Permafrost in JULES
Rutger Dankers, Eleanor Burke, Jennifer Price
JULES meeting, 12 January 2011
A world melting from the top down

Despite years of speculation, little can be said for sure about the future of the Arctic's permafrost. But that's no grounds for complacency, reports Gabrielle Walker.

Seams of Phil Camill's trees are drank. Once the black spruce trees on the flanks of woodlands that dominate in northern Manitoba stood as straight and honest as pilgrims. Now an ever-increasing number of them fall, leaving bleached stumps. The decline is not in the morphological standards of Canadian vegetation, but in the shifting ground beneath their roots. Once it was solid, it is now a permafrost. Never much of a surprise, it has thawed into a soggy sponge that no longer provides a steady footing for the trees. Some continue to grow in a sand-balled image, others have drowned as been replaced by baking muds of mosses or sedge. "It is really easy to tell when the permafrost has gone," says Camill. "The vegetation changes right before your eyes."

Camill, an ecologist from Carlton College in Northfield, Minnesota, has used these changes to trace the rate at which the permafrost is disappearing and in their desperate attempts to better themselves survive, his leaning spruce utan extra wood on the downwind side of their trunks. Counting the aromatic, red, tree rings that recall and measure the distance of each tree from the current boundary of the permafrost gives a measure of the rate of change. These wood chronicles an average warming across his sites of 1.3°C since 1970 has brought with it a thawing of the three-meter. In some places the permafrost perimeter is now from 50 to 100 years ahead of the trend. Camill estimates that a permafrost will be left in any of his five asober the end of the century.

The thawed-out permafrost has already undergone buildings, highways and other infrastructure. The effects on native cultures and their intact, source-sorcery, buildings can be subtle, asphalt rubber, and agricultural practices changed through adaptation, with the right policies and priorities (see page 716). But changes in the vegetation and, crucially, in the soils of the frozen northern latitudes might not be so easy to cope with. The soil of the Arctic are Boom with organic material — a frozen reservoir of unthinkful preserved on leaves and other renewable material that may contain as much carbon as the entire atmosphere. They are quite resilient to more temperate regions, which are more adaptable to changes that the bacteria cannot digest. "We are unplug the refrigerator in the far north," says Camill. "Everything that is preserved there is going to start to rot."

"We are unplugging the refrigerator in the far north. Everything that is preserved there is going to start to rot."

— Phil Camill
Permafrost in JULES

• Evaluating JULES for simulating large-scale permafrost characteristics

• NH grid runs, standard setup:
  • GSWP2: 1983-1995, 1×1 degree
  • WATCH: 1958-2000, 2×2 degree
Spatial extent

(a) IPA permafrost extent

(b) JULES / GSWP2 (1983-1995)

(c) JULES / WATCH (1960-2000)

Legend:
- 90 - 100 %
- 50 - 90
- 10 - 50
- 0 - 10
- 0.0 - 0.5 m
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- no permafrost
JULES captures ~97% of area underlain with discontinuous and continuous permafrost

... but overestimates total extent:

- 25% is isolated/sporadic permafrost in IPA map
- 14% has no permafrost in IPA map
Active Layer Thickness

- Observed end-of-season thaw depth at CALM sites

- Since 1990, i.e. limited overlap with model runs:
Soil Temperatures

- Mean annual soil temperature
- Observations at Russian meteorological stations
- Simulations from WATCH run (1958-2000)
Soil Temperatures

- Monthly soil temperatures
- Observations at Russian meteorological stations
- Simulations from WATCH run (1958-2000)
- Top soil (0-10 cm)
Soil Temperatures

- Monthly soil temperatures
- Observations at Russian meteorological stations
- Simulations from WATCH run (1958-2000)
- Sub soil (10-35 cm)
Soil Temperatures

- Monthly soil temperatures
- Observations at Russian meteorological stations
- Simulations from WATCH run (1958-2000)
- Deep soil (35-100 cm)
Soil Temperatures

- Monthly soil temperatures
- Observations at Russian meteorological stations
- Simulations from WATCH run (1958-2000)
- Deep soil (100-300 cm)

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Why cold bias?

1. Uncertainties in precipitation input → snow thickness

   • Bonanza Creek, 1996
Why cold bias?

2. Soil moisture dynamics / runoff

Atqasuk, 2000

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CALM
43 cm
Permafrost in JULES

• Evaluating JULES for simulating large-scale permafrost characteristics

• NH grid runs, standard setup:
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• Modifying JULES for simulating permafrost under climate change
  • Modified soil parameters for organic soils
  • Represent deep permafrost ‘heat sink’
Organic soil parameters

- Final soil parameters linear combination of mineral and organic soil parameters according to organic fraction

- Similar approach as in e.g. CLM (Lawrence & Slater, 2008)

Deep permafrost

- Aim is not a realistic simulation of deeper soil temperatures
  - Lack of information on sub-surface variability
- Rather, provide additional heat sink for response of upper soil layers to warming

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Impact on ALT

- Relatively small impact on ALT in GSWP2 run
Permafrost in JULES

- Evaluating JULES for simulating large-scale permafrost characteristics
- NH grid runs, standard setup:
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- Future climate runs
Future climate runs

• Driven by probabilistic climate scenarios from HadCM3 QUMP ensemble (Collins et al., 2010)

• 17 member perturbed physics ensemble
• 2 scenarios (A1B, A1FI), 1860-2100
• 2.5° x 3.75° grid

Mean annual temperature change north of 60°N relative to 1960-89
Future climate runs

- Surface permafrost projected to disappear
  - A1B: ~ 45% (20-60%) of current area
  - A1FI: ~ 60% (35-85%)
Future climate runs

- Probability of permafrost occurrence
Some conclusions…

• JULES simulates permafrost where it is known to occur…

• … but appears to overestimate total extent

• Overestimation of observed ALT…

• … but soil temperatures appear to be generally too cold (although least so in summer/autumn)
  • Precip input / snow depth highly uncertain
  • Soil moisture / runoff treatment
  • Very few observations available!
Some conclusions…

- Organic soil parameterisation + representation of deep permafrost heat sink
  - Relatively small impact on ALT
  - Counteract each other in many places
  - Slows down response to warming to some extent, but does not change overall pattern

- Future climate simulations suggest general decline in surface permafrost area
The future?

- Better understand cold bias in soil temperature
  - Snow → input issue?
  - Parameter values?
  - Point observations vs grid simulation?

- Dynamic soil carbon affecting soil properties?

- Sub-grid variability in soil properties / tiling?

- Higher vertical resolution for better representation of thawing front?

- ... ?
Thanks!

FCO Strategic Programme Fund, Joint DECC/Defra Met Office Hadley Centre Climate Programme, Andy Wiltshire, Doug Clark, Richard Essery, Matt Pryor…
Permafrost???

By definition, soil that is below $0^\circ\text{C}$ for two consecutive years or more.

Permafrost layer can be 100s of m deep and 1000s of years old.

Recent estimates of total carbon store: 1672 Gt (Schuur et al., 2008) (i.e. twice atmospheric carbon pool)
Permafrost in JULES

- Point simulation for Atqasuk, Alaska

![Graphs showing soil temperature for different layers (1-4) with dates from January to December.]

NB precipitation input corrected for snow undercatch

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