The role of the tropics in atmospheric forcing and ice sheet response in Antarctica on decadal to millennial timescales

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with major contributions from:

Qinghua Ding
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lots of others
Rapid ice sheet thinning in West Antarctica

Pritchard et al., 2012
Ice shelf thinning and deep water temperature
Intrusion of CDW into the Amundsen Sea Embayment

Colors show maximum temperature

Figure courtesy of Pierre Dutriuex

Friday, June 7, 2013
2012 observations: CDW flow onto the shelf has decreased

Figure courtesy of Pierre Dutriuex
2012 observations: CDW flow onto the shelf has decreased
2012 observations: winds predominantly easterly

Figure courtesy of Pierre Dutriuex
2011-2012 observations: major La Niña event

SST colored shading and 200, 500 geopotential heights and SLP, from ERA-interim reanalysis

Pine Island Glacier
West Antarctic $\delta^{18}O$ anomalies vs. Niño4 anomalies

Steig et al., 2013
Ice Core Sites in Antarctica

WAIS Divide

Accumulation Rate: 21.5 cm a\(^{-1}\)

Ice Thickness: 3460 m

Average Temperature: -30 °C

Gas-Age Ice-Age Difference: 208 years

Site was selected to be similar to Greenland deep ice cores
Dating WAIS Divide by Electrical Measurements

Photos: Bryan Holmes
Annual Layer Interpretation

Normalized Conductance vs. Depth (m)

DC

AC

Fudge, Steig, et al, 2013
High resolution of WAIS Divide ice core

Fudge, Steig, et al, 2013
High resolution of WAIS Divide ice core

Layer Count

- Byrd Isotope Match
- OpticalLog

Depth (m)

Age (ka)

1 to 2 cm thick annual layers

Fudge, Steig, et al, 2013
WAIS Divide $\delta^{18}O$ Sample Resolution

annual layering to 31 kyr

1/2 m samples

not (yet) annually layer-counted

Sample Resolution (years)

Age (thousands of years)

$\delta^{18}O$ (per mil)

Depth, m
WAIS Divide $\delta^{18}\mathrm{O}$ vs. Age

$\delta^{18}\mathrm{O}$ (per mil)

Age, thousands of years before 2000

20-year averages

Fudge, Steig, et al, 2013
WAIS Divide $\delta^{18}$O and global CH$_4$
WAIS Divide $\delta^{18}O$ and NGRIP $\delta^{18}O$
WAIS Divide $\delta^{18}O$ and global CH$_4$

Brad Markle, Eric Steig, Ed Brook, unpublished
WAIS Divide dxs and global CH$_4$
Reminder: methane decreases when the N. Atlantic cools.
Poleward shift of the westerlies in response to N Hem cooling

Figure 8. Austral winter (JJA) SH surface zonal wind in ECHAM model experiments. Shading denotes the mean zonal wind in m s$^{-1}$, while contours represent anomalies in the NH cooling experiment relative to the control. The contour interval is 0.5 m s$^{-1}$, with the zero line omitted.

Ceppi et al., 2013
Rainfall change in response to N Hem cooling
Deuterium excess change in response to N Hem cooling
Influence of moisture source location on δxs in Antarctic snow, from Petit, White et al., 1991
Correlation of precipitation with the SAM index
Correlation of deuterium excess with the SAM index
Monin et al. 2001

CO₂

“NADW”

McManus et al., 2004

LGM  OD  B–A  YD  Holocene

22  20  18  16  14  12  10  8

Age (kyr)

Friday, June 7, 2013
Monin et al. 2001

CO$_2$

“NADW”

McManus et al., 2004

LGM  OD  B–A  YD  Holocene

22  20  18  16  14  12  10  8

Age (kyr)
McManus et al., 2004

Monin et al. 2001

"NADW"

CO₂
WAIS Divide $\delta^{18}O$ and dxs

Abrupt shift in the westerlies?
WAIS Divide $\delta^{18}$O and dxs

Abrupt shift in the westerlies?
Abrupt shift in the westerlies?
Summary and Next Steps
Summary and Next Steps

• Tropical variability has a profound influence on atmospheric circulation at high Southern Latitudes--- with implications for ocean circulation and ice sheet stability

• WAIS Divide is well situated to examine the tropical-extratropical teleconnections through time

• WAIS Divide deuterium excess provides support for fast coupling between the D-O events and Antarctic climate, through the tropical teleconnection. This is in addition to the lagged ocean circulation response

• These data may provide support for the Heinrich event/Southern Westerlies argument for the CO2 rise at the end of the last glaciation
Thank you

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WAIS Divide field crew
upon reaching 3330 m
WAIS Divide $dx$s and WAIS Divide Methane

Methane data (preliminary) from T. Sowers
WAIS Divide $\delta^{18}O$ and WAIS Divide Methane

Methane data (preliminary) from T. Sowers

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