**Vegetation Modeling Workshop: How can Vegetation Dynamics under Climate Change Best be Modeled at Greater Ecosystem Scales?**

Introduction, *Andrew Hansen, Montana State University*

* Vegetation response to climate change linked to species demography:
	+ Establishment, growth, survival, reproduction, dispersal
	+ Climate can influence directly
	+ Also influenced by competition, disturbance, pests, dispersal, landscape pattern
		- Climate can influence these indirectly
* Can focus on one interaction and ignore others
* Or, consider all components and have high uncertainty
* Hansen lab, current studies
	+ Statistical modeling of climate conditions for species presence
	+ Add: life history, soils/topography, ecosystem process
* Needs:
	+ Need to increase complexity/realism of models but without too much uncertainty
	+ Ex. Where in GYE would controlling competing vegetation allow recruitment to reproductive age classes under climate change?
* Purpose of the workshop:
	+ Review current approaches being used in the Northern Rockies
	+ Evaluate utility, scope, limitations of each and needs for additional approaches
	+ Increase communication and synergy among the community working on vegetation/climate issues
	+ Ultimately, improve our ability to simulate, understand and manage Rocky Mountain ecosystems under climate change

FireBGCv2 Summary *Bob* *Keane, USFS RMRS Missoula Fire Sciences Laboratory*:

* FireBGCv2 focuses at the landscape scale, because
	+ Species’ response (to climate change, disturbance, etc.) are a key question for managers
	+ The landscape is where the “action” is – interactions between vegetation and disturbance determine the majority of the ecosystem change and these occur at the landscape scale
* FireBGCv2 simulates 6 scales, from the tree to the landscape
	+ Models the finest resolution but can sum up to larger scales
* The model is not accurate – because of uncertainties in all the different processes it models. But it is precise. The best use of the model is to compare different scenarios, rather than to expect predictions to hold true for a particular place and time.
* The appropriate use of the model is to explore long-term ecological effects
* Currently, disturbances modeled include white pine blister rust, fire, and harvest
* For climate change scenarios, GCM predictions need to be downscaled
	+ Bob uses the MT-CLIM model to downscale current climate data and GCM predictions
* The model has been applied at landscape scales – 50,000-300,000 ha
	+ Theoretically, it could be applied at larger scales, but limited by computational resources.
	+ Landscape needs to large enough to allow all potential species to migrate in – for example, needs to allow for potential upward migration of lower elevation species.
* Model results are one solution among many:
	+ Depends upon your input species, landscape, model algorithms
	+ Ex. The model projects western white pine will dominate the Lake McDonald landscape, but only because of a genetic feedback loop which allows western white pine to develop resistance to blister rust. Without the genetic feedback loop, western white pine abundance decreases.

BIOME-BGC Summary: *Steve Running, University of Montana*

* Forest-BGC was developed to explore gas exchanges at daily time steps
	+ At the time, most models operated at monthly or annual time steps
* Biome-BGC never modeled mortality, recruitment, disturbance, or biome transitions
* One part of all vegetation simulation models that is still weak is phenology. We still don’t model phenology well – problematic because of the large variability in bud burst, leaf senescence, etc.
* There have been no new developments/changes to Biome-BGC since Peter Thornton’s work.
* Advantages of LPJ over other methods: it models daily gas exchange and tries to model disturbance triggers and trigger for biome change.
* Suggestions for developing a regional-scale model:
	+ Build a stand-level model first and scale up once stand-level dynamics are capture well
	+ Run point model first before adding in spatial interactions
* Cathy Whitlock asked how to best model change at ecotones:
	+ Steve R: ecotones are good places to test climate thresholds, of intellectual interest to see how well models are doing but less important for management
	+ Bob K: Currently, neither FireBGCv2 or Biome-BGC would be appropriate for modeling change at ecotones – they don’t model cold-air drainages, for example.

LPJ-GUESS Summary, *Katie Ireland, Montana State University*

* To understand patterns of fire, insect outbreaks and disease, climate change, land-use we need science and management that crosses management boundaries and matches the scale of ecological processes.
* Need a model capable of simulating change at ecosystem scales, desired characteristics would be:
	+ Capable of simulating individual species/communities
	+ Links climate with ecosystem processes
	+ Simulates disturbance
	+ Simulates across large spatial scale
* Define ecosystem scales using PACE approach:
	+ areas large enough to maintain:
		- ecological flows – for example, spread of disturbance or water flow through watersheds
		- crucial habitat – or the area required to maintain a self-sustaining population of species of interest
		- effective size – the size of area needed to prevent isolation-induced loss of species of interest
		- human edge effects – large enough to mitigate the effects of human activities in adjacent lands spreading into core protected areas
* LPJ-GUESS is regional to global model simulates dynamics and composition of vegetation in response to changes in climate, atmospheric CO2 concentration
* It is a combination of 2 different models
	+ LPJ: physiological/biophysical processes
	+ GUESS: vegetation dynamics (tree establishment, growth, mortality) of a forest gap model
* Two modes:
	+ Population mode:
		- Corresponds to LPJ
		- Grid cells are large
		- Vegetation is simplistically represented as a mixture of plant functional types, where each PFT takes up some proportion of the modeled area.
		- No age cohorts are represented so succession and vertical stand structure are not modeled.
	+ Cohort mode
		- Corresponds to the gap model, GUESS.
		- Simulates growth of individuals within a cohort on replicate patches.
		- Individuals can represent PFTs or species.
		- More detailed – allows for simulation of competition for resources (light, moisture), successional processes.
* Bioclimatic limits:
	+ Defined for each PFT/species
	+ Determine whether each PFT/species can survive under the climatic conditions in a particular grid cell at a particular year in the simulation.
* Fire
	+ simulated in either population or cohort mode, using a process-based fire model, SPITFIRE.
	+ Fire ignitions can be from lightning or humans, but fire spread only occurs if there is enough fuel and it is dry enough
	+ Fire spread depends upon wind speed and direction and the amount, moisture content, and size of live/dead fuels
	+ Simulated fire effects include plant mortality (fxn of tree height and bark thickness), fuel consumption, and CO2 and other trace gas emissions.

**Discussions**

Paleoecology

* Workshop participants discussed the use paleo data to validate models and to explore future scenarios
* Cathy Whitlock: could test models against paleo scenarios
	+ Use past climate as a series of additional climate scenarios
	+ Problem: past resolution is coarse
		- Pollen can tell us which watersheds had a species (i.e., white bark pine) but not where in the watershed
		- Can tell whether white bark pine was more abundant in the past
	+ Could use paleo data to ask about the climate conditions behind species’ response to climate change
		- Ex. What would it take for white bark pine to go up 500-ft in elevation?

Questions, Tools, & Data at Different Scales

* Workshop participants discussed the different spatial and temporal scales at which different modeling approaches would be appropriate
* Questions
	+ Steve Running: one key question – when/where do forests shift to non-forest?
	+ Jesse Logan: mentioned the need to understand population dynamics of white bark pine and mountain pine beetle
		- Adaptive time scales: evolutionary strategies of white bark pine are at century time-scales, but changes in beetle populations are at decadal scales
		- White bark pine evolutionary strategies are decoupled from disturbance time scales
	+ Adam Markham: question of interest
		- How does modeling provide input for policy decision making?
		- Need information relevant to managers
			* Often too much uncertainty in model results
		- Need for modeling experiments of the implications of different management/policy scenarios
		- Changes in hydrologic processes – i.e., what would be the impact of losing white bark pine on snowpack, hydrology?
	+ General discussion: Look for the intersection of where active management should take place and maximum model certainty
		- Where do models predict active management is likely to succeed?
		- Where is the threshold of model certainty? Where is model certainty (or multi-model agreement) maximized?
* Data
	+ Jia Hu: her physiology work is at the watershed scale and smaller – this is the scale at which it is easiest to take measurements and get data.
		- But, this is the scale with the greatest variability – impacts on modeling (i.e. parameters)?
* Tools
	+ Bob Keane: there is a scale at which models converge on the same solution
* Tom Oliff diagrammed the spatial/temporal scales at which different questions are currently being addressed. Disconnect between the scale that managers are interested in – 5-50 years, stand to watershed – and current studies.
	+ But, models aren’t really capable of predicting response to climate change at such small spatial/temporal scales

Diagram of spatial/temporal scales of current modeling approaches:

