Parameterizing Landscape Fire Models From Data: Recent Progress and Remaining Challenges

Steve Cumming
Jean Marchal & Eliot McIntire

11e Colloque Annuel du CEF
May Day, 2017
Montréal

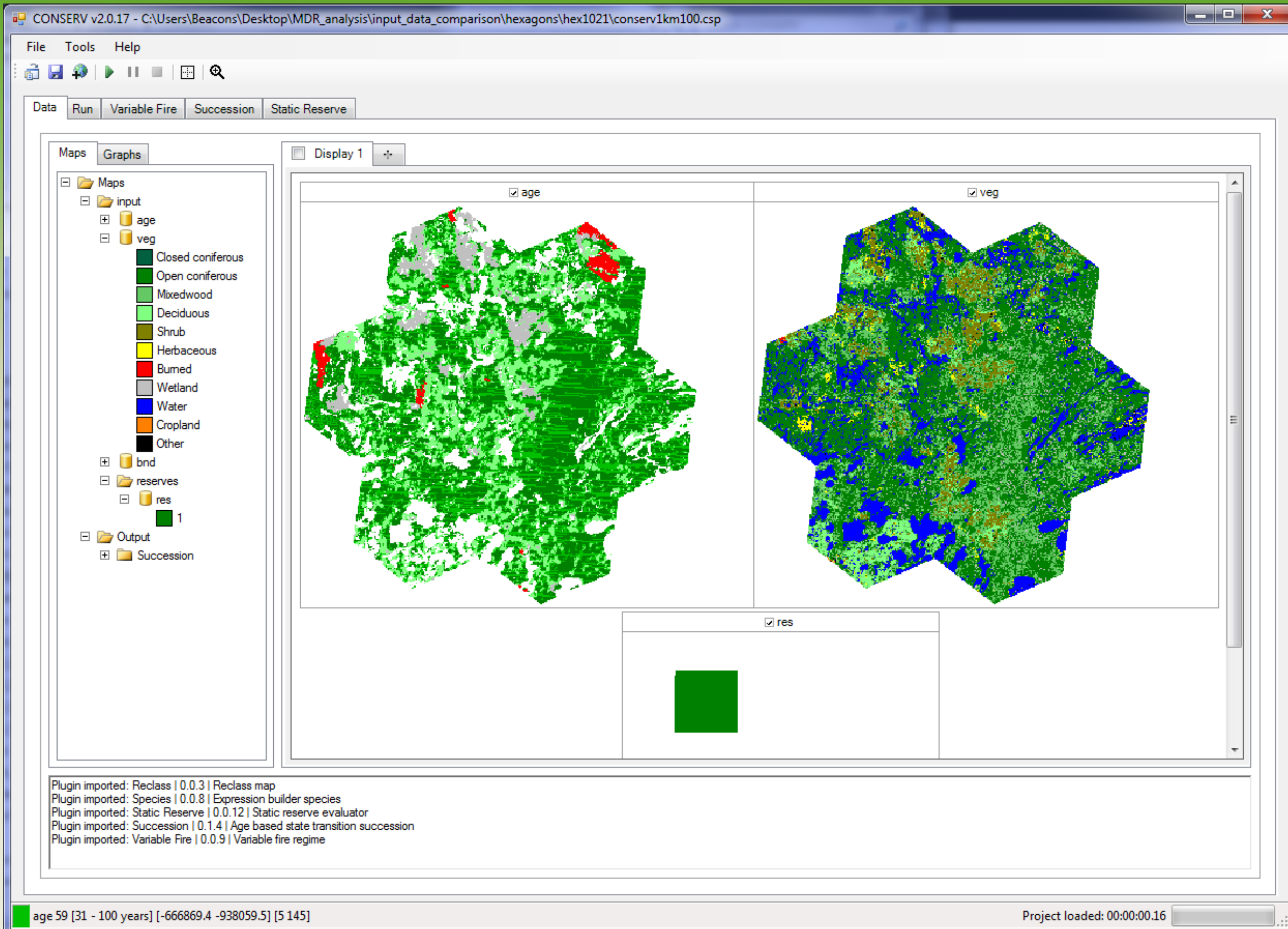
Natural Resources Canada
Canadian Forest Service

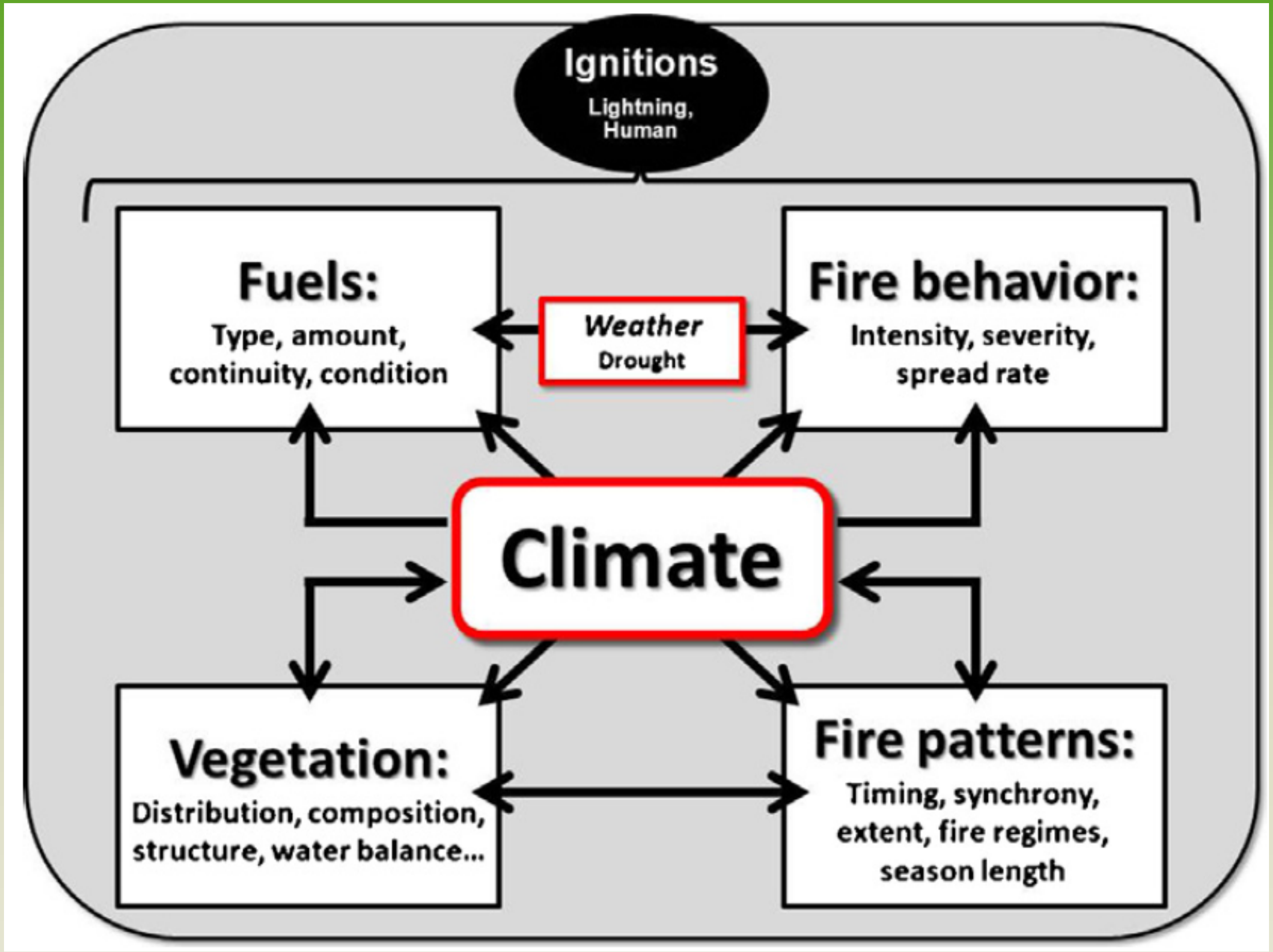
Ressources naturelles Canada
Service canadien des forêts

UNIVERSITÉ LAVAL

Thanks to the following:

Carl Walters and Roy Hilborn
Subhash Lele
Meg Krawchuk and Cecilia Arienti
John Braun David Martell
Doug Woolford, Reg Kulperger
Thierry Duchesne, Piers-Olivier Tremblay, Denis Talbot
The Provincial and Territorial Fire Agencies
The Canadian Forest Service
The Canadian Statistical Sciences Institute
NSRC-CRSNG et Réseau GEOIDE


CONSERV v2.0.17 - C:\Users\Beacons\Desktop\MDR_analysis\input_data_comparison\hexagons\hex1021\conserv1km100.csp
File
Tools
Help
Data
Run
Variable Fire
Succession
Static Reserve
Maps
Graphs
Display 1
Maps
input
age
veg
Closed coniferous
Open coniferous
Mixedwood
Deciduous
Shrub
Herbaceous
Burned
Wetland
Water
Cropland
Other
bnd
reserves
res
1
Output
Succession
age
veg
res
Plugin imported: Reclass | 0.0.3 | Reclass map
Plugin imported: Species | 0.0.8 | Expression builder species
Plugin imported: Static Reserve | 0.0.12 | Static reserve evaluator
Plugin imported: Succession | 0.1.4 | Age based state transition succession
Plugin imported: Variable Fire | 0.0.9 | Variable fire regime
age 59 [31 - 100 years] [-666869.4 -938059.5] [5 145]
Project loaded: 00:00:00.16



"Feedbacks … and synergies … are what separate true interactions from one-way forcings such as the effects of drought on wildfire."

Keane et al. 2015. Ecological Modelling 309-310

Complexity politely ignored

"In a more complex version of the model, fire behaviour is influenced by [everything important]. For the purposes of this paper, we did not apply the complex model so that fires burned independent of age, a common simplifying assumption for studies in boreal forests" (Fall et al. 2004).

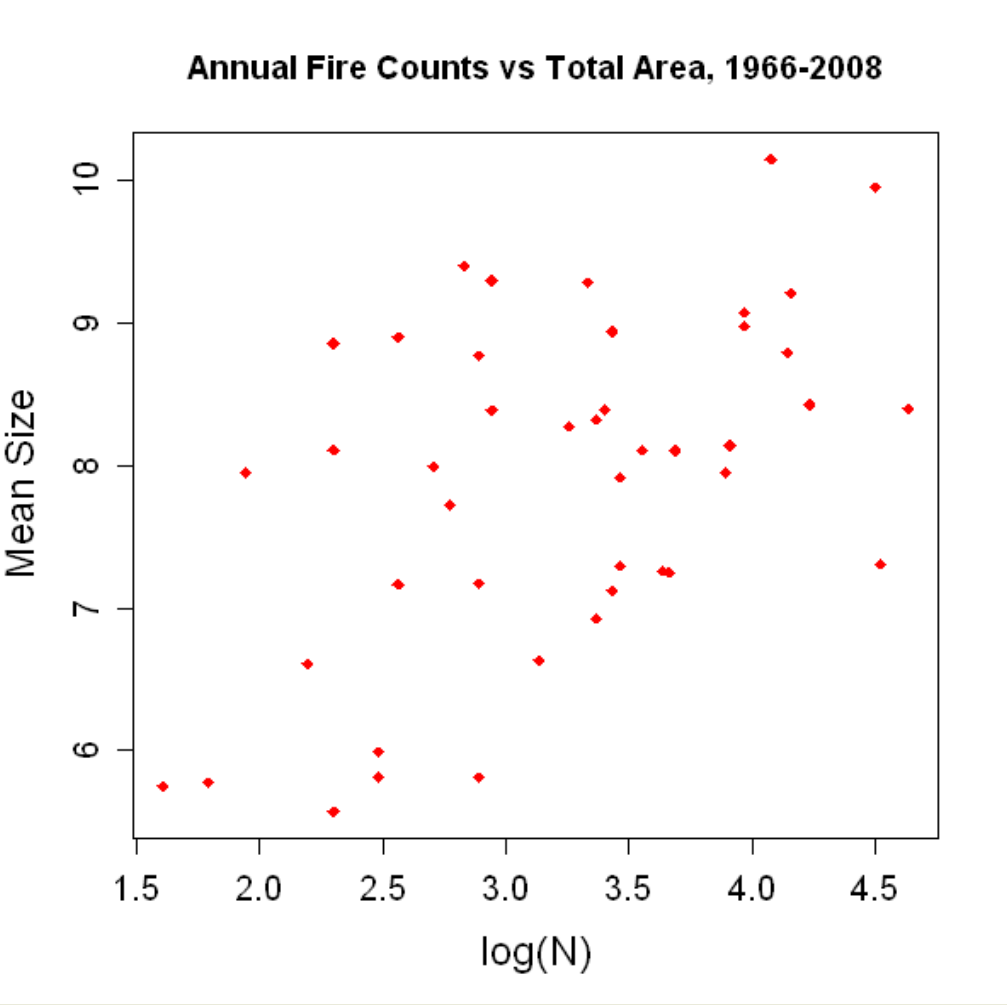
This assumption is so far from the truth that it can't form the basis for ecological forecasts.

A fire regime:

A quantitative description of the fires characteristic of a particular place *(Whelan 1994)*

- **Frequency (rate of occurrence)**
- **Size**
- Cause
- Annual Area Burned = Frequency X Size

Two components of fire regime



Number of fires

Size of fires

Modelling Objectives

- Forecast / simulated ecosystem responses to:
  - fire regime,
  - industrial development, and
  - climate change.
- *Not* individual fires as such.
- The focus in on *populations*
- Hence on parameter estimation.
- Link *distributional* to *simulation* parameters

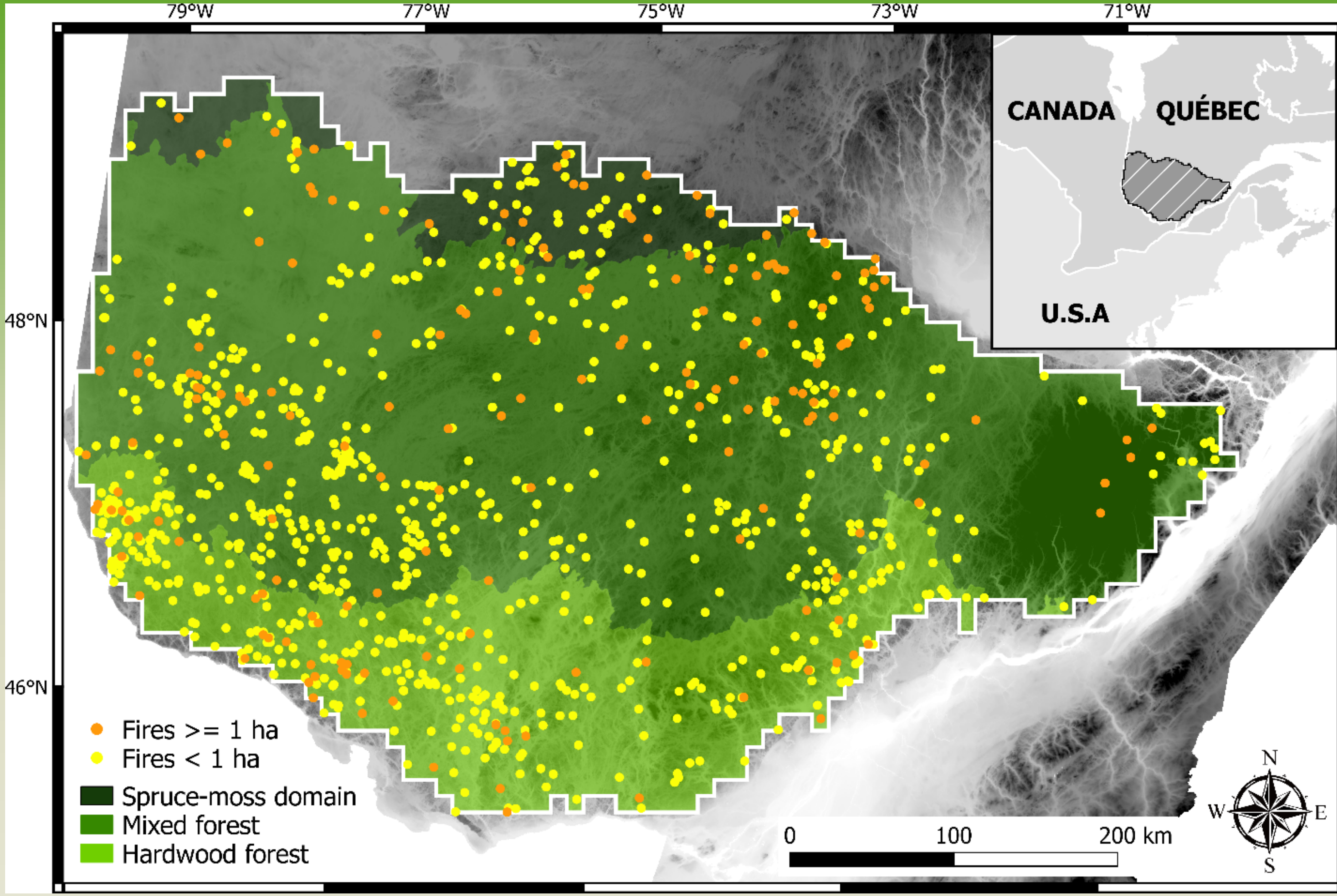
Parameters: Frequency

Distributional:

- Counts (Poisson)
- Fire size
  - Mean or expectation
  - Parametric model e.g. Tapered Pareto

Simulation:

- Occurrence (Bernoulli)
- Percolation *p*
  - *Calibration*
  - *Pattern oriented modelling*



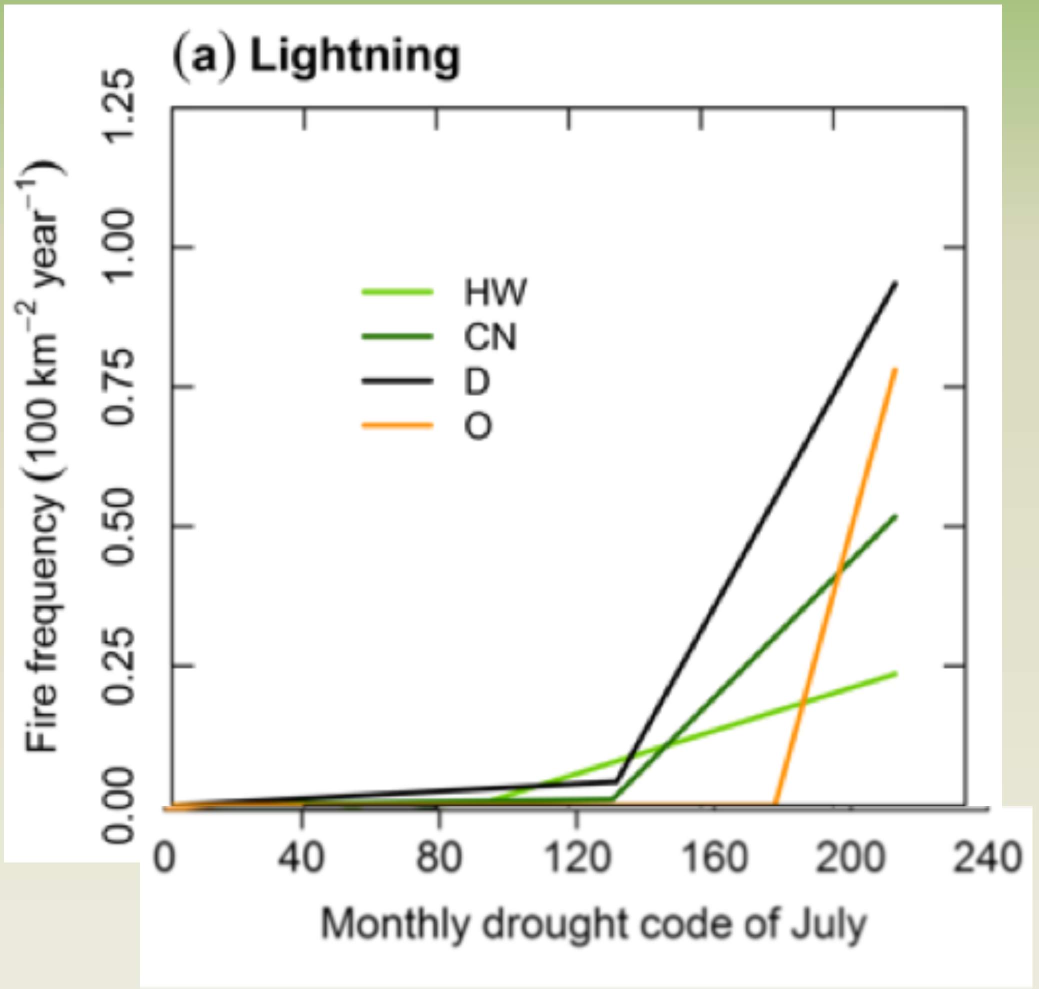
Fire Occurrences 2000-2010 +
Vegetation Maps
Interpolated Monthly Drought Code

1. Exploiting Poisson additivity to predict fire frequency from maps of fire weather and land cover in boreal forests of Québec, Canada. Marchal, Cumming and McIntire. Ecography 2016

Poisson rates can be scaled to arbitrary cell sizes and compositions.

For small, homogeneous cells, can be converted to Bernoulli probabilities. $1/100km^2 = 0.0001/ha$

Results for human caused fires (not shown) also depended on road density.



Fire size

“Neutral models” in landscape ecology

Simple fire simulations (one *spread* parameter, p)

The theory is opaque to some

No guide to empiricists like me

(5.4) Theorem. Exponential tail decay of the radius of an open cluster. *If $p < p_c$, there exists $\psi(p) > 0$ such that*

$$P_p(A_n) < e^{-n\psi(p)} \quad \textit{for all } n. \tag{5.5}$$

Parameters: Size

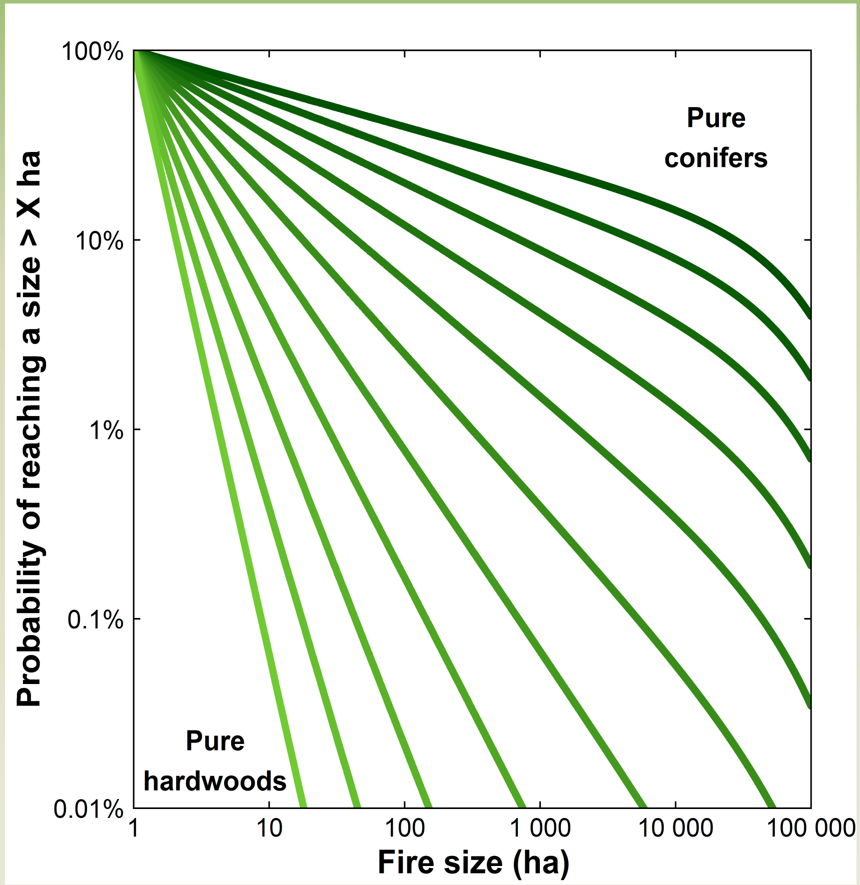
Distributional:

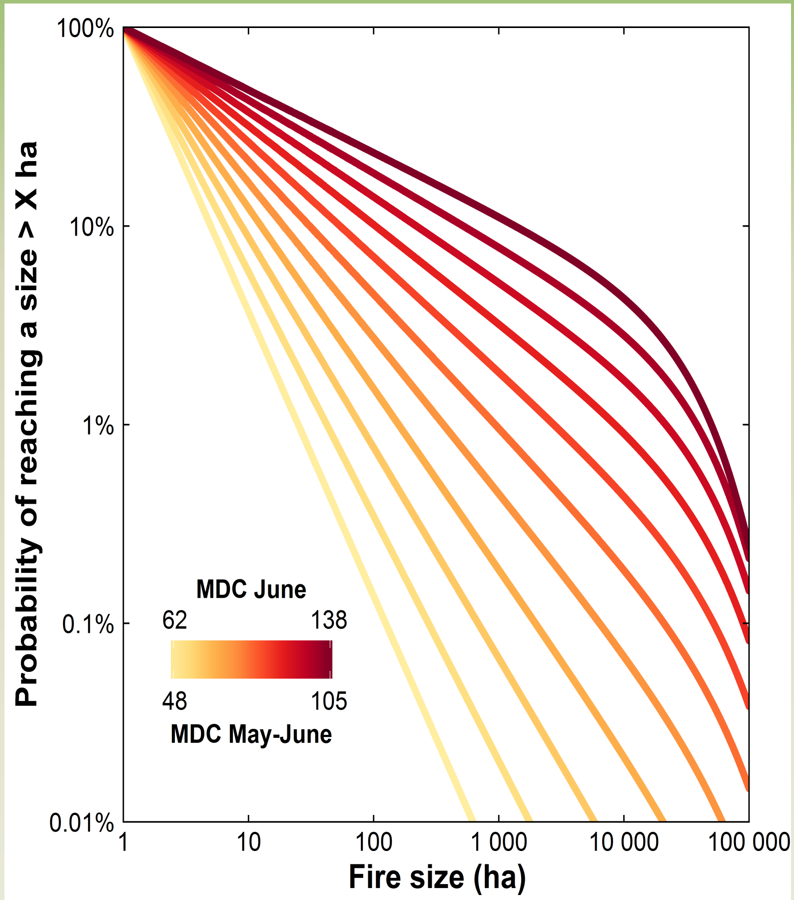
- Counts (Poisson)
- Fire size
  - Mean or expectation
  - Parametric model e.g. Tapered Pareto

Simulation:

- Occurrence (Bernoulli)
- Percolation *p*
  - *Calibration*
  - *Pattern oriented modelling*

2. Land cover, not monthly fire weather, drives fire sizes in Southern Québec forests: implications for fire risk management. Marchal, Cumming and McIntire. PLOS ONE *in review*.





Schoenberg FP, Peng R, Woods J (2003) On the distribution of wildfire sizes. *Environmetrics* **14**:583–592.

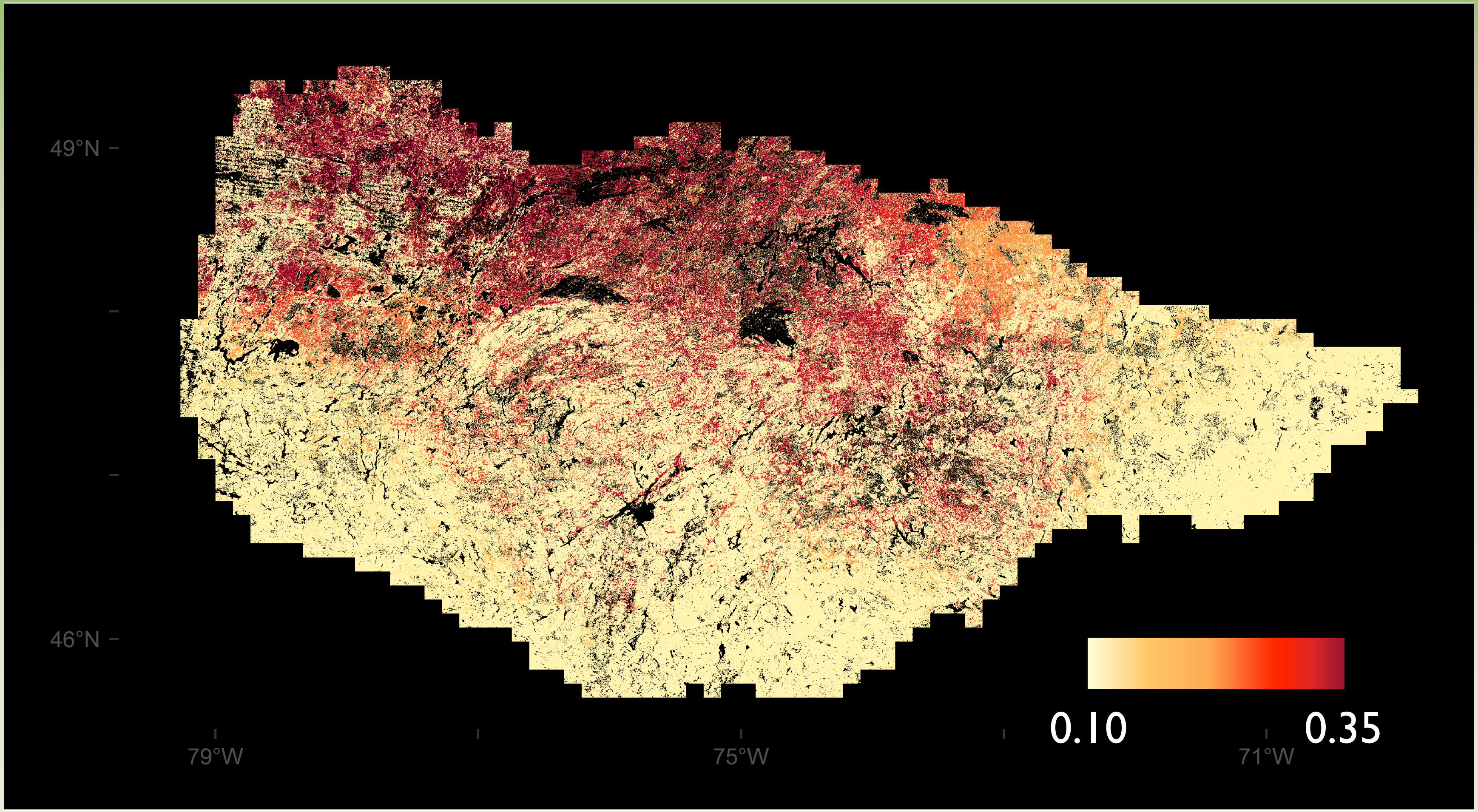
Cumming SG (2001) A parametric model of the fire size distribution. *Can J For Res* **31**:1291-1303.

Pattern Oriented Modelling

- Find the spatial pattern of p that best reproduces the observed fire size given vegetation and fire weather.
- Fit the logistic by simulation/optimisation
  - deoptim() calling SpaDES fire simulations
  - objective function based on A-D statistics

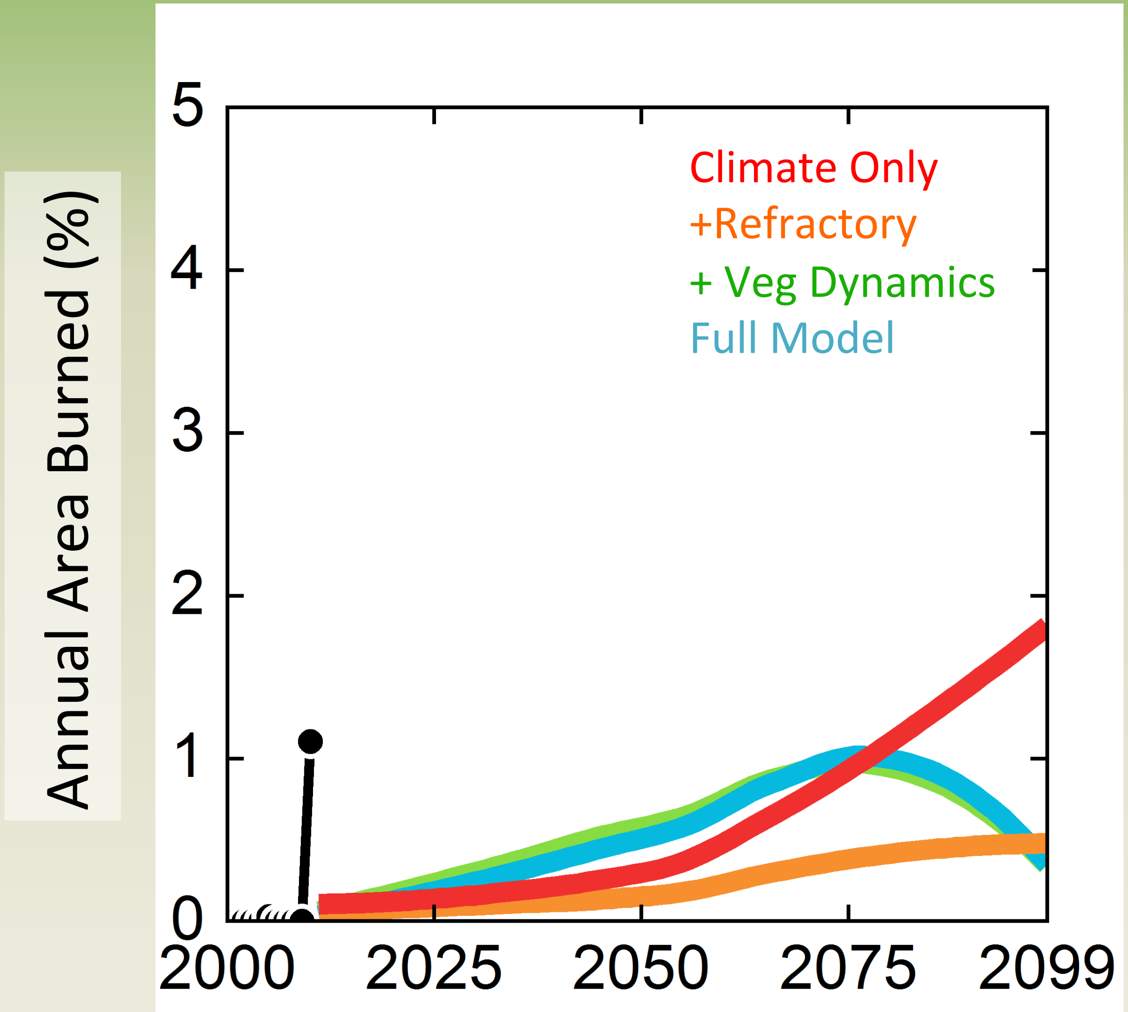
$$p_{i,t} = 0.113 + \frac{(0.499 - 0.113)}{\left(1 + \left(\frac{0.153}{\log \beta_{i,t}} + 0.00885 \log \theta_{i,t}\right)^{-7.45}\right)^{1.97}}$$

Predicted cell-level p, 2010



We don't think anyone has ever done this before

Negative feedbacks constrain fire regime response to climate change.



Challenges

- The data come from fire management agencies
- They try to put fires out: but how good are they?
- *Recent* data are biased; *older* data are worse.
- Frequency and Size are not the only paramaters of interest;
- Human caused fires are increasing in importance, but are not controlled only by biophysical factors.


Thanks for your attention