Canadian Forest Carbon Budgets at Multi-Scales:

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OUTLINE

- **Canada's Forests and C Accounting System**
- **Canadian Forest Carbon Budgets**
  - **Modelling Approaches**
  - **Data sources**
  - **Model validation and comparison**
- **Future Challenges**

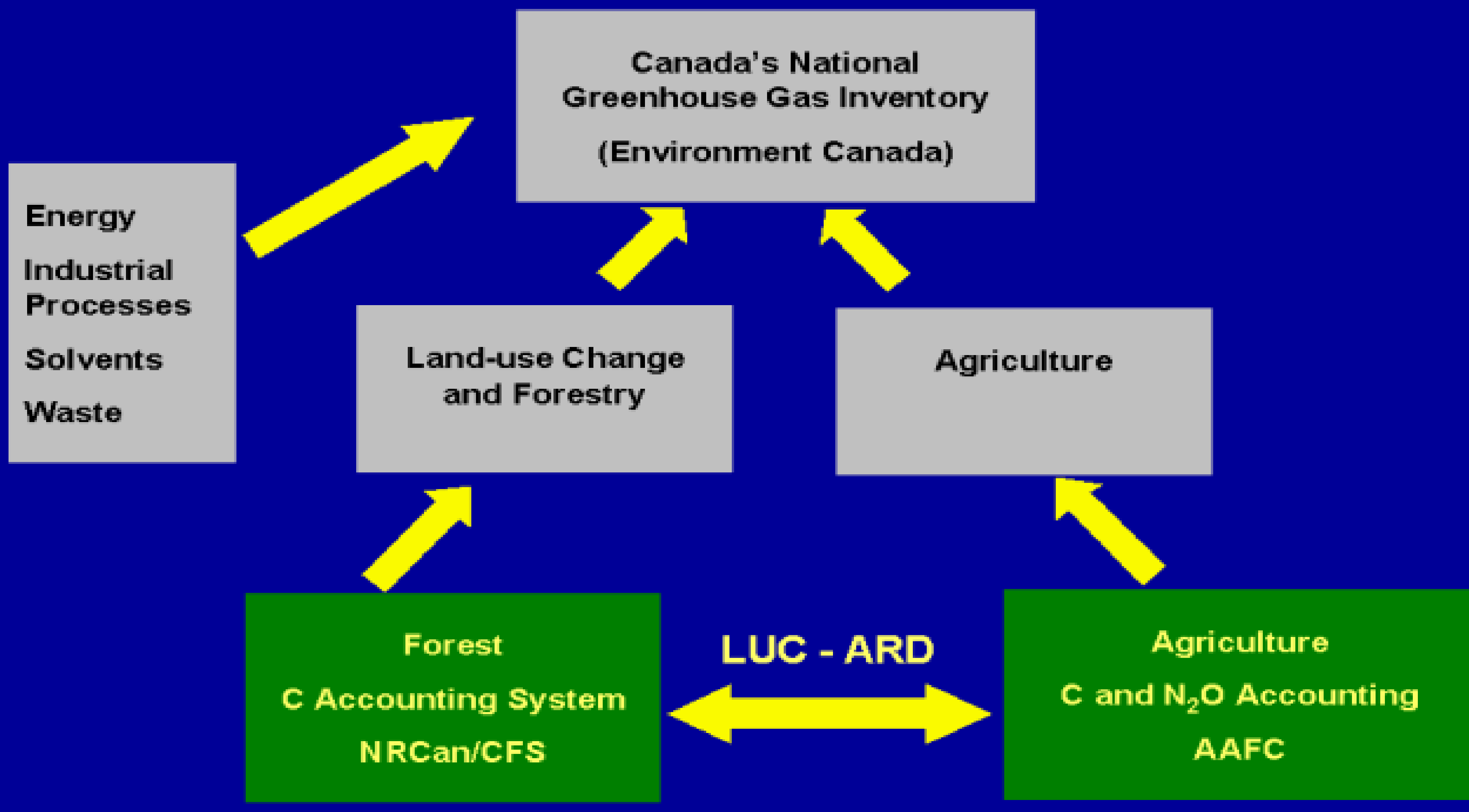
Canada's Forests

- 418 million ha of forest land – 75 % in the boreal zone
- 245 million ha timber productive
- 148 million ha accessible

- 10% of global forests
- 25% of global boreal forests

Source: Lowe et al. 1996

LULUCF in the National GHG Inventory



Key Components of Canada's National Forest C Accounting System

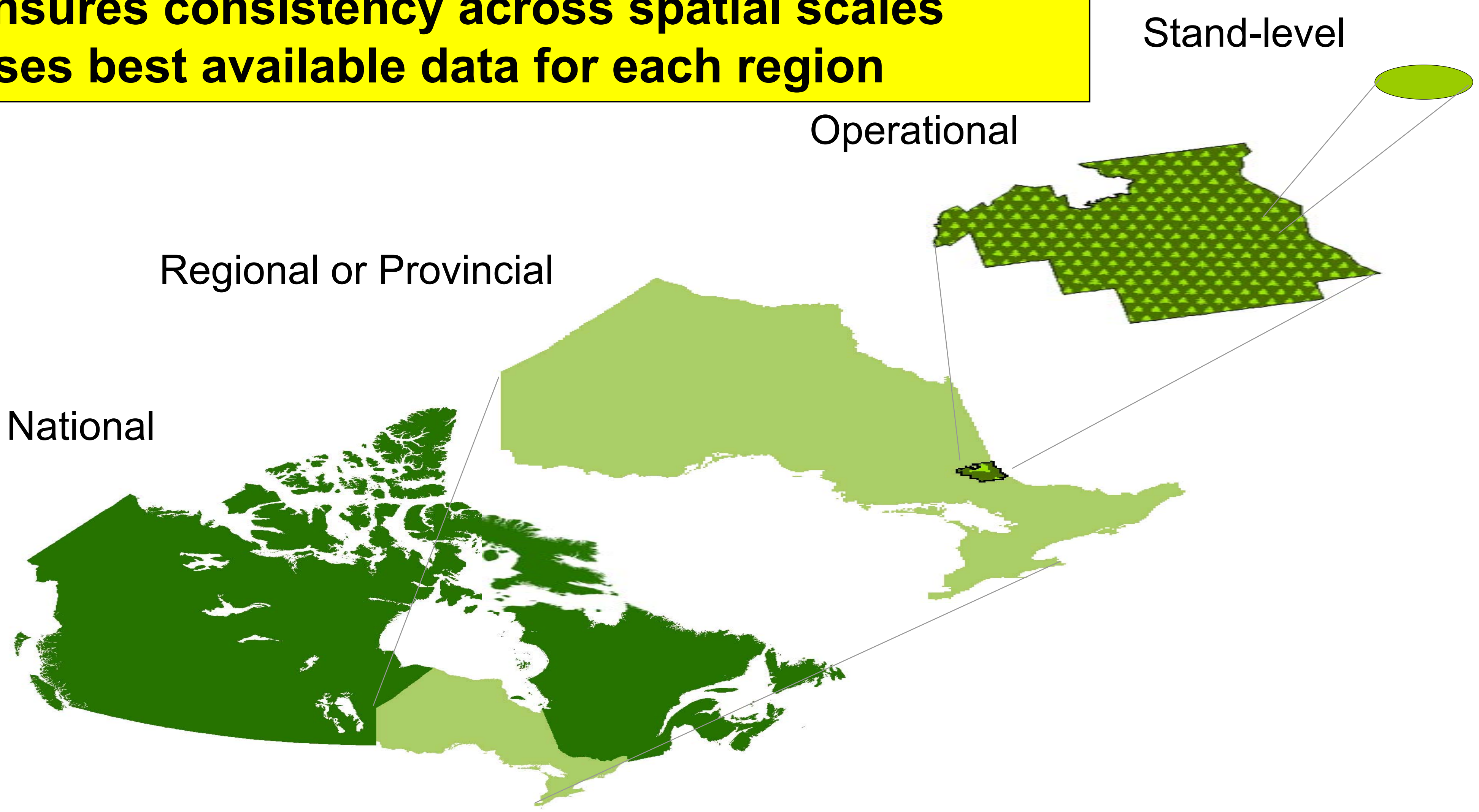
- A landscape-level computer simulation model
- The new National Forest Inventory and other inventories
- Remote sensing programs for change detection and inventory updates
- Growth and yield information for biomass dynamics
- Simulation of dead organic matter dynamics as affected by management and natural disturbances
- Statistics on natural disturbances, forest management activities and land-use changes (ARD)
- A research program to address remaining data gaps and to help operationalise the system.

Development of C Accounting Tools at four Spatial Scales

- National Scale
  - Required to determine national net balance, and
  - Required in support of international reporting
- Regional Scale
  - Biome-level and provincial/territorial analyses
  - Can be building block for regional and national scale
- Operational / Management Unit Scale
  - Scale of forest management decisions
  - Can be building block for regional and national scale
  - Can use high resolution, spatially explicit approach
- Stand
  - Ground measurements and model validation
  - Scientific analyses

C Accounting at Four Spatial Scales

Ensures consistency across spatial scales
Uses best available data for each region



Modelling Approach:

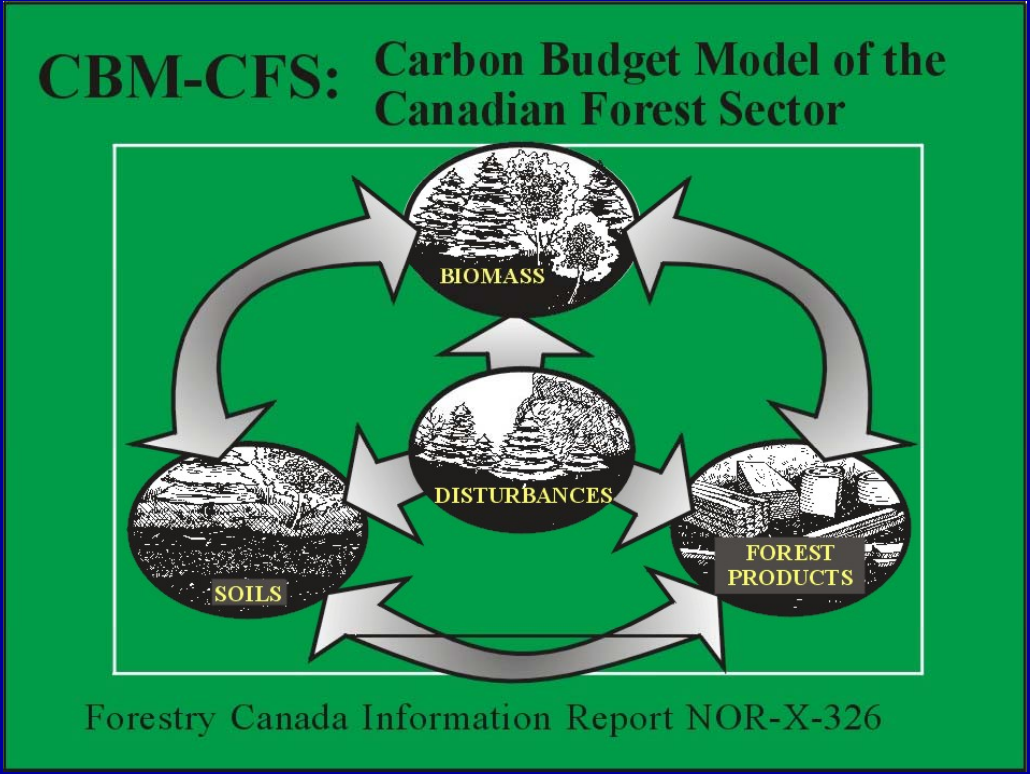
1. Forest Inventory Based Forest Carbon Accounting: CBM-CFS (Kurz and Apps, 1992, 1999)

2. Integrated Process-Model and Remote Sensing: InTEC (J. Chen et al, 2000, 2003)

3. Hybrid Model Simulation at Stand and Landscape Levels: TRIPLEX (Peng et al, 2002; Zhou et al. 2004)

CBM-CFS2: Carbon Budget Model of Canadian Forest Sector

- CBM-CFS
  - First national scale forest analysis
- Data Driven:
  - Forest Inventory (NFBI and CanFI)
  - Soil Data
  - Disturbances
    - Fire
    - Insects
    - Harvests



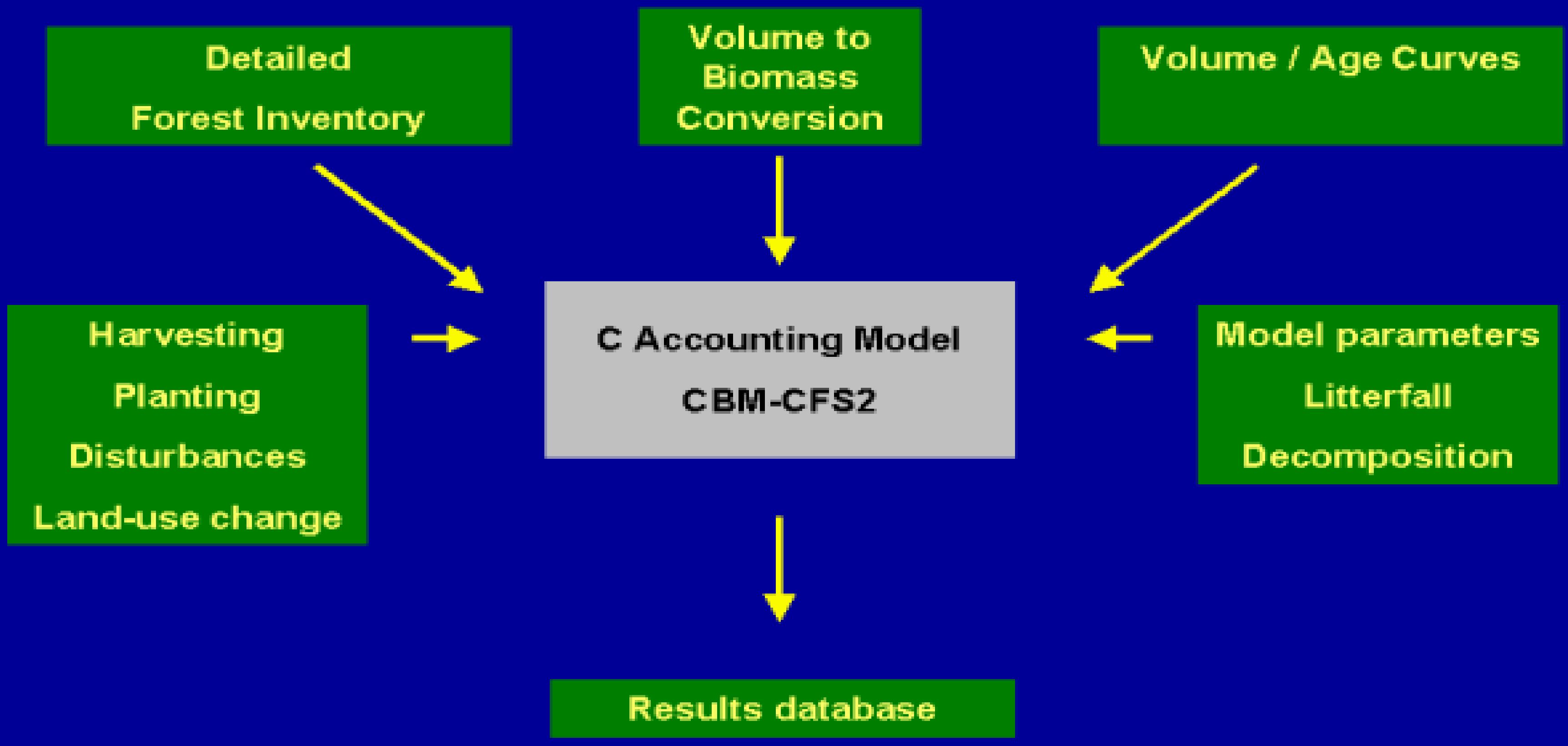
(Kurz, Apps, Webb, McNamee; 1992, Kurz and Apps, 1999)

The CBM-CFS2 accounts for all C pools

- Biomass
  - Aboveground
  - Belowground
- Dead Organic Matter
  - Litter
  - Dead Wood
  - Soil Organic Carbon

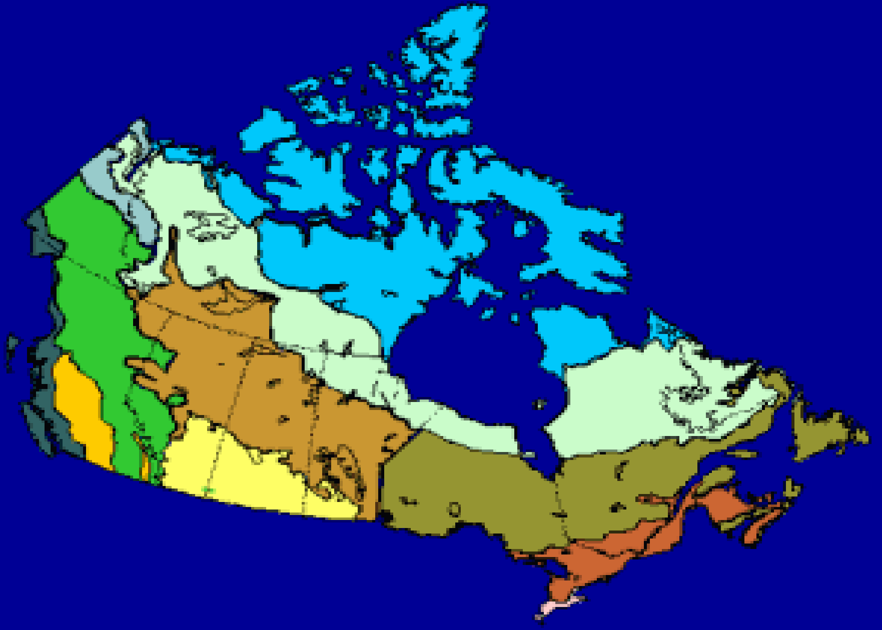
- Additional Forest Product Sector Model can track fate of carbon in harvested wood products using a variety of approaches

Forest C Stock Analyses



Carbon Budget Model of the Canadian Forest Sector (CBM-CFS2)

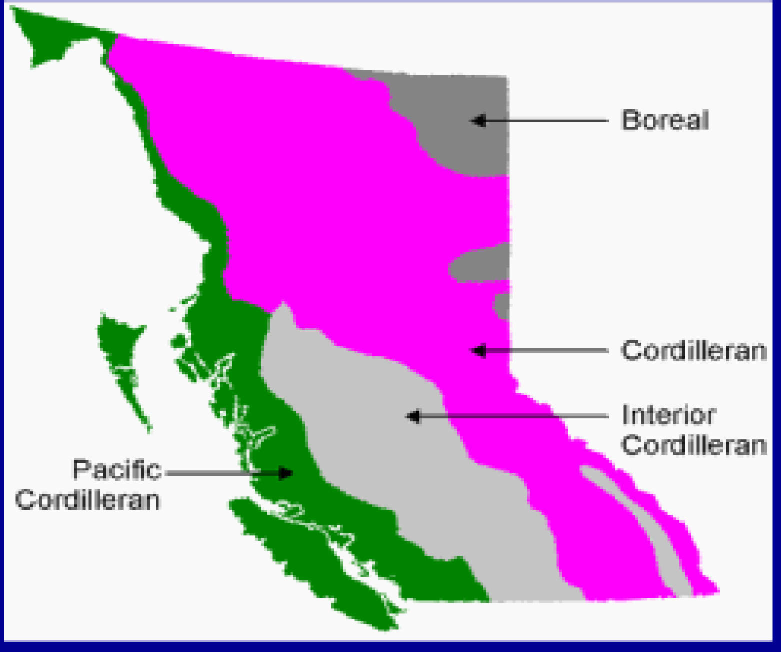
- Applied at
  - national scale (all forest, managed forest),



- Kurz et al. 1995
- Kurz and Apps 1999

Carbon Budget Model of the Canadian Forest Sector (CBM-CFS2)

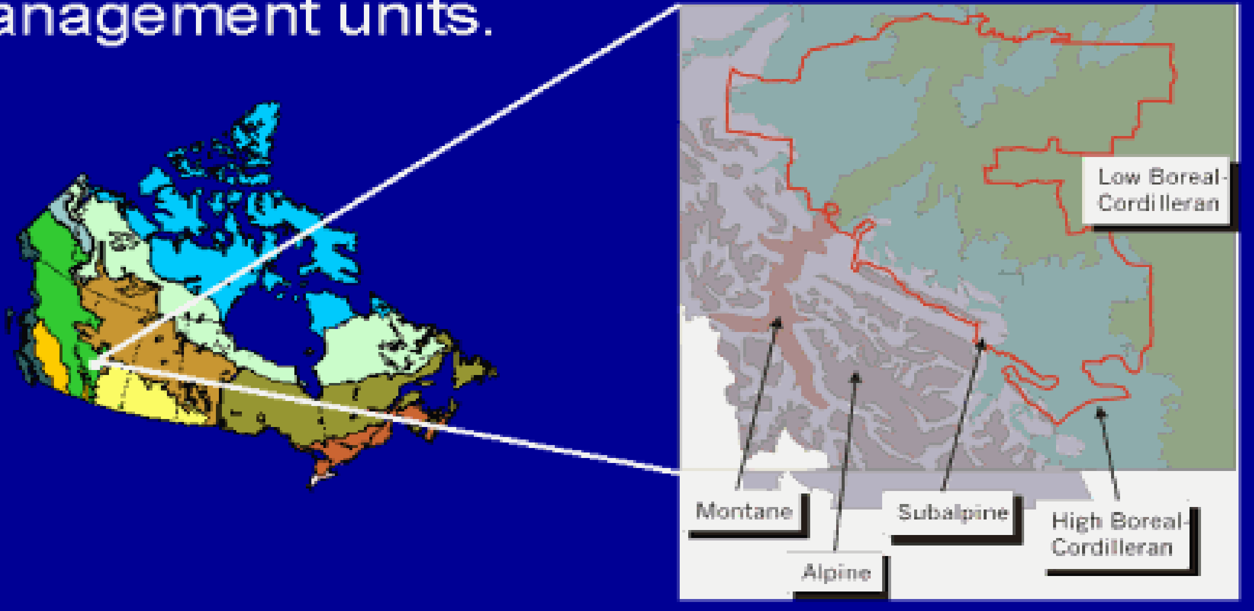
- Applied at
  - national scale (all forest, managed forest),
  - regional scale (boreal, British Columbia, Ontario),



- Kurz and Apps 1996
- Kurz et al. 1996
- Peng et al. 2000

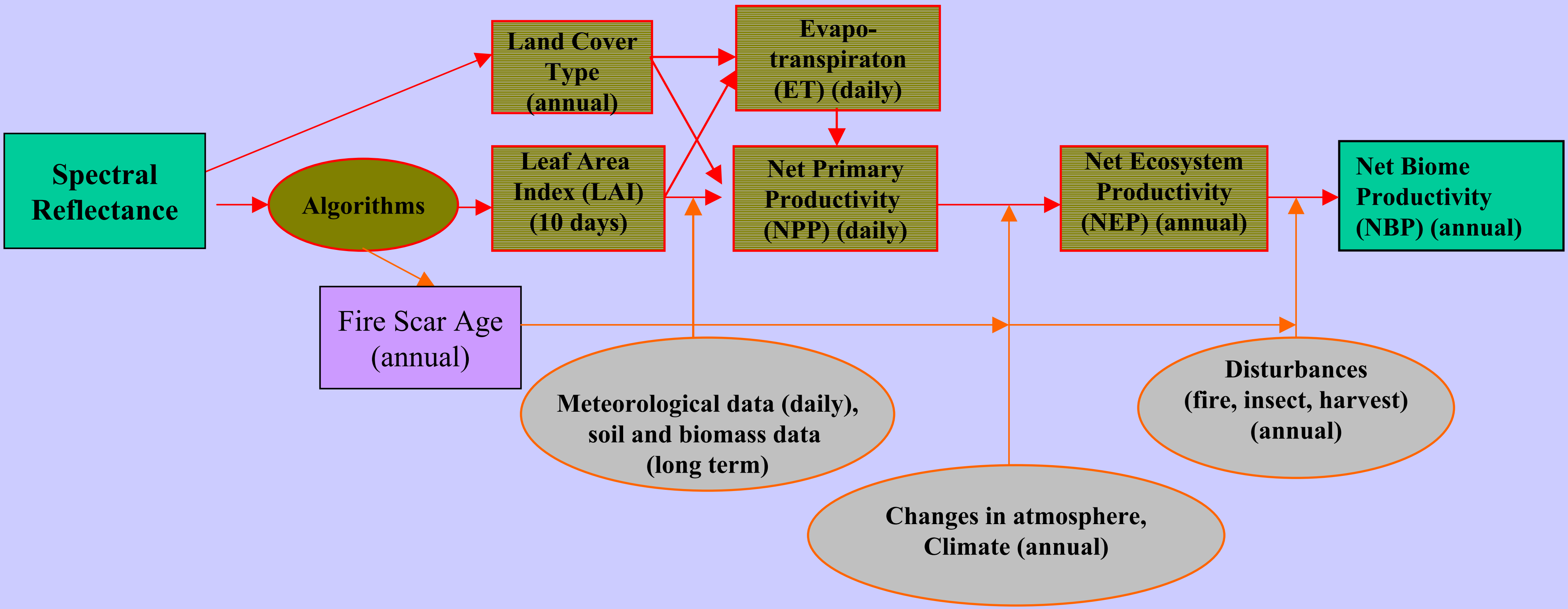
Carbon Budget Model of the Canadian Forest Sector (CBM-CFS2)

- Applied at
  - national scale (all forest, managed forest),
  - regional scale (boreal or provinces), and
  - forest management units.



- Price et al. 1997
- Kurz et al. 1998

Key steps in satellite-based estimation of carbon balance (NBP)



(J. Chen et al, 2003)

Additional datasets used

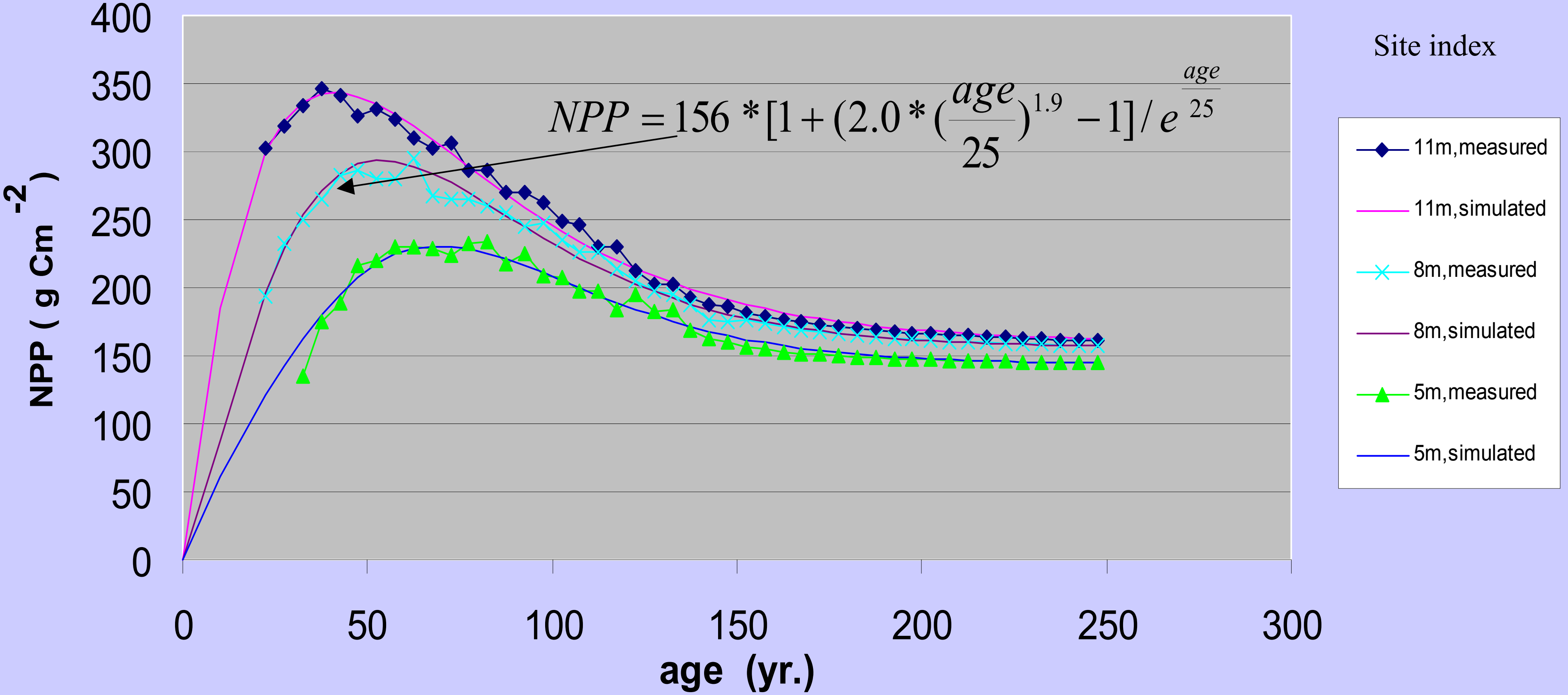
- Remotely sensed land cover and LAI maps (1 km resolution)
- Modeled and partially validated NPP map for 1994 (1 km resolution)
- Gridded climate data (1901-1998, U. East Anglia, 0.5°, monthly means)
- Soil Landscape of Canada (texture, total carbon, ~10k polygons)
- Nitrogen deposition data (1983-1998, 12 stations, CAPMoN)
- Tower flux data at 4 locations

Role of Disturbance

NBP = NEP – Fires – Harvest – Insect-induced Mortality

NBP: Net Biome Productivity

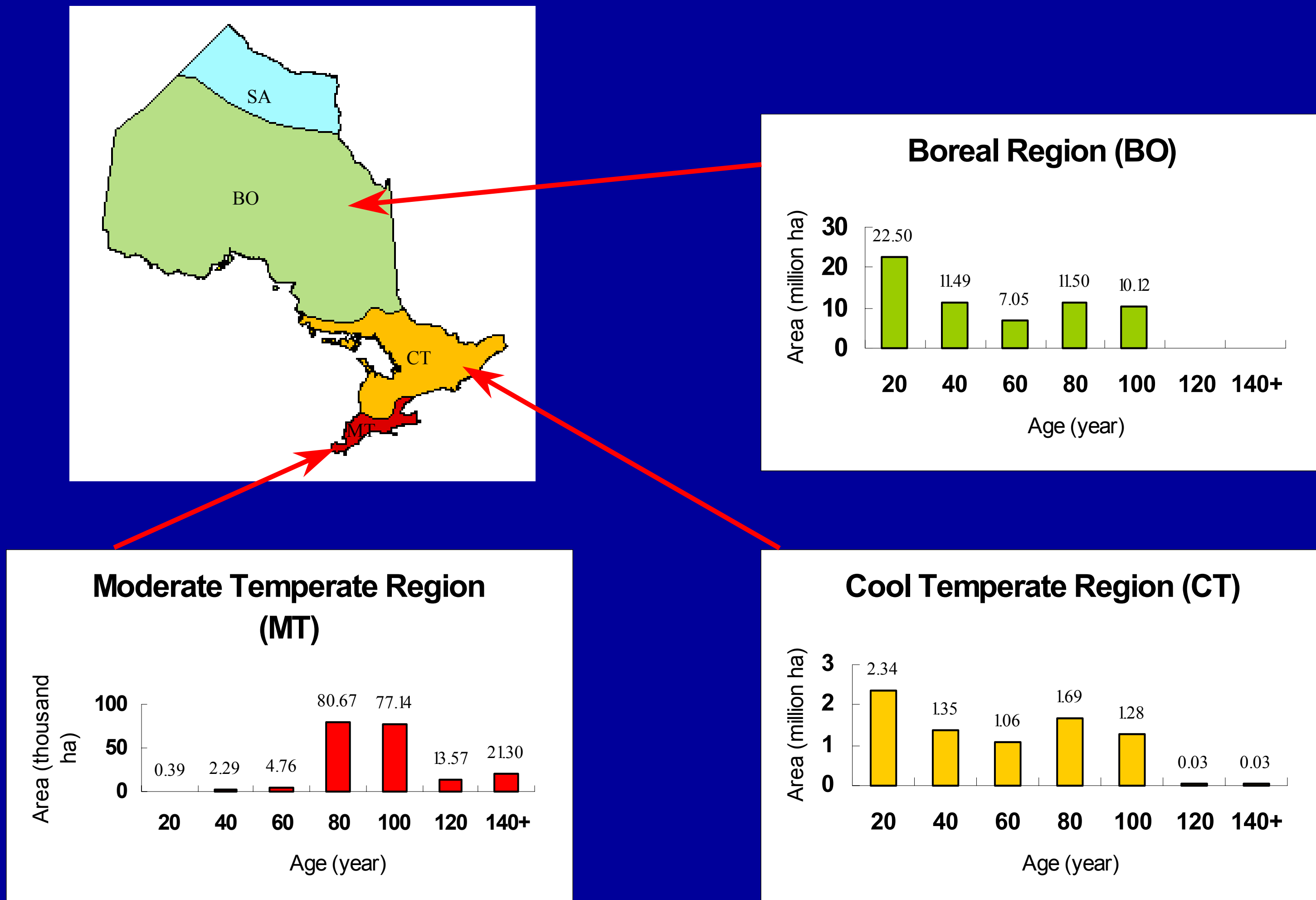
The variation of NPP with age (Black Spruce in Ontario)



(Chen et al. 2002)

Role of Forest Age

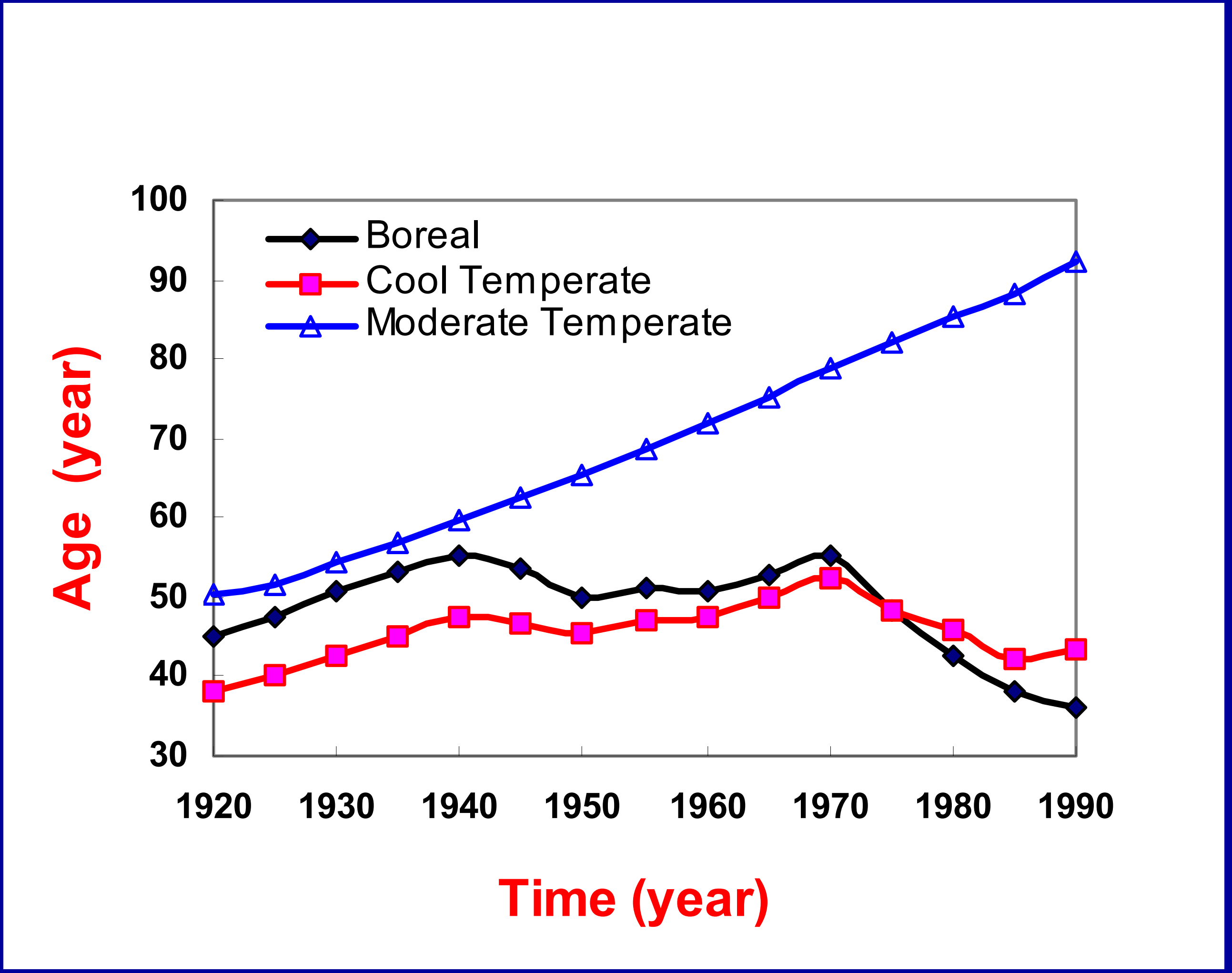
Ontario's Forest Age-class Structure (1990)



CBM-CFS2

(Peng et al. 2000)

Ontario's Forest Age (1920-1990)



CBM-CFS2

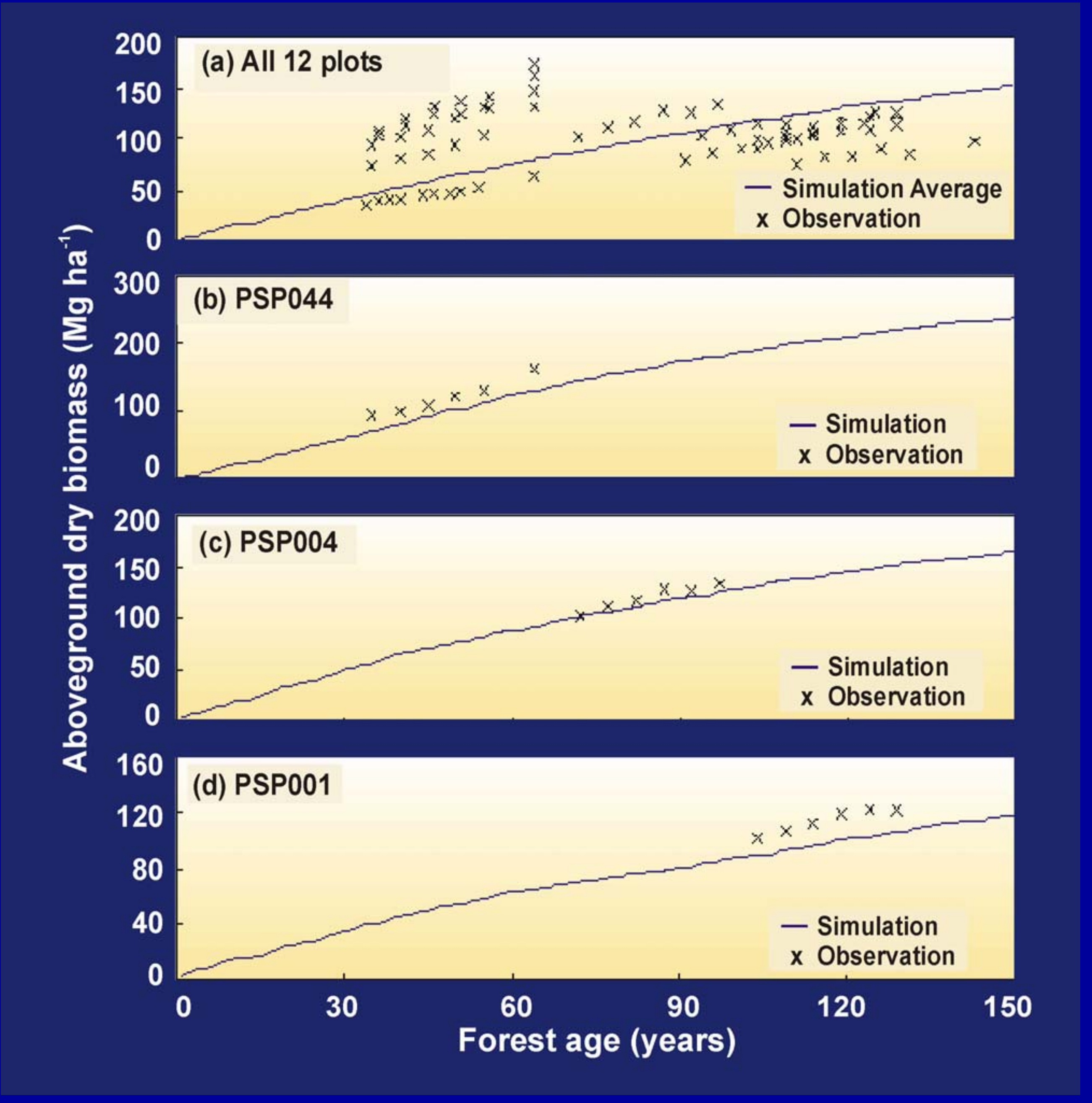
(Peng et al. 2000)

Model Validation and Comparison

Testing model simulations against:

- Forest Growth &Yield plots
- Forest Inventory
- Soil measurements
- Eddy Covariance Flux Towers

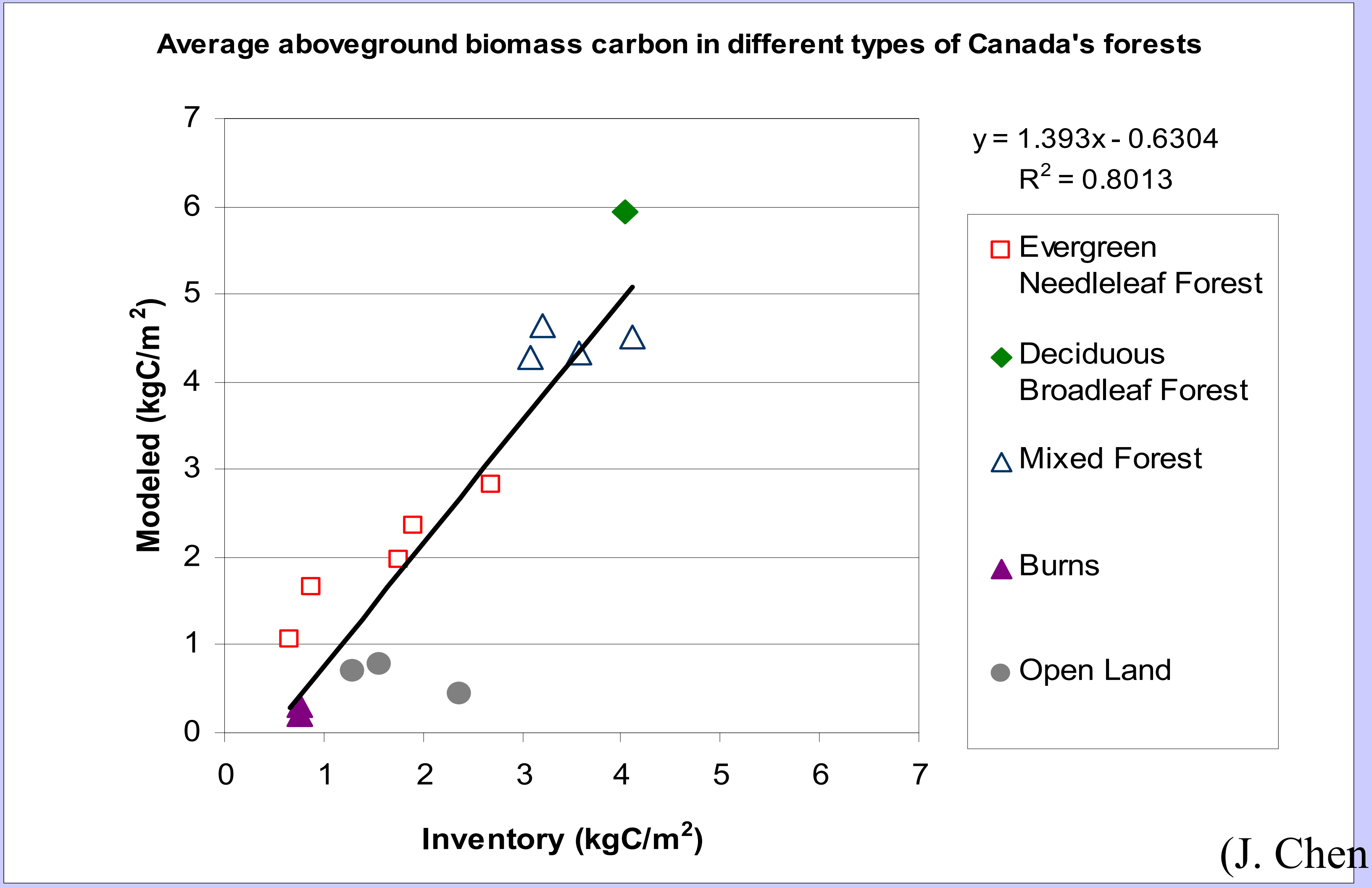
Comparison of Averaged Simulations and Observations - *Aboveground Biomass (Hegyi, 1972)*



TRIPLEX Simulations

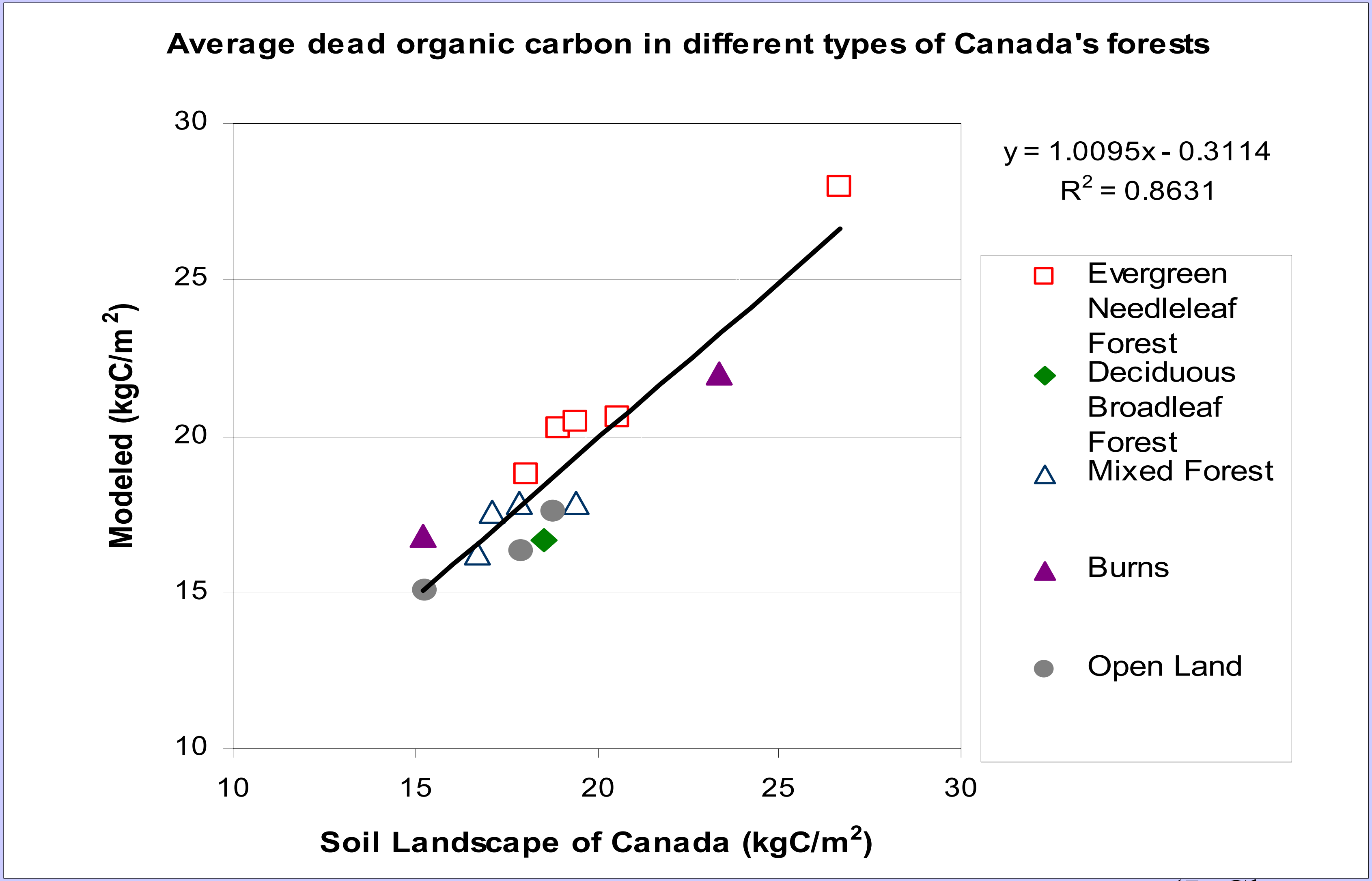
(Peng et al. 2002)

Comparison of modeled total aboveground biomass carbon with forest inventory



(J. Chen et al. 2003)

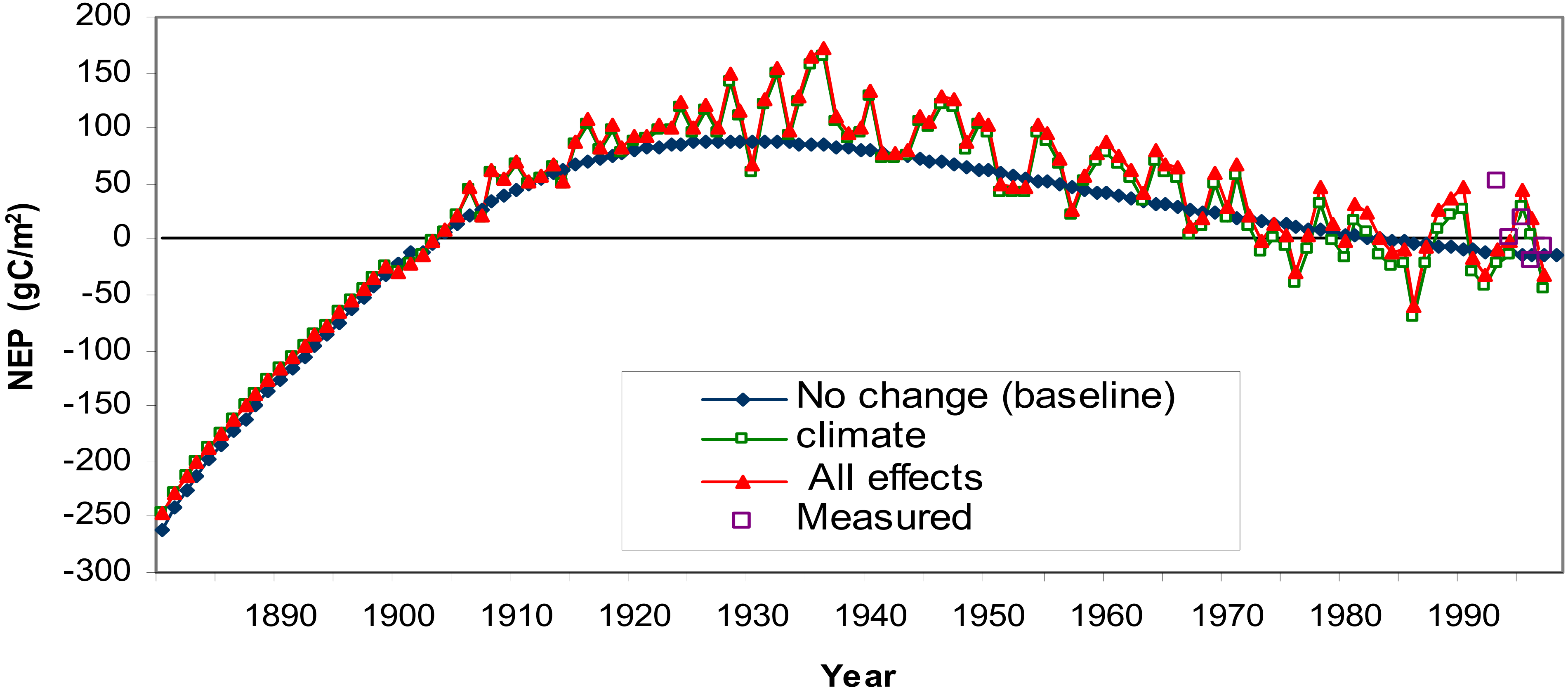
Comparison of modeled total soil organic carbon with polygon data from Soil Landscape of Canada



(J. Chen et al. 2003)

Historical Variation in NEP

121-year old black spruce stand, Saskatchewan (53.890 °N, 105.114 °W)



Tower data source: Paul Jarvis of U Edinburgh and Andy Black of UBC

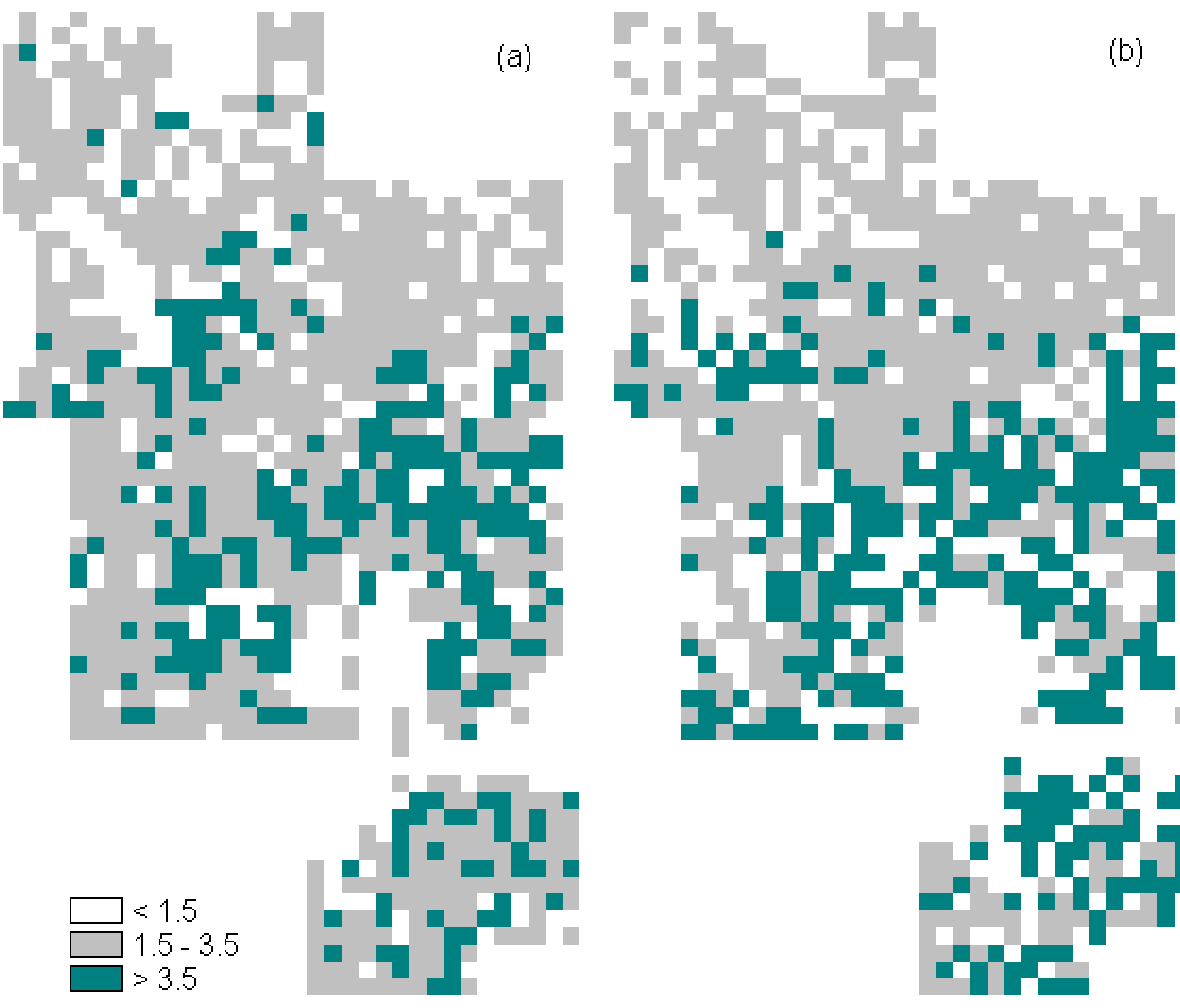
(J. Chen et al. 2003)

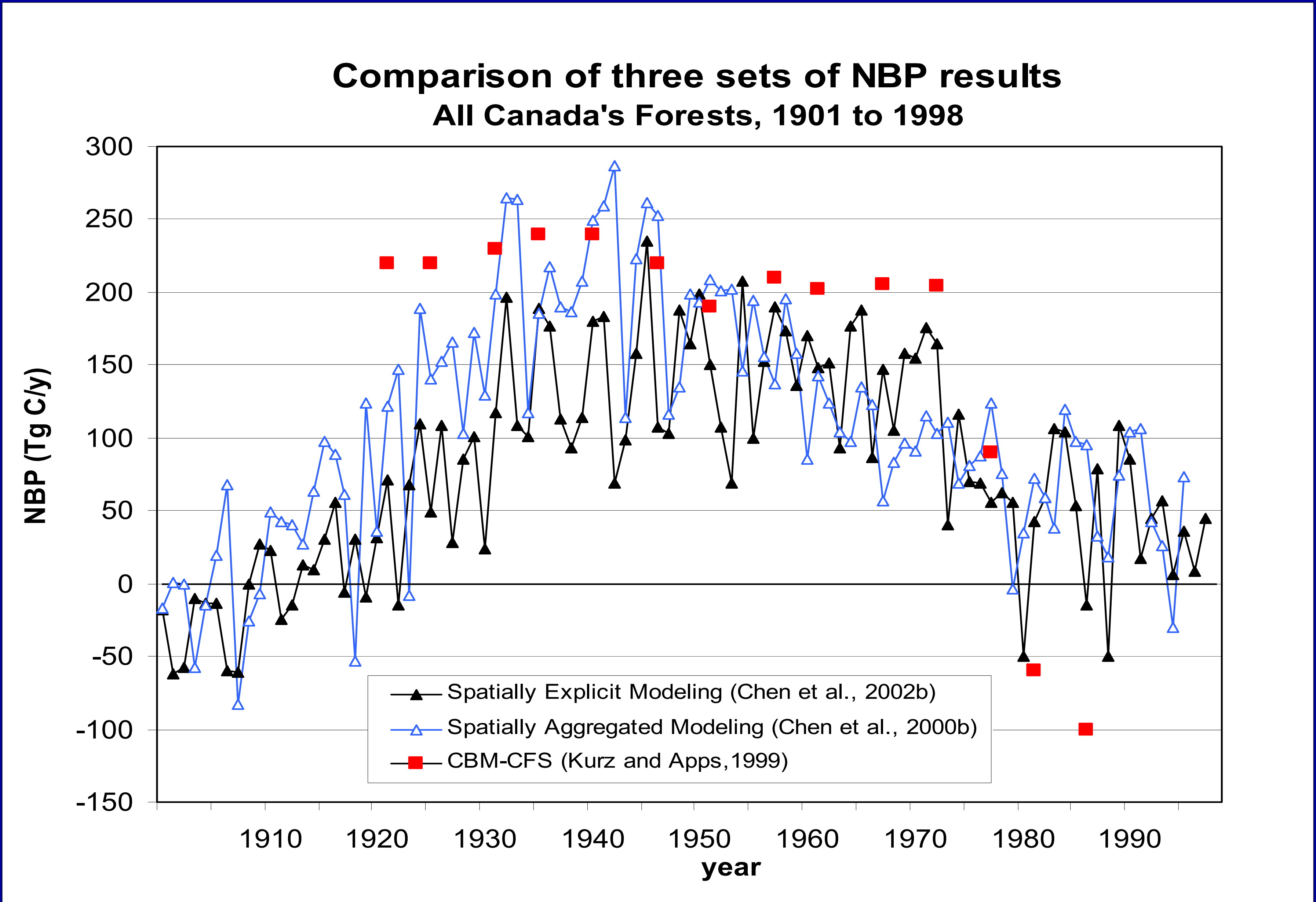
Comparison of simulated NPP with Remoted Sensing based estimation of NPP at Landscape Level (Lake Abitibi Model Forest)

(a) TRIPLEX Simulation (Zhou et al, 2004)

(b) Estimation based on Remote sensing (Liu et al.2002)

Kappa Statistic:
K=0.6
(Good agreement if 0.55<K<0.70)

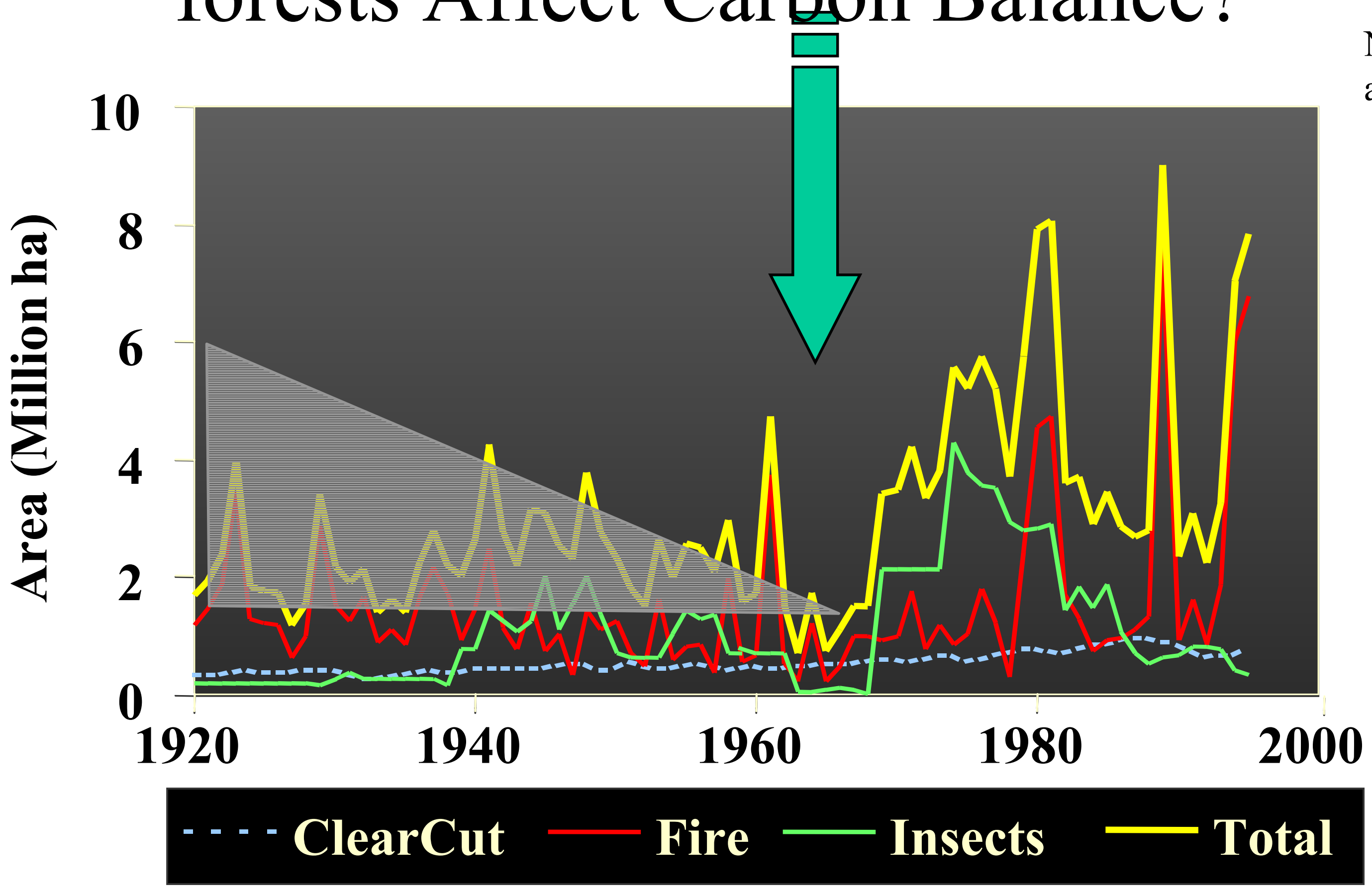




(J. Chen et al. 2003)

What do the changes in disturbances in Canada's forests Affect Carbon Balance?

Note apparent increase after 1970

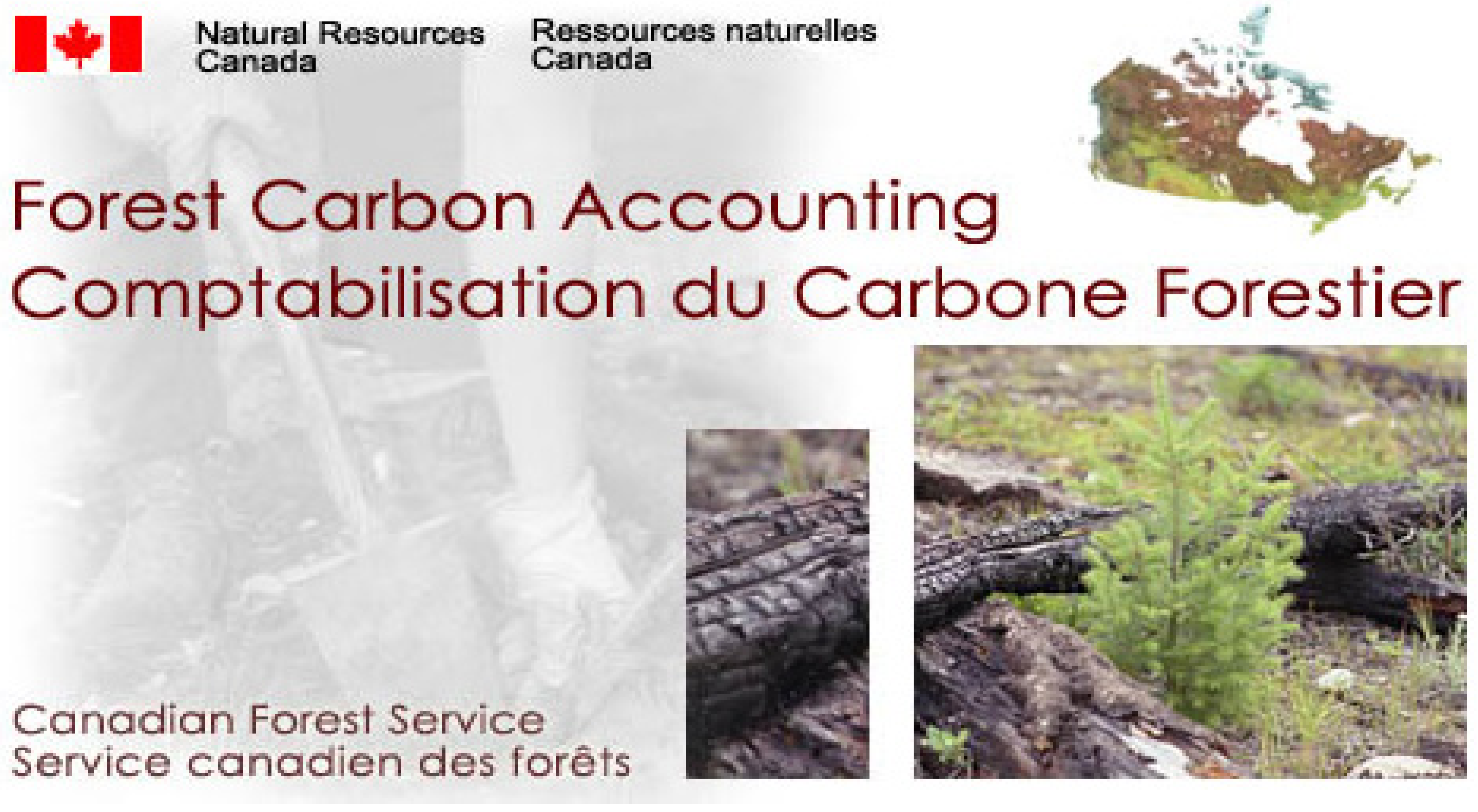


Challenges for Science

- **Weaknesses in Scientific Understanding:**
  - *Allocation of C in plant tissues*
  - *Nutrient feedback*
  - *CO_2 fertilization at ecosystem scale -* is it real? important?
  - Projecting *changes in disturbance regimes (fire, insect, harvesting, ice damage…)*
  - *Peatland carbon dynamics*
  - *etc….*

Scientific Challenges

- Quantifying land-use change at 1 ha resolution.
- Regional parameter databases and validation.
- Accounting for forest management impacts.
- Estimating C stock changes in forested wetlands.
- Estimating N_2O and CH_4 emissions.
- Incorporating inter-annual variability and long-term climate effects.
- Identifying, quantifying and reducing uncertainty.



http://carbon.cfs.nrcan.gc.ca

Canada

(Kurz and Apps, 2004)