Permafrost Carbon and Climate Feedbacks

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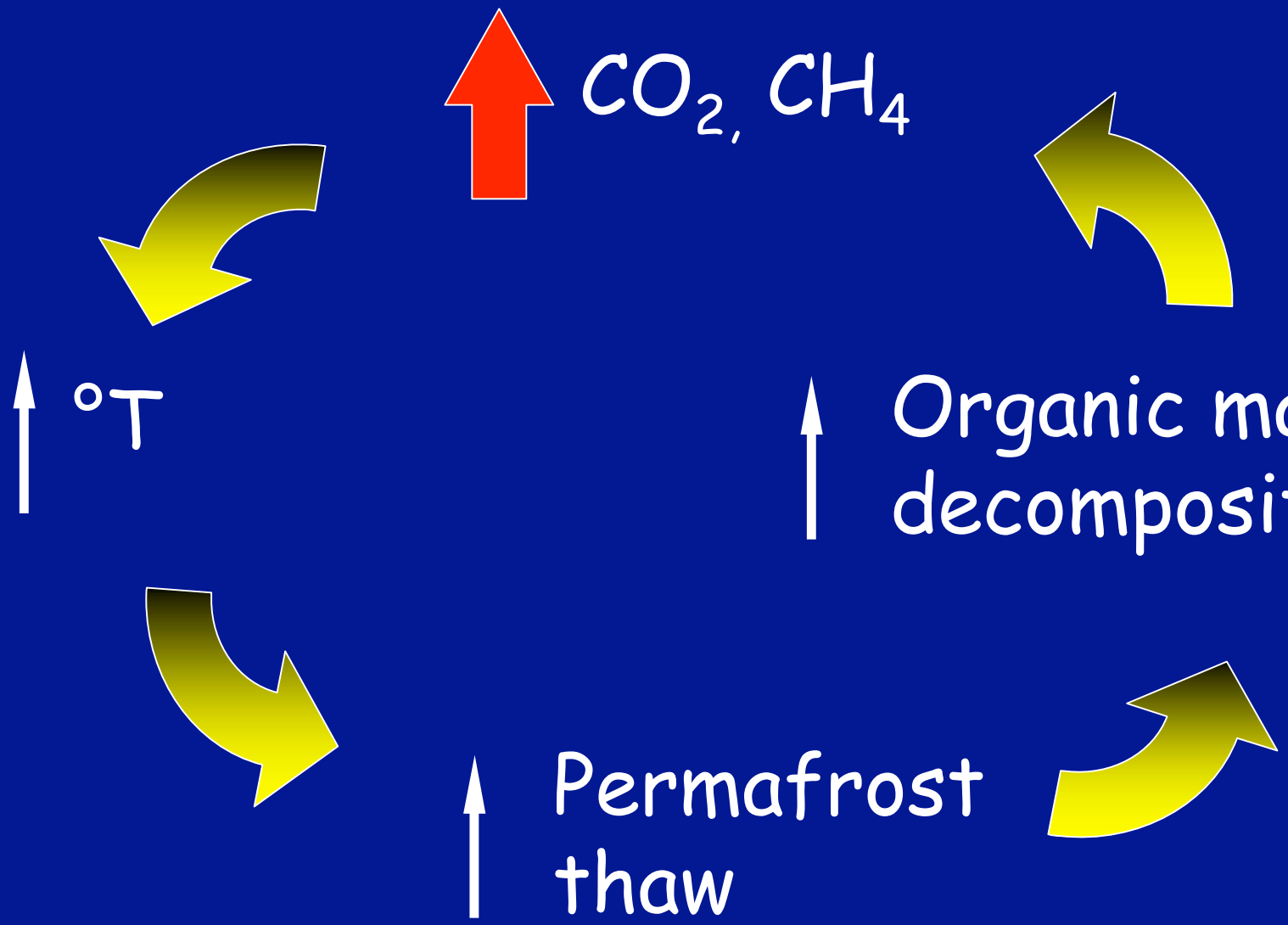
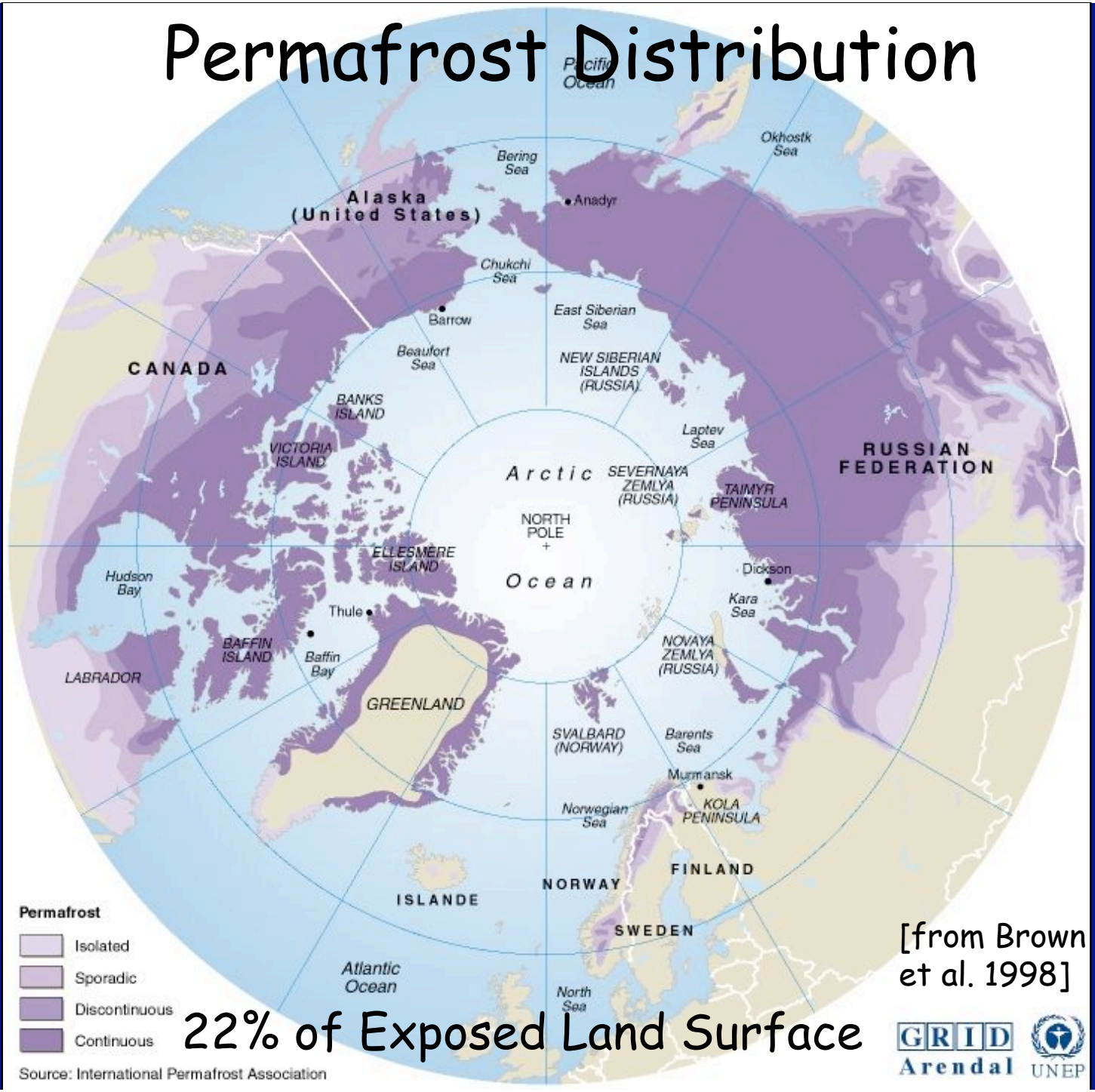
Permafrost Feedback to Climate Change



Permafrost Distribution

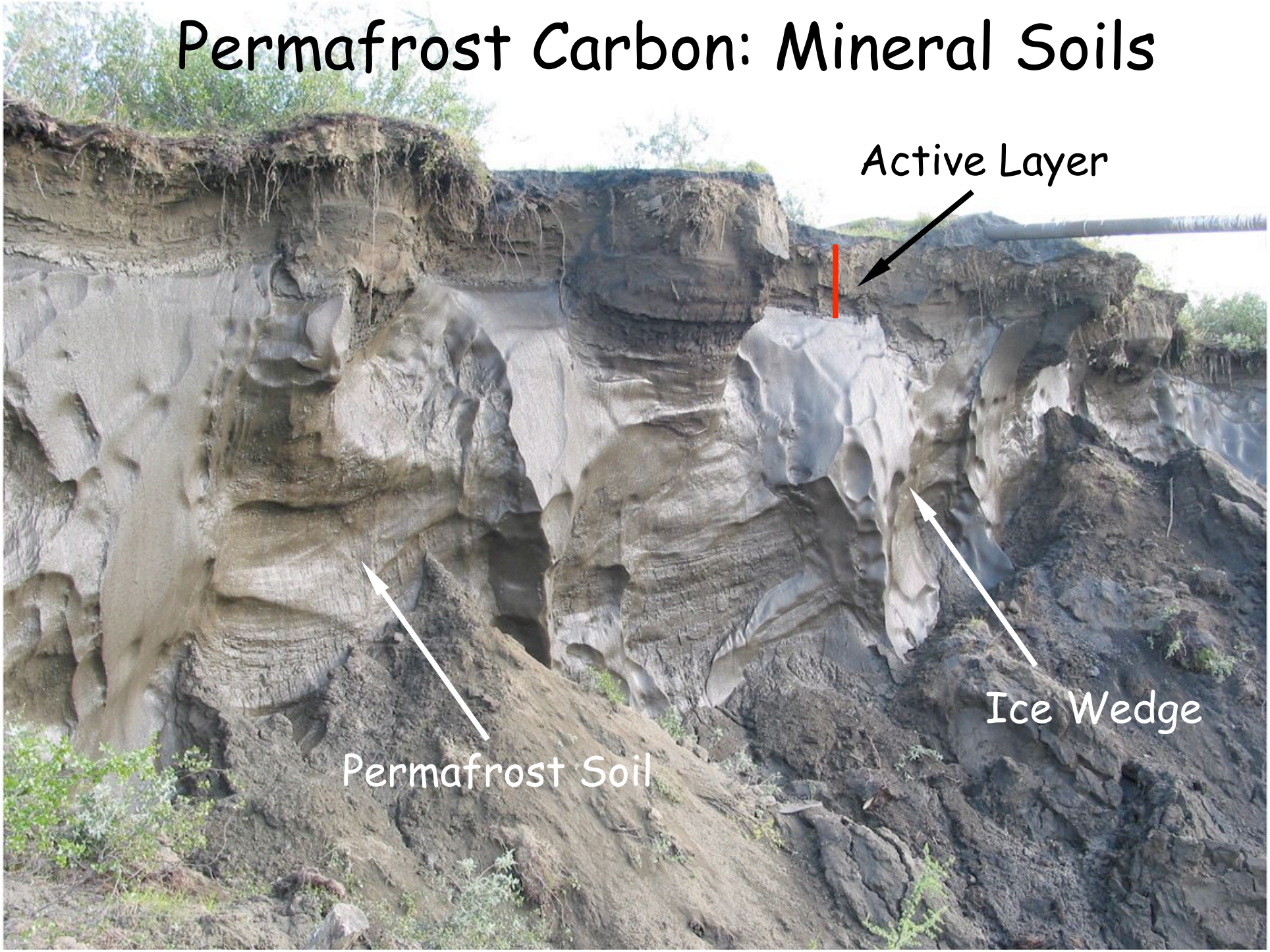


[from Brown et al. 1998]

22% of Exposed Land Surface

GRID Arendal UNEP

Permafrost Carbon: Mineral Soils



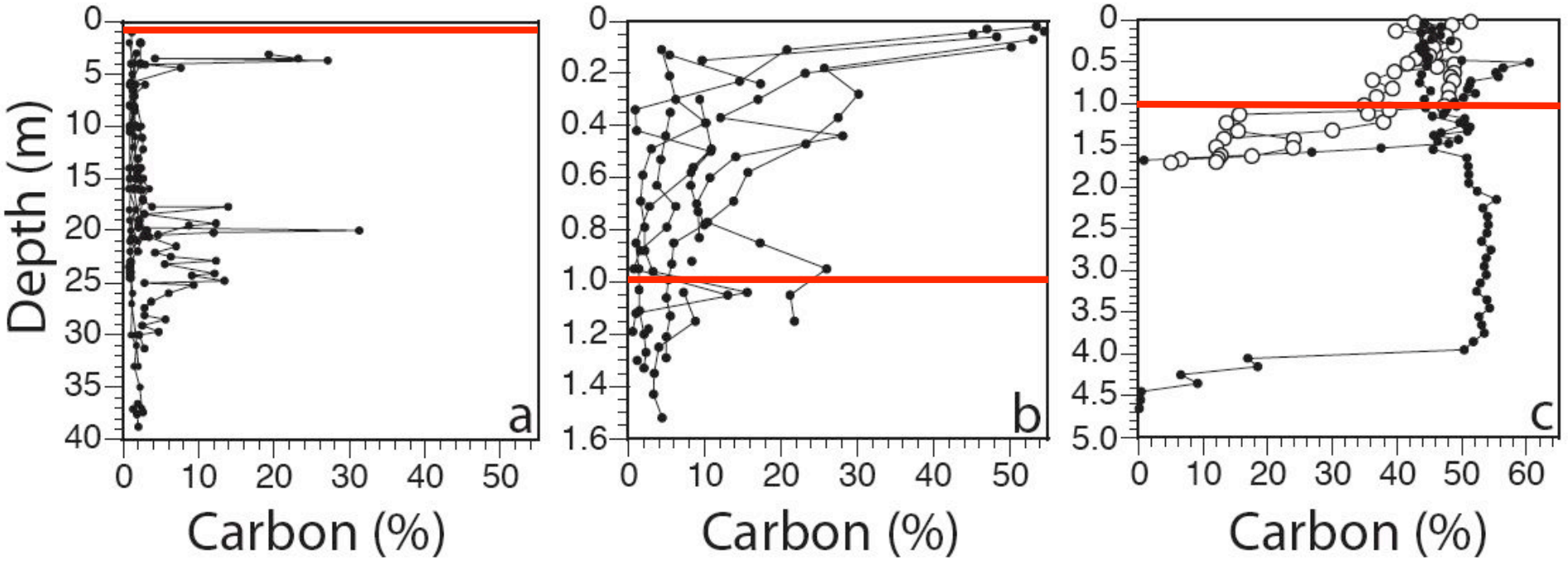
Permafrost Carbon: Peat Soils

Organic Soil
(>20% C)

Mineral Soil

Permafrost Carbon: Depth Distribution

Loess Soil | Mineral Soil | Peat Soil



Siberia | Alaska | Russia, Canada

[Zimov et al. 2006, Kuhry 1998, Kuhry unpublished, Bockheim 2006]

Permafrost Carbon Pool

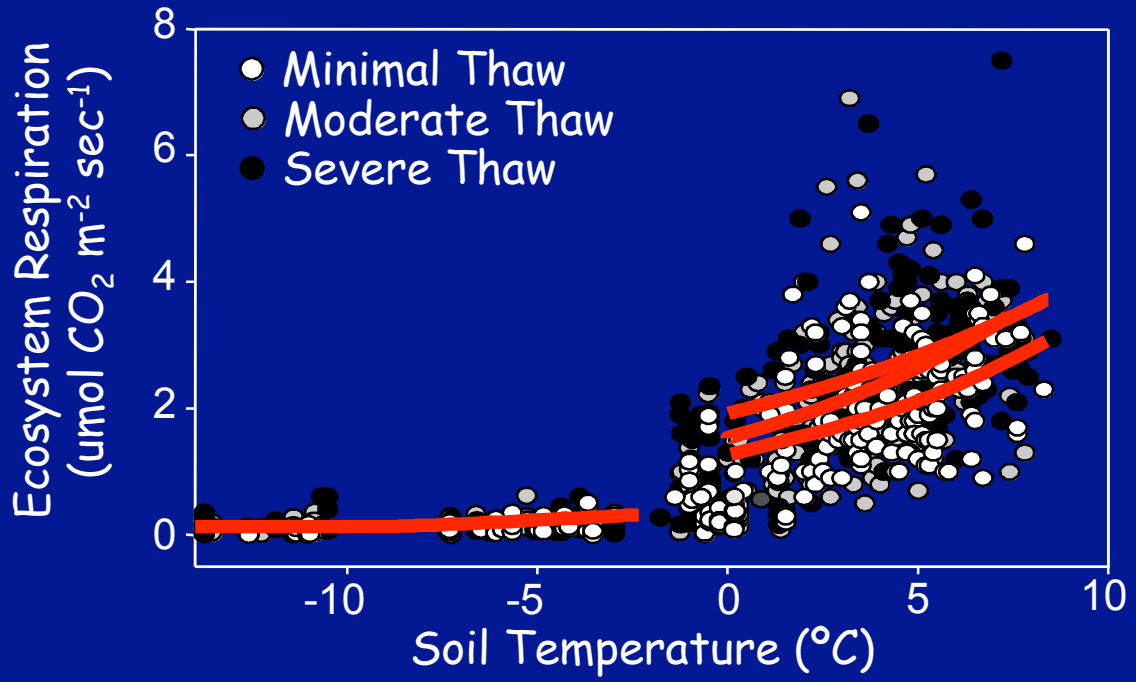
Global Vegetation C	650 Pg
Global Soil C (1m)	1500 Pg

Permafrost Zone Soil C

Peatlands (several m)	240 Pg
Mineral Soil (1m)	260 Pg
Siberian Deep C (25m)	450 Pg
	950 Pg

[Jobaggy & Jackson 2000, Field et al. 2007, Zimov et al. 2006, Tarnocai, unpublished]

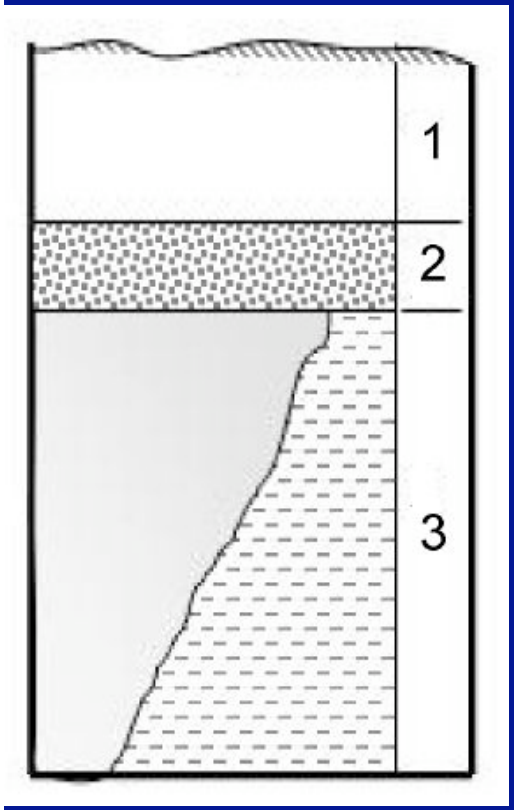
Permafrost Thaw: Threshold Dynamics



Biological Threshold

[Vogel & Schuur, unpublished]

Permafrost Thaw: Active Layer Thickening



Active Layer

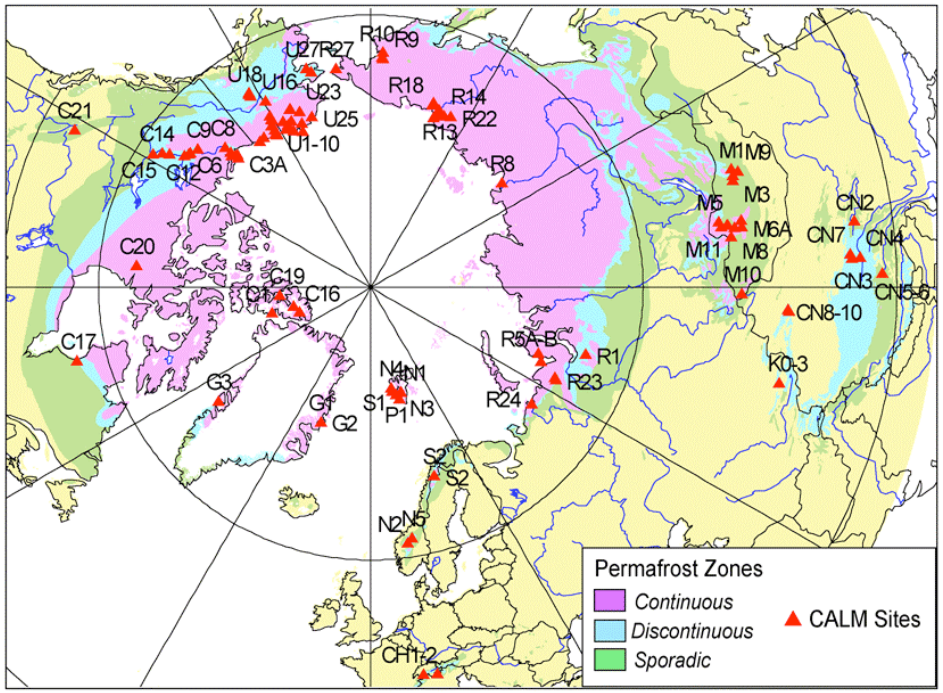
Transient Layer

Permafrost Soil

Projected Thaw (to 0°C):

Continuous Zone: 150 years

Discontinuous Zone: 60 years



Circumpolar Active Layer Network (CALM)

[Nelson et al. 2004, Oelke & Zhang 2004]

Permafrost Thaw: Thermokarst

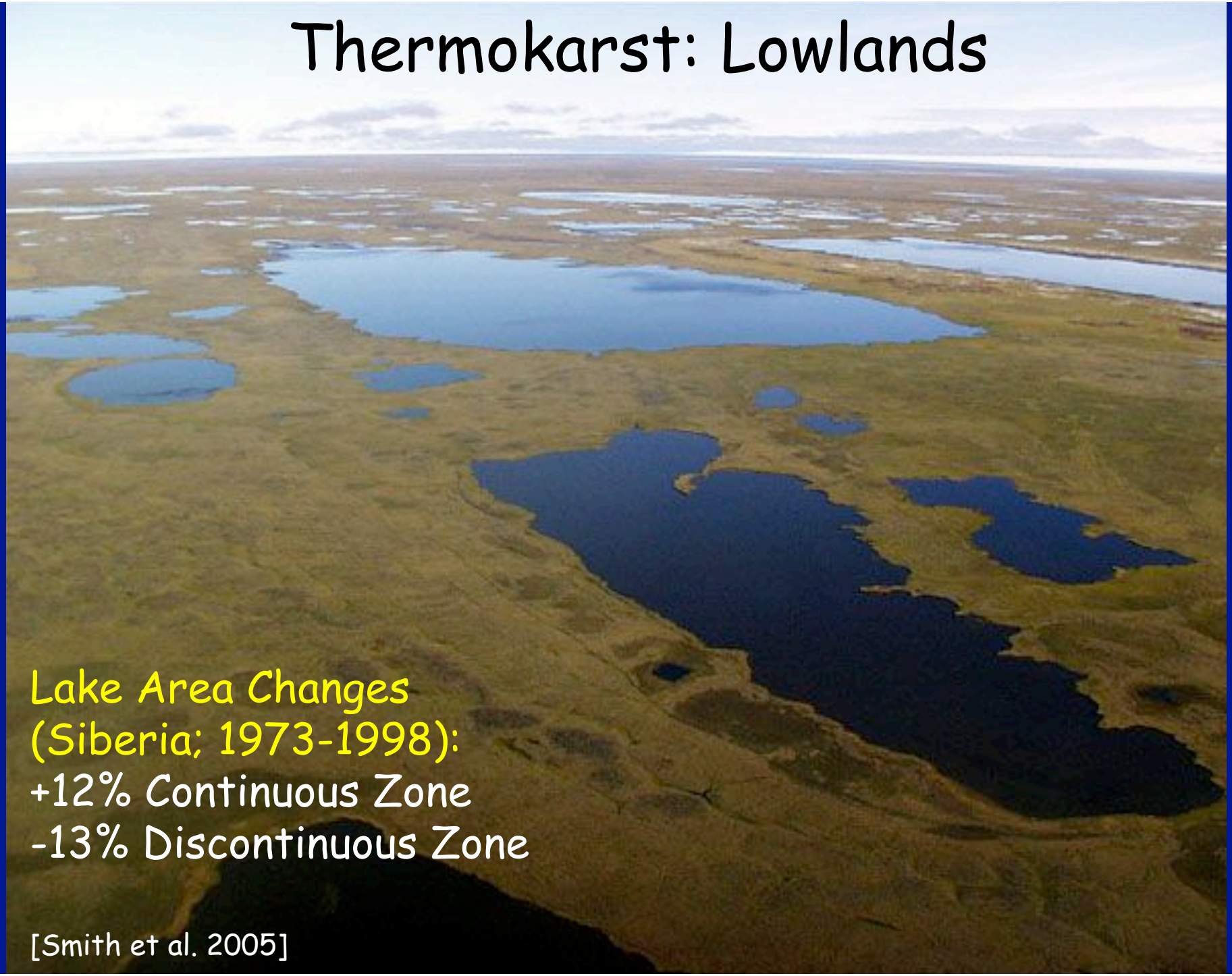
Thermokarst Distribution (Alaska):
54% Continuous Zone
5% Discontinuous Zone

[Jorgenson et al. 2006]

Thermokarst Change Over 5 Decades (Alaska):
0.6% → 4.4%; Continuous Zone
26% → 33%; Discontinuous Zone

[Jorgenson 2008]

Thermokarst: Lowlands



Lake Area Changes
(Siberia; 1973-1998):
+12% Continuous Zone
-13% Discontinuous Zone

[Smith et al. 2005]

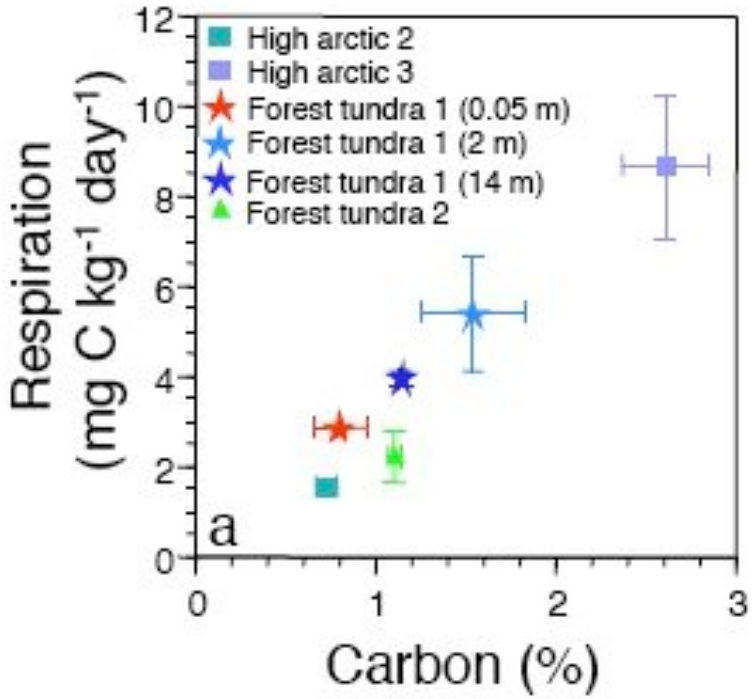
Fate of Thawed Permafrost Carbon

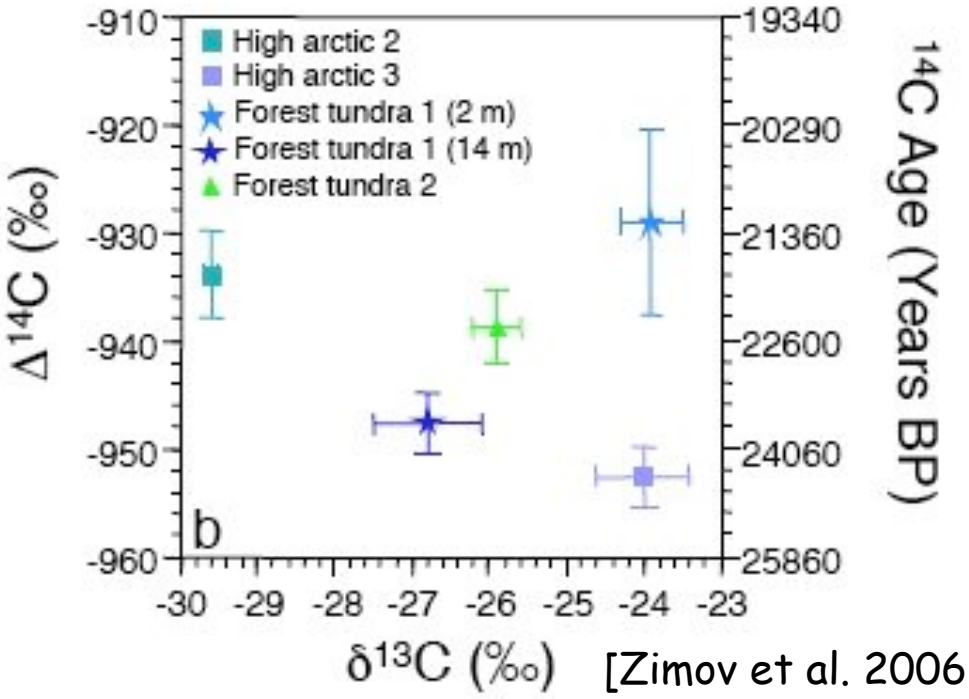
Decomposition Products

CO_2: 100-1000x emission rate

CH_4: 25x GWP/100 years

DOC: Export to aquatic ecosystems





[Zimov et al. 2006]

Permafrost Zone Impacts on Global Carbon

Estimated C emissions:

Siberia: 40 Pg over 40 yrs [Dutta et al. 2006, Zimov et al. 2006]

Canada: 48 Pg over 100 yrs [Tarnocai 1999]

Circumpolar: 50-100 Pg over 100 yrs [Gruber et al. 2004, Zhuang et al. 2006, Steiglitz et al. 2003]

Methane emissions:

Circumpolar: 2x over 100 yrs [Zhuang et al. 2006, Gedney et al. 2004]

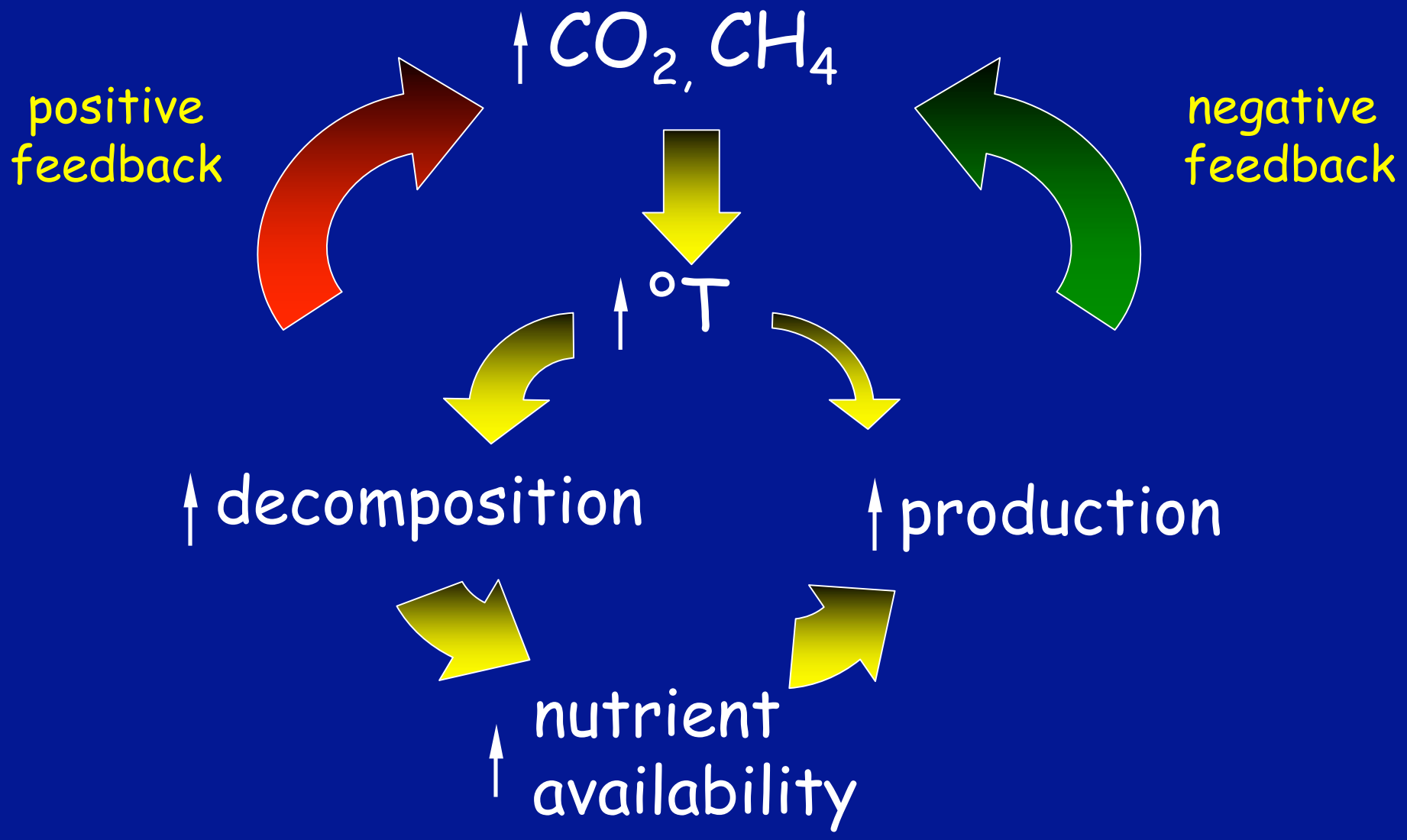
Dissolved organic C:

West Siberia: 30-45%↑ over 100 yrs [Frey and Smith 2005]

Yukon: observed ↓ from 1979-2002 [Striegl et al. 2005]

Arctic Ocean: 7 year half life [Hansell et al. 2004]

Feedbacks to the Carbon Cycle



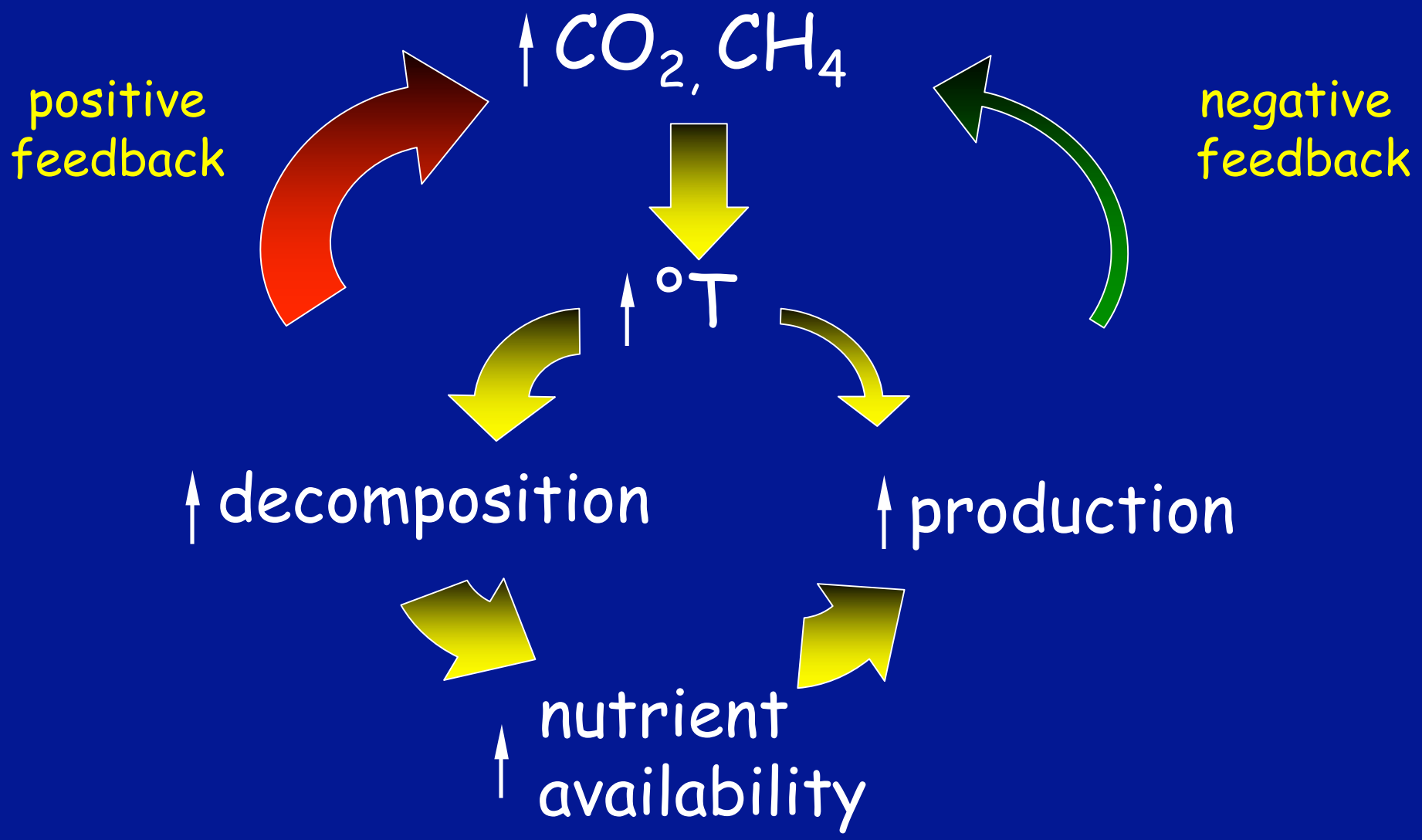
Terrestrial Carbon Pools

Vegetation

	Tundra	Shrub Tundra/ Woodland	Boreal Forest
Soil	52.0 kg/m³	0-1 m	9.3 kg/m³
	29.0 kg/m³	1-2 m	2.4 kg/m³
	~42.0 kg/m³	2-3 m	~0.8 kg/m³

[Schuur et al. 2006, Gower et al. 2001, Bockheim et al. 2007, Jobbagy & Jackson 2000]

Feedbacks to the Carbon Cycle



Conclusions

Permafrost C pools are large and quite sensitive to changes in temperature

Rapid (decadal scale) destabilization of these pools is possible given threshold dynamics

Future annual contribution to the atmosphere could be similar in size to land use change, but is currently poorly constrained

Acknowledgements

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