

- Data
- DISTRIB – our statistically based (tri-modeling) approach to predicting potential suitable habitat under climate change (coarse scale = 20x20 km)
- Web demo
- Strengths and weaknesses of DISTRIB
- Ecoregion analysis
- Modifying Influences Summary Score (MISS)
- Silvicultural Influence Percentage (SIP)

Pro/Con on Spatial Models

Mechanistic

- Pro
  - Can include some ecophysiological drivers
  - Can partially deal with competition, disturbance, and CO2
- Con
  - Can't know or parameterize all variables or empirical relationships finally driving distributions of each species
  - Can't track all the legacies of land in question

Statistical

- Pro
  - Data mining – all based on real abundance data at species level
  - Can quickly model multiple species without much parameterization
- Con
  - Assumes an integrated system in equilibrium with environmental conditions
  - Can't directly deal with competition, disturbance, or CO2

Bottom line: need both! When they agree, the case is stronger, when they disagree, look closer!

Our approach is different from most statistical modeling approaches

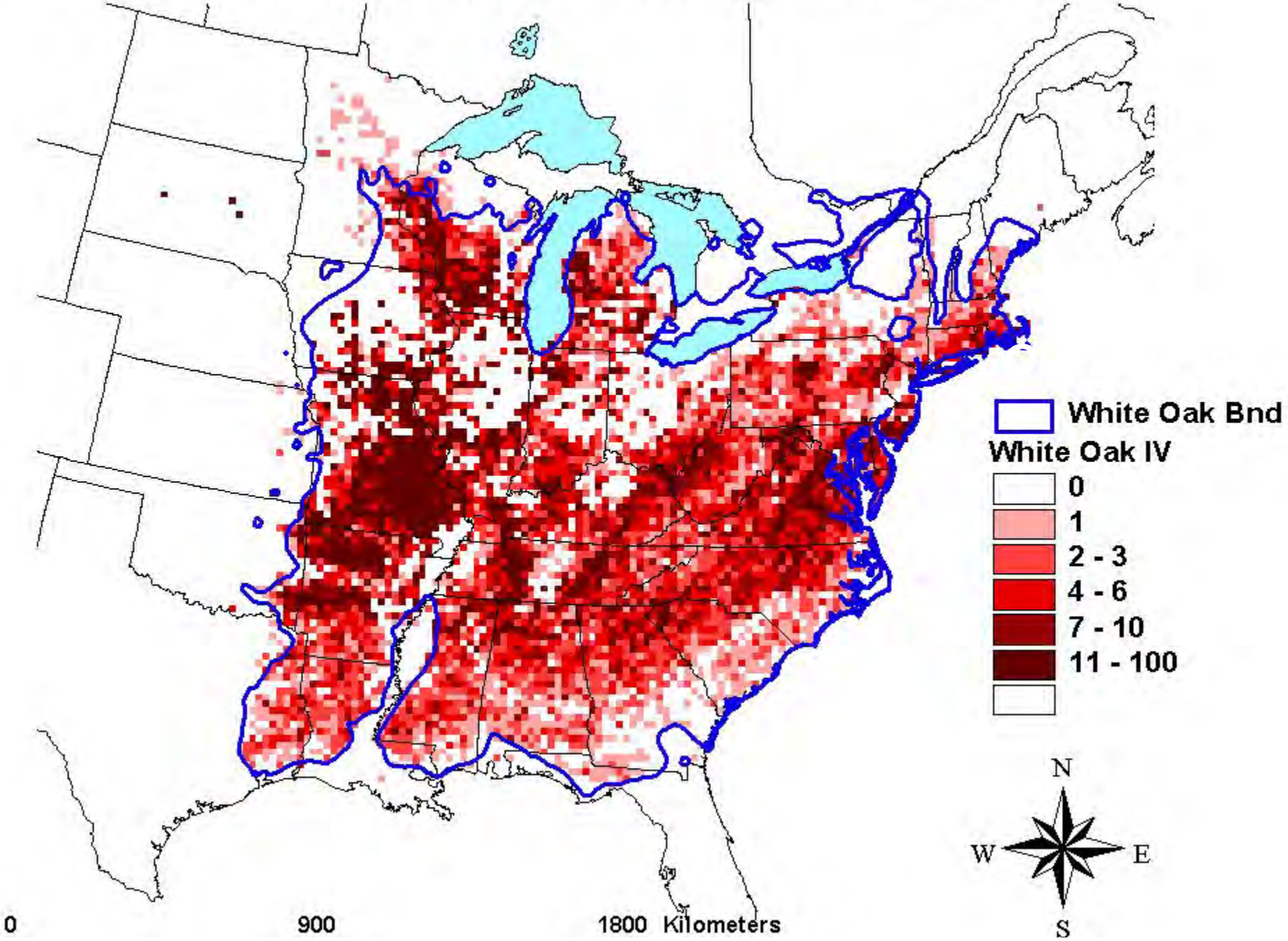
- Many models have been on regression approaches to fit a response surface – wildly inaccurate
  - We use extremely robust non-parametric statistical tools using ensemble techniques. There have been tremendous advances in this science since 2004 with a vast narrowing of appropriate tools, and Random Forests is surfacing in most every study as the best
- Most models use presence/absence data and with biased sampling (e.g., herbaria records)
  - We use unbiased FIA data to derive abundance values per cell
- Many models run at individual plot level with extrapolation
  - We use 20x20km cells which averages multiple FIA plots
- Most models use only climate data
  - We use 31 other variables to capture possible ‘barriers’ or ‘facilitators’ to movement
- Most models do not provide measure of reliability of each species’ model
  - We do
- Most models do not have a linked model for dispersal within the new suitable habitat
  - We have SHIFT

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
  - Aggregate points to 20 x 20 km polygons
- **OUTPUT**
  - Importance Value (IV) for 134 tree species, by 20 km cell

Available online: Prasad and Iverson 2003

White Oak Importance Value and Little's Bnd



Environmental Predictor Variables

- Response variable: FIA-derived importance values by 20 km

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

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 (%)

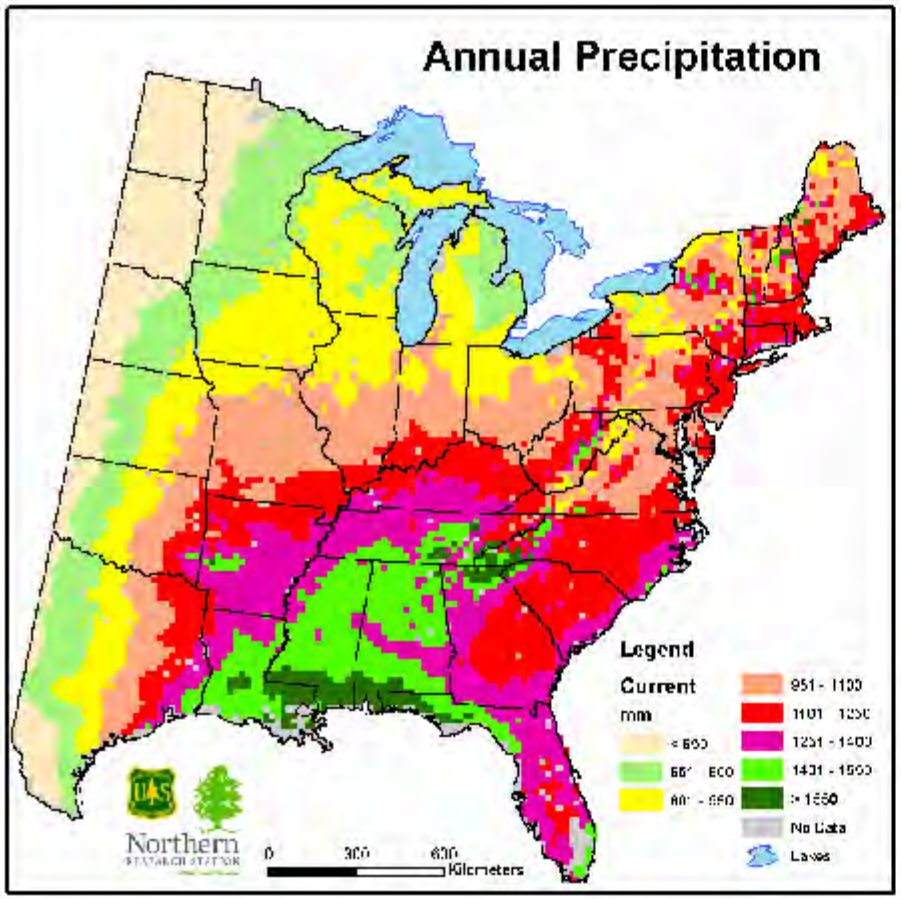
Soil Property

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)

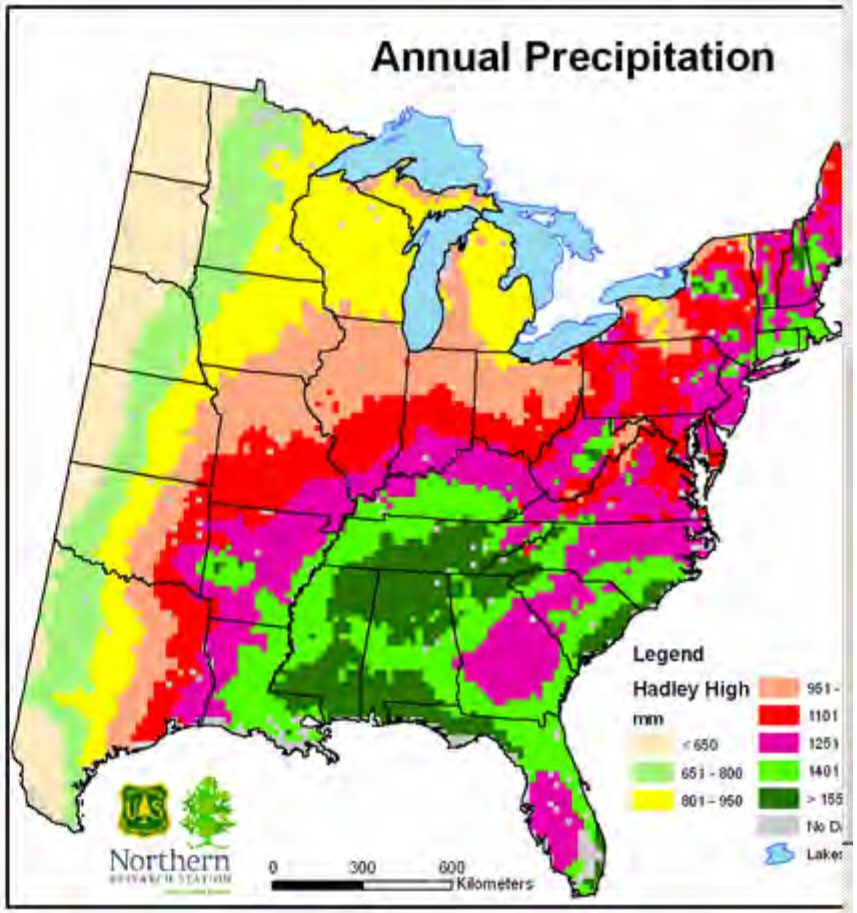
Land Use and Fragmentation

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

Current

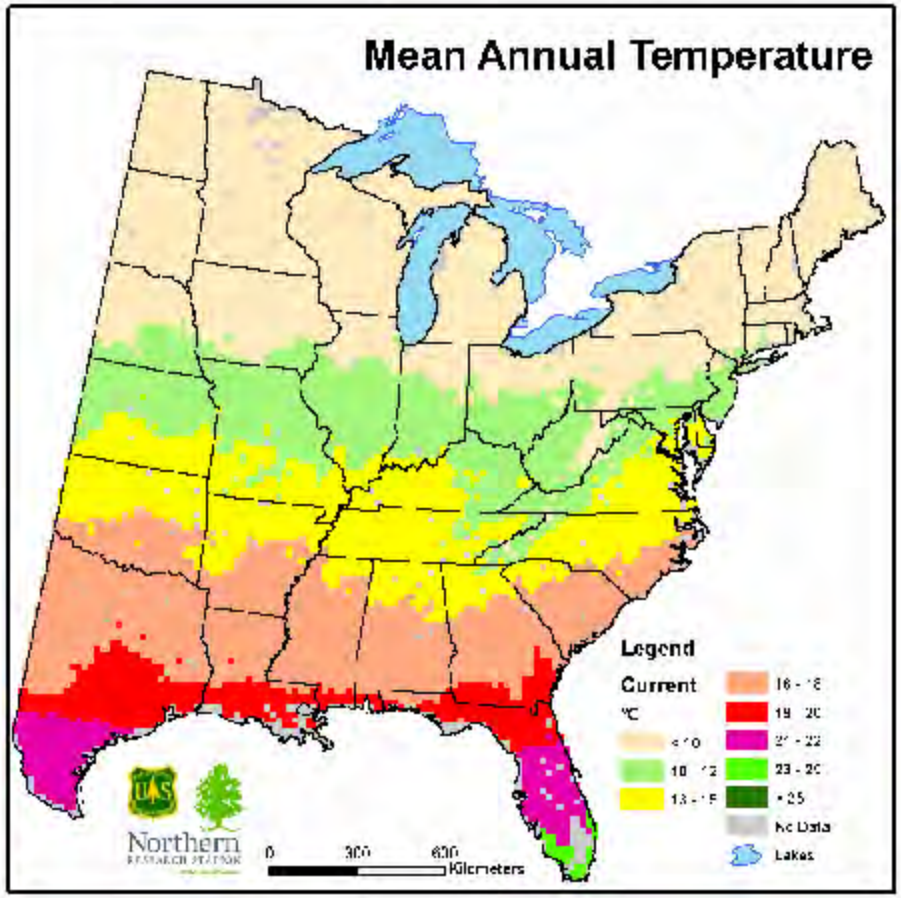


Hadley Hi

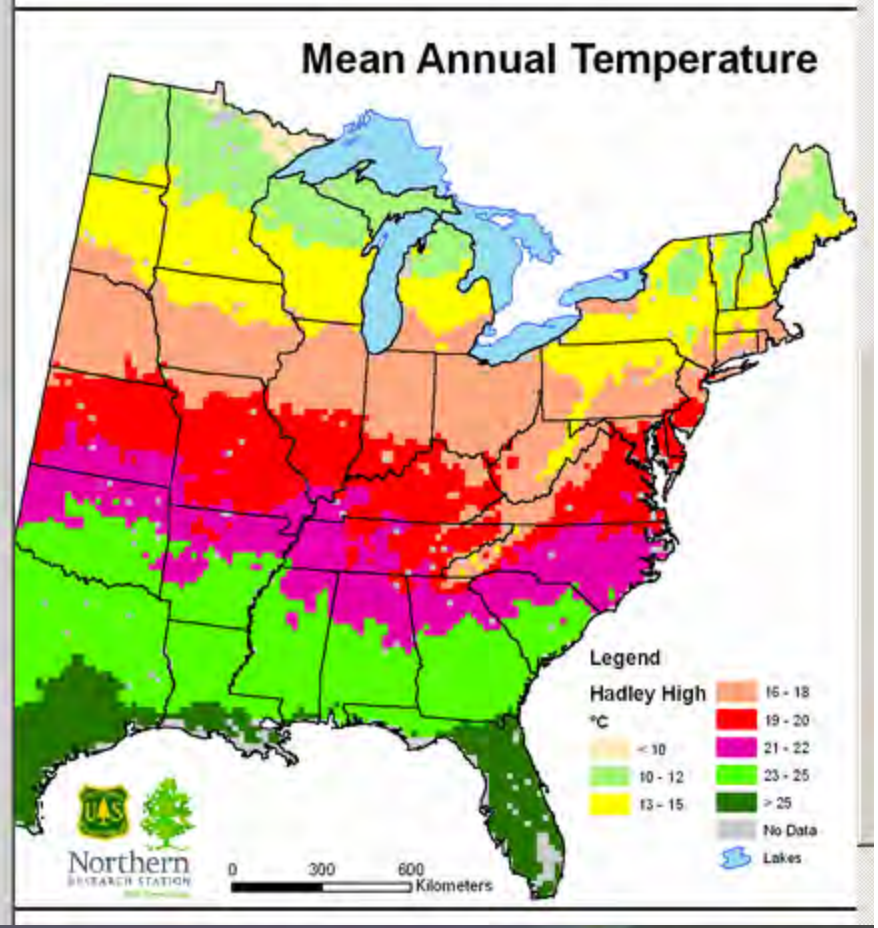


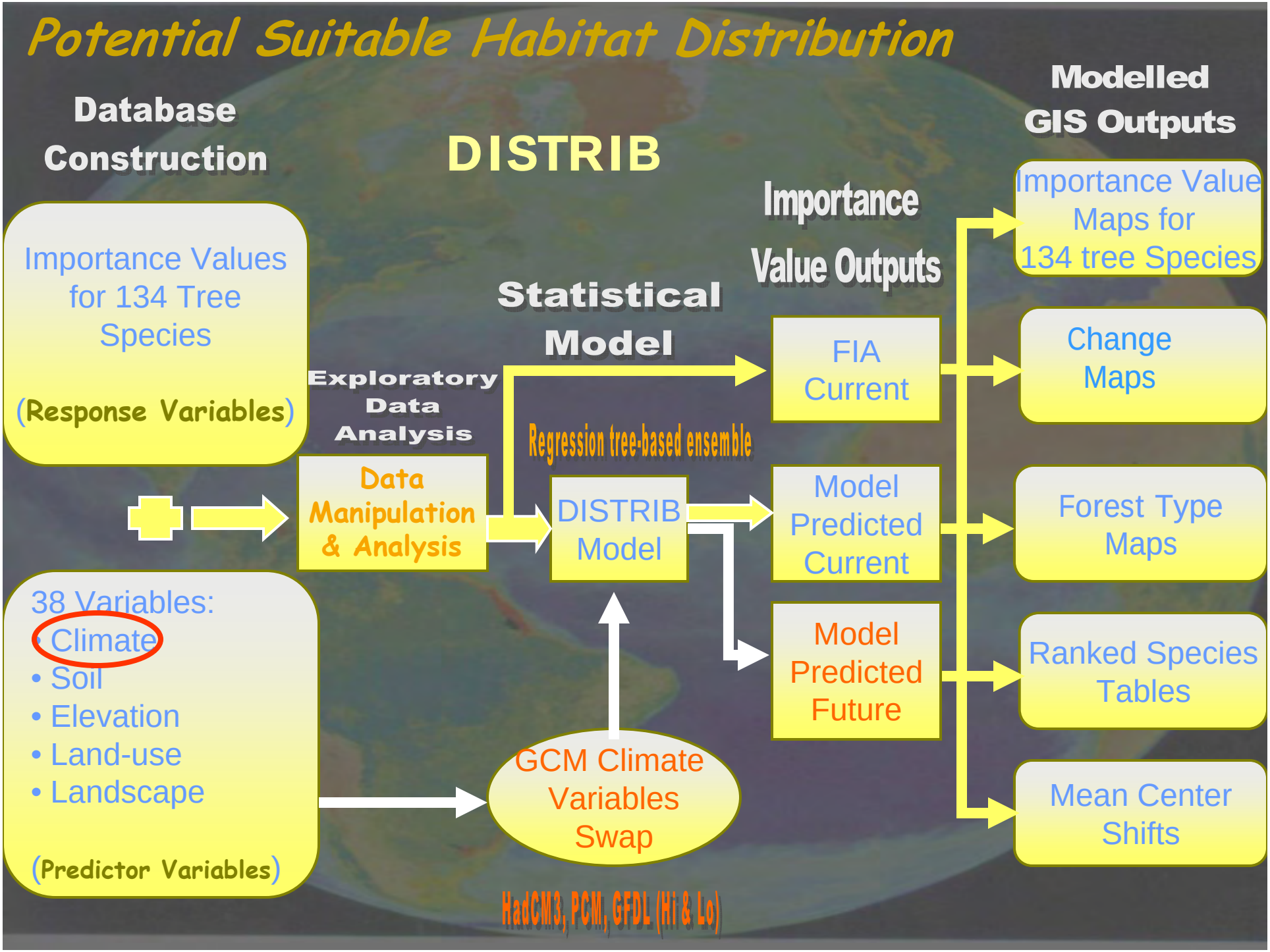
We use HadleyCM3, PCM, and GFDL under 2 emissions (A1fi, B1), and average Hi and Lo

Current



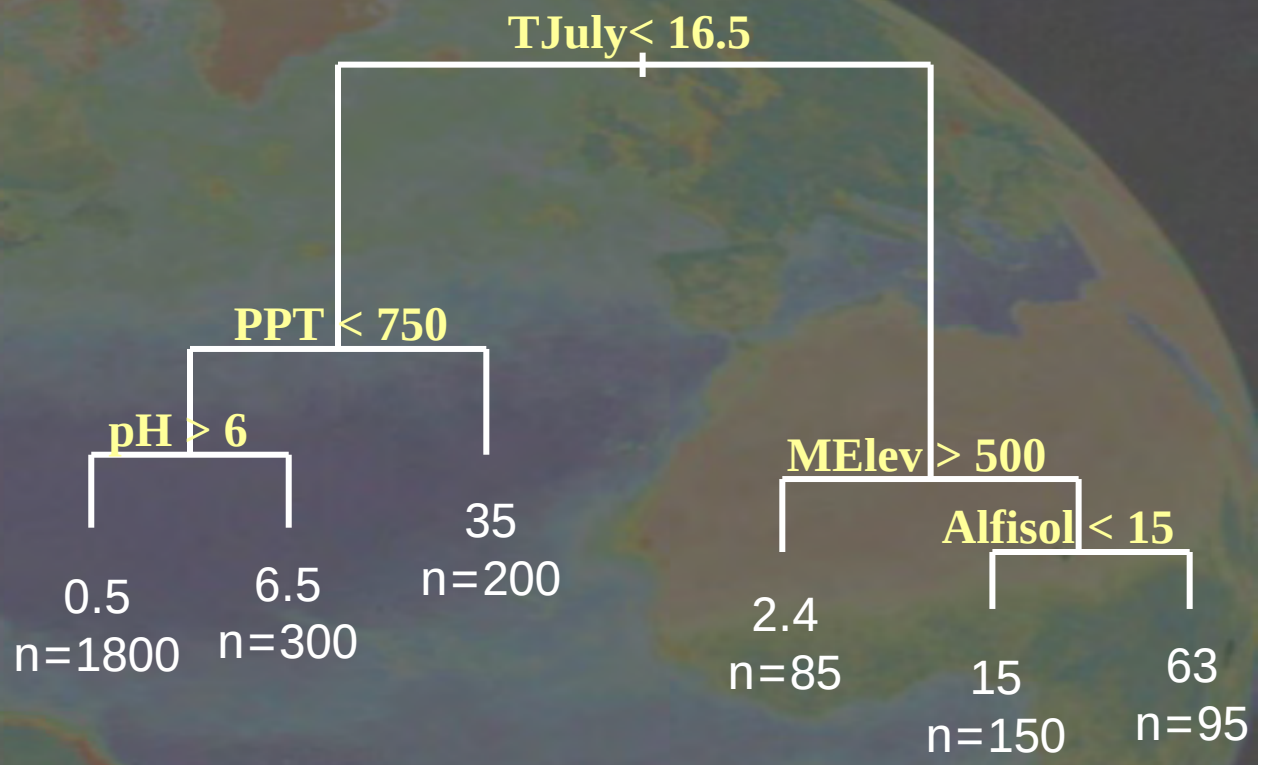
Hadley Hi



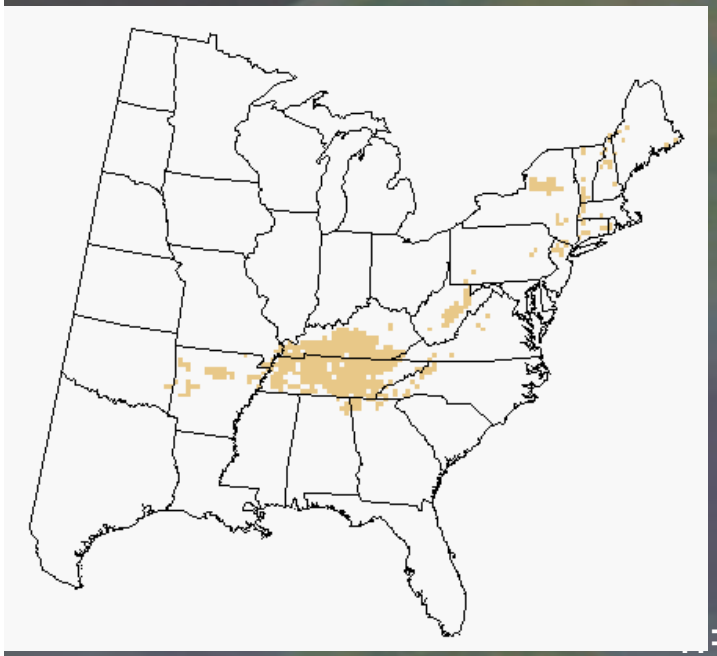

Potential Suitable Habitat Distribution
Database Construction
DISTRIB
Modelled GIS Outputs
Importance Value Outputs
Statistical Model
Importance Values for 134 Tree Species
(Response Variables)
Exploratory Data Analysis
Regression tree-based ensemble
Data Manipulation & Analysis
DISTRIB Model
FIA Current
Model Predicted Current
Model Predicted Future
Importance Value Maps for 134 tree Species
Change Maps
Forest Type Maps
Ranked Species Tables
Mean Center Shifts
38 Variables:
• Climate
• Soil
• Elevation
• Land-use
• Landscape
(Predictor Variables)
GCM Climate Variables Swap
HadCM3, PCM, GFDL (Hi & Lo)

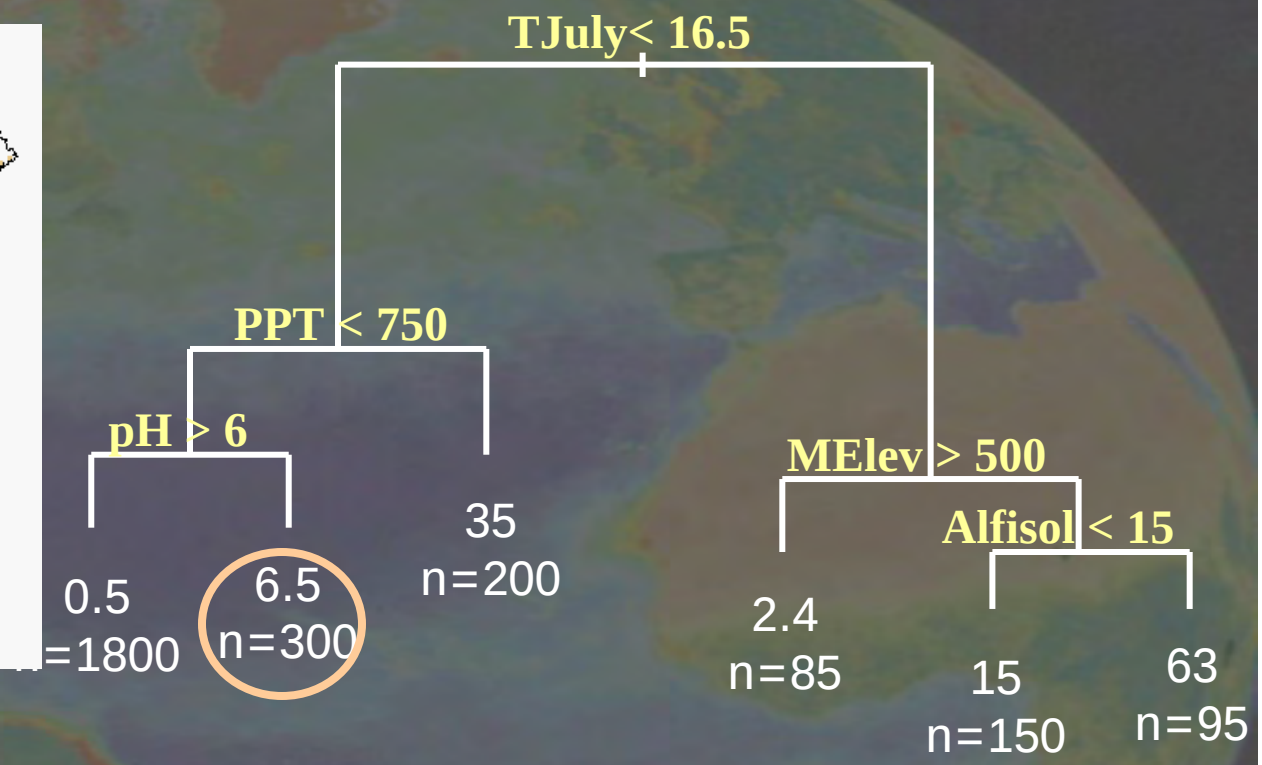
Regression Tree Analysis (RTA)

- A single (best) predictor is selected to split the data
- Additional best predictors are selected for each subset of data, thus creating 'branches' of a 'tree'
- At the bottom is series of *terminal nodes* which contains the predicted value of species importance
- These values are then mapped



Regression Tree Analysis (RTA)





TJuly < 16.5 &
PPT < 750 &
PH <= 6

Mapping Geographic Predictors

Highly suited for distributional mapping where different variables operate at different geographic regions – *can map predictor-rules driving the distribution.*

Iverson and Prasad 1998 Ecological Monographs

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)

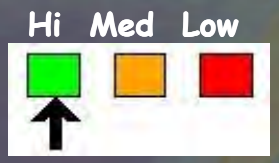
Assessment of Model Reliability

- Not all species models are equal – need to know about our confidence in the model
- 4 factors used in model reliability score:
  - R^2 equivalent of the Random Forest model
  - Fuzzy Kappa statistic comparing prediction to actual data
  - Of 30 BT trees, the CV of top five variables' predictor importance values
  - Of 30 BT trees, the consistency to use the same top 5 variables in the models

Model Reliability Scores

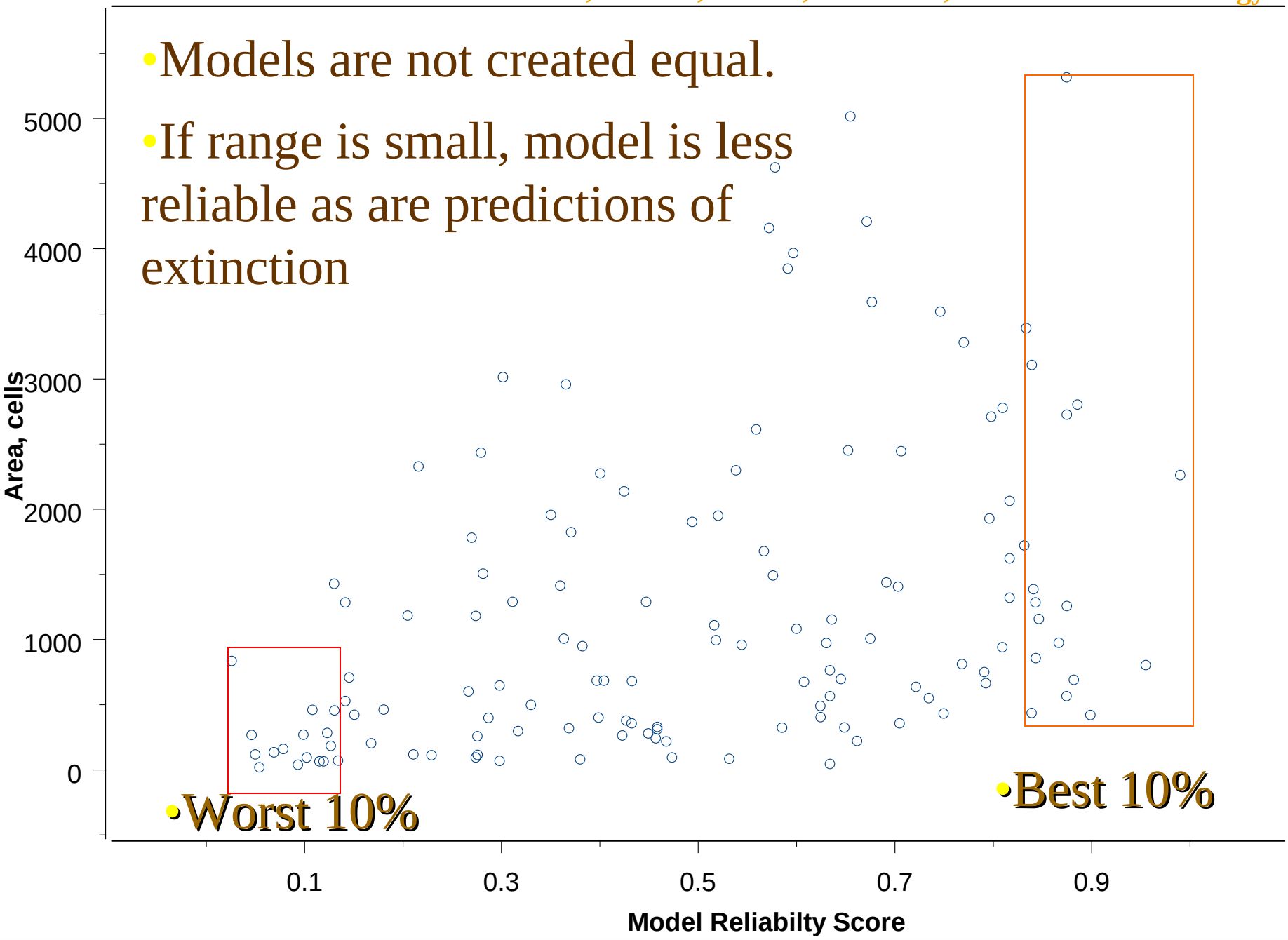
Species	ModRel
Abies balsamea	0.75
Acer barbatum	0.32
Acer negundo	0.34
Acer nigrum	0.21
Acer pensylvanicum	0.62
Acer rubrum	0.66
Acer saccharinum	0.33
Acer saccharum	0.59
Acer spicatum	0.55

Model Reliability



Schwartz, Iverson, Prasad, Matthews, O'Connor 2006 Ecology

- Models are not created equal.
- If range is small, model is less reliable as are predictions of extinction



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.

USDA United States Department of Agriculture Forest Service | Climate Change Tree Atlas | Northern Research Station

You are here: NRS Home / Tools & Applications / Climate Change Atlas / Tree Atlas

Climate Change Tree Atlas (A Spatial Database of 134 Tree Species of the Eastern USA)

Anantha M Prasad, Louis R Iverson, Steve Matthews, Matt Peters

NRS-4151, USDA Forest Service, Northern Research Station, Delaware, Ohio

Atlas Background | What's New | Citations | Credits | Atlas Help | Other Links (DropDownMenu)

Table of 134 Tree Species:

(Click Table-Header-Link to Sort by that Column - Ascending/Descending)

Model Reliability: High Medium Low

Reliability	Spp. #	Common Name	Scientific Name
	951	American basswood	*Tilia americana*
	531	American beech	*Fagus grandifolia*
	421	American chestnut	*Castanea dentata*
	972	American elm	*Ulmus americana*
	591	American holly	*Ilex opaca*
	391	American hornbeam:musclewood	*Carpinus caroliniana*
	935	American mountain-ash	*Sorbus americana*
	43	Atlantic white-cedar	*Chamaecyparis thyoides*

134 Species Combined/Compared

Combined Species Outputs

Summary of Predictors

Climate Change Tree Atlas

Climate Change Bird Atlas

http://www.nrs.fs.fed.us/atlas

month:	reqs:	pages:
Mar 2007:	130:	130:
Apr 2007:	707:	707:
May 2007:	14593:	14592:
Jun 2007:	14569:	14569:
Jul 2007:	15715:	15671:
Aug 2007:	18204:	18041:
Sep 2007:	21210:	21118:
Oct 2007:	28144:	28029:
Nov 2007:	45874:	45817:
Dec 2007:	47632:	47530:
Jan 2008:	42614:	42486:
Feb 2008:	30596:	28885:
Mar 2008:	44154:	39478:
Apr 2008:	74755:	67038:
May 2008:	146463:	119865:
Jun 2008:	78063:	62912:
Jul 2008:	72399:	59481:
Aug 2008:	62220:	51691:

Busiest month: May 2008 (119,865 requests for pages).

USDA United States Department of Agriculture Forest Service | Climate Change Bird Atlas | Northern Research Station

You are here: NRS Home / Tools & Applications / Climate Change Atlas / Bird Atlas

Climate Change Bird Atlas (A Spatial Database of 147 Bird Species of the Eastern USA)

Steve Matthews, Louis R Iverson, Anantha M Prasad, Matt Peters

NRS-4151, USDA Forest Service, Northern Research Station, Delaware, Ohio

Atlas Background | What's New | Citations | Credits | Atlas Help | Other Links (DropDownMenu)

Sortable Table of 147 Bird Species:

(Click Table-Header-Link to Sort by that Column - Ascending/Descending)

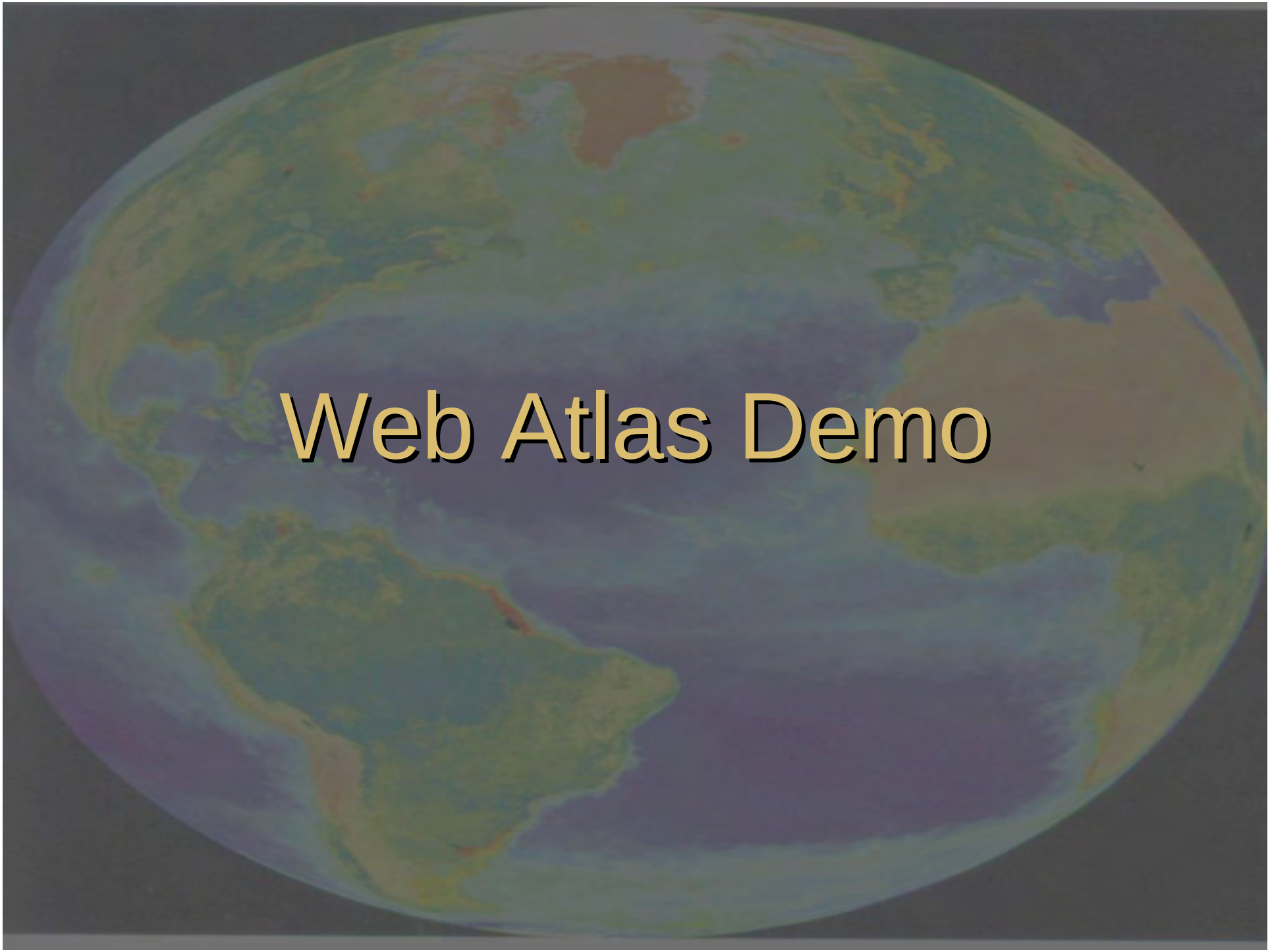
Model Reliability: High Medium Low

Reliability	Spp. #	Common Name	Scientific Name
	0070	Common Loon	*Gavia immer*
	1320	Mallard	*Anas platyrhynchos*
	1400	Blue-winged Teal	*Anas discors*
	1720	Canada Goose	*Branta canadensis*
	1840	White Ibis	*Eudocimus albus*
	1900	American Bittern	*Botaurus lentiginosus*
	1940	Great Blue Heron	*Ardea herodias*
	1960	Great Egret	*Ardea alba*

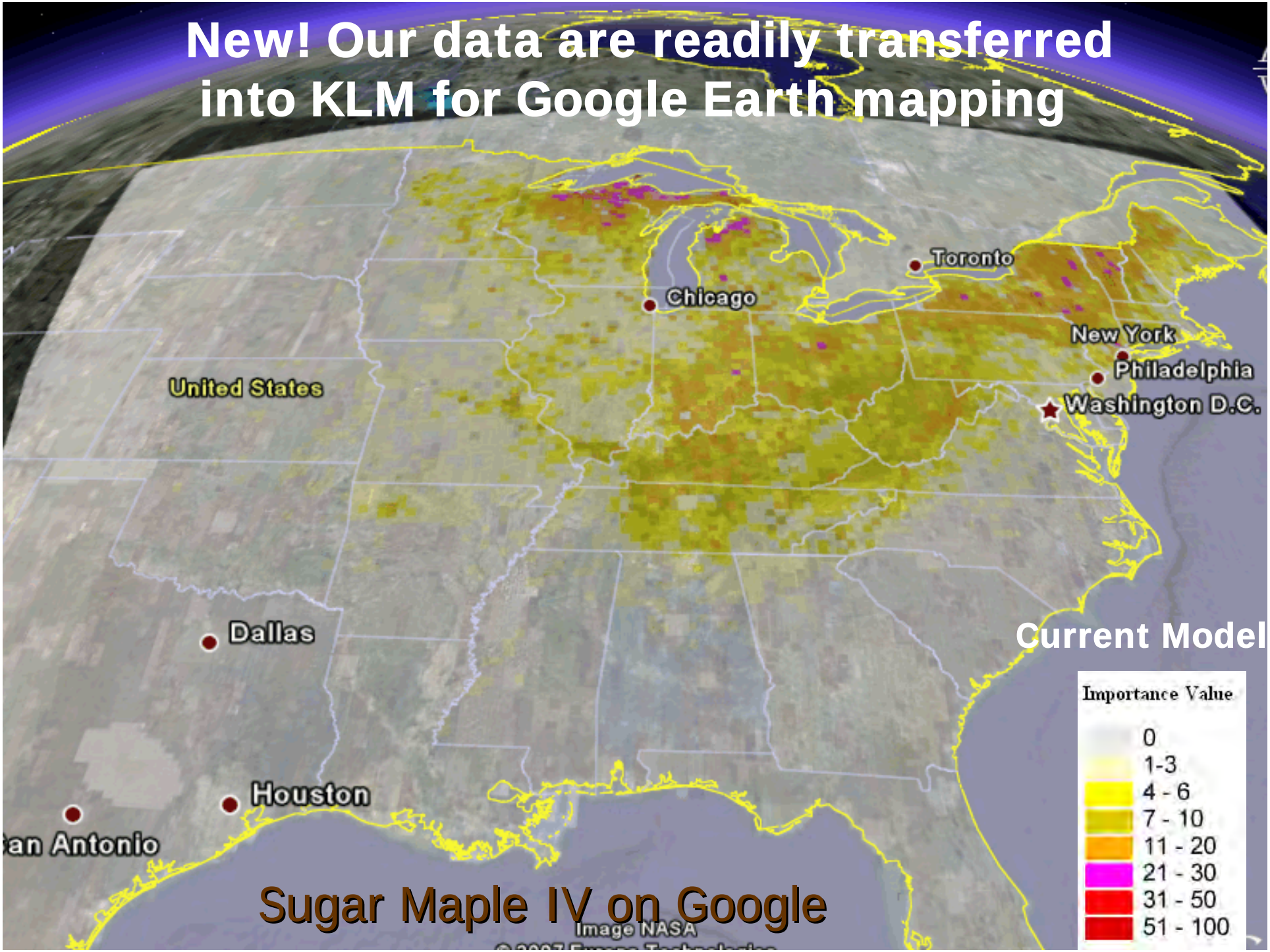
147 Species Combined/Compared

Combined Species Outputs

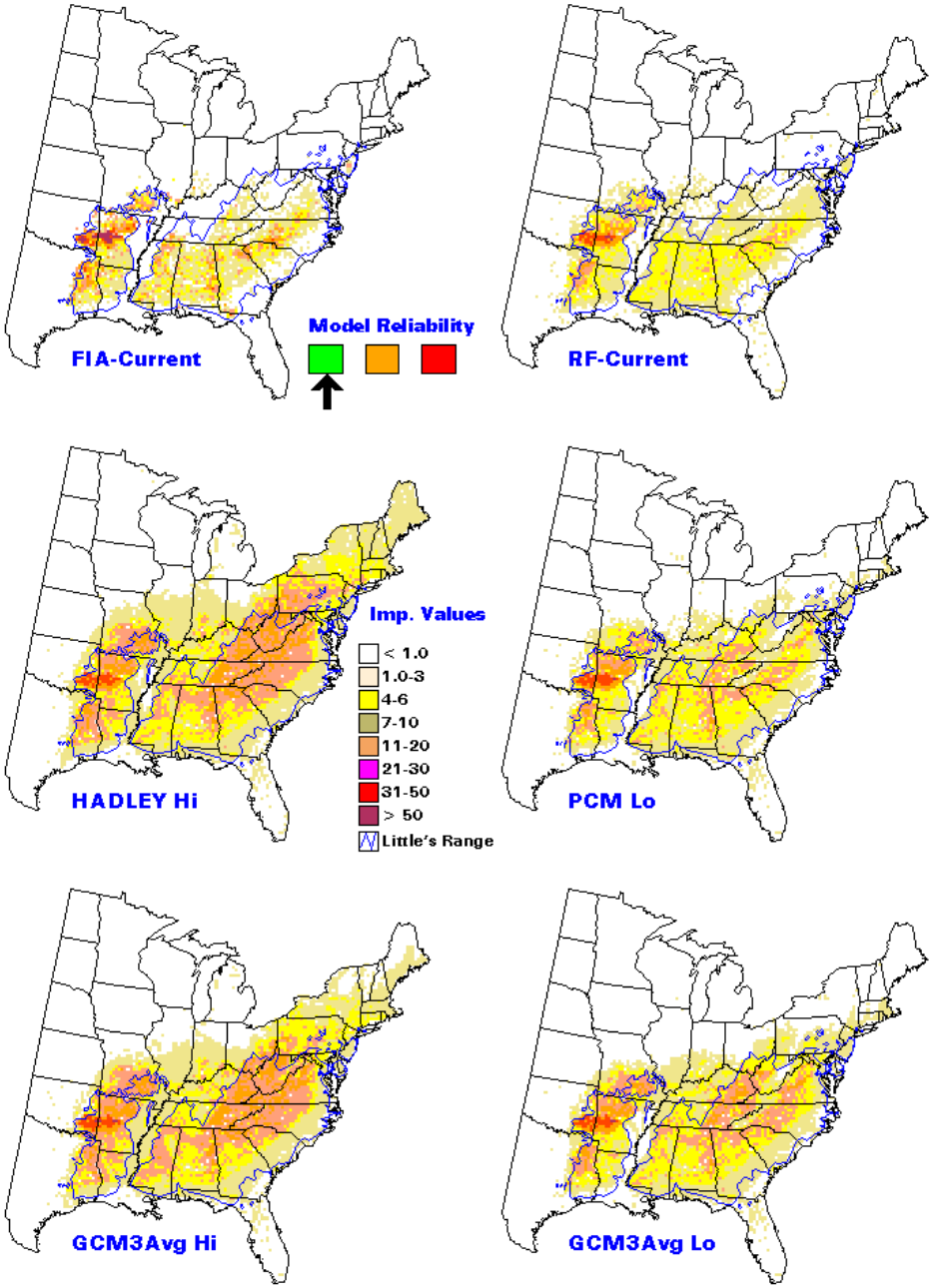
Summary of Predictors

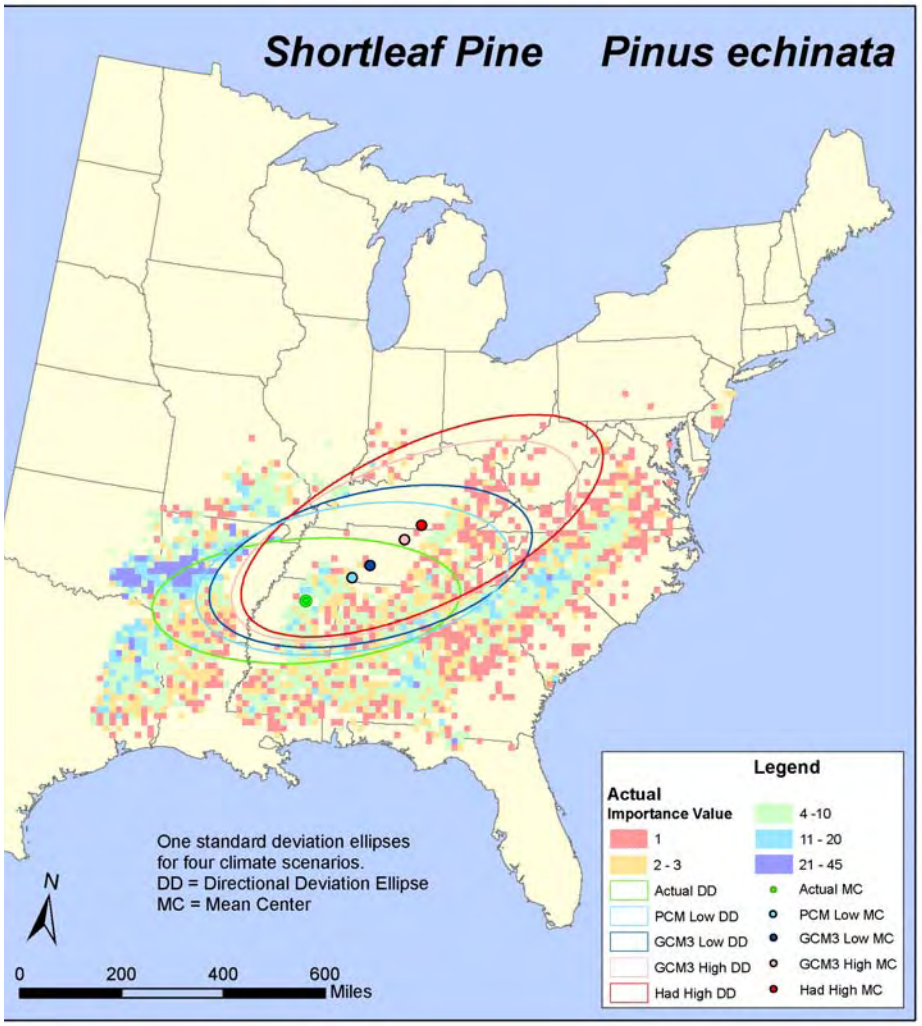


Web Atlas Demo

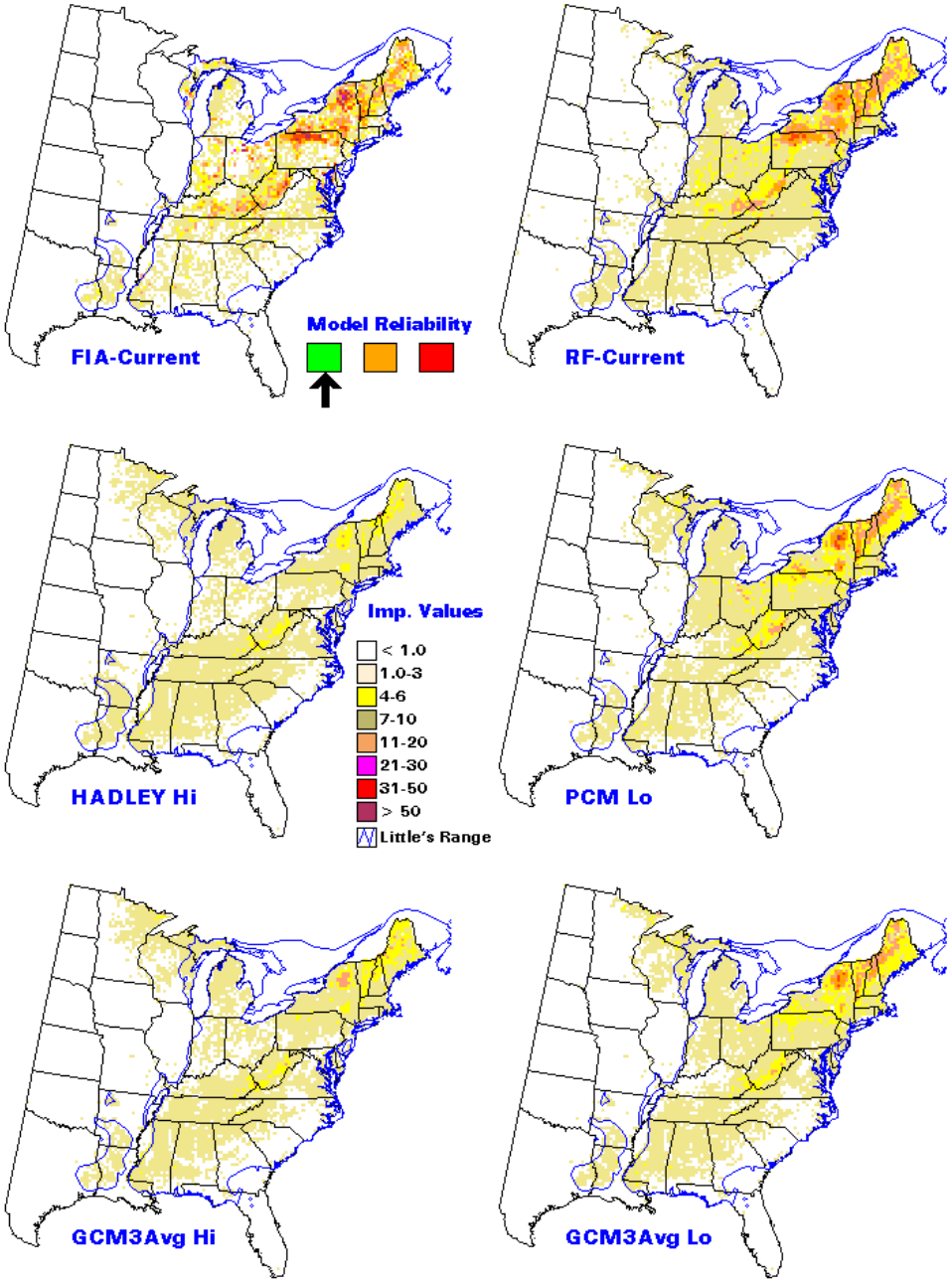

New! Our data are readily transferred into KLM for Google Earth mapping
Toronto
Chicago
New York
Philadelphia
Washington D.C.
United States
Dallas
Current Model
Importance Value
0
1-3
4 - 6
7 - 10
11 - 20
21 - 30
31 - 50
51 - 100
Houston
an Antonio
Sugar Maple IV on Google
Image NASA

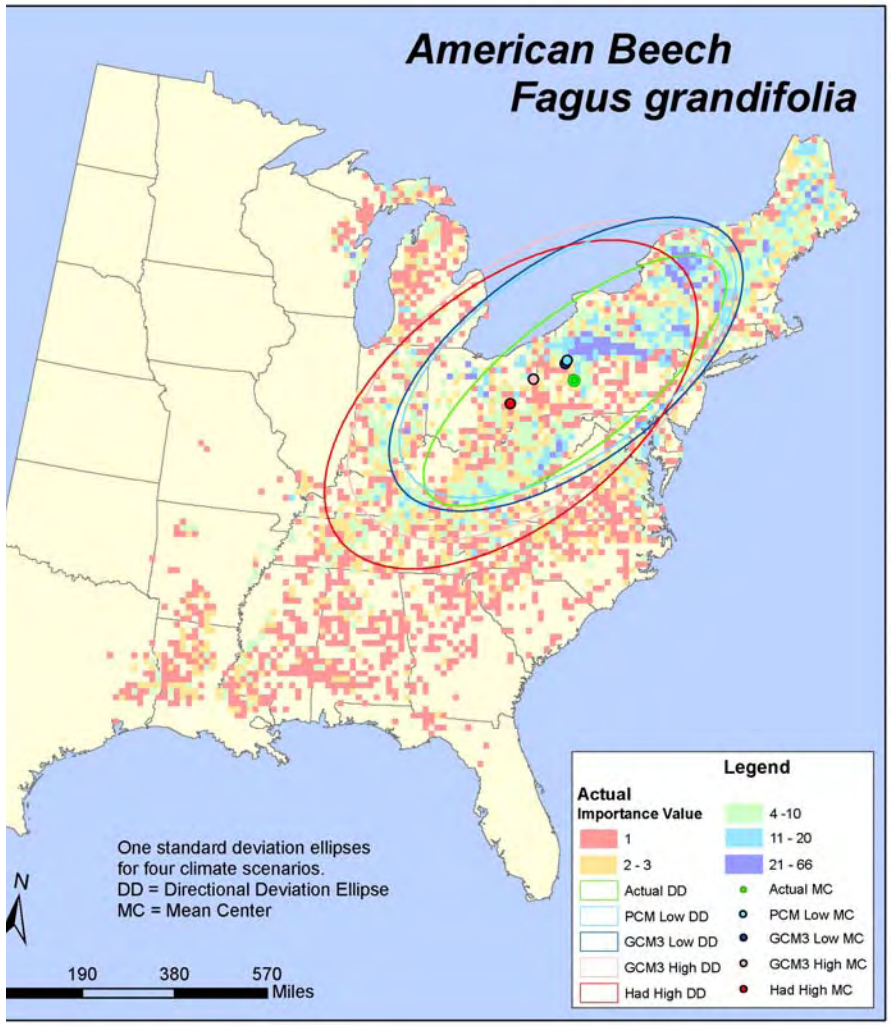
shortleaf pine - Pinus echinata - (110)



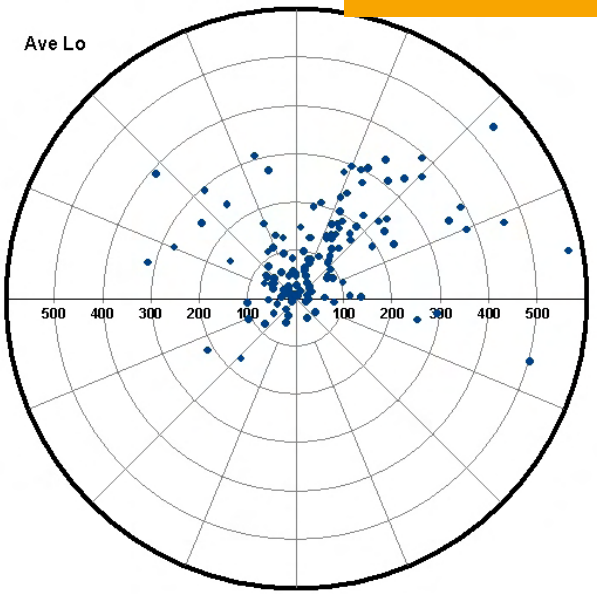


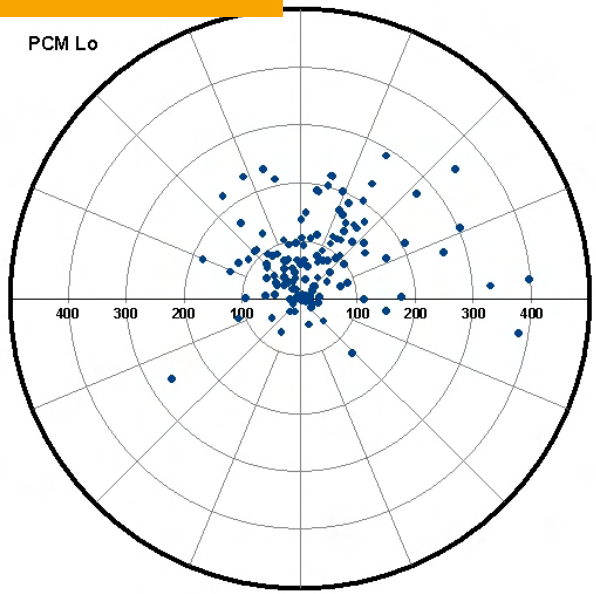
American beech - Fagus grandifolia - (531)

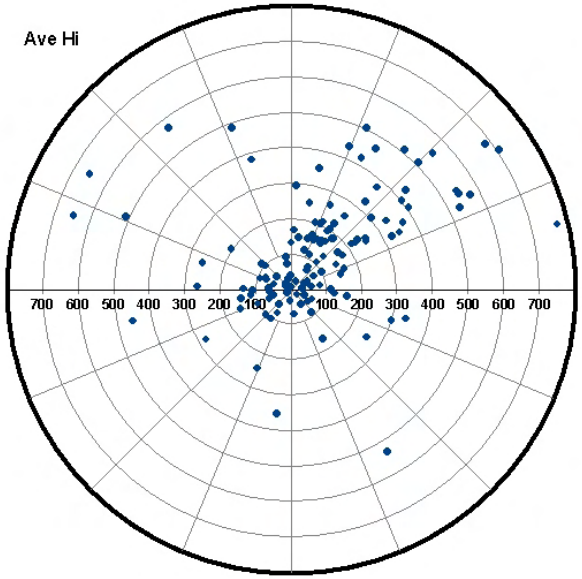


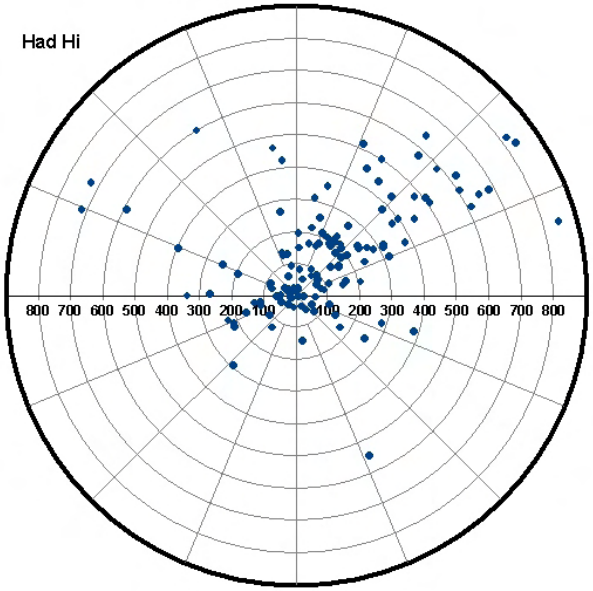


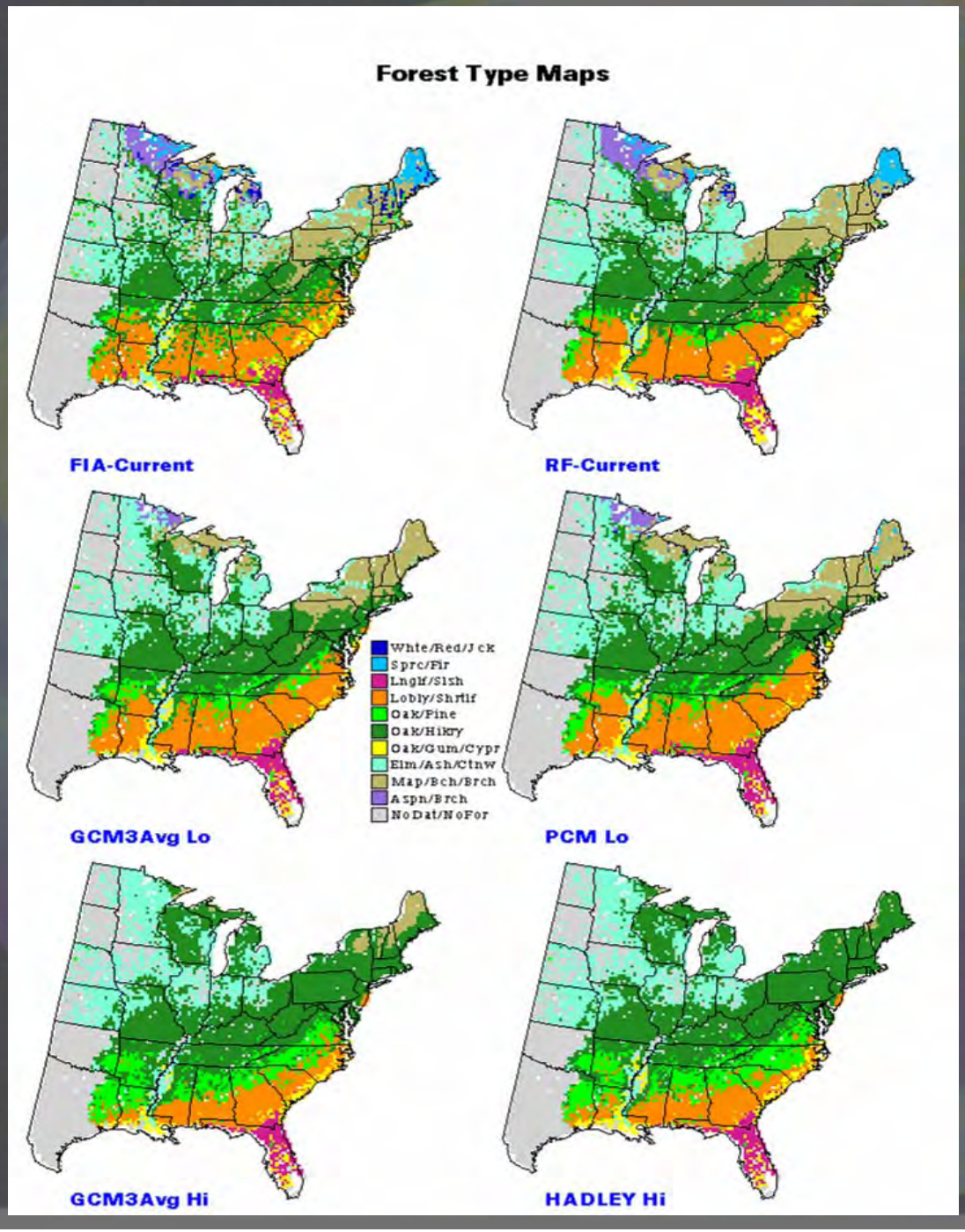
Mean Center Potential Movement - Trees











Forest Types from combinations of species.

Weaknesses of DISTRIB

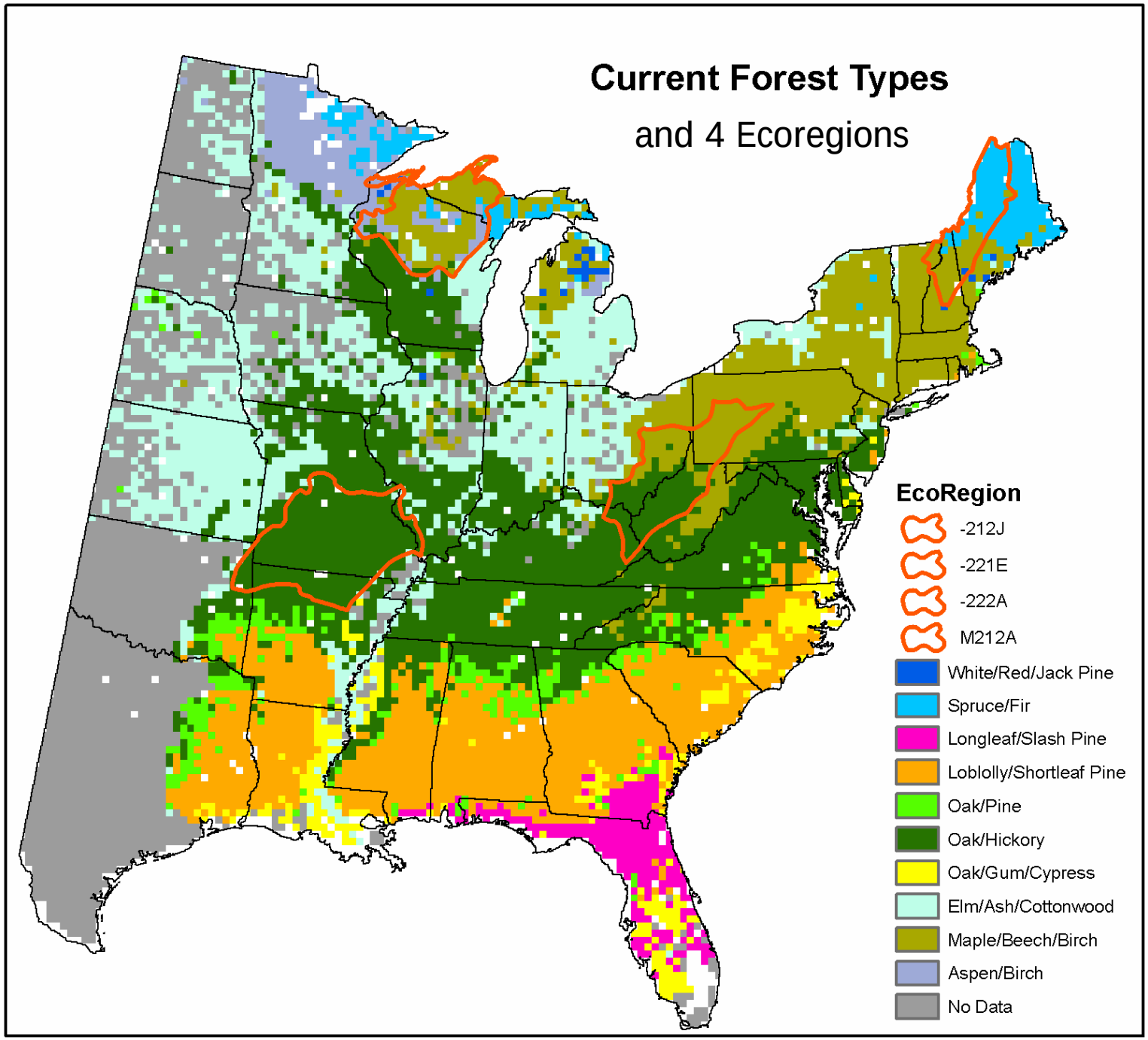
1. Limited in scope to modeling the potential current/future suitable habitats – not their actual future distributions. SHIFT begins to address this issue.
2. Designed for Eastern United States only.
3. FIA data are spatially sparse so that fine-scale analyses are not usually appropriate – 20 x 20 km is about right.
4. Depends on a decent sample size (>~50 cells), so not great for rare species.
5. Assumes equilibrium with environment.
6. There likely are better predictors that could be used.
7. Not all species have their entire ranges captured with IVs (Canada, West US).
8. Does not account for many biologic attributes and disturbance factors (addressed later).

Strengths 1 DISTRIB

1. FIA samples are statistically sound and non-biased
2. Analysis and prediction based more on core of distribution via IVs, not the range edges or just presence/absence maps that are more susceptible to error
3. Extremely robust non-parametric statistical tools using ensemble “tri-model” approach
4. The reliability of individual species models can be evaluated
5. RF is stable predicting into novel environments
6. Can use different variables/parameters to describe primary drivers in different parts of its geographic setting
7. Accounts for reality in that a particular species exists where it is, in spite of all legacies over decades and centuries. It therefore integrates over historic disturbances and climatic phenomena.

Strengths 2 DISTRIB

8. Need not be parameterized with a large suite of variables that are imperfectly known or cannot be adequately generalized for a species throughout its range.
9. Can rank among species for the most vulnerable to change (mean center changes).
10. Can produce ranked lists of species that may be in greatest risk or likely to have sufficient suitable habitat for future management


Current Forest Types
and 4 Ecoregions
EcoRegion
-212J
-221E
-222A
M212A
White/Red/Jack Pine
Spruce/Fir
Longleaf/Slash Pine
Loblolly/Shortleaf Pine
Oak/Pine
Oak/Hickory
Oak/Gum/Cypress
Elm/Ash/Cottonwood
Maple/Beech/Birch
Aspen/Birch
No Data

Section 212J--Southern Superior Uplands - Data

FIA	Scientific Name	Mod Rel	CURR MN IV	CURR AW IV	PCMLO MN IV	PCMLO AW IV	GCM3 LO MN IV	GCM3 LO AW IV	GCM3HI MN IV	GCM3 HI AW IV	HADHI MN IV	HADHI AW IV
12	Abies balsamea	High	7.2	1389	-5.09	-982	-6.07	-1171	-6.45	-1245	-6.44	-1243
43	Chamaecyparis thyoides	Low	0	0	0	0	0	0	0	0	0	0
68	Juniperus virginiana	Med	0	0	1.03	199	3.02	582	7.15	1380	7.12	1375
71	Larix laricina	High	2.02	389	-0.24	-47	-0.39	-76	-0.8	-155	-0.81	-156
94	Picea glauca	Med	1.52	293	-0.95	-183	-0.87	-167	-1.03	-199	-1.03	-198
95	Picea mariana	High	2.92	563	-2.36	-456	-2.64	-510	-2.69	-520	-2.67	-516
97	Picea rubens	High	0.13	26	0.02	4	0	0	0.01	2	0.04	7
105	Pinus banksiana	High	2.39	461	-0.39	-75	-0.34	-65	-0.85	-165	-0.61	-118
107	Pinus clausa	Med	0	0	0	0	0	0	0	0	0	0
110	Pinus echinata	High	0	0	0	0	0	0	0	0	0	0
111	Pinus elliottii	High	0	0	0	0	0	0	0	0	0	0
115	Pinus glabra	Med	0	0	0	0	0	0	0	0	0	0
121	Pinus palustris	High	0	0	0	0	0	0	0	0	0	0
123	Pinus pungens	Med	0	0	0	0	0	0	0	0	0	0
125	Pinus resinosa	Med	2.23	430	0.2	38	0.51	98	-0.51	-98	-0.55	-107
126	Pinus rigida	High	0	0	0	0	0	0	0	0	0	0
128	Pinus serotina	High	0	0	0	0	0	0	0	0	0	0
129	Pinus strobus	High	2.15	414	0.38	74	0.89	171	-1	-193	-1.17	-226

... for 134 species

Section 212J--Southern Superior Uplands - Losers

FIA	Scientific Name	Model Reliability	CURRENT AW IV	PCMLO AW IV %Change	GCM3LO AW IV %Change	GCM3HI AW IV %Change	HADHI AW IV %Change
319	Acer spicatum	High	33	-100	-100	-100	-100
601	Juglans cinerea	Low	16	119	231	-100	-100
761	Prunus pensylvanica	Medium	23	-35	91	-100	-100
763	Prunus virginiana	Low	72	26	74	-97	-93
95	Picea mariana	High	563	-81	-91	-92	-92
12	Abies balsamea	High	1389	-71	-84	-90	-89
375	Betula papyrifera	High	1156	-47	-55	-86	-85
371	Betula alleghaniensis	High	492	-48	-68	-83	-83
746	Populus tremuloides	High	2839	-51	-49	-83	-82
241	Thuja occidentalis	High	571	-40	-62	-74	-74
318	Acer saccharum	High	2714	-36	-51	-70	-73
94	Picea glauca	Medium	293	-62	-57	-68	-68
743	Populus grandidentata	High	456	-3	-18	-67	-71
261	Tsuga canadensis	High	332	-2	-29	-65	-65
315	Acer pensylvanicum	High	14	-36	-21	-50	-64
129	Pinus strobus	High	414	18	41	-47	-55
543	Fraxinus nigra	High	707	-22	-25	-45	-43
741	Populus balsamifera	High	95	-63	-45	-43	7
316	Acer rubrum	High	2128	-2	-14	-42	-45
977	Ulmus thomasii	Low	32	-25	-25	-41	-53
71	Larix laricina	High	389	-12	-20	-40	-40
105	Pinus banksiana	High	461	-16	-14	-36	-26
125	Pinus resinosa	Medium	430	9	23	-23	-25

Section 212J--Southern Superior Uplands - Gainers

FIA	Scientific Name	Model Reliability	CURRENT AW IV	PCMLO AW IV %Change	GCM3LO AW IV %Change	GCM3HI AW IV %Change	HADHI AW IV %Change
97	Picea rubens	High	26	15	0	8	27
951	Tilia americana	Medium	590	10	27	10	5
809	Quercus ellipsoidalis	Medium	163	7	39	16	28
833	Quercus rubra	High	674	59	83	21	12
701	Ostrya virginiana	Medium	284	17	37	68	77
762	Prunus serotina	High	358	189	177	76	39
391	Carpinus caroliniana	Medium	97	76	81	93	94
541	Fraxinus americana	High	246	76	66	102	95
544	Fraxinus pennsylvanica	Medium	149	-4	26	134	150
972	Ulmus americana	Medium	578	60	83	150	148
531	Fagus grandifolia	High	75	261	225	156	148
823	Quercus macrocarpa	Medium	250	77	115	173	204
402	Carya cordiformis	Low	68	135	243	299	301
802	Quercus alba	High	218	239	317	365	343
837	Quercus velutina	High	110	353	485	820	850
313	Acer negundo	Medium	59	281	539	878	1086
317	Acer saccharinum	Medium	46	448	804	963	1002
407	Carya ovata	Medium	14	1736	2486	2771	2593
975	Ulmus rubra	Medium	13	1692	2969	3562	3746
742	Populus deltoides	Low	8	925	2300	6075	6000
922	Salix nigra	Low	5	2960	5740	8020	8680
641	Maclura pomifera	Medium	1	700	3500	17700	19300

Section 221E--
Southern
Unglaciated
Allegheny Plateau

Losers

FIA	Scientific Name	Model Reliability	CURRENT AW IV	PCMLO AW IV Change	GCM3LO AW IV Change	GCM3HI AW IV Change	HADHI AW IV Change
125	Pinus resinosa	Medium	2	-100	-100	-100	-100
314	Acer nigrum	Low	15	-60	-93	-100	-93
315	Acer pensylvanicum	High	19	-79	-95	-100	-100
331	Aesculus glabra	Low	5	-100	-100	-100	-100
371	Betula alleghaniensis	High	28	-93	-96	-100	-100
743	Populus grandidentata	High	234	-86	-99	-100	-100
746	Populus tremuloides	High	33	-100	-100	-100	-100
761	Prunus pensylvanica	Medium	8	-100	-100	-100	-100
763	Prunus virginiana	Low	27	-89	-100	-100	-100
129	Pinus strobus	High	185	-39	-83	-99	-99
951	Tilia americana	Medium	140	-41	-81	-91	-91
261	Tsuga canadensis	High	106	-61	-80	-90	-89
318	Acer saccharum	High	1417	-10	-51	-89	-94
372	Betula lenta	High	172	-41	-69	-87	-88
762	Prunus serotina	High	1818	-60	-78	-81	-82
367	Asimina triloba	Low	101	-4	-52	-81	-80
126	Pinus rigida	High	38	-66	-79	-76	-76
621	Liriodendron tulipifera	High	1051	-4	-52	-72	-72
316	Acer rubrum	High	2092	-33	-57	-72	-70
531	Fagus grandifolia	High	595	-12	-47	-66	-69
541	Fraxinus americana	High	1047	-27	-48	-61	-61
901	Robinia psuedoacacia	Low	492	-47	-58	-59	-62
832	Quercus prinus	High	620	-18	-44	-56	-55
975	Ulmus rubra	Medium	430	-21	-31	-53	-53
711	Oxydendrum arboreum	High	181	-12	-45	-52	-49
806	Quercus coccinea	High	314	18	-7	-51	-56

Section 221E--Southern Unglaciated Allegheny Plateau

Gainers

FIA	Scientific Name	Model Reliability	CURRENT AW IV	PCMLO AW IV %Change	GCM3LO AW IV %Change	GCM3HI AW IV %Change	HADHI AW IV %Change
802	Quercus alba	High	1096	37	55	5	-5
731	Platanus occidentalis	Medium	203	5	9	8	7
693	Nyssa sylvatica	High	402	30	18	20	26
471	Cercis canadensis	Medium	208	39	41	24	30
313	Acer negundo	Medium	129	-4	3	30	23
409	Carya tomentosa	High	518	18	23	31	36
701	Ostrya virginiana	Medium	264	-2	-6	38	48
830	Quercus palustris	Medium	2	0	350	50	250
837	Quercus velutina	High	652	41	122	99	67
407	Carya ovata	Medium	141	79	95	133	128
544	Fraxinus pennsylvanica	Medium	53	175	230	313	315
317	Acer saccharinum	Medium	58	0	12	317	324
68	Juniperus virginiana	Medium	104	496	597	663	633
641	Maclura pomifera	Medium	33	36	18	670	730
521	Diospyros virginiana	Medium	49	257	376	759	784
462	Celtis occidentalis	Medium	29	314	500	786	797
552	Gleditsia triacanthos	Low	23	91	174	1035	1122
826	Quercus muehlenbergii	Medium	16	1069	1181	1113	1075
110	Pinus echinata	High	36	1078	2233	4700	5139
835	Quercus stellata	High	56	1511	3338	5671	5805
682	Morus rubra	Low	5	240	1240	6180	6520
402	Carya cordiformis	Low	5	2580	3600	7240	8480
611	Liquidambar styraciflua	High	4	2725	3675	8575	11400
922	Salix nigra	Low	1	3200	7100	10000	10200
742	Populus deltoides	Low	1	100	200	16500	19500

Section 222A--
Ozark Highlands

Losers

FIA	Scientific Name	Model Reliability	CURRENT AWIV	PCMLO AWIV Change	GCM3LO AWIV Change	GCM3HI AWIV Change	HADHI AWIV Change
129	Pinus strobus	High	1	-100	-100	-100	-100
331	Aesculus glabra	Low	3	-100	-100	-100	-100
804	Quercus bicolor	Low	12	-58	-100	-100	-100
531	Fagus grandifolia	High	49	-100	-98	-98	-90
318	Acer saccharum	High	499	-71	-88	-98	-99
602	Juglans nigra	Medium	574	-39	-66	-86	-89
405	Carya laciniosa	Low	6	-100	-83	-83	0
367	Asimina triloba	Low	25	-24	-56	-76	-76
806	Quercus coccinea	High	593	-65	-73	-73	-73
830	Quercus palustris	Medium	59	29	-56	-64	-56
977	Ulmus thomasii	Low	5	-100	-100	-60	400
802	Quercus alba	High	3428	-37	-47	-54	-57
832	Quercus prinus	High	48	-100	-92	-52	-23
403	Carya glabra	High	760	-46	-53	-51	-51
826	Quercus muehlenbergii	Medium	417	-23	-35	-42	-53
491	Cornus florida	High	1211	-41	-44	-41	-38
975	Ulmus rubra	Medium	422	-36	-41	-39	-35
931	Sassafras albidum	High	666	-22	-28	-38	-41
833	Quercus rubra	High	760	16	7	-36	-50
901	Robinia psuedoacacia	Low	74	50	-32	-35	-39
407	Carya ovata	Medium	525	-26	-34	-34	-41
837	Quercus velutina	High	3808	-5	-18	-31	-36
68	Juniperus virginiana	Medium	1574	-13	-13	-20	-34
462	Celtis occidentalis	Medium	451	-4	-24	-18	-20
972	Ulmus americana	Medium	850	-9	-23	-18	-18
356	Amelanchier sp.	Medium	12	-33	-67	-17	-67

Section 222A--
Ozark Highlands

Gainers

835	Quercus stellata	High	3629	34	40	44	36
521	Diospyros virginiana	Medium	393	8	26	45	41
544	Fraxinus pennsylvanica	Medium	238	47	66	71	68
824	Quercus marilandica	Medium	1087	73	76	71	54
682	Morus rubra	Low	269	35	55	135	91
552	Gleditsia triacanthos	Low	211	27	76	151	136
701	Ostrya virginiana	Medium	246	26	69	185	178
110	Pinus echinata	High	745	100	149	201	203
641	Maclura pomifera	Medium	145	154	147	241	189
317	Acer saccharinum	Medium	148	75	59	265	149
132	Pinus virginiana	High	24	-13	46	267	617
922	Salix nigra	Low	72	-17	-22	272	65
812	Quercus falcata var. falcata	High	210	120	203	285	320
813	Quercus falcata var. pagodaefolia	Medium	5	80	300	360	480
971	Ulmus alata	High	417	240	356	387	377
611	Liquidambar styraciflua	High	115	111	225	403	721
381	Bumelia lanuginosa	Low	7	286	329	457	457
391	Carpinus caroliniana	Medium	35	34	131	460	634
742	Populus deltoides	Low	46	17	87	474	346
404	Carya illinoensis	Low	13	692	469	500	508
822	Quercus lyrata	Medium	1	0	0	800	800
831	Quercus phellos	Medium	8	175	425	838	1413
313	Acer negundo	Medium	133	43	105	905	456
694	Nyssa biflora	High	2	0	1050	1650	1350
461	Celtis laevigata	Medium	30	1753	1933	2017	1963
823	Quercus macrocarpa	Medium	30	120	297	2297	1293
951	Tilia americana	Medium	7	-86	-71	3443	414
131	Pinus taeda	High	45	800	1584	3471	5320

Section M212A--White Mountains - Losers

FIA	Scientific Name	Model Reliability	CURRENT AW IV	PCMLO AW IV Change	GCM3LO AW IV Change	GCM3HI AW IV Change	HADHI AW IV Change
95	Picea mariana	High	223	-61	-77	-100	-100
319	Acer spicatum	High	148	-60	-73	-100	-100
373	Betula nigra	Low	5	-100	-100	-100	60
741	Populus balsamifera	High	20	-30	-70	-100	-100
935	Sorbus americana	Medium	12	-100	-100	-100	-100
12	Abies balsamea	High	2011	-41	-59	-84	-85
375	Betula papyrifera	High	754	-36	-39	-80	-91
97	Picea rubens	High	1094	-48	-60	-69	-69
241	Thuja occidentalis	High	434	-42	-50	-69	-73
371	Betula alleghaniensis	High	792	-20	-33	-68	-68
315	Acer pensylvanicum	High	330	-18	-30	-52	-58
94	Picea glauca	Medium	162	-28	-38	-46	-57
761	Prunus pensylvanica	Medium	120	-6	-6	-45	-71
531	Fagus grandifolia	High	823	-3	-4	-38	-50
318	Acer saccharum	High	1090	-3	-6	-28	-35
746	Populus tremuloides	High	261	12	28	-16	-49

Section M212A--White Mountains - Gainers

FIA	Scientific Name	Model Reliability	CURRENT AW IV	PCMLO AW IV %Change	GCM3LO AW IV %Change	GCM3HI AW IV %Change	HADHI AW IV %Change
543	Fraxinus nigra	High	89	-26	-11	4	-10
316	Acer rubrum	High	1082	23	24	19	-11
379	Betula populifolia	Medium	41	37	49	44	34
71	Larix laricina	High	31	-13	84	45	29
743	Populus grandidentata	High	83	33	39	58	4
129	Pinus strobus	High	375	25	21	59	8
261	Tsuga canadensis	High	309	87	99	73	40
701	Ostrya virginiana	Medium	89	16	25	83	187
541	Fraxinus americana	High	160	101	123	171	154
126	Pinus rigida	High	4	-100	-100	175	375
356	Amelanchier sp.	Medium	19	105	200	205	216
763	Prunus virginiana	Low	6	17	33	283	183
762	Prunus serotina	High	127	128	164	313	215
833	Quercus rubra	High	93	292	411	511	478
125	Pinus resinosa	Medium	34	-15	35	559	341
951	Tilia americana	Medium	15	233	413	620	1120
972	Ulmus americana	Medium	33	152	294	718	1061
317	Acer saccharinum	Medium	13	138	215	1131	1431
105	Pinus banksiana	High	1	-100	400	2800	6200
802	Quercus alba	High	2	3200	7650	20550	29950
372	Betula lenta	High	1	7200	9400	23500	17900
837	Quercus velutina	High	1	4500	9700	29600	45400

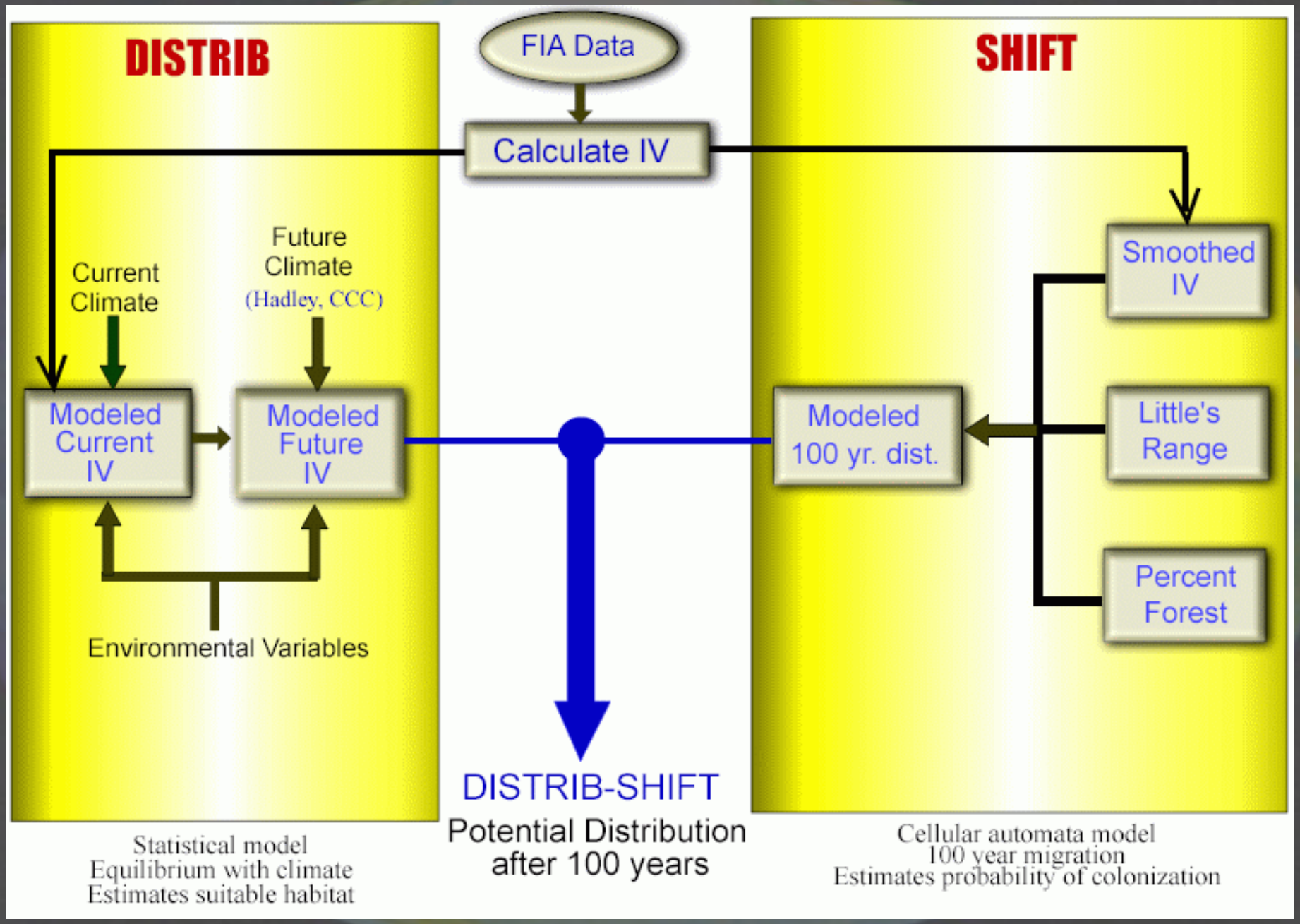
Potential species changes in area-weighted importance value for habitat suitability

(Chicago region)

Future: current ratio

Scenario	< 0.5	0.5 - 0.9	0.9 - 1.1	1.1 - 2	> 2	Total
PCM lo	32	17	6	26	33	114
Ave lo	35	22	13	17	33	114
Ave hi	43	17	4	17	33	114
Had hi	44	18	8	15	27	114

A future : current ratio below 1 indicates a loss (red), while a value above 1 indicates a gain (green).


DISTRIB
FIA Data
SHIFT
Calculate IV
Current Climate
Future Climate
(Hadley, CCC)
Smoothed IV
Modeled Current IV
Modeled Future IV
Modeled 100 yr. dist.
Little's Range
Percent Forest
Environmental Variables
DISTRIB-SHIFT
Potential Distribution after 100 years
Statistical model
Equilibrium with climate
Estimates suitable habitat
Cellular automata model
100 year migration
Estimates probability of colonization

Migration Potential into New Suitable Habitat in 100 yrs

Shift Output Summary

% of potential new suitable species habitat occupied in 100 years					
	Loblolly	Persimmon	Sweetgum	Sourwood	S. Red Oak
CCC					
>2%	8.4	2.7	11.6	12.7	7.6
>20%	1.5	0.8	2.2	2.4	2.0
>50%	0.6	0.6	1.2	1.0	1.2
HAD					
>2%	9.9	3.8	14.7	8.2	11.5
>20%	3.2	1.3	5.1	2.2	4.1
>50%	1.6	0.9	3.0	0.9	2.5

So, DISTRIB accounts for edaphic barriers or facilitators to migration, along with defining the suitable habitat, while SHIFT accounts for dispersal into a fragmented landscape.

Influencing Factors

- We have the model outputs showing tendencies towards gaining or losing under climate change
- Many other factors come in to play to determine final outcomes
- Can we rate these other factors for relative positive or negative impacts, along with some assessment of uncertainty?
- We would like to understand more about the climate factors' uncertainty within the models
  - Climate Uncertainty Score (CUS)
- We would like to generate a scoring system to help evaluate modifications:
  - Modifying Influences Summary Score (MISS)
- We would like to indicate the relative potential for silviculture to play a role in managing for climate change:
  - Silvicultural Influence Percentage (SIP)

National 2006 Composite Insect and Disease Risk* Map

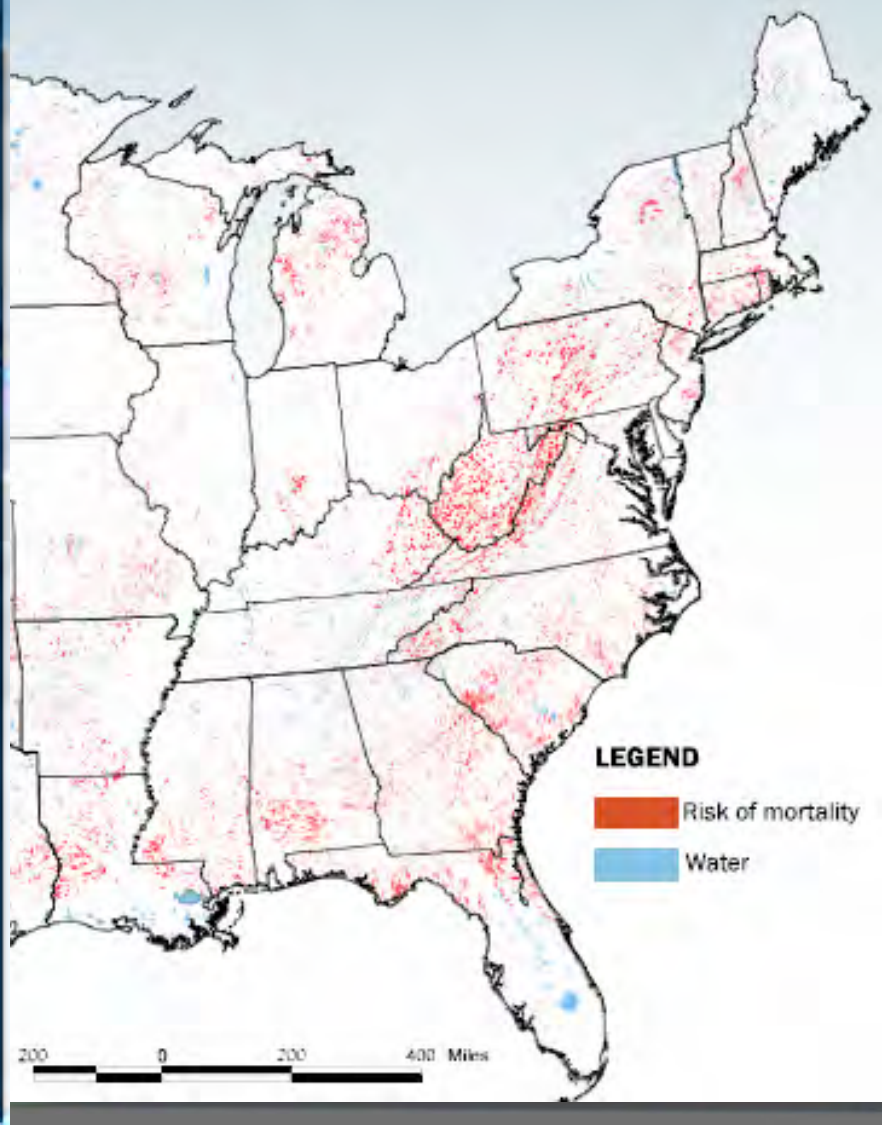
Acres at risk: Approximately 58 million

TOP AGENTS BY RANK

1. Mountain Pine Beetle
2. Red Oak Decline
3. Southern Pine Beetle
4. Root Diseases - All
5. Gypsy Moth
6. Pine Engraver Beetle
7. Fir Engraver Beetle
8. Douglas-Fir Beetle
9. Spruce Beetle
10. Hardwood Decline
11. Western Pine Beetle

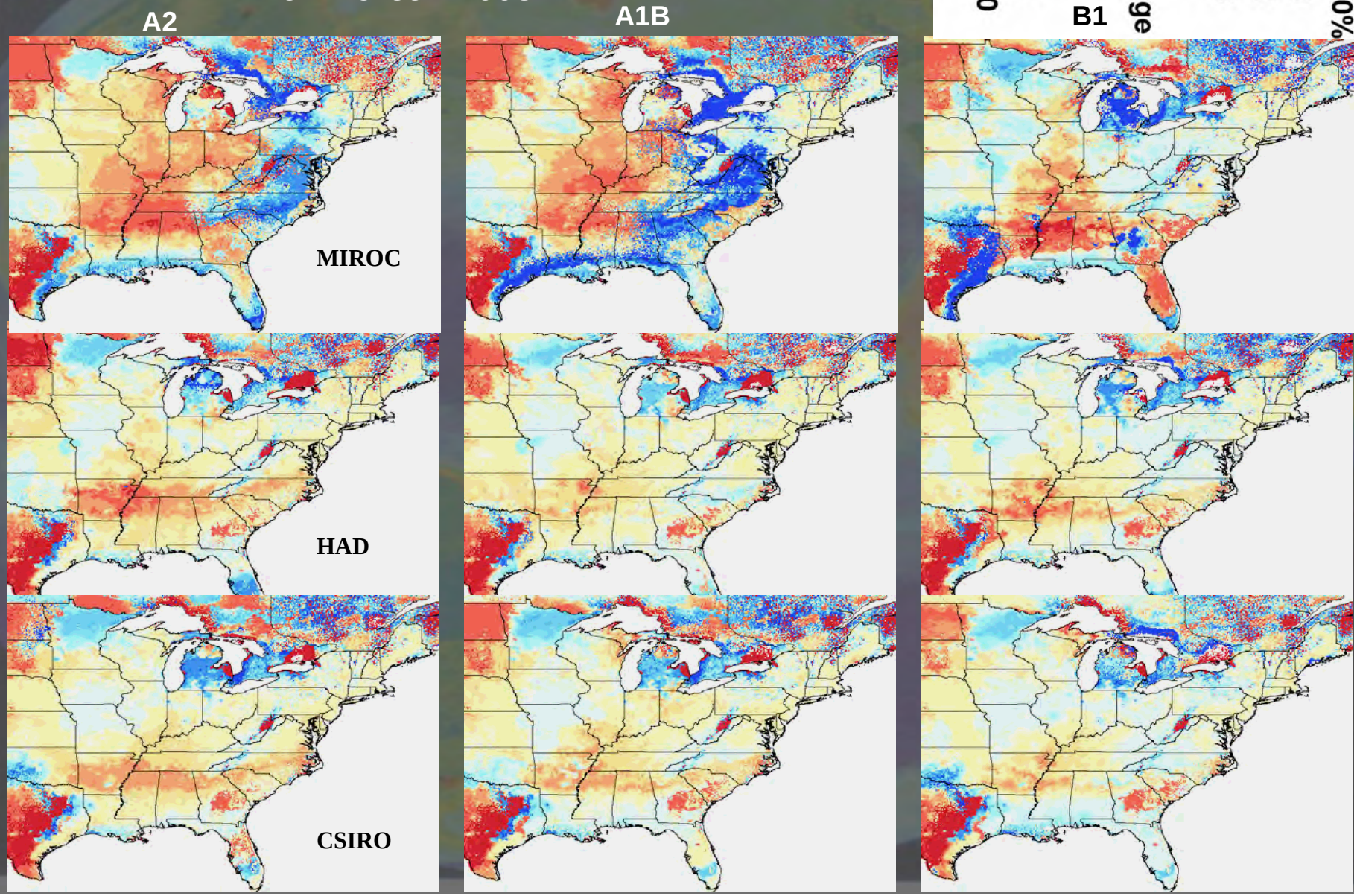
ADDITIONAL AGENTS BY RANK

Spruce Budworm
Beech Bark Disease
Douglas-Fir/White/Grand Fir Def.
Jeffrey Pine Beetle
Dwarf Mistletoes
Aspen Decline
Western Balsam Bark Beetle
Sudden Oak Death
Hemlock Looper
Western Red Cedar Mortality
Balsam Woolly Adelgid
Hemlock Woolly Adelgid
White Pine Blister Rust
Roundheaded Pine Beetle
Fusiform Rust
Oak Wilt
Aspen Forest Tent Caterpillar
Dutch Elm Disease
Northern Spruce Engraver Beetle
Jack Pine Budworm
Douglas-Fir Tussock Moth
Bronze Birch Borer
Alaska Yellow Cedar Decline
Western Spruce Budworm
Emerald Ash Borer
Butternut Canker
Eastern Larch Beetle
Asian Longhorn Beetle
Pacific Silver Fir Beetle
Spruce Aphid
Pacific Madrone Decline

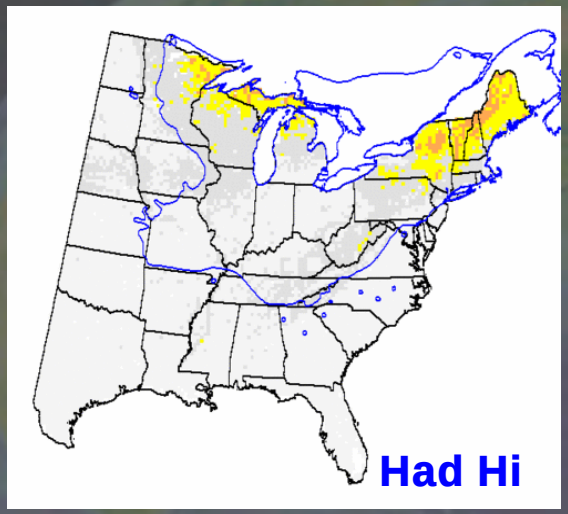


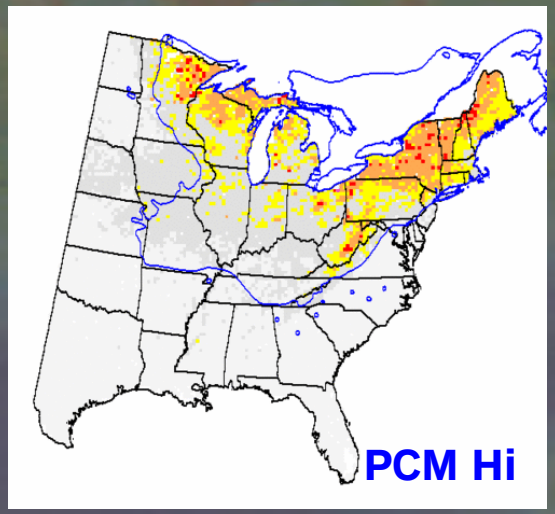
Percent Change in Biomass Consumed by Fire
1950 – 2000 vs. 2050 – 2099

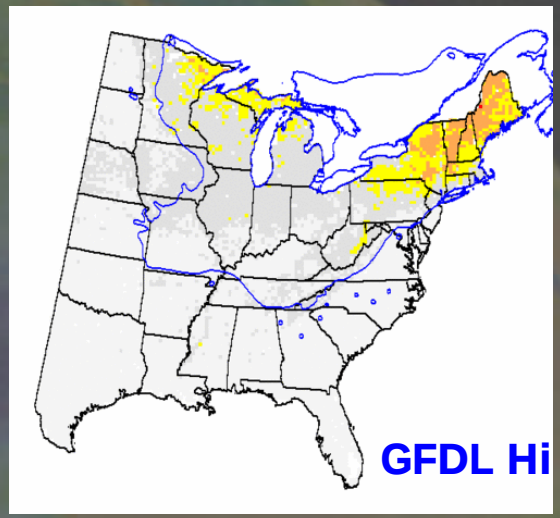
Ron Neilson 2008

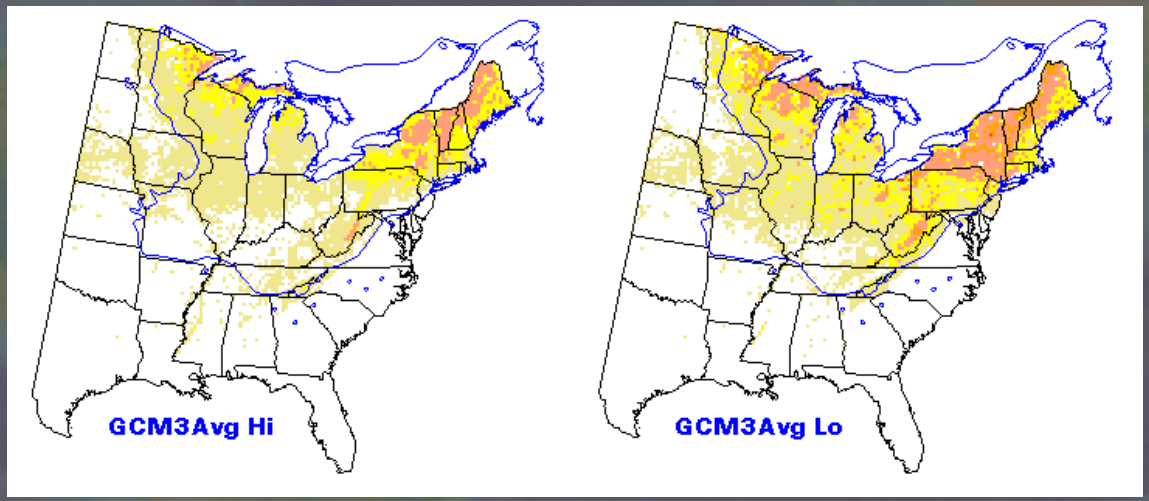


Variation among models





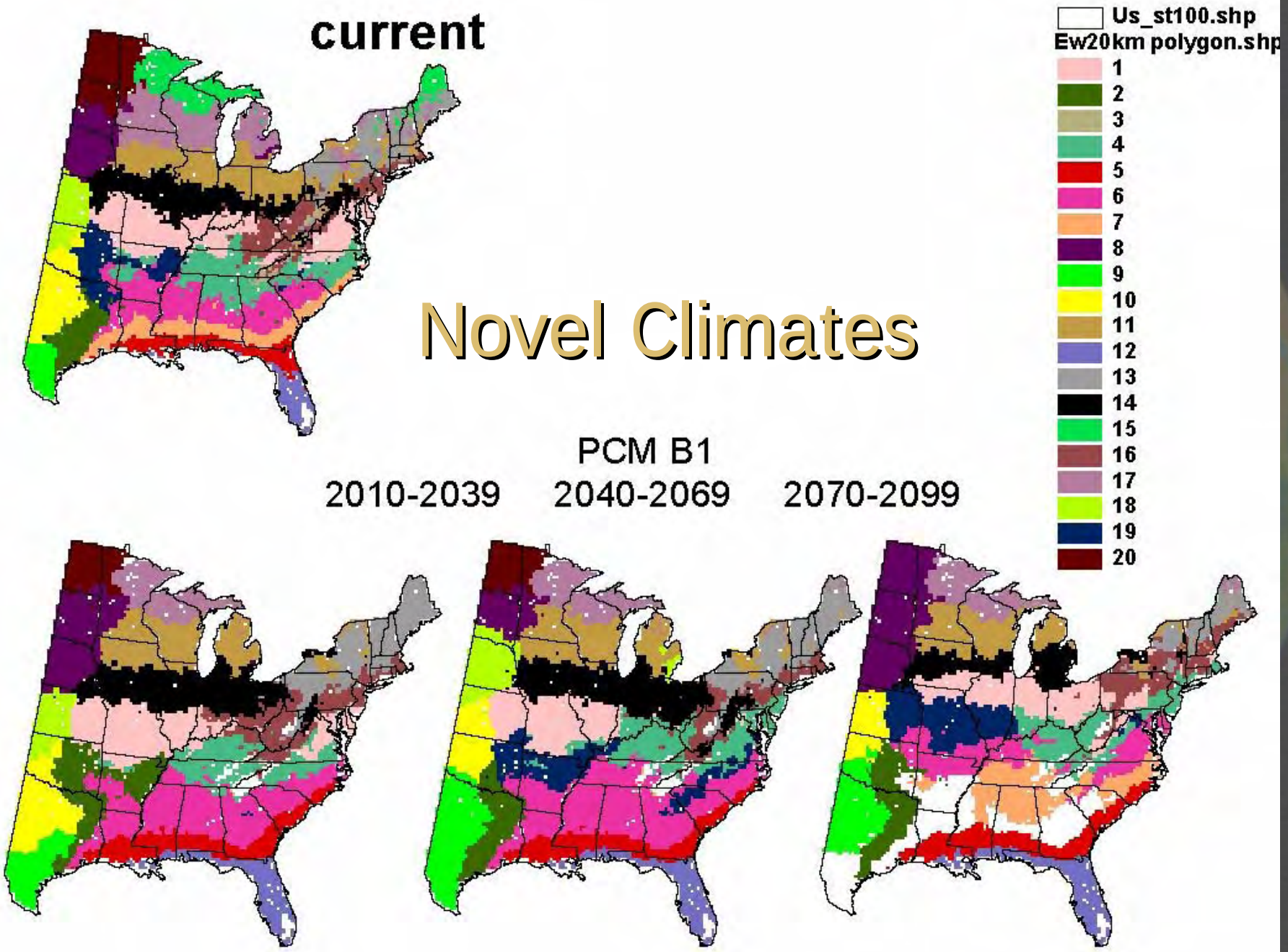




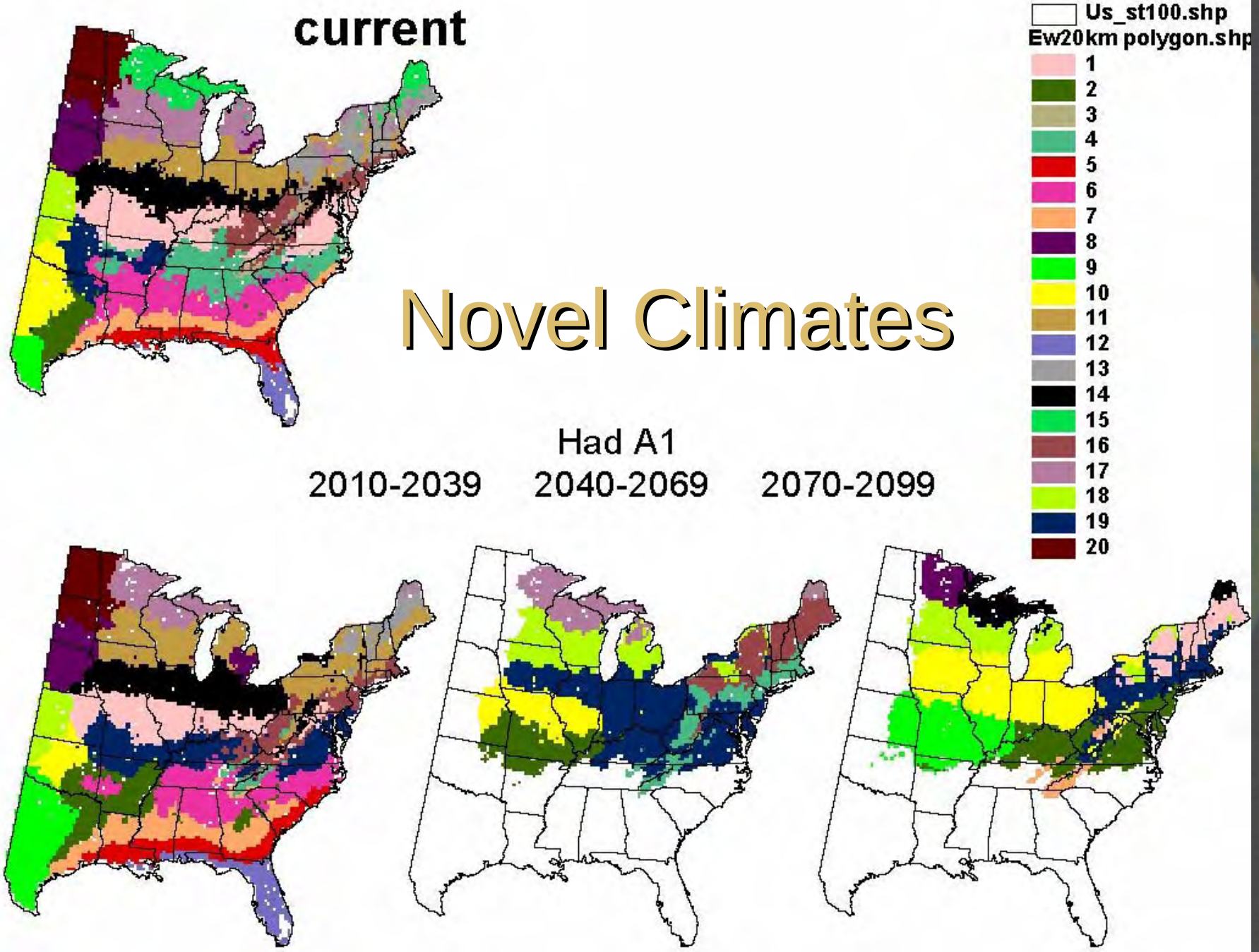
Sugar Maple

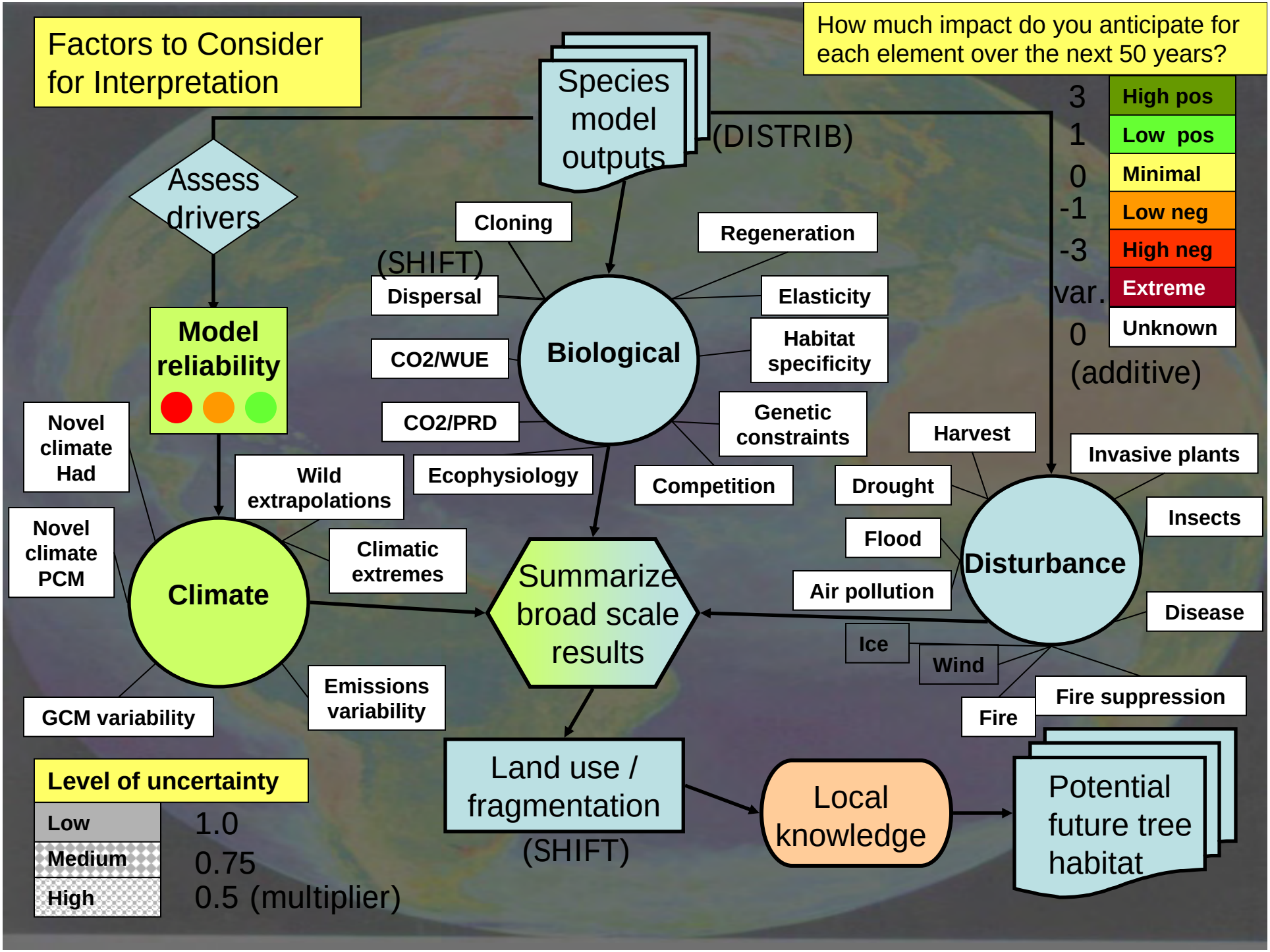
Variation among emission scenarios

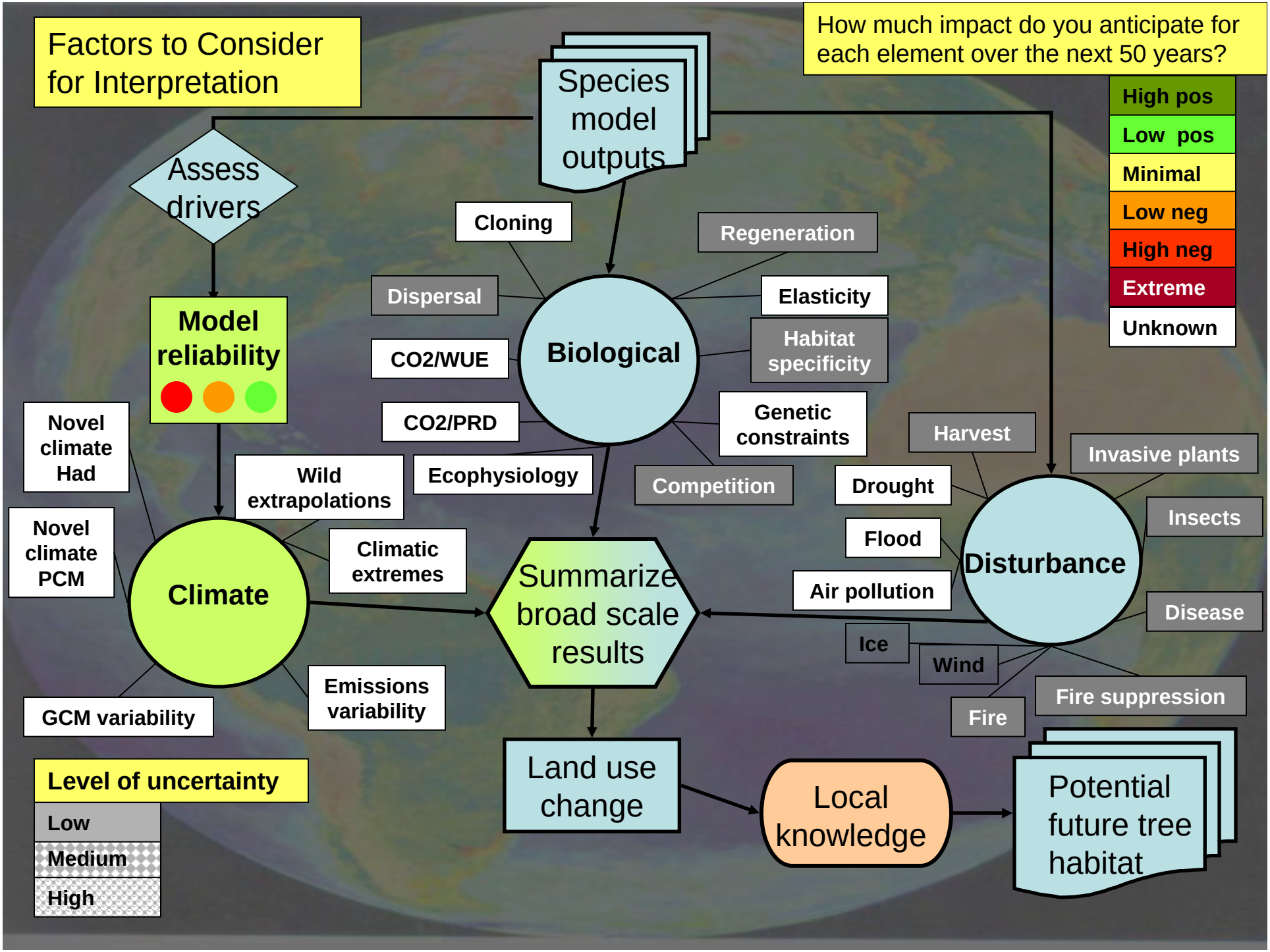
Novel Climates



Novel Climates




Factors to Consider for Interpretation
How much impact do you anticipate for each element over the next 50 years?
Species model outputs
(DISTRIB)
Assess drivers
Model reliability
Biological
(SHIFT)
Cloning
Dispersal
CO2/WUE
CO2/PRD
Ecophysiology
Regeneration
Elasticity
Habitat specificity
Genetic constraints
Competition
Climate
Novel climate Had
Novel climate PCM
Wild extrapolations
Climatic extremes
GCM variability
Emissions variability
Summarize broad scale results
Disturbance
Harvest
Drought
Flood
Air pollution
Ice
Wind
Fire
Fire suppression
Invasive plants
Insects
Disease
3
1
0
-1
-3
var.
0
(additive)
High pos
Low pos
Minimal
Low neg
High neg
Extreme
Unknown
Level of uncertainty
Low
Medium
High
1.0
0.75
0.5 (multiplier)
Land use / fragmentation
(SHIFT)
Local knowledge
Potential future tree habitat


Factors to Consider for Interpretation
How much impact do you anticipate for each element over the next 50 years?
High pos
Low pos
Minimal
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Species model outputs
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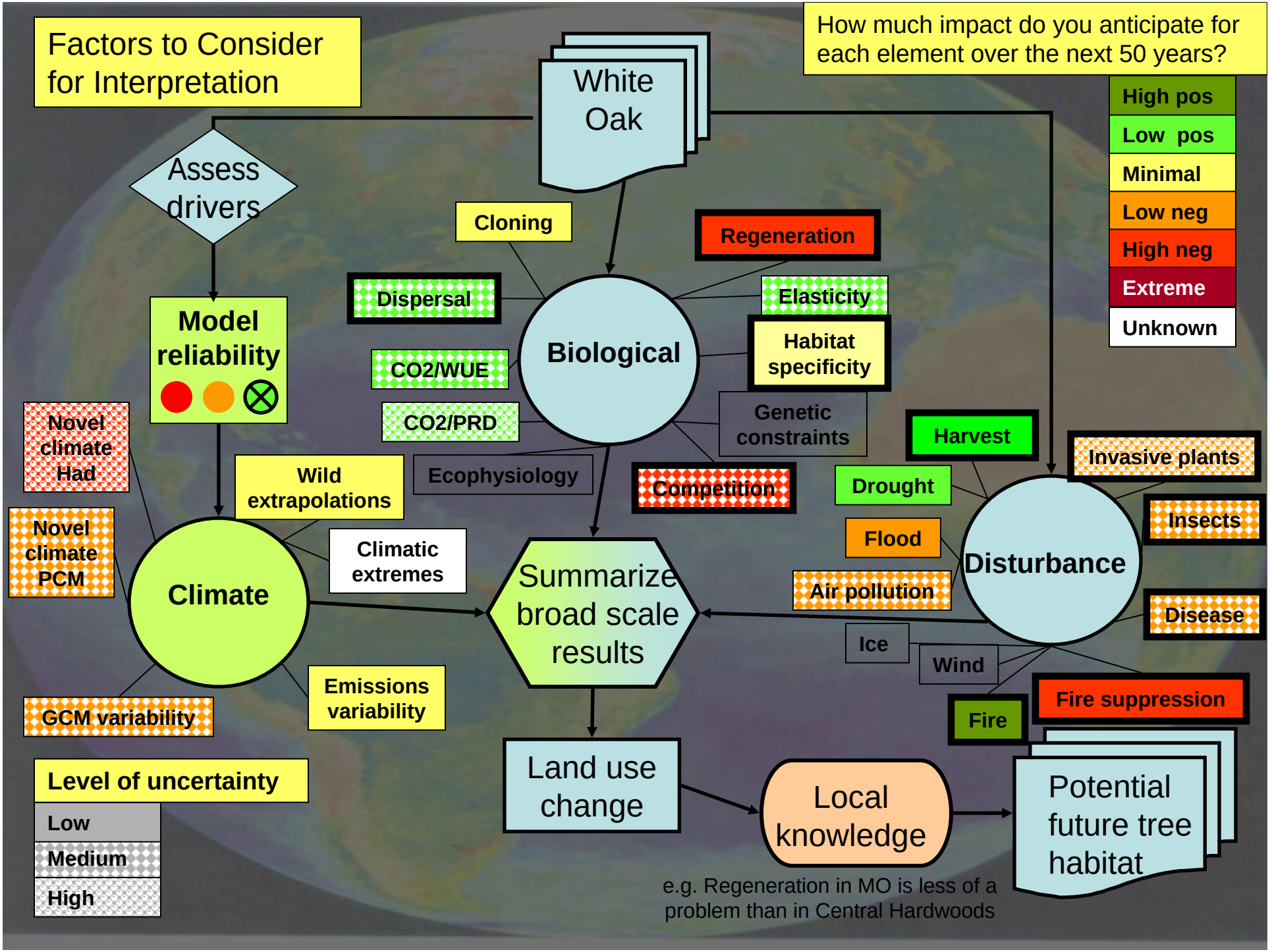
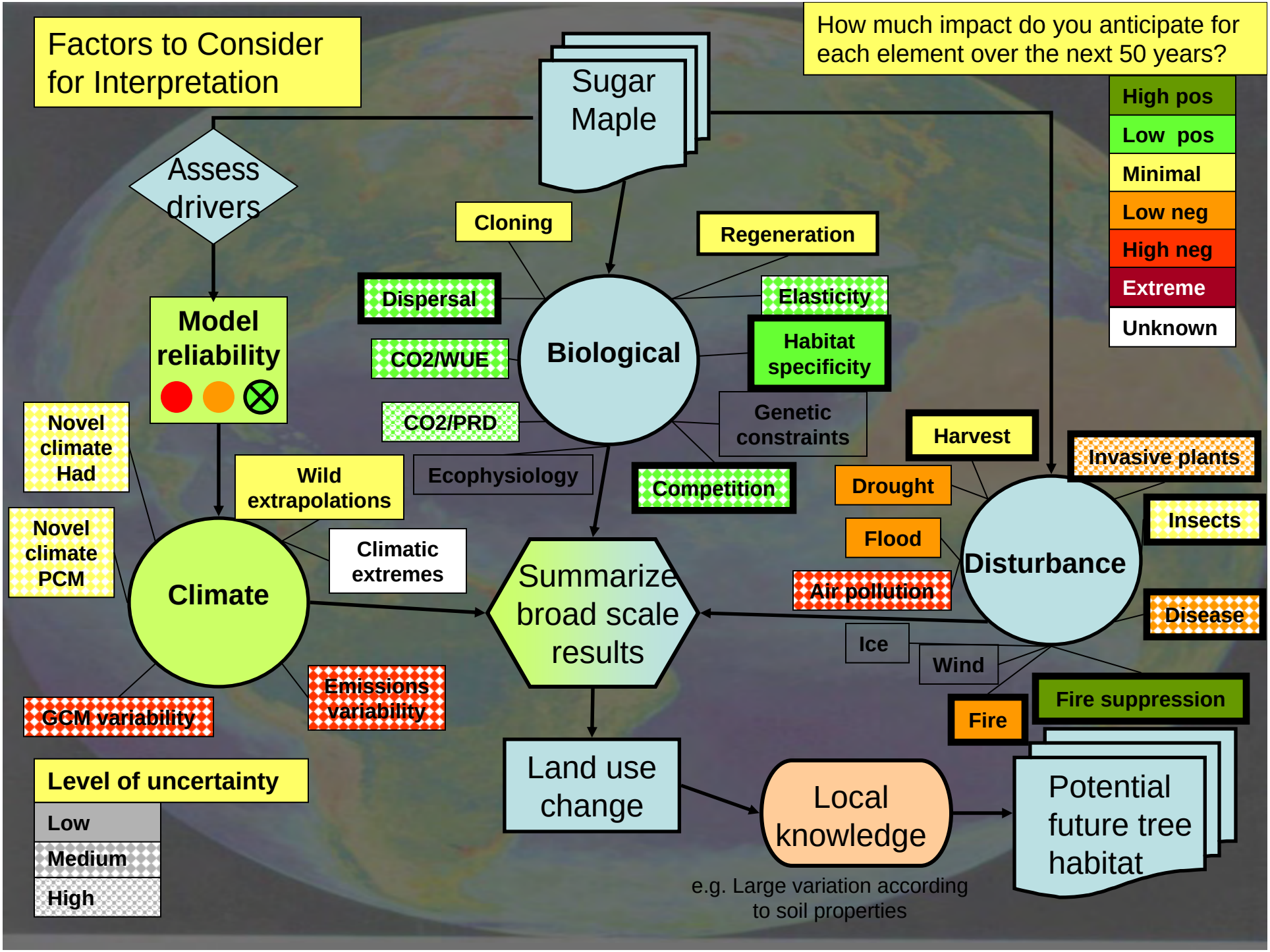
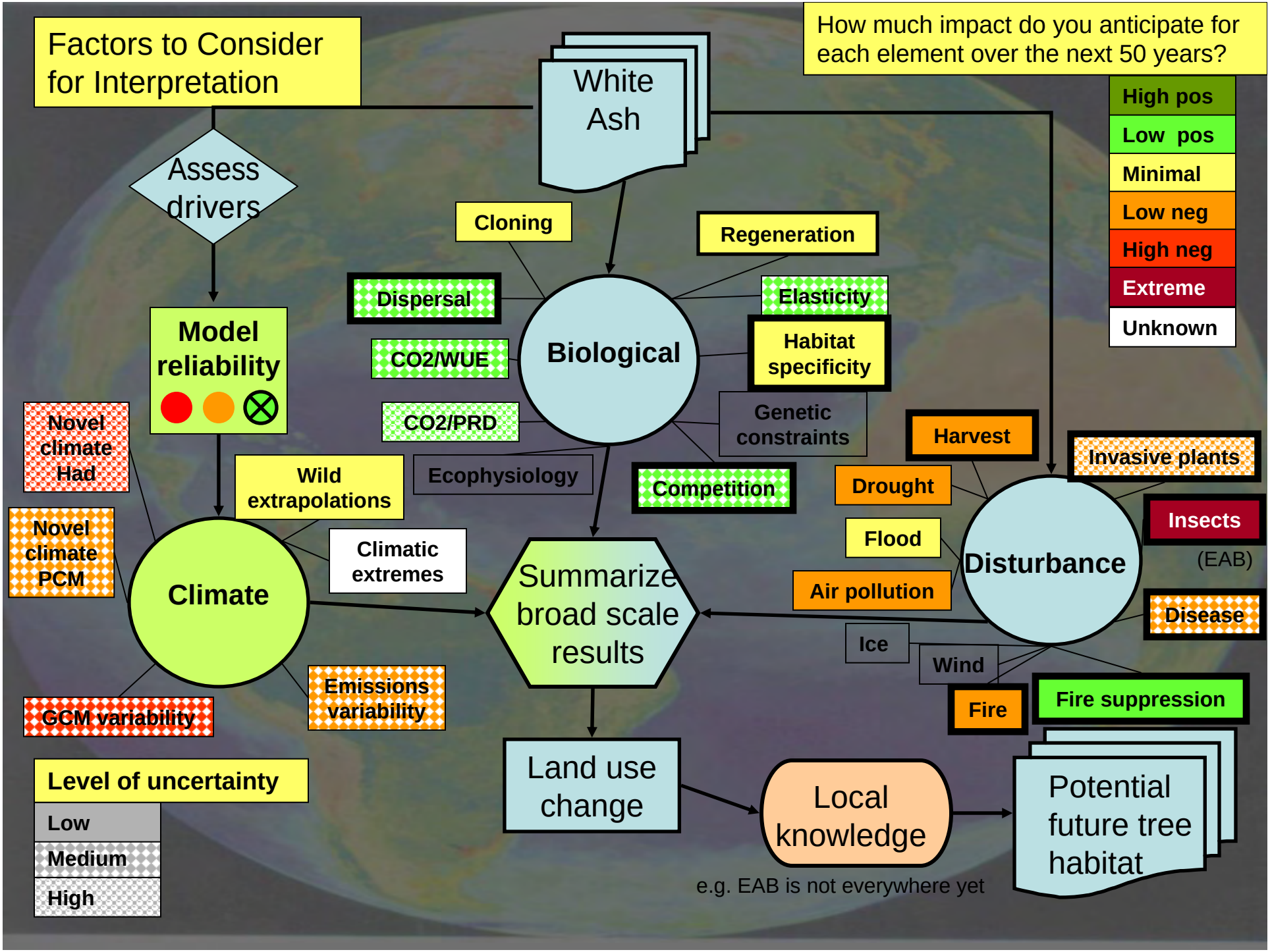
Fire
Land use change
Local knowledge
Potential future tree habitat
Level of uncertainty
Low
Medium
High


Factors to Consider for Interpretation
How much impact do you anticipate for each element over the next 50 years?
High pos
Low pos
Minimal
Low neg
High neg
Extreme
Unknown
White Oak
Assess drivers
Model reliability
Cloning
Regeneration
Dispersal
Elasticity
Biological
Habitat specificity
CO2/WUE
CO2/PRD
Genetic constraints
Harvest
Invasive plants
Novel climate Had
Wild extrapolations
Ecophysiology
Competition
Drought
Insects
Novel climate PCM
Climatic extremes
Flood
Disturbance
Air pollution
Climate
Summarize broad scale results
Disease
Ice
Wind
Emissions variability
Fire suppression
GCM variability
Fire
Land use change
Local knowledge
Potential future tree habitat
Level of uncertainty
Low
Medium
High
e.g. Regeneration in MO is less of a problem than in Central Hardwoods


Factors to Consider for Interpretation
How much impact do you anticipate for each element over the next 50 years?
High pos
Low pos
Minimal
Low neg
High neg
Extreme
Unknown
Sugar Maple
Assess drivers
Model reliability
Cloning
Regeneration
Dispersal
Elasticity
CO2/WUE
Biological
Habitat specificity
CO2/PRD
Genetic constraints
Harvest
Invasive plants
Novel climate Had
Wild extrapolations
Ecophysiology
Competition
Drought
Insects
Novel climate PCM
Climatic extremes
Flood
Disturbance
Climate
Summarize broad scale results
Air pollution
Disease
Ice
Wind
Emissions variability
GCM variability
Fire suppression
Fire
Land use change
Local knowledge
Potential future tree habitat
Level of uncertainty
Low
Medium
High
e.g. Large variation according to soil properties


Factors to Consider for Interpretation
How much impact do you anticipate for each element over the next 50 years?
High pos
Low pos
Minimal
Low neg
High neg
Extreme
Unknown
White Ash
Assess drivers
Model reliability
Cloning
Regeneration
Dispersal
Elasticity
CO2/WUE
Biological
Habitat specificity
CO2/PRD
Genetic constraints
Novel climate Had
Wild extrapolations
Ecophysiology
Competition
Harvest
Invasive plants
Drought
Insects
(EAB)
Novel climate PCM
Climatic extremes
Flood
Disturbance
Climate
Summarize broad scale results
Air pollution
Disease
Ice
Wind
Emissions variability
Fire
Fire suppression
GCM variability
Land use change
Local knowledge
Potential future tree habitat
Level of uncertainty
Low
Medium
High
e.g. EAB is not everywhere yet

CUS, MISS, and SIP

	Climate Uncertainty Score (CUS)	Biological Modifying Score (BIS)	Disturb-ance Modifying Score (DIS)	Modifying Influence Summary Score (MISS=BIS+DIS/2)	Silvicultural Influence Percentage (SIP)
White Oak	-0.60	-0.31[1]	-0.19	-0.25	51
Sugar Maple	-0.90	0.56[1]	-0.39	0.09	37
White Ash	-1.05	0.44	-2.67[2]	-1.12	58[3]

Scores range from -3 to 3: lesser scores indicate probable further reductions in suitable habitat than modeled; higher scores indicate probable enhancements in suitable habitat over that modeled.

SIP = indicates the relative role that silviculturists may play through management of the species under climate change.

[1]"Mesophication effect" underway in eastern U.S.

[2]Emerald Ash Borer effect for ash

[3]Assumes something will be able to be done for EAB (else 42%)

Advice to Managers 1

1. With climate change predictions, plan for the worst (high emissions) and encourage lower emissions.
2. Ignore any species distribution models produced before 2005. Insist on robust predicting tools like Random Forest.
3. Pay attention to the reliability of each species model – and regardless, there still will be errors!
4. Less common species are more prone to error.
5. Edge boundaries are ‘fuzzy’, both now and in future – core areas of higher IVs are more indicative
6. Use these models as guidelines for regional trends – they are not appropriate for stand level management without the regional context
7. Use flowchart/spreadsheet type techniques to rate modifying factors to model outputs
8. Concentrate on the factors you can do something about

Advice to Managers 2

7. But if you abide by these caveats, and you live in the Eastern US, you can use these to:
   a. Learn which species are in, or could be in, your location now
   b. Learn which environmental factors are likely driving species' suitable habitat, e.g., which are most susceptible to climate drivers
   c. Learn what species are most and least likely to have their habitats move, and how much
   d. Learn which species could incur the most risk under climate change
   e. Learn which species could become newly suitable for your location (from the south)
   f. With SHIFT, learn where potential colonization could occur within 100 yrs
   g. Identify which factors are most likely to modify model outputs, and which ones you might be able to do something about

Advice to Research Managers

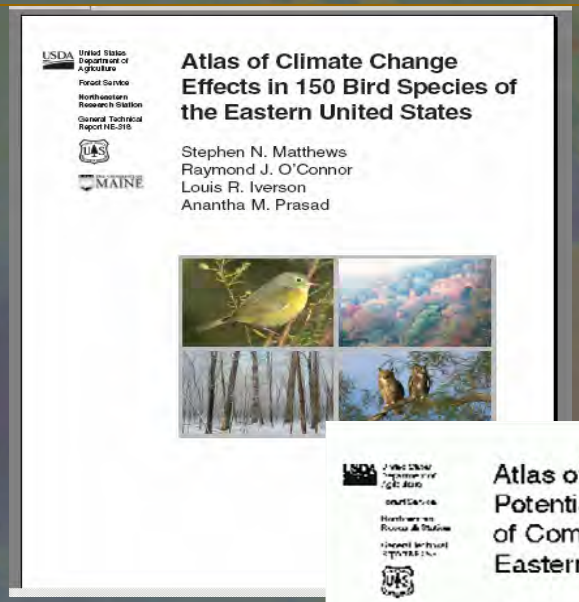
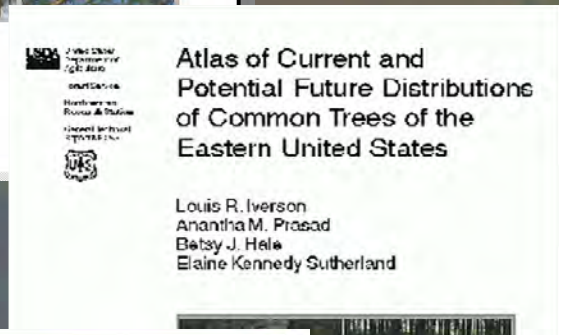
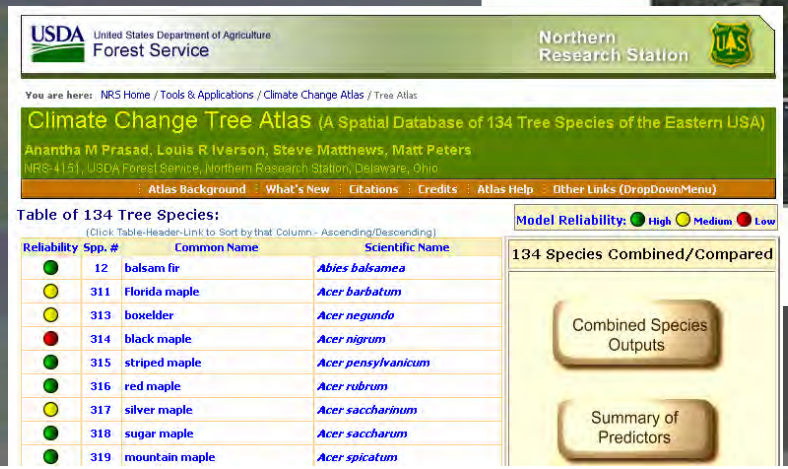
1. Bottom line – we need both mechanistic and statistical models
2. Support merger of models (like this workshop and beyond) so that we can get the “best of the best”
3. Support the building of decision support systems to help land managers

Thank you for your attention!

- Web site for most data presented today:
  - Little's boundaries
  - FIA data grouped by 20x20 km cell
  - Climate change atlases
  - Species-environment data for 134 trees
  - Pdfs of related papers

www.nrs.fs.fed.us/atlas

- For free hard copy of atlases or reprints:

liverson@fs.fed.us

Thanks to USDA FS Northern Global Change Program for support