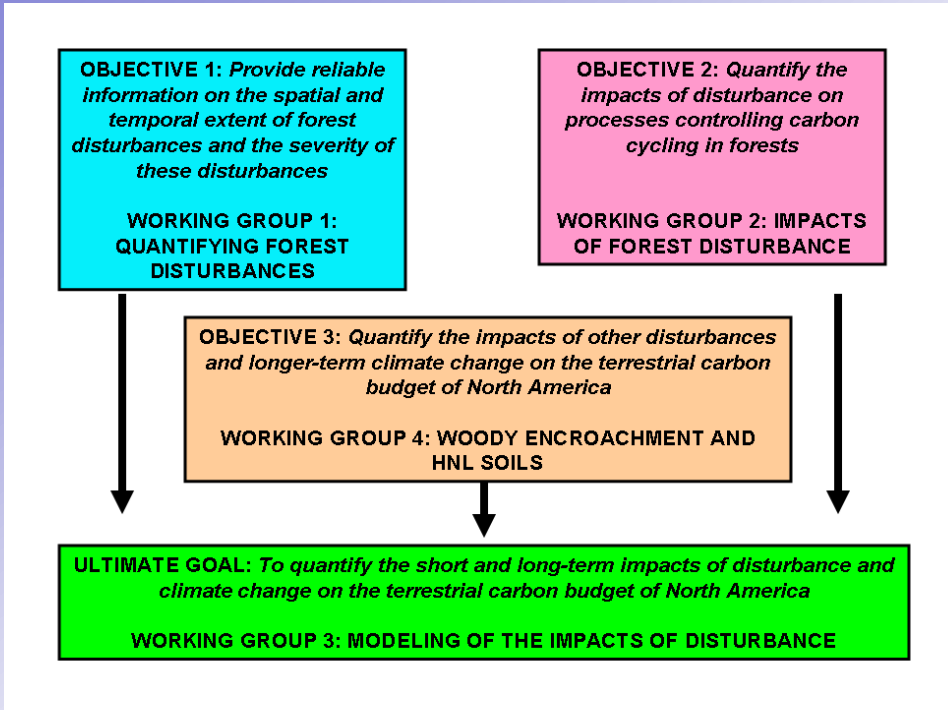
Impacts of Disturbance on the North American Carbon Cycle – A NACP Synthesis Activity

Eric S. Kasischke and a cast of > 100

3rd NACP All Investigators Meeting

2 February 2011



Summary of Papers from Disturbance Synthesis JGR Biogeosciences (in press)

Lead	Paper Title
Kasischke	Impacts of disturbance on the terrestrial carbon budget of North America
Masek	Recent rates of forest harvest and conversion in North America
Hicke	The effects of biotic disturbances on carbon budgets of North American forests
Kasischke	Quantifying burned area from fires in North American forests - implications for direct reduction of carbon stocks
Amiro	Ecosystem carbon dioxide fluxes after disturbances in forests of North America
French	Carbon emissions from North American wildland fires: A comparison of modeling approaches
Goetz	Observations and assessment of forest carbon recovery following disturbance in North America
Harmon	Heterotrophic respiration fluxes in disturbed forests - a review with examples from North America
Barger	Woody plant encroachment and the North American carbon budget
Grosse	Vulnerability of high latitude soil carbon in North America to disturbance
Liu	Simulating the impacts of disturbances on forest carbon cycling in North America: processes, data, models, and challenges

Key activities

- **Synthesized recent research in key areas**
- **Assessed the state of the science**
- **Identified key information and research gaps**

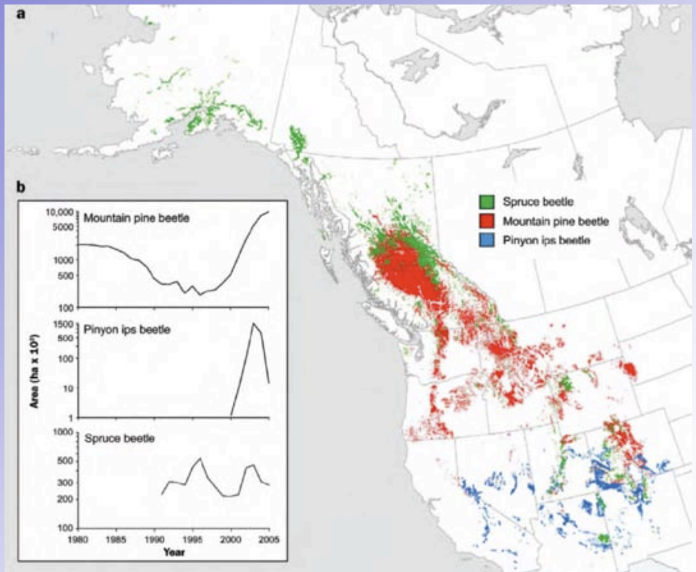
Significant Findings from Disturbance Research on North American Forests

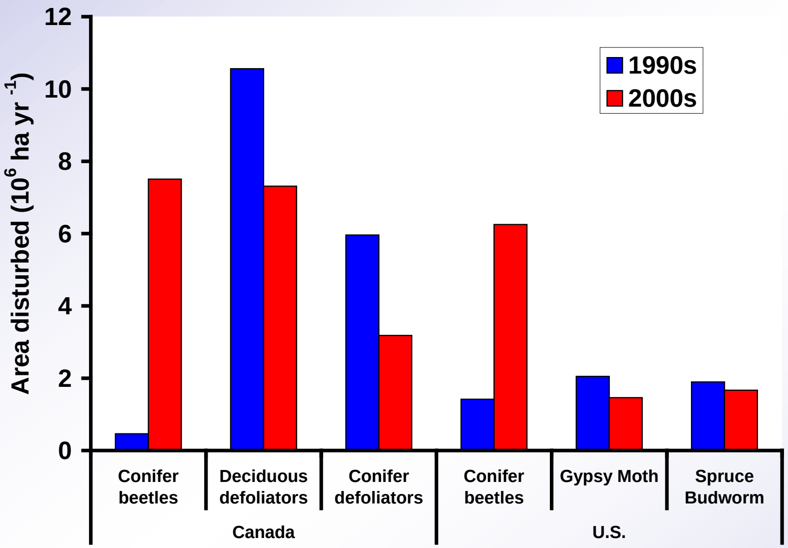
1. **While the overall rates of deforestation activities have been fairly constant, regional patterns have shifted in the U.S. (NW to SE) and decreased in Canada between the 1990s and 2000s**
2. **In many regions, *area disturbed by fire, insects, and hurricanes were much greater in the 2000s compared to the 1990s***
3. **Natural disturbances tend to occur in clusters at regional scales that take place over multiple years (*regional disturbance clusters*)**
4. **These disturbance clusters can result in large pulses of carbon being released to the atmosphere (*regional disturbance carbon pulses*) from *increased heterotrophic respiration of dead woody debris and biomass combustion***
5. **In all regions of North America, disturbances control exchanges of carbon with the atmosphere at multiple temporal scales, but *current capabilities to assess the net impacts are limited***
6. **In a changing climate, the *legacies* of recent and past regional disturbance clusters *are highly uncertain***

Examples of regional disturbance clusters and regional disturbance carbon pulses

1. Insect outbreaks in western N.A.
2. Hurricanes in the S.E. U.S.
3. Western N.A. wildland fires

Raffa et al. Bioscience June 2008

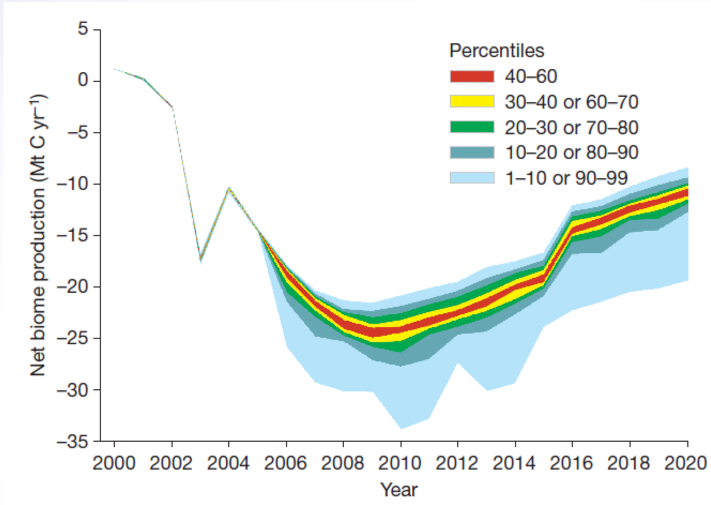




Vol 452|24 April 2008|**doi:10.1038/nature06777**

Mountain pine beetle and forest carbon feedback to climate change

W. A. Kurz[1], C. C. Dymond[1], G. Stinson[1], G. J. Rampley[1], E. T. Neilson[1], A. L. Carroll[1], T. Ebata[2] & L. Safranyik[1]



Net effects of pine beetles in 2000s relative to 1990s

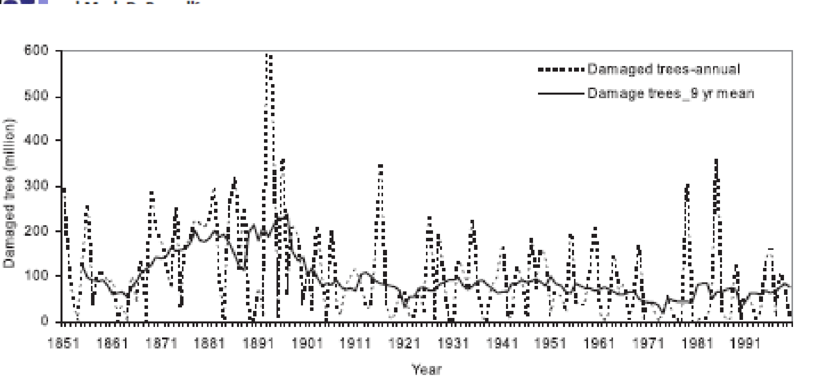
Canada (Kurz): +12.9 Tg C yr^{-1}

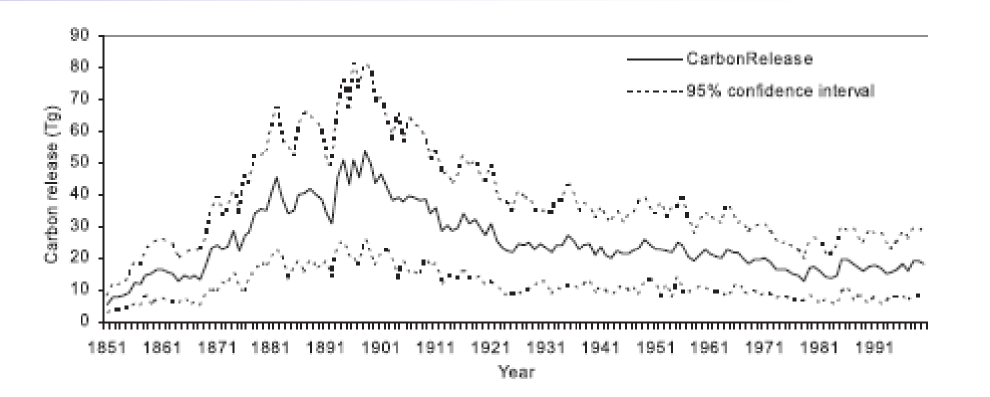
West. U.S. (Edburg): +2.0 Tg C yr^{-1}

Question – how do large scale defoliations affect NEP

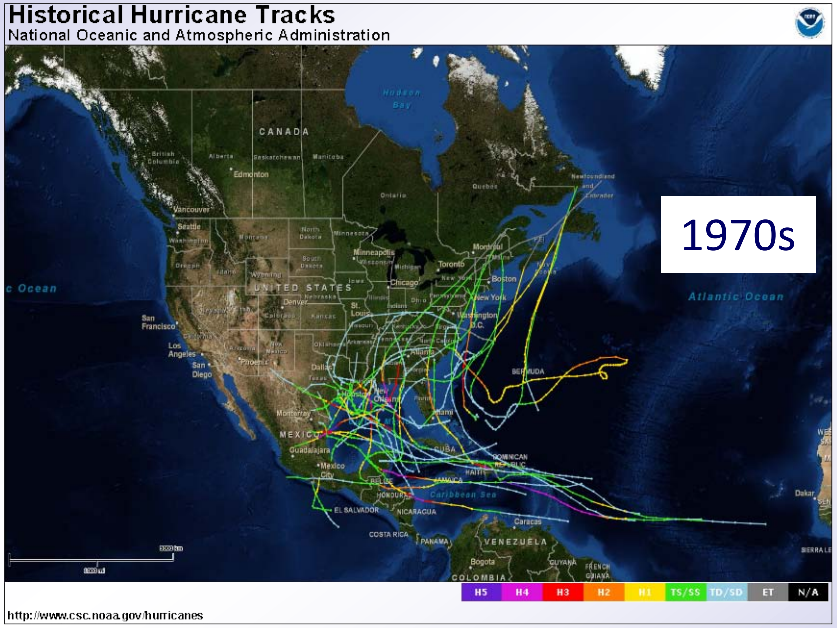
Impacts of tropical cyclones on U.S. forest tree mortality and carbon flux from 1851 to 2000

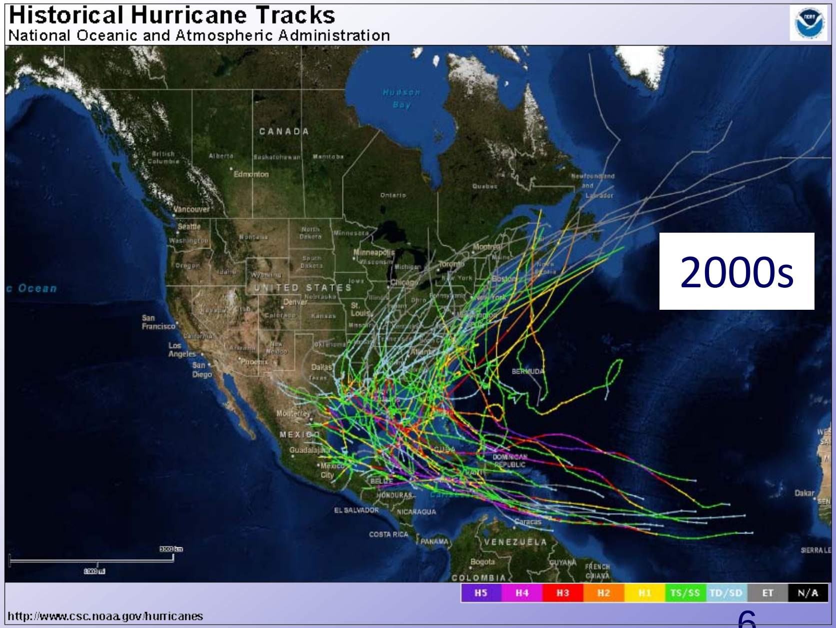
Hongcheng Zeng[a,1], Jeffrey Q. Chambers[a], Robinson I. Negrón-Juárez[a], George C. Hurtt[b], David B. Baker[a],





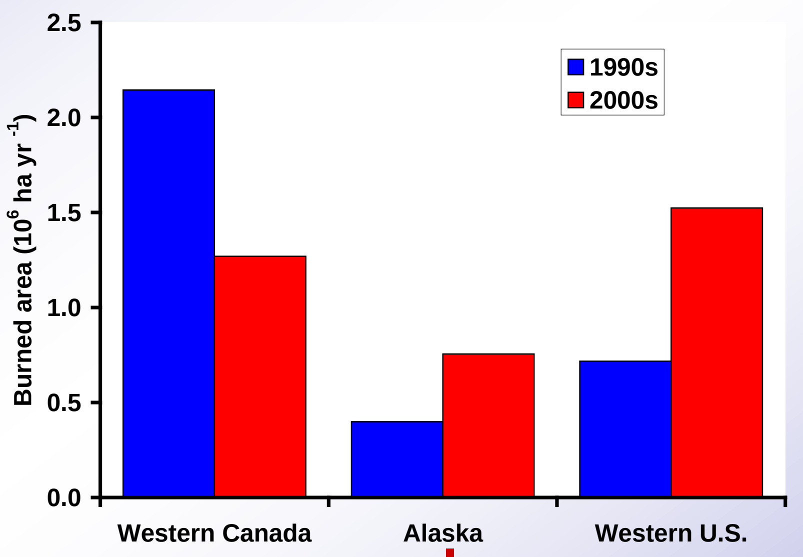
An increase of 40-50% in forest damage from hurricanes in the 2000s = +8 to 10 Tg C year in emissions from heterotrophic respiration

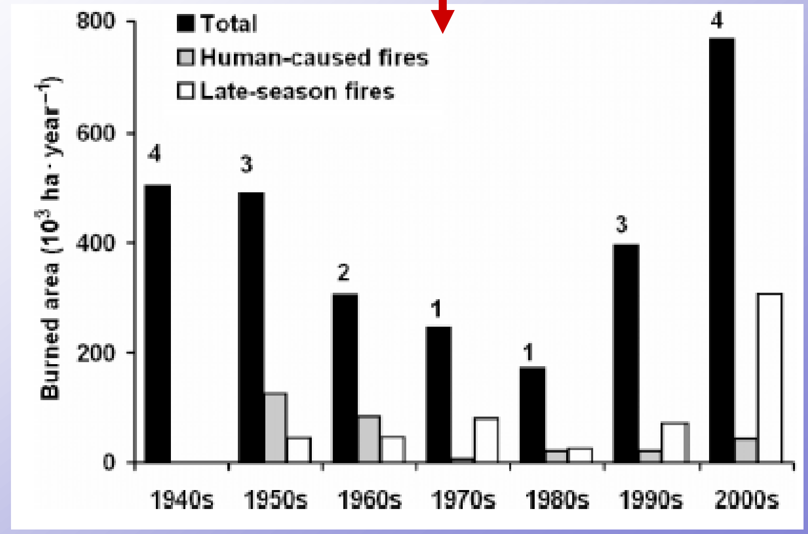




	Alaska Boreal Interior	Western Canada Ecoregions		
		Taiga Plains	West Taiga Shield	West Boreal Shield
1990	2.7%			
1991	1.5%			
1992				
1993		1.5%		
1994		2.7%	5.5%	1.1%
1995		4.9%		2.5%
1996				
1997	1.6%			
1998		1.3%	2.2%	1.9%
1999				
2000				
2001				
2002	1.9%			
2003				
2004	5.8%			
2005	3.9%			
2006				
2007				
2008				
2009	2.0%			

% of ecoregion burned





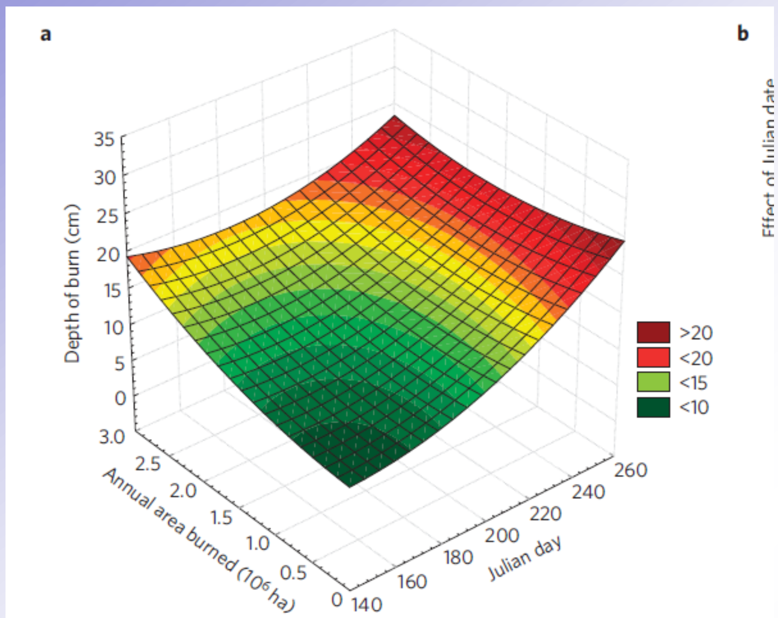
nature geoscience — LETTERS

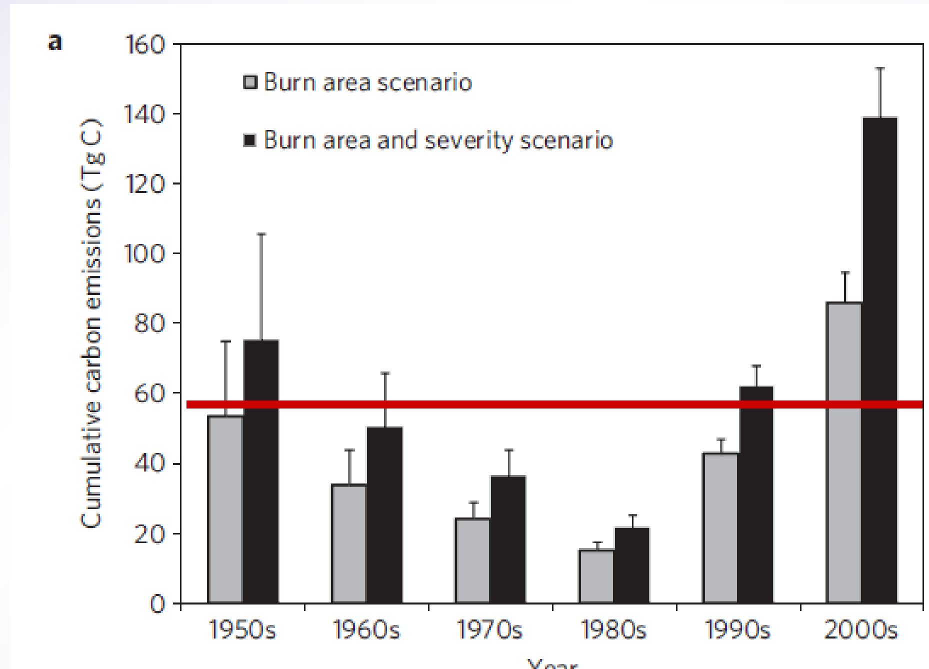
PUBLISHED ONLINE: 5 DECEMBER 2010 | DOI: 10.1038/NGEO1027

Recent acceleration of biomass burning and carbon losses in Alaskan forests and peatlands

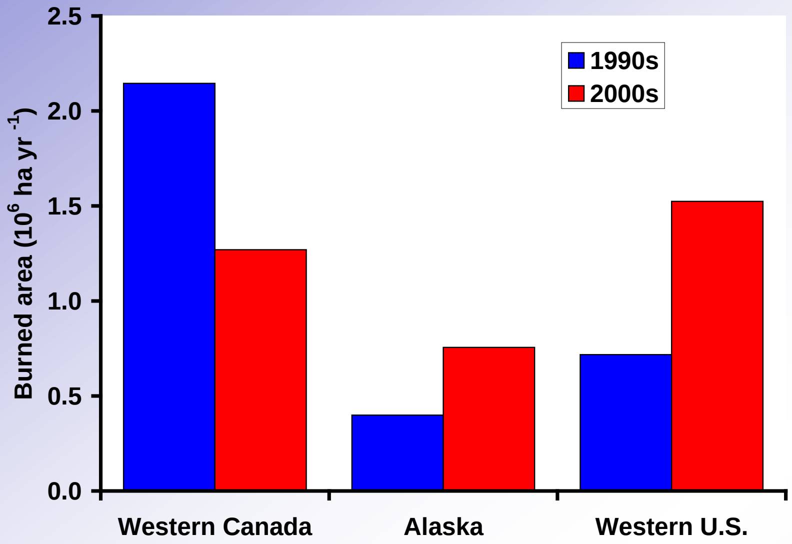
Merritt R. Turetsky[1]*, Evan S. Kane[2], Jennifer W. Harden[3], Roger D. Ottmar[4], Kristen L. Manies[3], Elizabeth Hoy[5] and Eric S. Kasischke[5]

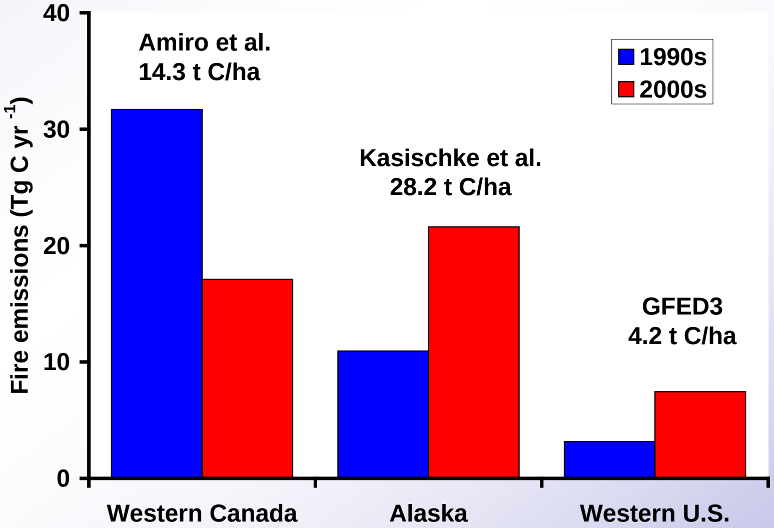
The organic layers of Alaskan BS forests contain 875 Tg C, accumulated at a rate of 55 Tg / decade (MossNPP + Litter – Rh)





The deeper burning fires in the 2000s resulted in changing the organic soil layer of Alaska black spruce forests from a net sink to a net source of atmospheric carbon

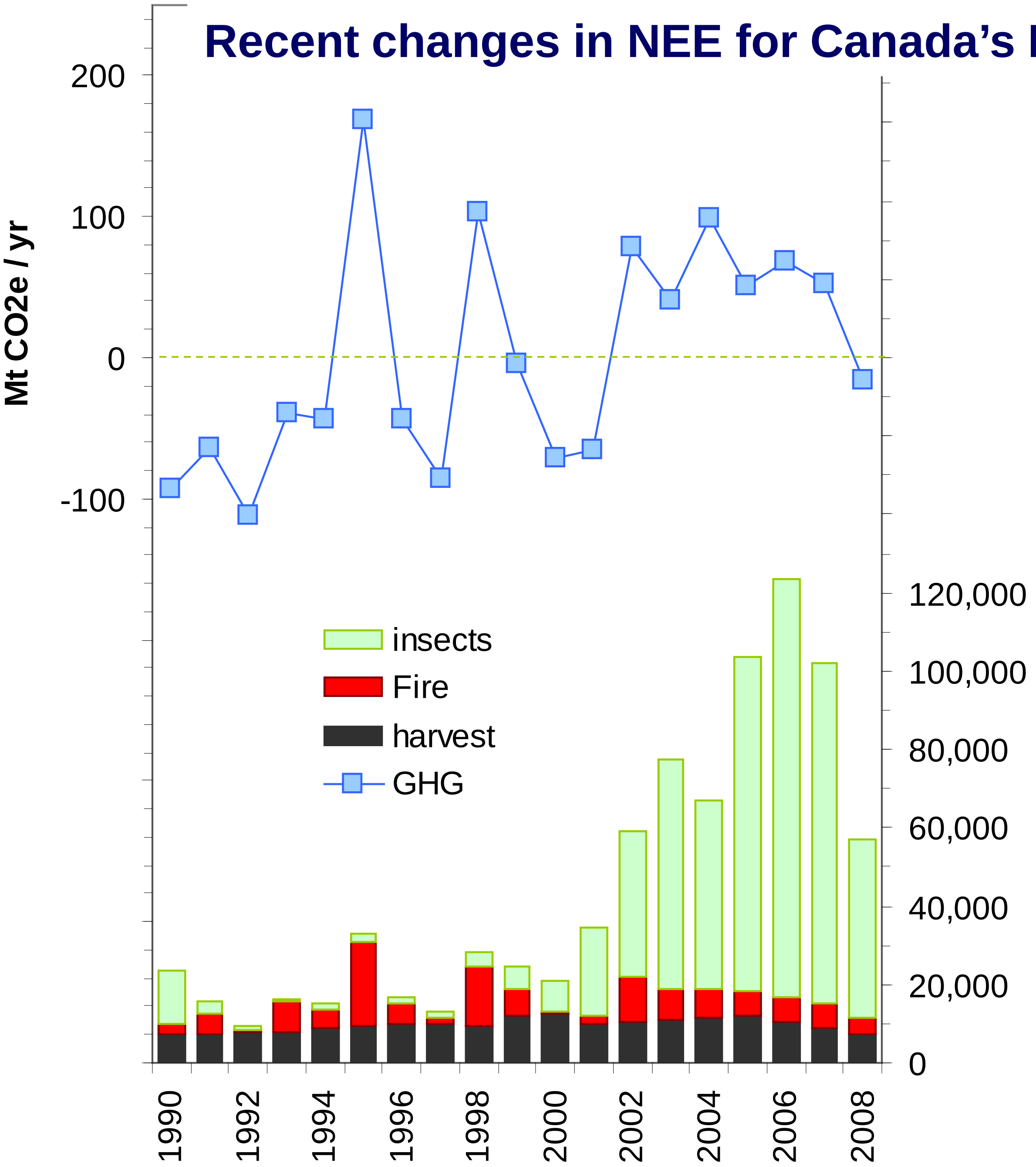




Regional burned area clusters lead to regional disturbance carbon pulses

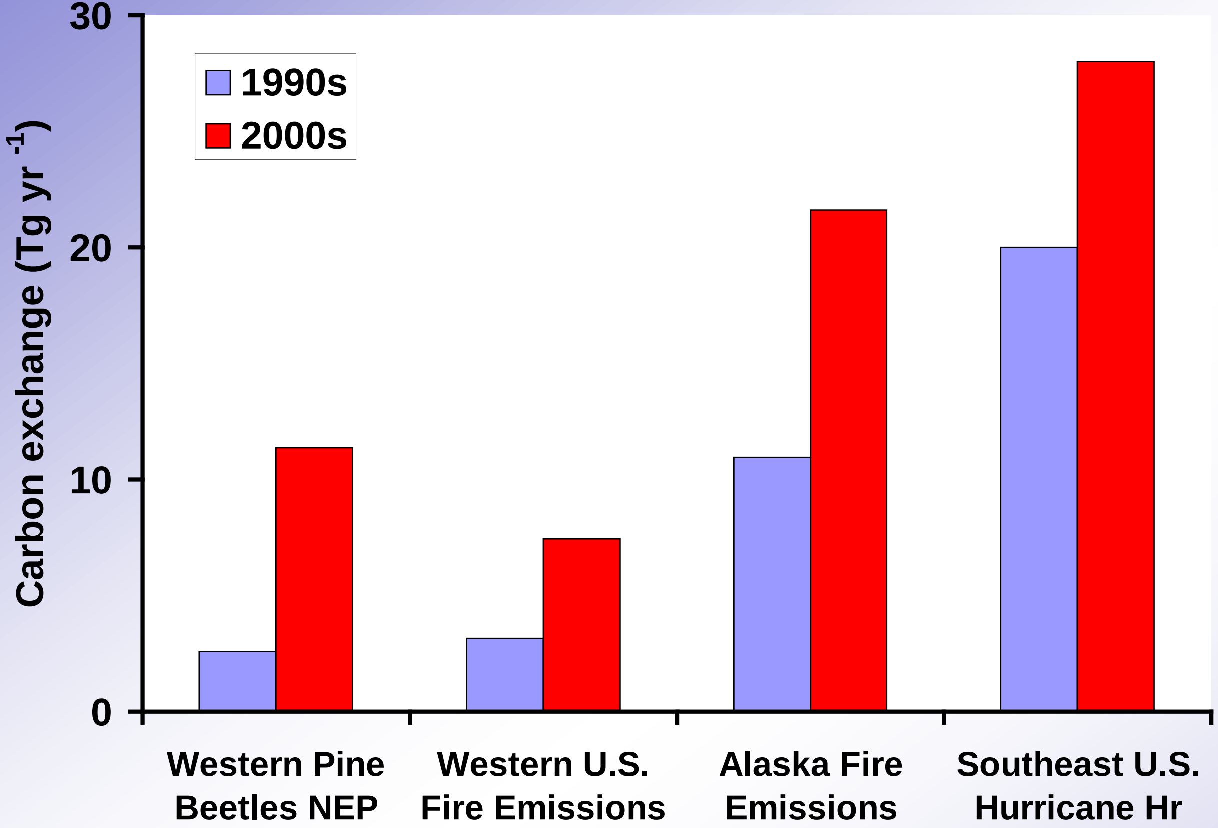
While burned area increased dramatically in the western U.S., changes in combustion emissions were lower because of overall lower average fuel loads

Recent changes in NEE for Canada's Managed Forests



Stinson et al.
***Global Change Biology*, in press**

Does not include decreases in combustion emissions and changes in NEP for unmanaged forests and peatlands in Canada



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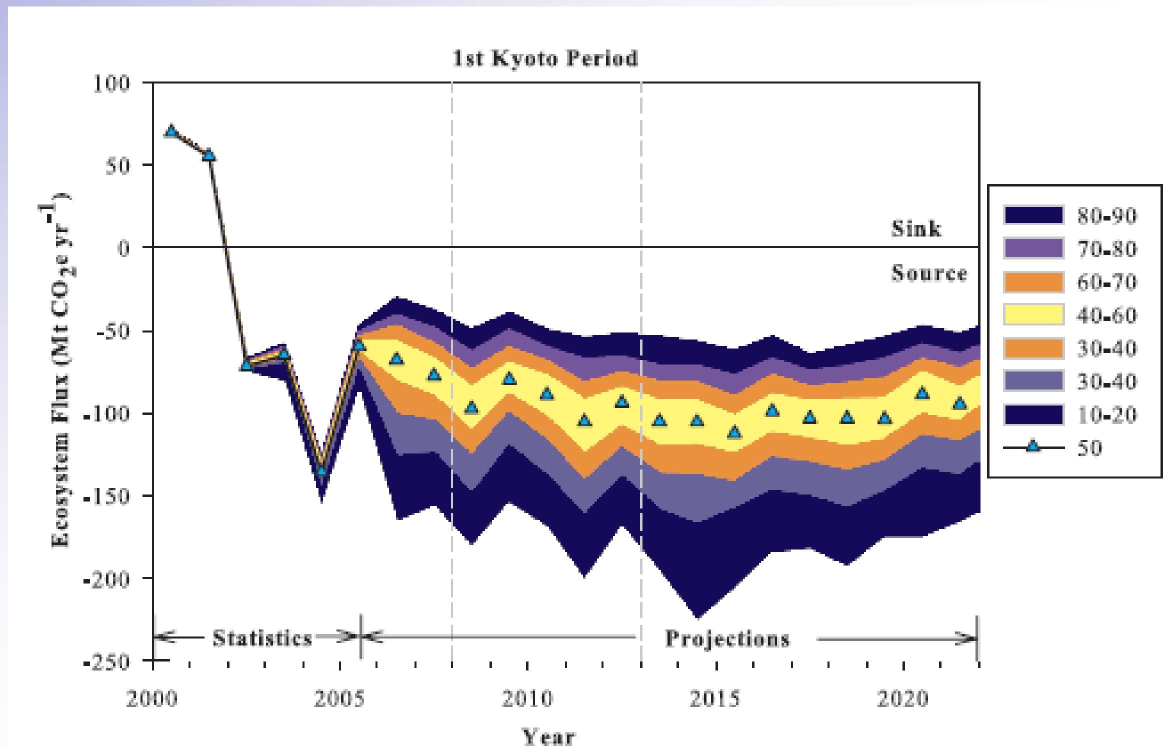
- Post-Disturbance NEP
- Changing Patterns of Forest Harvest
- Woody Encroachment
- Forest Defoliators
- Forest Dieback
- HNL Soil Warming

The net effects of increased natural forest disturbances in the U.S. between the 1990s and 2000s are unknown

Risk of natural disturbances makes future contribution of Canada's forests to the global carbon cycle highly uncertain

Werner A. Kurz*, Graham Stinson, Gregory J. Rampley, Caren C. Dymond, and Eric T. Neilson

www.pnas.org/cgi/doi/10.1073/pnas.0708133105



Uncertainty in future projects of the forest carbon budget are based on uncertainties in the longer-term legacy effects of disturbance

Recommendations from the Disturbance Synthesis

There needs to be coordinated programmatic support for integrated assessment of the impacts of disturbance on the North America's terrestrial carbon budget, to include

1. *Development of an integrated modeling framework across North America for assessment of disturbance impacts – (diagnostics and predictions)*
2. *Systematic quantification of disturbances (area and severity) on an annual time scale*
3. *Research to address key uncertainties*
   a. *Factors controlling disturbance regimes*
   b. *Integrated impacts of multiple disturbances*
   c. *Post –disturbance recovery (vegetation community dynamics, heterotrophic respiration, dynamics of dead woody debris pools, controls on NEP)*

Key Carbon Pools, Fluxes, and Processes Involved in Disturbance Research

Carbon pools to quantify	Fluxes to measure or estimate				Processes to quantify				
	Combustion	Heterotrophic Respiration	Autotrophic Respiration	Photosynthesis	Area Disturbed	Harvest	Mortality**	Pool Transfers	Changes to Abiotic Conditions
Mineral soil carbon		Independent of type			1,2,3,4,5,6				1,2,3,4,5,6
Organic soil carbon*	1	Independent of type			1,2,3,4,5,6	2			1,2,3,4,5,6
Dead woody debris	1	Independent of type			1,2,3,4,5,6	2		1,2,3,4	1,2,3,4,5,6
Live biomass	1		Independent of type	Independent of type	1,2,3,4,5,6	2	1,2,3,4	1,2,3,4	1,2,3,4,5,6

includes litter
*****includes partial mortality to branches and limbs***

Disturbance category
1 – Fire
2 – Land Management
3 – Insect/Biological Impacts
4 – Weather Events
5 – Thermokarst
6 – Woody Encroachment