

# Uncertainty in 21st century ocean temperature projections near Greenland

The bulk of Greenland's accelerating glaciers are located in Southeast and West Greenland where the warmest subsurface ocean waters flow along the coast and, also, where historical data indicate we should expect to see the largest amplitude variability [Straneo et al., 2012]. Climate model projections, furthermore, predict that this is where the most pronounced ocean warming will occur, roughly 2°C in the upper 500 m by 2100, which is almost double the global mean and much stronger than around Antarctica [Yin et al., 2011].

*BAMS, 2013*

- ★ **What are the sources and patterns of uncertainty in AOGCM projections of “far-field” ocean temperature?**
- ★ **Where should we look for signals of ocean heat content changes that might force future changes in mass balance, either via (direct) oceanic or (indirect) atmospheric forcing?**

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# CMIP5 ensemble

Model	Hist	RCP			
		2.6	4.5	6.0	8.5
CCSM4	X				
CNRM-CM5	X				
CSIRO-Mk3.6	X				
FGOALS-g2	X				
FGOALS-s2	X				
GFDL-ESM2M	X	X	X	X	X
GFDL-ESM2G	X	X	X	X	X
GFDL-CM3	X	X	X	X	X
GISS-E2-R	X	X	X	X	
HadGEM2-ES	X	X	X	X	X
IPSL-CM5A-LR	X	X	X	X	X
IPSL-CM5A-MR	X	X	X		X
IPSL-CM5B-LR	X				
MIROC5	X	X	X	X	X
MIROC-ESM	X	X	X	X	X
MIROC-ESM-CHEM	X	X	X	X	X
MPI-ESM-LR	X	X	X		X
MPI-ESM-MR	X		X		X
MRI-CGCM3	X	X	X	X	X
NorESM1-M	X	X	X	X	X
NorESM1-ME	X	X	X	X	X
<b>TOTAL</b>	<b>21</b>	<b>14</b>	<b>15</b>	<b>12</b>	<b>14</b>

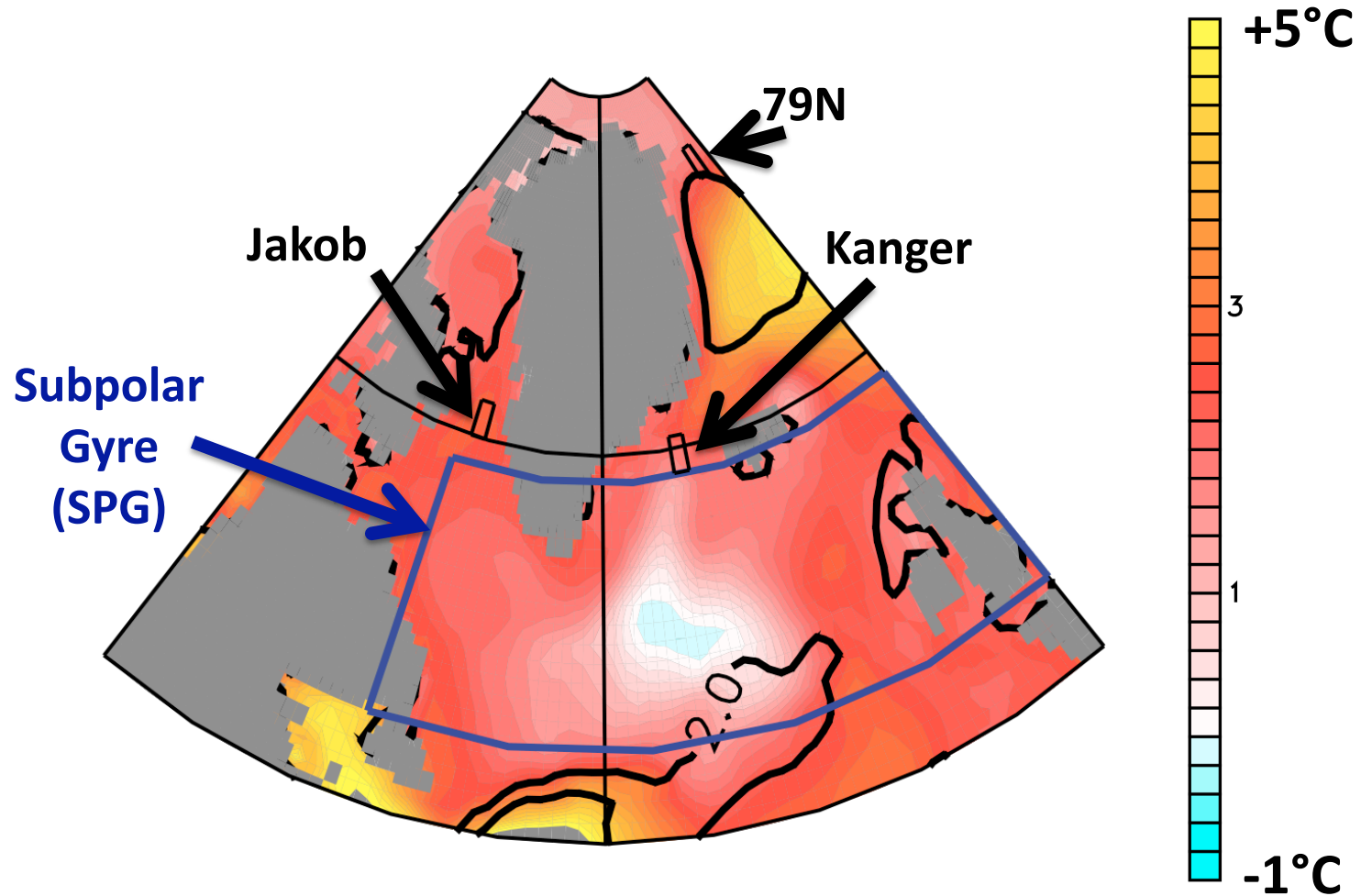
★ Examine “warming” – change in ocean temperature from a baseline period in a simulation run with historical forcing

$$\Delta T(t, \text{RCP}) = T(t, \text{RCP}) - \bar{T}_{1980-2005}(\text{Hist})$$

★ “Model uncertainty” – mean ensemble spread across all emissions scenarios

★ “Scenario uncertainty” – spread of the ensemble mean projections

**Multimodel mean warming (shading); Multimodel SD (contours)  
(RCP 8.5; 2090-2099; 0-500m mean temperature; °C)**



- ★ Patterns of mean warming and ensemble spread very similar across scenarios
- ★ Little depth-dependence in magnitude or pattern of warming (between 0-500m)

# Initial findings

- ★ **Model and scenario uncertainty in ocean temperature reach their global maxima in the North Atlantic subpolar gyre (NASPG).**
- ★ **The expected ocean warming rates are larger and the inter-model spread is reduced closer to Greenland.**
  - ★ **Counter-intuitively, projections of ocean forcing of the Greenland ice sheet are more robust at small(er) scales, closer to outlet glaciers**
  - ★ **Observed decadal variability in ocean heat content (e.g. the mid-1990's warming of the NASPG) may not be analogous to the century-timescale changes projected by AOGCM's (?)**

Multimodel mean warming  $\pm$  Multimodel SD  
(ALL RCP's; 0-500m mean; °C)

	<b>SPG</b>	<b>Kanger</b>	<b>Jakob</b>	<b>79N</b>
<b>2050s</b>	<b>0.5 <math>\pm</math> 0.8</b>	<b>0.6 <math>\pm</math> 0.6</b>	<b>1.0 <math>\pm</math> 0.4</b>	<b>0.7 <math>\pm</math> 0.5</b>
<b>2090s</b>	<b>0.9 <math>\pm</math> 1.2</b>	<b>1.1 <math>\pm</math> 1.0</b>	<b>1.6 <math>\pm</math> 0.9</b>	<b>1.5 <math>\pm</math> 1.2</b>