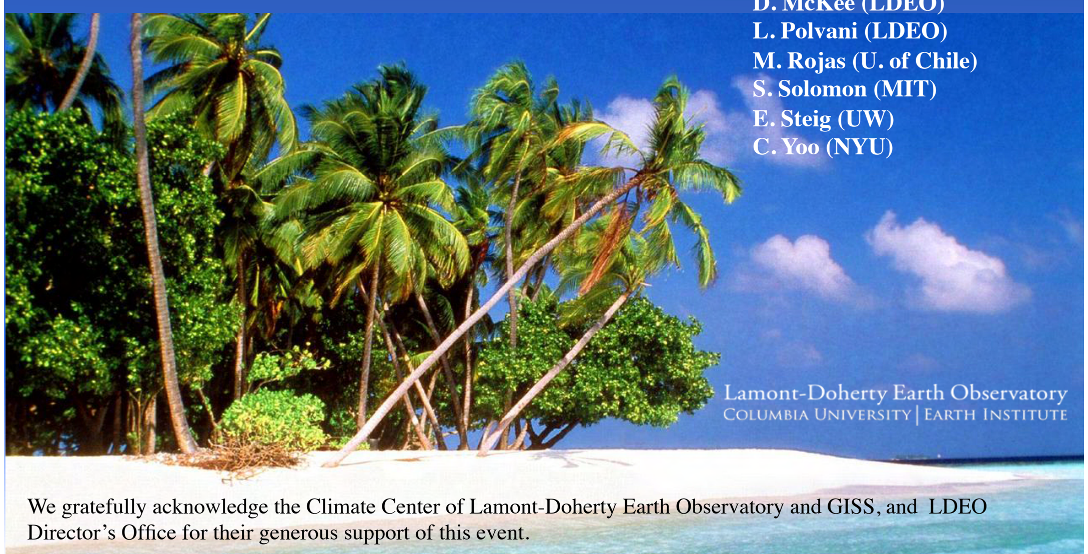
Connecting the Tropics to Polar Regions

A Mini-Conference Hosted by Lamont-Doherty Earth Observatory of Columbia University

June 2-3, 2014
Monell Auditorium
Lamont-Doherty Earth Observatory
Palisades, New York
Presentations start at 9:00 a.m.

Conveners:
Xiaojun Yuan, Mark Cane, Michael Kaplan

Invited Speakers
R. Anderson (LDEO)
C. Bitz (UW)
D. Battisti (UW)
D. Bromwich (Ohio State)
E. Barnes (Colorado State)
J. Chiang (UC Berkeley)
E. Cook (LDEO)
Q. Ding (UW)
M. Hitchman (U. Wisconsin-Madison)
X. Li (NYU)
R. Fogt (Ohio University)
J. Marshall (MIT)
D. McKee (LDEO)
L. Polvani (LDEO)
M. Rojas (U. of Chile)
S. Solomon (MIT)
E. Steig (UW)
C. Yoo (NYU)



Lamont-Doherty Earth Observatory
COLUMBIA UNIVERSITY | EARTH INSTITUTE

We gratefully acknowledge the Climate Center of Lamont-Doherty Earth Observatory and GISS, and LDEO Director's Office for their generous support of this event.

An Inter-Connected Global Climate System

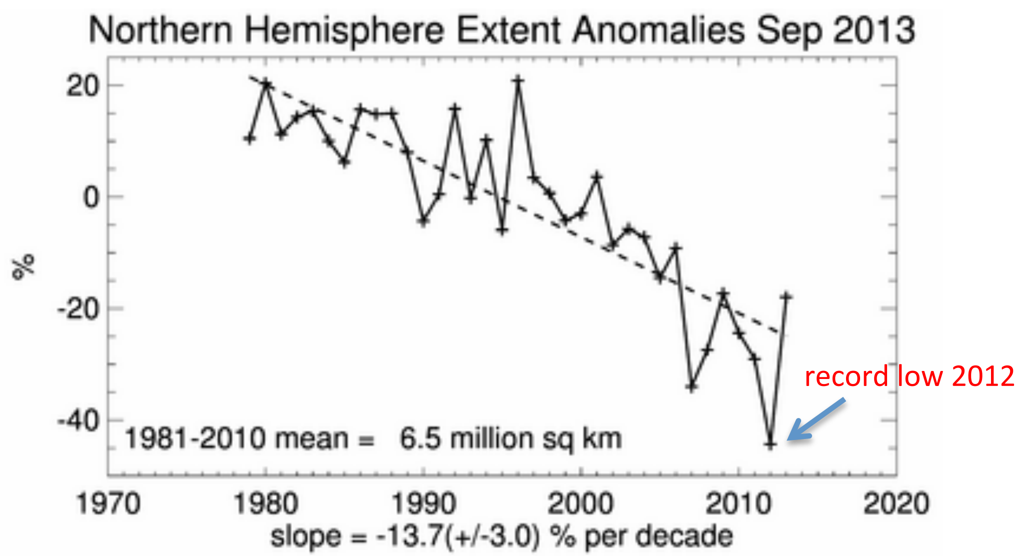
Xiaojun Yuan

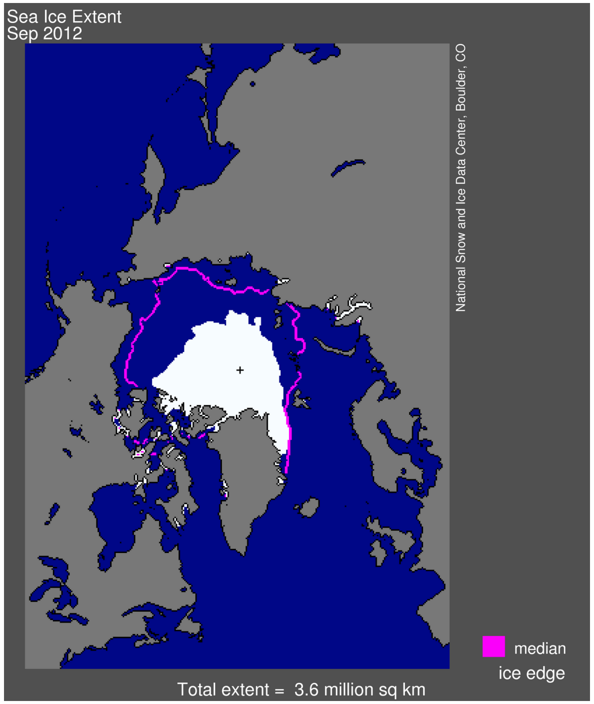
Lamont-Doherty Earth Observatory of Columbia University

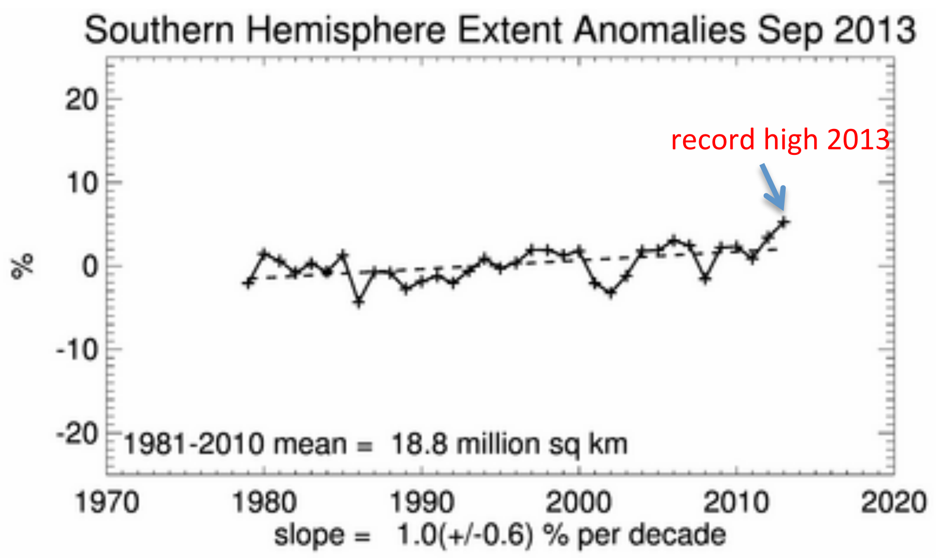
Mini-Conference: Connecting the Tropics to Polar Regions, Lamont Campus
Palisades, New York, June 2-3, 2014

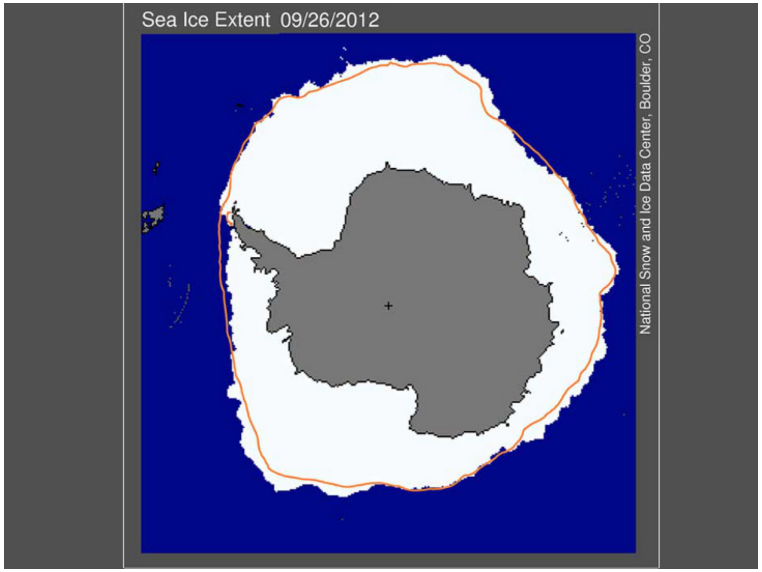
Polar Amplification

Changing Sea Ice Extent



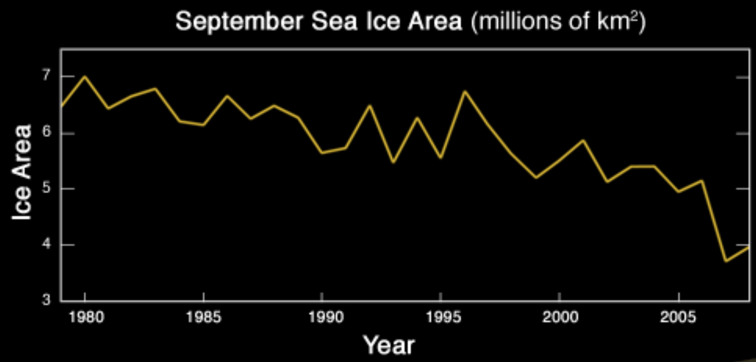


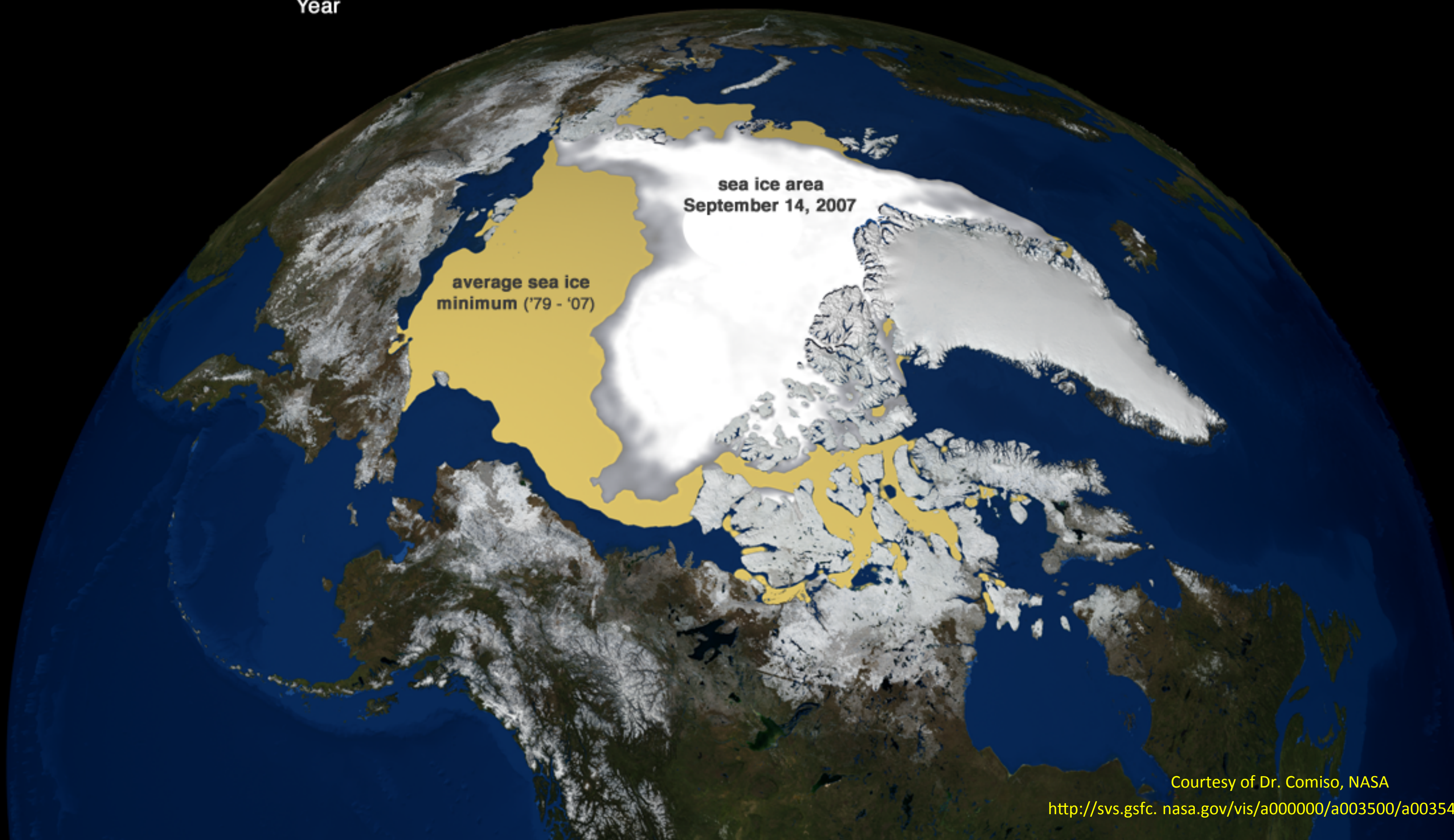




Courtesy of NSIDC

➢The main causes of the rapid reduction: warming due to green house gas rising, non-linear feedback from decrease of albedo, wind-driven variability and increase of SST in the Arctic

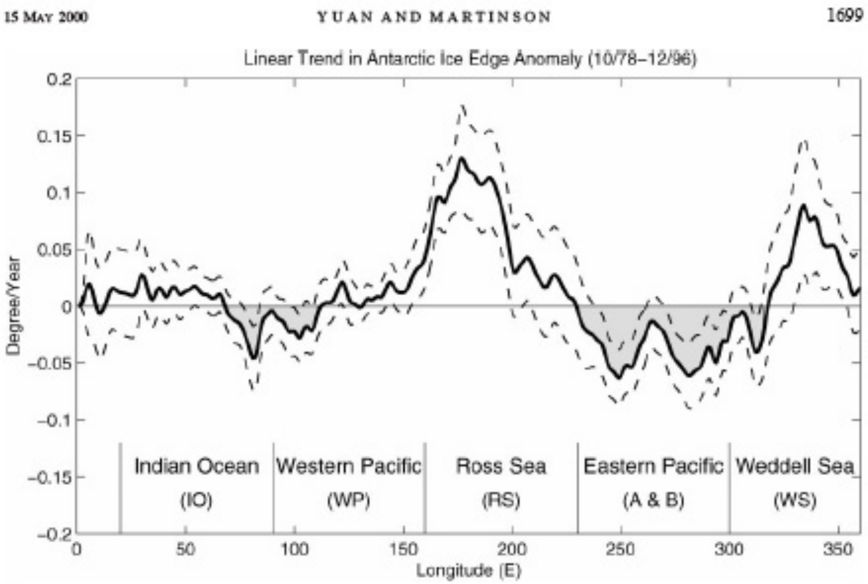




Courtesy of Dr. Comiso, NASA
http://svs.gsfc. nasa.gov/vis/a000000/a003500/a003547/index

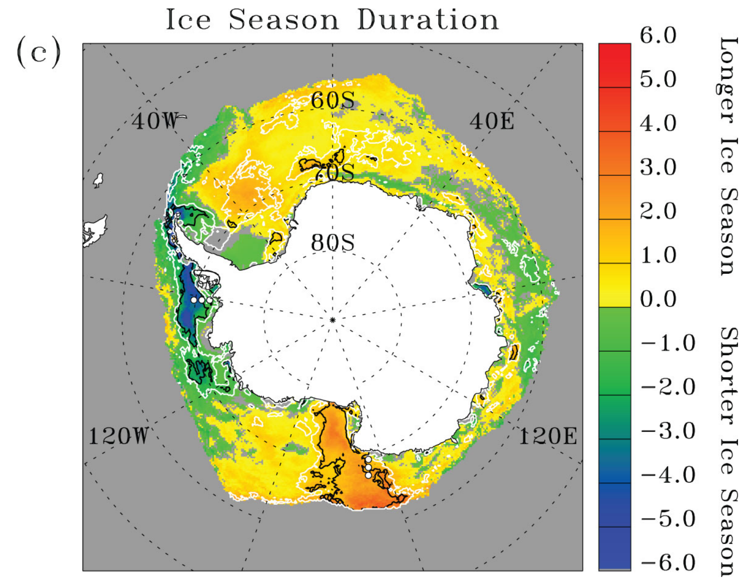
Trends in Antarctic Sea Ice

Trend in ice edge anomaly 1978-1996

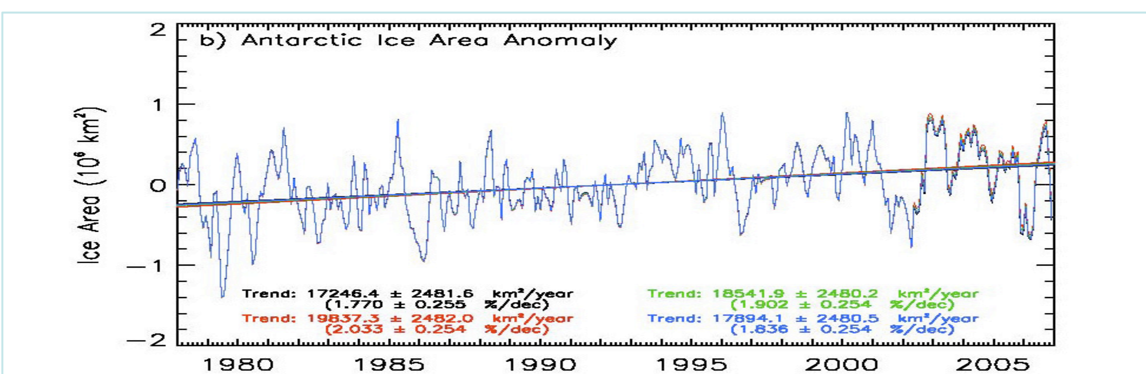


Yuan and Martinson 2000

Trend in ice season duration 1978-2004



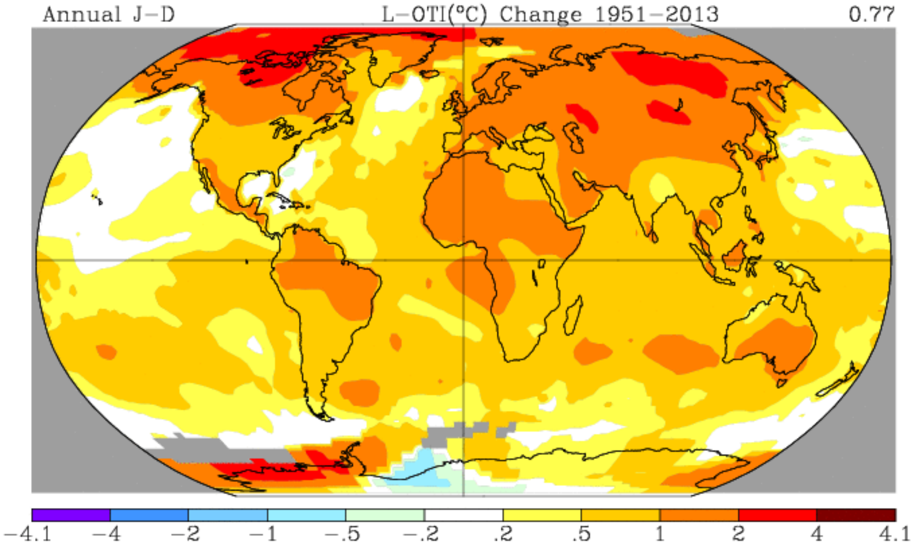
Stammerjohn et al, 2008

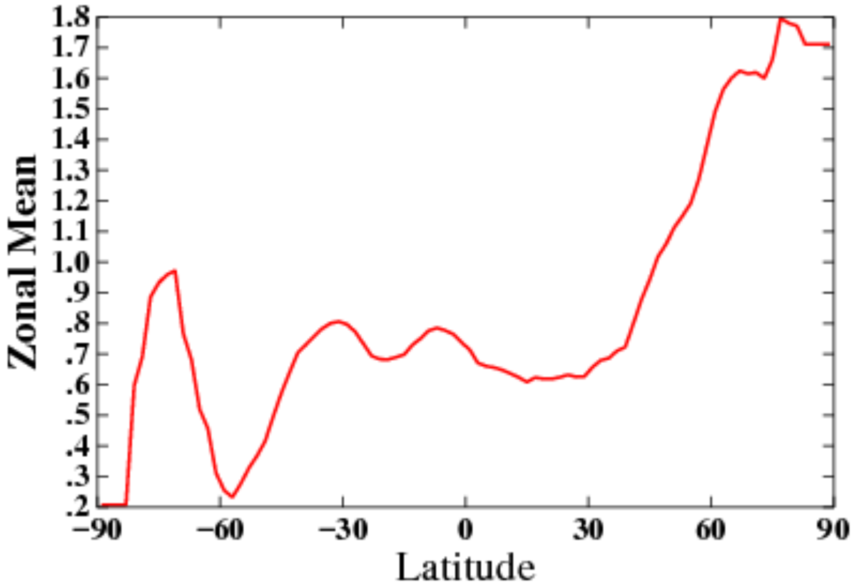


Trend in ice area over satellite period 1979-2006
1.7% +/- 0.3% per decade
Significant at 95% confidence level
(Comiso and Nishio, 2008; Cavalieri and Parkinson, 2008)
1979-2010 update 1.5%+/-0.4%
Parkinson and Cavalieri, 2012)

Polar Amplification

Trend in Annual Mean Surface Air Temperature (1951-2013)

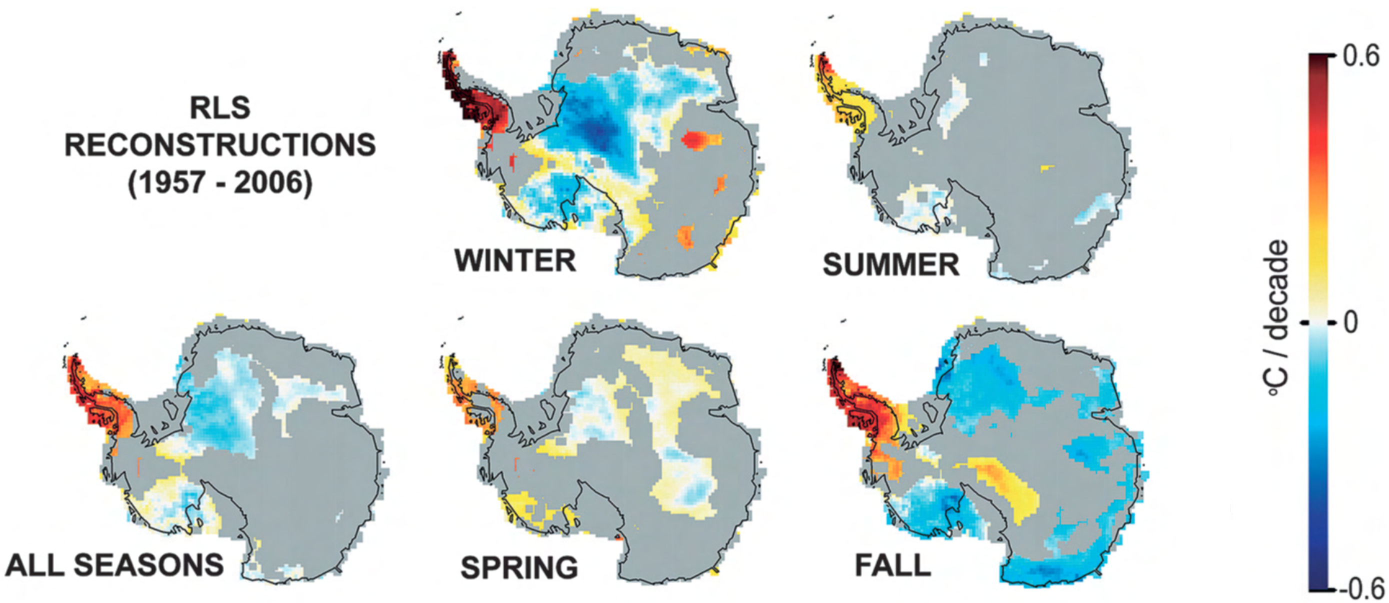




NASA GISDS Surface Temperature Analysis

Polar Amplification

Surface temperature trend in the instrumental era (1957-2006)



RLS	winter	Spring	Summer	Fall
Continental average	0.08+/-0.10	0.11+/-0.06	0.07+/-0.06	-0.02+/-0.09
East Antarctic	0.06+/-0.11	0.07+/-0.07	0.06+/-0.07	-0.06+/-0.11
West Antarctic	0.07+/-0.11	0.21+/-0.10	0.06+/-0.07	0.05+/-0.10
Peninsula	0.51+/-0.16	0.26+/-0.09	0.20+/-0.05	0.41+/-0.09

5 times of global winter average (Vaughan et al., 2003)

O’ Donnell et al., 2011

What cause the fast warming in the Peninsula and cooling or not warming on the continent?

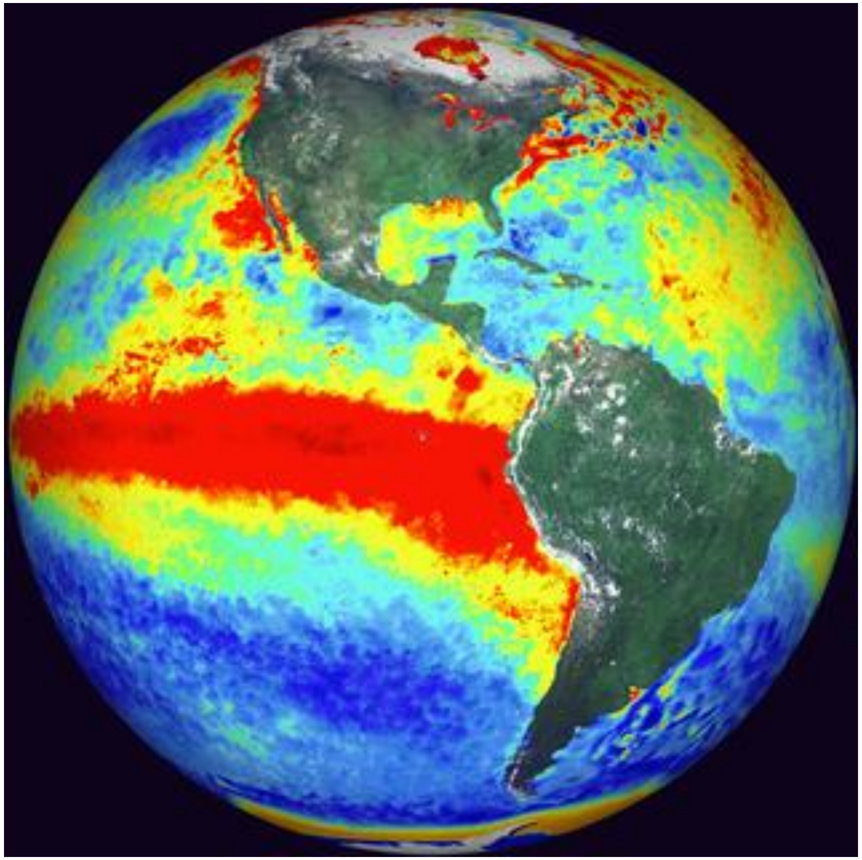
- SAM has an increasing trend in the last 50+ years, resulting in strengthening of westerly (Thompson and Solomon, 2003; Marshall 2003). The trend is linked to the Peninsula warming and Antarctic continental cooling (Marshall et al. 2002, 2006; Van den Broeke and van Lipzip, 2003).

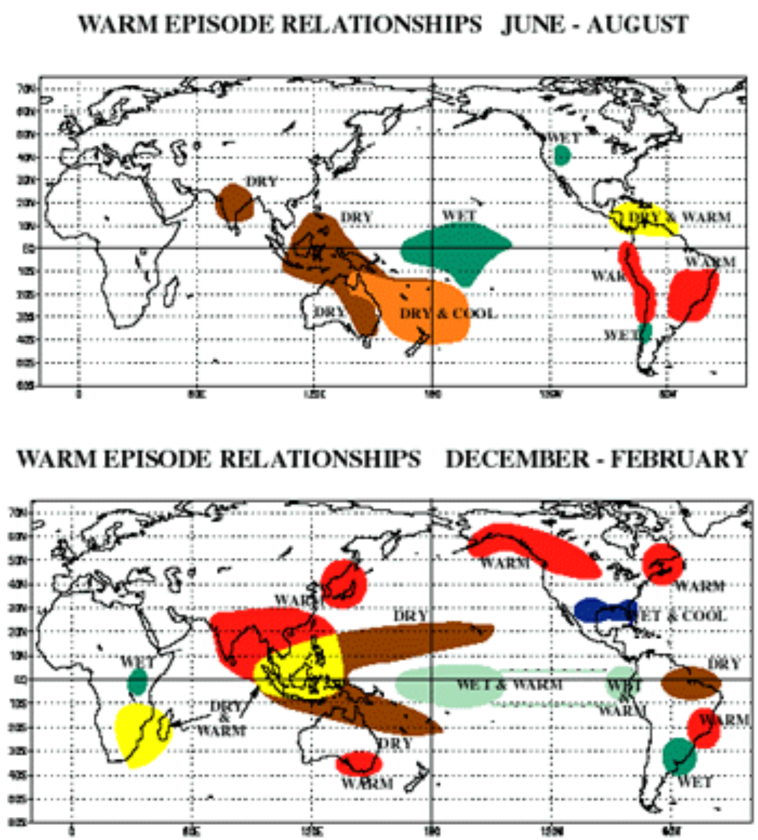
Increasing of SAM:

- Ozone hole in the stratosphere (Sexton, 2001; Thompson and Solomon, 2002; Gillett and Thompson, 2003)
- GHG in the troposphere (Cai et al., 2003; Rauthe et al., 2004)
- Changes in shortwave radiation (Marshall et al., 2004)
- Nature variability in the tropics (Fogt and Bromwich, 2006; Mo, 2000; Zhou and Yu, 2004; L'Heureux and Thompson, 2006)

- Recent studies (Ding et al. 2012; Steig et al. 2013) have attributed the Peninsula warming to the tropical forcing

ENSO is the largest short-term climate variability in the tropics and has influences on the climate of tropical and subtropical regions





NOAA CPC ENSO Monitoring

ENSO's impact in the Polar Regions have been clearly documented in satellite era.

Mechanisms of connecting the tropics to Antarctica

1. Rossby wave mechanism

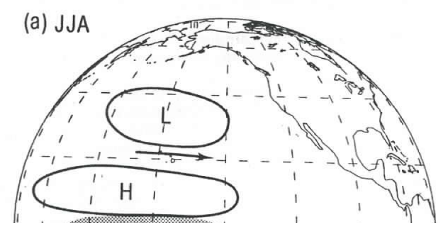
   (Karoly, 1989; *Mo and Higgins*, 1998; *Kiladis and Mo*, 1998)

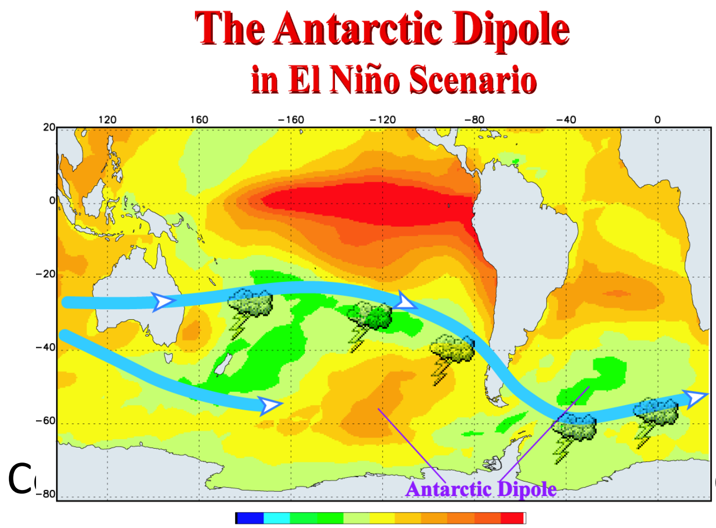
2. Changes in jet stream/storm distribution induced by changes in meridional thermal gradient

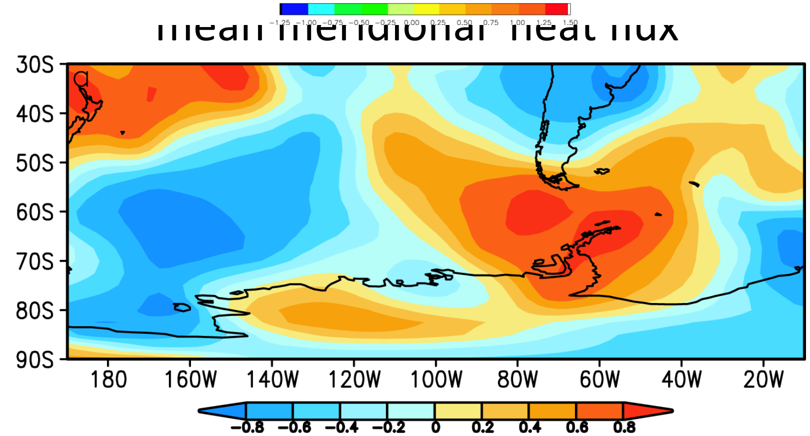
   (Chen et al., 1996, *Rind et al, 2001*)

3. Heat fluxes changes due to the change in the regional Ferrel Cell

   (*Liu et al., 2002*)

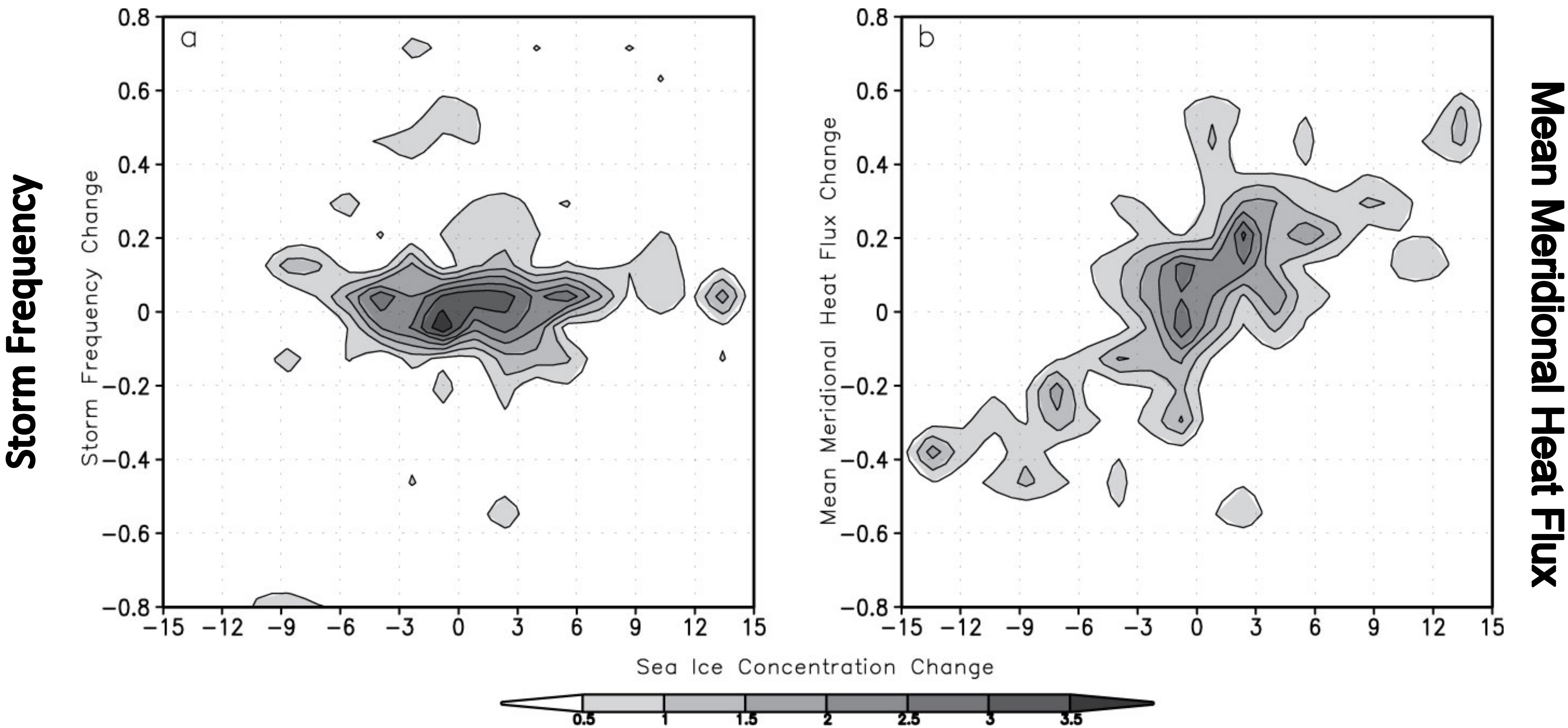






Joint Frequency distribution between Storm, mean heat flux and sea ice concentration anomaly

Composite difference between El Nino and La Nina in western Hemisphere (45S-90S)

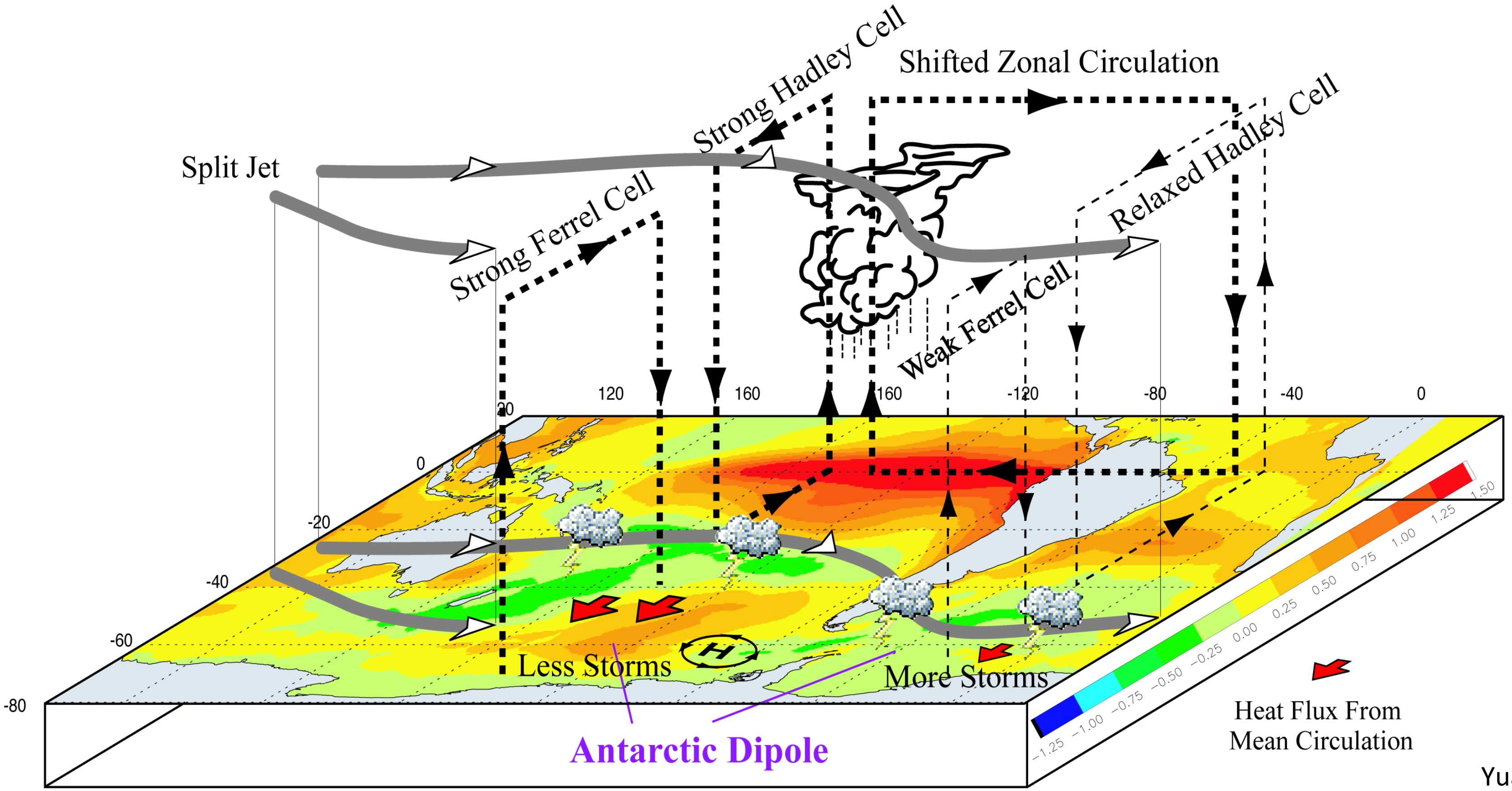


Liu et al, 2002

Mechanisms of ENSO/ADP Teleconnection

The Antarctic Dipole

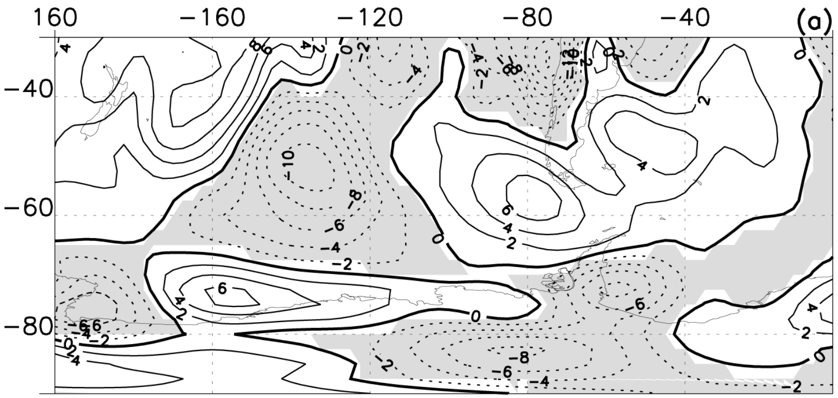
in El Niño Scenario



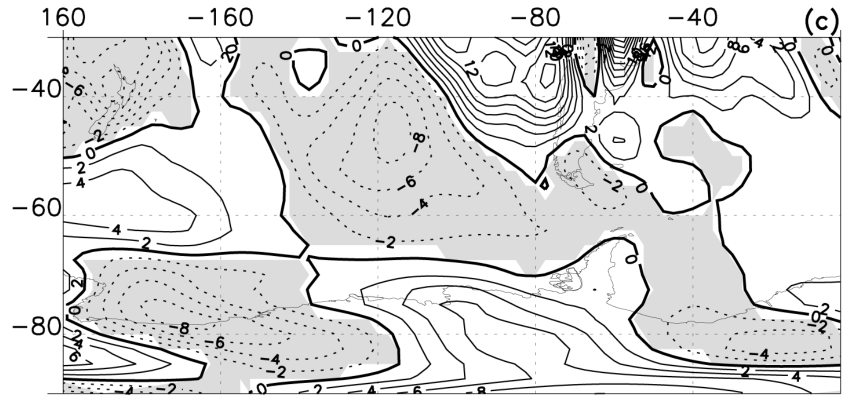
Yuan, 2004

Meridional Heat Flux Anomaly at Lower Atmosphere

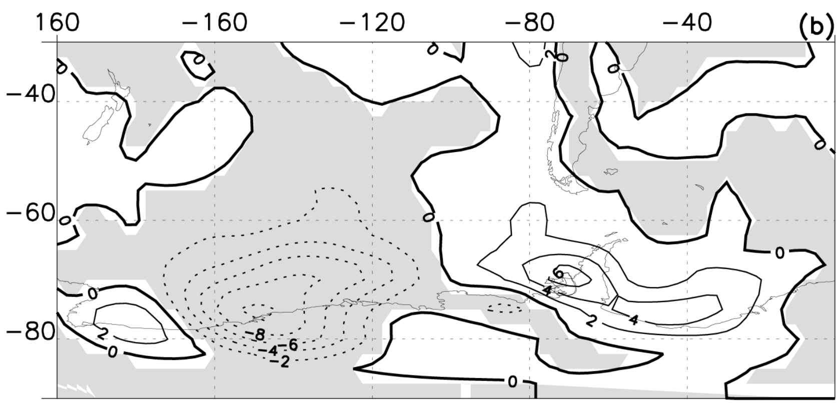
El Nino Composite (mean circulation)



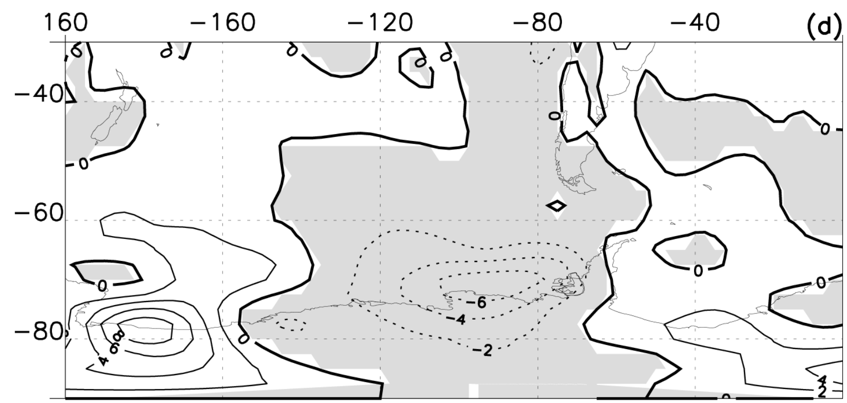
La Nina Composite (mean circulation)



El Nino Composite (stationary wave)



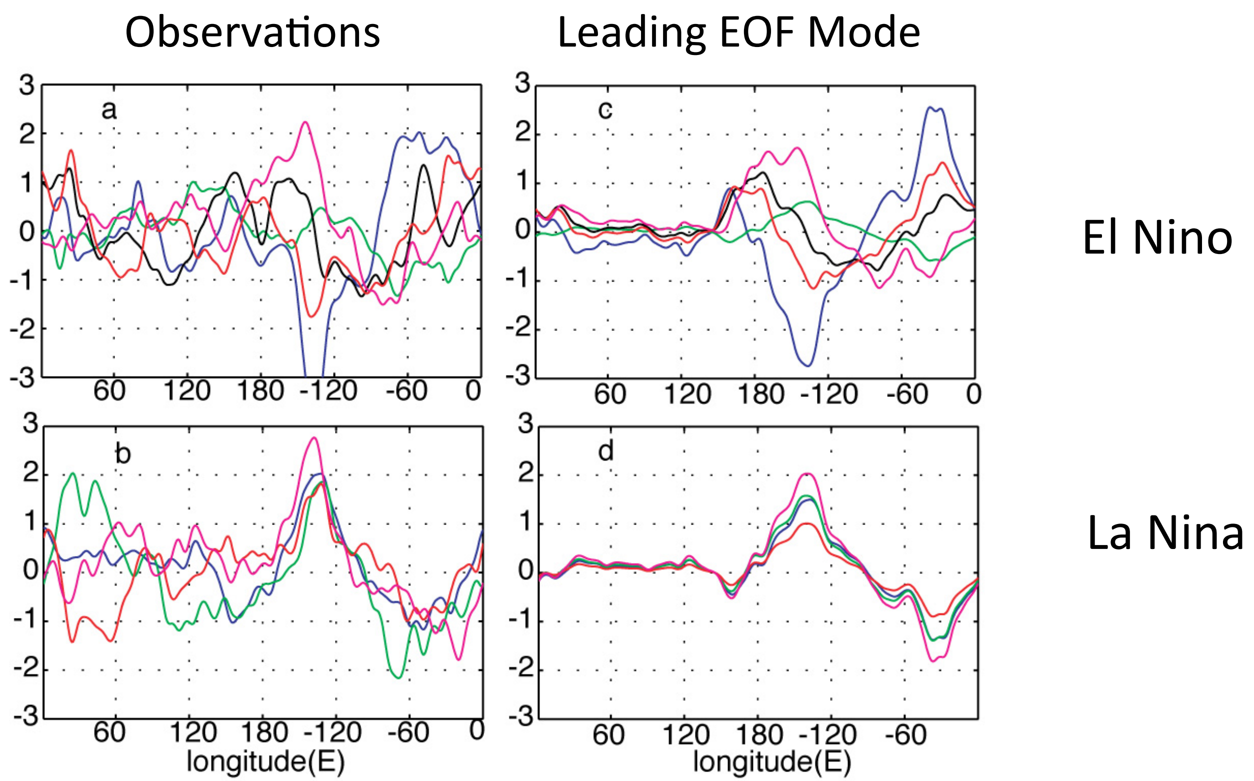
La Nina composite (stationary wave)



Shaded areas indicate polarward heat transport

Yuan, 2004

Ice Edge Anomalies During ENSO Events



El Nino events: 1980,1983,1988,1992,1997

La Nina event: 1985,1989,1996,1999

Yuan and Martinson, 2001

Science Questions and New Advances

- Does the tropic-pole connection only happen in the troposphere?
- How important are the tropical Indian Ocean and tropical Atlantic in terms of teleconnection?
- Do different mechanisms dominate the tropic-pole connection at different time scales?
- Is the tropic-pole connection one way traffic? (What is the polar feedback to lower latitudes?)
- How far the polar influence can reach?

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Feedback of Arctic cryosphere to lower latitudes

- In response to the dramatic Arctic sea ice reduction, models predict that precipitation increases in the Canadian Rockies and Alaska regions and decreases in the western United States (Sewall and Sloan, 2004; Sewall, 2005).
- Sea ice in Barents Sea plays an important role for local and regional climate variability but has a rather small impact on large climate condition likely because of its location (Koenigk et al., 2008)
- Eurasian land snow cover is more skillful in predicting surface temperature in eastern North America than the AO and ENSO (Cohen and Saito, 2003).

Polar Feedback

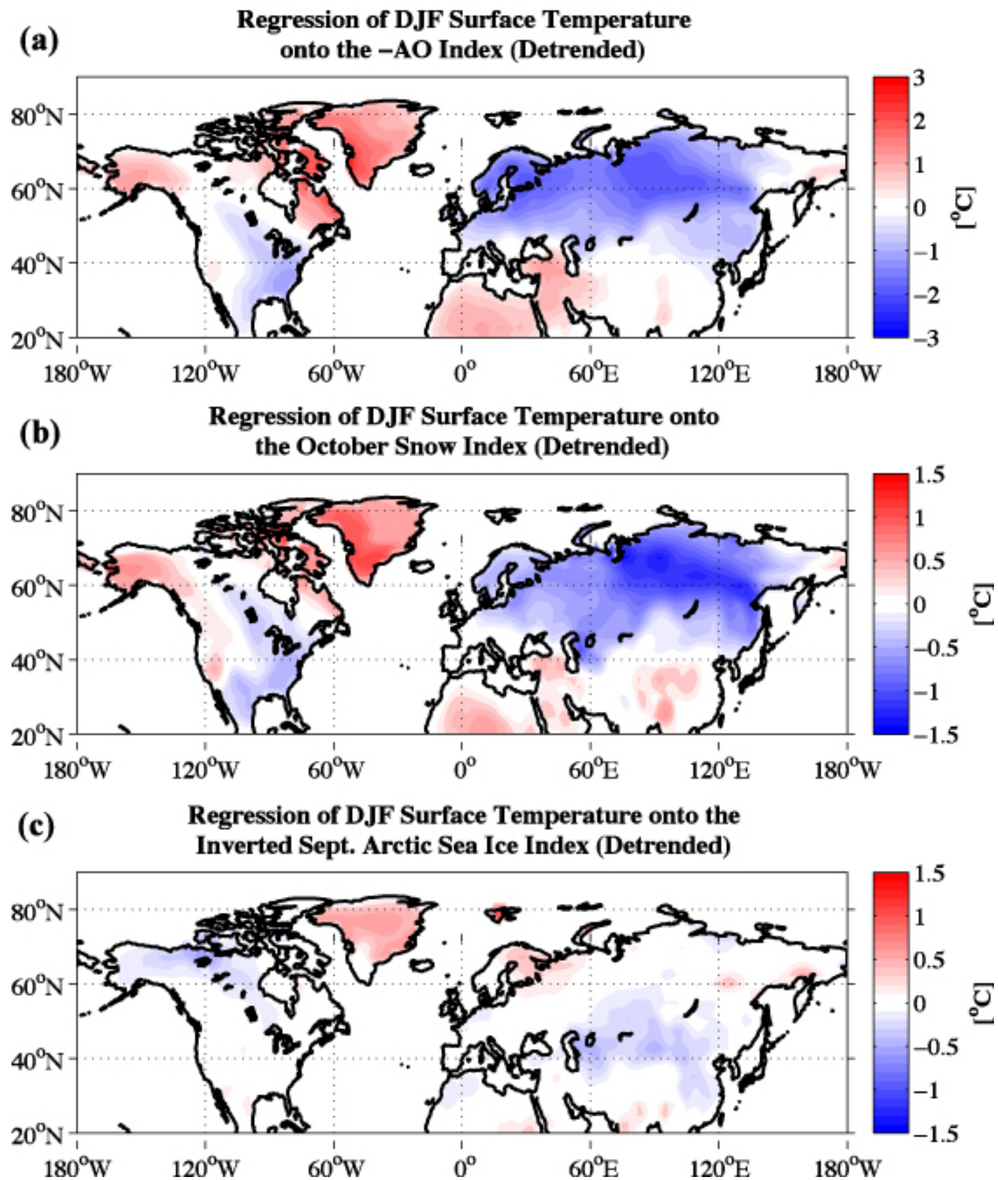
Hypothesized link between warming Arctic/reduced sea ice to winter cooling of eastern North America and northern Eurasia

- Warmer air temperature, low sea ice in summer and fall
- Increased atmospheric moisture in high latitudes in fall and winter
- Increased Eurasian snow cover in fall and winter
- Stronger diabatic cooling and strengthened Siberian High
- Increase upward propagation of planetary waves
- Weaken Polar vortex and westerlies – negative AO in lower troposphere
- Increased Arctic outbreaks into mid-latitudes

This dynamic link is consistent with Jaiser et al., 2013

Figure 4 from Judah L Cohen et al

2012 Environ. Res. Lett. 7 014007

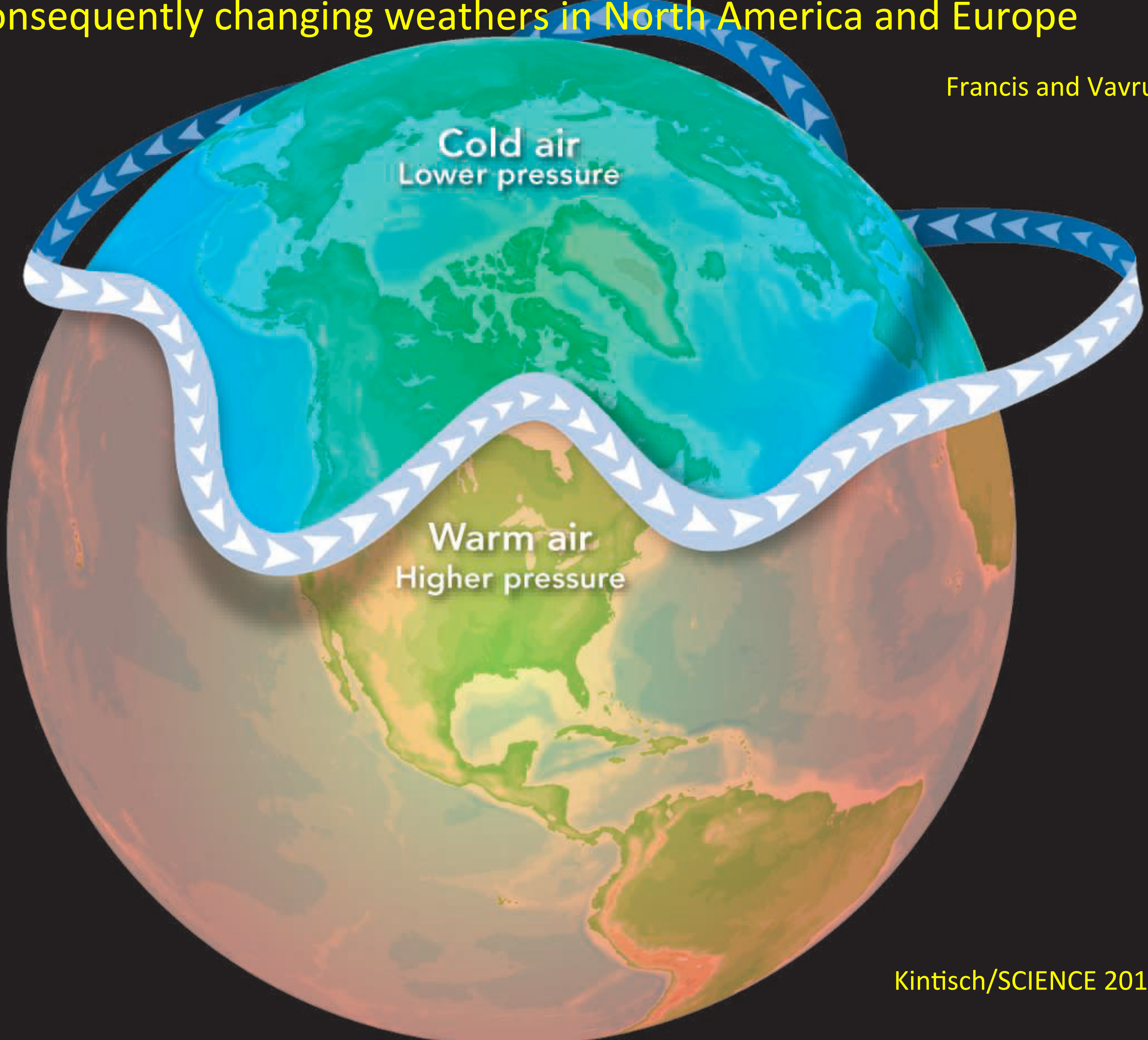


Cohen et al., 2012

Polar Feedback

Francis' Hypothesis: Warming Arctic is altering the polar jet stream, consequently changing weathers in North America and Europe

Francis and Vavrus, 2012



Kintisch/SCIENCE 2014

How important is the warming Arctic and drastic sea ice retreat in influencing weather in North America and Europe? Could the polar region become a comparable forcing as the tropics?

Modeling studies on atmospheric responses to the Arctic sea ice retreat

1. Agreements:

- While maximum Arctic sea ice loss occurs in summer and early fall, the climate impacts tend to maximize in winter and spring.
- The main pathway is the latent and sensible heat fluxes from the ocean to atmosphere through larger open water area.
- Longer ice free summer allows the Arctic Ocean absorbs more heat.
- Warmer and wetter Arctic atmosphere leads to amplified polar warming, changes in atmospheric stability, cloudiness, hydrological cycle, etc.

2. Discrepancies (large):

- In responding to the sea ice loss, some studies have negative AO and less storminess (Seierstad and Bader, 2009; Screen et al., 2013); other find positive AO and northward shift of storm tracks (Bhatt et al., 2008); or enhanced storminess (Singarayer et al., 2006).
- The timing of the maximum response also differs among different studies, ranging from October and November (Porter et al., 2012) to March (Seierstad and Bader, 2009).

Modeling studies on oceanic responses to the Arctic sea ice retreat

Decrease Arctic sea ice → enhanced ice export to the Labrador Sea → surface freshening → reduction of deep convection → strength of the Atlantic MOC decreases.

Holland et al., 2013 (CCSM4)

SAM’s impact on Indian Ocean SST

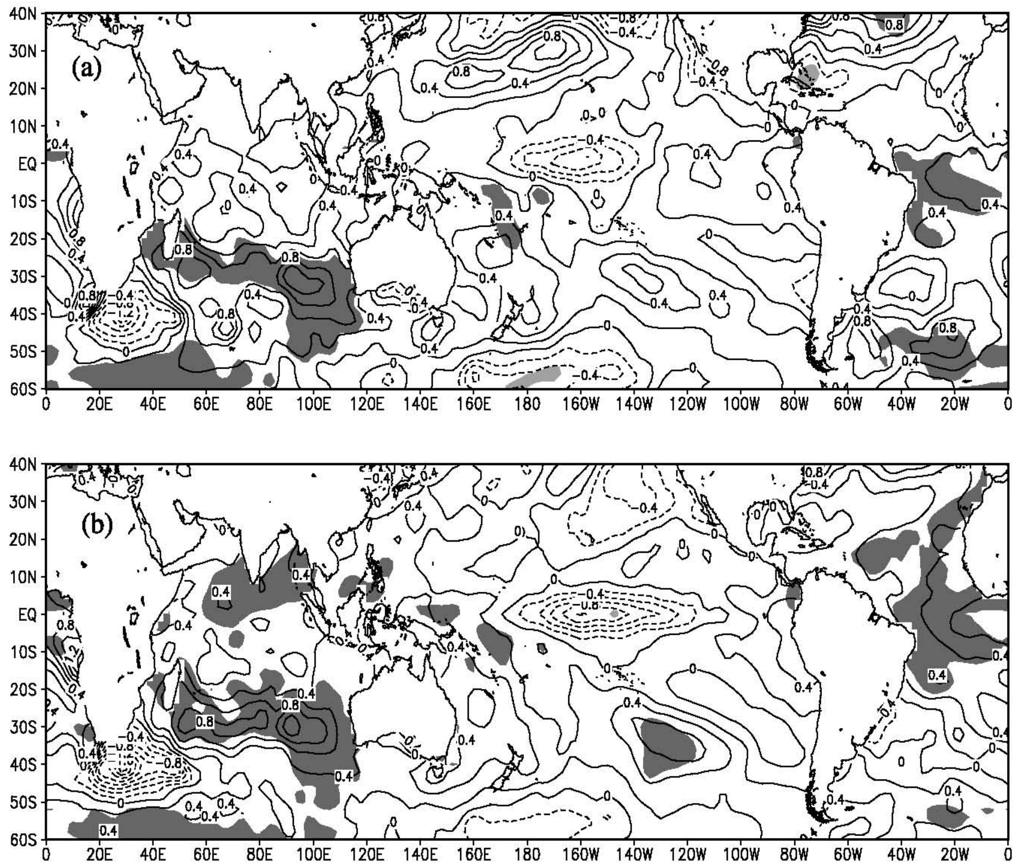
Composite differences in SST between high and low austral fall SAM index

Austral fall

April-May

Austral winter

June-August

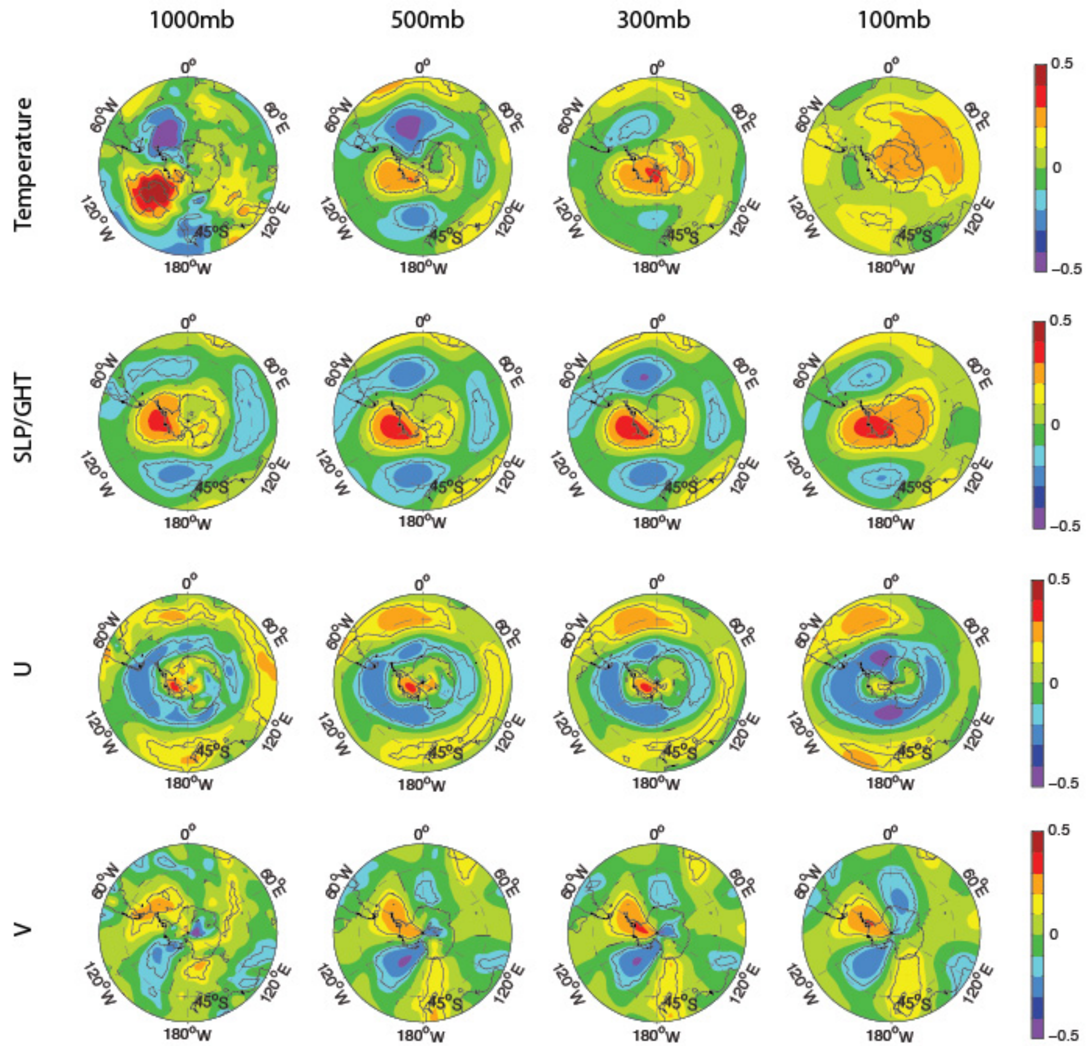


- ➢Positive SAM anomalies
- ➢Weakened regional Ferrel Cell
- ➢Anomalies upward motion 20-30S
- ➢Increased cloud cover and downward longwave radiation
- ➢Warmer SST

Nan et al. 2009

Antarctic Dipole's influence on the overlaying atmosphere

Correlations between ADP index and atmospheric variables



Yuan, Smith and Jensen, in prep

Connecting the Tropics to Polar Regions

- **Why is Antarctic sea ice increasing?**
  - Do the tropics have a role?
- **Why is there polar amplification?**
  - Do the tropics have a role?
- **(How) do the polar regions affect the tropics?**
  - Paleoclimate records – what happened
  - Do different processes dominate at different time scales?
- **Are there pathways through the stratosphere?**


Thank You