Western Canadian Cryospheric Network
WC^2N - Recent Progress

Investigators:

Andrew Bush (**U. Alberta**); John Clague (**SFU**); Garry Clarke (**UBC**); Stephen Déry (**UNBC**); Peter Jackson (**UNBC**); Shawn Marshall (**U. Calgary**); Brian Menounos (**UNBC**); Dan Moore (**UBC**); Dan Smith (**U. Victoria**); Eric Steig (**U. Washington**); Roger Wheate (**UNBC**)

Research Collaborators:

Doug Clark (**Western Washington University**); Mike Demuth (**Natural Resources Canada**); Howard Conway (**U. Washington**); Kenichi Matsuoka (**U. Washington**); Joseph McConnell (**Desert Research Institute –** U. Nevada); Al Rasmussen (**U Washington**); Sonia Talwar (**Natural Resources Canada**); Paul Whitfield (**Environment Canada**)

Research Partners:

BC Hydro; BC Ministry of Sustainable Resources Management; BC Parks; BC Ministry of Environment (MoE); Columbia Basin Trust (CBT); Fisheries and Oceans Canada (DFO); Environment Canada - Cryosphere System in Canada (CRYSYS); Environment Canada - Meteorological Service of Canada (MSC); Global Land Ice Measurement from Space (GLIMS); Natural Resources Canada - National Glaciology Programme (NGP); Natural Resources Canada - Terrain Sciences Division National Snow and Ice Data Center (NSIDC); Parks Canada

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Fondation canadienne pour les sciences du climat et de l'atmosphère (FCSCA)

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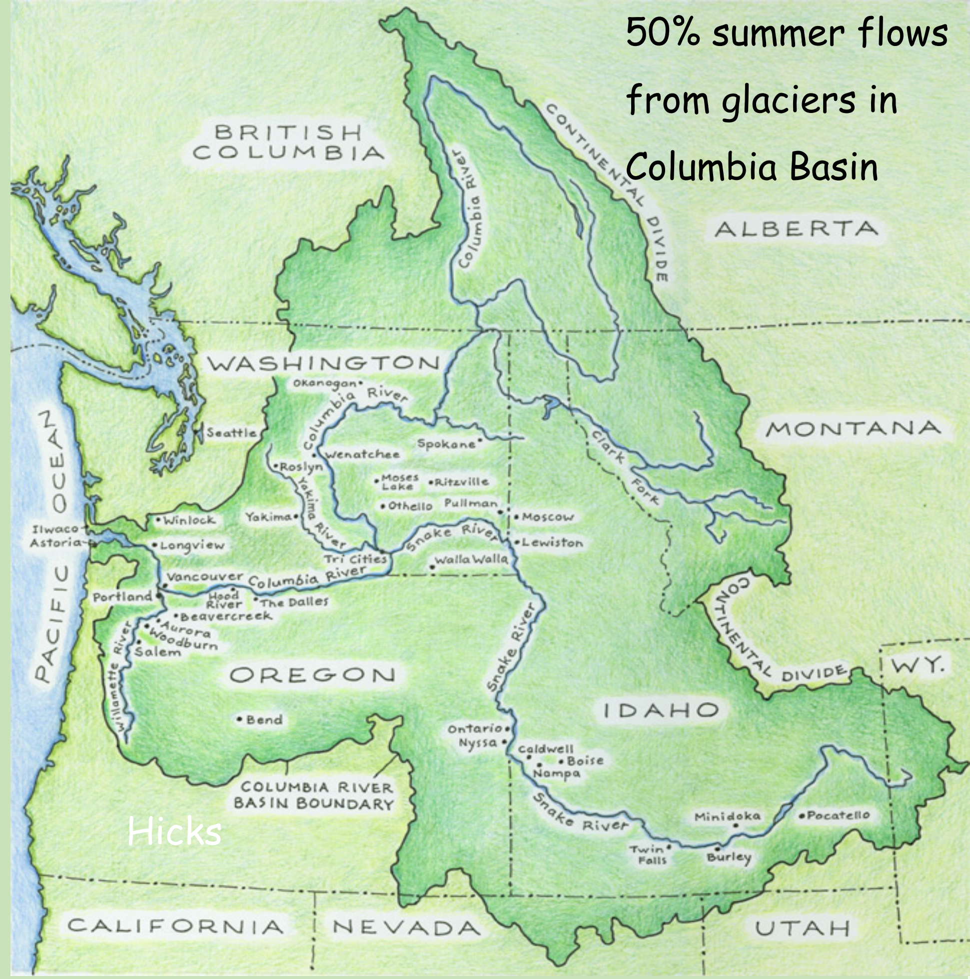
Western Canadian glaciers

- Natural climate stations
  - Winter ppt.; summer temp.

- Critical resource
  - 30, 000 km^2 in BC (~ 3% landmass)
  - Freshwater (Canada and US)
  - Downstream ecosystems vulnerable:
    flow regulators
    thermostats
  - Hydro power from surface runoff
    (90% BC; 17% AB)

50% summer flows from glaciers in Columbia Basin



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Western Canadian Cryospheric Network (WC^2N)

- Research Objectives

1) Document N. Pacific climate variability and glacier extent (400 yrs to present)

2) Detail meteorological processes and their links to glacier nourishment (glacier mass balance)

3) Predict how glaciers will respond to projected climate change over the next 50-150 years

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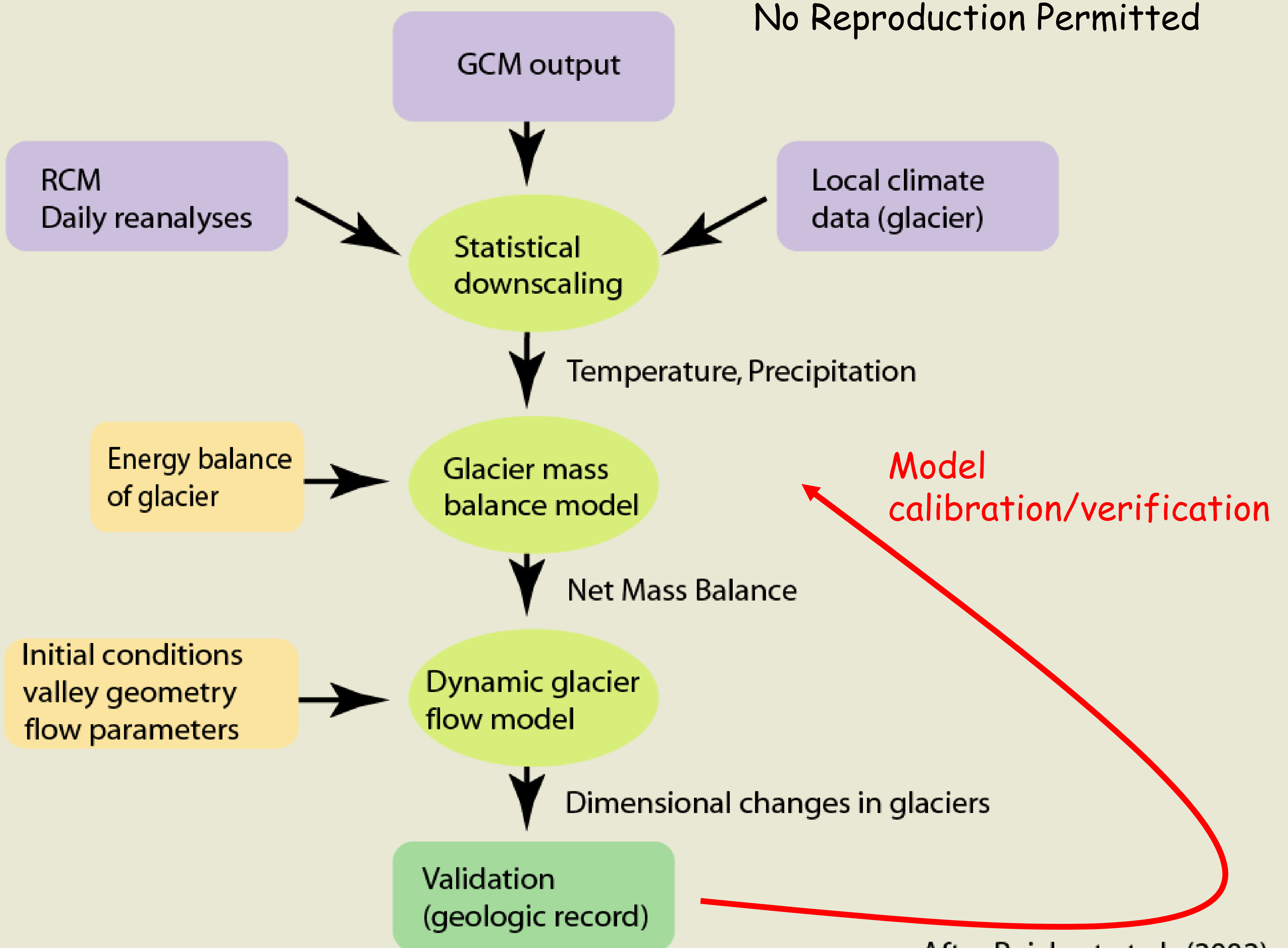
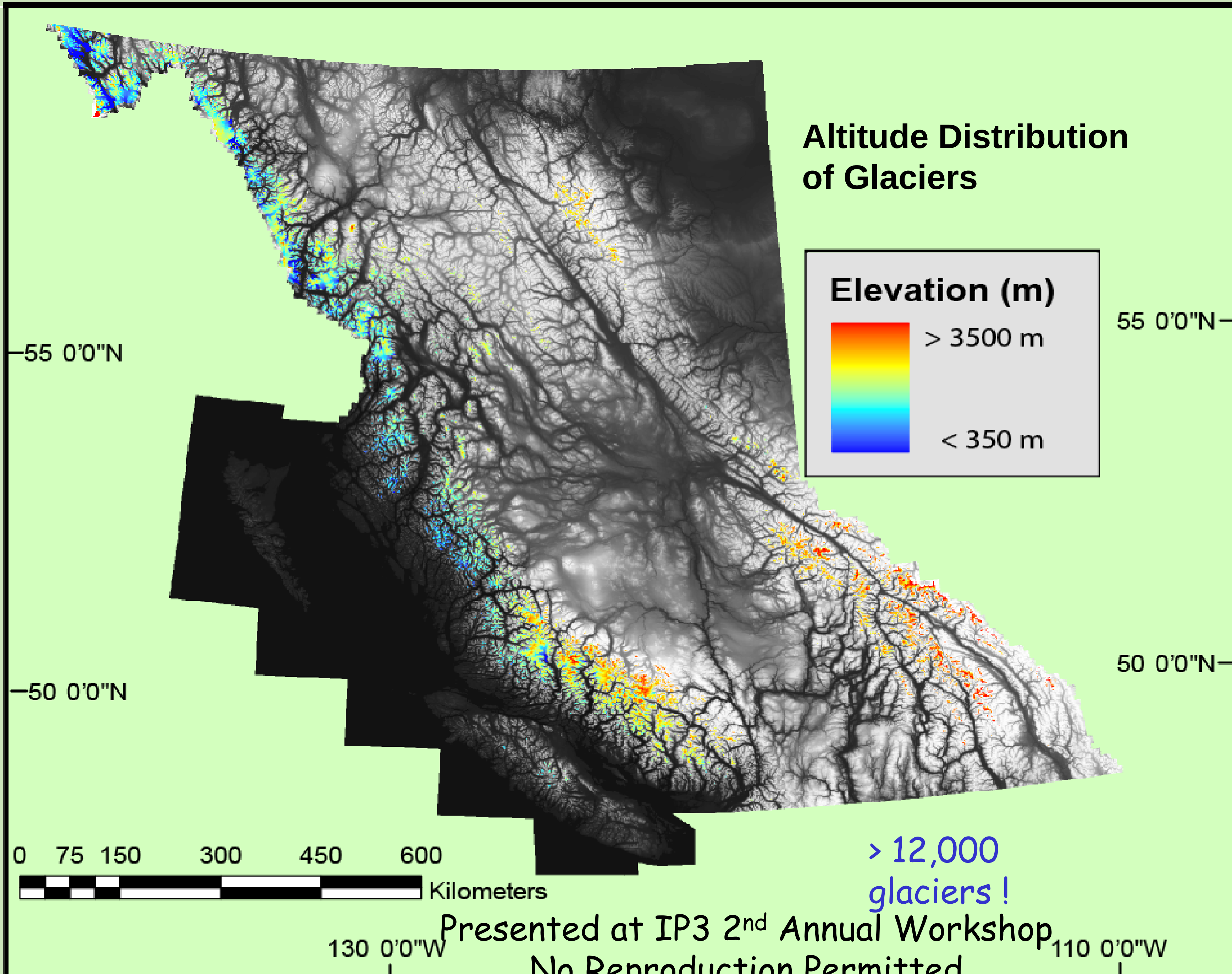


After Reichert et al., (2002)



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Targeted Regions

1) S. Coast Mountains (BC Hydro)

2) Columbia, Selkirks (BC Hydro; CBT)

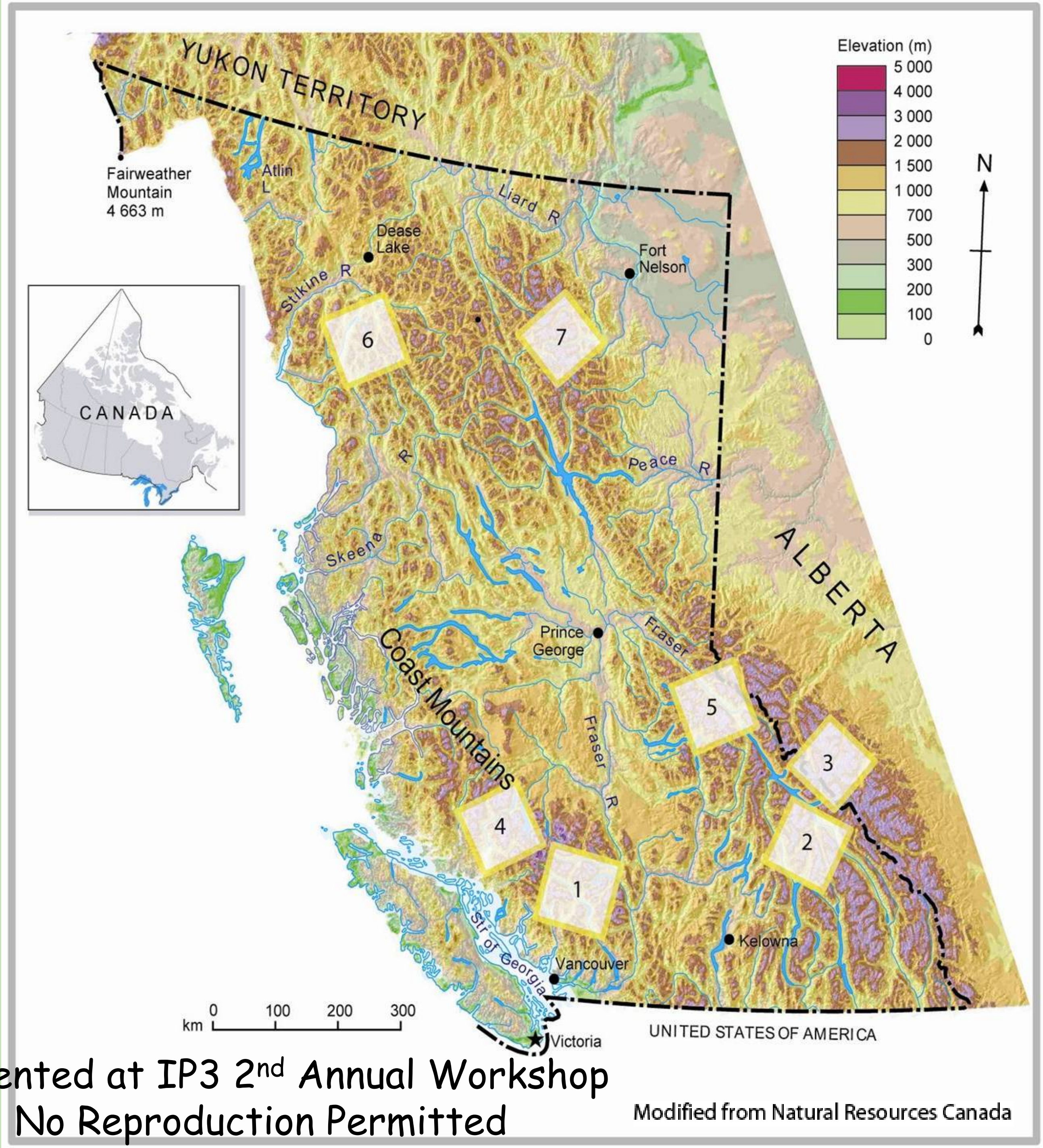
3) S. Rockies

4) Waddington, Homathko

5) Cariboo Mtns. (Quesnel)

6) Central-N. Coast

7) N. Rockies



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Western Canadian Cryospheric Network (WC^{2}N)

- Research Objectives

1) Document N. Pacific climate variability and glacier extent (400 yrs to present)

- Dan Smith (U of Victoria)
- Eric Steig (U of Washington)

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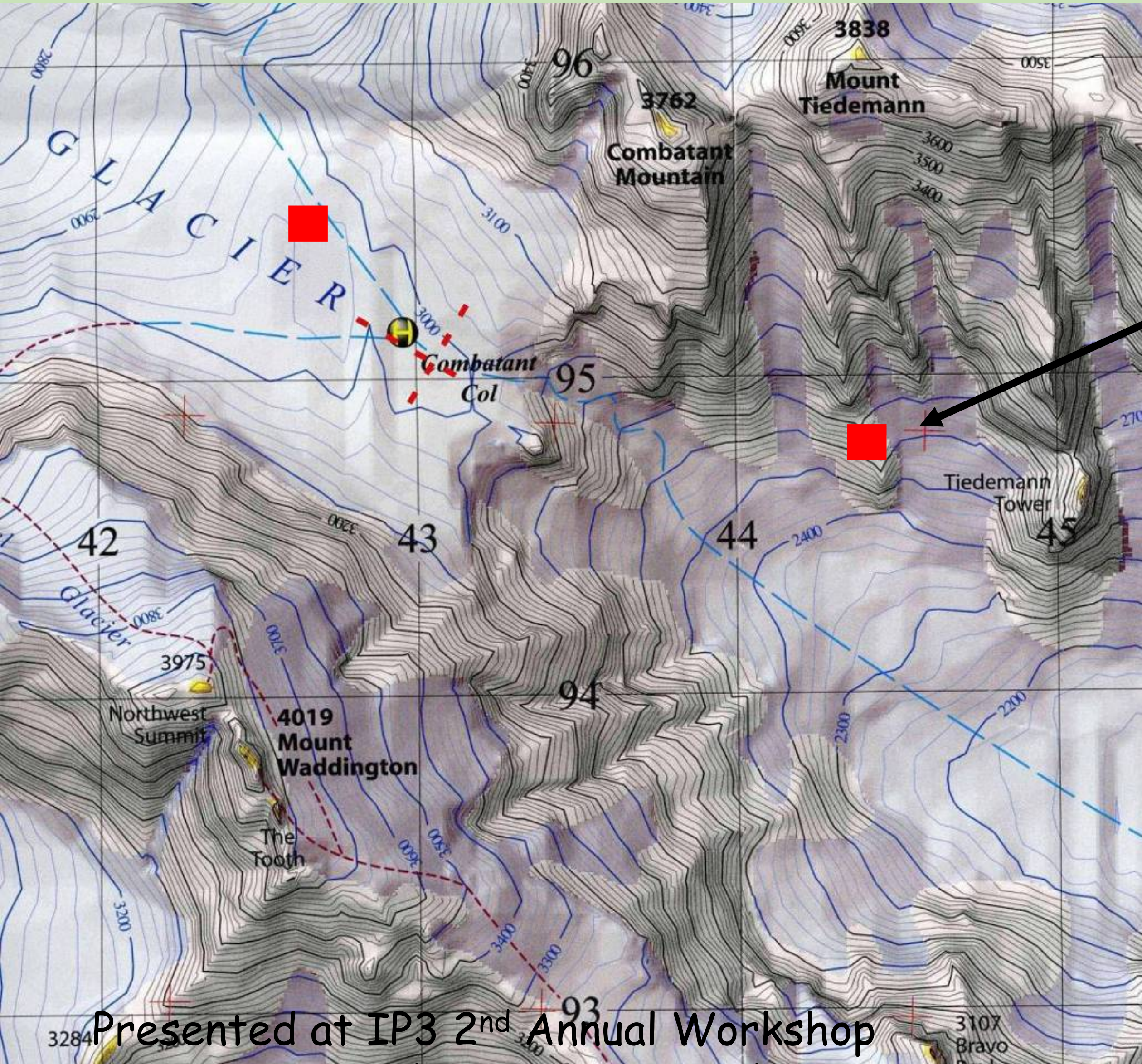
Combatant Col, Coast Mtns., BC



Sunny Knob Weather station

E. Steig and D. Clark

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ICDS 4" Drill and Combatant Mt.

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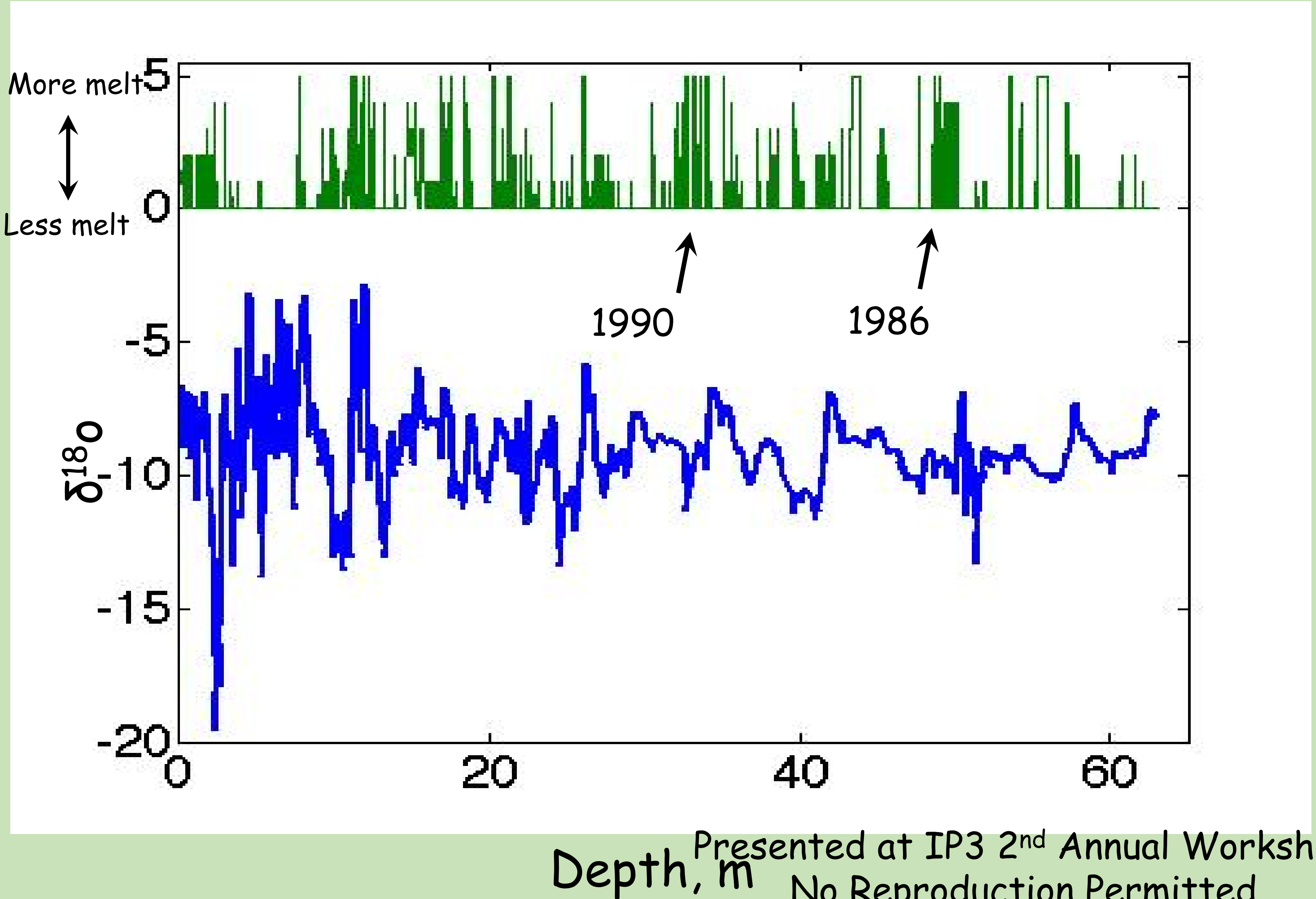
Isotope, Melt Stratigraphy



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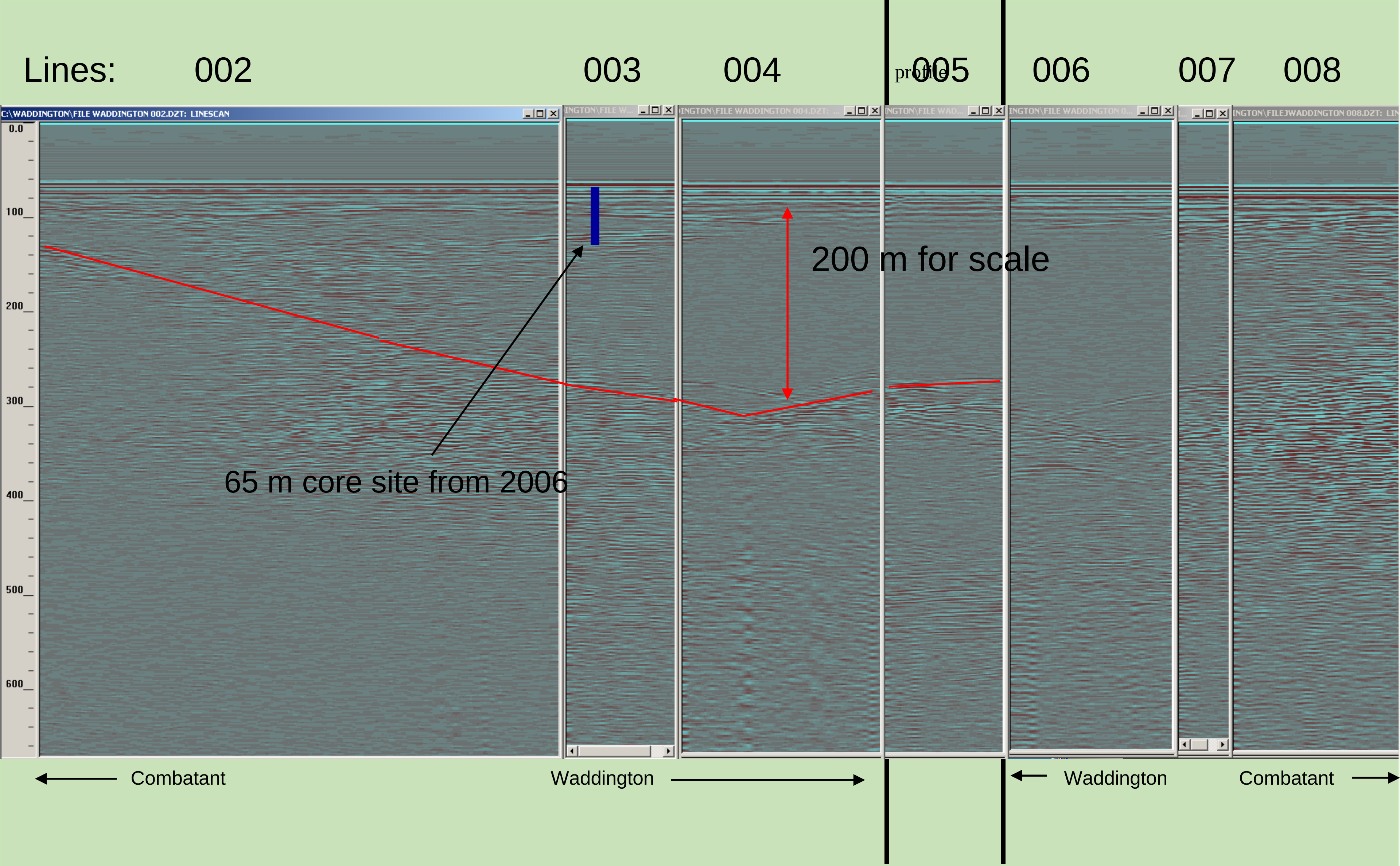

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Western Canadian Cryospheric Network (WC^{2}N)

- Research Objectives

1) Document N. Pacific climate variability and glacier extent (400 yrs to present)

   - Roger Wheate, Brian Menounos
   - John Clague (SFU)
   - Dan Smith (U of Victoria)

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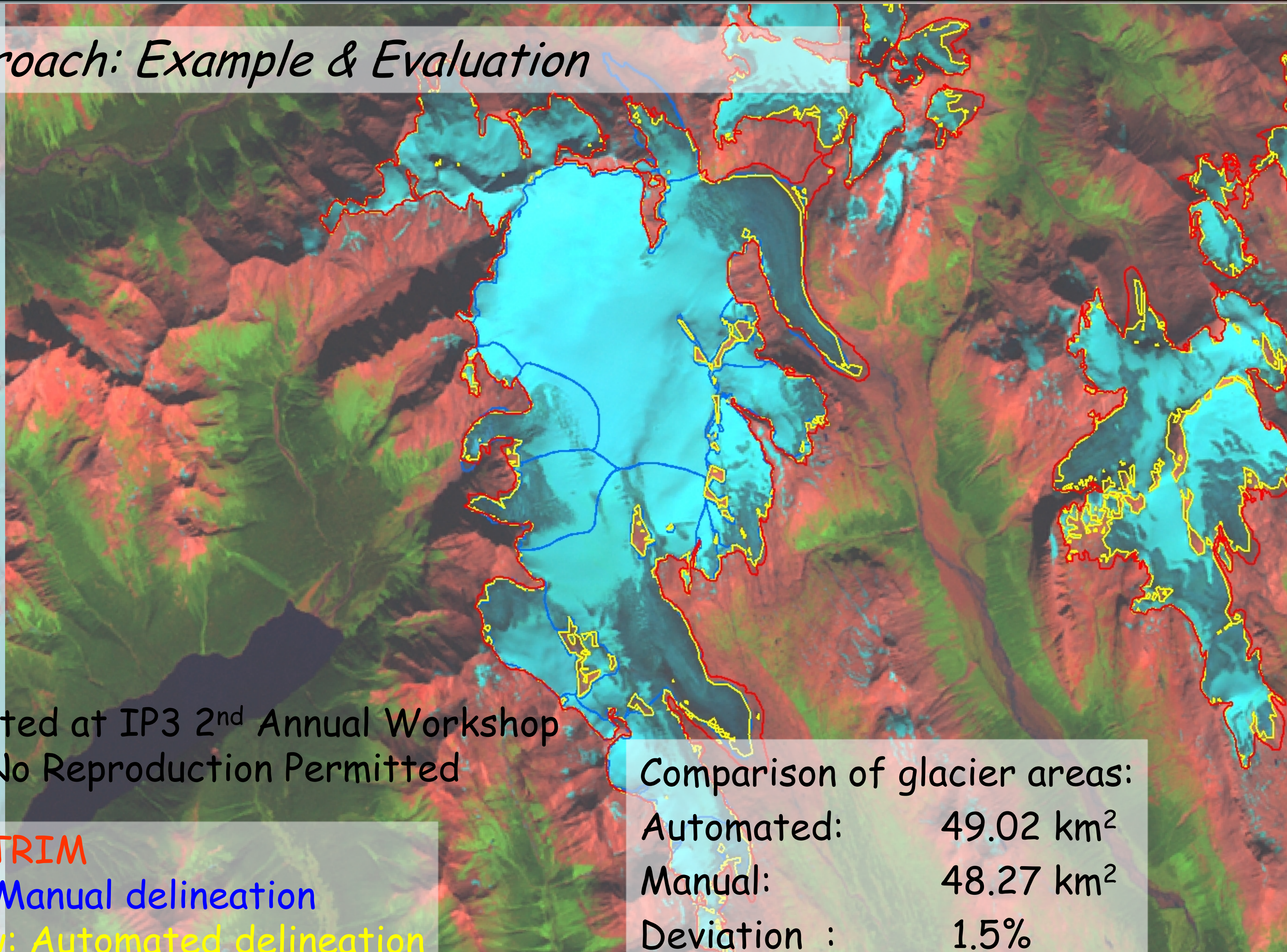
Satellite-based Glacier Inventory for Western Canada

Canadian Foundation for Climate and Atmospheric Sciences (CFCAS)
Fondation canadienne pour les sciences du climat et de l'atmosphère (FCSCA)

Approach: Example & Evaluation



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Red: TRIM
Blue: Manual delineation
Yellow: Automated delineation

Comparison of glacier areas:

Automated:	49.02 km^2
Manual:	48.27 km^2
Deviation :	1.5%

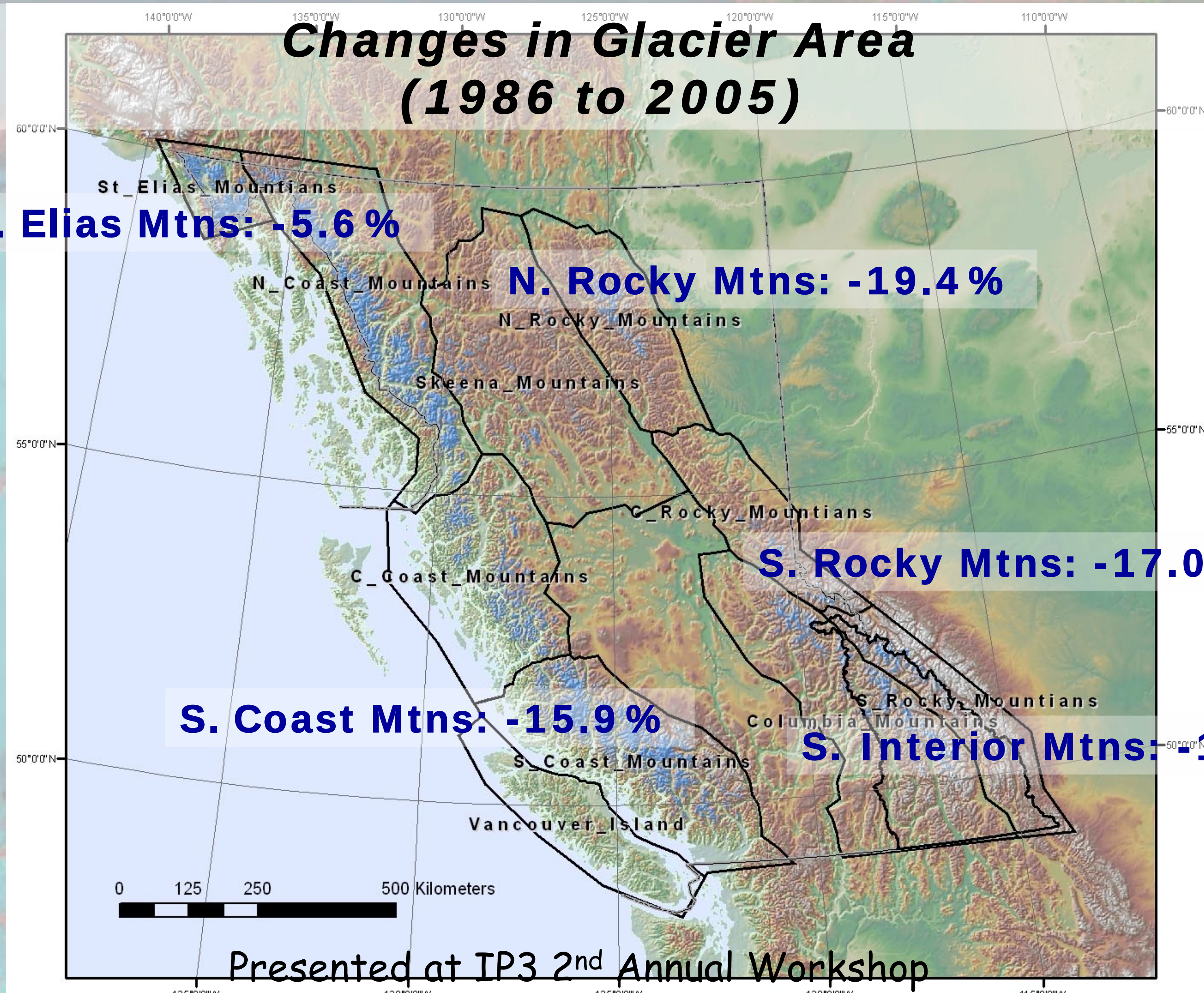
Tobias Bolch

Satellite-based Glacier Inventory

UNBC

Canadian Foundation for Climate and Atmospheric Sciences (CFCAS)
Fondation canadienne pour les sciences du climat et de l'atmosphère (FCSCA)

Changes in Glacier Area (1986 to 2005)



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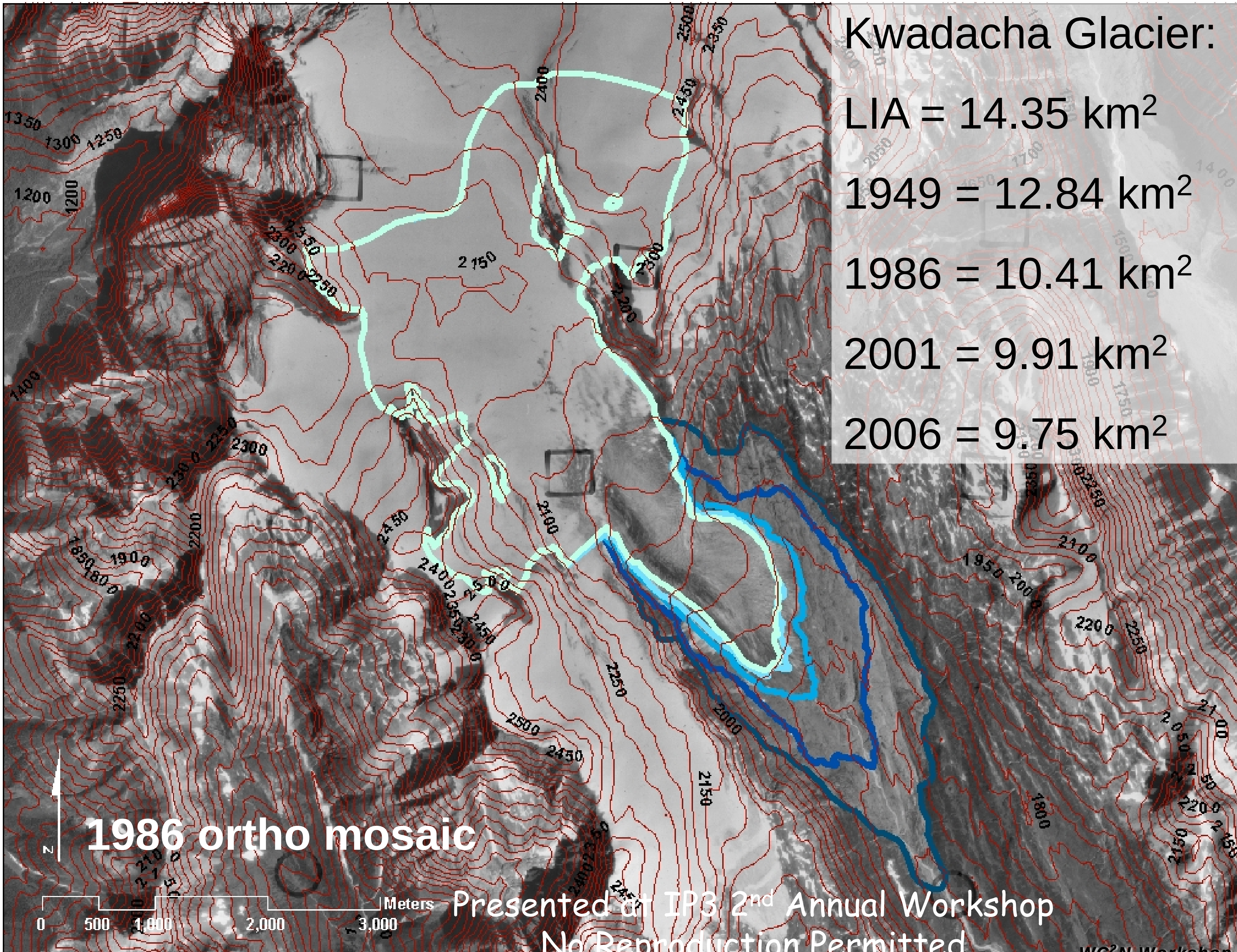
Tobias Bolch


Kwadacha Glacier:
LIA = 14.35 km^2
1949 = 12.84 km^2
1986 = 10.41 km^2
2001 = 9.91 km^2
2006 = 9.75 km^2
1986 ortho mosaic
N
0 500 1,000 2,000 3,000 Meters
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Presented at IP3 2nd Annual Workshop Garibaldi Neve (27 Aug. 2006)

LiDAR DEM

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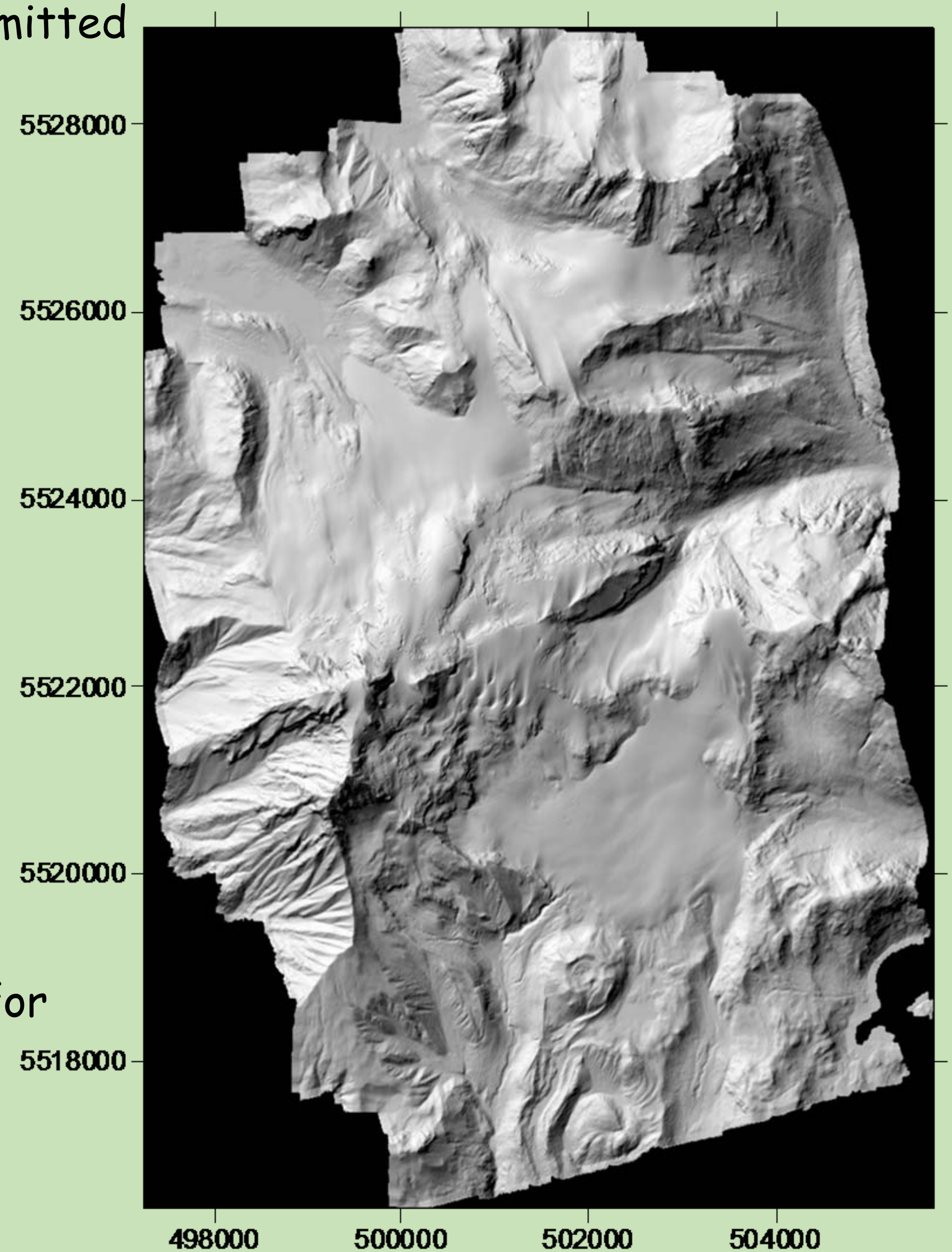
- invaluable for accumulation zones



M. Demuth (GSC)
C-CLEAR[1]

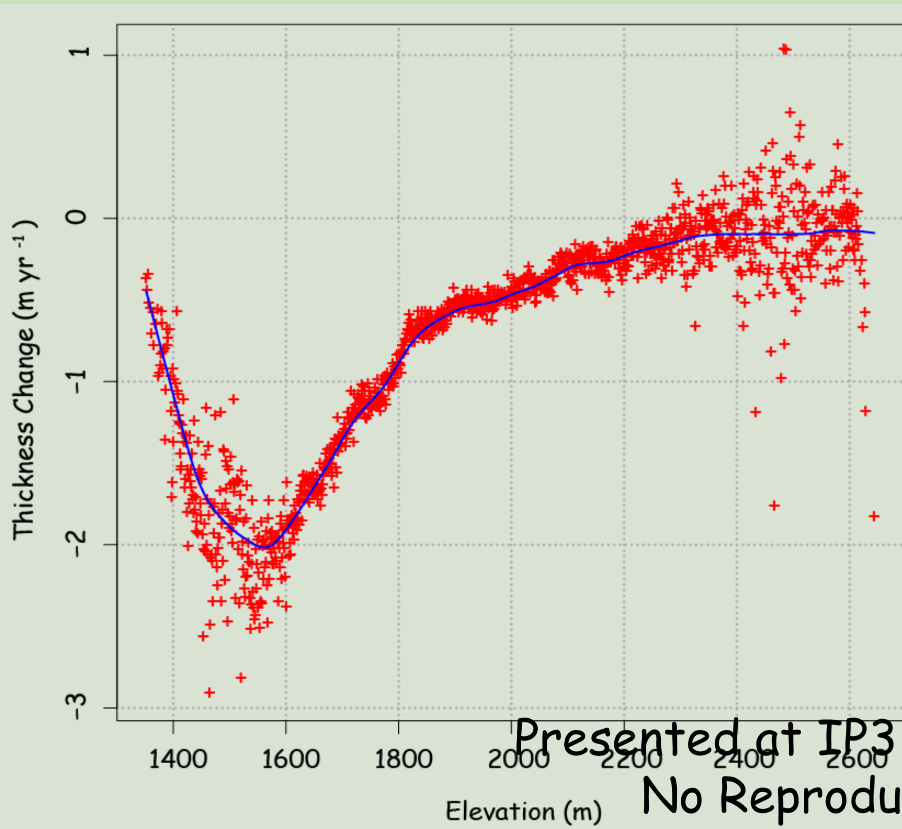
Canadian- Consortium for LiDAR Env. App. Res.

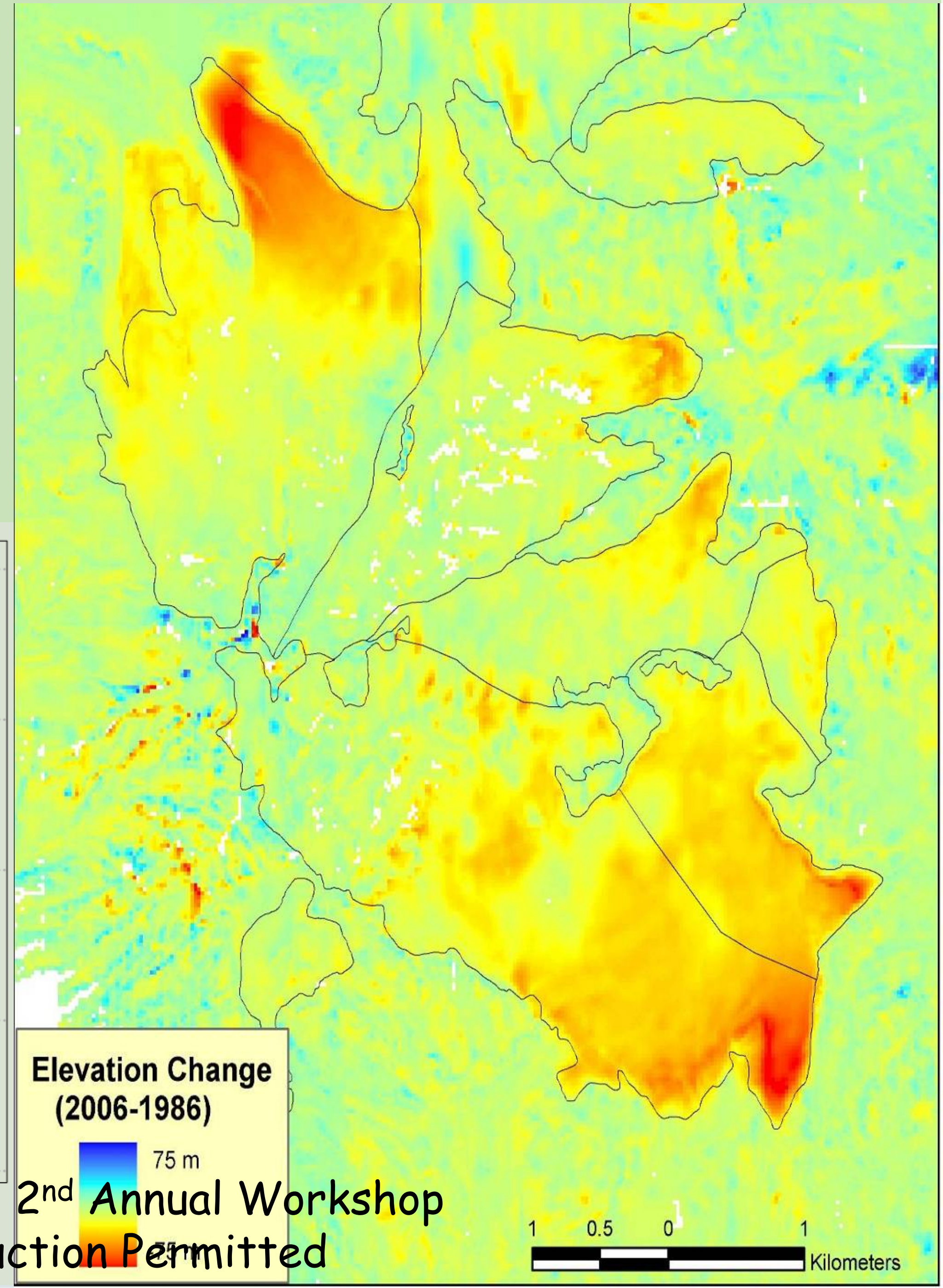
Thanks Chris

LiDAR – TRIM (2006-1987)

- 15 m thinning

0.25 km^3 ice loss





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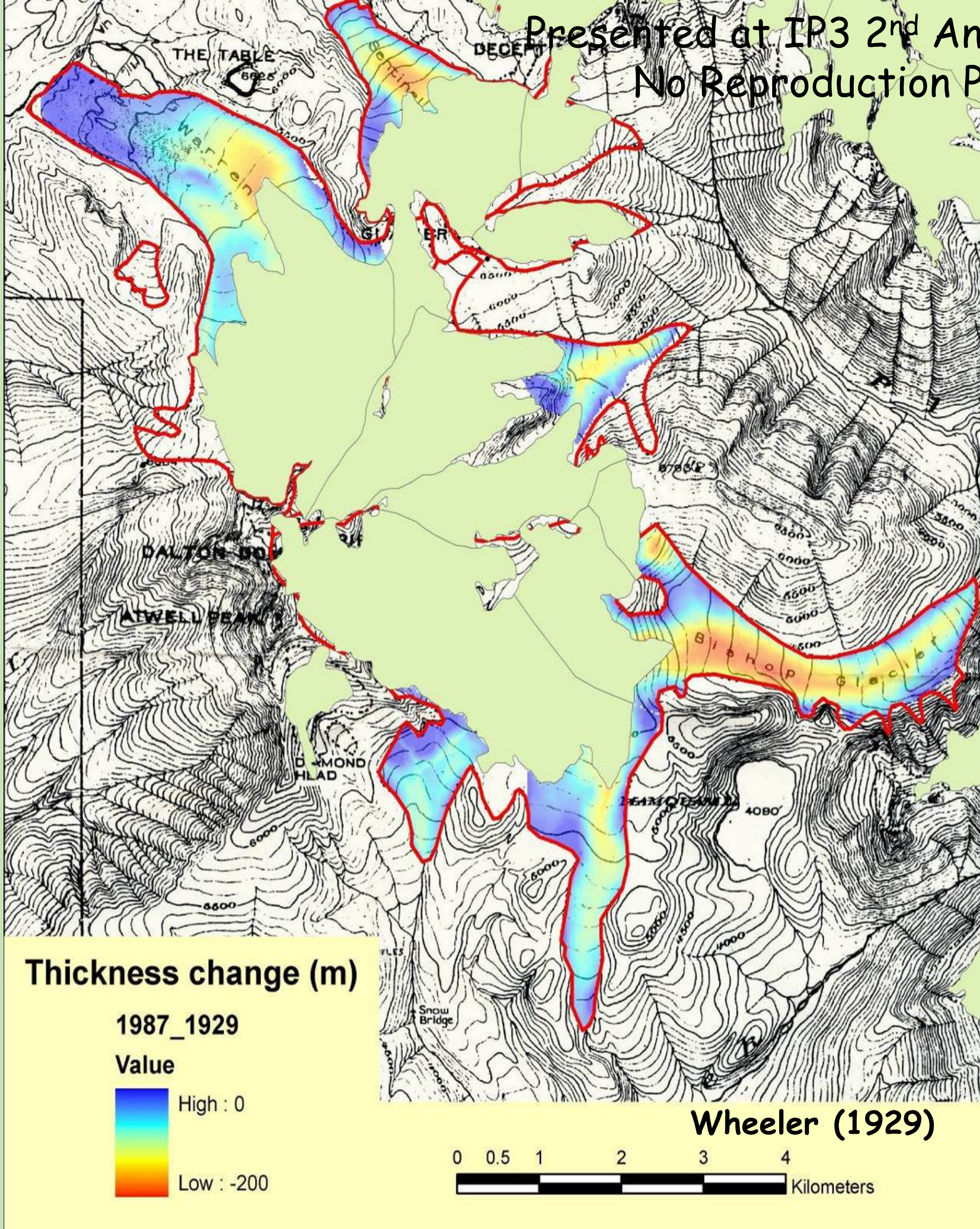

Wheeler (1929)

Western Canadian Cryospheric Network (WC^{2}N)

- Research Objectives

2) Detail meteorological processes and their links to glacier nourishment (glacier mass balance)

   - Dan Moore (UBC)
   - Peter Jackson, Stephen Dery (UBC)
   - Shawn Marshall (U of Calgary)

- <u>Good ground for collaborative research between IP3 and WC^{2}N</u>

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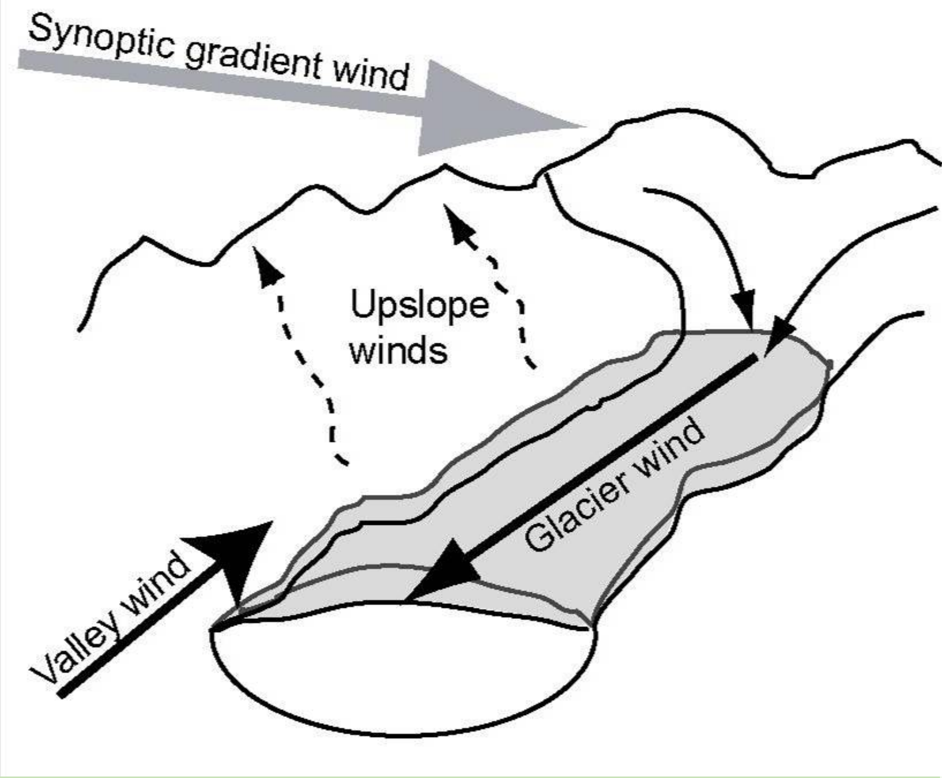
Distributed melt modelling challenges

- Method: degree-day versus energy balance
- Specification of input meteorological data (T, e_a, u)
- Turbulent and longwave energy fluxes
- Glacier boundary layer

- Ways to upscale local meteorological data to drive regional, glacial melt models



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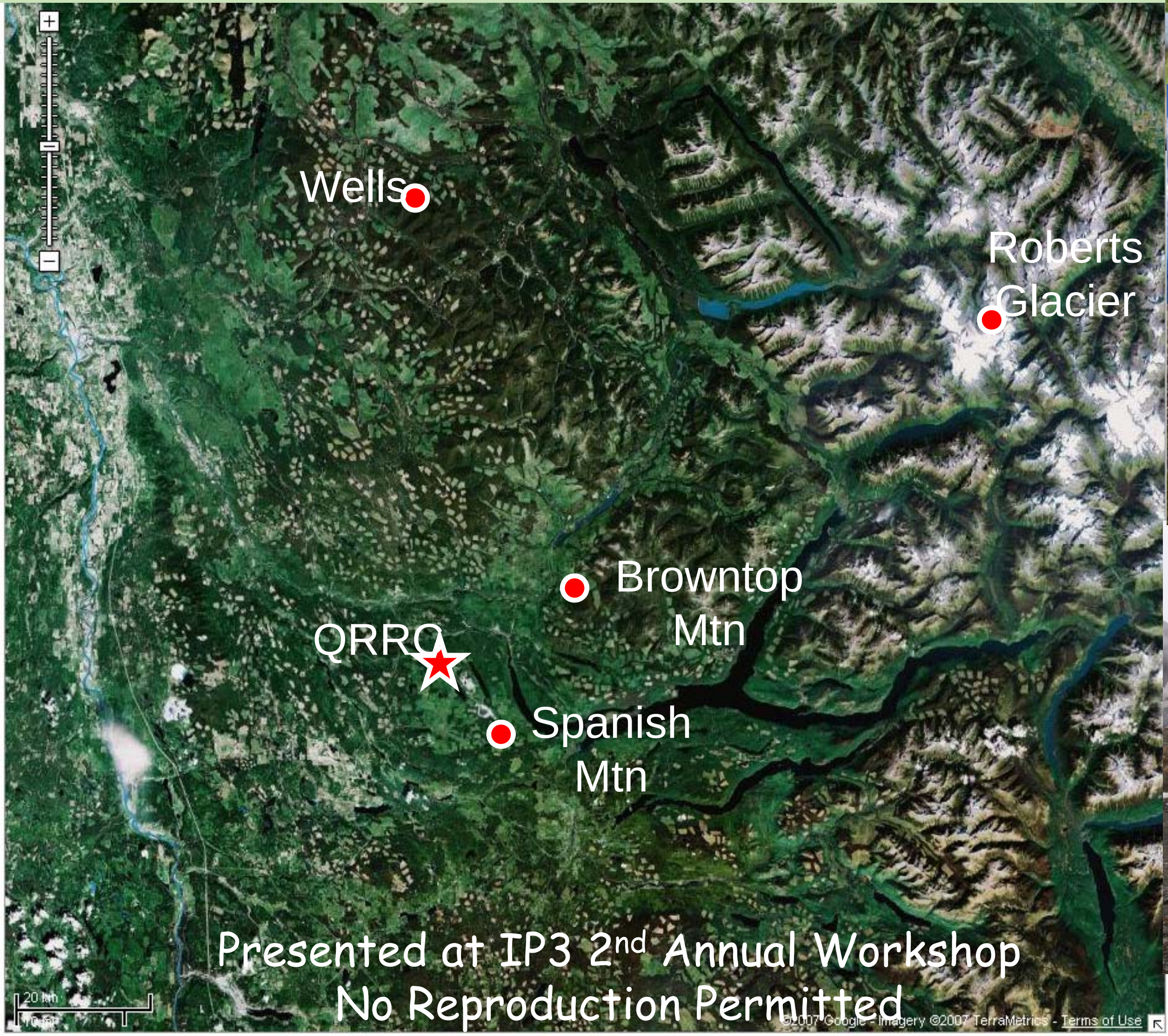
No Reproduction Permitted Joe Shea (UBC)

Cariboo Alpine Mesonet Network (CAMnet)



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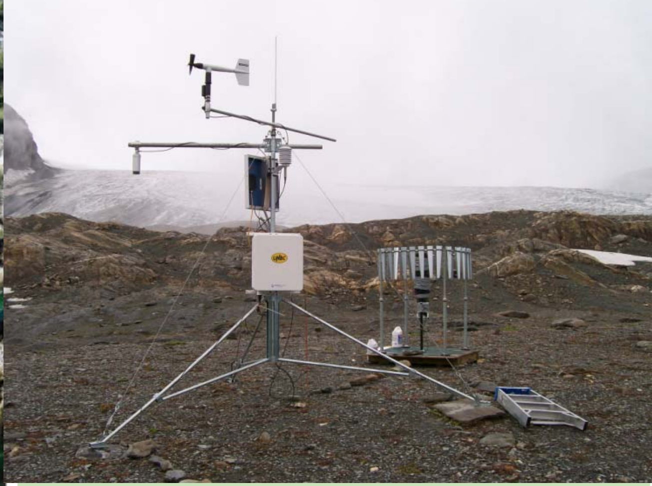

Stephen Dery

Downscaling (DS)

Coarse resolution (e.g. GCM) information to understand climate at a higher resolution (i.e. regional or local scale)

Two types:

1) Statistical Downscaling (SDS) – Empirical relation between historical coarse resolution field and observations. Relationship assumed to hold in future. Computationally efficient.

2) Dynamical Downscaling (DDS) – uses a regional climate (mesoscale) model nested within a coarse res model to dynamically produce high resolution fields. Not restricted by historical range of observations. Computationally expensive: model re-run for new scenarios.

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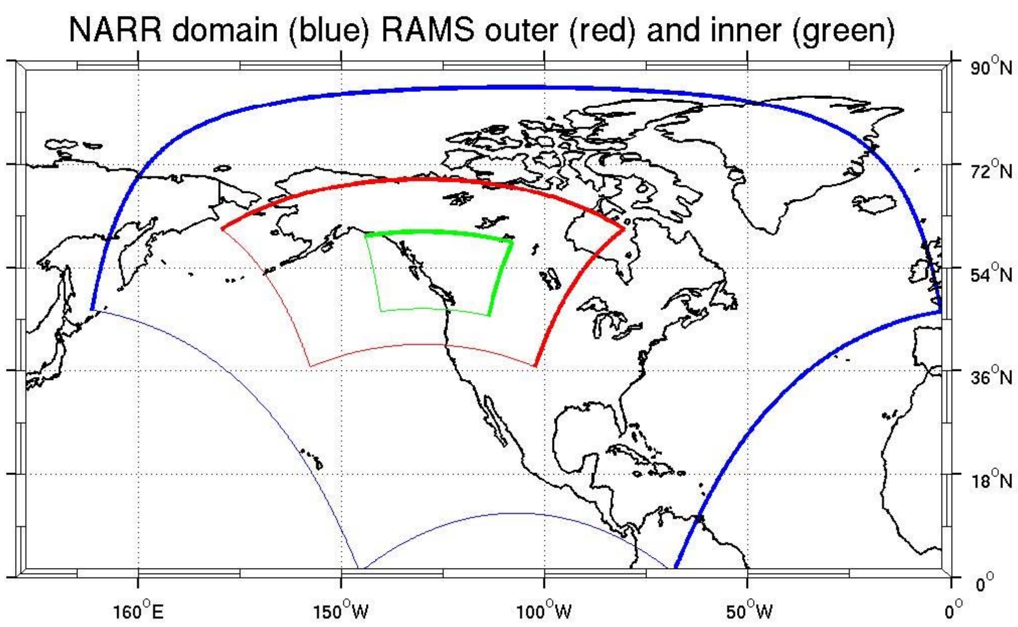
B.Anslie and P. Jackson

Hybrid Downscaling Approach

- Interested in fields over glaciers – data sparse areas, so it seems likely that standard SDS techniques are inadequate

- Interested in ensembles of multiple GHG scenarios for future predictions, so DDS techniques too expensive

- Therefore are testing a hybrid approach…



Western Canadian Cryospheric Network (WC^2N)

- Research Objectives

3) Predict how glaciers will respond to projected climate change over the next 50-150 years

   - Garry Clarke (UBC-EOS)
   - Shawn Marshall (U of Calgary)
   - Andy Busch (U of Alberta)

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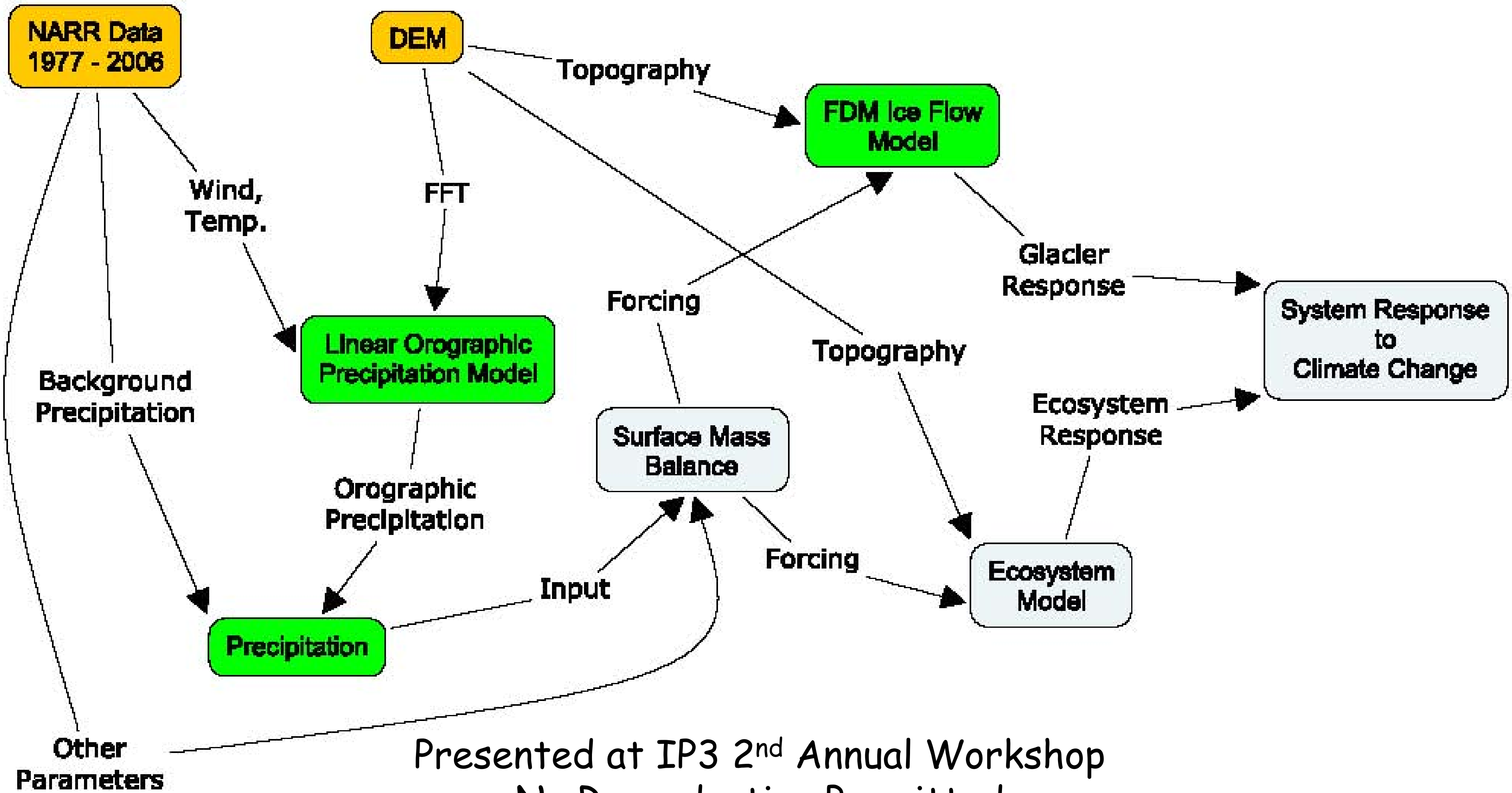
What are we up to at UBC?



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Linear orographic precipitation theory

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$$\hat{P}(k,l) = \frac{iC_w \sigma \hat{h}(k,l)}{(1 - imH_w)(1 + i\sigma\tau_c)(1 + i\sigma\tau_s)}$$

- σ ... wind vector
- $\hat{h}(k,l)$ ... FFT from topography
- C_w ... uplift sensitivity factor
- H_w ... water vapor scale height

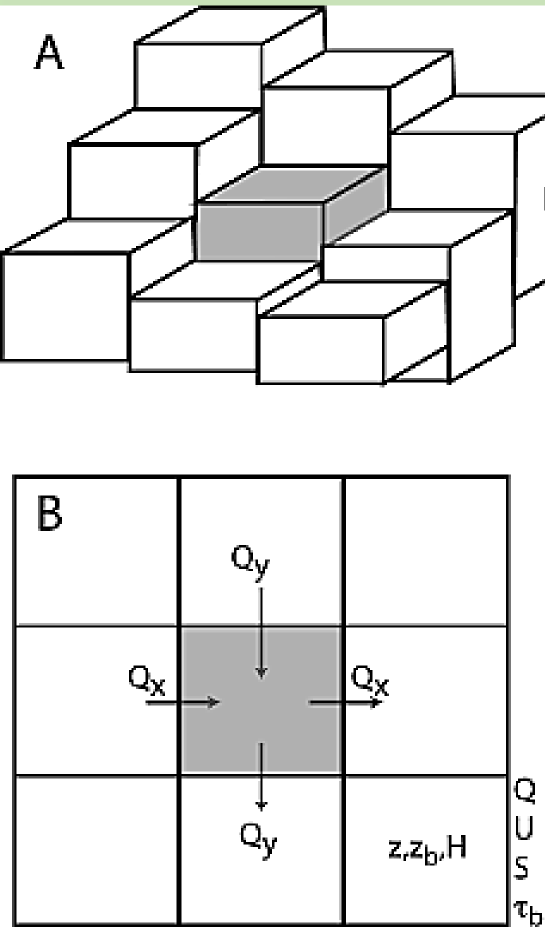
(Smith, R. B. and Barstad, I. 2004. J. Atmos. Sci.)

2 ½ D Glacier Flow Model

Kessler et al, (2005)

-Temp fields (GCM, RCM analysis)

- Ppt. (field and orographic forcing)



$$\frac{dh}{dt} = b_z - \frac{dq_x}{dx} - \frac{dq_y}{dy}$$

$$q = h(U_d + U_s)$$

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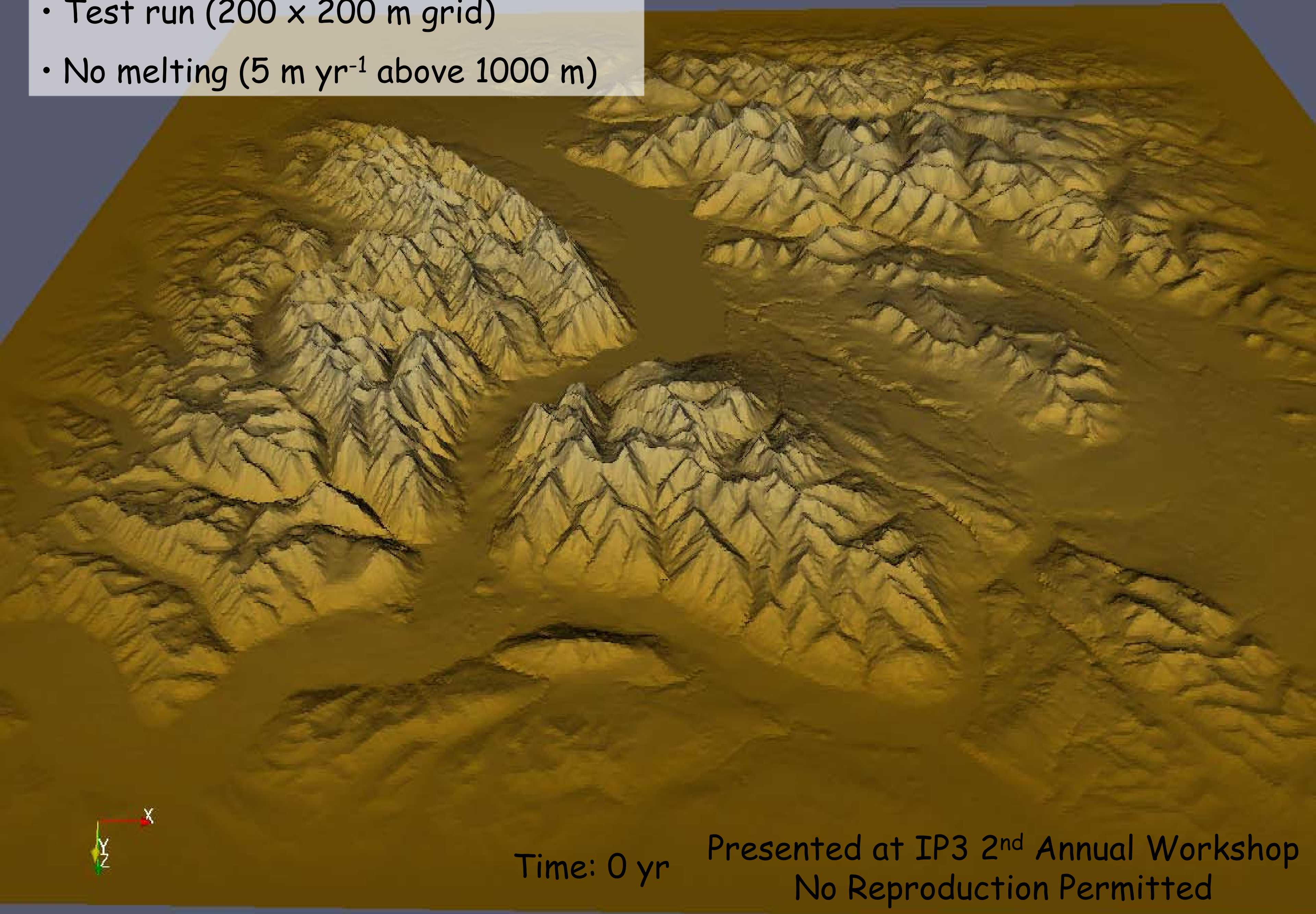
- Test run (200 x 200 m grid)
- No melting (5 m yr^{-1} above 1000 m)



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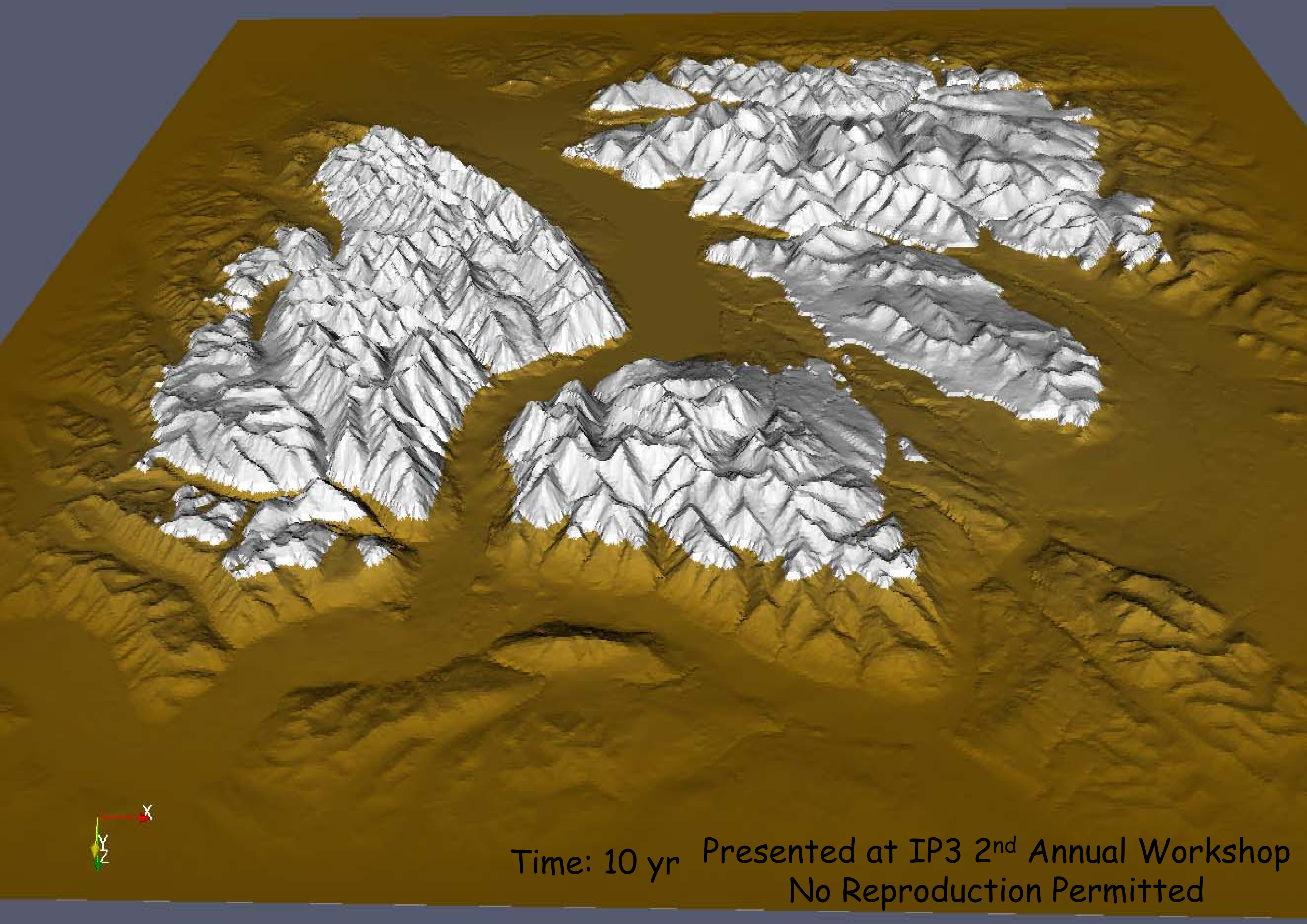

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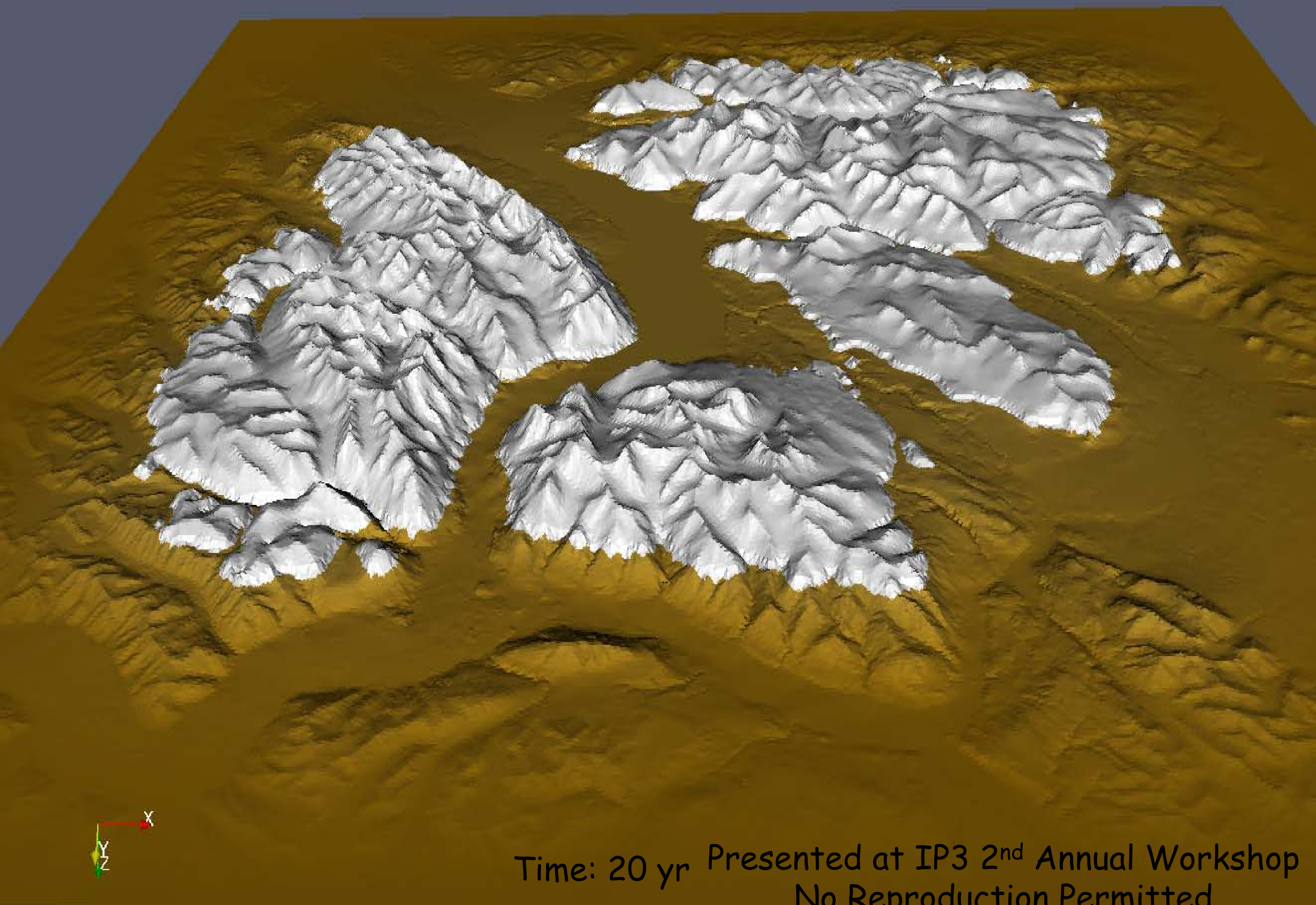

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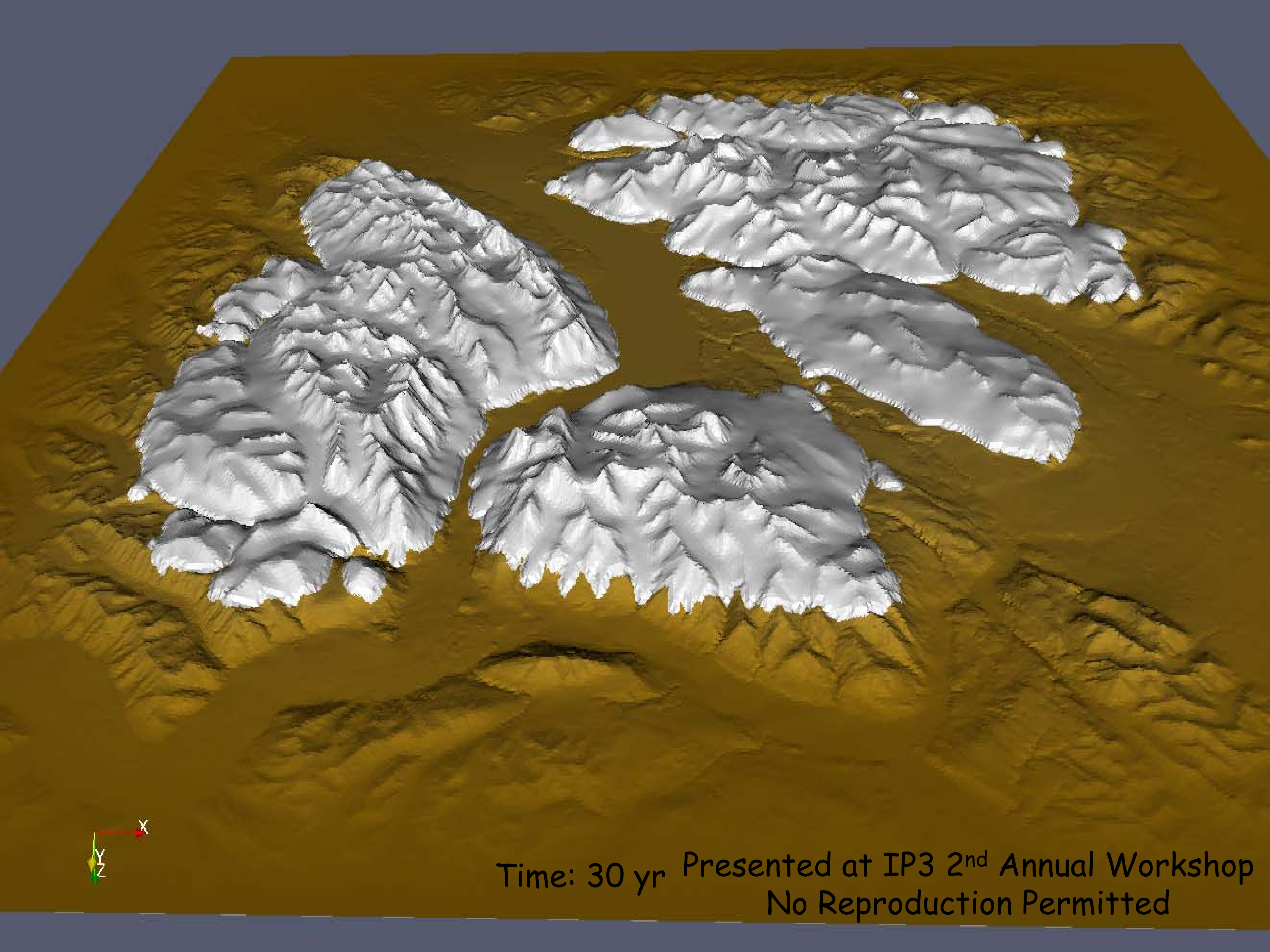

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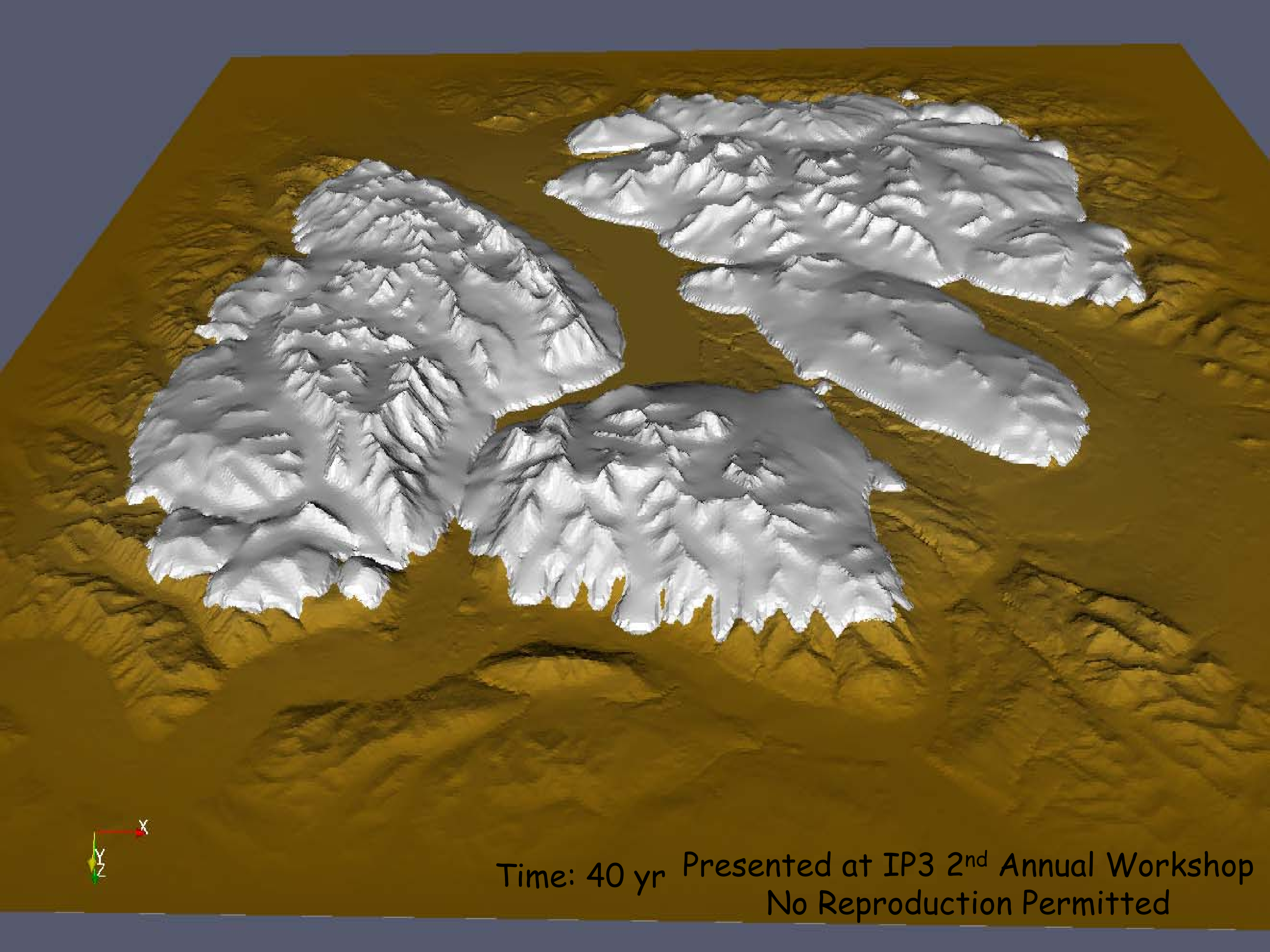

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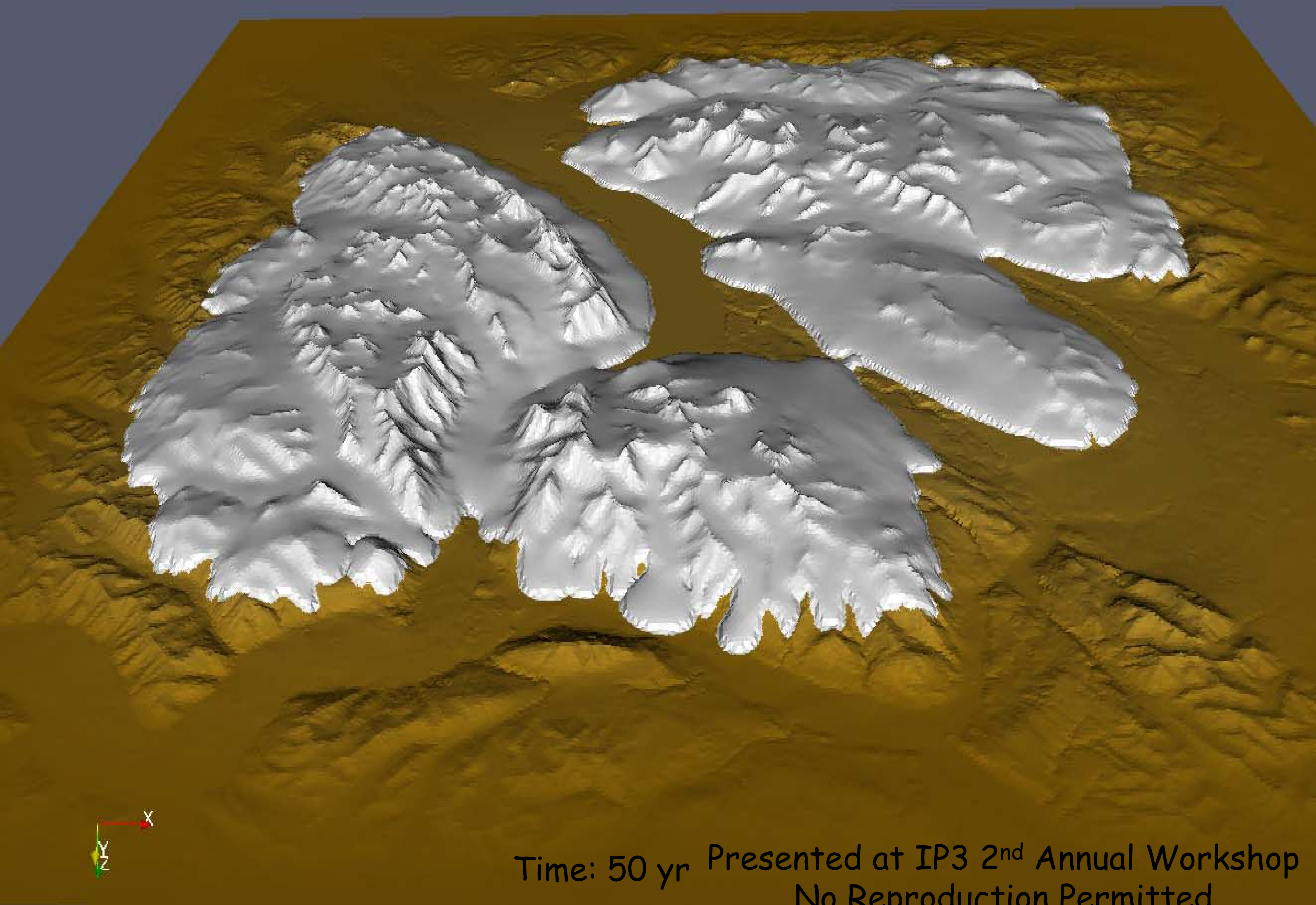

Time: 50 yr

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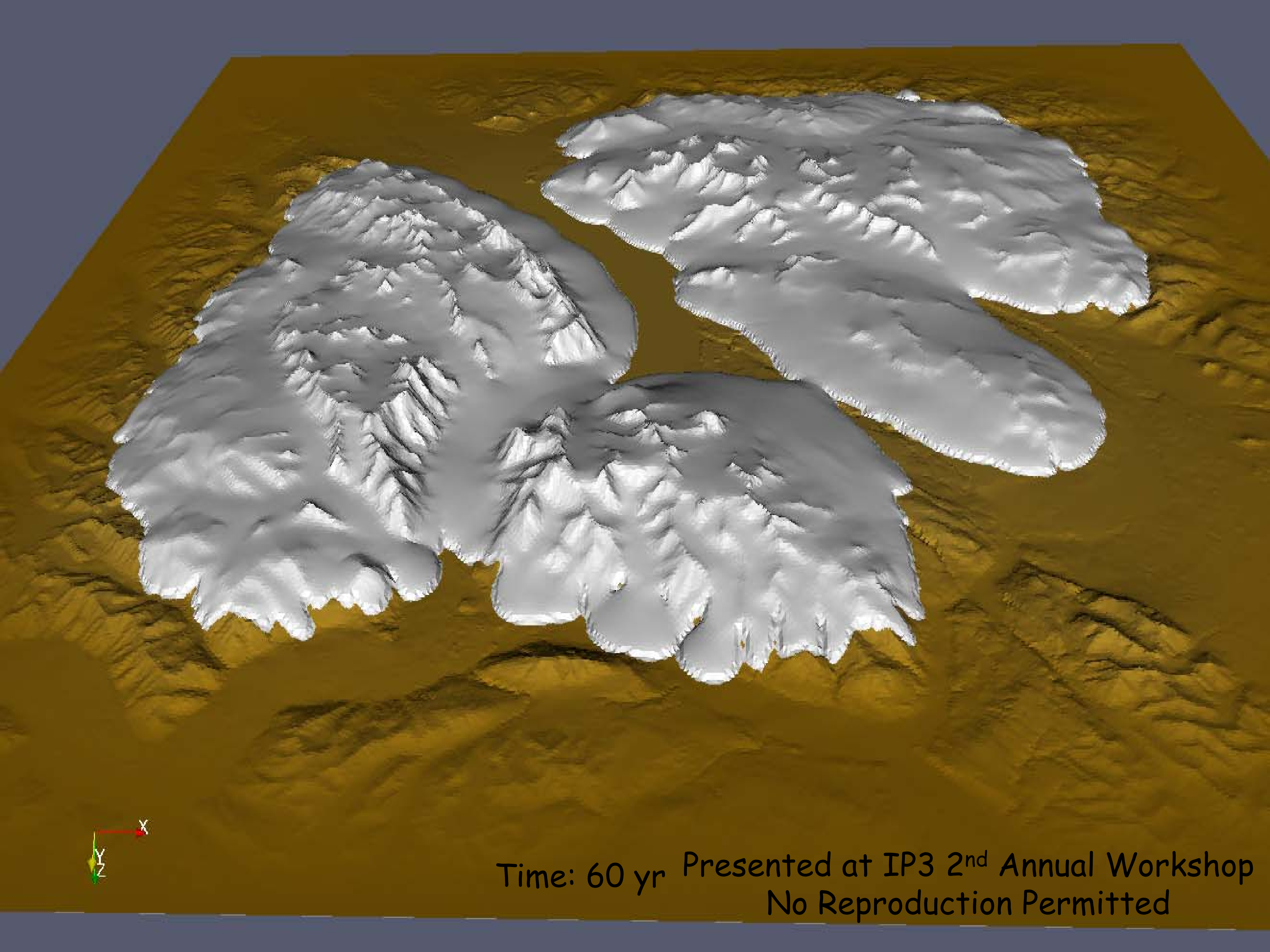

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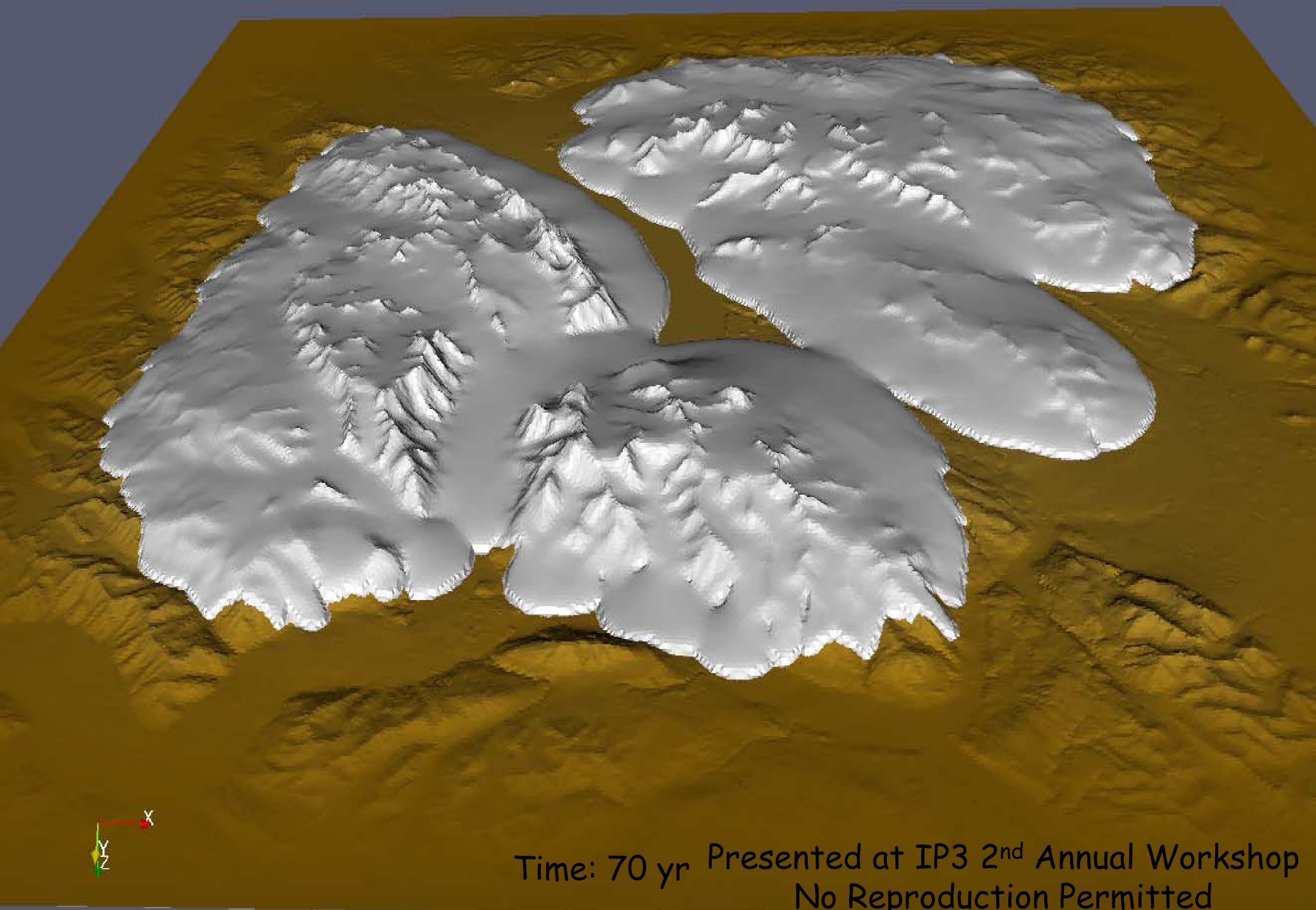

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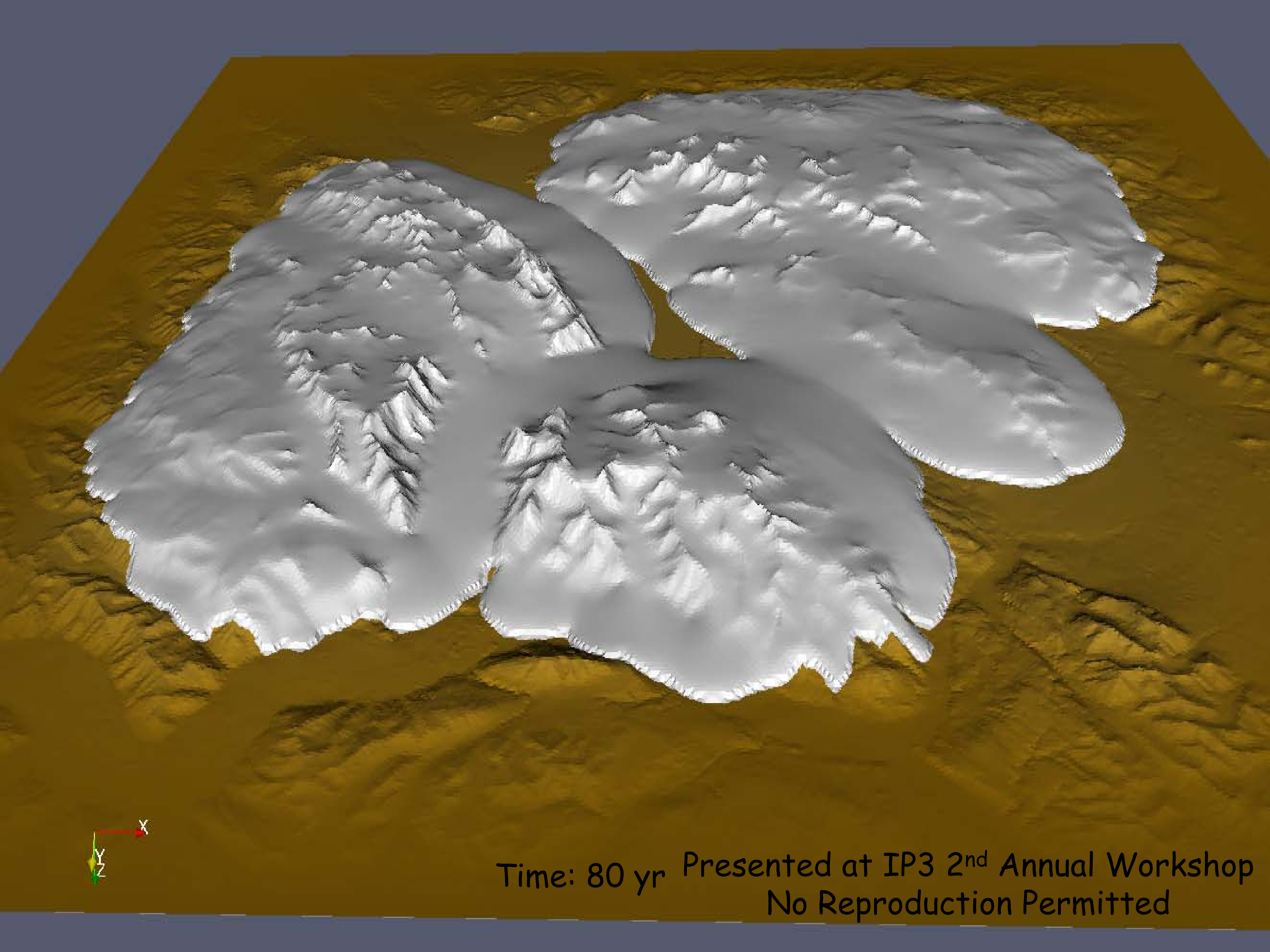

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Bayesian EOF analysis

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Temp. & Ppt.

Climate

Proxy

Station
Proxy

Reanalysis
Station
Proxy

~1900

1979

2006

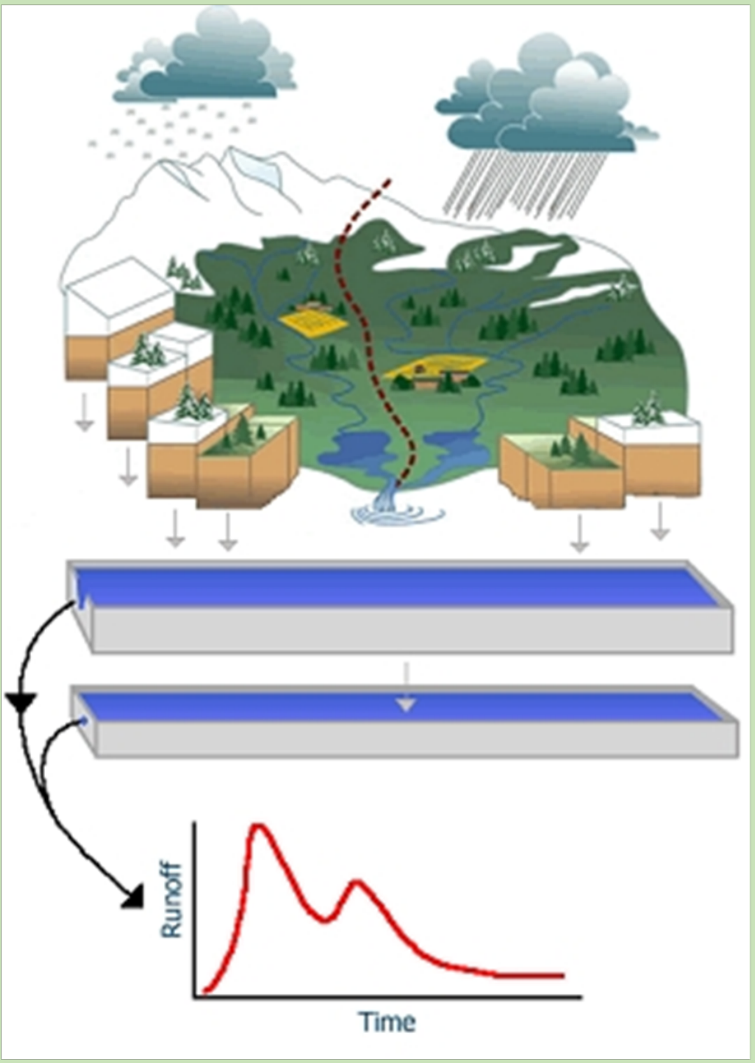
Mass Balance

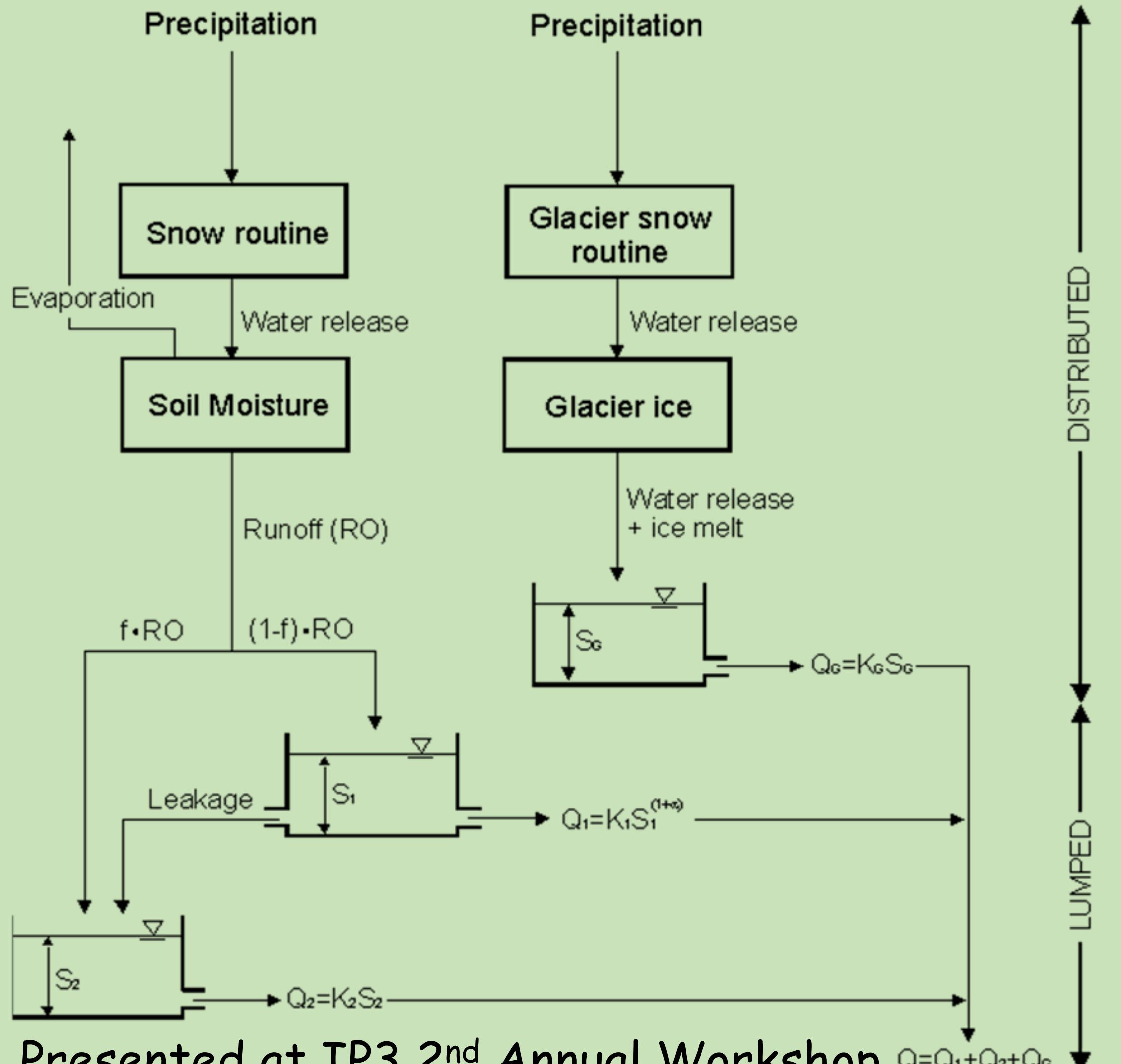
Historical records and observations

Glaciers

C. Reuter

HBV-EC hydrological model





D. Moore

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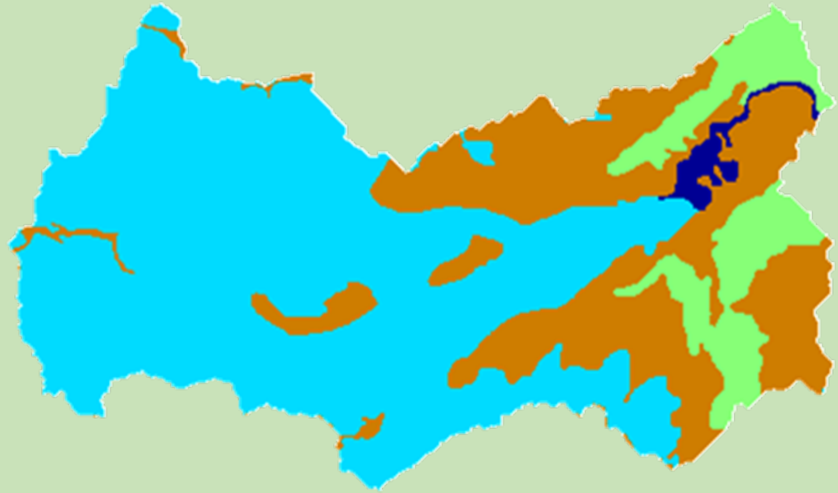
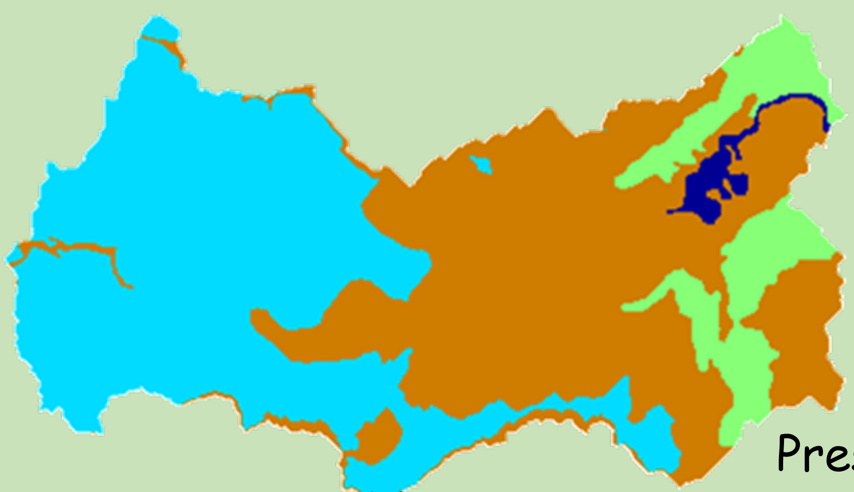
Glacier cover change: (1990 to 2095) Bridge Glacier Basin



BTM Land Cover
(Landsat Image mid-1990s)

Glacier
Open
Forest
Lake

S0: "No change"



S2: SRES A2

D. Moore, K. Stahl

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Changes to August streamflow

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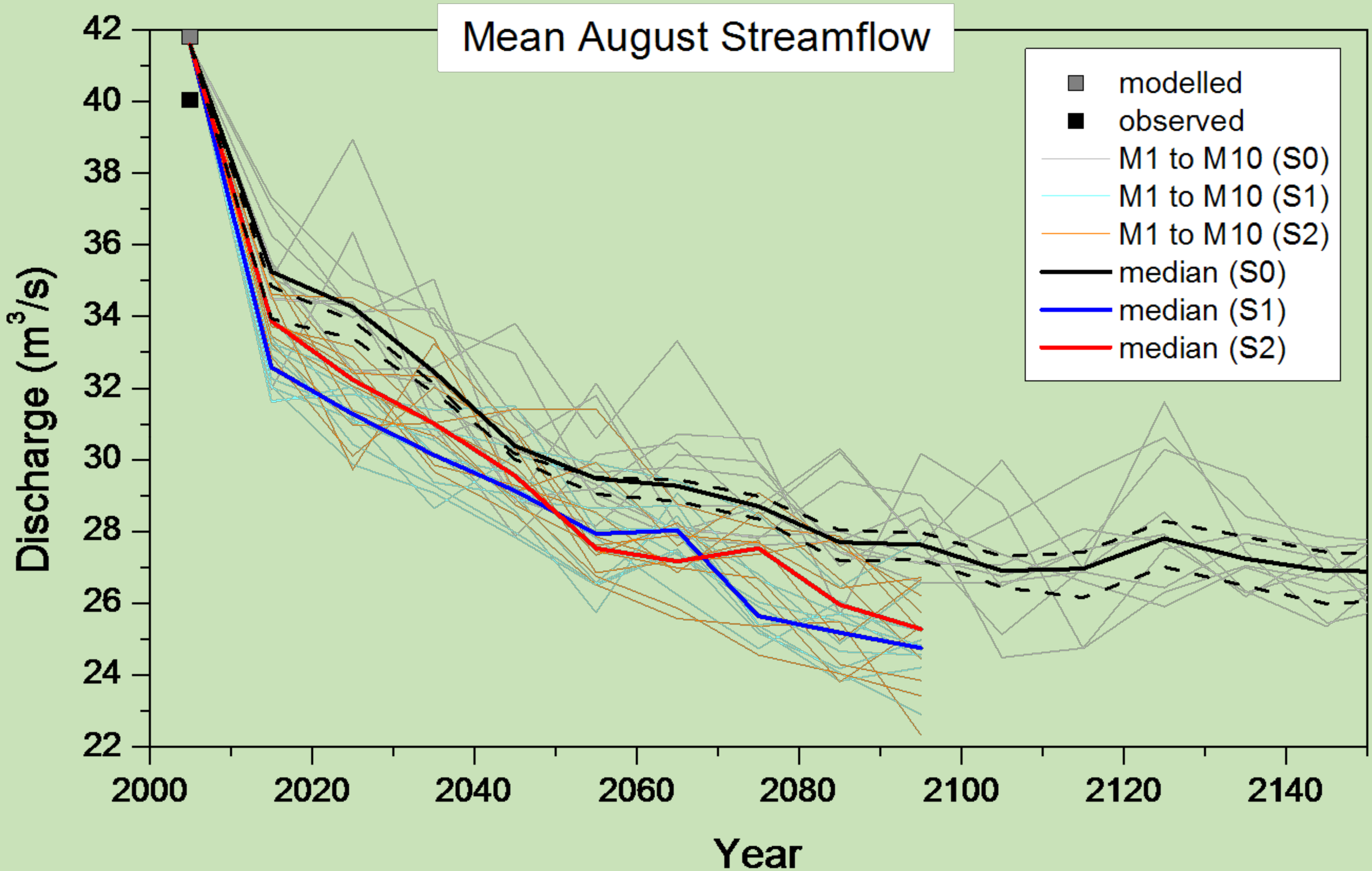
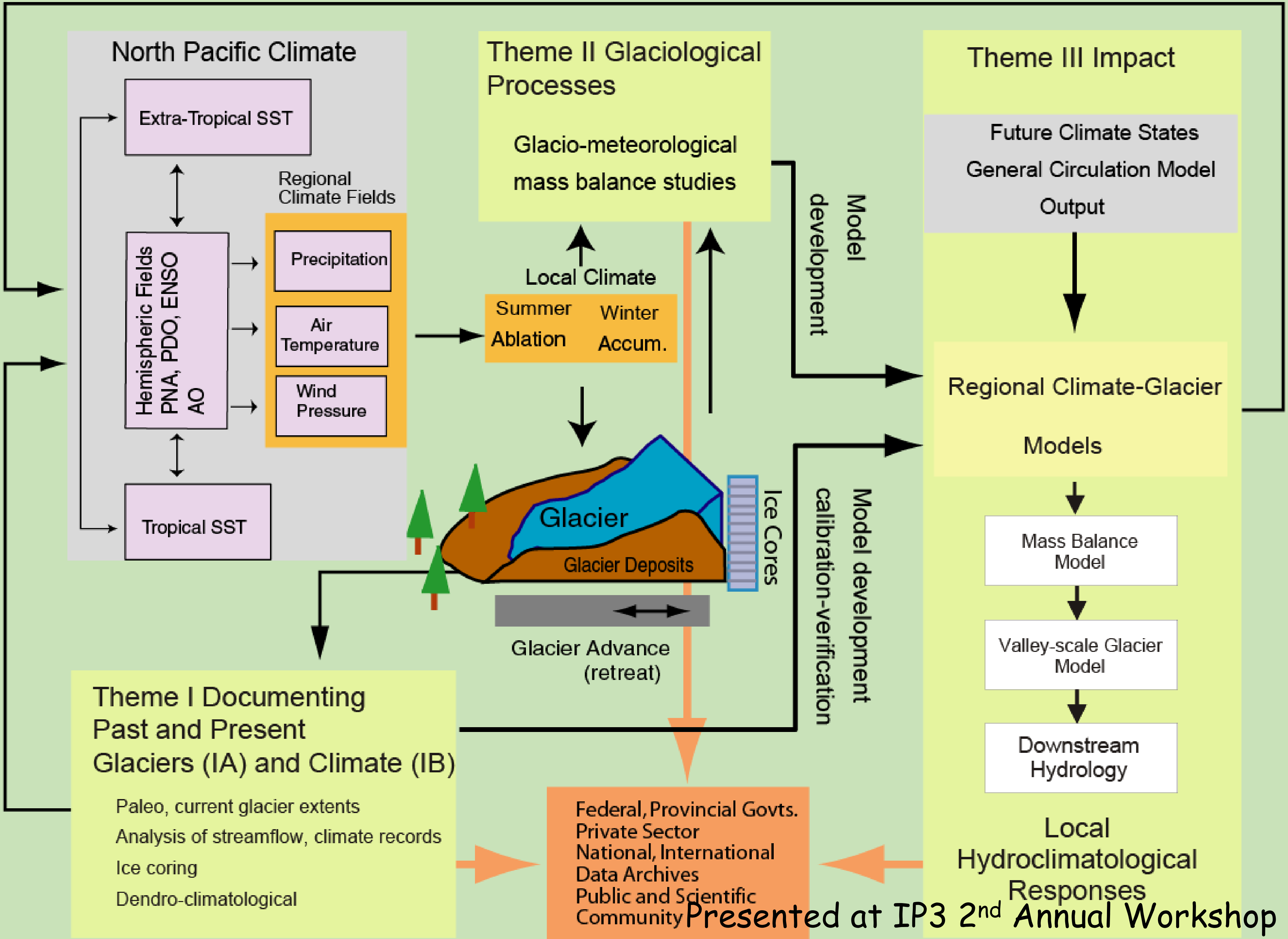


D. Moore



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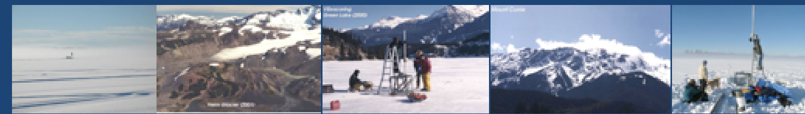
Western Canadian Cryospheric Network

Canadian Foundation for Climate and Atmospheric Sciences



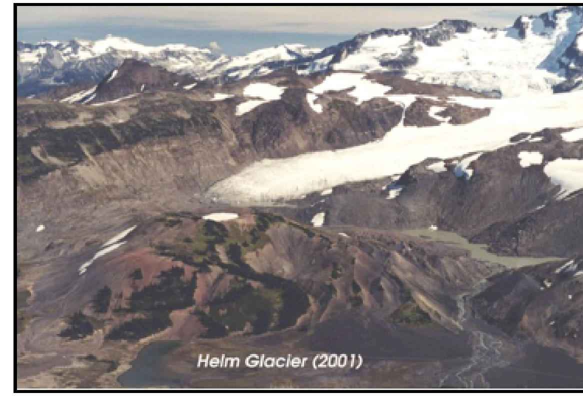
- WC²N Homepage
- Members
- Partners
- Media Events
- Conferences
- Members Area
- Opportunities
- Objectives
- Links
- Contacts

WC²N Mailing List

Website last updated: Oct 25, 2007; 11:16:07

Western Canadian Cryospheric Network

The Western Canadian Cryospheric Network (WC^{2}N) is a consortium of six Canadian universities, two American universities and government and private scientists who are examining the links between climatic change and glacier fluctuations in western Canada. Glaciers provide windows into past and present behavior of the climate in the North Pacific region since they they are well distributed in western Canada and are sensitive to changes in precipitation and temperature. Glaciers are also important for western Canada since they serve as frozen reservoirs of freshwater.



http://wc2n.unbc.ca/

We greatly appreciate funding from CFCAS and our research partners !

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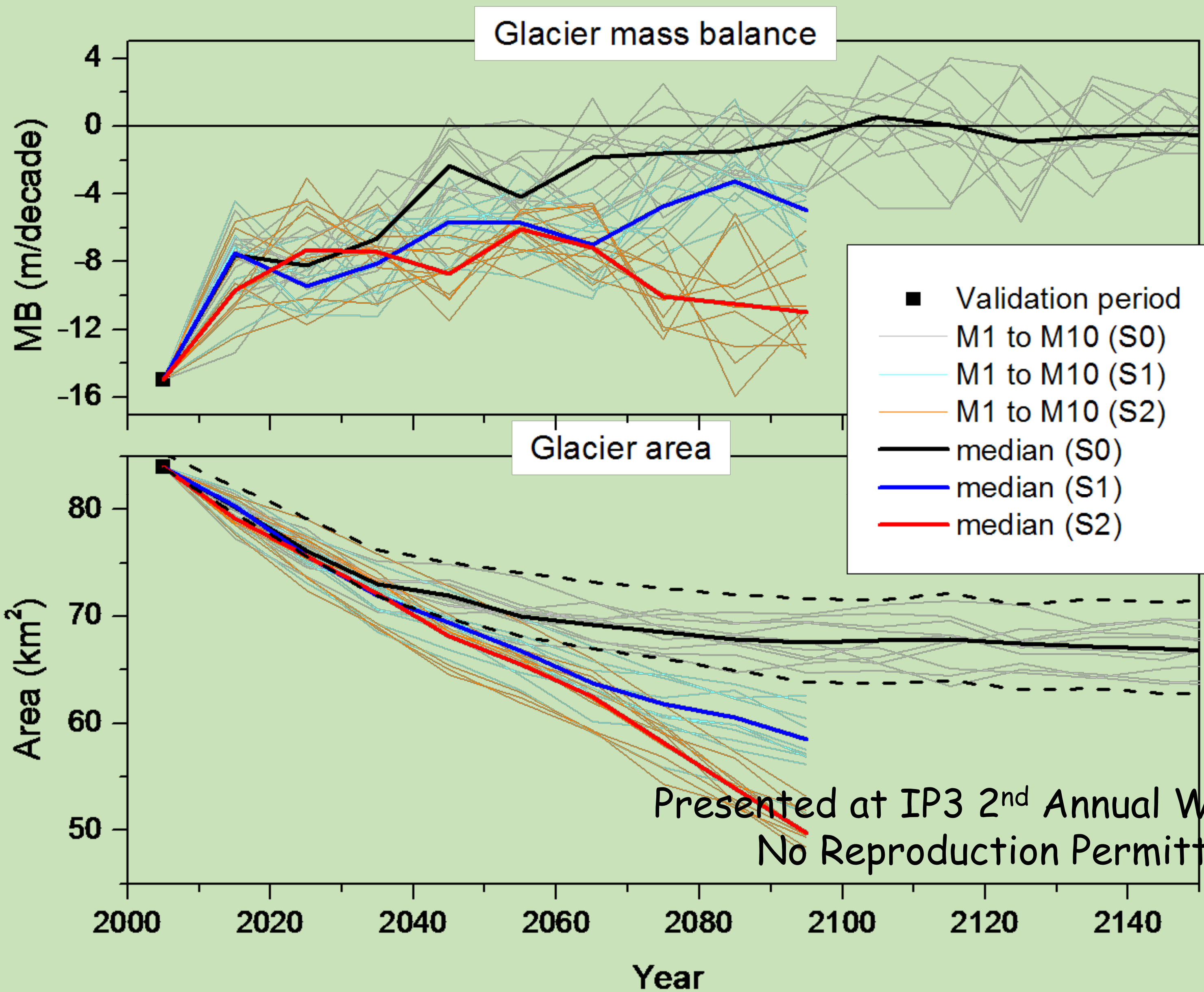
Graduate students and PDFs make this work possible

Trends in Mb and Area



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Theme I (A, B) Documentation

- Inventory and analyze glacier cover for western Canada (1990, 2000)
- Inventory and analyze glacier extent (1600-present) for regions 1-4
- Finalize site selection and commence ice core recovery
- Produce and distribute 'Glacierscapes' poster
- Inventory and analyze glacier extent (1600-present) for regions 4-7
- Archive and distribute glacier coverages to Themes II and III and GLIMS, CRYSYS, WGMS
- Assemble and analyze climate proxy data sets
- Distribute ice core data to national, international archives

Year I | Year 2 | Year 3 | Year 4 | Year 5

Theme II Process

- Establish glacio-meteorological monitoring stations
- Continue glacio-meteorological process studies
- Commence integration of historical climate forcings from theme IB
- Develop higher-order valley glacier dynamics model
- Integrate theme IA,B results into glaciological modelling
- Couple local glacier mass balance records to hemispheric climate models
- Assess the importance of wind redistribution of snow for glacier mass balance
- Develop regional scale glaciological model
- Apply regional-scale glaciological flow models

Year I | Year 2 | Year 3 | Year 4 | Year 5

Theme III Impact

- Begin and complete subgrid terrain characterization for western Canada
- Commence development of Cordilleran-scale ice dynamics model
- Aggregate present-day glacier cover to 10 x10 km gridded data
- Develop suite of gridded 1961-1990 climate states
- Commence field data collection for modelling stream temperature and water flow
- Train ice dynamics model and develop climate downscaling strategies
- Simulate glacier response to different climate states
- Annual reports to CFCAS (progress and financial)
- WC^{2}N annual meeting (CGU)
- Assess changes in glacier runoff and stream temperatures under future climates

Mid-Term Review