Dynamic inland propagation of thinning due to ice loss at the margins of the Greenland ice sheet

Weili Wang[1]

Jun Li[1]

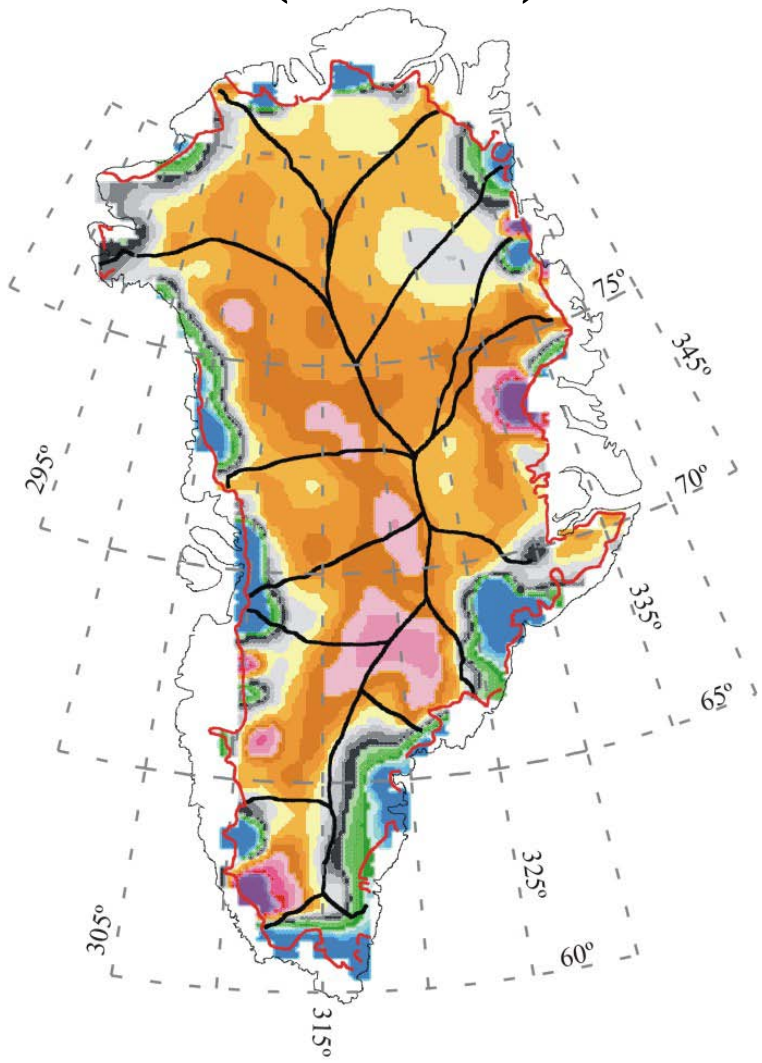
Jay Zwally[2]

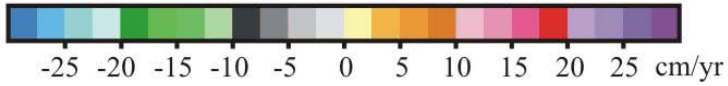
1. SGT, NASA/GSFC, Code 615, Greenbelt, MD 20771, USA
2. Cryospheric Sciences Branch, NASA/GSFC, Code 615, Greenbelt, MD 20771, USA

CESM-LIWG Meeting, February, 15-17,2012

Elevation Change (dH/dt)

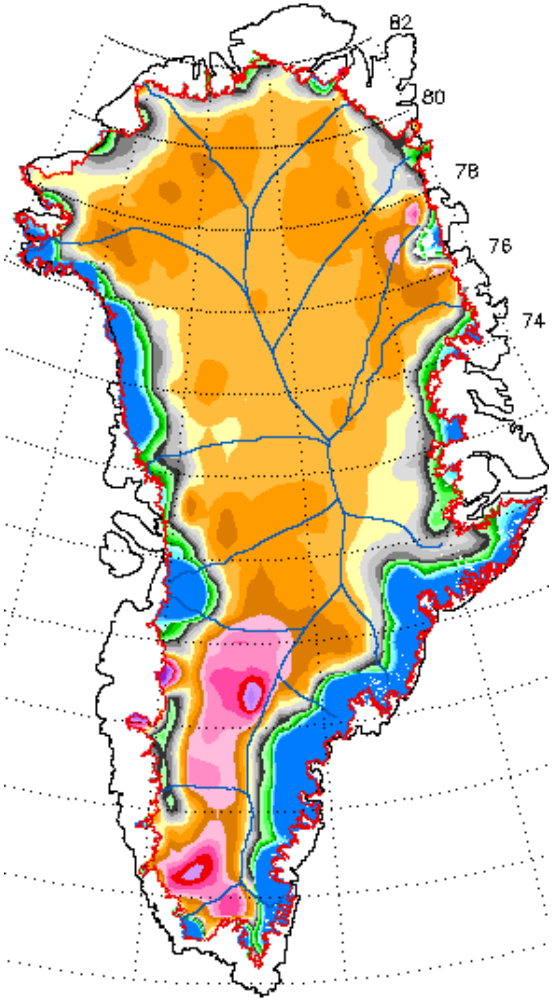
ERS (1992-2002)

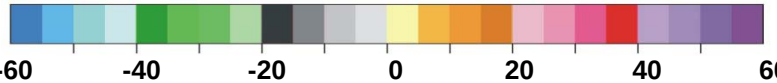




(Zwally, et. al. 2005)

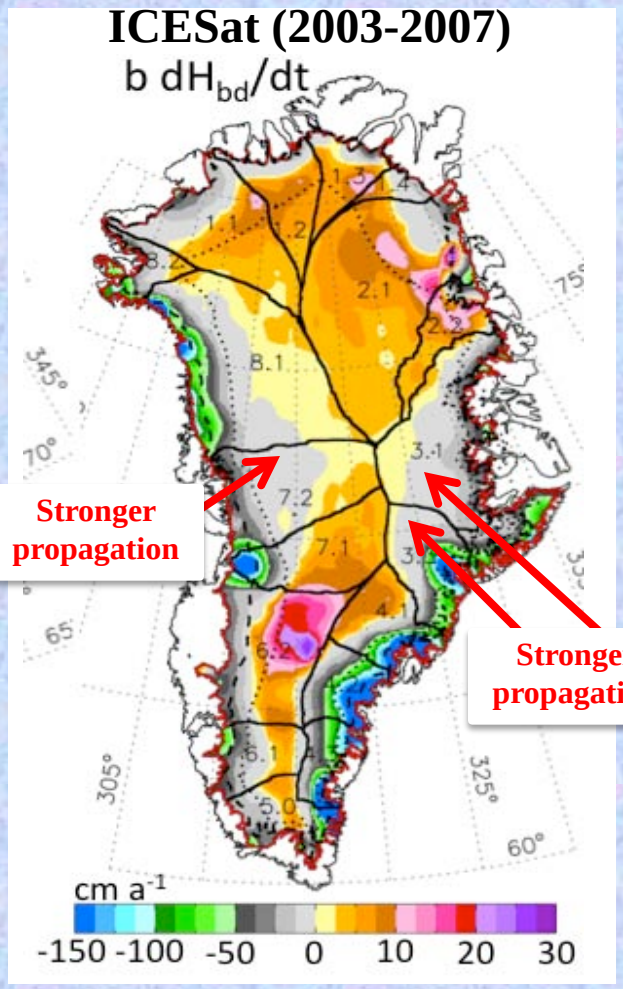
ICESat (2003-2007)

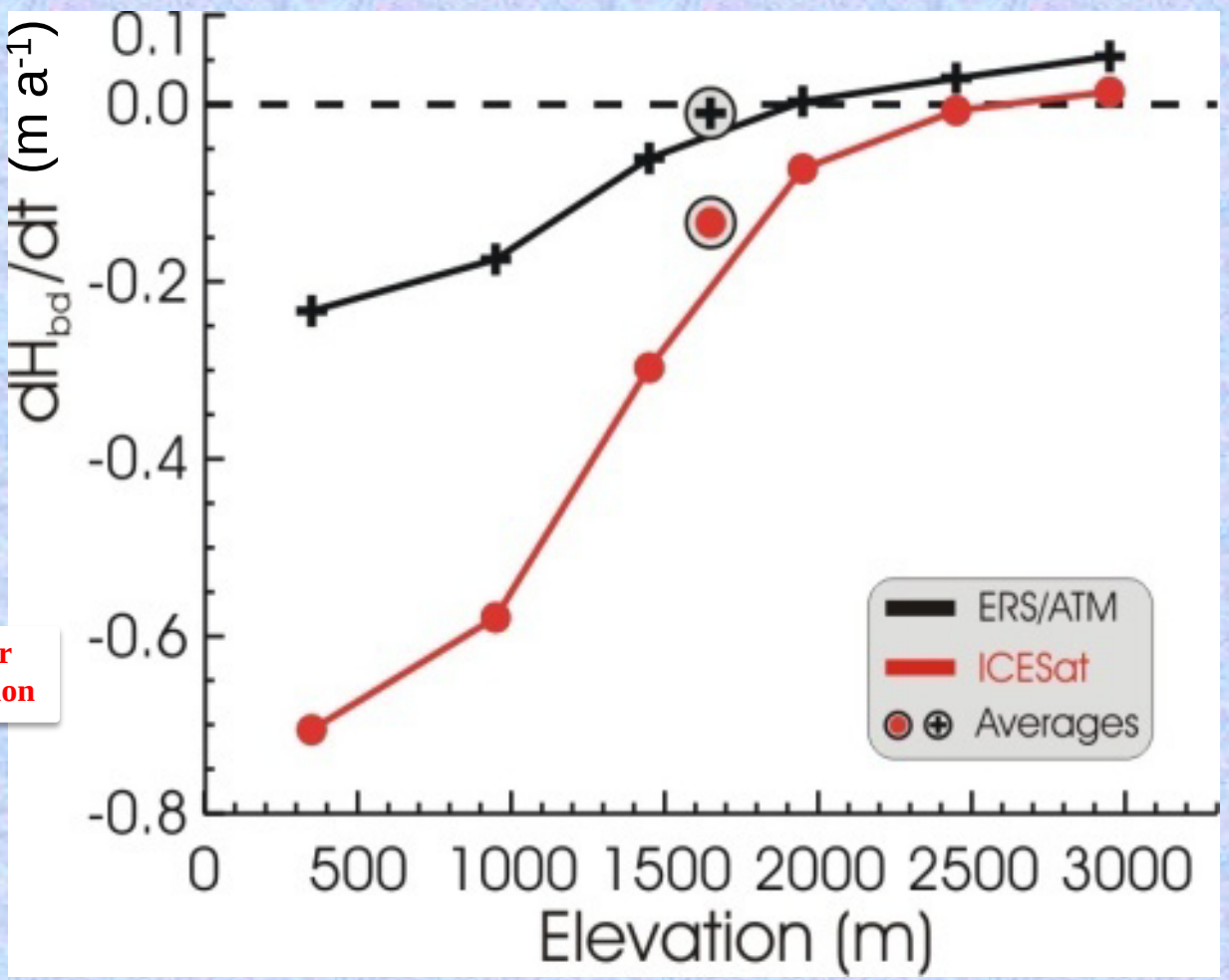




(Zwally, et. al. 2011)

Elevation Change (dH_{bd}/dt)





(Zwally, et. al. 2011)

dH_{bd}/dt : The rate of the ice-thickness change driven by changes in ice dynamics and ablation (below equilibrium line only).

Questions

1. How far and how rapidly will the strong mass loss from the coastal regions propagate inland?

2. How many years will the impact remain?

Greenland Ice-sheet Model

- A 3D time-dependent model is applied to the Greenland ice sheet to investigate the upstream propagation.

- The satellite (ICESat and ERS) derived dynamic thickness changes (dH_{bd}/dt) in the regions below 2000m of the ice sheet are used as the perturbation inputs.

Greenland Ice-sheet Model

Model Features:

- **Three dimensional**
- **Time dependent**
- **50km horizontal resolution and 31 vertical layers**
- **Finite difference scheme**
- **Thermo-mechanical (*temperature dependent flow rates*)**
- **Basal sliding and melting**
- **Depth-dependent enhancement factor based on the stress configurations (*Anisotropic ice rheology*)**
- **Higher-order**

Flow Law For Anisotropic Ice

$$\dot{\varepsilon}_{shear}^{3} - E(\lambda_c)A(T)\tau_{shear}^{3}(\dot{\varepsilon}_{shear}^{2} + \dot{\varepsilon}_{long}^{2}) = 0$$

Higher-order term

Enhancement factor:

$$E(\lambda_c) = E_s(E_c / E_s)^{\lambda_c}$$

$$\lambda_c = \tau_{long}^{'} / (\tau_{shear}^{2} + \tau_{long}^{'2})^{1/2}$$

Along with λ_c varies from ***1*** (τ_{shear}=*0*) to ***0*** (τ_{long}=*0*) enhancement factor ***E*** increases from ***3*** to ***10***, which corresponds to the fabric changes from small-circle girdle pattern to single-maximum pattern.*(Wang and Warner, 1998).*

Greenland Ice-sheet Model

Model inputs

Constant data

- Surface mass balance
- Surface temperature
- Bedrock
- Basal geothermal heat flux
- Perturbation input (dH_{bd}/dt)
  (<2000m elevation)

Model outputs

Time serial data

- Ice-sheet thickness
- Temperature
- Velocities
- Stresses
- Strain-rates

The Model Experiment

Step 1:

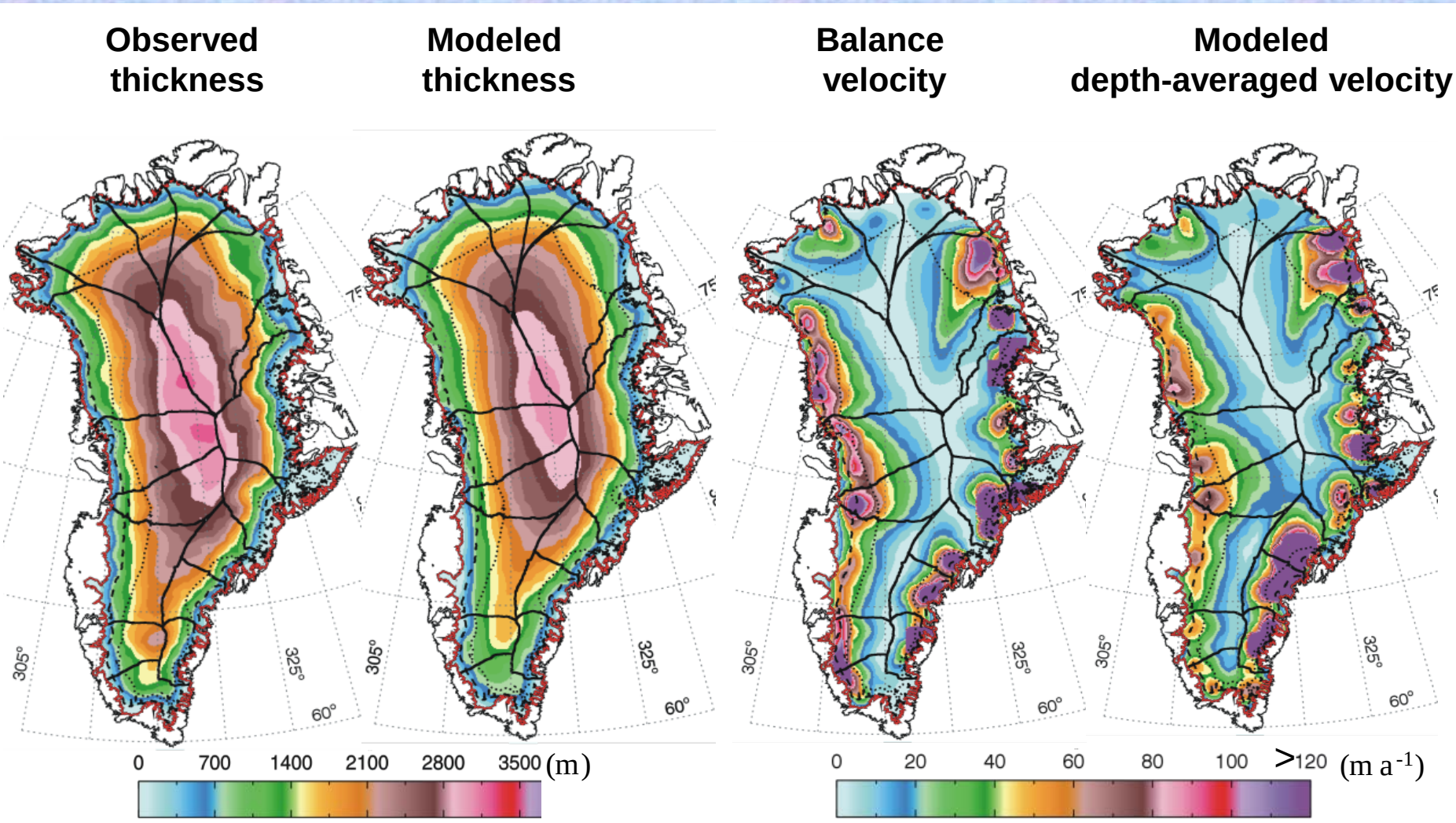
Establishing a steady-state ice sheet corresponding to present climate conditions.

Step 2:

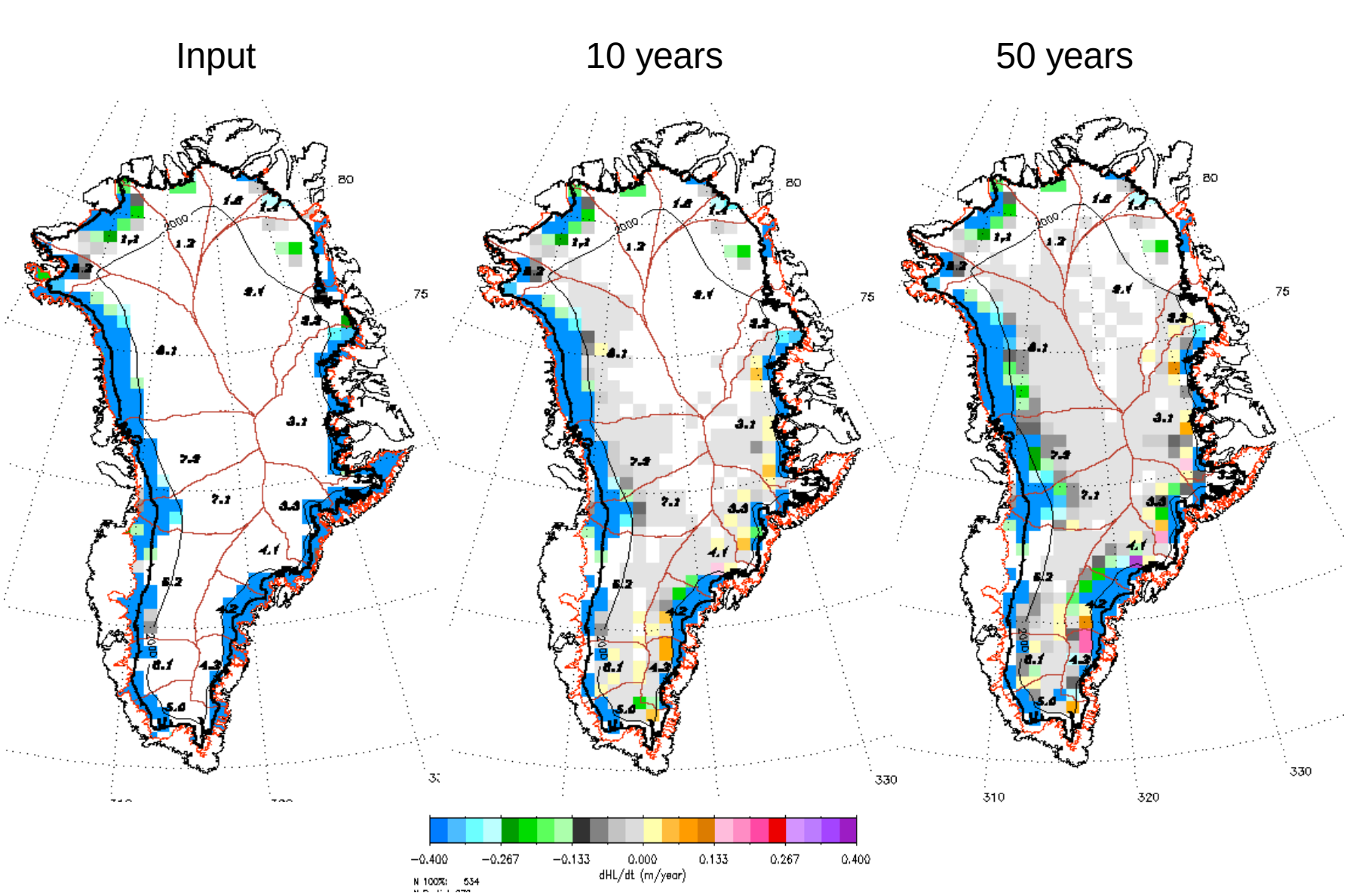
Running the model forward with the perturbation inputs for 10 years.

perturbation inputs = dH_{bd}/dt (ICESat – ERS) below 2000m elevation.

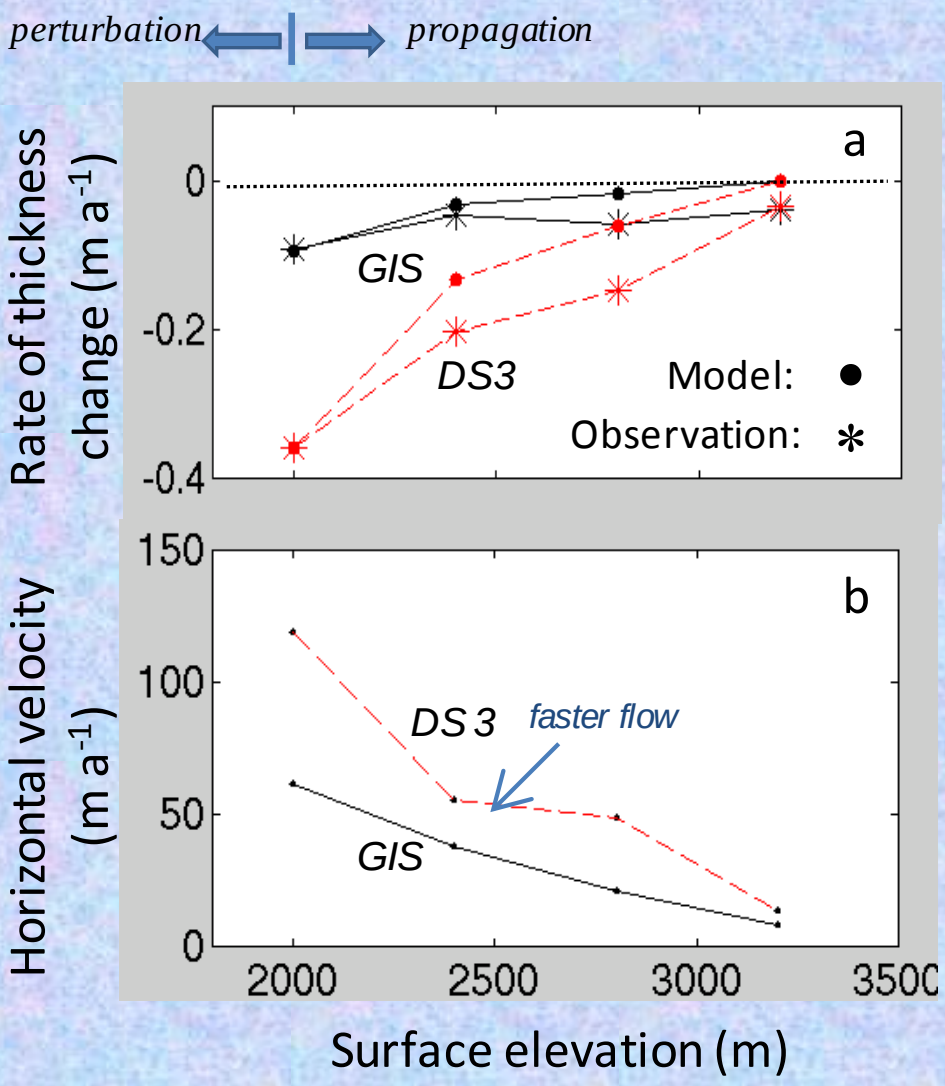
The Model Experiment



The Model Experiment (dH/dt)



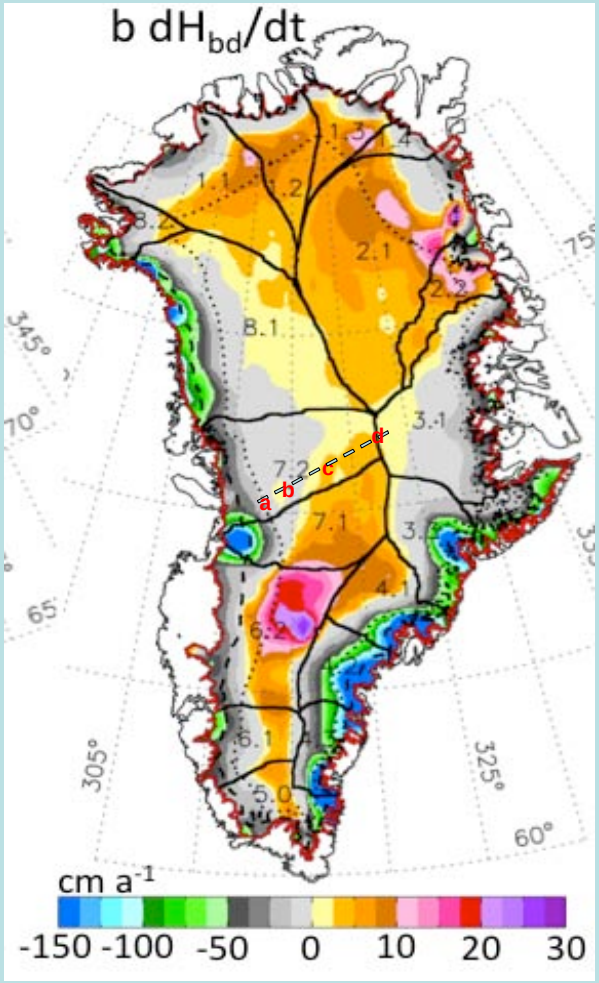
Compression



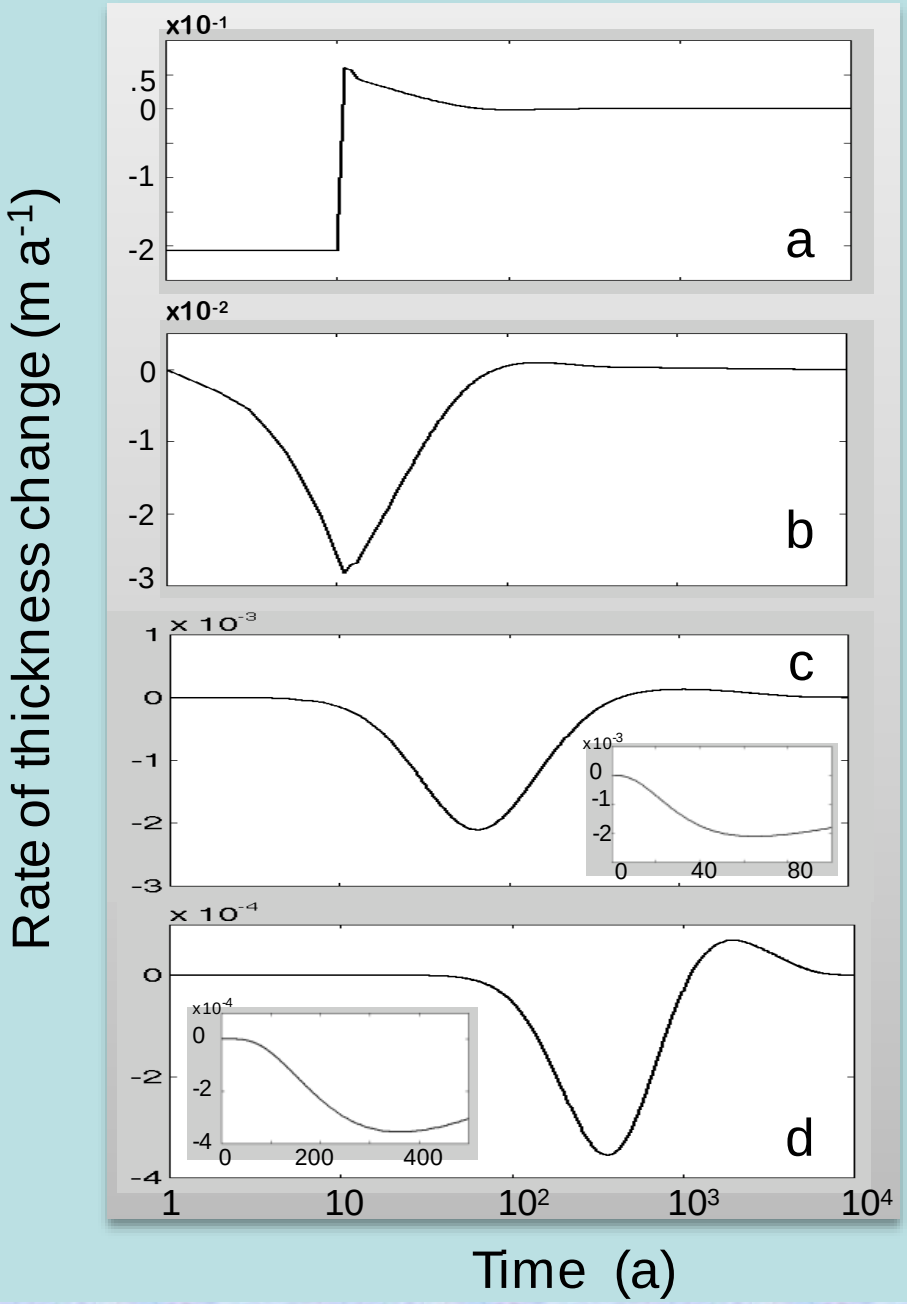
DS3: Drainage System 3.

GIS: Over the whole ice sheet.

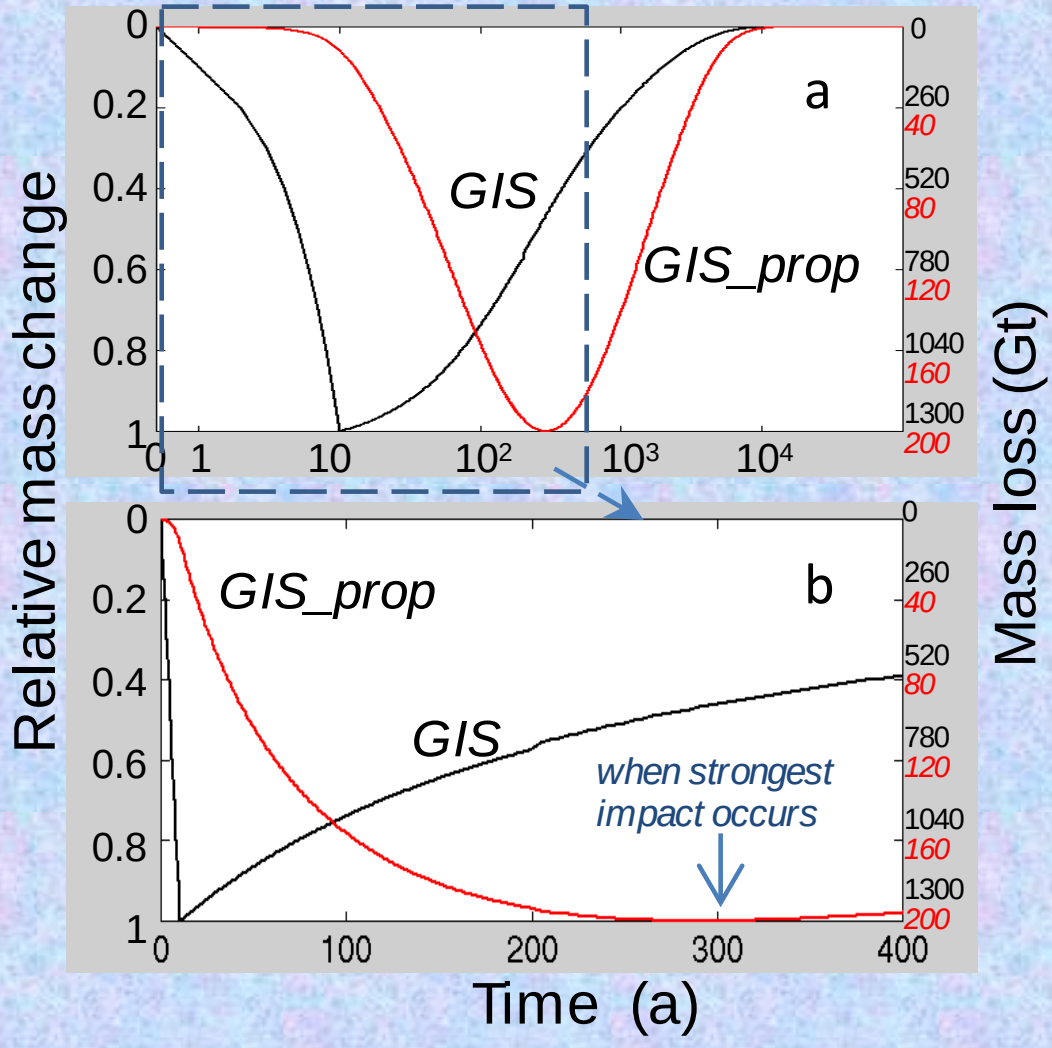
The Model Experiment (dH/dt)



a: at perturbation area.
b: ~100 km to *a*.
c: ~200 km to *a*.
d: ~400 km to *a*.



Ice-sheet change



GIS:	*Over the whole ice sheet.*
GIS_prop:	*Ice sheet above 2000m .*

Conclusions

- **The strong mass loss since the early 2000's at low elevations has had a dynamic impact on the entire ice sheet.**
- **The strongest impact for an isolated 10-year perturbation will occur at 300 years, and it will take 10ka for the complete dynamic recovery.**
- **Even if the large mass loss at the margins stopped, the interior ice sheet would continue thinning for 300 years.**

Wang, W., J. Li and J. Zwally. Dynamic inland propagation of thinning due to ice loss at the margins of the Greenland ice sheet. ***Journal of Glaciology***. In press.

INTERNATIONAL GLACIOLOGICAL SOCIETY

International Symposium on

Changes in Glaciers and Ice Sheets:
observations, modelling and environmental interactions

Beijing, China
28 July–2 August 2013

Co-sponsored by:
- Institute of Tibetan Plateau Research, Chinese Academy of Sciences (ITP, CAS)
- Cold and Arid Regions Environment and Engineering Research Institute, Chinese Academy of Sciences (CAREERI, CAS)
- Chinese Academy of Sciences (CAS)
- National Natural Science Foundation of China (NSFC)
- Third Pole Environment (TPE)

FIRST CIRCULAR
February 2012
http://www.igsoc.org/symposia/
http://www.localsite.cn/

The International Glaciological Society will hold an International Symposium on 'Changes in Glaciers and Ice Sheets: observations, modelling and environmental interactions' in 2013. The symposium will be held in Beijing, People's Republic of China, from 28 July to 2 August 2013

THEME

Glaciers and ice sheets are important components that control sea level change. In response to a warming climate, Greenland and West Antarctic ice sheets have significantly lost mass during the last decade, and mountain glaciers worldwide have rapidly declined. Changes in mountain glaciers have direct impacts on human activities, especially in mid-latitude regions, where high-altitude snow and ice contribute to the hydrological controls of human activity. Therefore, the symposium specifically includes topics pertinent to the Earth's 'Third Pole'. To improve our understanding of the dynamics of cryospheric change, interactions with the climate and impact on the living environment of mountainous regions, it aims to provide a general discussion of changes in these components of the global cryosphere with broader aspects from recent in situ observations, remote sensing measurements and modelling efforts.

TOPICS

Meeting participants are encouraged to present on a wide variety of topics. These include:

1. *Assessment of the current state of ice sheets and glaciers*, and their trajectories of change, determined by remote sensing, including airborne and satellite
2. *Remote sensing methodologies and techniques* for providing critical information on glacier and ice sheet profiles, thickness, melt patterns, flow fields, snow layer characteristics and other parameters relevant to the changing cryosphere
3. *Ground-based field studies* of glacier and ice sheet change, including in-situ observations of mass and dynamic changes of mountain glaciers, ice caps, ice sheets and ice shelves, glacier inventories and firn layers, permafrost, snow cover, and observation method
4. *Ice-core records* of past change that is relevant to understanding the current changing states of ice sheets and glaciers both in polar and non-polar environments; special emphasis will be placed on ice-core records from Asia
5. *Subglacial and proglacial sediment–landform* records relevant to understanding present rates of ice sheet and glacier change
6. *Glacier and ice sheet mass balance*, including glacier meteorology, surface energy exchange, snow accumulation processes, mass-balance indices and the relation between glacier mass balances and atmospheric indices. Verification and assessment from in situ observations and remote sensing techniques. Challenges related to scaling assumptions
7. *Assessment of changing ice in the 'Third Pole'*, impacts and drivers. Including glacier monsoon meteorology, dust impact on snow and ice albedo, proglacial lake dynamics, debris-cover effects and human impacts, commonalities between Asian and South American glacier systems
8. *Modelling the processes of glacier and ice-sheet change*, including the thermal and mechanical processes that govern how ice-sheets and glaciers respond to changing environmental conditions. Partitioning of climatic and dynamic mass-balance components, key unknowns, critical observations and limitations to progress
9. *Projection and prediction* of changing glaciers and ice sheets, response to climate change, ice-atmosphere-ocean iterations. Challenges of downscaling methods. Model intercomparison. Sea-level rise experiments specifically designed to inform policy makers, including the AR6 of the IPCC
10. *Glacio-hydrological processes* that have a bearing on accelerating current rates of ice-sheet and glacier change, including the impact of meltwater and subglacial processes in glacier changes, supraglacial water effects, ice-shelf stability in response to surface meltwater ponding, surface lakes on Greenland, moulin dynamics
11. *Hazards and societal impacts* relating to changing glaciers and ice sheets, including the contribution of glacier wastage on sea-level rise, water resources in different climate, glacier engineering, glacier hazards, glacier outburst floods, ocean circulation, terrestrial and marine bio-geochemical cycles and ecosystems, as well as isostatic changes
12. *General glaciology*: all topics relevant to glaciological science are welcome at the symposium (subject to time and space availability); however, presenters wishing to publish papers on topics not related to those listed above will be invited to submit their manuscripts to the *Journal of Glaciology* rather than to the specifically themed *Annals of Glaciology*.

Additional topics may be added on the basis of requests and abstract submissions. Questions and ideas can be referred to the co-Chief Editors/ co-Chairs of the Scientific Committee.

PROGRAMME

The symposium will consist of a mixture of oral and poster sessions, with a large amount of free time to allow participants to exchange scientific information in an informal setting. Wednesday afternoon will be reserved for a symposium activity or excursion. A symposium banquet will be held on Thursday evening. A post-symposium tour to the Tibetan Plateau and gaciers is currently being contemplated by the organizing committee and will be announced later.

ABSTRACT AND PAPER PUBLICATION

Participants wishing to present a paper at the symposium are required to submit an abstract. A digest of submitted abstracts will be provided to all participants at the symposium. The Council of the International Glaciological Society has decided to publish a thematic issue of the *Annals of Glaciology* on topics consistent with the Symposium themes. Participants and non-participants alike are encouraged to submit manuscripts for this volume.

SYMPOSIUM ORGANIZATION

Magnús Már Magnússon (International Glaciological Society)

SCIENCE STEERING AND EDITORIAL COMMITTEE

Douglas MacAyeal (University of Chicago, USA) and Weili Wang (NASA, USA),
Co-Chief Editors. Scientific editors for the special themed issue of *Annals of Glaciology* will be chosen in the near future.

LOCAL ORGANIZING COMMITTEE

Qin Dahe (Co-Chair), Yao Tandong (Co-Chair), Weili Wang, Ren Jiawen, Ding Yongjian, Wang Ninglian, Tian Lide, Xu Baiqing, Kang Shichang, Wu Guangjian

FURTHER INFORMATION

If you wish to attend the symposium please log on to the IGS website at
http://www.igsoc.org/symposia/2013/china/preregistration/
and register your details and interest in attending the symposium.

Although we strongly encourage prospective attendees to register online it can also be done by filling in and returning the form on the back page of this circular as soon as possible.

The Second Circular will give further information about accommodation, the general scientific programme, additional activities, preparation of abstracts and final papers. Copies will be sent to those who pre-register or return the attached reply form. Members of the International Glaciological Society will automatically receive one. Information will be updated on the conference website, http://www.igsoc.org/symposia/2013/china/ and the local website when this is set up (a link will be introduced on the IGS site).