

The Role of GCM Resolution in Simulated Glacial Inception

Steve Vavrus

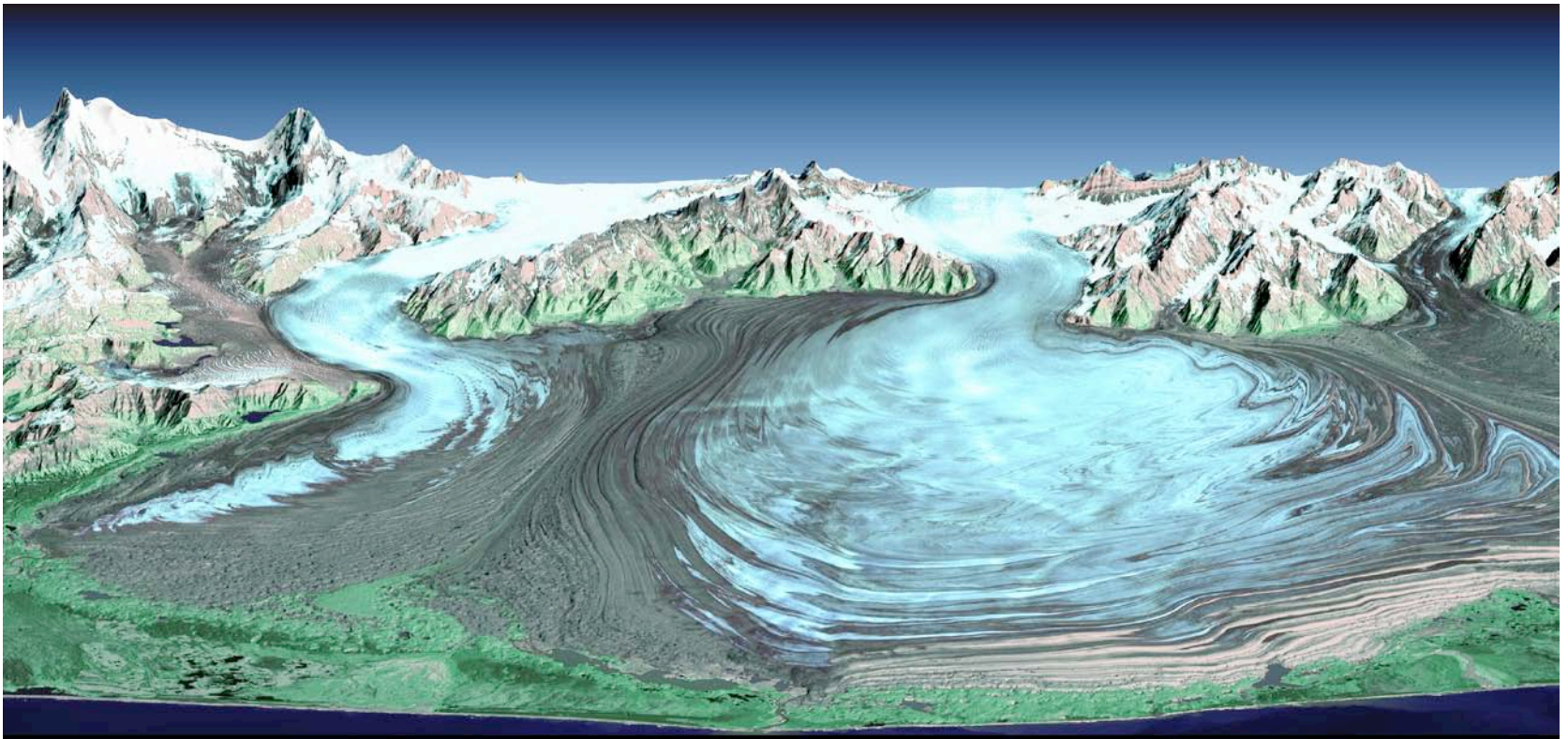
Gwenaëlle Philippon-Berthier

John Kutzbach

Bill Ruddiman

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University of Virginia*



Glacial Inception Studies with Climate Models

- Rind et al. (1989) -- GISS GCM (8° x 10°)
- Oglesby (1990) -- CCM1 GCM (R15)
- Dong and Valdes (1995) -- UGAMP GCM (T42)
- Gallimore and Kutzbach (1996) -- CCM1 GCM (R15)
- Pollard and Thompson (1997) -- Off-line Ice Sheet Model
- Khodri et al. (2001) -- IPSL GCM (T31)
- Yoshimori et al. (2002) -- AGCM
- Vettoretti and Peltier (2003) -- CCCMA GCM (T32)
- Kageyama et al. (2004) -- CLIMBER EMIC
- Calov et al. (2005) -- CLIMBER EMIC
- Kubatzki et al. (2006) -- CLIMBER EMIC
- Mysak (2008) -- McGill EMIC
- Vavrus et al. (2008) -- CAM3-SOM GCM (T42)
- Otieno and Bromwich (2009) -- CLM3-ERA40

Usual target is orbitally forced 115 ka BP event with coarse model

Early Anthropogenic Hypothesis

news feature

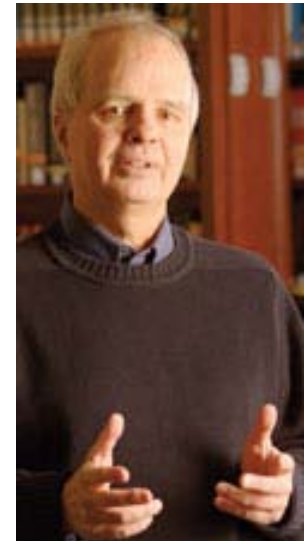
The hot hand of history

We may not have known we were doing it, but humans have been changing the climate for thousands of years, a new theory suggests. Could our ancestors have saved us from an ice age? Betsy Mason investigates.



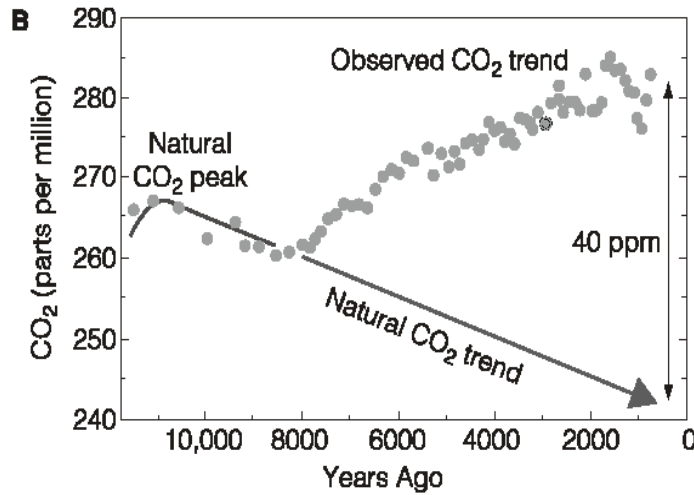
Clear cut: did deforestation 8,000 years ago set in motion a pattern of global warming that has since staved off a mini ice age?

Bill Ruddiman



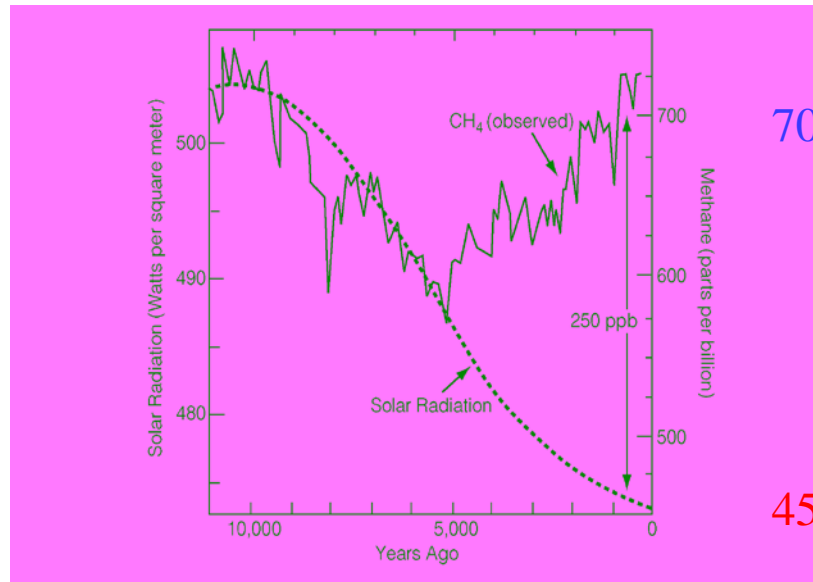
Nature (2004)

Deforestation -----> Increased atmospheric CO₂ (8,000 years ago)
Rice Cultivation -----> Increased atmospheric CH₄ (5,000 years ago)



280 ppm pre-industrial CO₂

240 ppm CO₂ naturally



700 ppb pre-industrial CH₄

450 ppb CH₄ naturally

Enough greenhouse cooling to promote glacial inception?

CAM3 Atmosphere/Slab-Ocean Model (SOM)

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graph TD; A[CAM3 Atmosphere/Slab-Ocean Model (SOM)] --> B[T42 Resolution (2.8° x 2.8°)]; A --> C[T85 Resolution (1.4° x 1.4°)]; B --- D[CONTROL: 355 ppm CO2 1700 ppb CH4]; B --- E[NOANTHRO: 240 ppm CO2 450 ppb CH4]; C --- D; C --- E;
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T42 Resolution
(2.8° x 2.8°)

T85 Resolution
(1.4° x 1.4°)

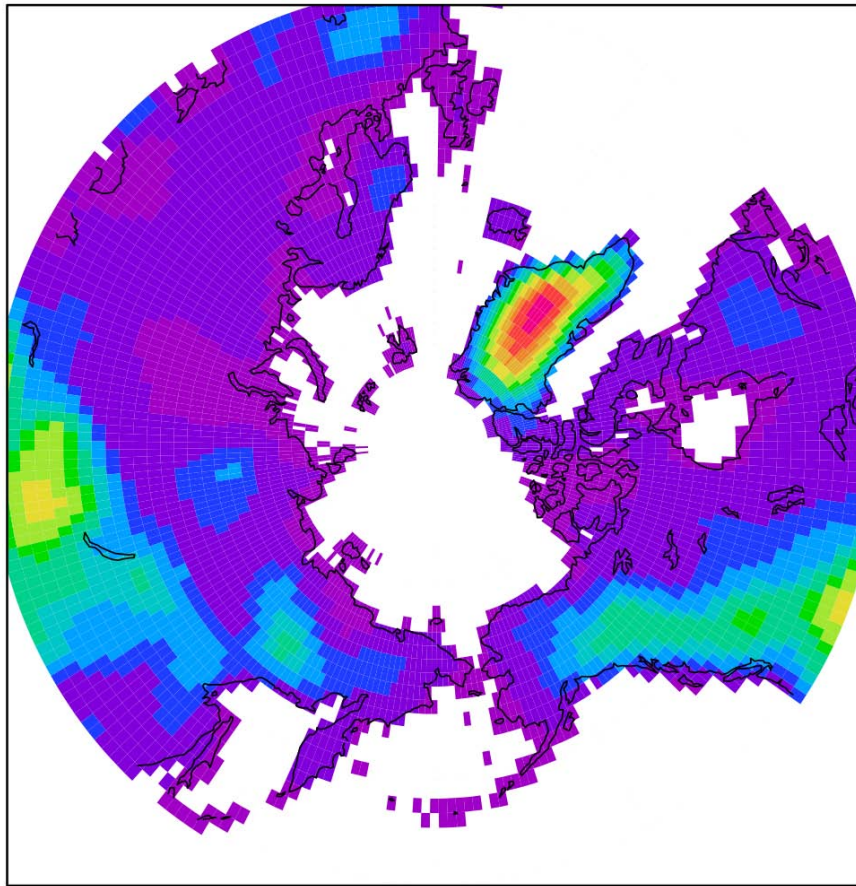
CONTROL: 355 ppm CO₂ 1700 ppb CH₄

NOANTHRO: 240 ppm CO₂ 450 ppb CH₄

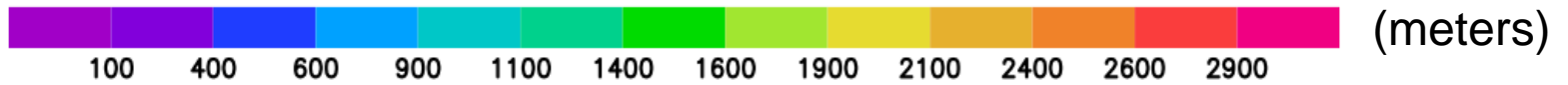
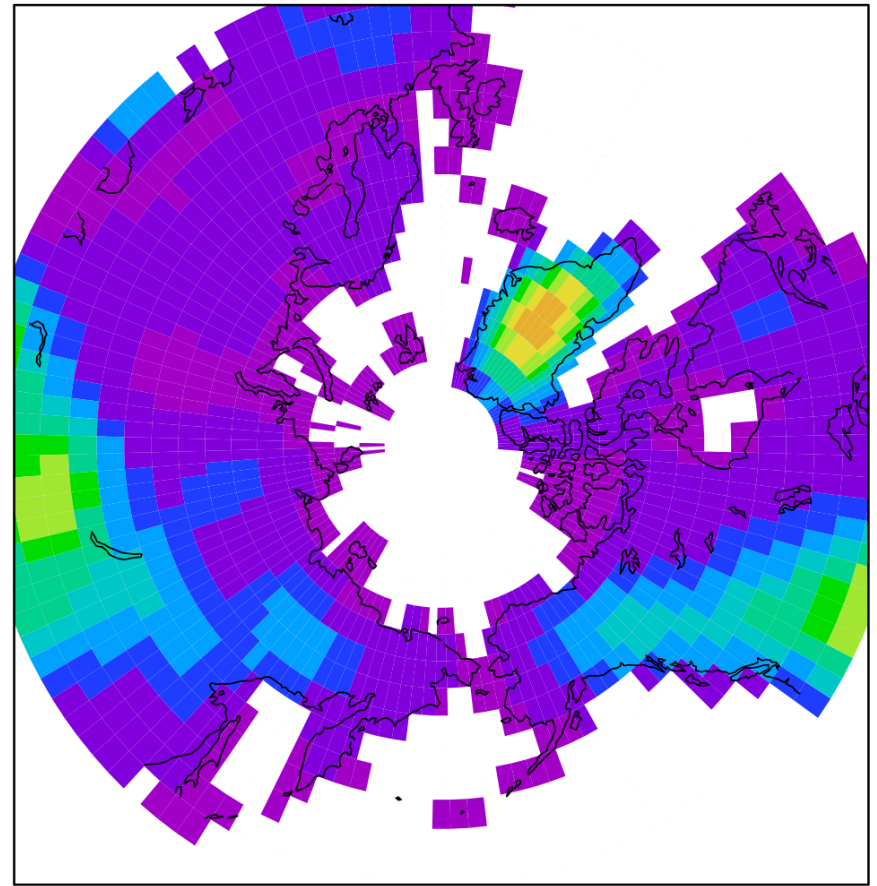
(modern orbital configuration)

GCM Topography

T85

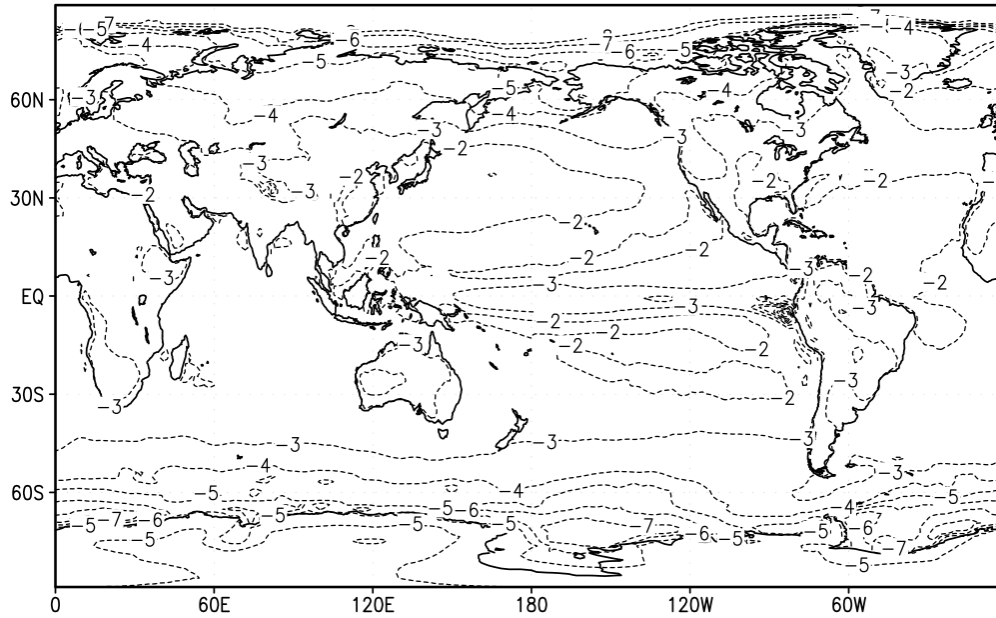


T42



Surface Temperature Changes (NOANTHRO minus CONTROL)

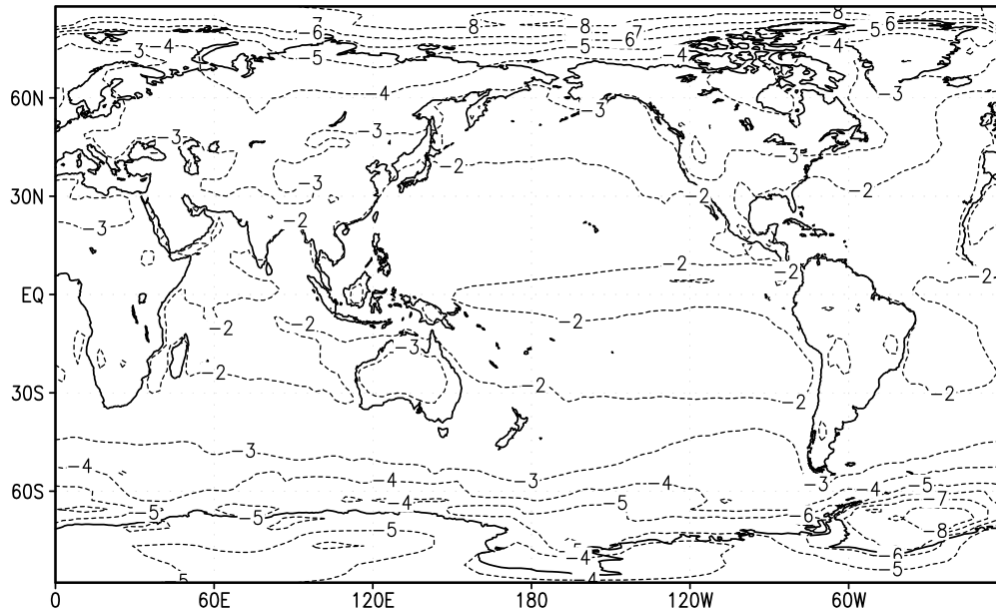
T85



Global Average

-2.85 K

T42



-2.65 K

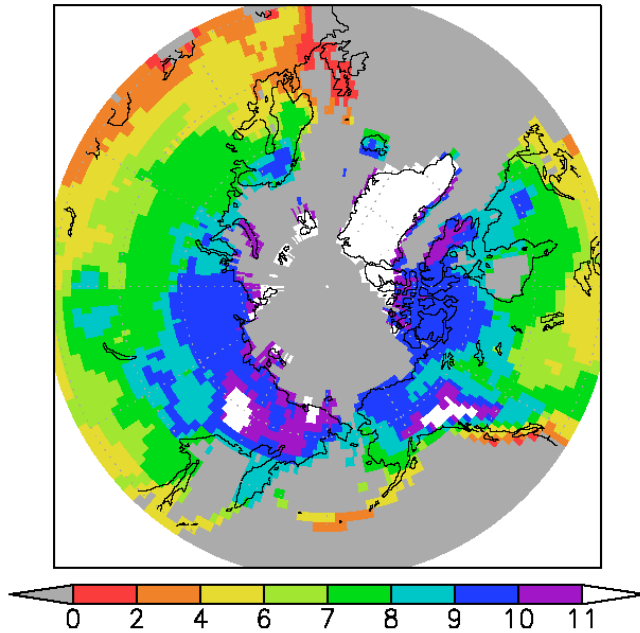
Boreal High Latitude Climate Changes

45° - 90°N:

	<u>T42</u>	<u>T85</u>	<u>T85 - T42</u>
Surface Temperature (K)	-3.6	-3.7	-0.1
Precipitation (%)	-11.8	-12.3	-0.5
Snowfall (%)	18.9	20.8	1.9
Snow Cover Duration (%)	11.4	10.4	-1.0
Sea Ice Area (%)	15.9	16.8	0.9
Permanent Snow Cover Area (%)	80	147	67

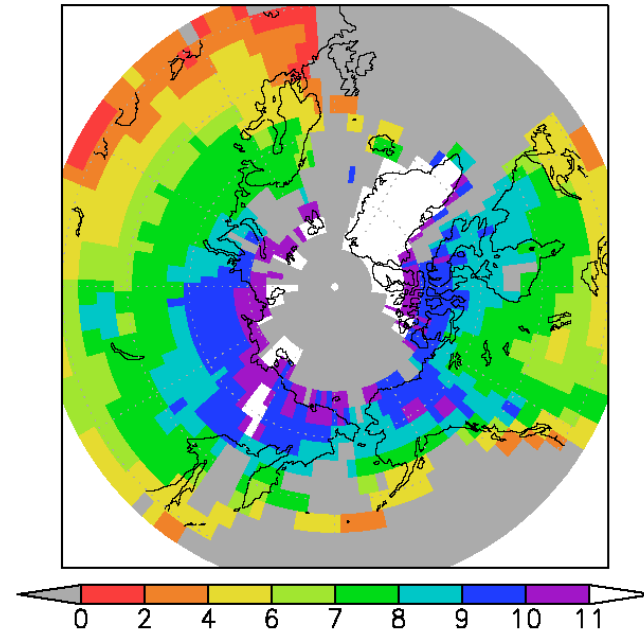
Months of Snow Cover (CONTROL_SOMT85)

T85



Months of Snow Cover (CONTROL_SOMT42)

T42



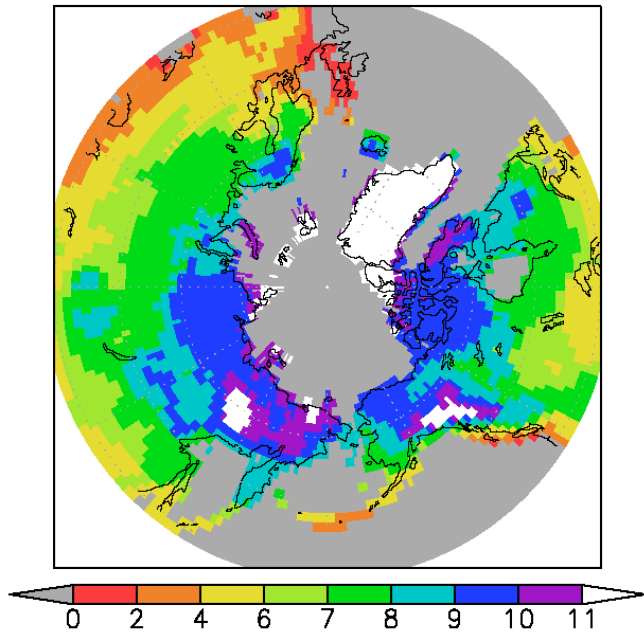
Permanent Snow Cover Area (incl. Greenland):

$3.8E6 \text{ km}^2$

$4.0E6 \text{ km}^2$

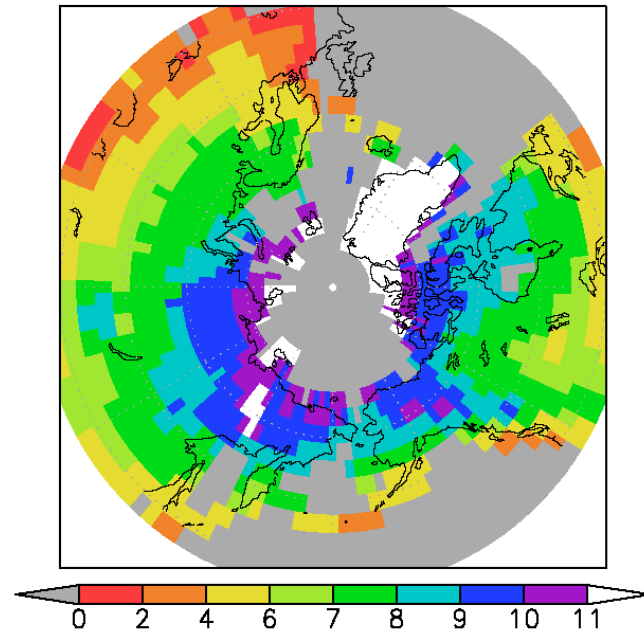
Months of Snow Cover (CONTROL_SOMT85)

T85

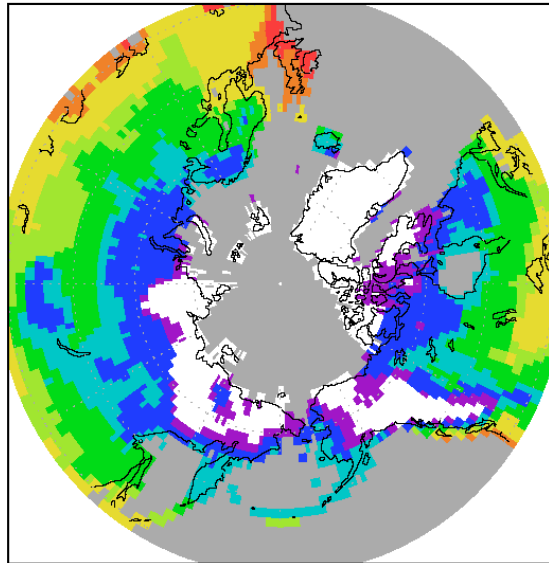


Months of Snow Cover (CONTROL_SOMT42)

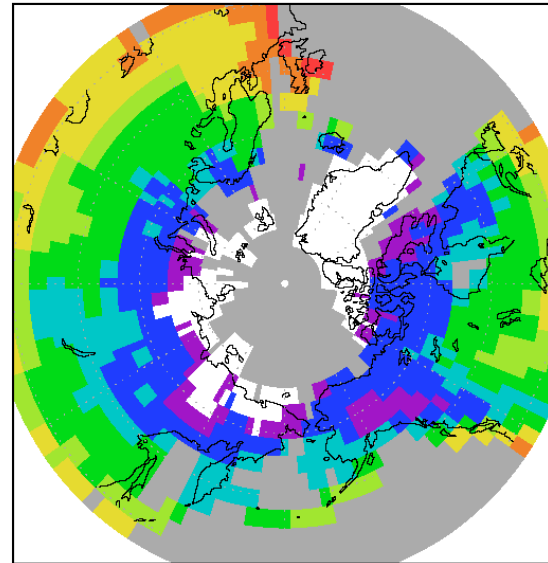
T42



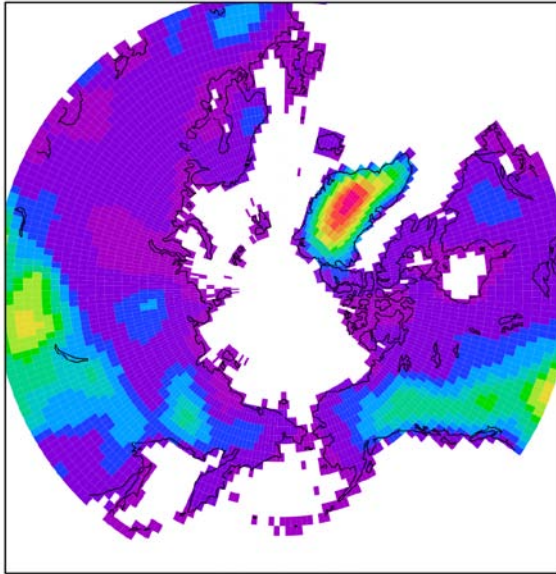
Months of Snow Cover (NOANTHRO_SOMT85)



Months of Snow Cover (NOANTHRO_SOMT42)

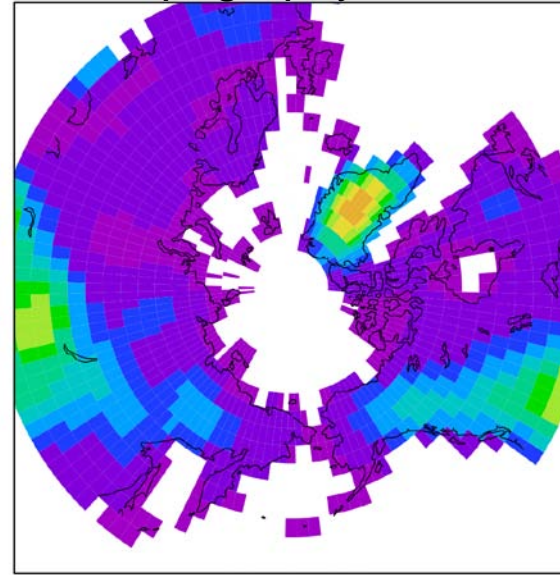


Topography_T85

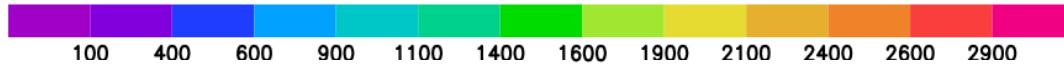


T85

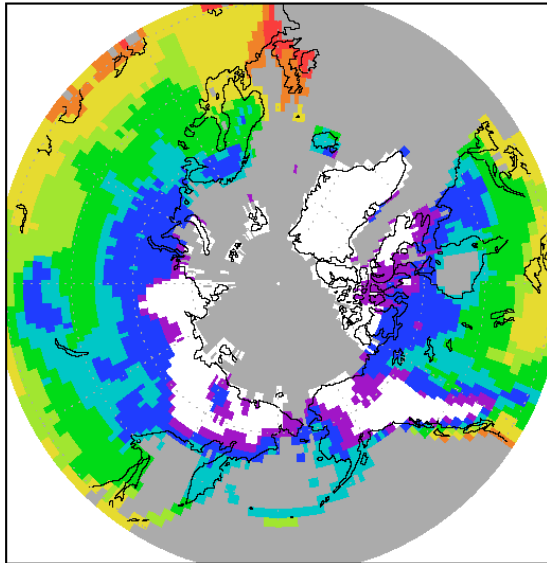
Topography_T42



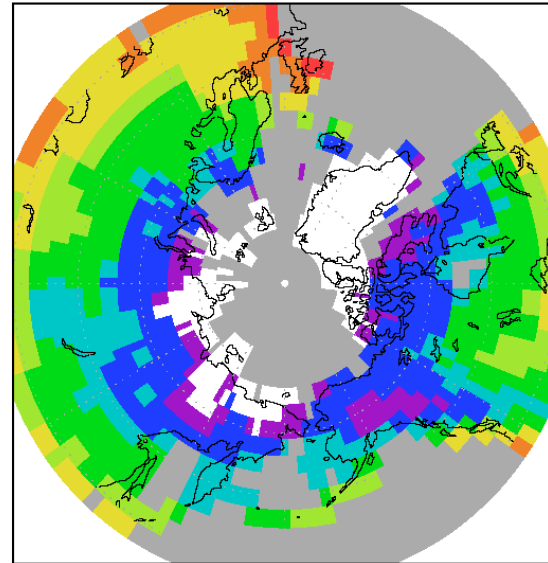
T42



Months of Snow Cover (NOANTHRO_SOMT85)



Months of Snow Cover (NOANTHRO_SOMT42)

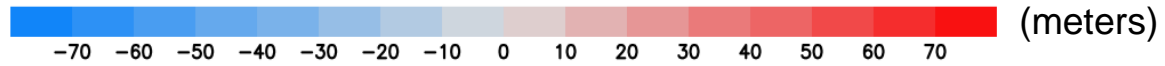
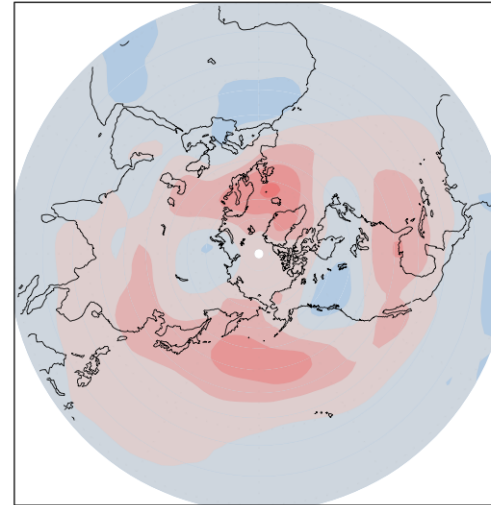
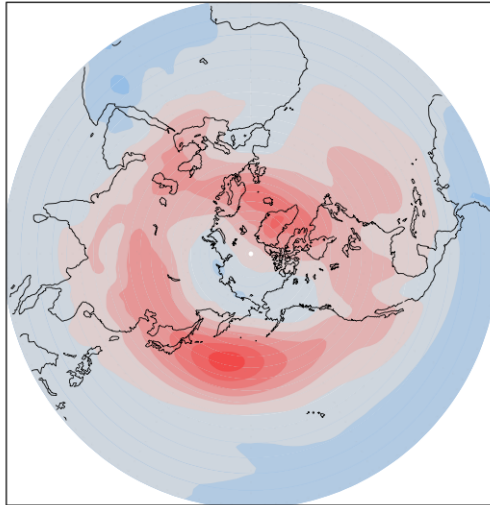


300 hPa Geopotential Height Response (global mean change removed)

T85

T42

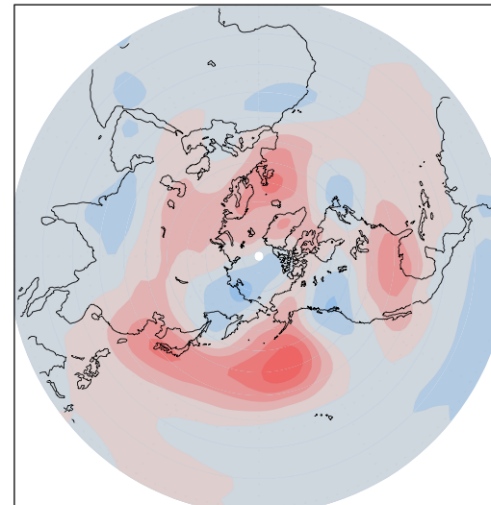
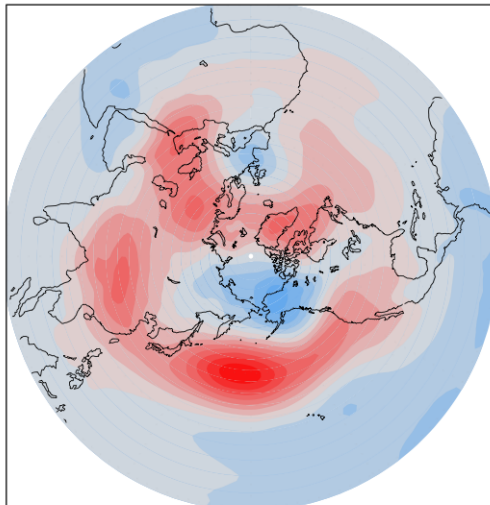
Annual



T85

T42

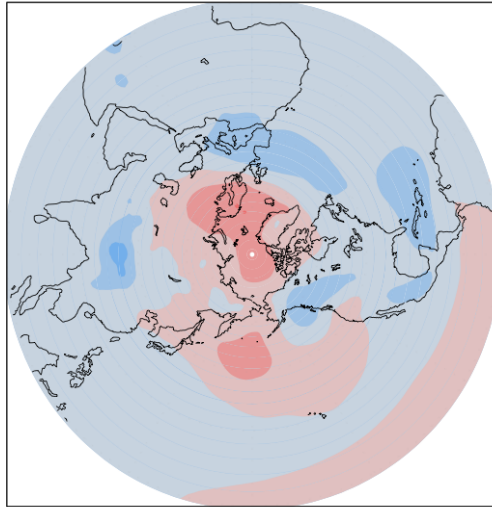
Winter



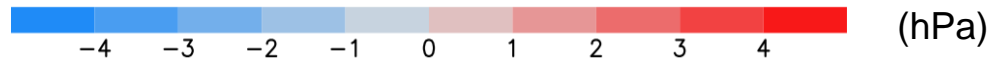
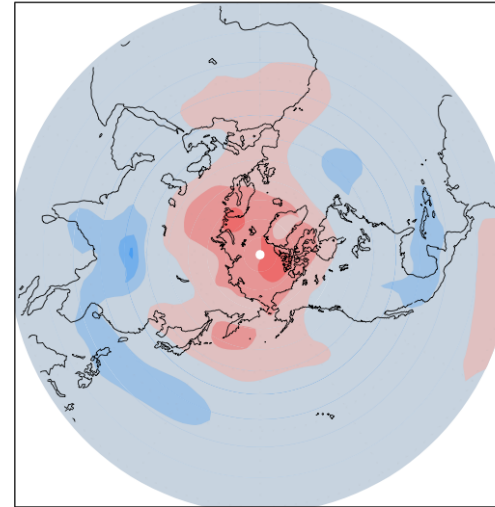
Sea Level Pressure Response

Annual

T85

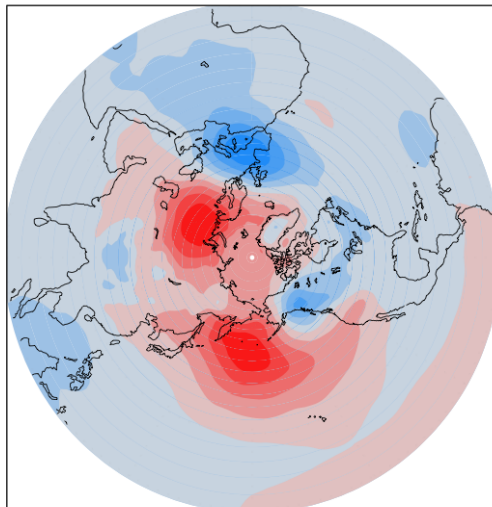


T42

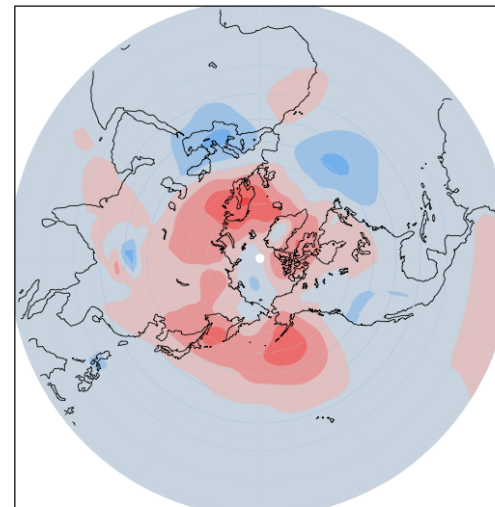


Winter

T85



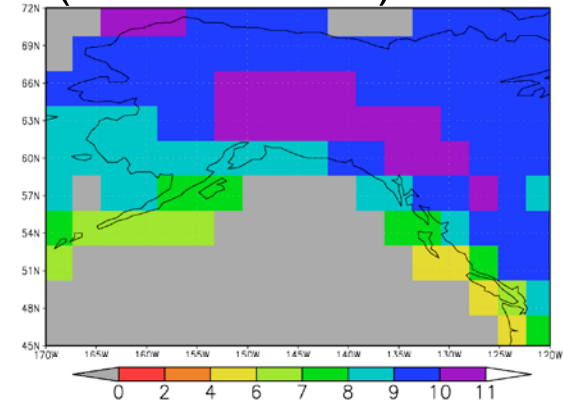
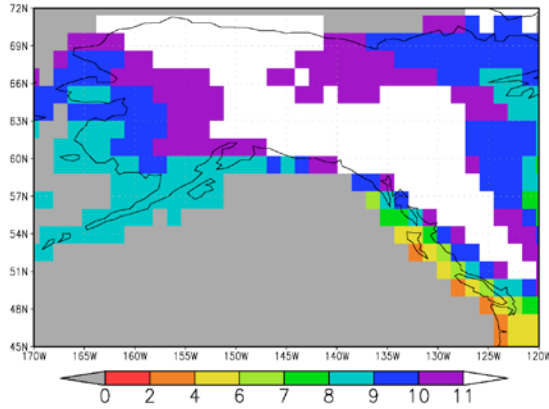
T42



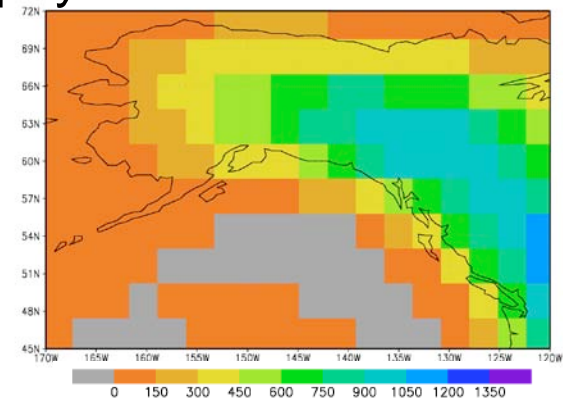
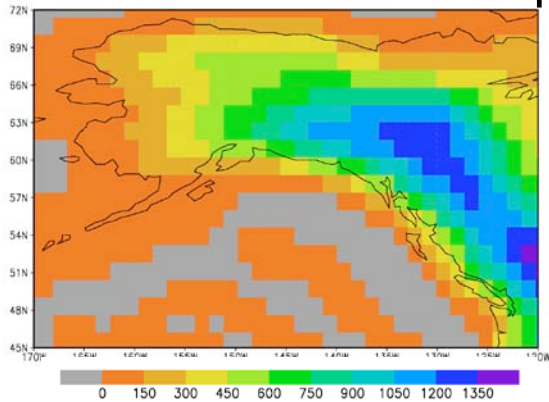
Months of Snow Cover (NOANTHRO)

T85

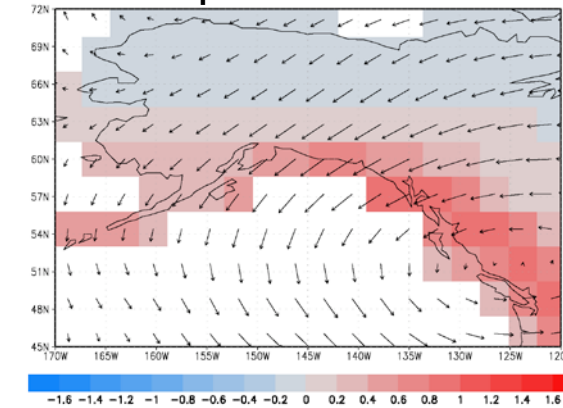
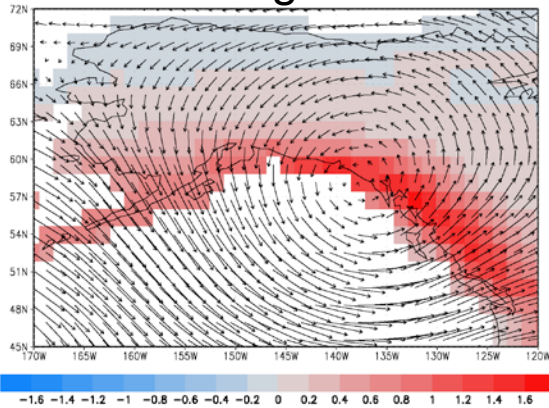
T42



Topography



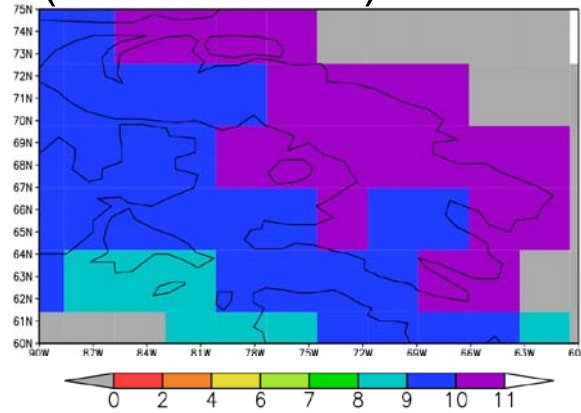
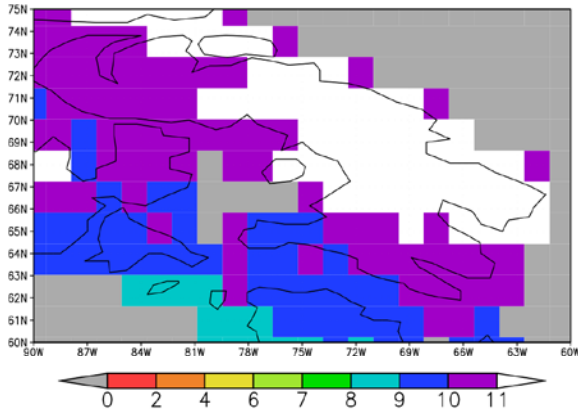
Change in Snowfall, Lower Atmospheric Wind



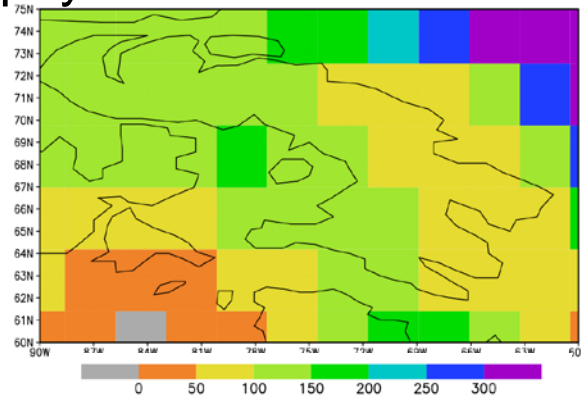
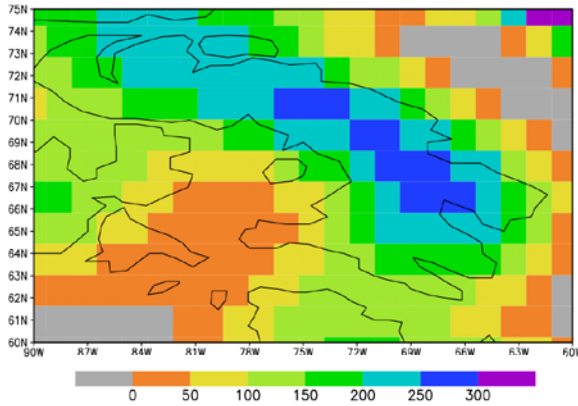
Months of Snow Cover (NOANTHRO)

T85

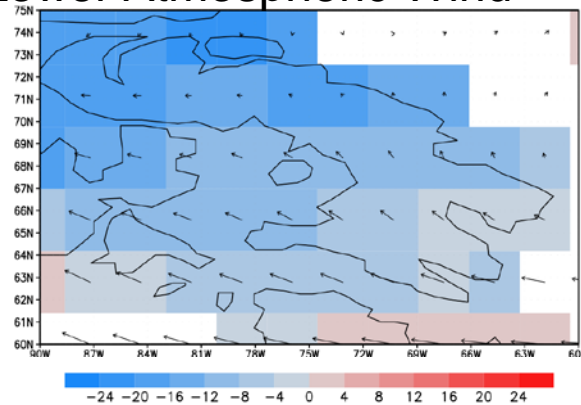
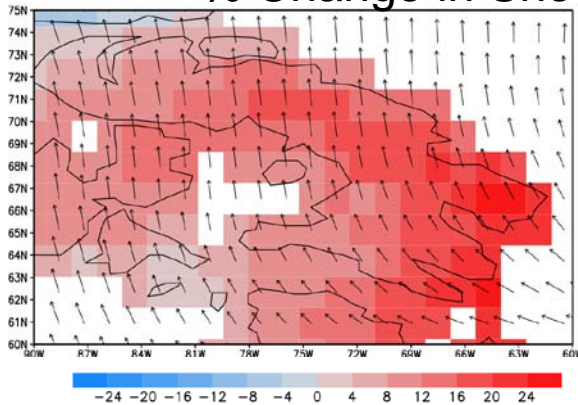
T42



Topography



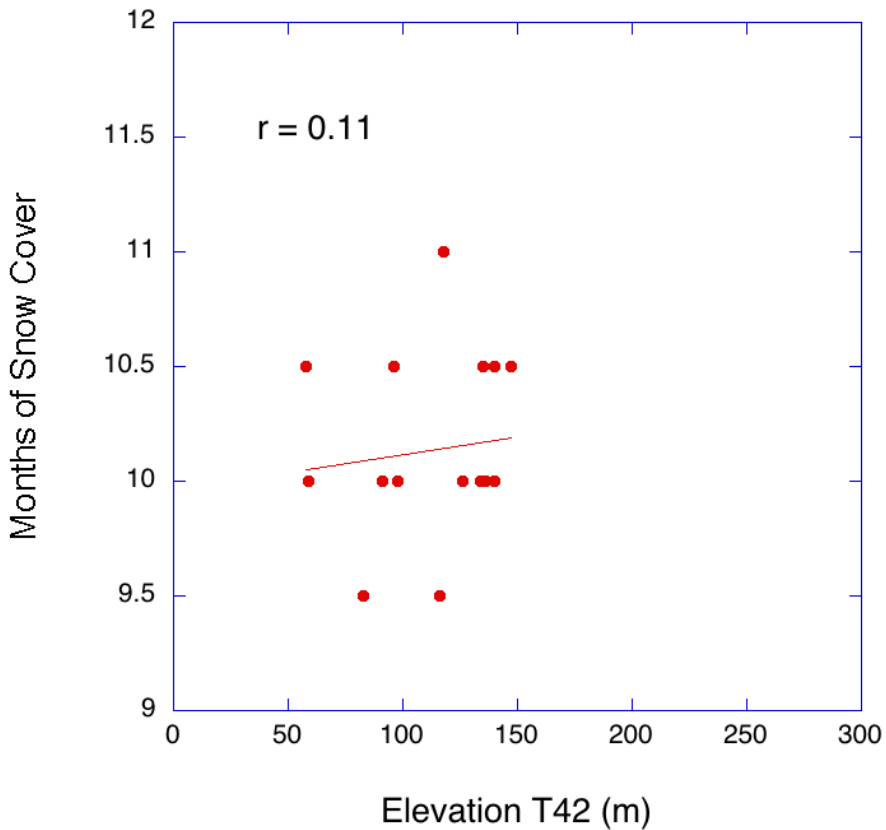
% Change in Snowfall, Lower Atmospheric Wind



Baffin Island: role of elevation

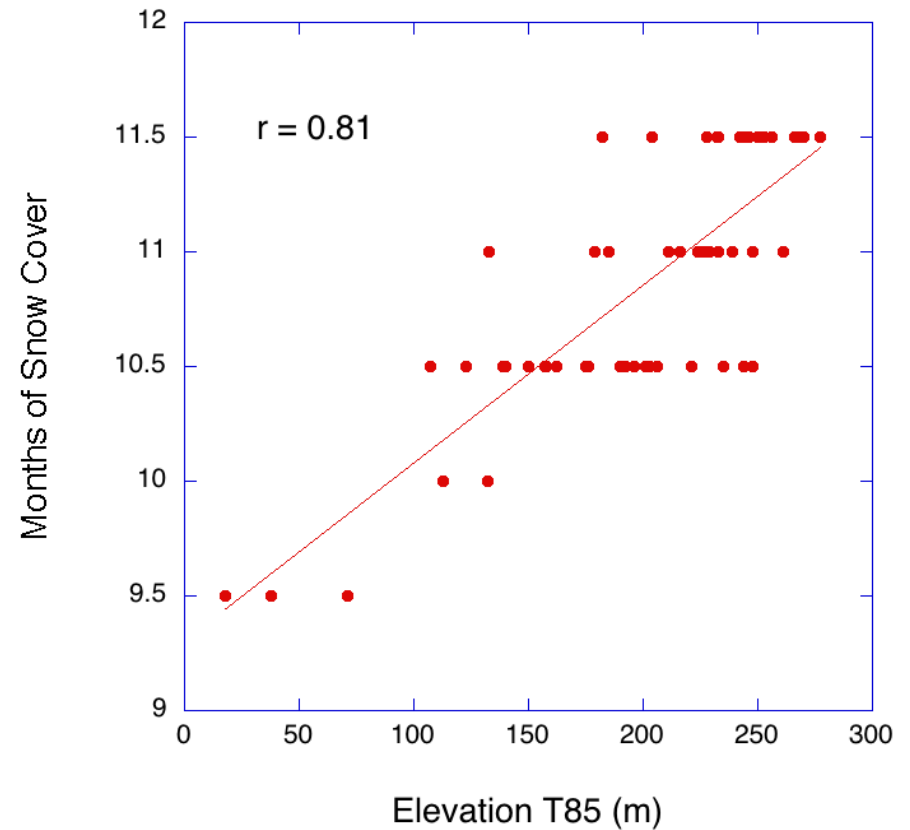
T42

Elevation vs. Snow Cover Duration T42



T85

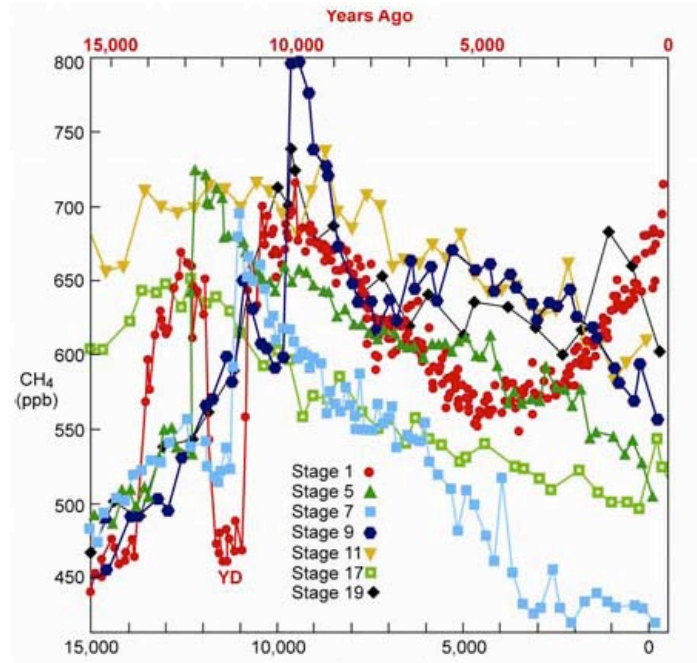
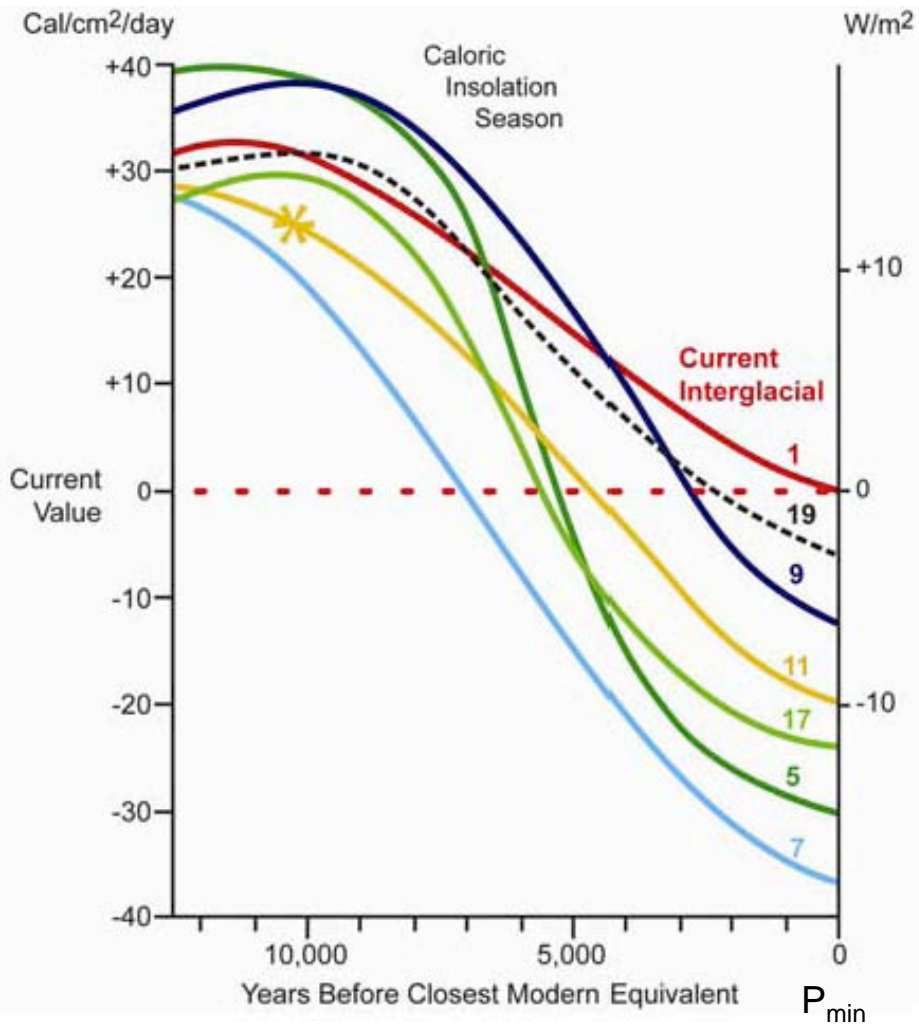
Elevation vs. Snow Cover Duration T85



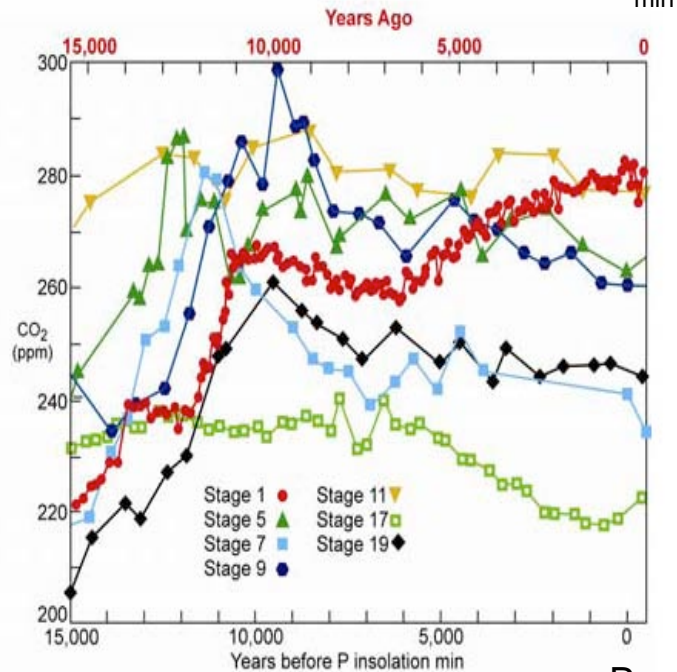
Conclusions

- Much more extensive glacial inception with higher model resolution (N. Amer.)
 - Expanded permanent snow cover at T85 mostly a *regional* response
 - Dependence of glacial inception on model resolution is a function of both:
 - (a) local topography
 - (b) large-scale dynamics ---> regional circulations
 - No ocean dynamics or interactive vegetation used here
 - Role of tropical Pacific bears investigation in a fully coupled simulation
- ? Would even higher model resolution lead to even more glacial inception?

N.H. Insolation Trends



CH_4



CO_2