



Action Group:

Permafrost extension during the Last Glacial Maximum in the northern hemisphere and derived mean annual temperatures

Deliverables:

a. **Map** of permafrost distribution during the period of maximum permafrost extent in the northern hemisphere around 17-20 years ago (specified for different kinds of permafrost). The individual parts of the map are completed according to plans. After final tuning they were compiled in one map at NSIDC and Lanzhou University by Xudong Wan under supervision of Tingjun Zhang. It is now in press by the journal BOREAS (the individual papers are already online). As discussed during our oral presentation at the IPA Council meeting in Salekhard, it is the firm intention to make the map in digital format freely available for everyone. It is also planned to put all data at NSIDC, Colorado. It will be presented at the EUCOP4 conference.

b. **Paper** focusing on methodology and main conclusions of spatial patterns of permafrost as evidenced in (a), published in c. (now available online).

c. **A special issue of an international peer-reviewed journal** (Boreas).

We have now finished a special issue for the journal Boreas including publication of the map (guest-edited by me and Hugh French). The content is outlined in Annex 1. This special issue contains a discussion paper of the map (b) and papers that are related to the extent of permafrost in the northern hemisphere during LPM.

The special Boreas issue containing the accompanying article (b) and the fold out map (c) is scheduled to be published online 27th June 2014 and in print 3rd July 2014.

Activities:

Apart from investigations in the individual regions by the participants, we had

- A one-day workshop in Lanzhou (September 2011, hosted by Lanzhou CAREERI) –Report see Annex 1;
- A work meeting at Salekhard on 24th June 2012; - Report see Annex 2
- A meeting of the 2 guest editors of the special Boreas issue to finalize the LPM permafrost map (Victoria, BC, Canada; June 2013).

Realisation and remaining challenges:

Original Objectives as outlined in the AG-proposal:

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1. Defining the different categories of permafrost that occurred during the LGM in the northern hemisphere, with the aim to map their spatial distribution.
 2. Mapping these permafrost categories in the different regions of the northern hemisphere.
 3. Deriving mean annual air temperatures corresponding to the different categories and compile a paleo-temperature map corresponding with the permafrost extension map (2).

Ad 1: satisfactorily done for lowland areas. Apart from distinguishing continuous and discontinuous/sporadic permafrost, we mapped also permafrost occurrence on land that is now submerged and we even made, for the first time, a rough estimate of relict permafrost. But, there remains a problem in defining appropriate categories of permafrost in high-altitude regions. In addition, we did not distinguish between latitudinal and altitudinal permafrost.

Ad 2: done. But, in some regions the occurrence of permafrost indicators is weak and needs additional observations.

Ad 3: In the concerned large region, local circumstances often interfere with general climatic impact on permafrost occurrence. As a result, we refrained from a new paleoclimatic reconstruction as no progress was expected in comparison with previous estimates.

It is planned to cover the remaining challenges in a next AG-proposal (submitted beginning April 2014).

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ANNEX 1 Content of the special issue of Boreas

Permafrost extension during the Last Permafrost Maximum (LPM) in the northern hemisphere. [guest editors Jef Vandenberghe and Hugh French]

1. Vandenberghe et al. 075 "The Last Permafrost Maximum (LPM) map of the northern hemisphere: permafrost extent and mean annual air temperatures, 25-17 ka BP."
2. French & Millar 014 "Permafrost at the time of the Last Glacial Maximum (LGM) in North America"
3. Bertran et al. 018 "Distribution and chronology of Pleistocene permafrost features in France: database and first results."
4. Zielinski et al. 021 "Periglacial structures within fluvio-aeolian successions of the end of the last glacial– examples from southeast Poland and northwest Ukraine."
5. Fabian et al. 017 "Distribution of relict permafrost features in the Pannonian Basin (Hungary)"
6. Vasilchuk & Vasilchuk 029 "Spatial distribution of mean winter air temperatures in Siberian permafrost at 18-20 ka BP using oxygen isotope data"
7. Zhao et al. 053 "The extent of permafrost in China during the Local Last Glacial Maximum (LLGM)"
8. Saito et al. 016 "Evaluation of LPM Permafrost Distribution in Northeast Asia Reconstructed and Downscaled from GCM simulations"
9. Orvosova et al. 020 "Permafrost occurrence during the Last Permafrost Maximum (LPM) in the Western Carpathian Mountains of Slovakia as inferred from cryogenic cave carbonate"

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ANNEX 2

Discussed points, conclusions and appointments of the Workshop at Lanzhou Sept. 2011

1. Participants and the regions for which they are responsible:

Jef Vandenberghe: W and C Europe (except Russia).

Andrey Velichko: southern Russia (Europe and Asia),

Arpad Gorbunov and Sergey Marchenko: C Asia (Kazakhstan, Uzbekistan, Kirgizia, Tajikistan,...) until Pamir,

H. Jin, Z. Cui, T. Zhang: E. Asia (China, Mongolia),

H. French: N. America.

It is possible and sometimes advisable to invite also other colleagues to contribute (for instance scientists from Tyumen, Novosibirsk, Krasnoyarsk for Russia, Vandenberghe for China).

2. Definition of LGM:

We are not aiming to define the boundary of maximum ice-sheet extent, but we are aiming to reconstruct the maximum extent of permafrost occurrence towards the end of the last glacial, and therefore preferentially will use the term LPM (Last Permafrost Maximum). This extent is defined irrespective of age, which means that the age of this maximum extent is not necessarily identical in all regions.

Criteria used to identify the existence of former permafrost seem to be uniform and need no further discussion. They include polygons of ice-wedge casts and sand wedges, pingo's, large cryoturbations, etc. The use of aerial photos is advised, next to vertical sections. In addition to these traditional criteria, also modeling of subsoil temperatures can fulfill the role of a proxy at a specific point when they indicate former temperature values that indicate undoubtedly permafrost at that specific place.

We have a positive idea on the production of 'derived maps', as for instance paleo-temperature maps. But the discussion of how to do that is postponed to the meeting of next year.

3. Permafrost boundary mapping:

- give priority to the southern limit of all permafrost, including altitudinal, sporadic, discontinuous and continuous permafrost,
- no distinction between altitudinal and latitudinal permafrost at all, but in the base map the contour lines of 1000 m, 2000 m and 4000 m elevation should be given,
- we attempt to make a distinction in the lowlands (below 1000 m) to delineate also the boundary between continuous and discontinuous permafrost (based on the principle to map discontinuous permafrost when permafrost indicators occur only in favorable conditions of topography, lithology, etc.) -- a decision will be taken at the meeting next year dependent on the results of the attempt,
- We will make no distinction between warm and cold permafrost due to expected problems of definition and reconstruction,

4. Map production:

T. Zhang offers to take care at NSIDC for the final compilation of the map. The base map to be produced will use the Lambert projection that is also used for the present-day permafrost map

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by Brown et al (1997) available at NSIDC. For each region a map must be provided on that same base map. The scale has yet to be decided. For the purpose of journal publication a different scale may be used according to the areal extent of the covered region.

Originally, Jef who had the contact with Jerry Brown, was supposed to take care for the extraction of that map from NSIDC, but after all he thinks that Tingjun is in a better position to do that as he is certainly nearer to the source. He asks Tingjun also to distribute that map to participants and to make a proposal of the map scale to work on.

5. Next meeting of the Action Group:

at the occasion of the next IPA congress in Russia (June 2012).

Task before that deadline: make the LPM map for your region ready (1st draft)

Also on the agenda, next to the discussion on these drafts and the connections at their meeting points:

- distinction in the lowlands (below 1000 m) to delineate the boundary between continuous and discontinuous permafrost,
- decision on the production of a paleo-temperature map.

In the meantime:

- provide intermediary results to Jef in order to prepare an extended abstract for the IPA-congress, before 15 January 2012.
- send relevant publications to participants

6. Publication:

- Preference is given to publication in BOREAS irrespective of the response to our inquiry to PPP. Special issue of BOREAS with also papers of related interest.
- Provisional results on next TICOP congress, co-authored by all participants.
- Sponsors will be mentioned on the map; IPA-logo will also occur on the map.

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ANNEX 3

Report of discussions held at the occasion of TICOP June 2012 in Salekhard, Russia

made up by Jef on 4th July 2013

Participants: Tingjun Zhang, Sergey Marchenko and Jef Vandenberghe

1. Report of the Action Group activities and state-of-the art for the IPA Council Meeting given by Jef on 23rd June. Summary attached. Result: approved by Council; see also point 4. Scientific abstract orally presented by Jef during session 8 (many reactions and questions). Abstract, see TICOP proceedings and attached.
2. Mapping:
 - *Ice sheets* during LGM should be included (N America already done, for Eurasia I suggest the map by Svendsen et al. 2004 in QSR - I can send a pdf on request);
 - Also include LPM *subsea permafrost*. We suggest, in a maximum approach, considering the presence of LPM subsea permafrost in all shelf areas between 0 m and -120 m; or, in a minimal approach, take present-day relict permafrost in that area (For Russia, map by Ershkov & Kondratieva 1991 at 1/2.500.000). Jef suggests to map a 'shaded area' without a line border because of the imprecision of the position of such a border.
3. Map Scale:

in accordance with Tingjun we finally propose to reproduce the final map at 1/20.000.000 + CD.
4. Ownership/copyright:

IPA insists to have the map online in digital format *freely available*. Jef will contact the editor of BOREAS. In case the publisher (Wiley) does not agree, we have to look for another journal (maybe 'open access' journal). Jef keeps contact with H. Lantuit for IPA on this and other matters (as reports of Action Group, finances).
5. Boundary between continuous/ discontinuous permafrost in regions below 1000 m altitude:

In principle, continuous permafrost zone should be restricted to the region where permafrost indicators are found in all conditions (also the unfavourable ones), while the discontinuous zone should incorporate the areas where permafrost indicators occur only in favourable conditions.

We see possibilities for Europe and Asia up to the Tibetan Plateau. East of the Tibetan Plateau, we deal mostly with high elevations. For N. America the permafrost zone is so narrow that a differentiation in cont-discont has probably no sense. Hugh, is that zone to be considered as 'discontinuous', it means including both kinds of permafrost?

Hugh, some people think that we should not distinguish mountain and alpine permafrost in the overall map, but group all of those elevated permafrost regions (>1000 m) under 'altitudinal permafrost'. What do you think, or do you agree? Of course, in the accompanying paper (see 8a) you could make and defend a specification for N America as you did in the text version you sent me by 15th June, if you like that.
6. Map of palaeo-temperatures (MAAT):

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In principle, the mean annual air temperatures corresponding with boundaries of continuous and discontinuous permafrost could be derived from modern analogues. One practical problem is that those modern temperatures are not the same everywhere; for the southern permafrost boundary: -4° in N America (correct Hugh?), -4° in Europe, -3° in Russia (according to the map by Andrey?, but higher (up to -0.5°) as told by other Russian scientists), in China also $>-4^{\circ}$. For the cont-discont boundary a temperature of -8° could be taken. In addition, present-day and past temperature-permafrost relations may be slightly different (French, 2007). Finally, they depend on local conditions as topography, soil lithology, vegetation and snow thickness.

It appears from those considerations, and we have to stress that, such reconstructed temperatures are an average. Consequently, an error bar of $\pm 2^{\circ}$ may be adopted.

Such a palaeo-temperature map could be made at smaller scale.

7. Time schedule:

- Mapping to be terminated by the end of summer 2012 for Kazakhstan and China; other regions are almost ready by now.

- Tingjun sends a completed base map to all participants by 15th July.

- 1st October: drafts (manually on the base map) are to be sent to Jef. It is advised to talk before with neighbours to fit the boundaries between sectors with each other.

- October- November: Jef will check for uniformity of procedures and final result and –if necessary- communicates with participants about changes. Jef compiles one map for the northern hemisphere, and sends this draft to Tingjun by 1st December.

-December-January 2013: preparing map in Boulder for publication, and communication between participants, Jef and Tingjun where necessary.

8. Special issue:

a. As an Action Group we have to prepare a text explaining objective, principles, importance, working method of our map. It might also include the palaeo-temperature map (see 6). But Jef thinks it is also interesting to derive some (first) conclusions from the results of the LPM permafrost boundaries. Apart from such a general paper, papers may ideally be prepared for each individual sector (Hugh made already a draft for the N America sector).

b. As discussed before, we hope to attract a number of manuscripts, not specifically from our group, on LPM permafrost matters (geoscientific reconstructions and modelling). Advertising for such manuscripts was not possible at TICOP and thus should be done now. Each of us should use his own contacts and contact lists to invite such manuscripts. I will use at least the membership list of the IGU Commission on 'Cold environments'. Other suggestions, initiatives and actions are welcomed.

Tentative time frame:

-Manuscripts to be delivered by 15th January 2013;

-Reviewing finished by 15th March;

-Revision finished by 15th May;

-Last corrections finished by 15th June 2013.

9. Additional participation:

Some individuals may wish to follow the progress of our work and are even interested to contribute where possible. We suggest including them in our mailing list, but keep the 'participant list' as we have it until now.

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Dr. K. Saito, University of Alaska, Fairbanks is such a person (modeller with field experience in easternmost Asia).

Final important remark:

All the mentioned items are the results of talking with a limited number of people. Therefore, this text has to be regarded as a draft and I invite all of you urgently to look at the described items and express your agreement, give additional suggestions and/ or amend at specific points. Please do it before 1st July.

State-of-affairs June 1st 2012:

per geographical sector:

- North America: update of the 1983 Péwé map in North America (ready) and map for the ice-free areas adjacent to the Laurentide Ice Complex in Canada and Alaska (ready)- provisional accompanying text by French ready, summarising advances in understanding of the extent of past permafrost and the problems of mapping relict and past permafrost.
- west, south and central Europe: update of the existing map by Vandenberghe et al. 2008 ready in draft by Vandenberghe (new data from France and Hungary for the southern permafrost boundary).
- Asian Russia: update of Velichko and Nechaev map of 1992, produced by Velichko and co-authors (ready).
- China: no progress until now, will be started in the next months by H. Jin
- Kazakhstan: no news.

map production and publication:

base-map production: first draft available, to be continued by full-time post-doc starting in June or July 2012 at NSIDC also taking care for the final map compilation.

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