The changing effects of Alaska boreal forests on the climate system

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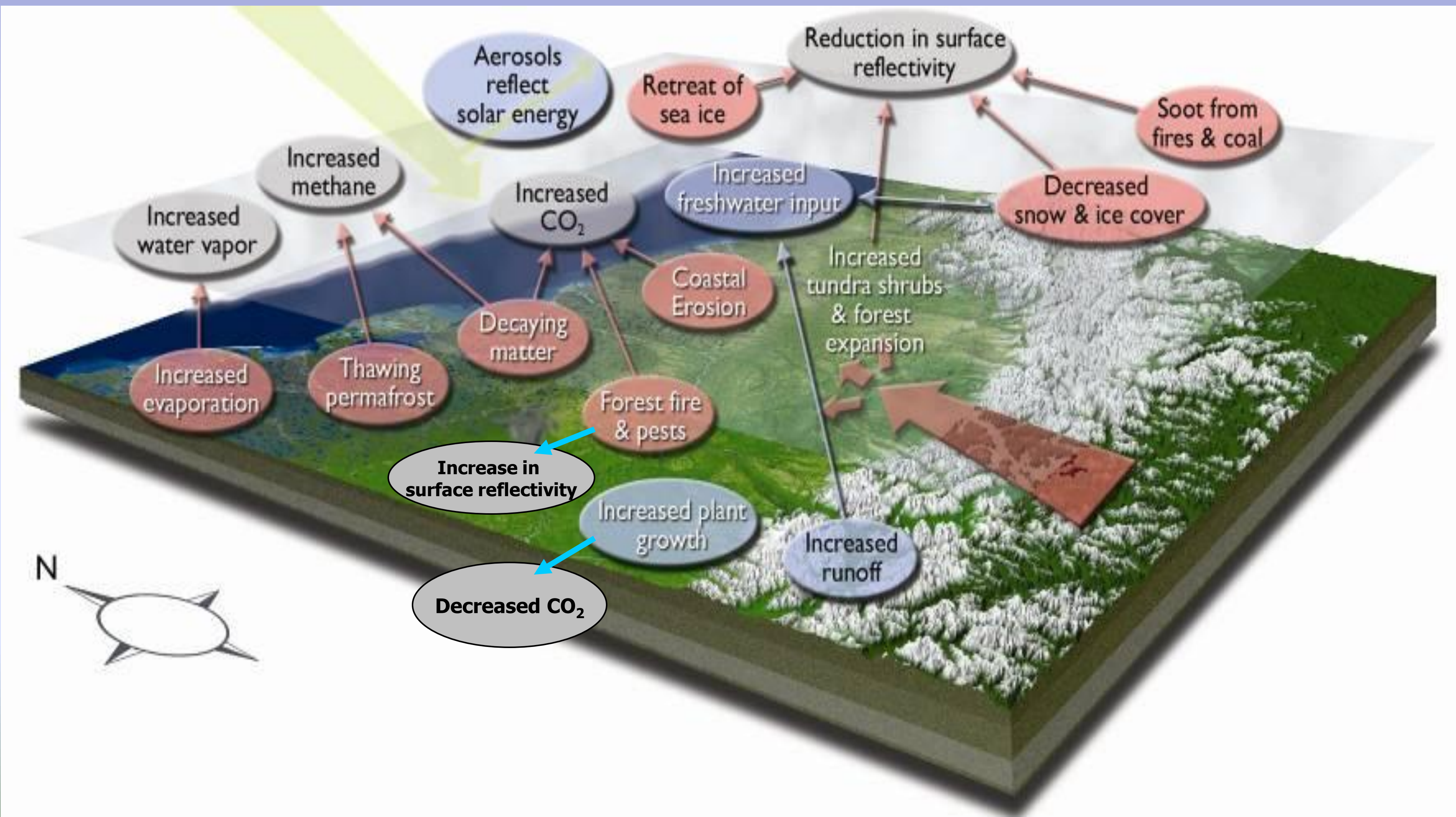
Climate influences the terrestrial ecosystems

The terrestrial ecosystems influence the climate



Examine the various issues of change presented in this special issue with regard to climate feedbacks:

-**Vegetation (Yarie et al., McGuire et al.)**

-**Fire regimes (Kasischke et al., Johnstone et al.)**

-**Permafrost integrity (Jorgensen et al.)**

Other issues of change in relation to climate feedbacks:

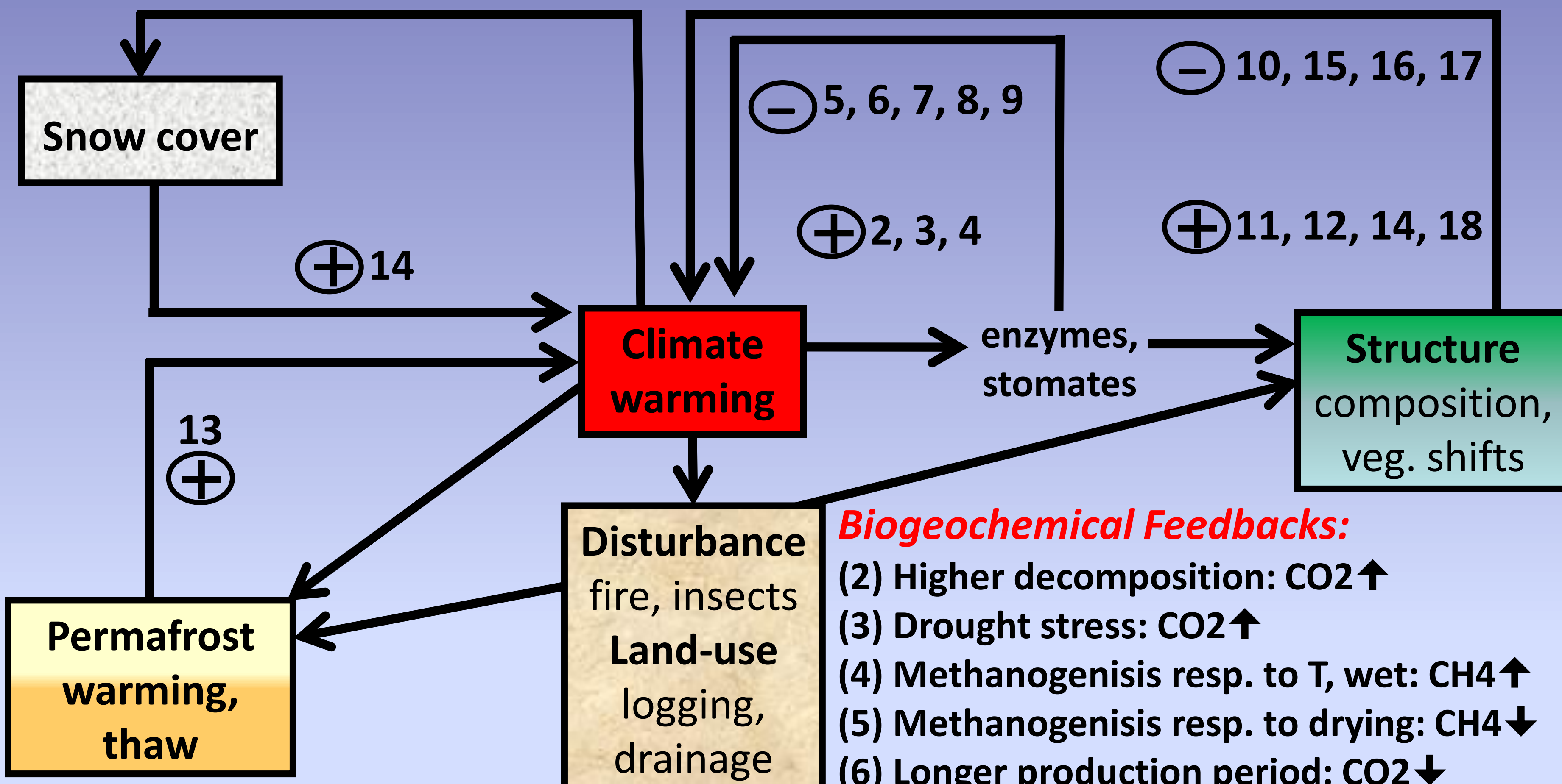
-**Insect outbreaks**

-**Snow cover**

-**Land use**

-**Regional comparisons of the feedbacks**

-**Also examine these feedbacks in relation to the resilience of the boreal forest**



Biogeochemical Feedbacks:

(2) Higher decomposition: CO2↑
(3) Drought stress: CO2↑
(4) Methanogenisis resp. to T, wet: CH4↑
(5) Methanogenisis resp. to drying: CH4↓
(6) Longer production period: CO2↓
(7) NPP response to N min: CO2↓
(8) NPP response to T: CO2↓
(9) NPP response to [CO2]: CO2↓
(10) Treeline advance: CO2 ↓
(11) Forest degradation: CO2↑
(12 Fire, insects, logging, agriculture:CO2 ↑
(13) Release of inorganic C from permafrost thaw: CO_2, CH_4↑

Biogeophysical Feedbacks:

(1) Reduction in the period of snow covered ground: α↓
(14) Treeline advance: α↓
(15) Forest degradation: α↑
(16) Increase the area of young stands: α↑
(17) Increase the area of lakes: α↑
(18) Decrease the area of lakes: α↓

Changes in vegetation

Longer growing season length

Moisture a limiting factor =
Positive feedback

Nitrogen a limiting factor =
Positive feedback

Respiration increases =
Positive feedback

Greater C accumulation (moisture
and N not limiting) =
Negative feedback

Treeline advance

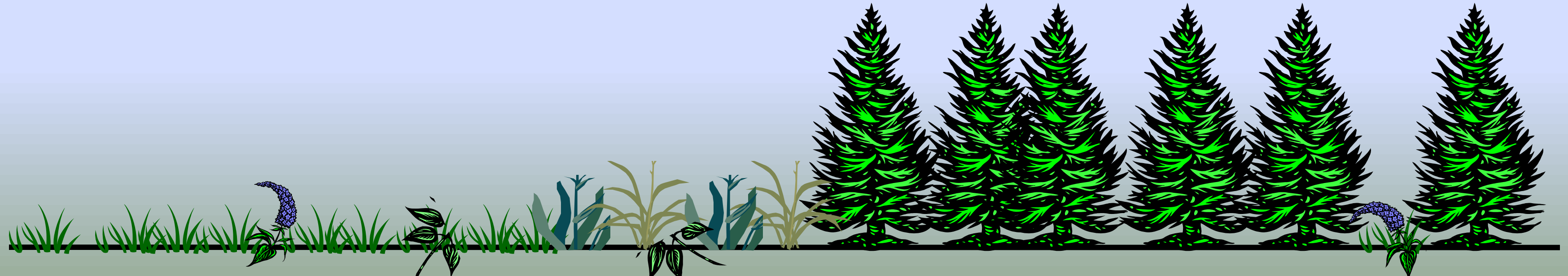
Greater C accumulation =
negative feedback

Reduced albedo = positive
feedback

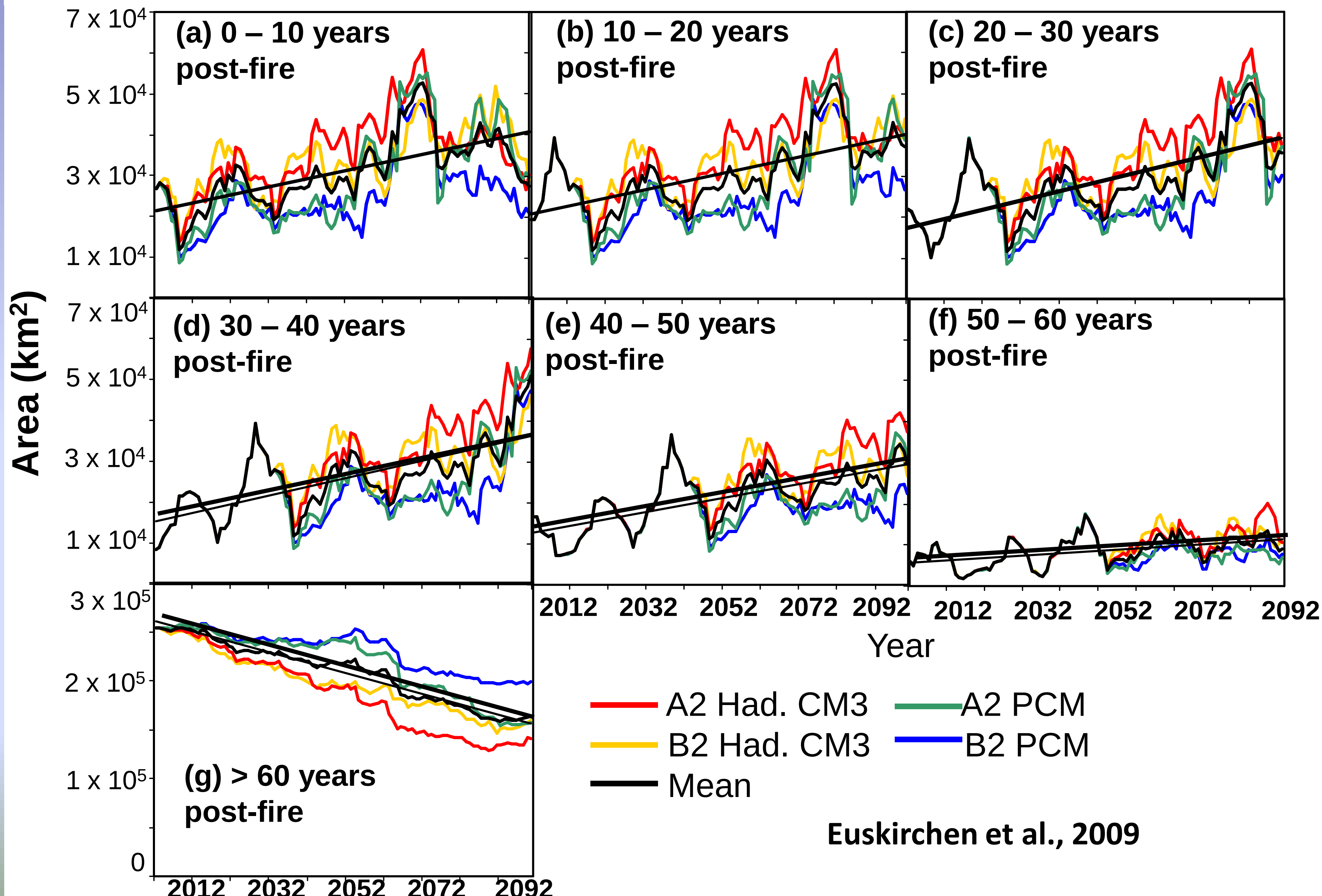
Treeline retreat

Reduced C accumulation =
positive feedback

Increased albedo = negative
feedback



Changes in the Age Structure of Forest Ecosystems in Alaska due to a Changing Fire Regime

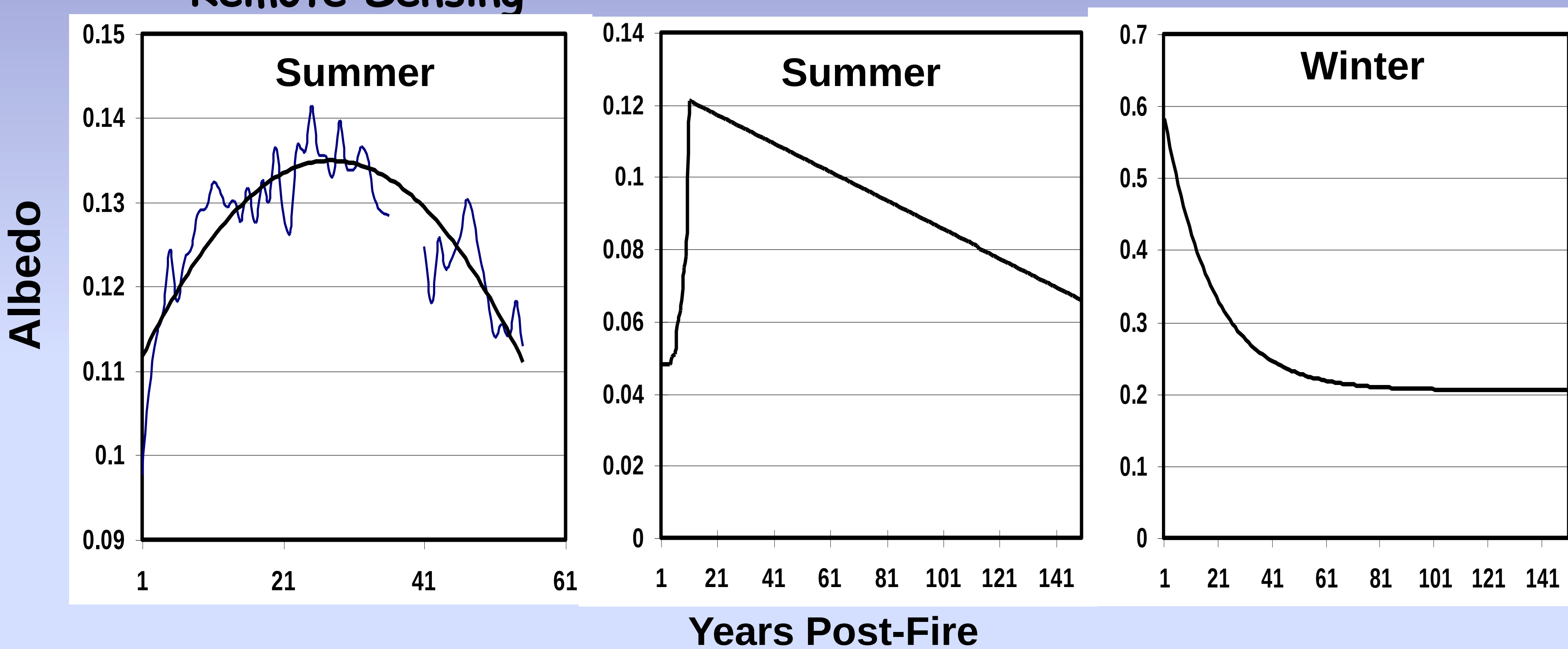


Euskirchen et al., 2009

Albedo vs. Years Post-Fire

Randerson et al. (2006);
Lyons et al. (2008)
Remote Sensing

From Amiro et al. (2006)
Observational



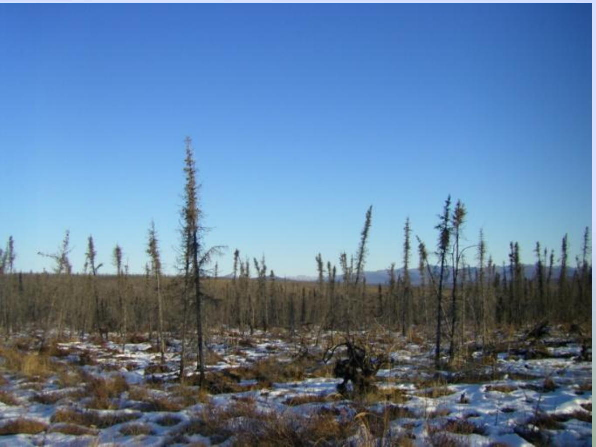
An increase in the number of young stands due to a shorter fire return interval increases the multidecadal albedo.

Fire Regimes

Relay succession disrupted

Regeneration of black spruce disrupted, potential long-term loss of C= Positive feedback

Deciduous forests with greater albedo = Negative feedback



Large fire years

More permafrost thaws than normal = positive feedback

More smoke and haze =Negative feedback

Greater greenhouse gas emissions = positive feedback

Black carbon (fire aerosol) = positive feedback

Permafrost Integrity

Large pool sizes of C stored in the permafrost degrade

Greater microbial CO_2 respiration = Positive feedback

Greater anaerobic methane production = Positive feedback

Large fire years

More permafrost thaws than normal = positive feedback

Forests replaced by bogs

Greater C accumulation = Negative feedback

Greater methane emissions = positive feedback

Changes in lake area

Increases in lake area (northern permafrost zone)

Decreased albedo = Positive feedback

Greater methane emissions = Positive feedback

Decreases in lake area (southern permafrost zone)

Increased albedo = Negative feedback

Fewer methane emissions = Negative feedback

Changes in land use (Mainly due to land clearing for agriculture or agroforestry)

Reduced carbon uptake by vegetation and losses of soil C = positive feedback

Increased albedo = Negative feedback

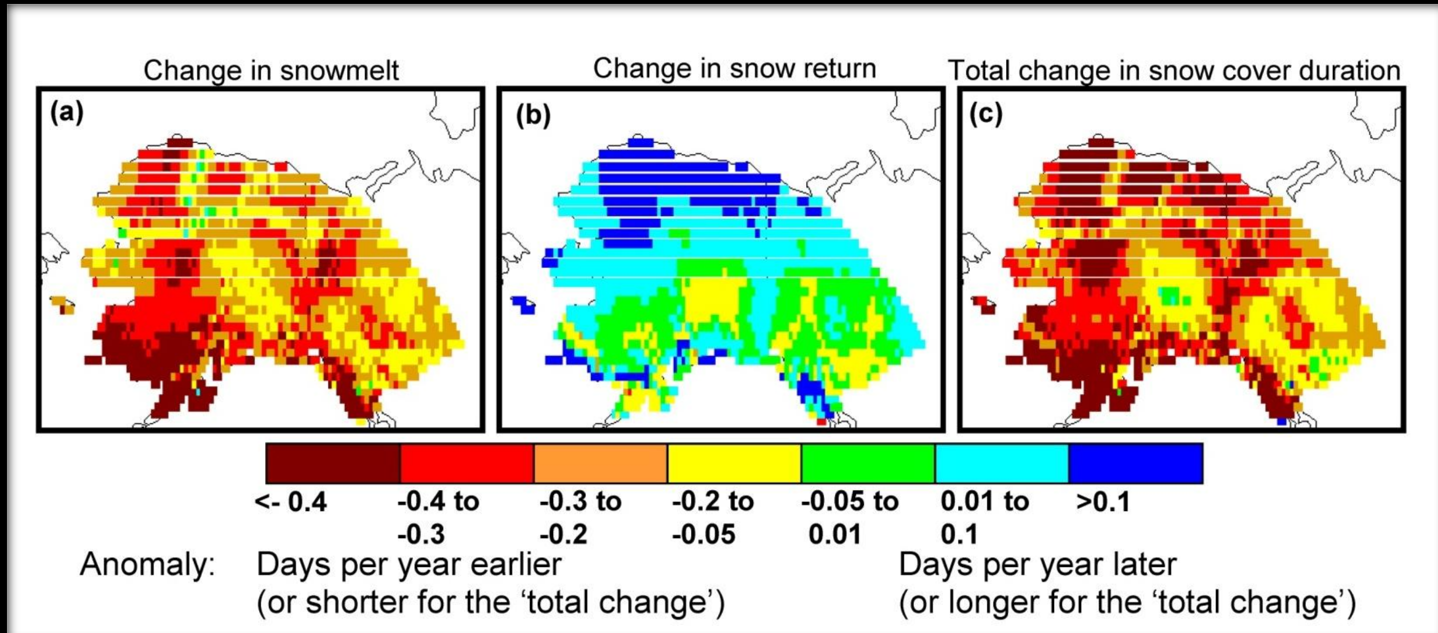
But, likely to be a much smaller feedback to climate than in other biomes.

Insect outbreaks

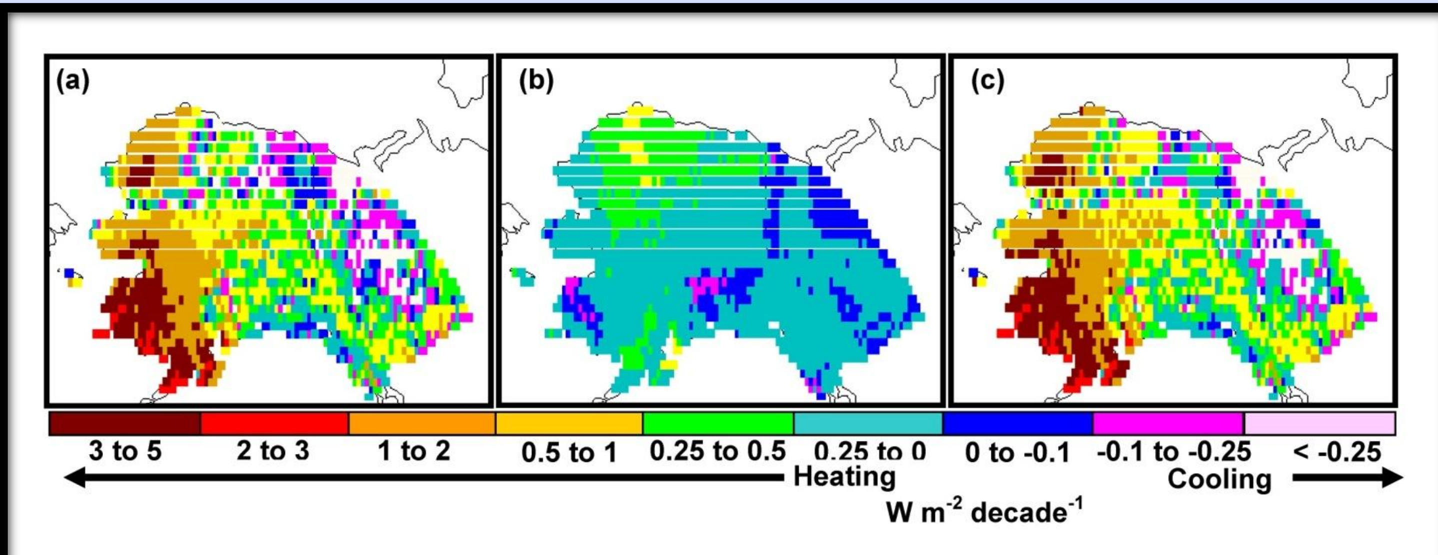
Reduced carbon uptake & storage = positive feedback

Increased albedo = negative feedback

-Tree mortality or reduced growth
-An increase in salvage timber



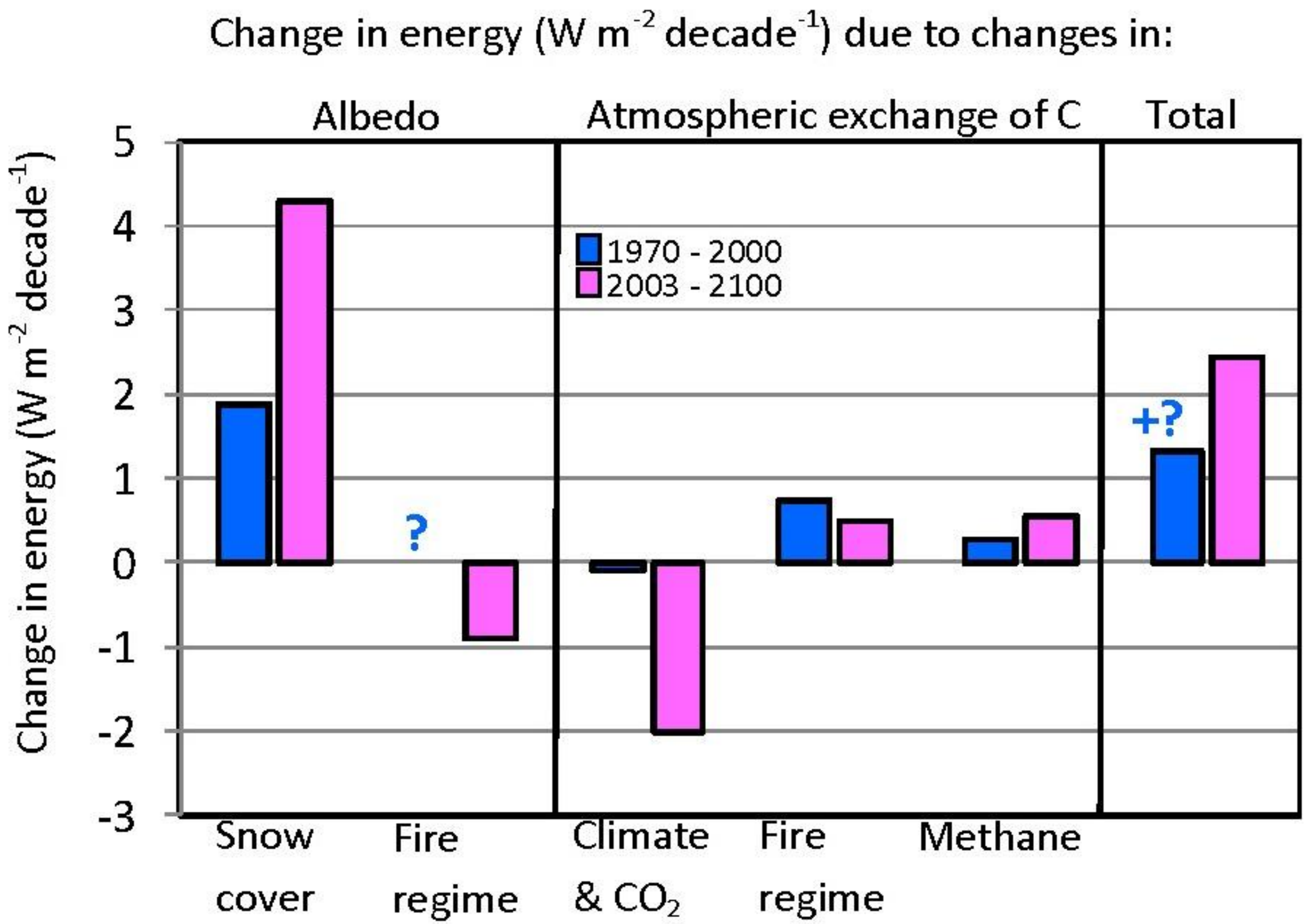
Snow season changes 1970 - 2000



Changes in atmospheric heating due to snow season changes 1970 - 2000

Euskirchen et al., 2007

Regional Comparisons Based on Model Simulations in Boreal Alaska



Sources: Balshi et al., 2007, 2009; Euskirchen et al., 2007, 2009; Zhuang et al. 2007

Conclusions

1. The largest and most rapid feedbacks to climate from boreal forests are related to snow cover changes, reducing resilience of the boreal-climate system by amplifying the rate of warming.

2. The overall influence of increases in C uptake by the Alaska boreal ecosystems on the global climate is likely to be relatively small.

3. A number of subsequent slower changes caused by changes in the fire regime, vegetation, permafrost, and trace gas fluxes result in both positive and negative feedbacks.

4. We do not yet understand if the net effect of the climate feedbacks from Alaska's boreal forest would enhance or mitigate warming.