Science Needs in the Arctic

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Arctic Environmental Change

Key Scientific Challenges

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The Arctic ecosystem is comprised of complex linkages and dynamic interactions. If the sensitive balance between frozen and thawed conditions is disturbed, a cascade of impacts begins, affecting geomorphology, biogeochemistry, hydrology, plant communities and local and regional climate.

Our challenge remains to grasp these subtle interactions and feedback processes, to integrate our understanding and to build a comprehensive synthesis of the changing Arctic.

How does permafrost thaw and degradation, and the associated changes in landscape evolution, hydrology, soil biogeochemistry and plant community dynamics, affect feedbacks to the climate system?

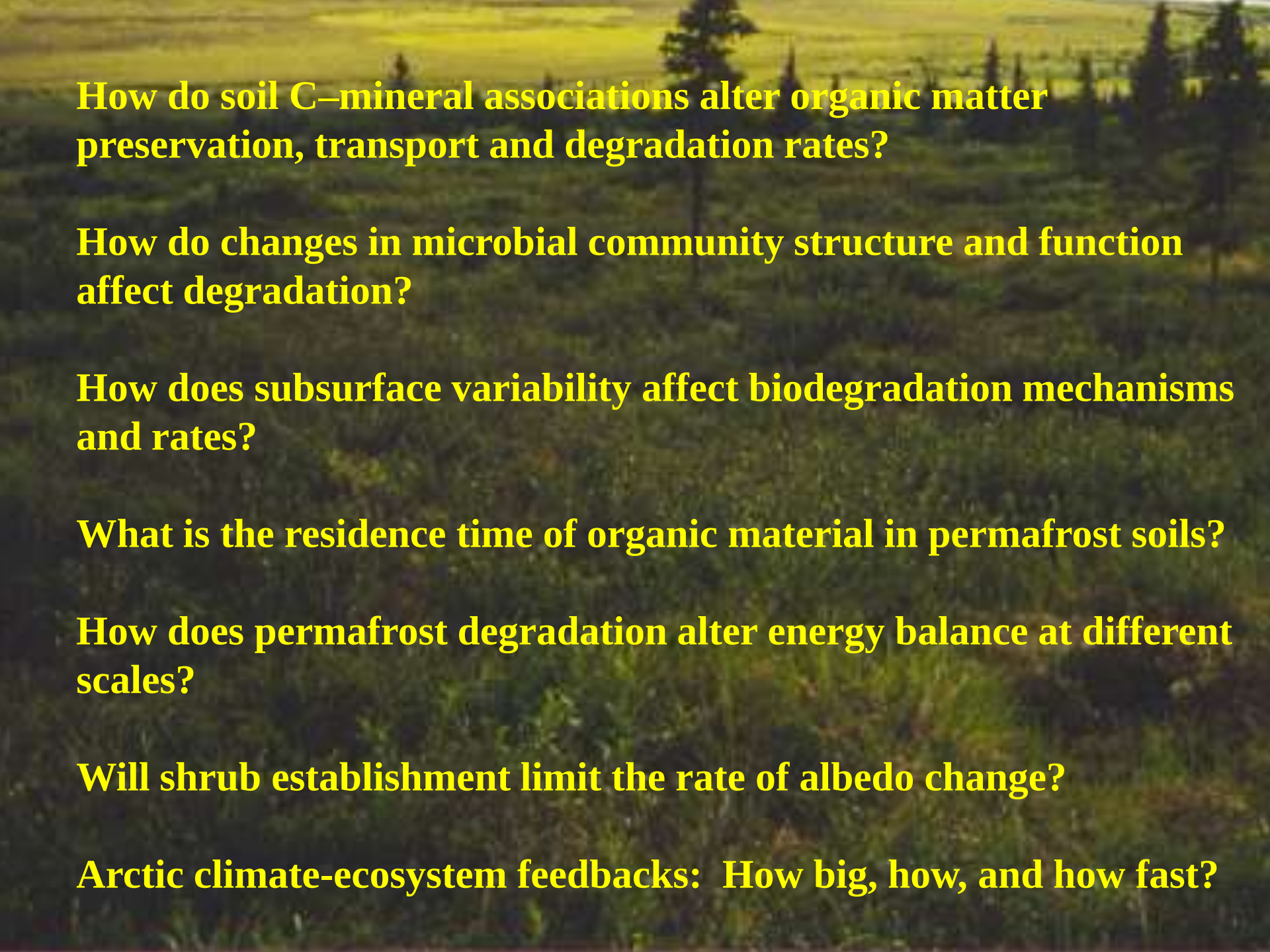
Can we quantify and predict landscape response to climate change?

How does permafrost degradation impact hydrological states, stocks, fluxes and pathways?

How do liquid water films and freeze-thaw processes influence microbial activity and GHG production?

How do soil carbon structure and interactions affect degradation of soil organic matter?

What are the distinguishing chemical signatures of organic matter that is degraded and mobilized in Arctic soils?



How do soil C–mineral associations alter organic matter preservation, transport and degradation rates?

How do changes in microbial community structure and function affect degradation?

How does subsurface variability affect biodegradation mechanisms and rates?

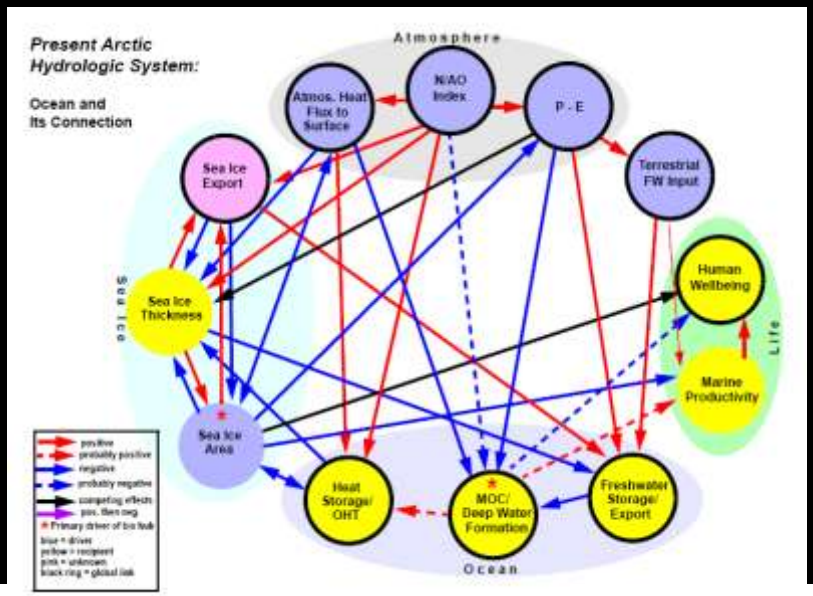
What is the residence time of organic material in permafrost soils?

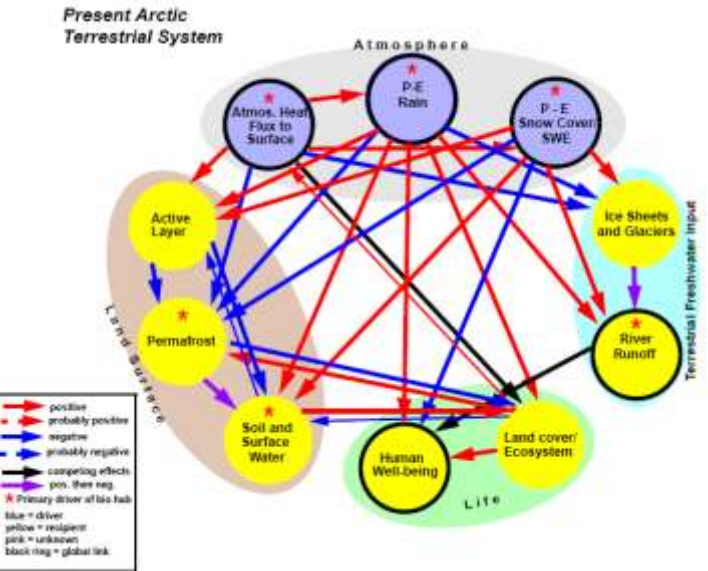
How does permafrost degradation alter energy balance at different scales?

Will shrub establishment limit the rate of albedo change?

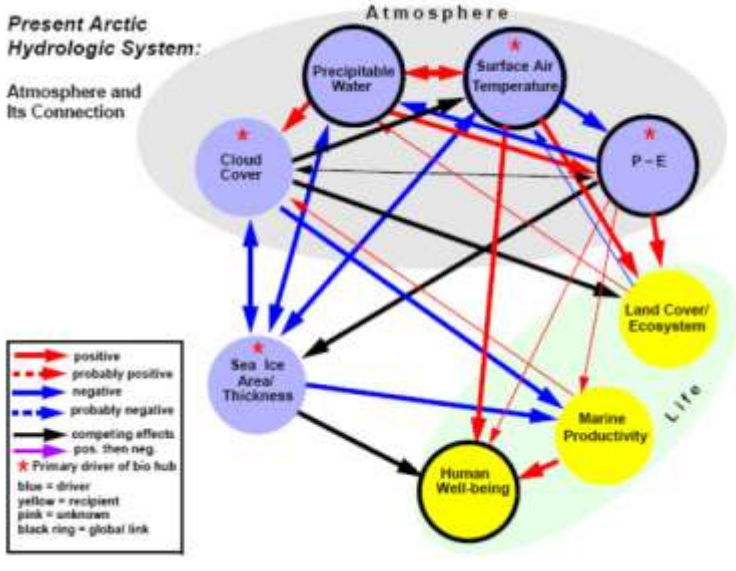
Arctic climate-ecosystem feedbacks: How big, how, and how fast?

Resolving and quantifying the system interconnections is the first step to prediction



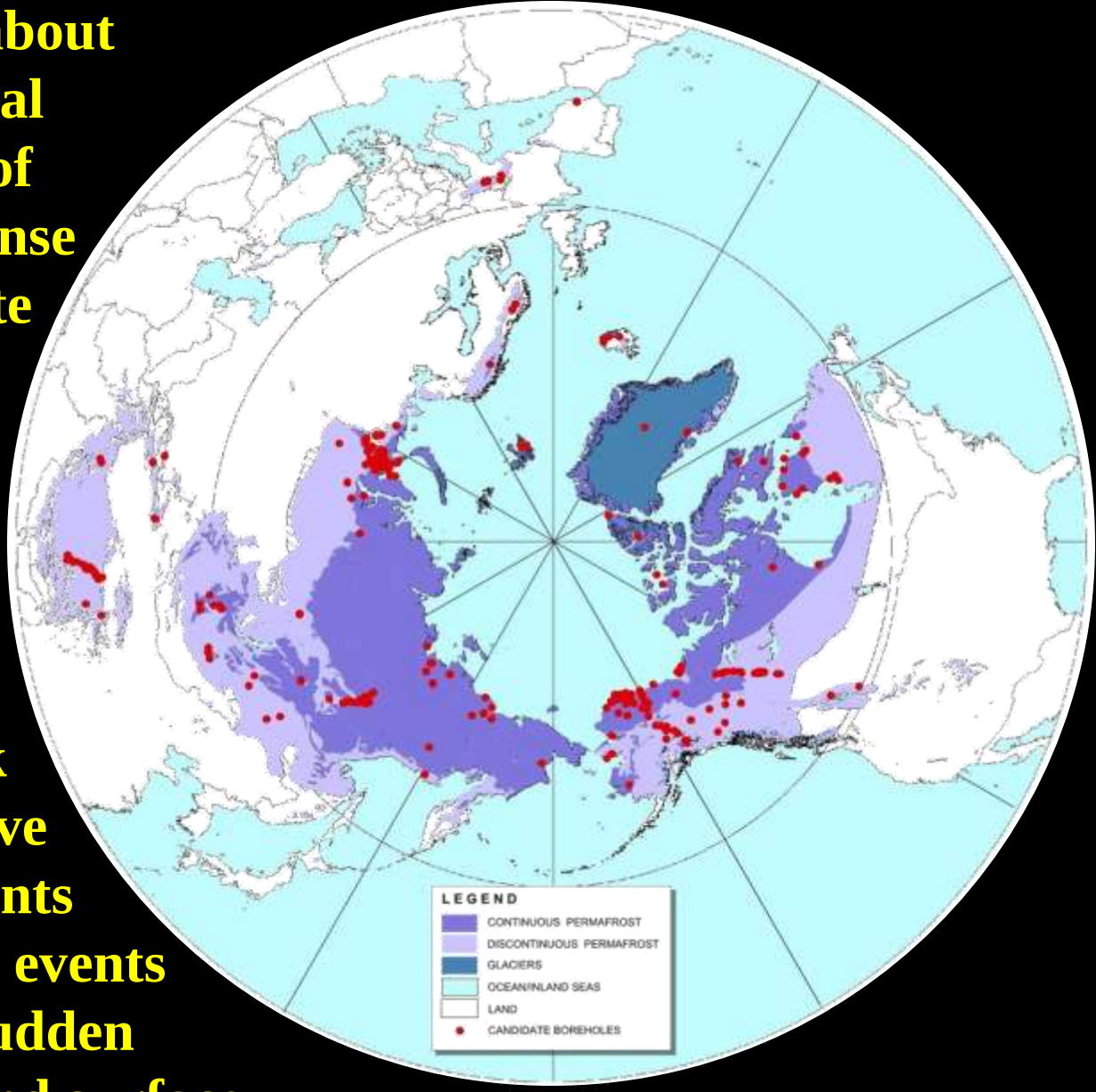


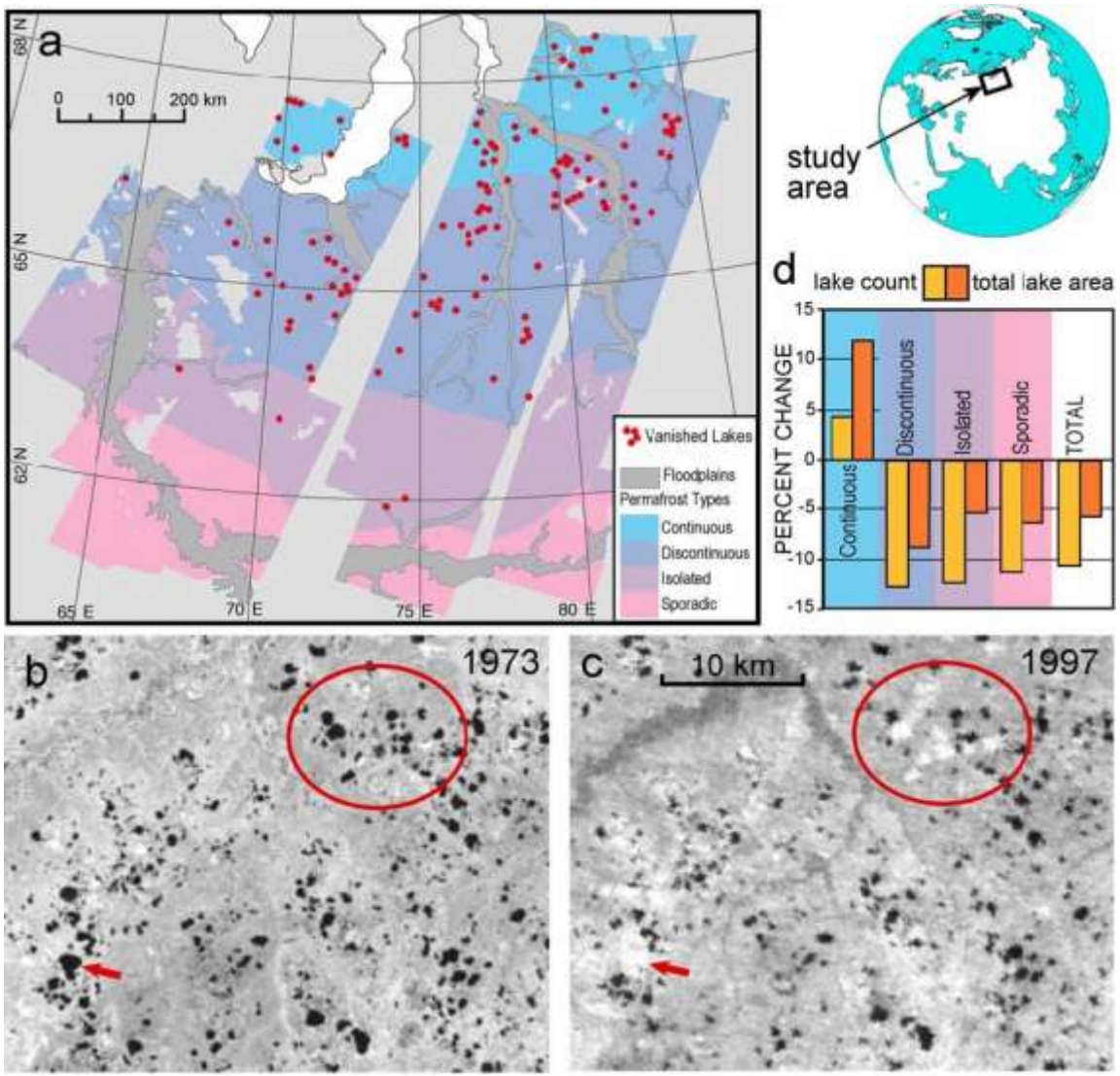
Francis et al., JGR 2009



Permafrost covers about 25% of the terrestrial area. Degradation of permafrost in response to a warming climate will have dramatic impacts to local infrastructure, hydrology, and ecology.

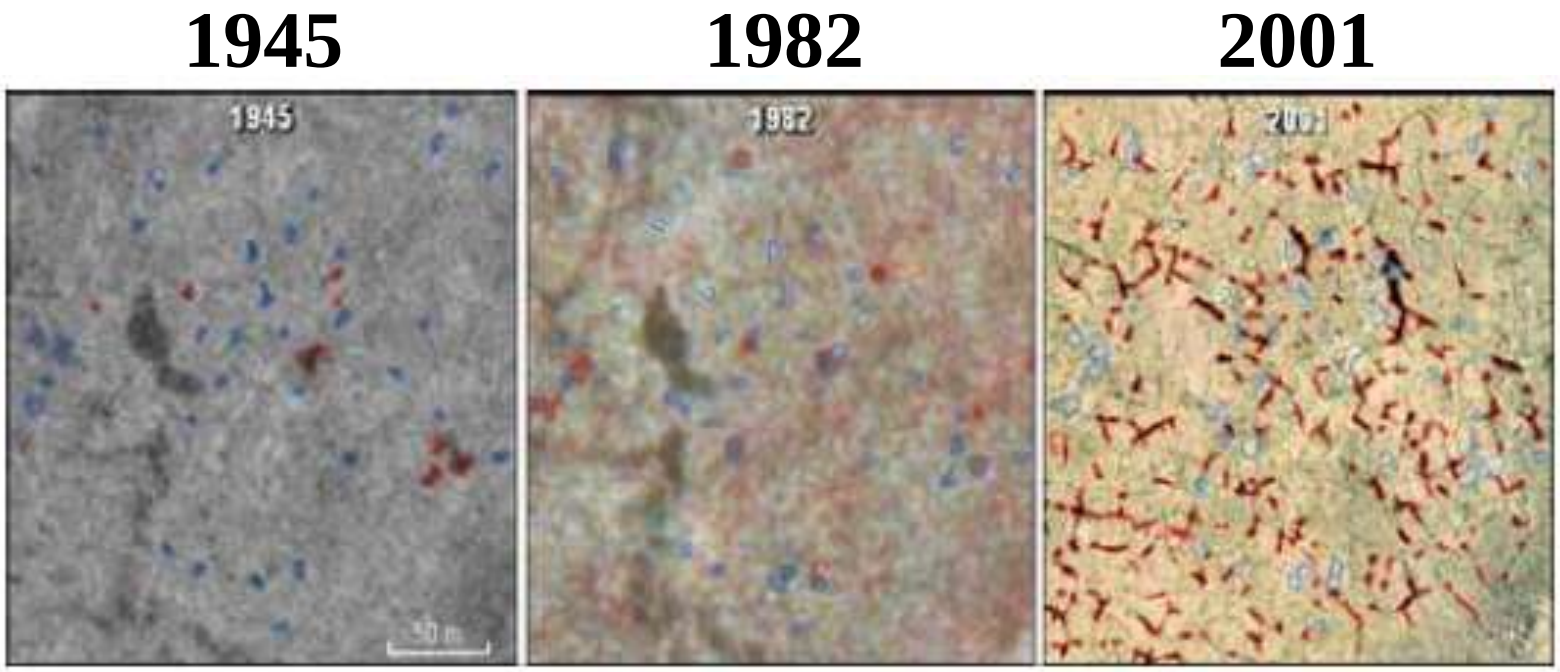
Formation of a talik (unfrozen layer above permafrost) represents one of the threshold events that will initiate a sudden change in ecology and surface energy balance.





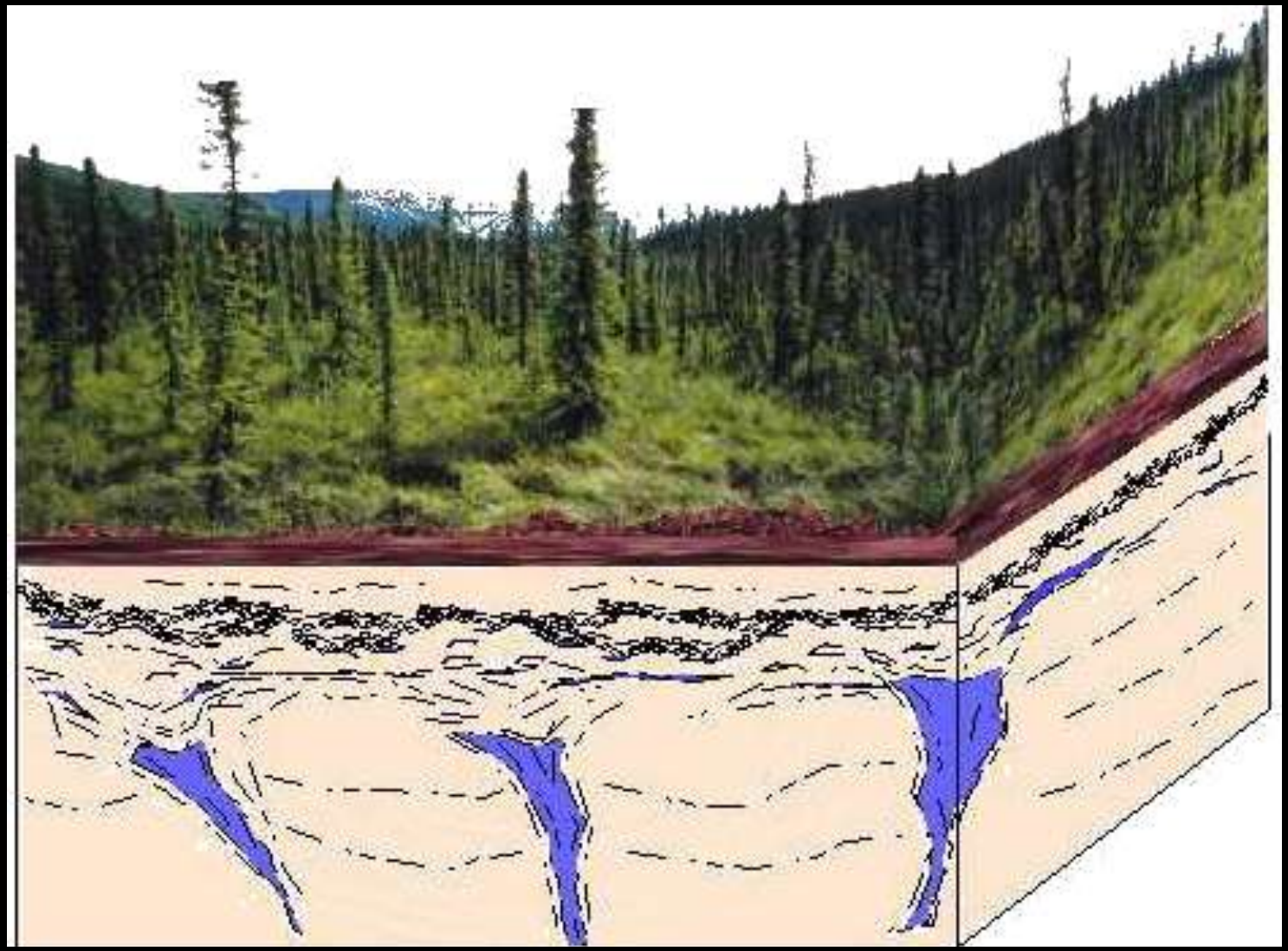
(a) Locations of Siberian lake inventories, permafrost distribution, and vanished lakes. Total lake abundance and inundation area have declined since 1973 (b), including permanent drainage and re-vegetation of former lakebeds (c). Interestingly, net *increases* in lake abundance and area have occurred in continuous permafrost (d), suggesting an initial but transitory increase in surface ponding (Larry Smith et al., 2005).

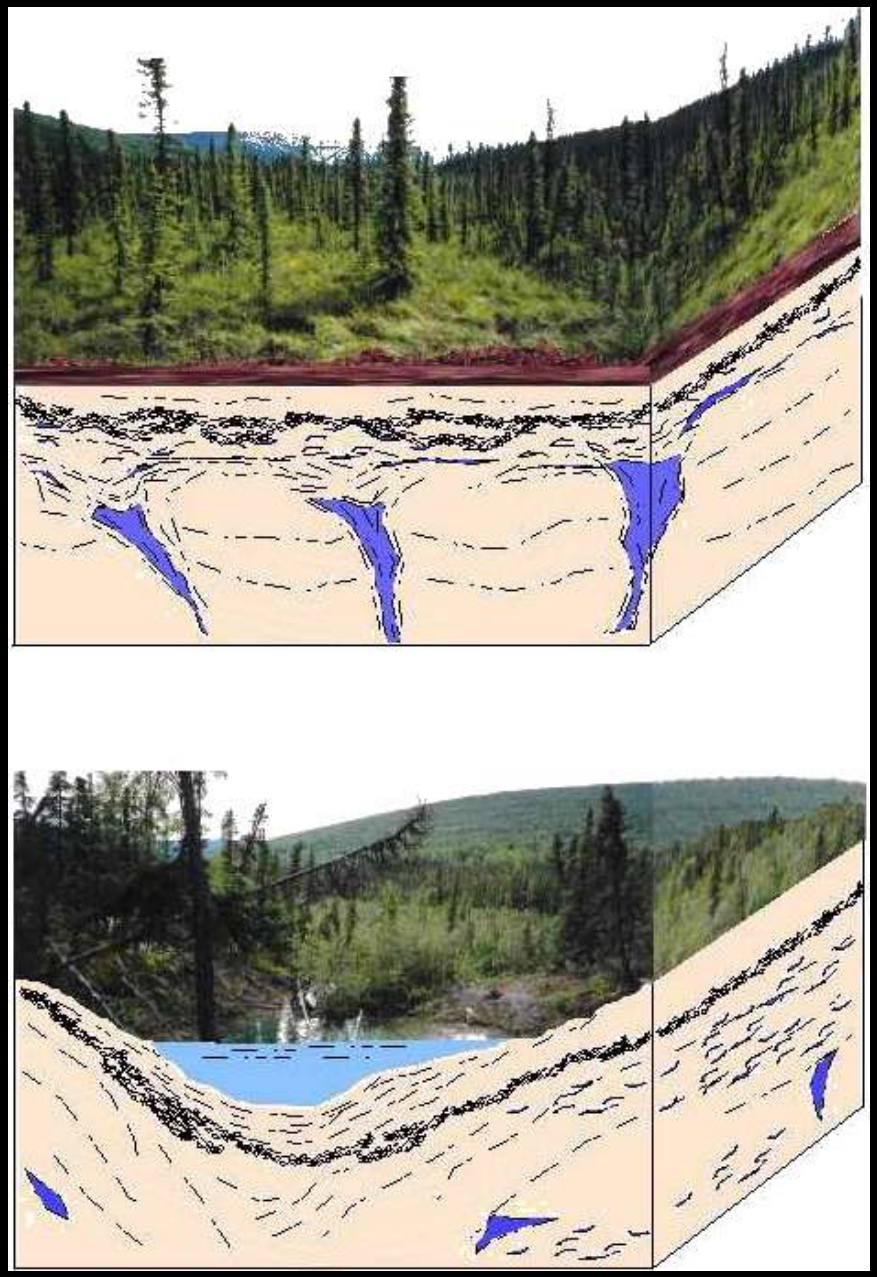
In colder permafrost, located in more northern regions of Canada, Alaska and Siberia, evidence of climate impacts to ecosystem is also apparent.



Abundance of degrading (advanced stage only in red) and stabilizing (initial and advanced stages in blue) thermokarst pits within the 0.6 km^2 intensive study area.

Jorgenson et al., 2006. GRL





1949

Chandler River, 50 miles S. of Umiat: Sturm, Racine and Tape: Fifty Years of Change in Arctic Alaskan Shrub Abundance

2001

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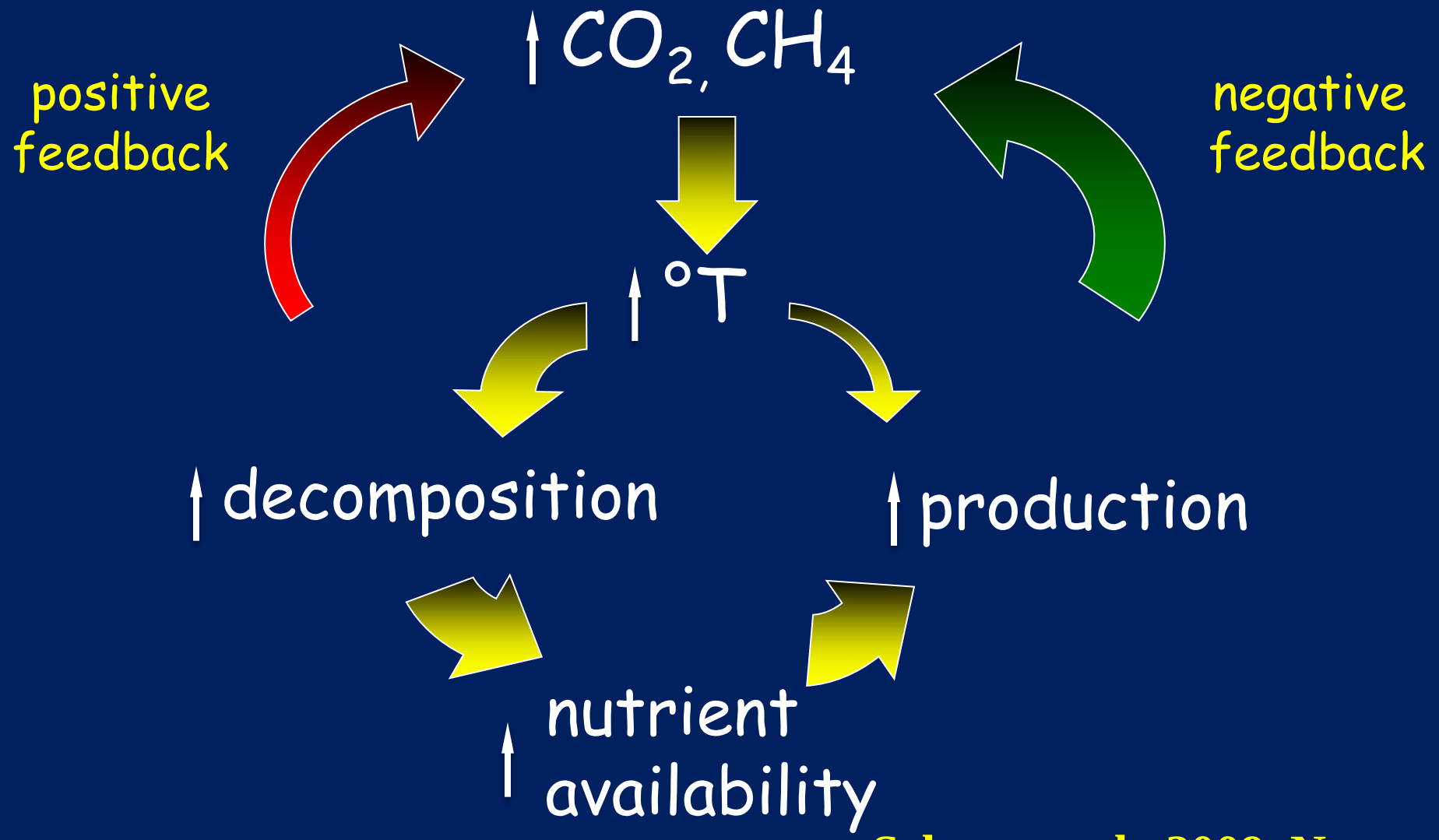
Global Carbon Pools

Global Vegetation C	650 Pg
Global Soil C (1m)	1500 Pg
Atmosphere	777+ Pg

Permafrost Zone Soil C	
Peatlands (several m)	277 Pg
Mineral Soil (3m)	747 Pg
Siberian Deep C (~25m)	407 Pg
Alluvial Deep C (~25m)	241 Pg
	1672 Pg

[Jobaggy et al. 2000, Field et al. 2007, Zimov et al. 2006, Tarnocai, in press, Schuur et al. 2008]

Feedbacks to the Carbon Cycle



Schuur et al., 2009, Nature

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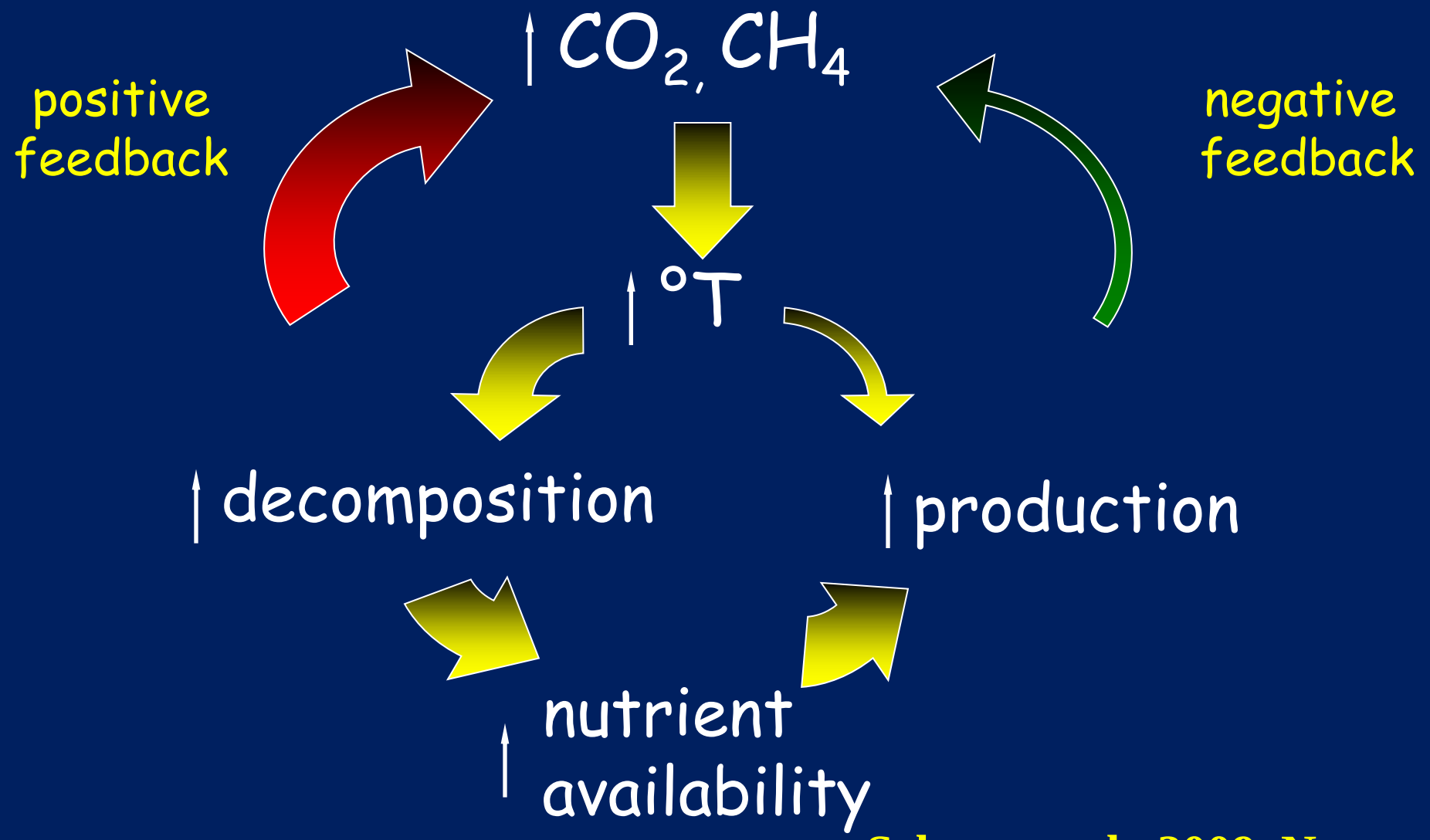
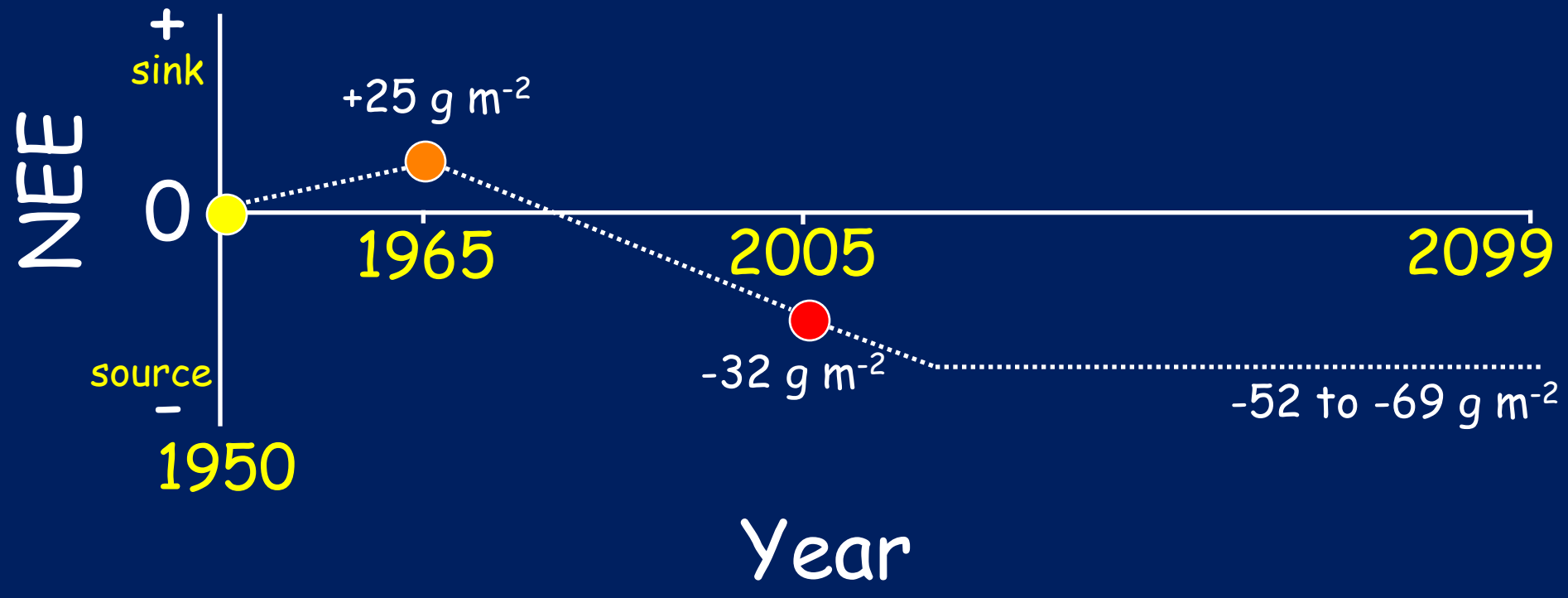


Schuur et al., 2009, Nature

Net Carbon Exchange Projections



Carbon loss by 2099: 4.4-6.0 kg/m^{-2} (9.4-12.9%)

Equilibrium C loss much higher over centuries

[Schuur et al. , 2009]