T143B Permafrost-snow-ecosystem in the late Quaternary climate: Distribution and interactions examined by global system modeling

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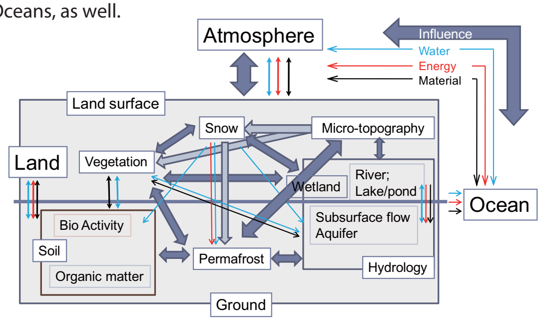
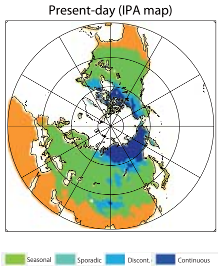
Acknowledgement We acknowledge the international modeling groups for providing their data for analysis, the Laboratoire des Sciences du Climat et de l'Environnement (LSCE) for collecting and archiving the model data. The PMIP2/MOTIF Data Archive is supported by CEA, CNRS, the EU project MOTIF (EVK2-CT-2002-00153) and the Programme National d'Etude de la Dynamique du Climat (PNEDC). The analyses were performed using version Sep 5, 2008 of the database. This study was partly supported by the National Science Foundation under Agreement No. ARC-0327664, and ARC-1107524, USA.

Introduction

Change in the distribution and states of permafrost in time and space is an important non-local factor to understand the attribution and consequence of Quaternary climate change, and project and adapt to the future environment. The subsurface hydrological-thermal system interacts with overlying snow and the eco-system, offering physical foundation and conditions to the various terrestrial activities, from the physical to hydrological to biogeochemical to the societal aspects. Through the various environmental pathways subsurface changes are significantly connected to the atmosphere and to the Oceans, as well.

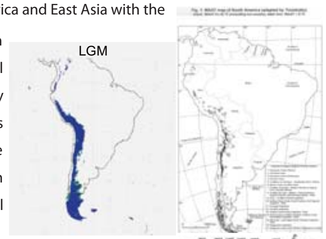


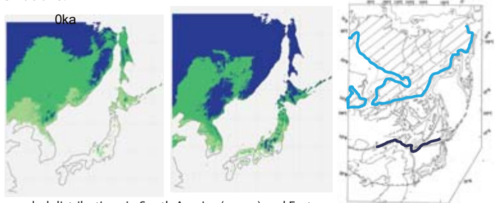
Changes in the frozen ground distributiontion in the Late Quaternary



Downscaling and Regional Verification

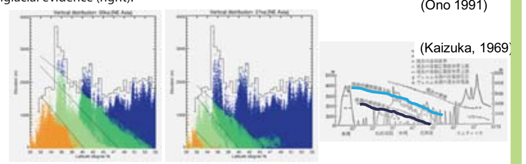
The coarse-scale reconstruction maps from the PMIP2 outputs were downscaled to the finer-resolution. The examples are for South America and East Asia with the GTOPO30 Digital Elevation Model (DEM) and the local temperature corrections by the rapse rate. The results were compared with the periglacial evidence taken from the geomorphological observations.





Downscaled distributions in South Ameica (upper) and East Asia (lower) for the present (left) and the LGM (middle). The periglacial evidence (right).

(Ono 1991)



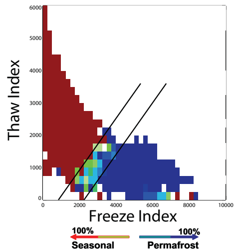
Altitude-Latitude distribution of frozen ground types in East Asia for 0ka (left) and 21ka (middle). Observation-based distibution for the current and the last glaciation era (right)

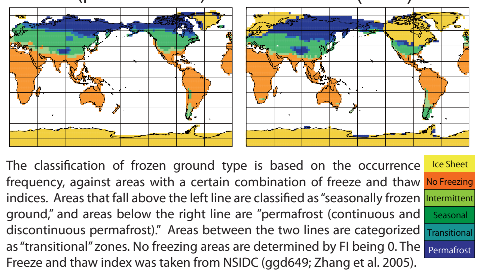
Reconstruction

Statistical Approach

Saito et al. 2008

Frozen Ground (FG) Classification (IPA)





The classification of frozen ground type is based on the occurrence frequency, against areas with a certain combination of freeze and thaw indices. Areas that fall above the left line are classified as "seasonally frozen ground," and areas below the right line are "permafrost (continuous and discontinuous permafrost)." Areas between the two lines are categorized as "transitional" zones. No freezing areas are determined by FI being 0. The Freeze and thaw index was taken from NSIDC (ggd649; Zhang et al. 2005).

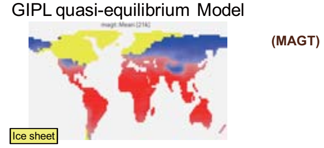
The permafrost distribution was taken from the IPA map (Brown et al. 1997). The seasonally frozen ground was diveded into two categories ("intermittent (less than two weeks)", and "seasonal (longer than two weeks)") by the length of freezing.

The constructed frozen ground classification was applied to the freeze/thaw index combination calculated from the PMIP2 outputs for the pre-industrial (0ka) and the Last Glacial Maximum (21ka) eras. The areas of different frozen ground types are shown by different colors.

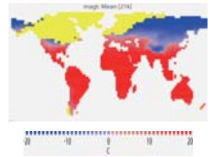
Numerical Approach

1) Offline Simulations

GIPL quasi-equilibrium Model



Land surface component in a GCM

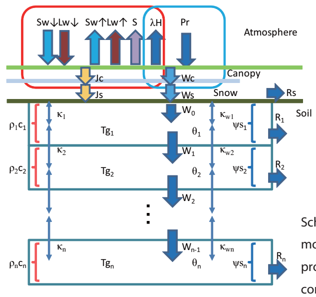


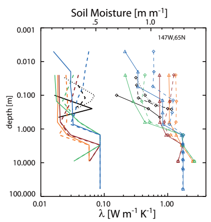
This three-year project focuses on evaluating the structure and function of the permafrost-snow subsystem under different climate conditions by combining "Reconstruction," "Model Improvement," and "Dynamic Analysis:"

1. How well do the permafrost distributions simulated by GCMs agree with reconstructions from the proxy data?
2. How widely did the permafrost distribution change under different climate conditions? Will permafrost change have serious consequences in nature, life, and societies in the Arctic?
3. Correspondingly, by which processes and interactions does the permafrost-snow subsystem impact the climate of the past and present? How important are the vegetation and soil types?
4. What can we learn from the permafrost-snow subsystem simulations under different climatic conditions to mitigate or adapt to future changes?

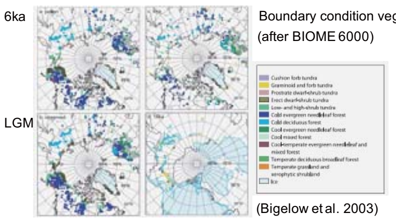
Model Improvement ⟷ Dynamical Analysis

- Permafrost-snow dynamics in GCM/ESMs
- Investigation and inclusion of realistic property values for soil (e.g. organic layer), snow.
- Use of other paleo-proxy data for model validation/ calibration (e.g., pollen, beetle, chironomids, plant macrofossil; loess; lake)





Schematic permafrost-snow process model (right). Modeled and observed profiles of soil moisture and thermal conductivity (upper)

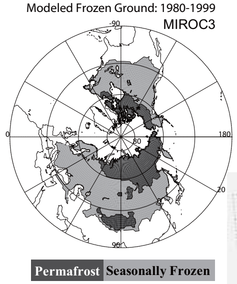


Boundary condition vegetation (after BIOME 6000)

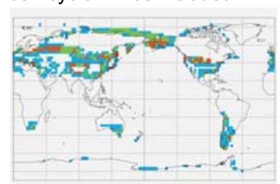
(Bigelow et al. 2003)

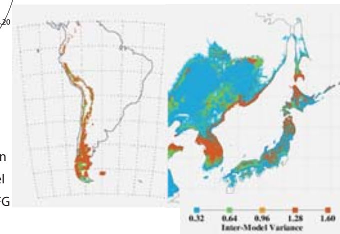
- Structure and function of the permafrost-snow subsystem in the cold-region dynamics, to be examined by GCMs (coupled and offline), process-based, statisitacal, and conceptual models.
- At this stage, vegetation is passive only; no dynamic vegetation or interactive carbon cycle will be included.

Modeled Frozen Ground: 1980-1999



Saito et al. (2007)





Modeled current FG distribution by MIROC3 (upper). Inter-model variations in the PMIP2-based FG classification (right)

References

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