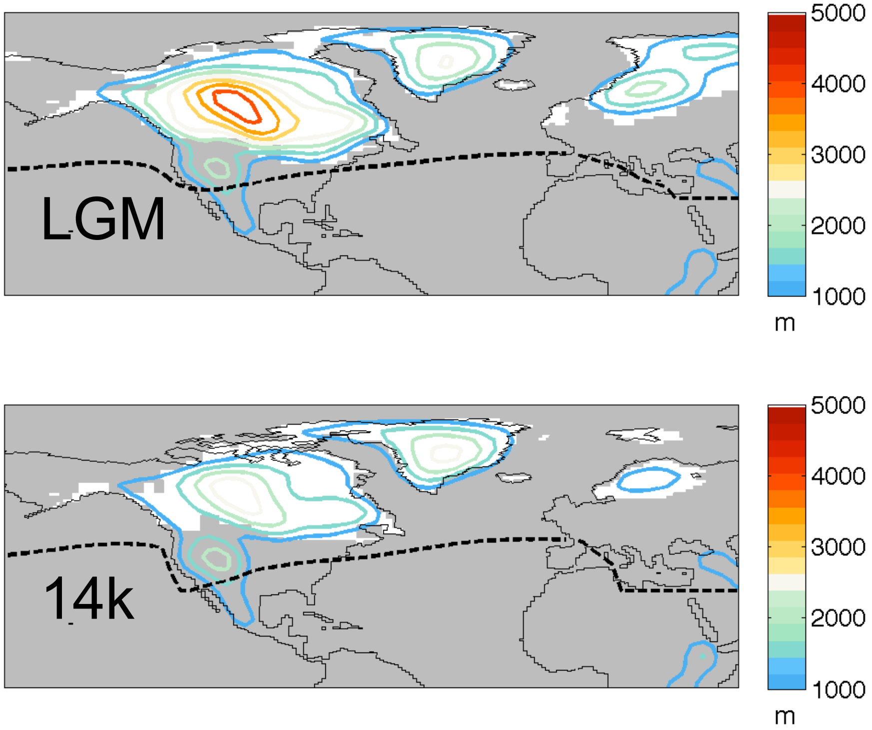
North Atlantic Climate Variability at LGM, 14k, and present day

By Cecilia Bitz
with help from Joe Barsugli, Kevin Rennet, Camille Li, Susan Bates, and David Battisti



Topography
and jet position

Greenland temperature and global ice volume

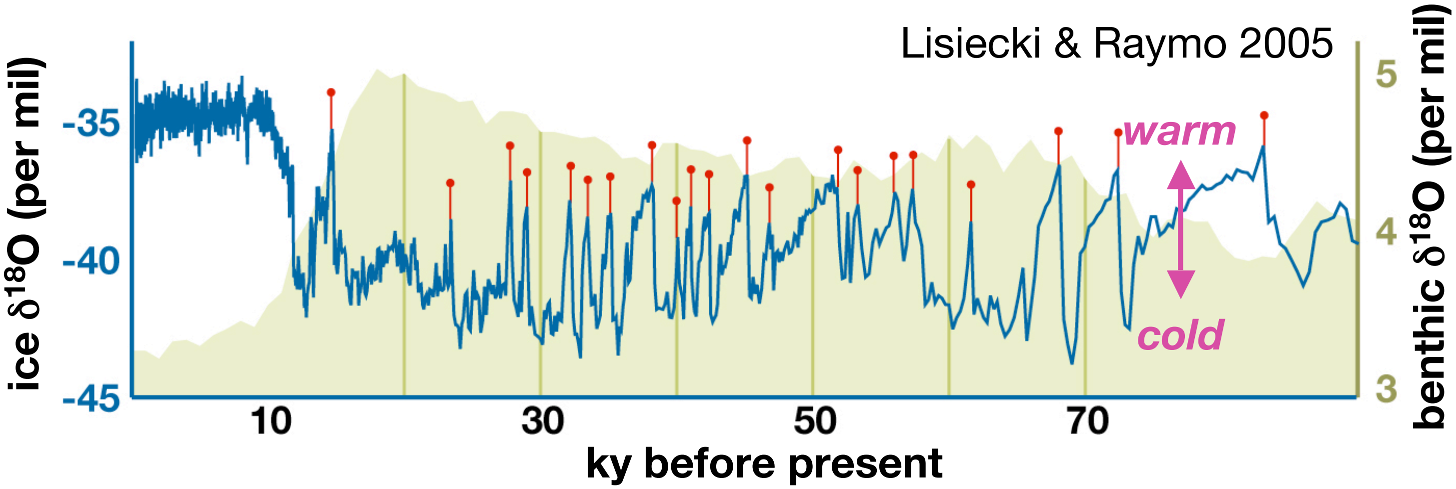


figure by Camille Li

Absence of abrupt change at LGM

First set of experiments with CAM3 and LGM SST and sea ice surface conditions

Laurentide ice sheet height scaled by a percentage - 40, 50, 60, 70, 80, 90, 100%

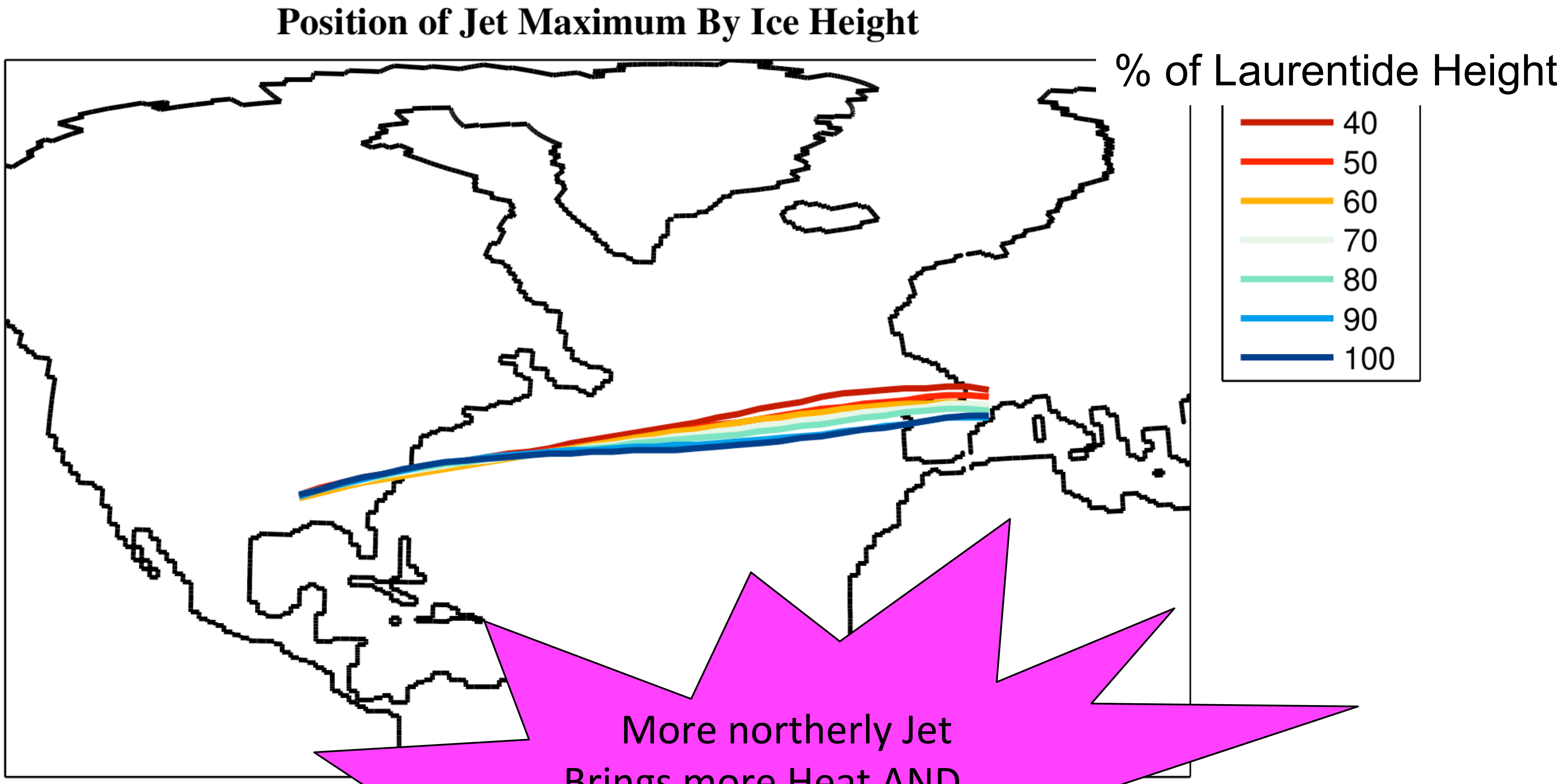
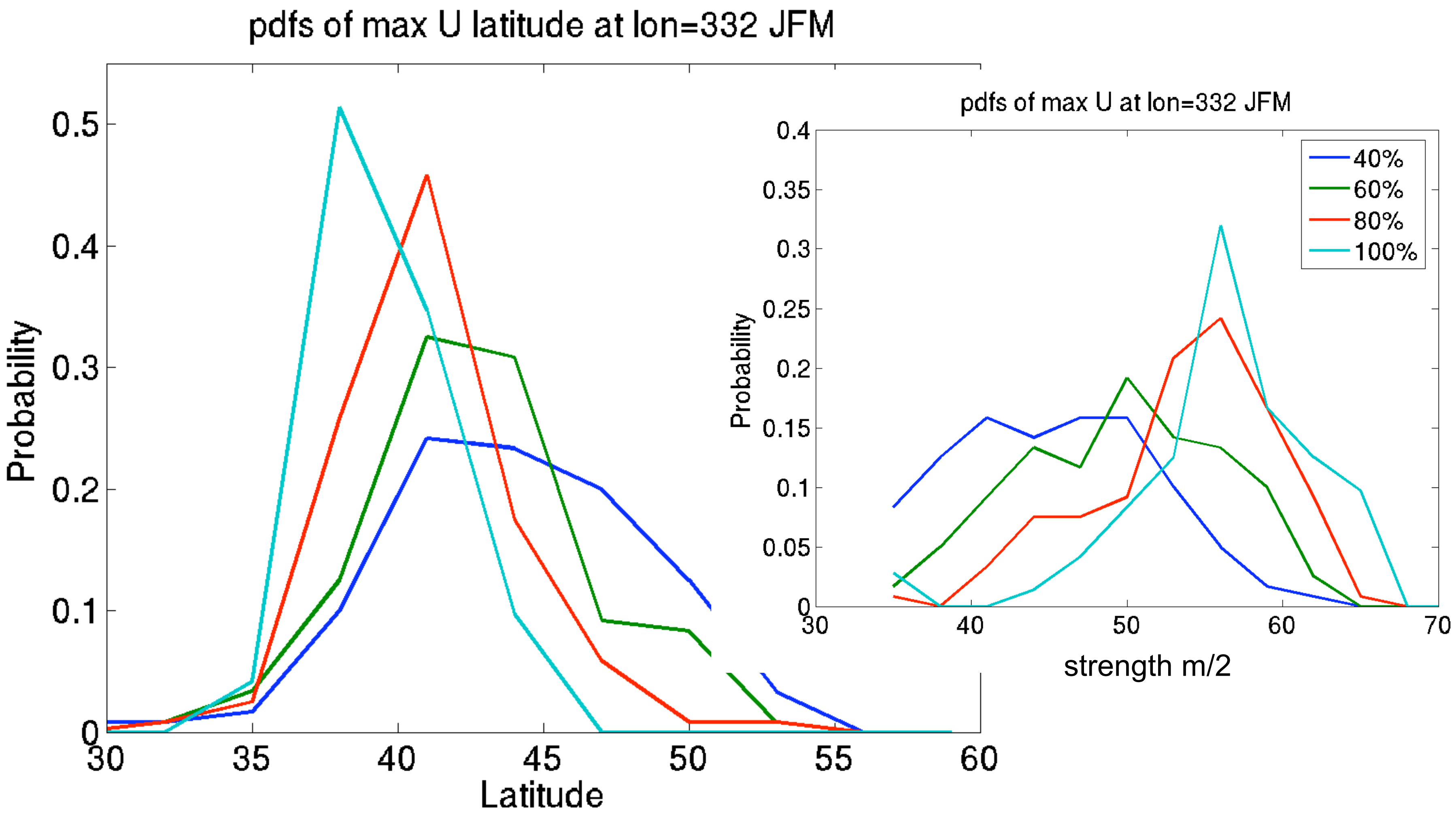


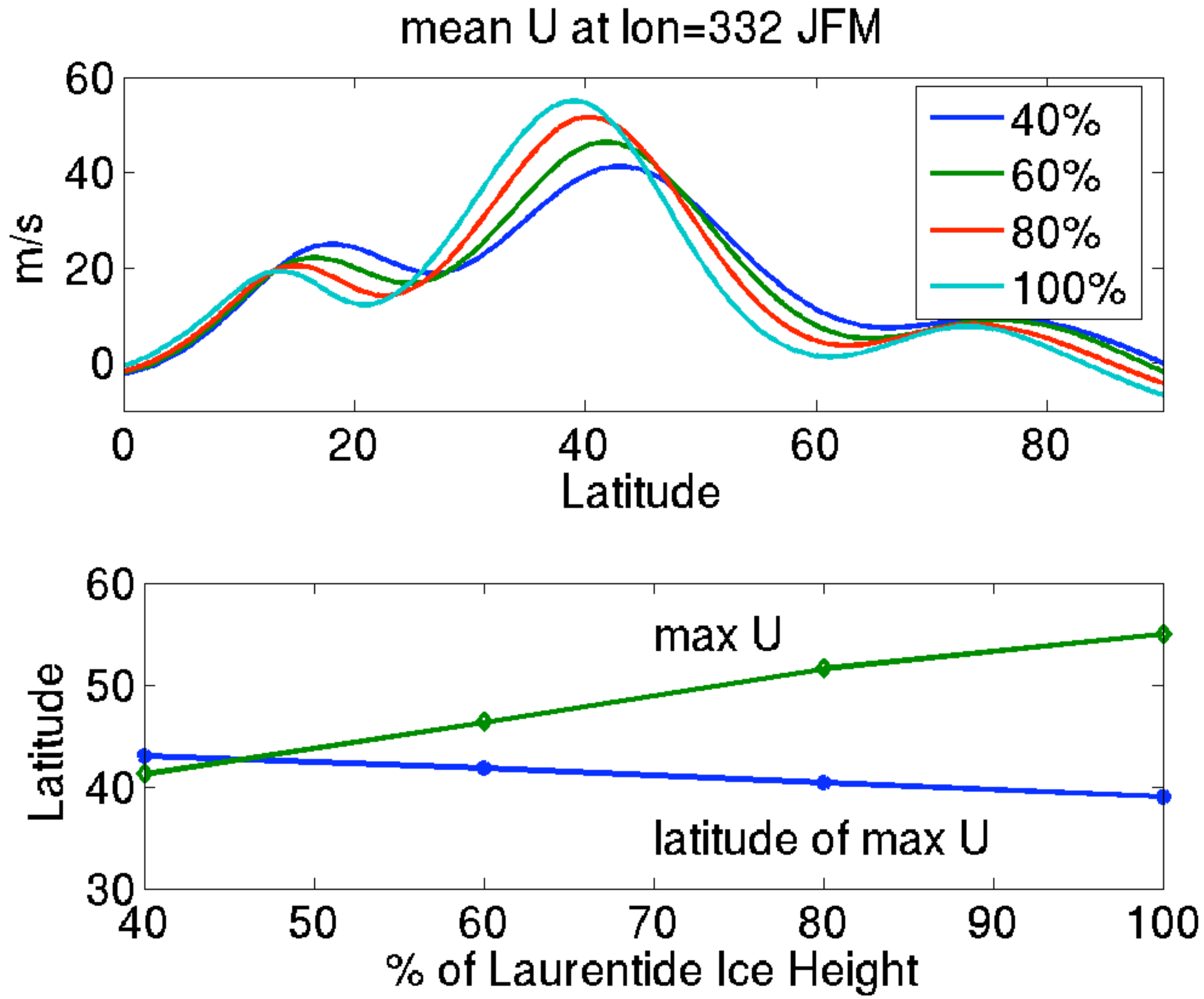
Figure by Kevin Rennert

More northerly Jet
Brings more Heat AND
More Rain to the Northern
North Atlantic
Eisenman et al 2008



Jet axis (peak wind position) not only moves southward with taller ice, it becomes focused and stronger

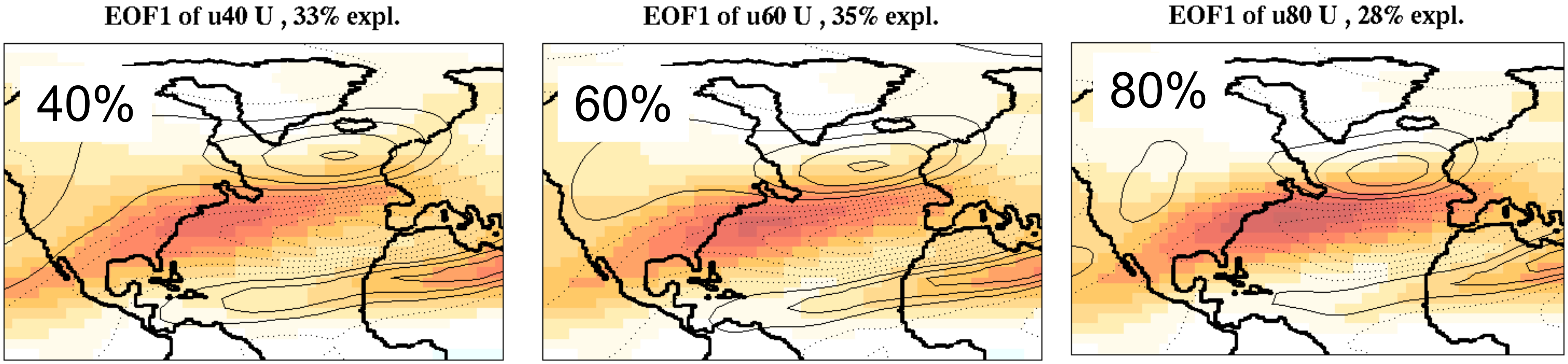
Figures by Kevin Rennert



% of Laurentide
Height

Figure by Kevin Rennert

Leading EOF (contoured) and mean U at 250 mb

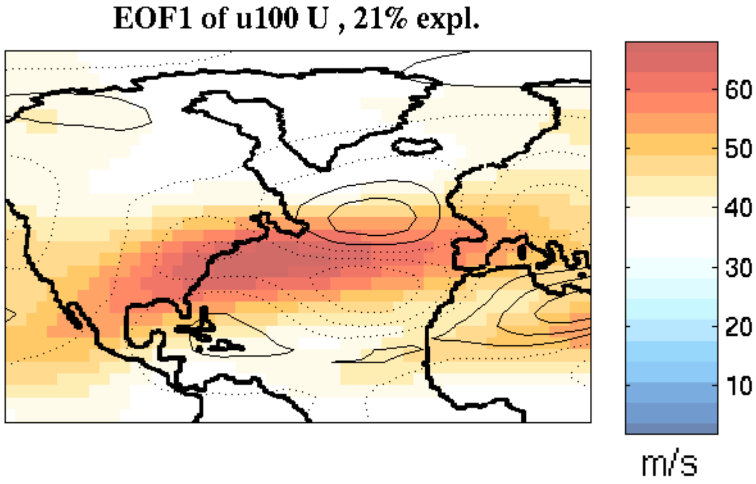

EOF1 of u40 U , 33% expl.

EOF1 of u60 U , 35% expl.

EOF1 of u80 U , 28% expl.

Leading jet variability in shorter ice sheet height runs is a broadening-shifting mode

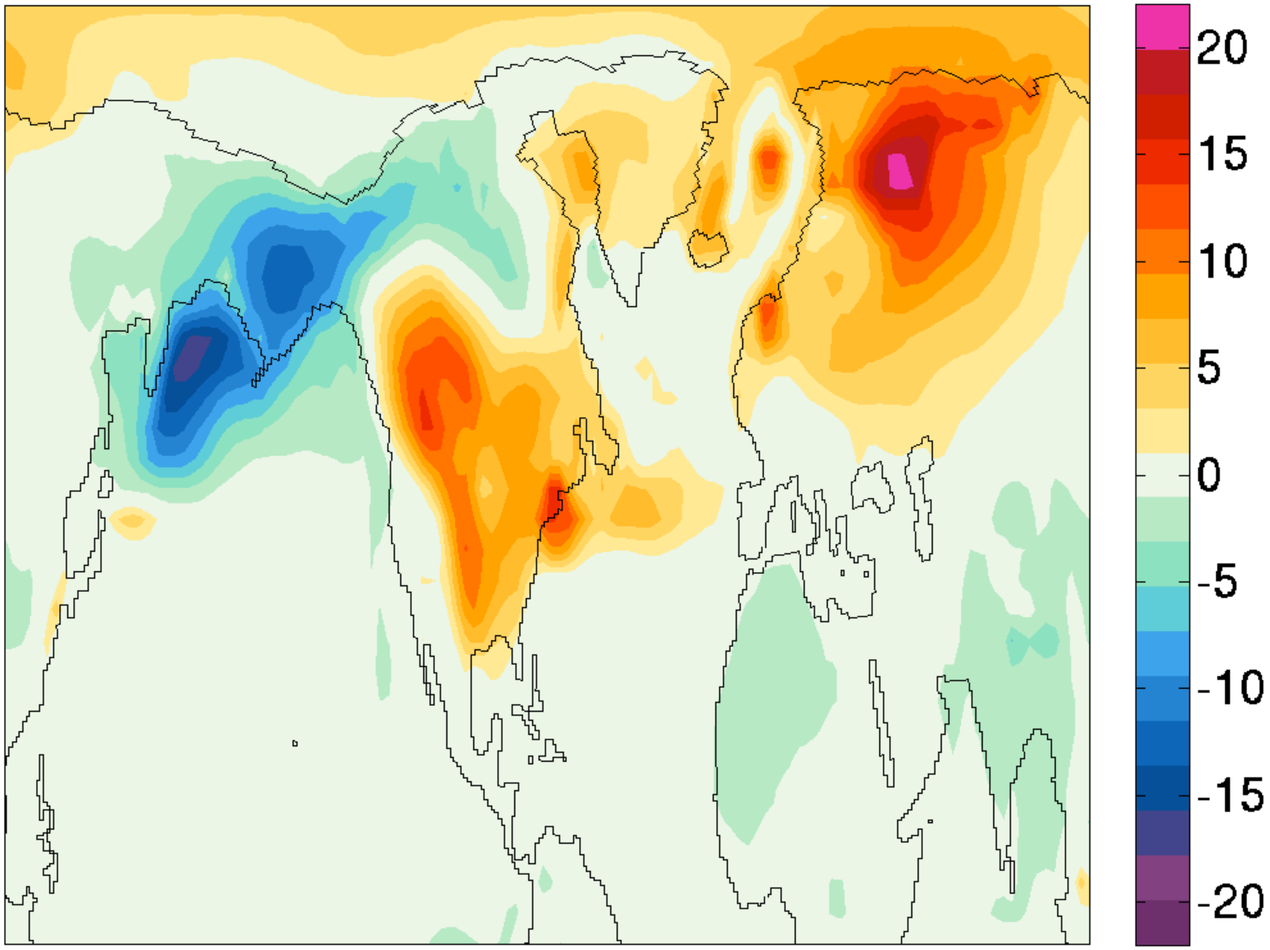
Full height ice sheet run has jet variability is a shifting mode


EOF1 of u100 U , 21% expl.

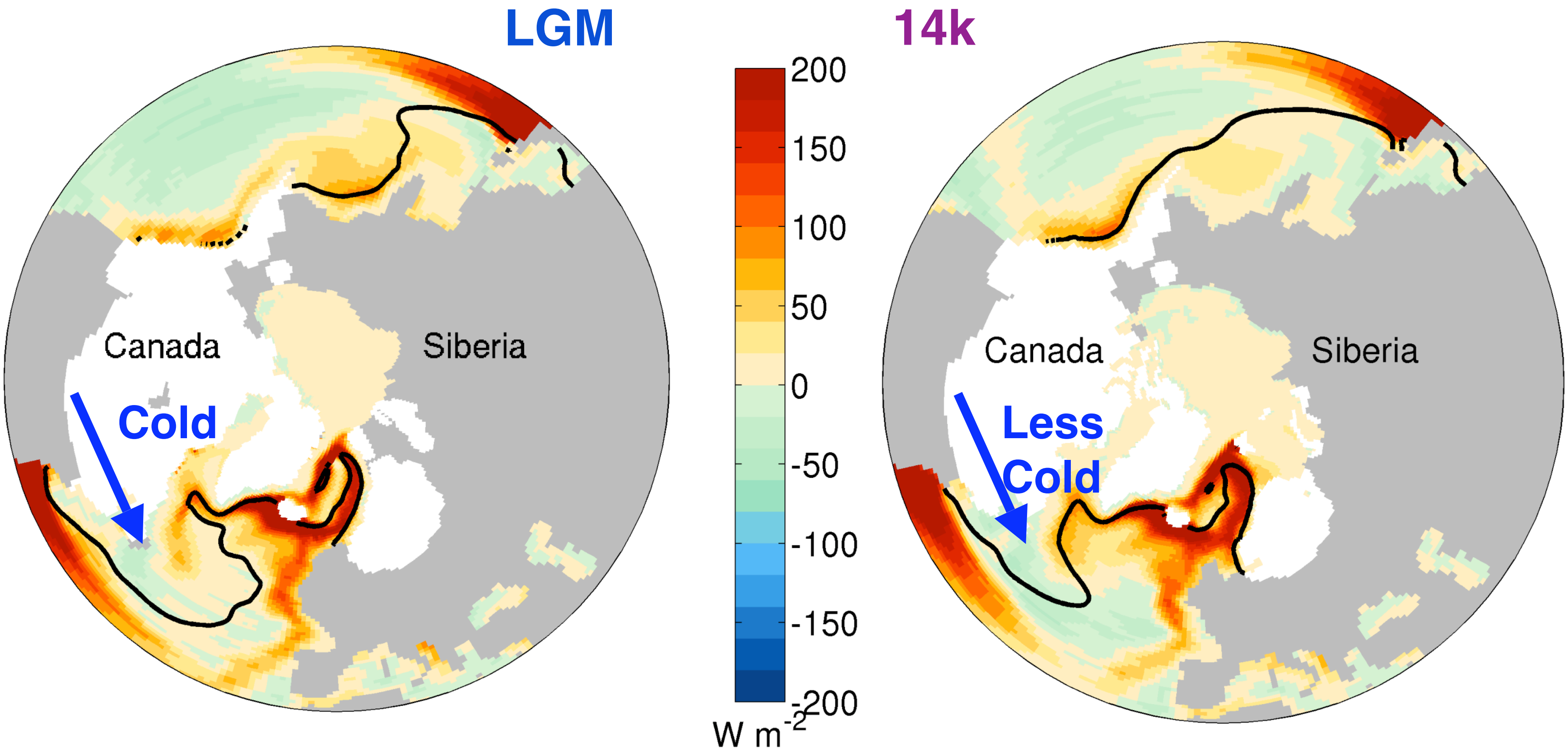
Remaining slides show results from fully coupled CCSM3 runs at LGM, 1990 control, and new 14k run

all at T42 X 1

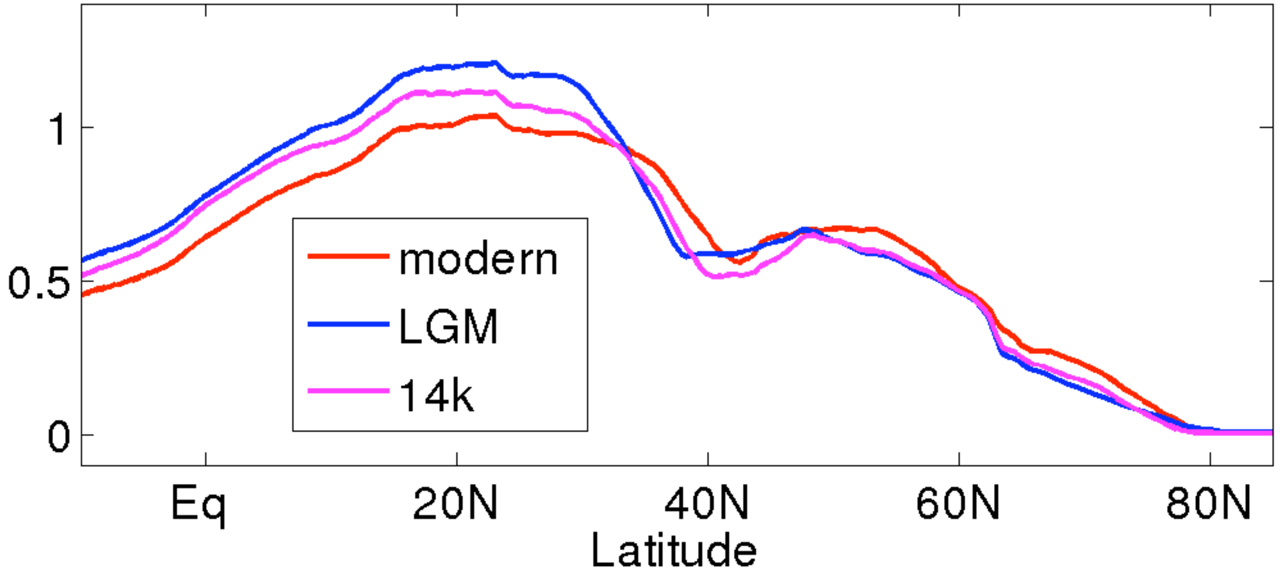
DJF Surface Temperature 14k minus LGM - deg C



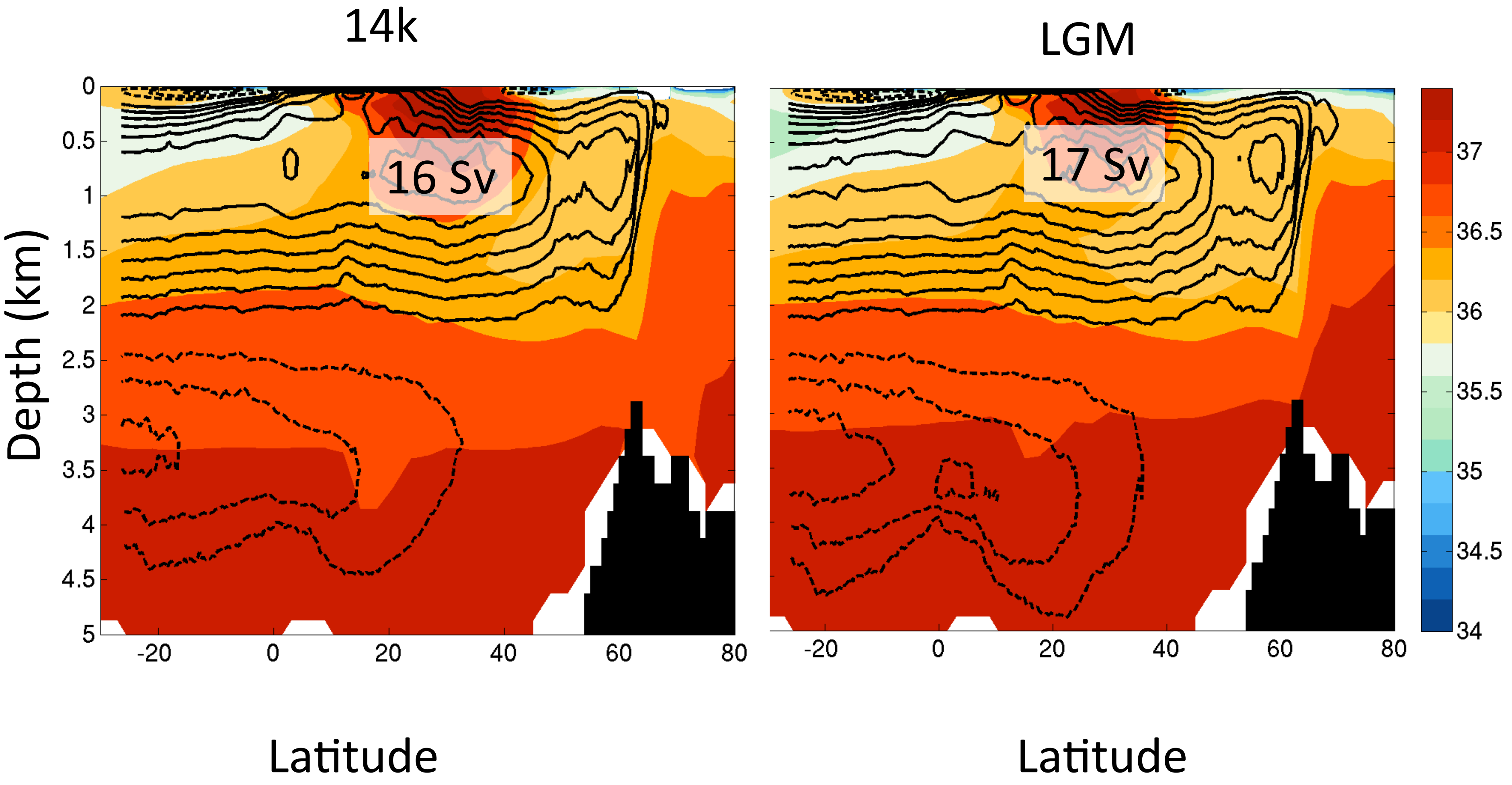
Ocean Heat Flux Convergence Sets the Sea Ice Edge



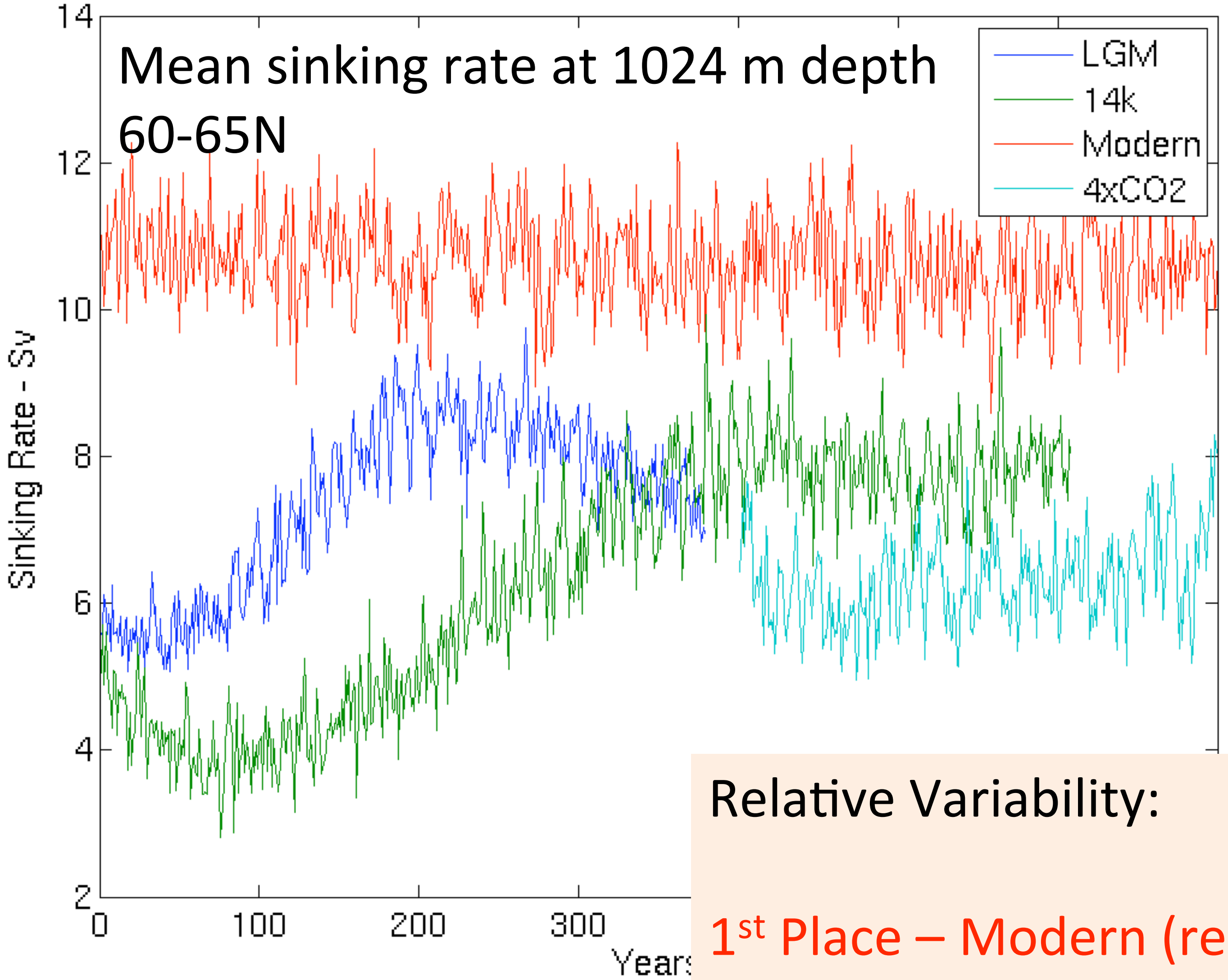
Atlantic Northward Heat Transport - PW



Atlantic Overturning Streamfunction (2 Sv black contours) and Salinity (in psu color)



Climate affects MOC (and Vice Versa)


Mean sinking rate at 1024 m depth
60-65N

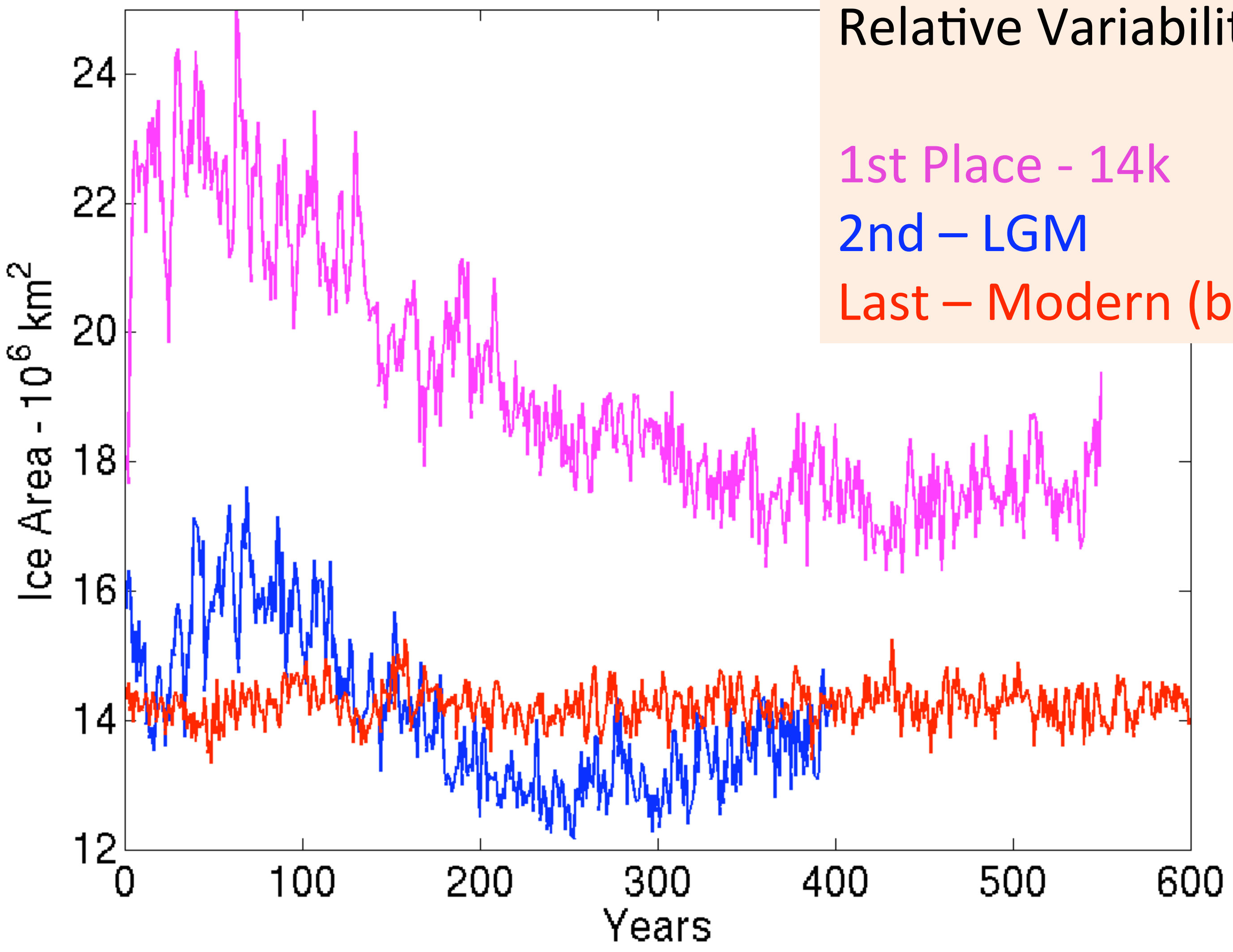
Relative Variability:

1st Place – Modern (redder too)

2nd Place - 14k and 4XCO2

Last - LGM (by a lot)

Northern Hemisphere Sea Ice Area



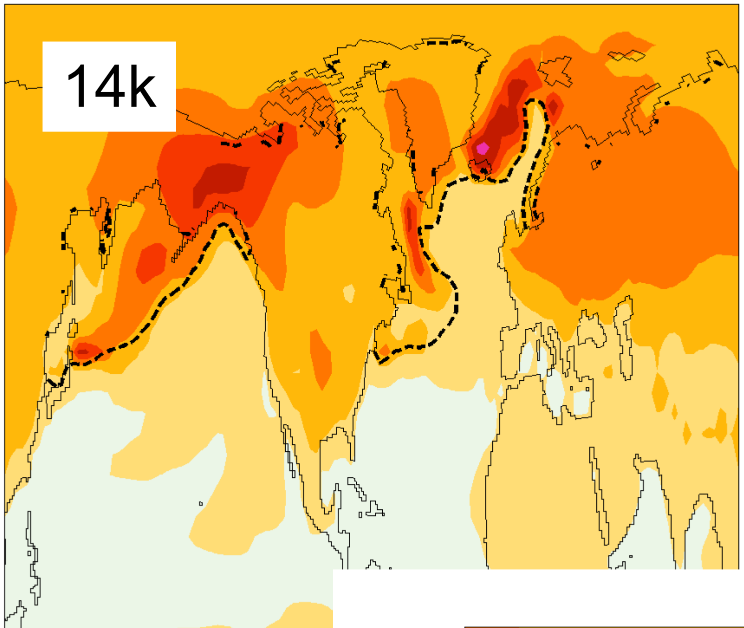
Relative Variability:

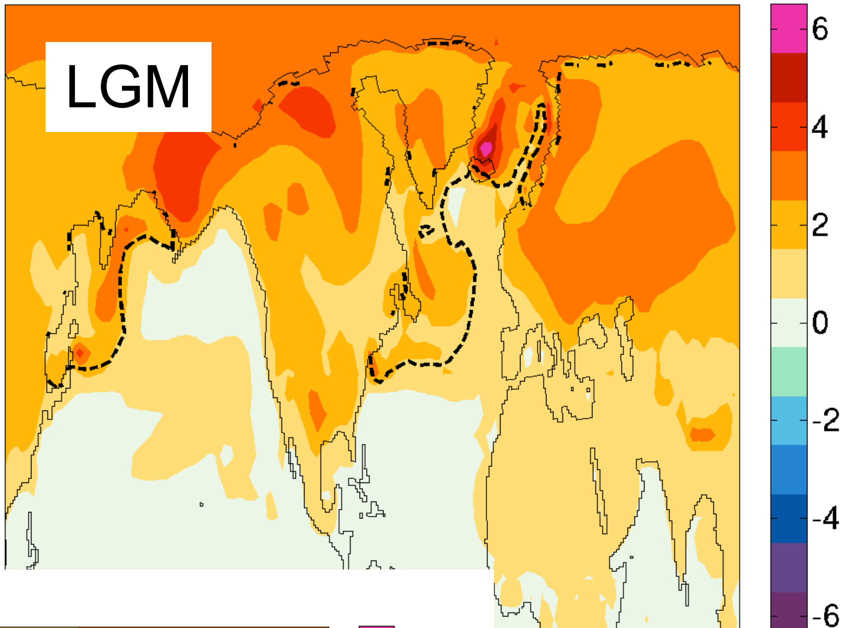
1st Place - 14k

2nd – LGM

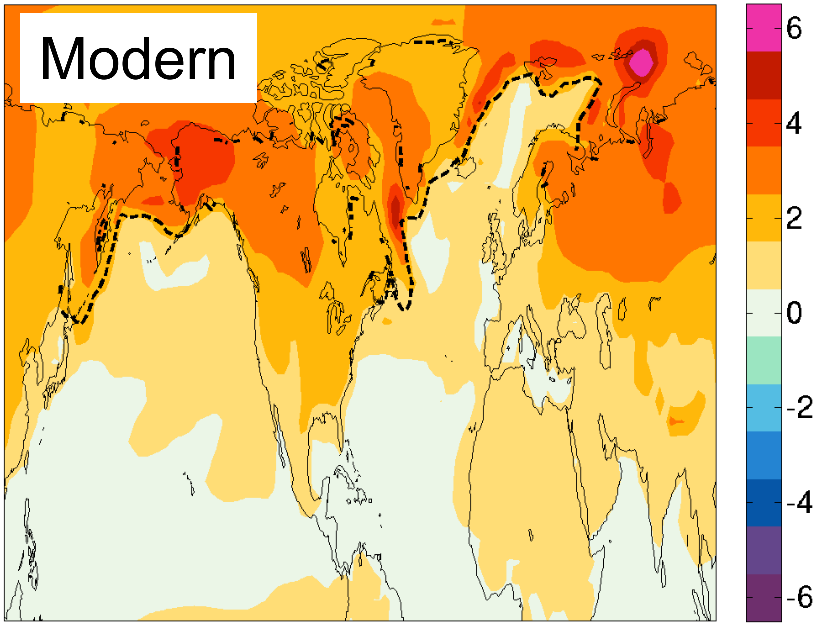
Last – Modern (by a lot)

DJF Surface Temperature Standard Deviation - deg C

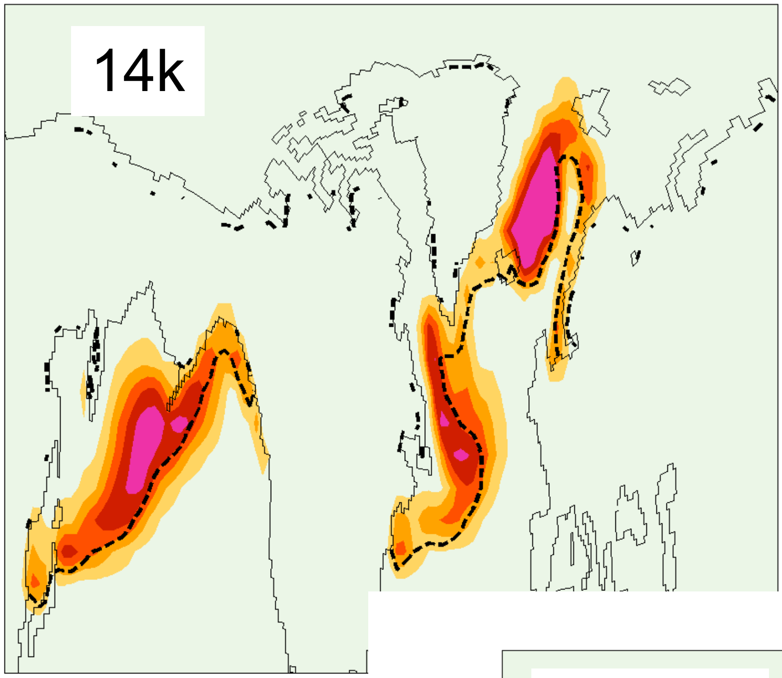


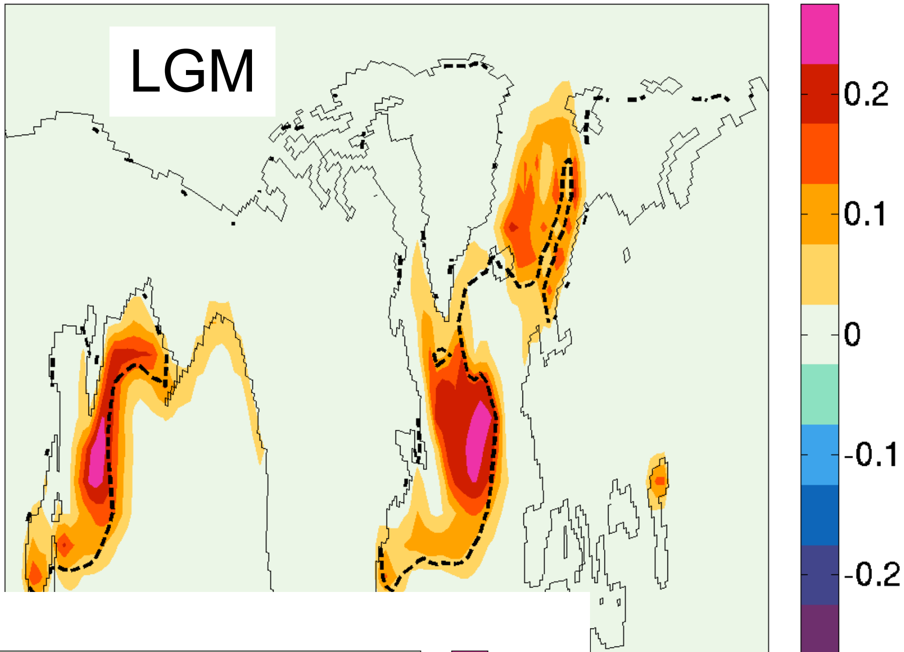


DJF sea ice extent
is dashed

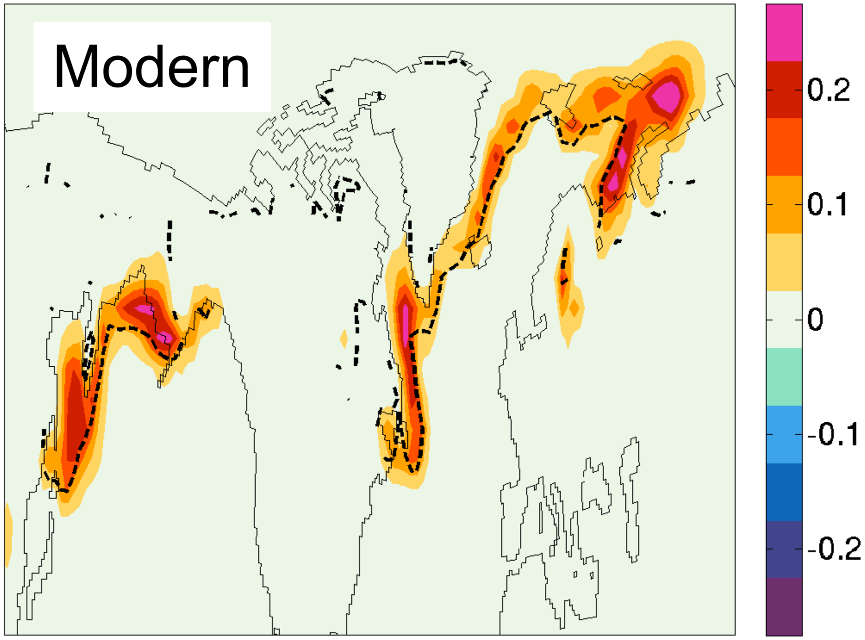


DJF Sea Ice Fraction Standard Deviation





DJF sea ice extent is dashed

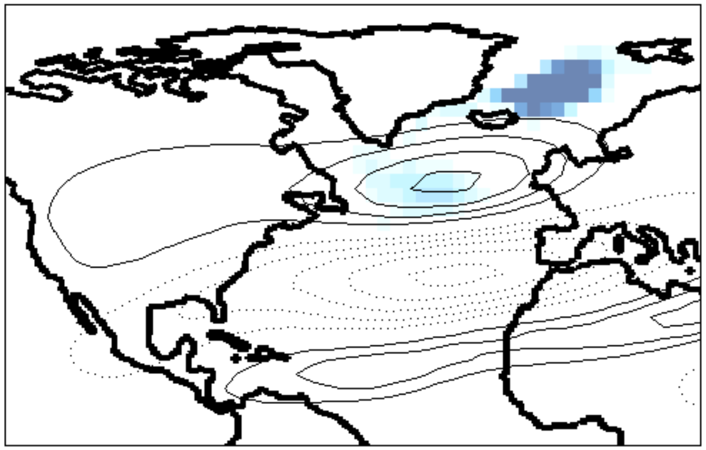


14k modes of variability in U at 250 mb and sea ice fraction

normalized
units

(uncoupled
variability)

EOF mode 1, U at 250 mb(contoured) , ice fraction(color), perc expl=29, 22%



EOF mode 2, U at 250 mb(contoured) , ice fraction(color), perc expl=14, 22%

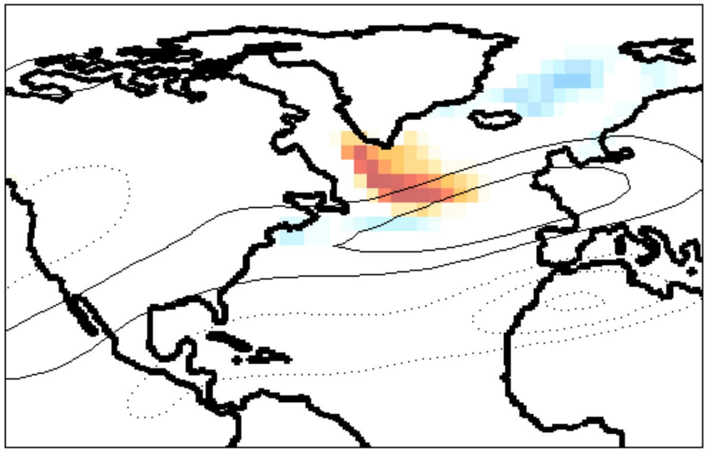


Figure by Kevin Rennert

LGM modes of variability in U at 250 mb and sea ice fraction

normalized
units

(uncoupled
variability)

EOF mode 1, U at 250 mb(contoured) , ice fraction(color), perc expl=20, 27%

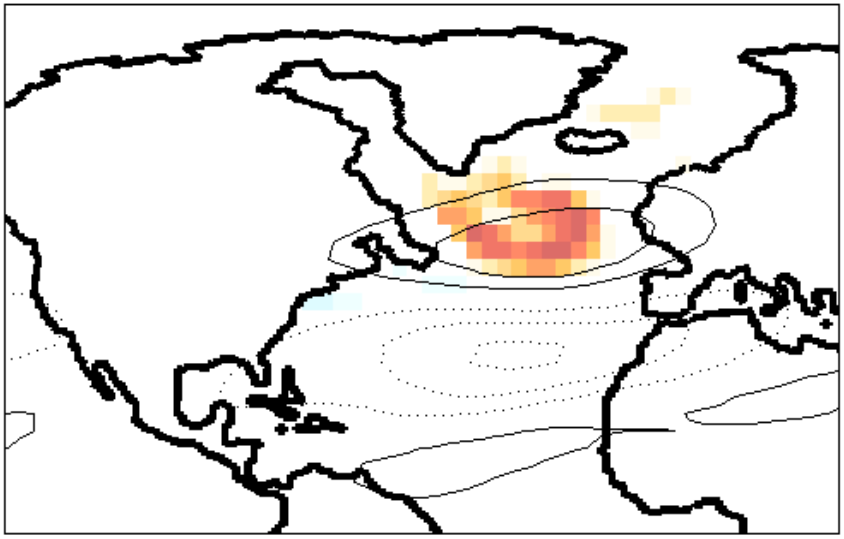
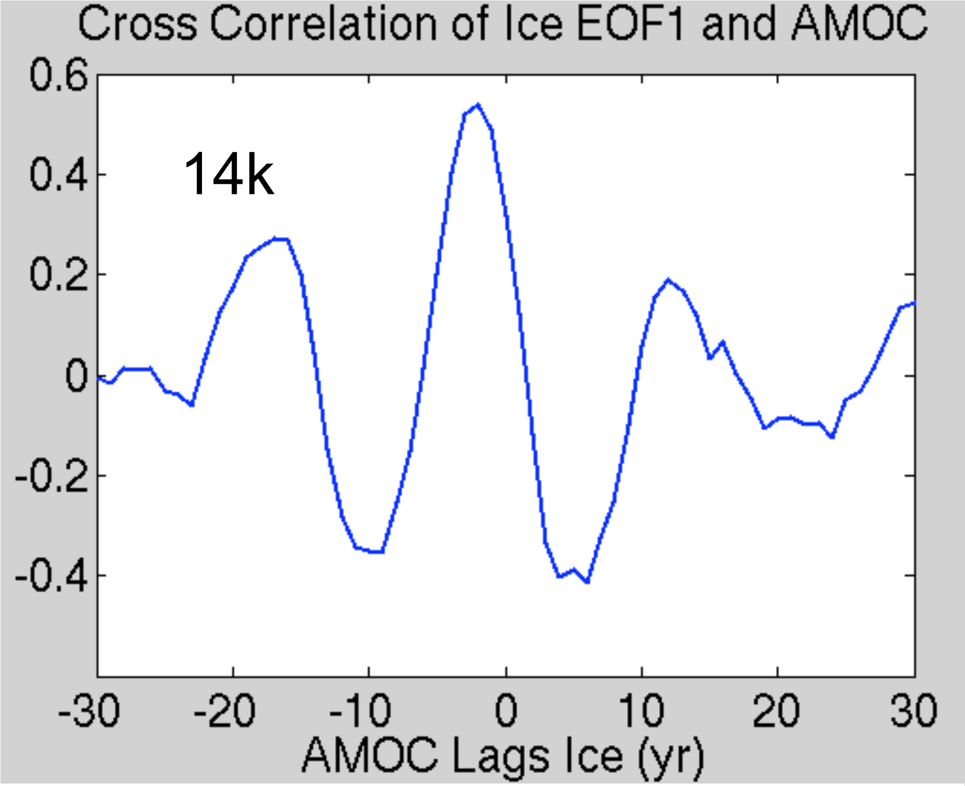
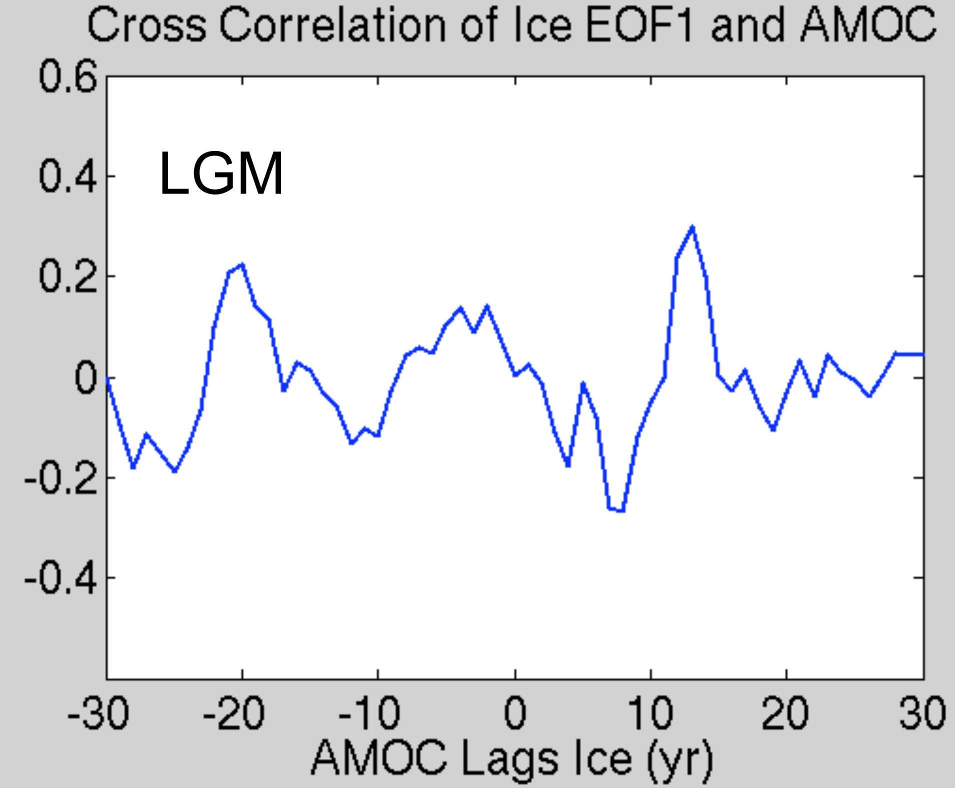


Figure by Kevin Rennert

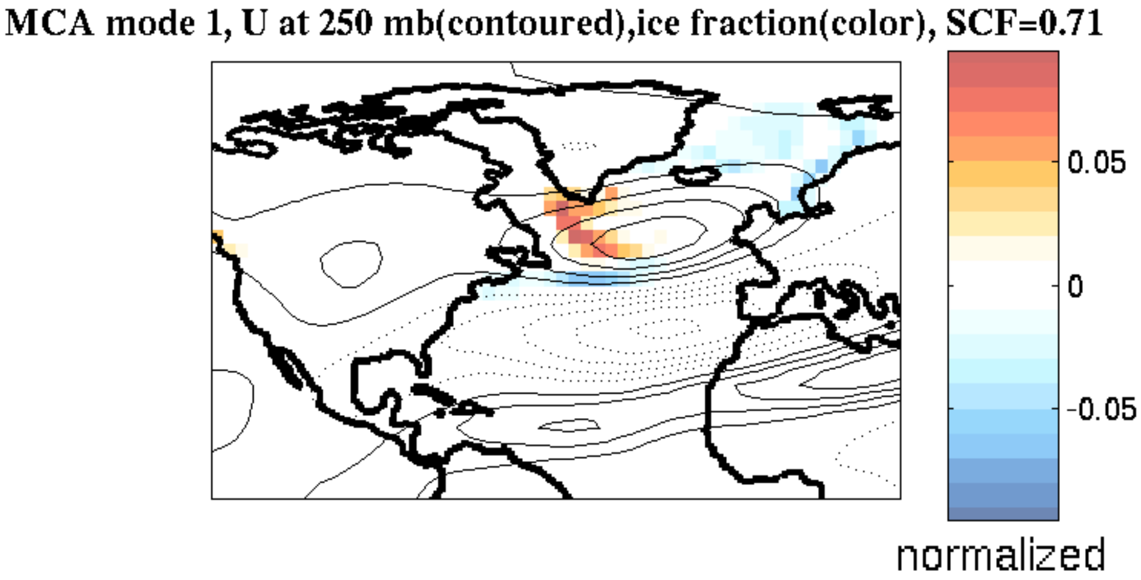
14k run has greater co-variability between sea ice and AMOC





Leading mode of co-variability between jet and sea ice

14k - resembles eof1 of jet and eof2 of sea ice



LGM

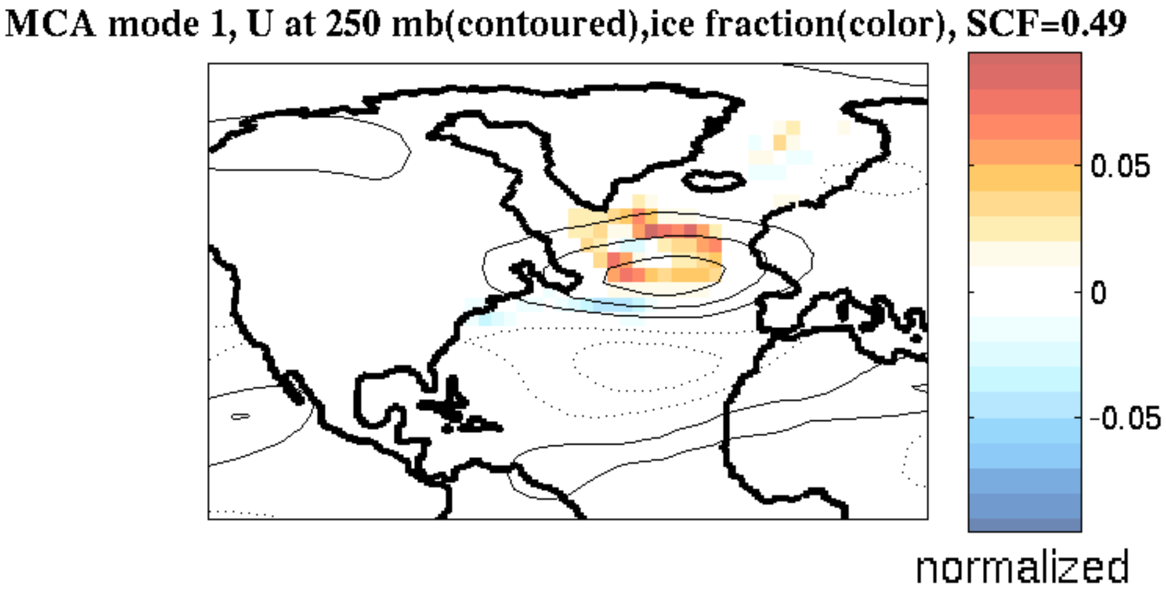
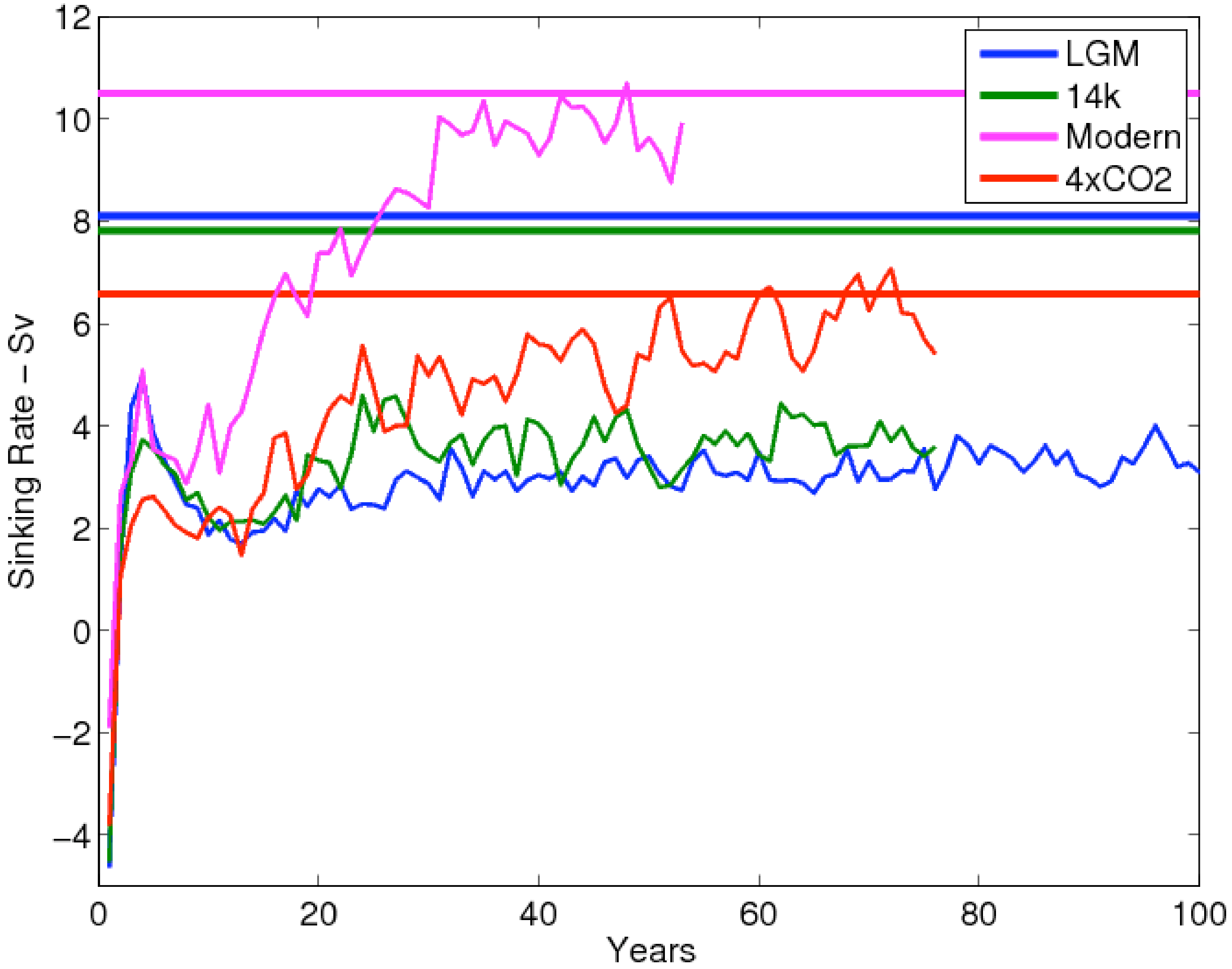
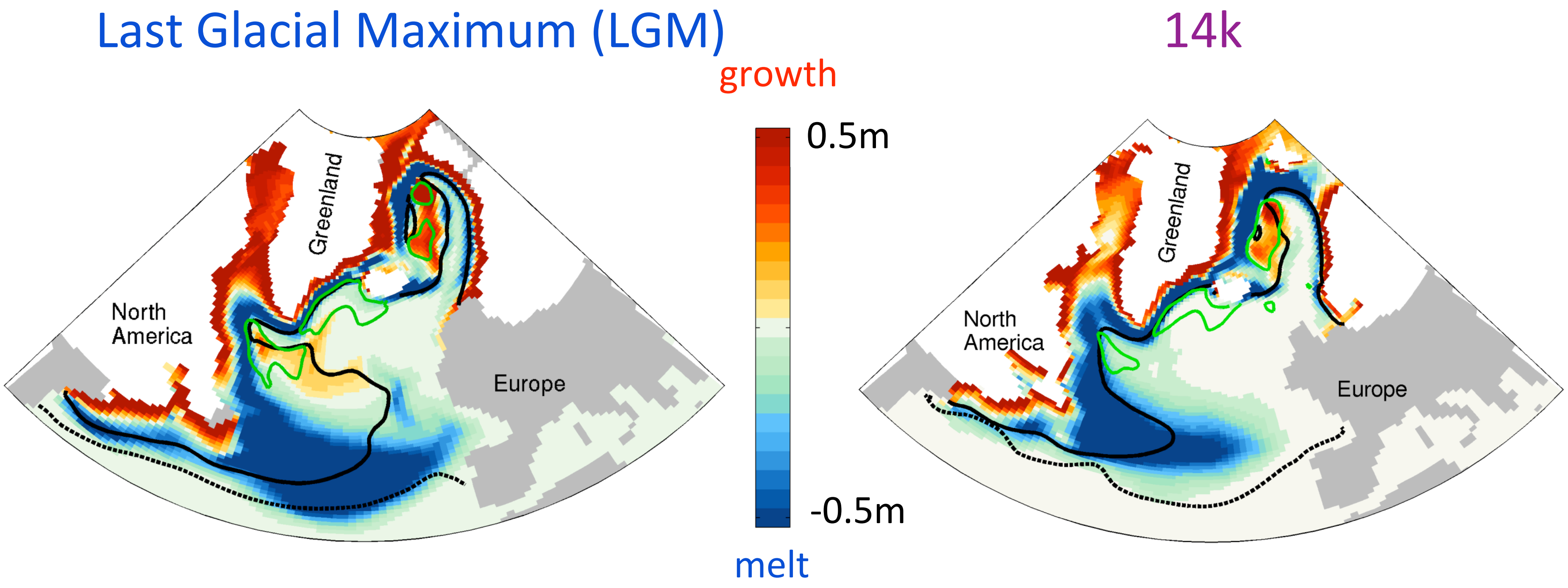


Figure by Kevin Rennert

14k Rate of recovery from Hosing is similar to LGM



Net sea ice growth before freshening


Last Glacial Maximum (LGM)

14k

net sea ice growth (shading),
DJF sea ice edge (black),
and deep mixing (green)

Summary

Reducing the Laurentide ice sheet causes the jet to shift northward, broaden and become more variable

14k AMOC at first weakens, due to higher rainfall, but eventually nearly equals the LGM AMOC

Sea ice variability is much greater in cold climates, though MOC variability is less great

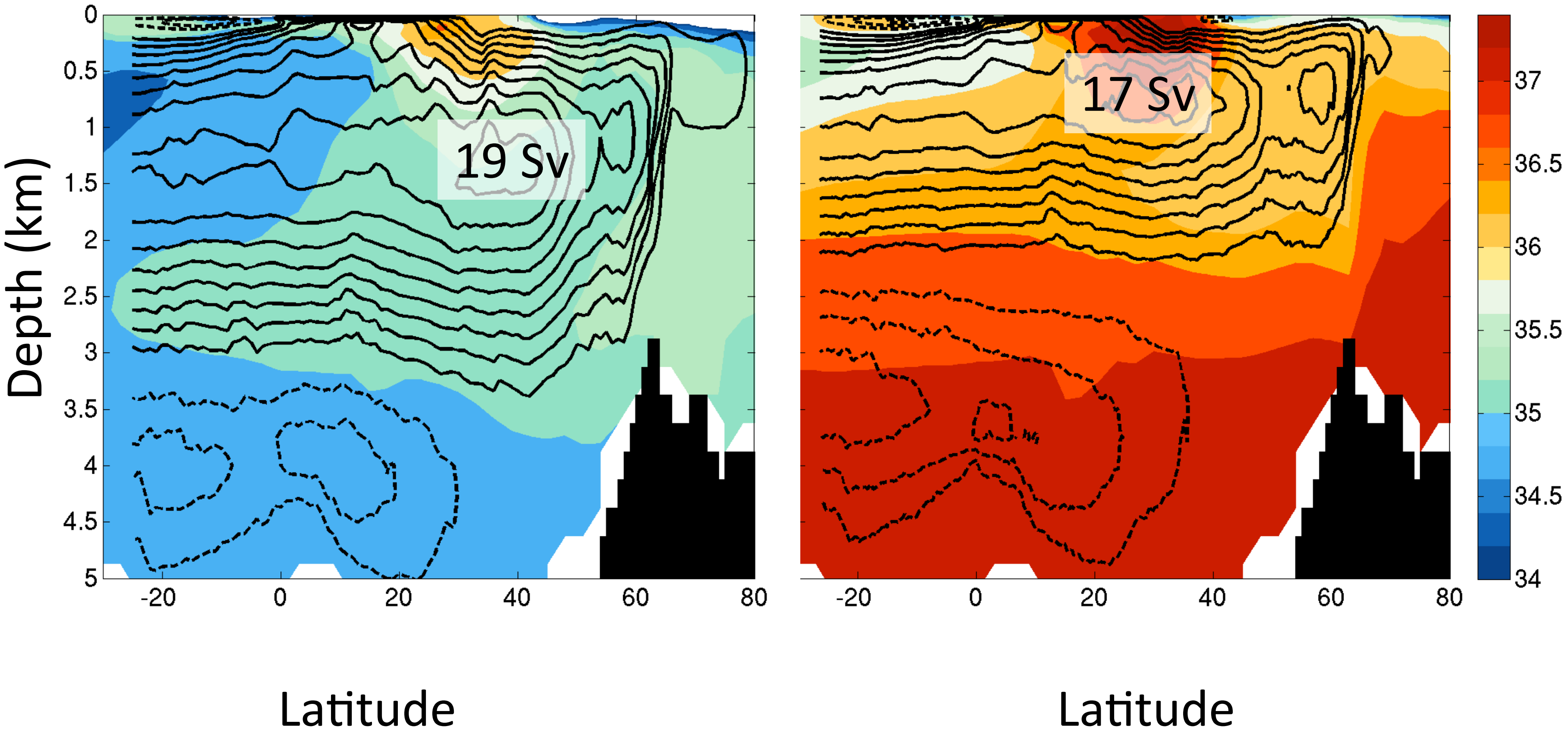
14k jet shifting mode is more strongly coupled to the sea ice

A leading modes of variability in the sea ice is strongly coupled to decadal variability in AMOC at 14k. LGM AMOC has much less decadal variability and it is more weakly coupled to the sea ice

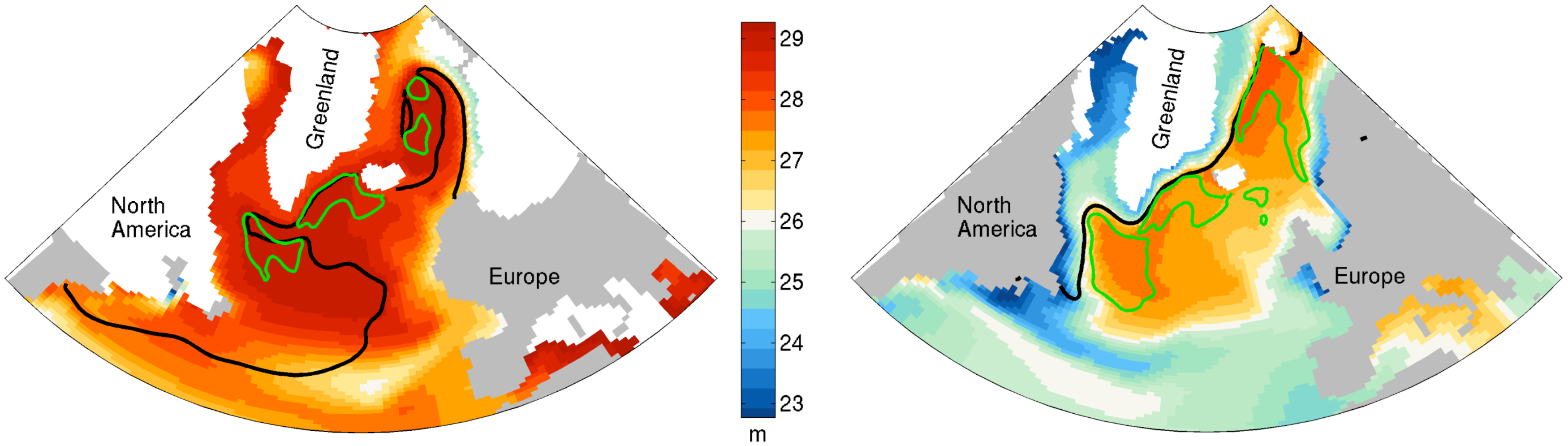
Fresh water pulse has a longer lasting impact on cold climates - 14k rate of recovery is about the same as LGM

Atlantic Overturning Streamfunction (2 Sv black contours) and Salinity (in psu color)

Which one is LGM and which one is Modern?



Sinking locations and sea ice edge

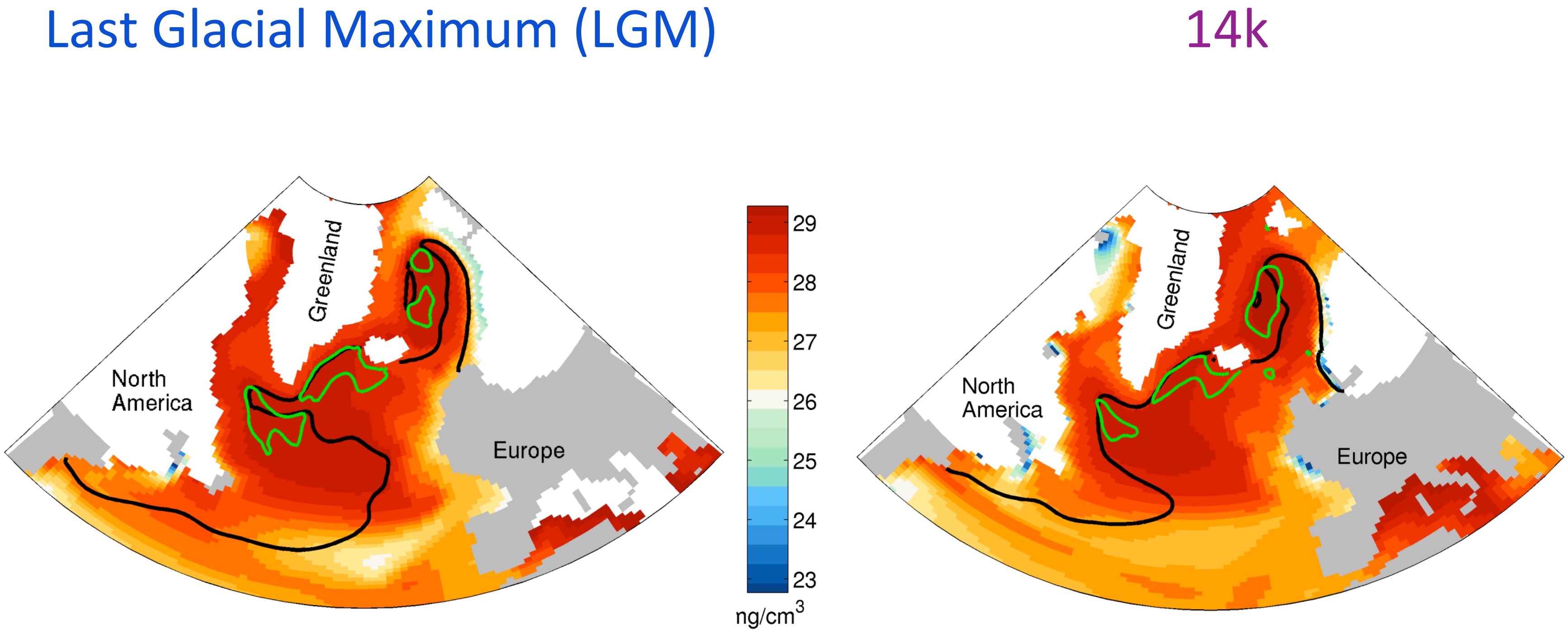

Last Glacial Maximum (LGM)

Modern

surface density (shading),
sea ice edge (black),
and deep mixing (green)

model result

Sinking locations and sea ice edge

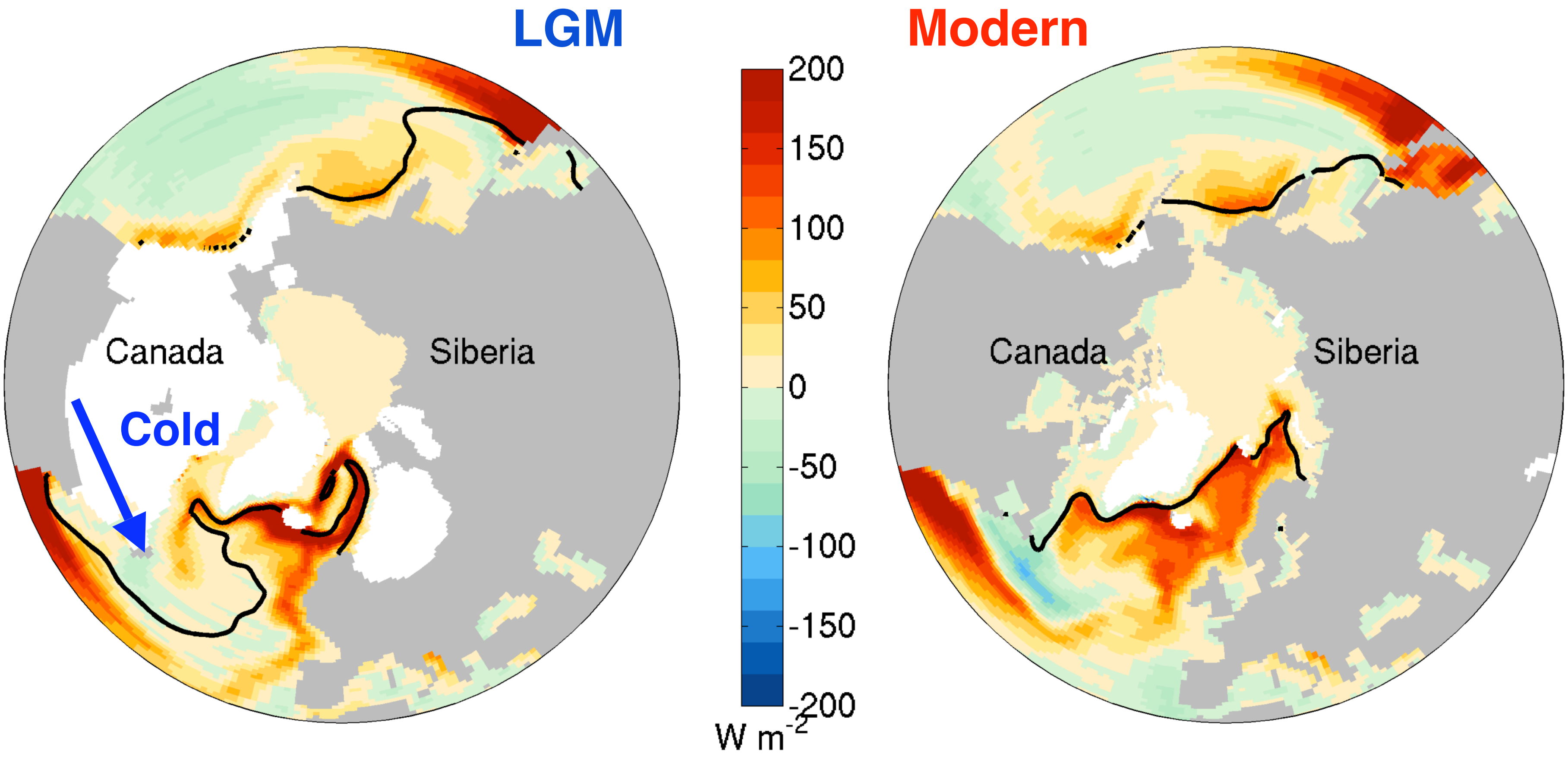


Last Glacial Maximum (LGM)

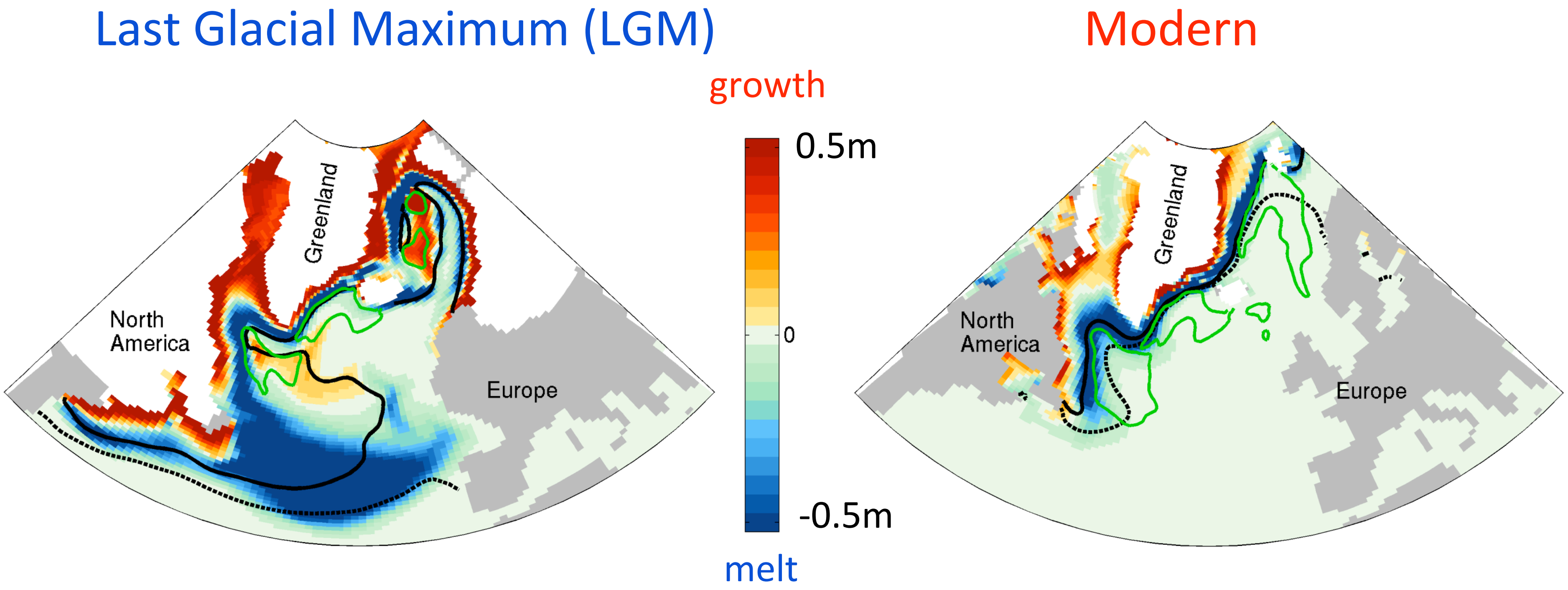
14k

surface density (shading),
sea ice edge (black),
and deep mixing (green)

Ocean Heat Flux Convergence Sets the Sea Ice Edge



Net sea ice growth before freshening



Last Glacial Maximum (LGM)

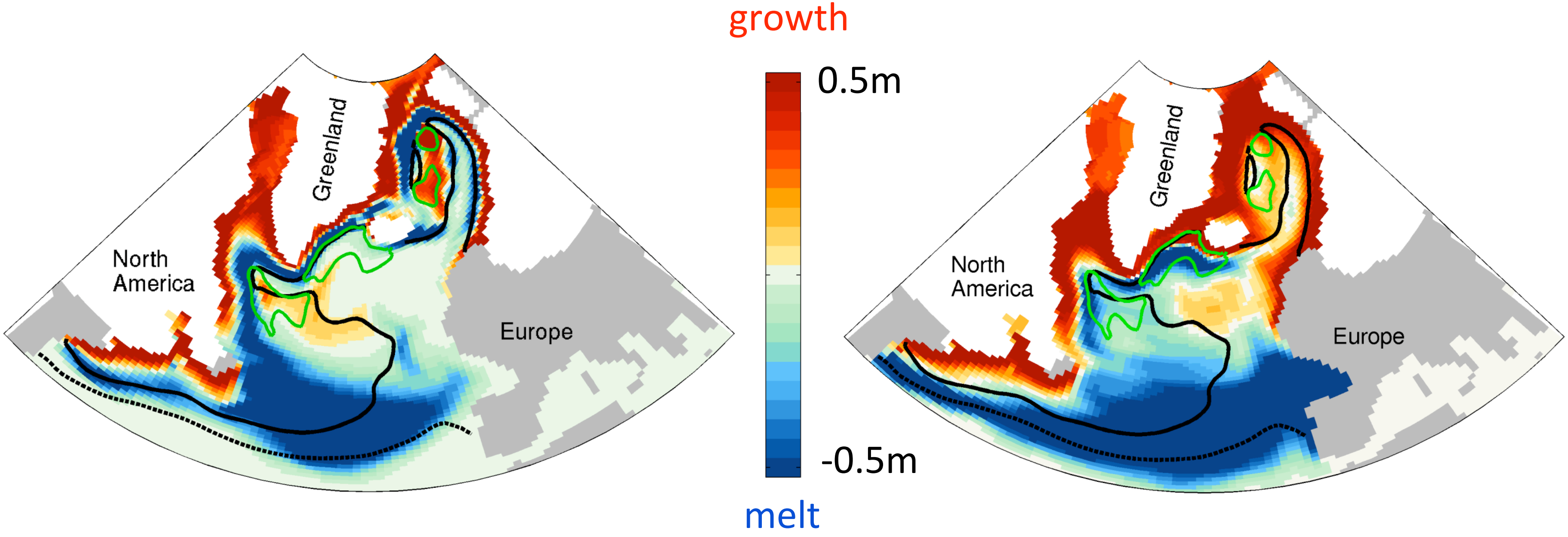
Modern

net sea ice growth (shading),
sea ice edge (black),
and deep mixing (green)

Net sea ice growth before freshening

Last Glacial Maximum (LGM)

LGM - hosed



net sea ice growth (shading),
sea ice edge (black),
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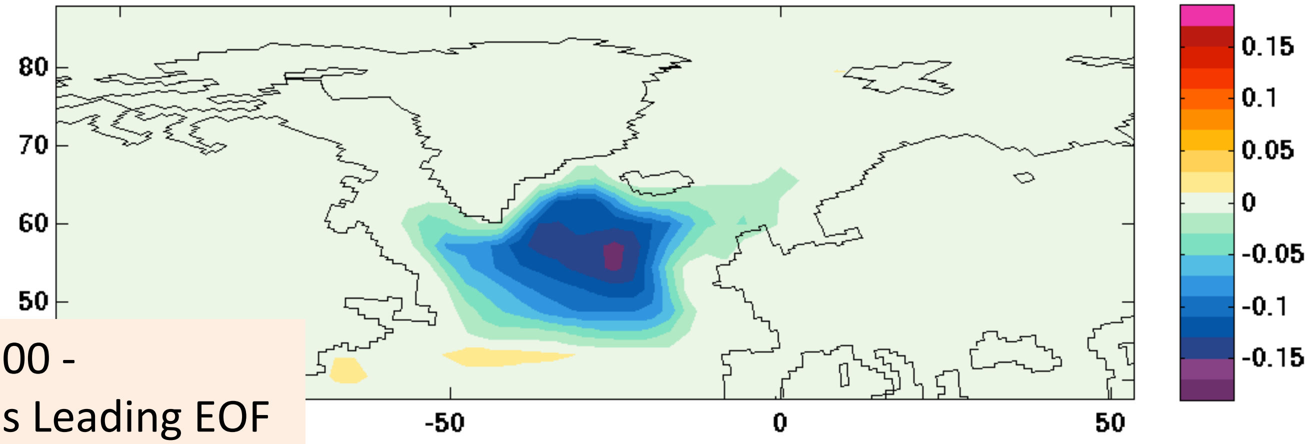
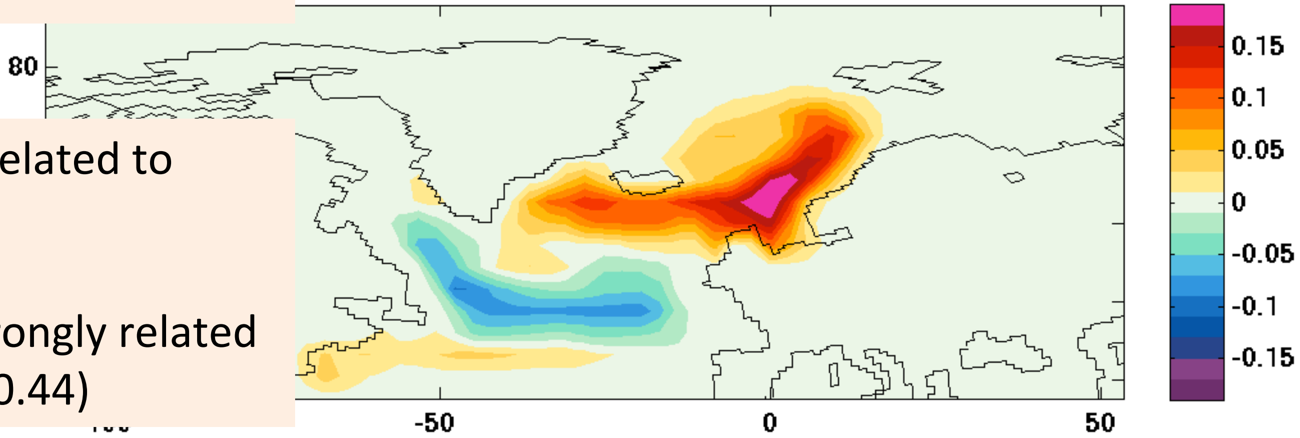
Leading EOFs of 14k Sea Ice Concentration 100-200yrs

32% Explained Variance



AFTER YEAR 200 -
EOF2 becomes Leading EOF
EOF1 is much less significant

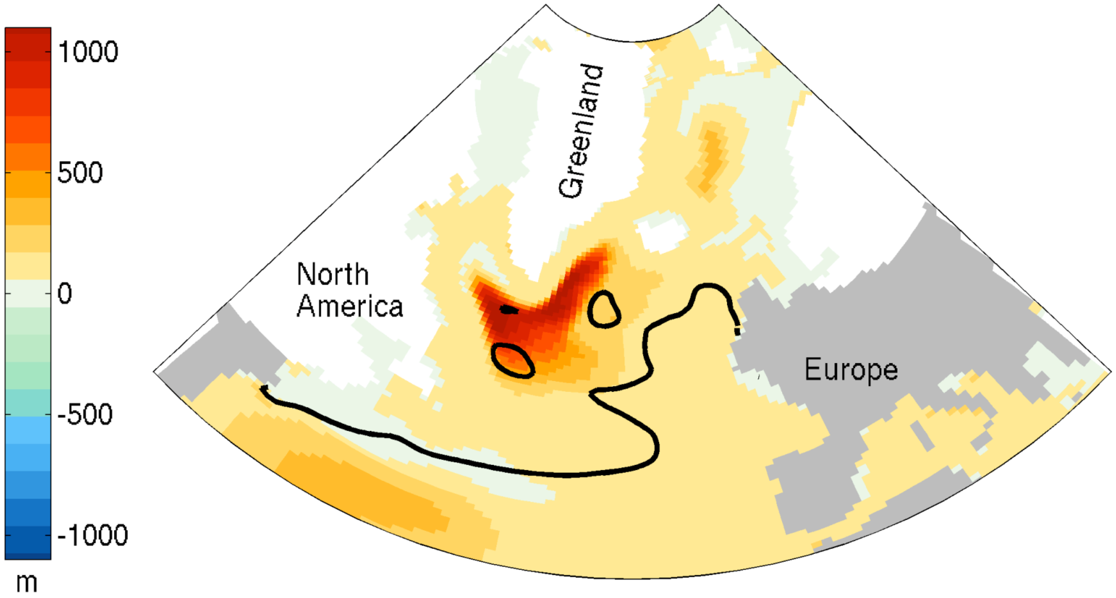
19% Explained Variance



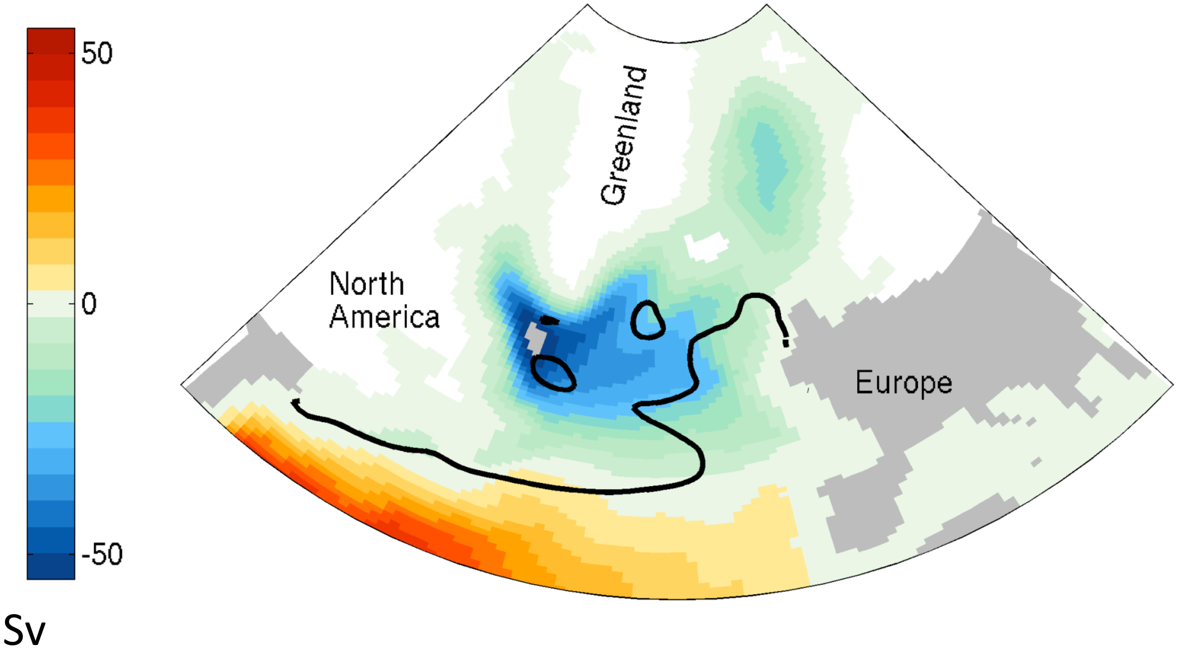
EOF1 weakly related to AMOC

EOF2 more strongly related to AMOC (R=-0.44)

Mean DJFM

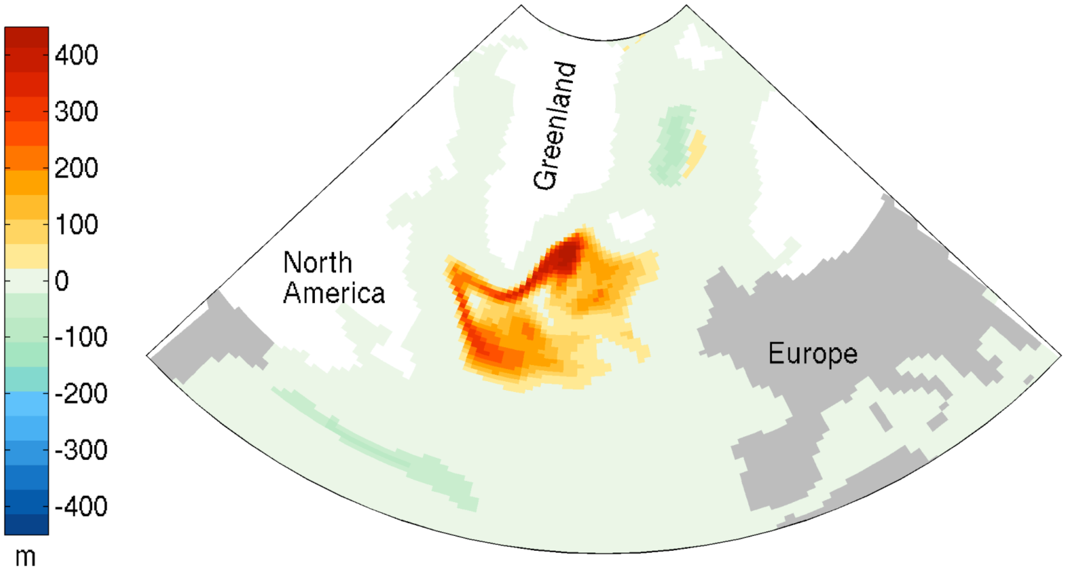


Mixed Layer Depth
And Sea Ice Edge

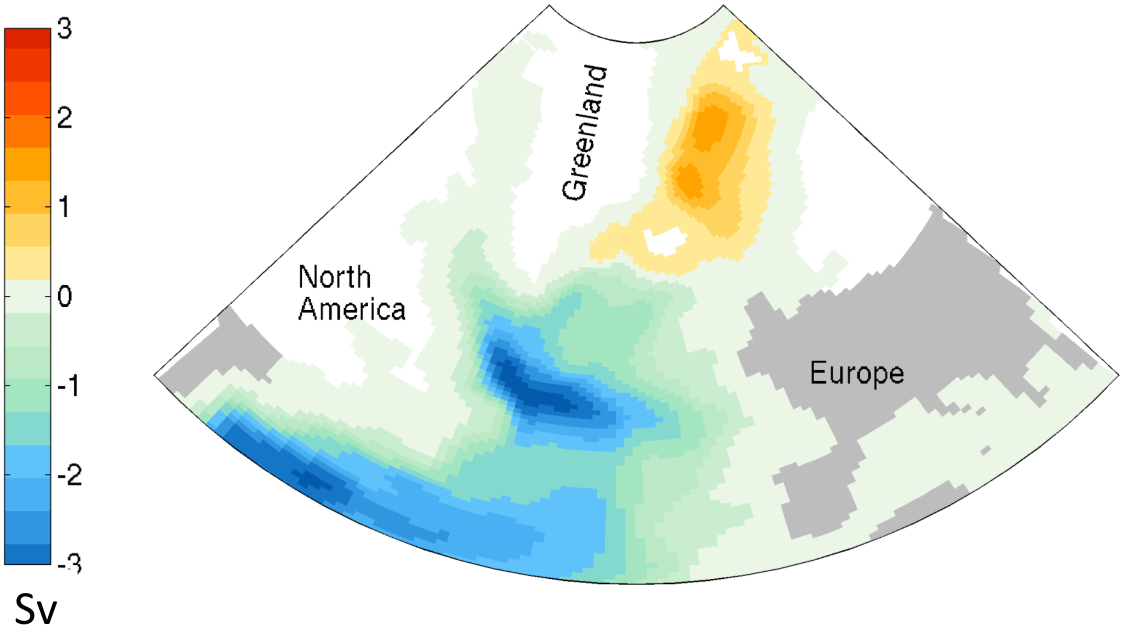


Barotropic Streamfunction
Aka Gyre Strength

Composites against Ice EOF1

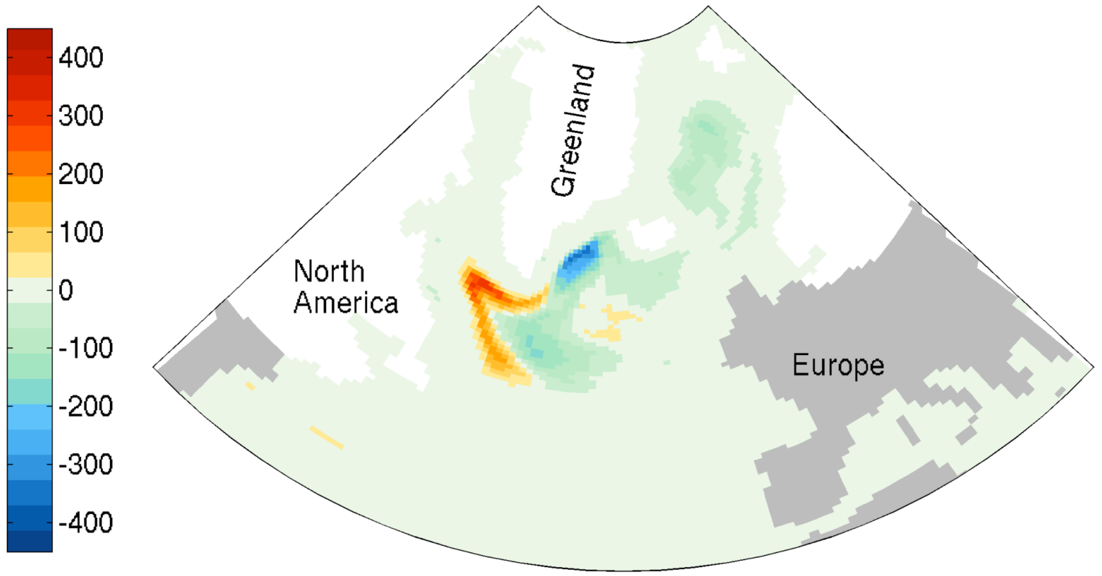


Mixed Layer Depth

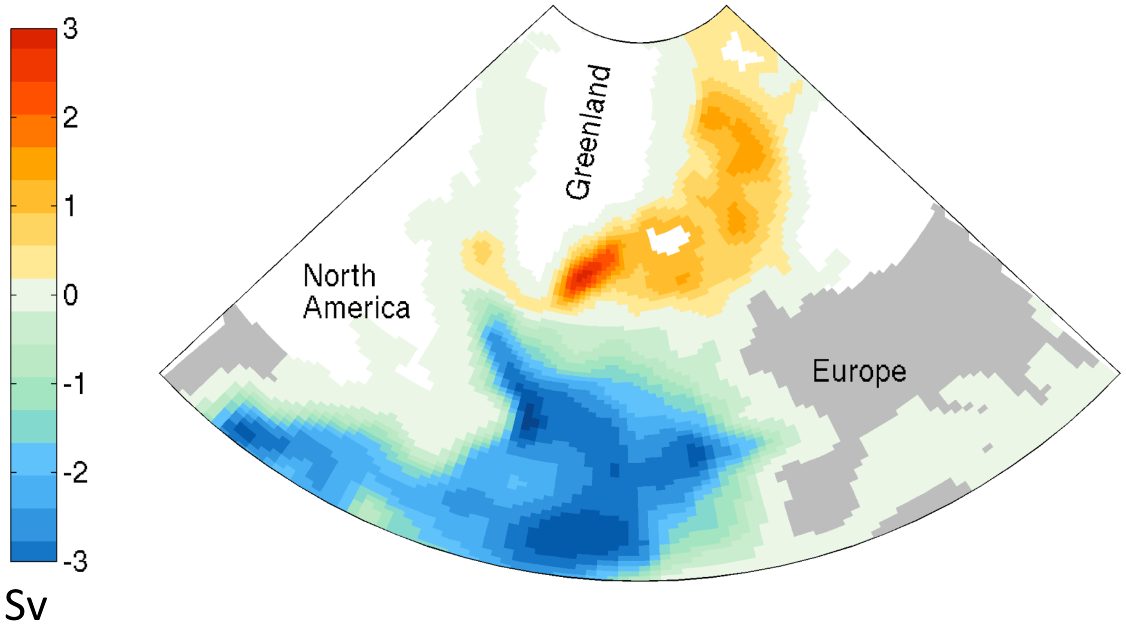


Barotropic Streamfunction
Aka Gyre Strength

Composites against Ice EOF2

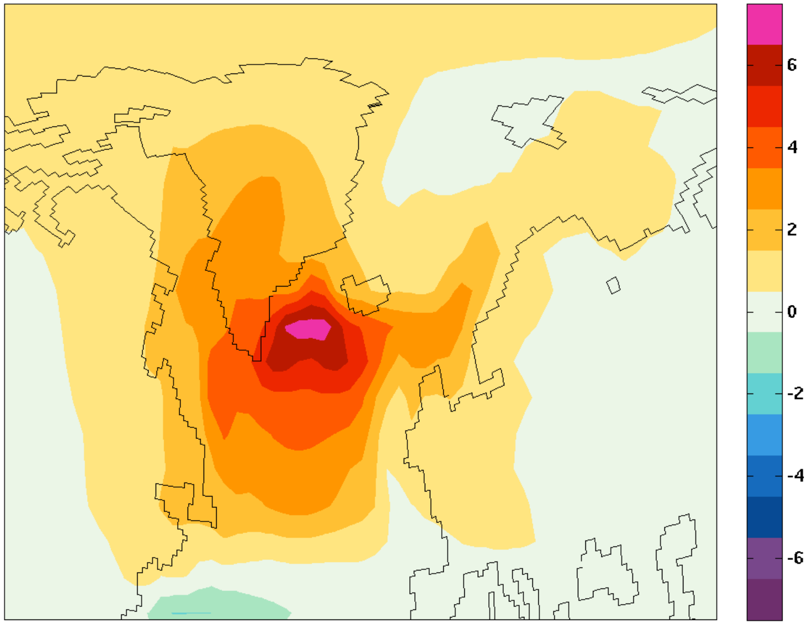


Mixed Layer Depth

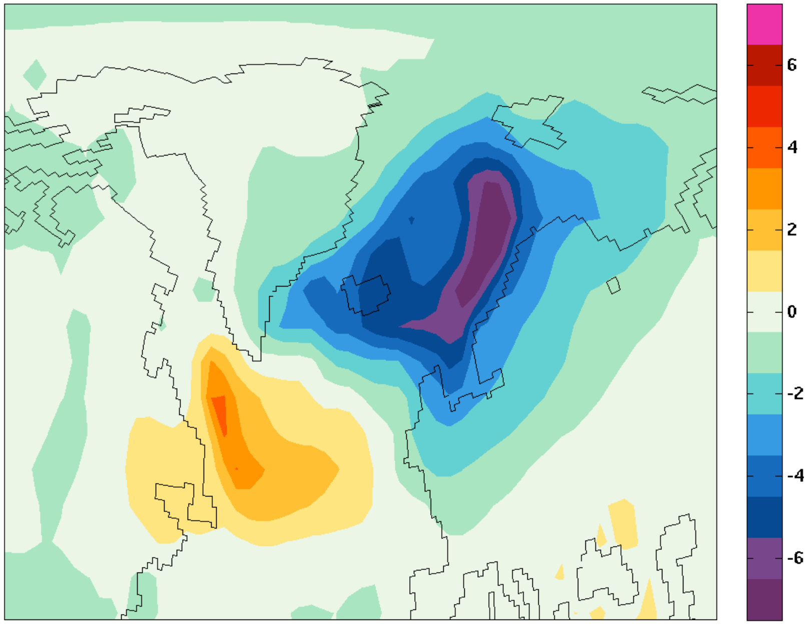


Barotropic Streamfunction
Aka Gyre Strength

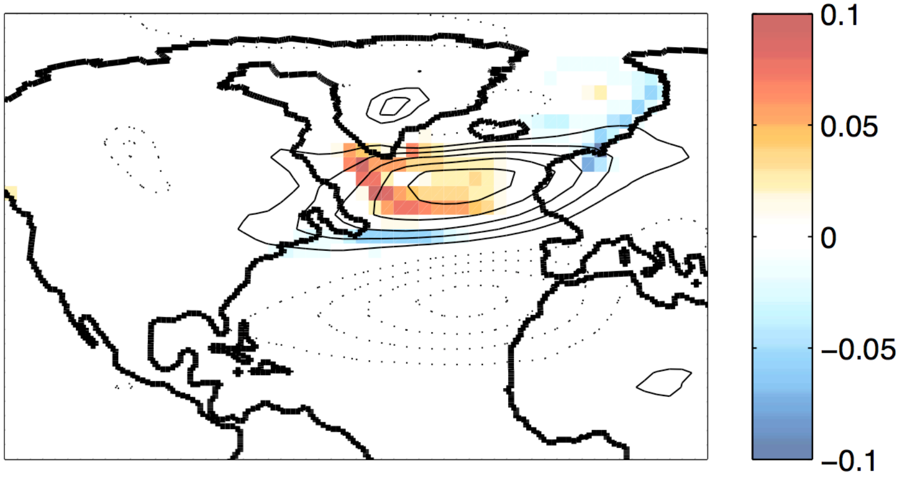
JFM Surface Air Temperature
In Degree C Composites from



Ice EOF1 &



Ice EOF2


14k−169−320 MCA mode 1, U at 850 mb(cont= 0.5) ice fraction(color), SCF=0.72

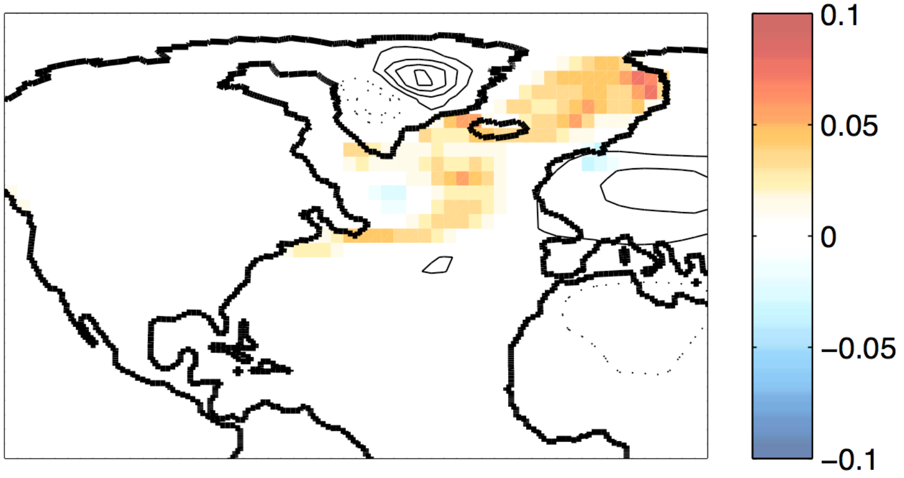

14k−169−320 MCA mode 2, U at 850 mb(cont= 0.5) ice fraction(color), SCF=0.16

Figure by Kevin Rennert