Virtual Experiments
and
Environmental Policy

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Overview of paper

- We want instruments that have
  - Controls and replicability, like lab experiments
  - Natural referents and context, like field experiments
- Harness tools from three domains
  - Experimental economics
  - Virtual reality
  - Psychology, particularly “naturalistic decision making”
- Applications
  - Policy reform as a simulated policy lottery
  - Representation constrained by models of underlying reality
  - Conflicts between experts and non-experts

Overview of presentation

- Why virtual experiments?
- How?
  - Virtual Reality
  - Naturalistic Decision Making
- Applications
  - Land-use planning
  - Wildfire risk
- What is new here?

Experimental economics and environmental policy

- Environmental valuation
  - Hypothetical bias – identification, mitigation, and calibration
  - Risk attitudes
  - Risk perception
  - Temporal preferences
- Free riding and common pool problems
  - Extent of the problem
  - Institutions to mitigate the problem
- Emission permit markets
  - Efficiency and equity effects of alternative institutions

Why virtual experiments?

- Lab experiments provide many controls, but…
  - Use abstract stimuli
  - Use artefactual stimuli
  - Use sterile environment

Typical lab lottery choice

Typical process generating lab uncertainty

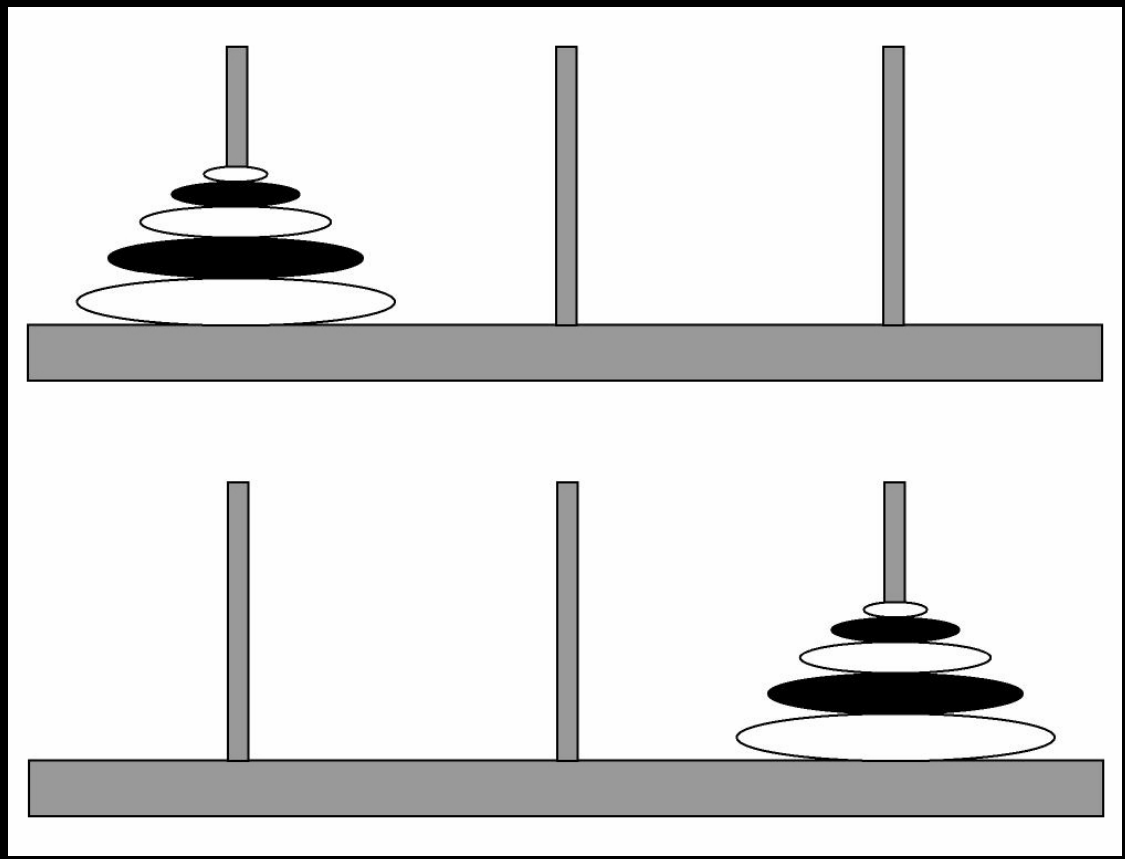
Typical lab environment

Why virtual experiments?

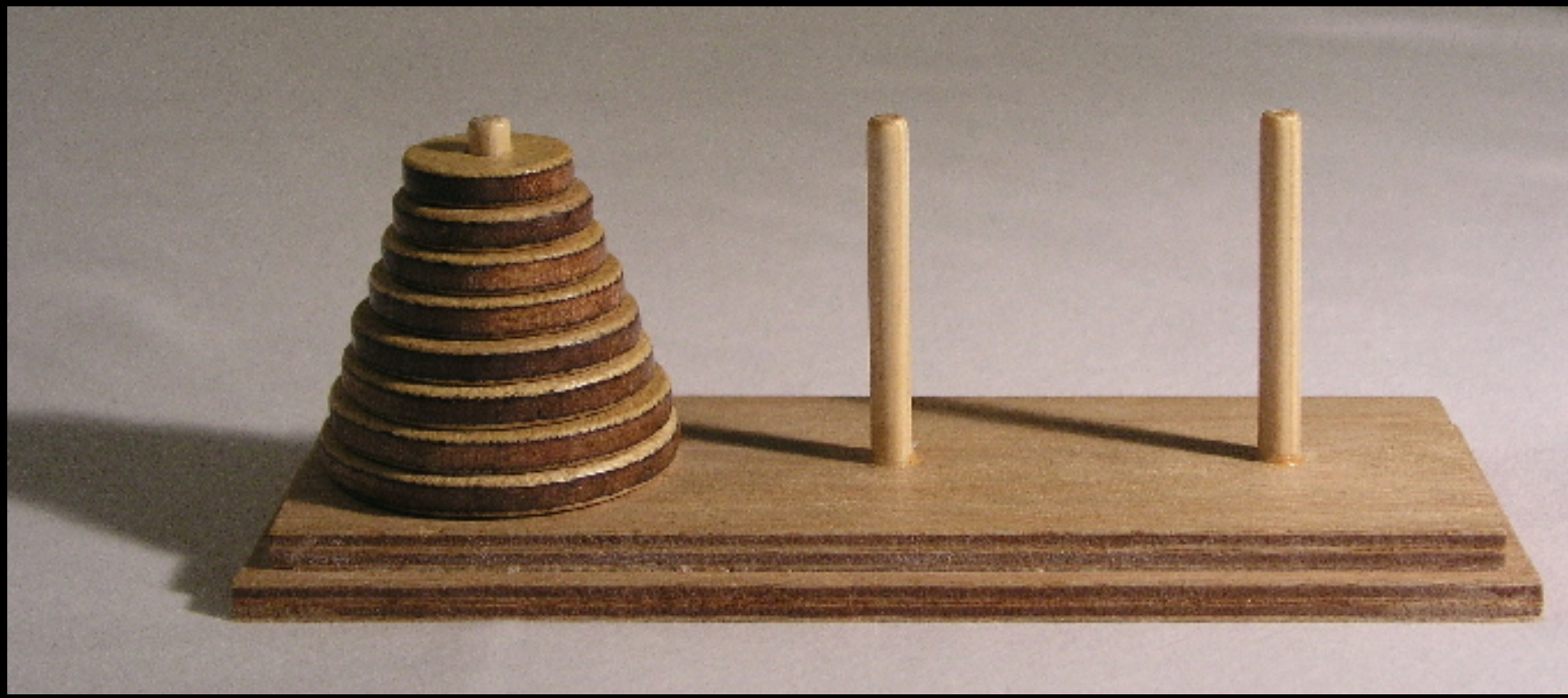
- Lab experiments provide many controls, but…
  - Use abstract stimuli
  - Use artefactual stimuli
  - Use sterile environment

- In fact, in some cases these features of lab experiments generate a lack of control
  - Stimuli lack field referents, to cue field-tested heuristics
  - Stimuli lack credibility
  - Environment generates unrepresentative responses

Tower of Hanoi in the lab



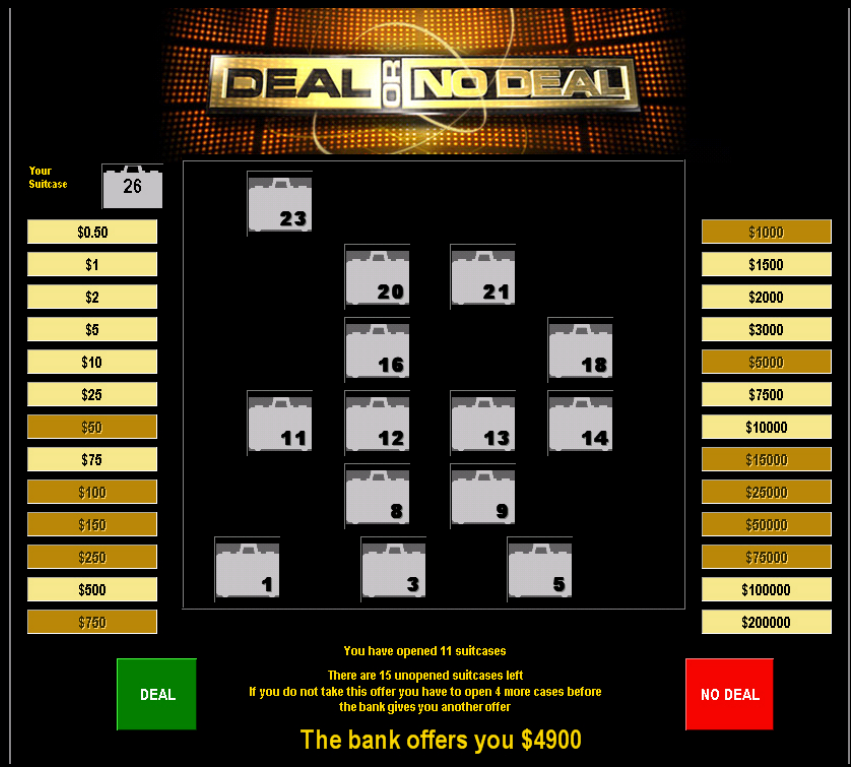
Tower of Hanoi in the field



Uncertainty in a field experiment

Types of field experiments

Complementary experiments



How?

- Simulate complex phenomena
  - Ensure fidelity with underlying processes
  - Dependent on existing simulation models
  - Must allow counterfactuals
- Render environment using VR
  - Images consistent with underlying process
  - Responses of environment consistent with underlying process
- Allow natural choices
  - Natural response modes
  - Natural consequences, to extent possible

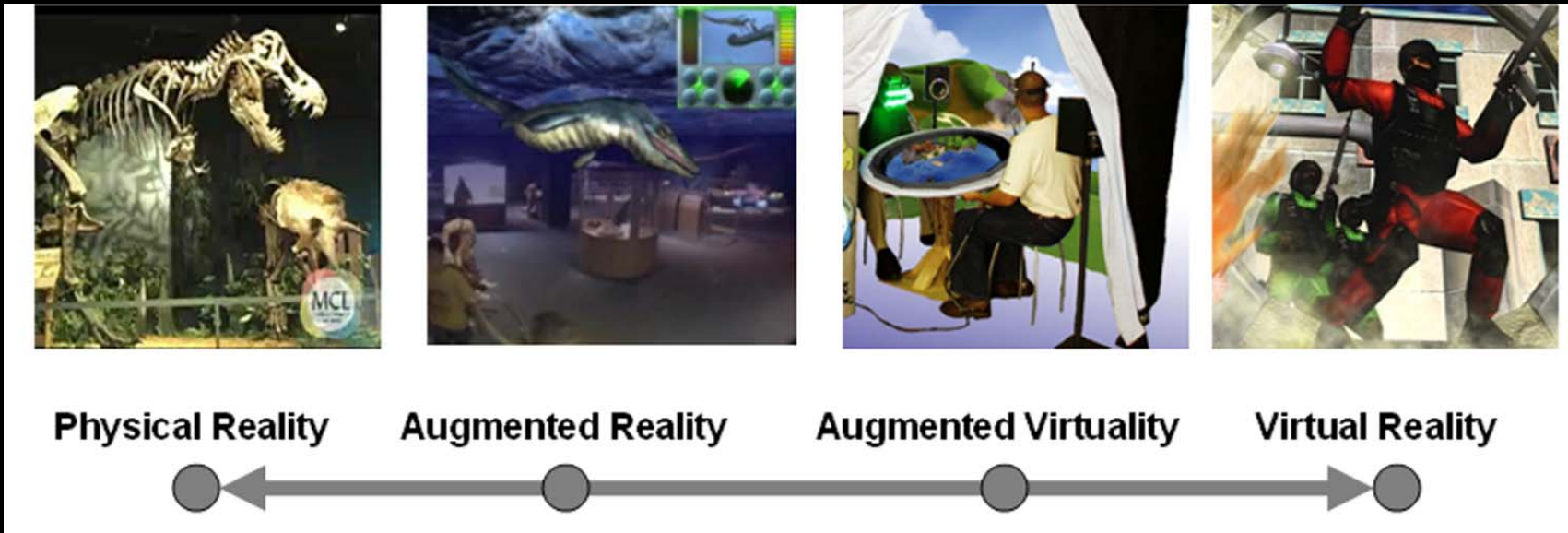
What is VR?

- World we experience is entirely synthetic
- Objects react interactively, in real-time

- We visualize it
  - Immersive, via a stereoscopic head-mounted display
  - Non-immersive using a monitor or dome screen

- Additional sensory inputs
  - Olfactory
  - Audio
  - Wind
  - Heat

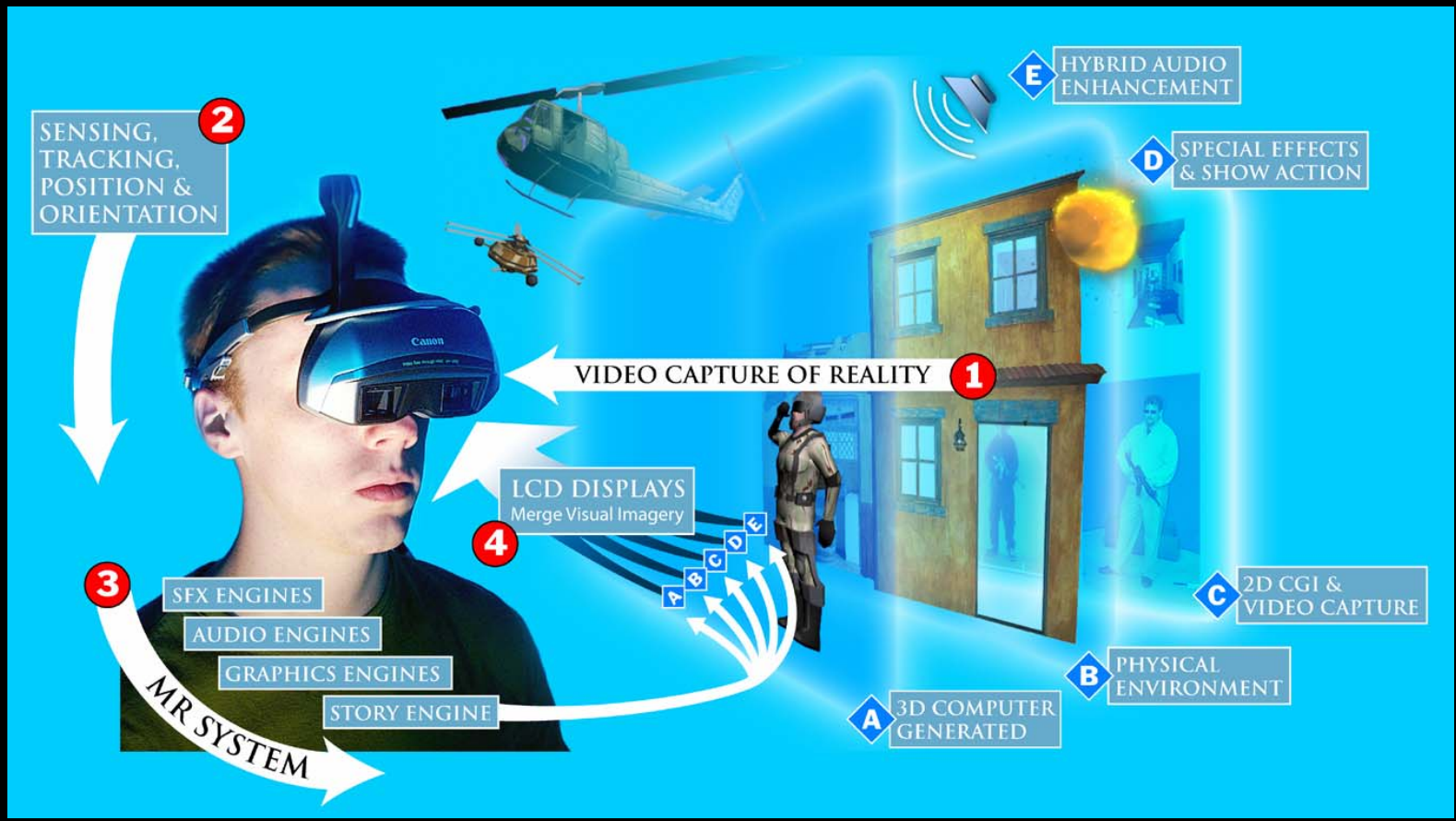
Virtual Reality is on a continuum



- Physical Reality (PR) – naturally occurring world
- Augmented Reality (AR) – virtual objects in a real setting
- Augmented Virtuality (AV) – real objects in a virtual setting
- Virtual Reality (VR) – purely synthetic

Mixed Reality & cognitive rehabilitation

Mixed Reality infrastructure



Naturalistic Decision Making (NDM)

- Understanding complex cognitive processes as they occur naturally
- What do we mean, cognitively, by “expertise”?
- Emerged as a reaction to normative models of decision-making in complex (military) environments
  - Focus often situation-based rather than rule-based problem solving
  - Presented with poorly structured and complex problems
  - Occurs in uncertain, dynamic environments
  - Shifting, ill-defined or competing goals
  - Time stress and high stakes

Typical task domains for NDM

Expertise

- Cognitive processes of experts/non-experts when they solve complex problems
  - Perceptual processes: experts rapidly recognize cues in the environment
  - Conceptual processes: experts easily interpret the meaning and importance of these cues
  - Decision-making: experts recognize patterns and then use cues to qualify the representation
- These steps allows experts to
  - Build accurate representations of problem
  - Build deeper level representation
  - Make better decisions

General implications

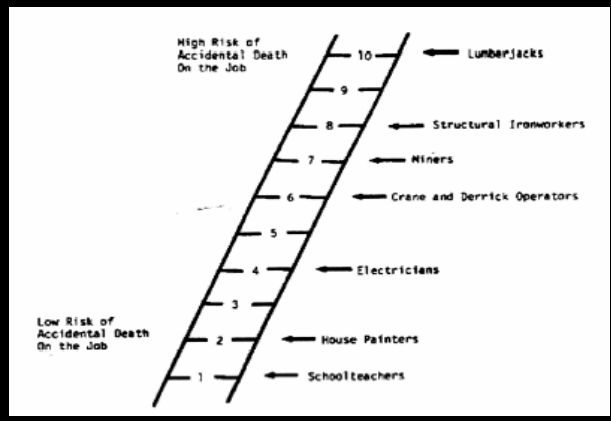
- Insight into behavioral differences between experts and non-experts
  - Familiar from work of Herb Simon in chess, etc.
  - Familiar from work of Howard Margolis on paradigm shifting in science and environmental policy
- Helps us design a naturalistic VR interface
  - To build the right bridge between lab and field experiments
  - To generate better decisions
  - To encourage consistency between expert and non-expert
- BUT… these are “Keynesian dentist” experts!

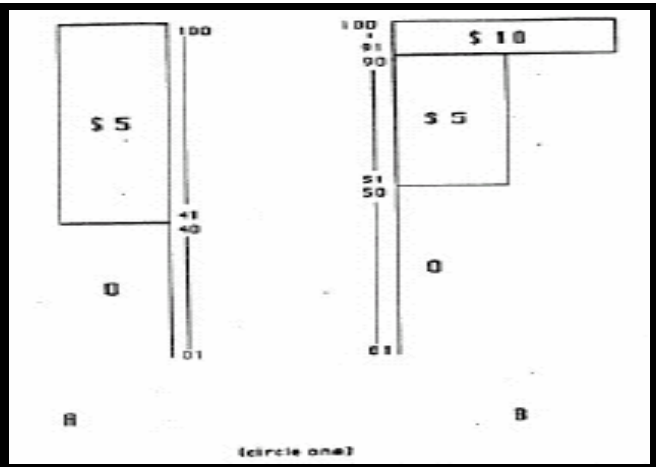
Specific application to risk perception

A: Winning $11 if 1-20 (20%)
Winning $5 if 21-200 (80%)

B: Winning $25 if 1-6 (6%)
Winning $5 if 7-100 (94%)

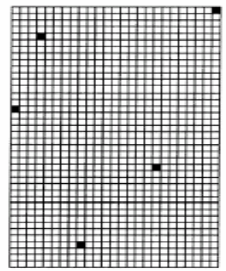
Answer: (1) I prefer A. (2) I prefer B. (3) Indifferent.

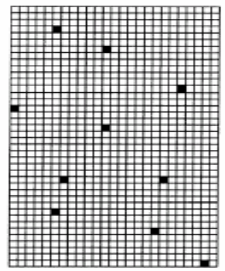




Suppose there are two people:

Person 1: Chance of death = FIVE in 1,000 over the next ten years.



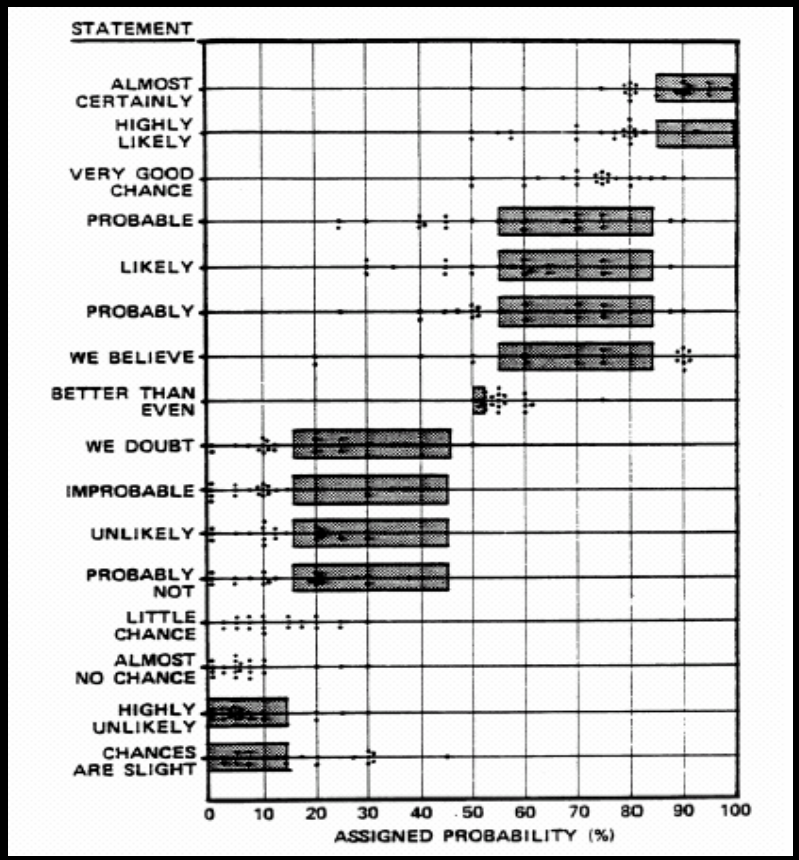


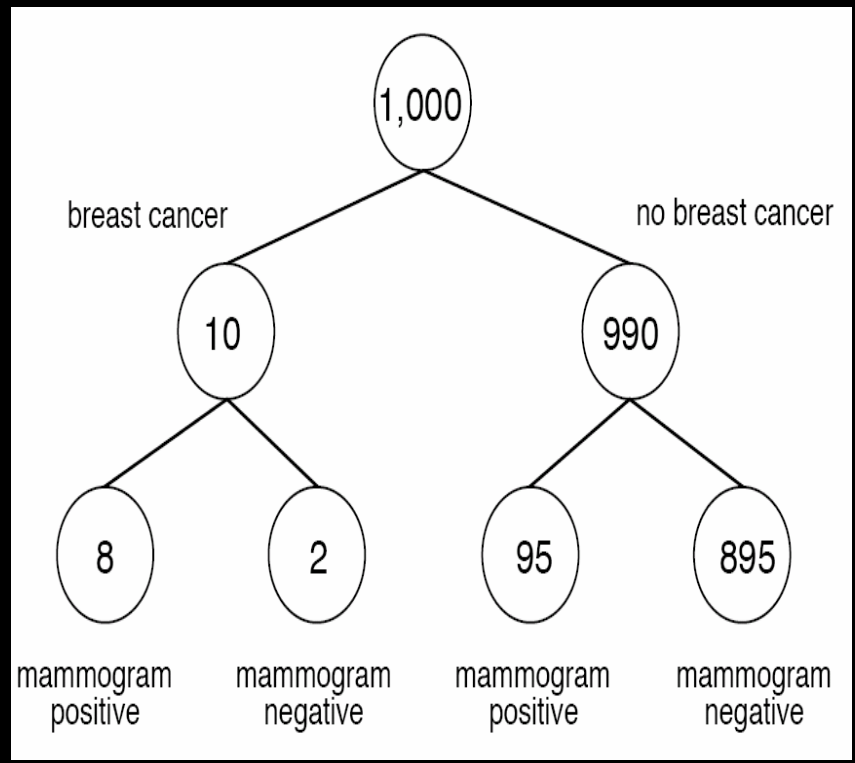
Person 2: Chance of death = TEN in 1,000 over the next ten years.

Which person is the most likely to die in the next ten years?

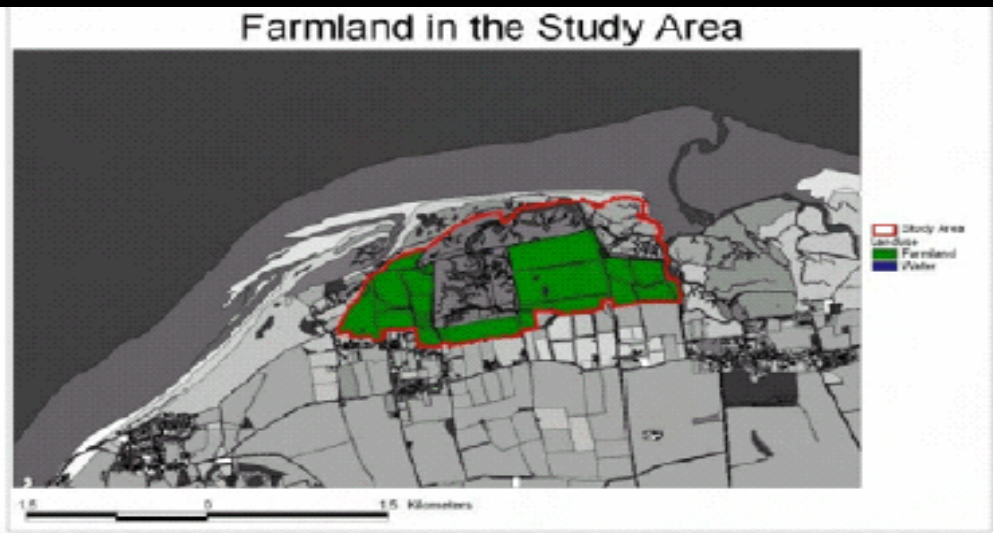
1. Person 1 2. Person 2

Additional dimensions



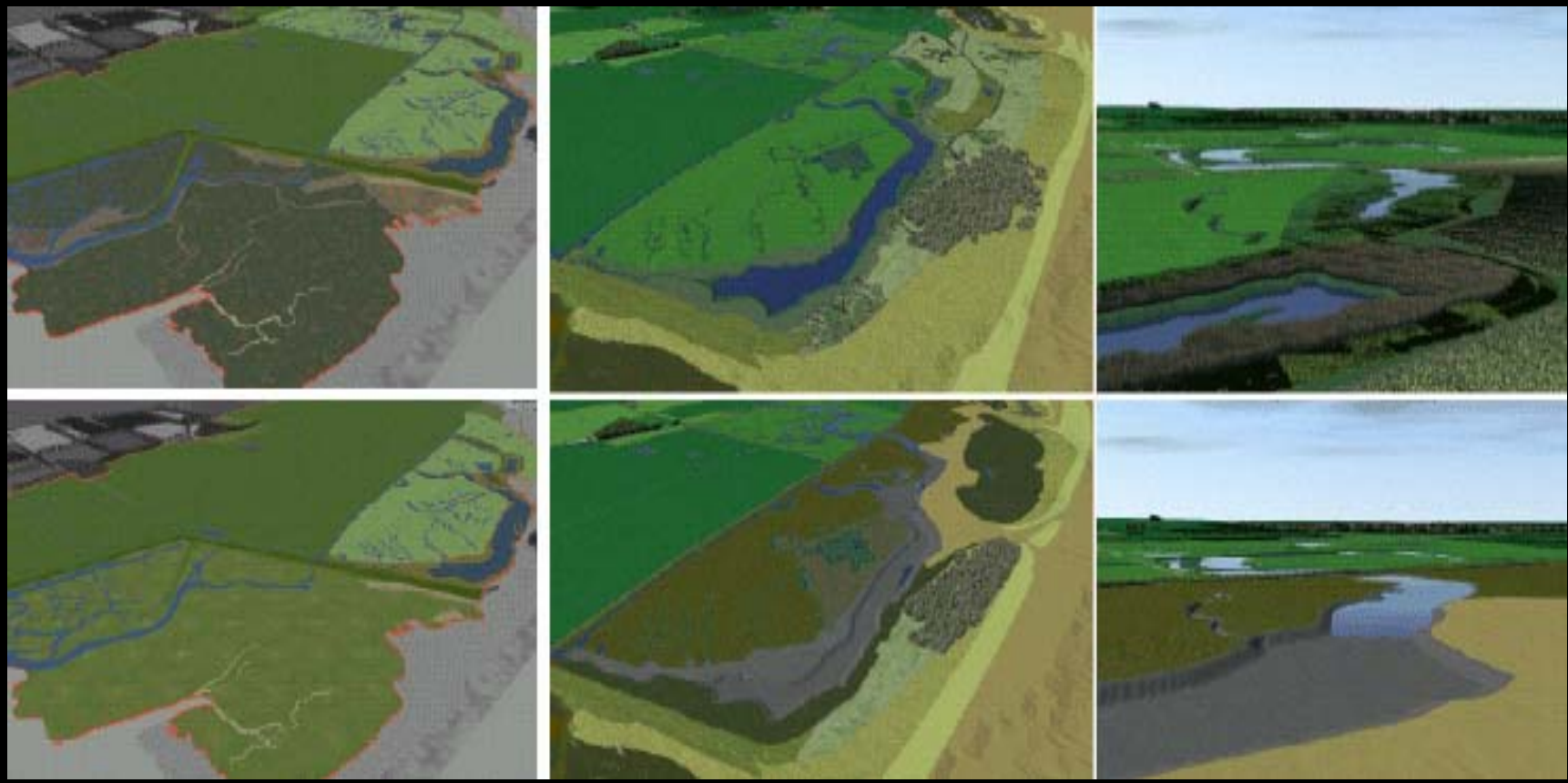


Application: land-use (Bateman et al.)



This photograph illustrates what the farmland at the site looks like.

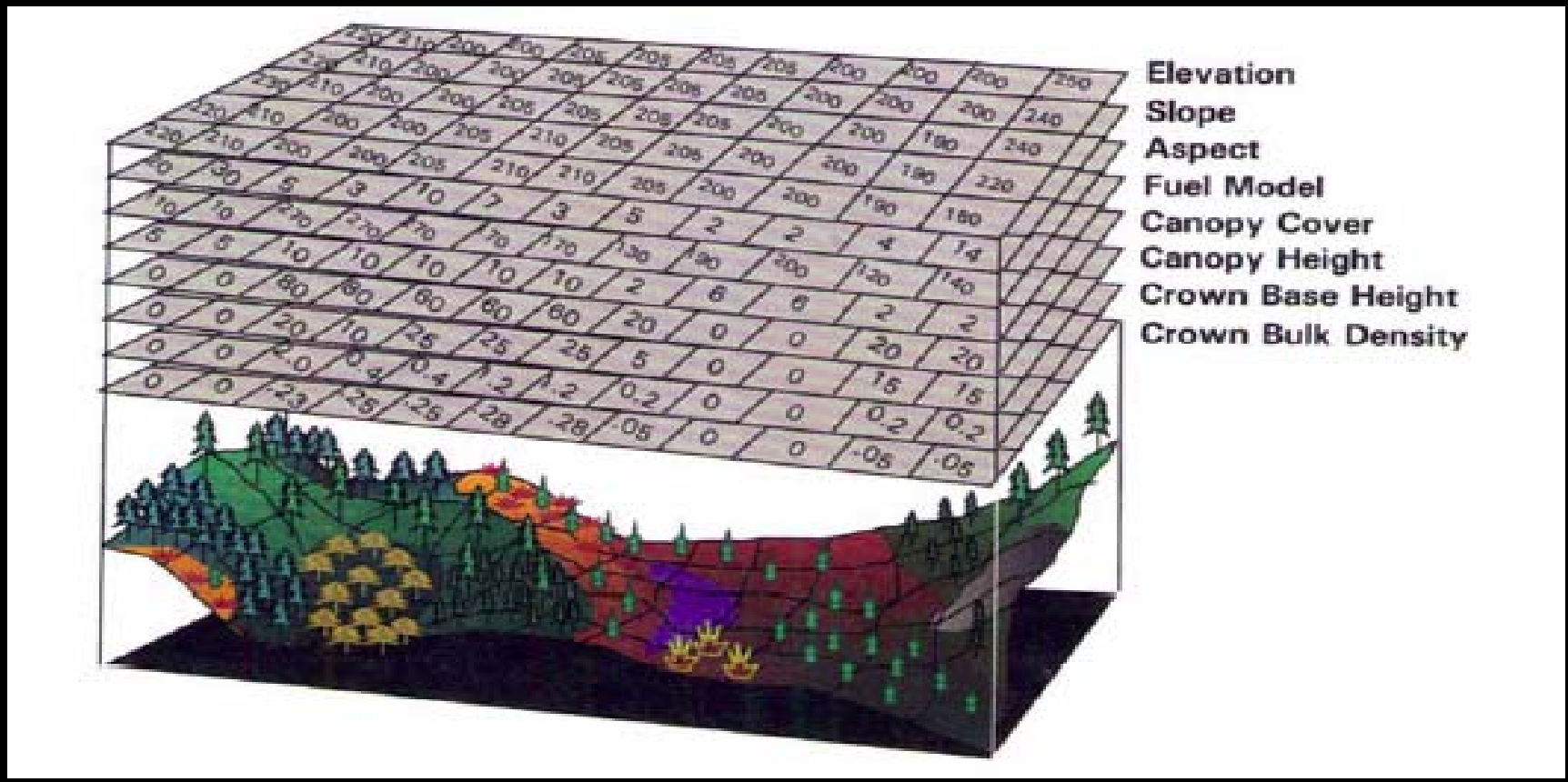
Rendering the “before and after”



Application: Wildfire Risk

- Policy context
  - Risk of wildfires depends on prescribed burns
  - Low risk lottery with PB in place
  - High risk lottery with no PB
- Simulate spread of wildfire
  - Use FARSITE simulation model, used by USDA for fire management
  - Calibrate to actual conditions in an area
  - Monte Carlo runs over uncertain events
- Render wildfire
  - Consistent with FARSITE simulation
  - Allows decision-maker to view as they wish

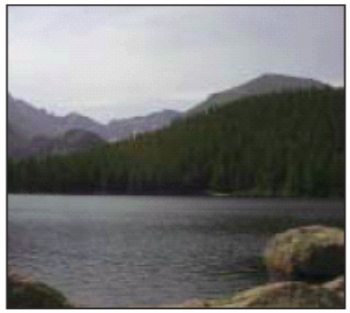
GIS input layers for FARSITE simulation

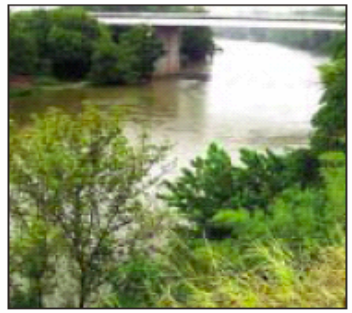


Fuel models

NB8 (98)

Open Water





Description: Land covered by open bodies of water such as lakes, rivers and oceans comprises NB8.

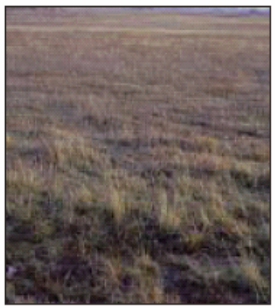
Expected fire behavior:

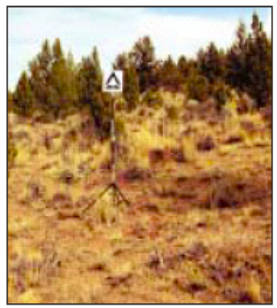
No fire spread

Fuel models

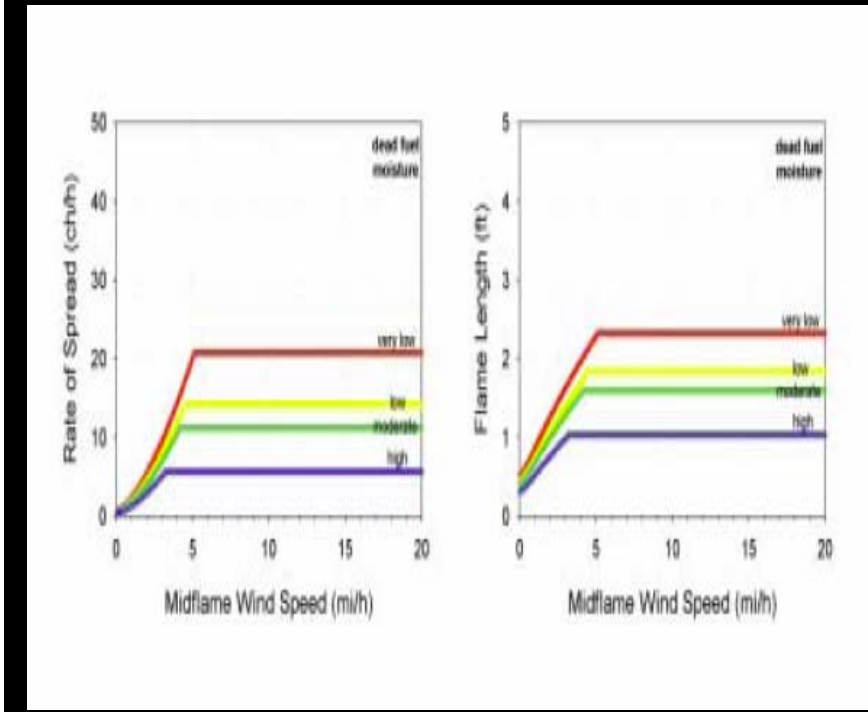
GR1 (101)

Short, Sparse Dry Climate Grass (Dynamic)





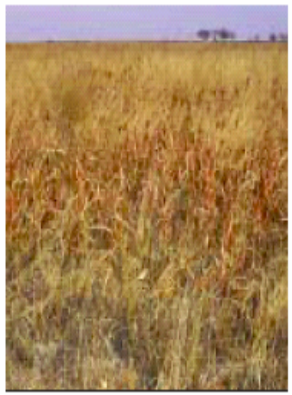
Description: The primary carrier of fire in GR1 is sparse grass, though small amounts of fine dead fuel may be present. The grass in GR1 is generally short, either naturally or by grazing, and may be sparse or discontinuous. The moisture of extinction of GR1 is indicative of a dry climate fuelbed, but GR1 may also be applied in high-extinction moisture fuelbeds because in both cases predicted spread rate and flame length are low compared to other GR models.



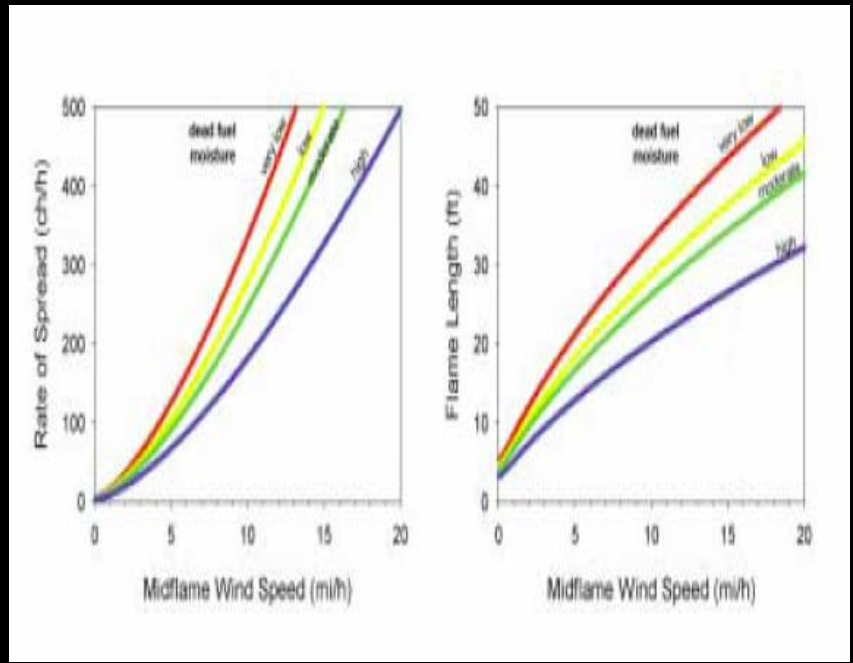
Fuel models

GR7 (107)

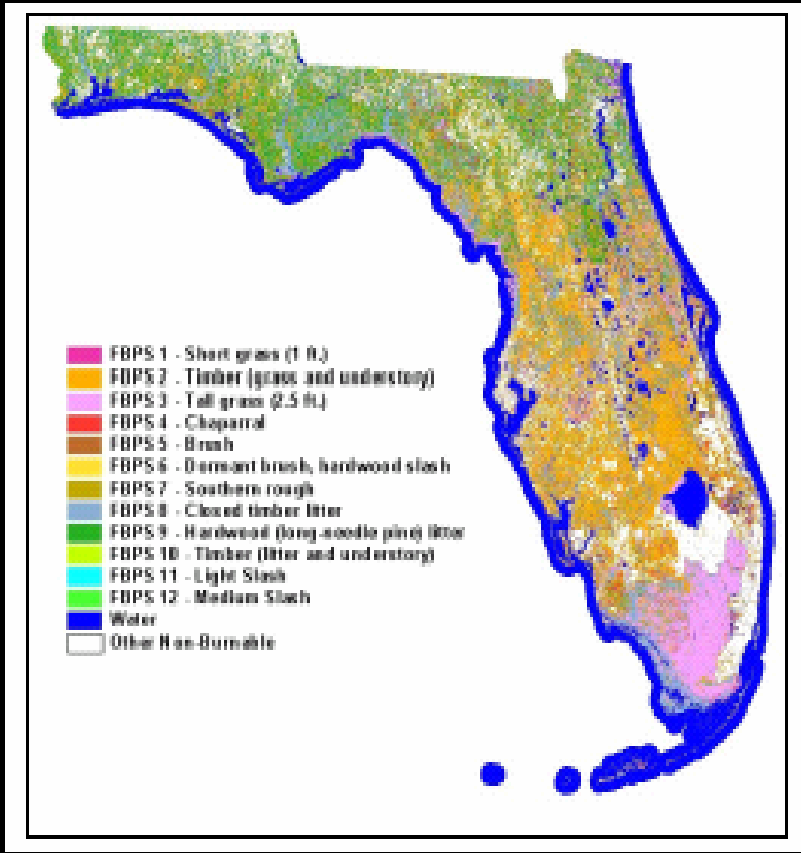
High Load, Dry Climate Grass (Dynamic)



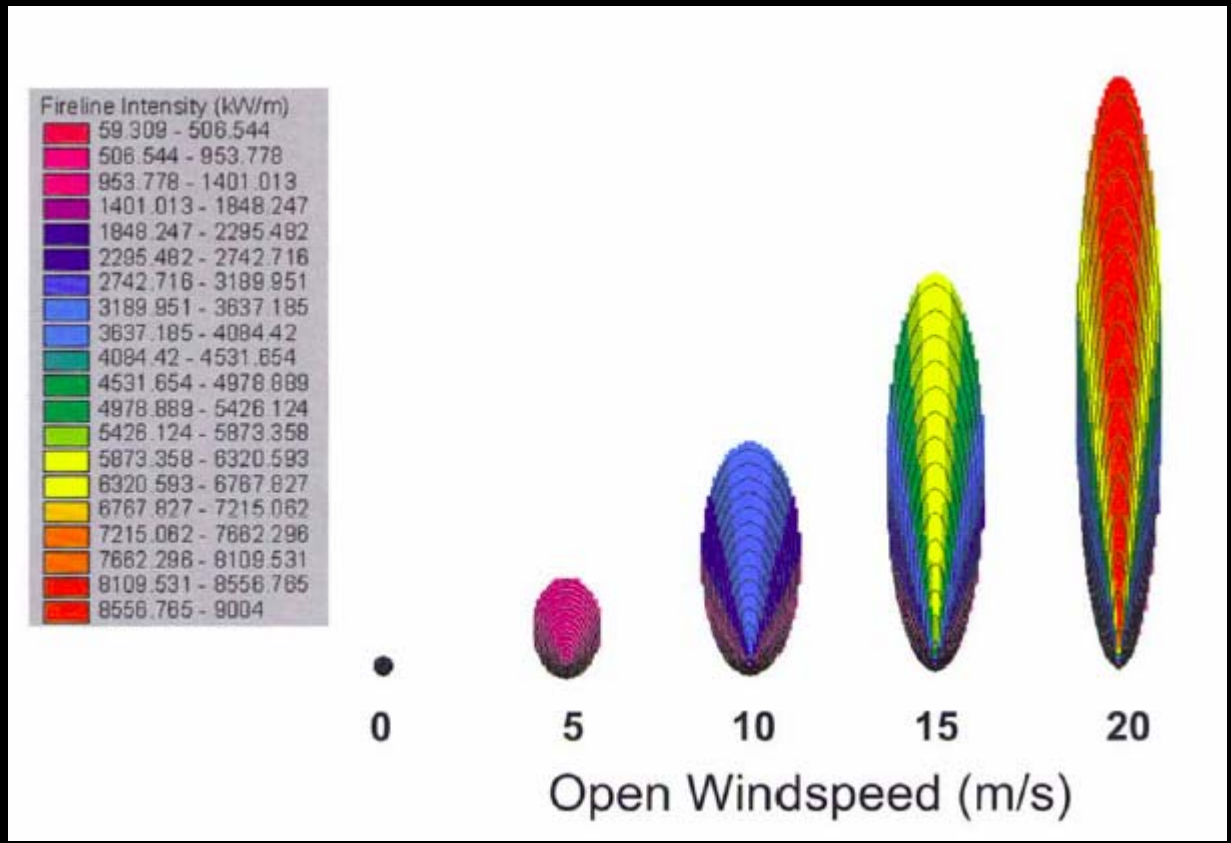
Description: The primary carrier of fire in GR7 is continuous dry-climate grass. Load and depth are greater than GR4. Grass is about 3 feet tall.



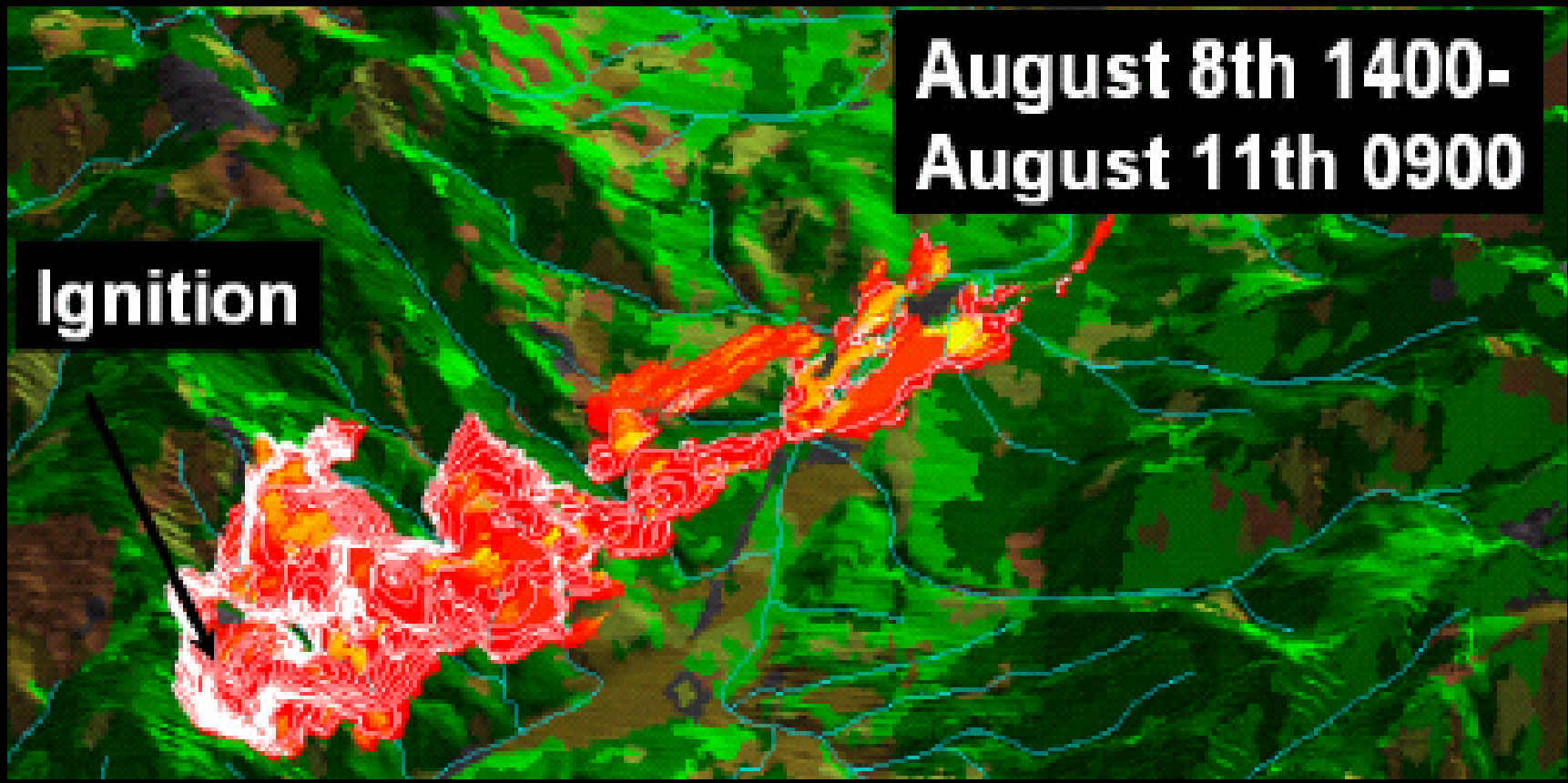
Surface fire fuel models for FL



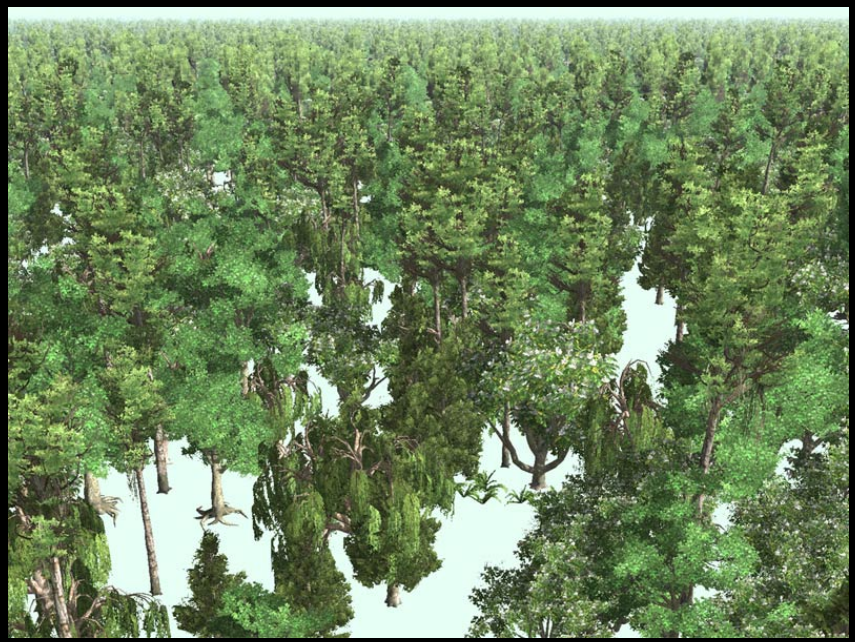
Numerically simulating a wildfire path



FARSITE simulation output



Visual rending of the forest



Detailed enough for a walk-through…

... or even a picnic

Wildfire dynamics

Our simulated fire

UCF

Our simulated fire

Please refer to the video file on the conference WebPage

Choices with consequences

- Subject has virtual property in area and a cash endowment
- Gets to visualize wildfires in that area
- Told the baseline risks of wildfire destroying property
  - Over 30 years
  - Simulated effects from FARSITE, displayed as a histogram
  - Damages modeled after typical FL impacts, including health costs
- Told the alternative distribution of risks if invest in PB
  - PB is a certain cost, akin to buying insurance
- Chooses binary policy option
- Play out one 30-year simulation at random, and pay subject

Subject pool and treatments

- Non-experts
  - FL residents from communities affected by 1998 wildfires
  - GIS representation of topography, vegetation and weather in their area
- Experts
  - FL fire managers
- Treatments
  - VR or no VR
  - Hypothetical or actual financial consequences

What is familiar, but with a new twist?

- Policy lottery concept
  - Recognize that simulations are uncertain
  - Hence proposed policy effect is uncertain
  - Should evaluate accordingly (e.g., Stern Report)
- Nature of information
  - Allow choices about the information set by decision-maker
  - Study differences between experts and laymen
  - Normative effects of using cues used by experts
- Nature of choices
  - Simple binary lottery choice here
  - Temporal dimension – visualizing latent effects
  - Could simulate and render a “walk in the park”

What is new?

- Rendering a VR environment with coherently simulated underlying process
  - VR generated from a simulated process
  - Based on laws and relationships from physics, biology, economics

- Better understanding of causal processes, when environment changes
  - Conditional on our modeling of that process
  - But again, constrained by laws and relationships in our models

Conclusions

- Virtual Experiments are a viable bridge between lab & field
  - Focus on cognitive differences between performance in lab and field
  - Control for differences in preferences (e.g., risk aversion, probability weighting, loss or regret aversion)
- Normative tool
  - Differences between experts and non-experts
  - Risk – communicate the underlying process, not just the output
  - Risk – allow people to choose their own representation
- Applications
  - Fire risk (and hurricanes)
  - Latency in land-use planning and global warming mitigation

UCF