# Sudden recent Antarctic sea ice retreat, connections to the tropics, and sustained changes to the upper ocean around Antarctica

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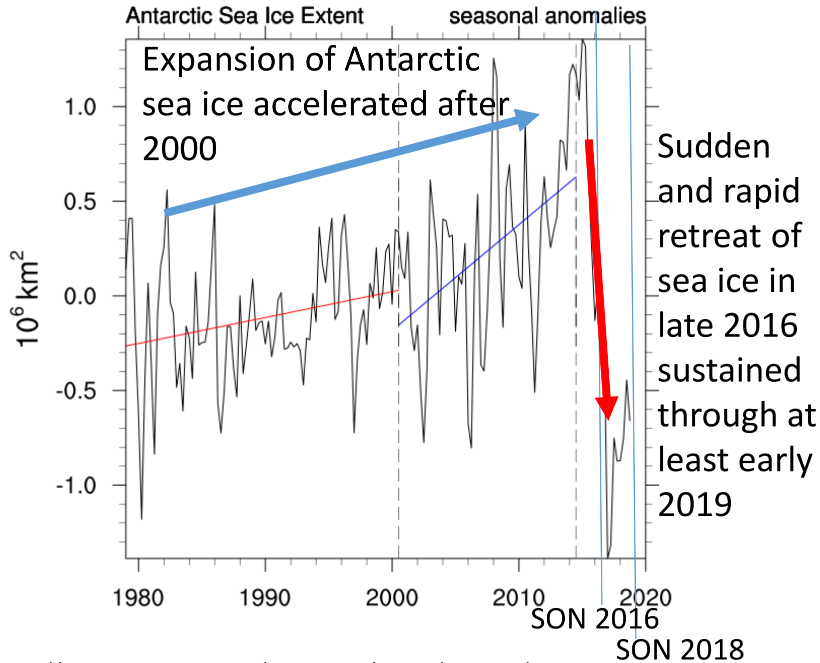
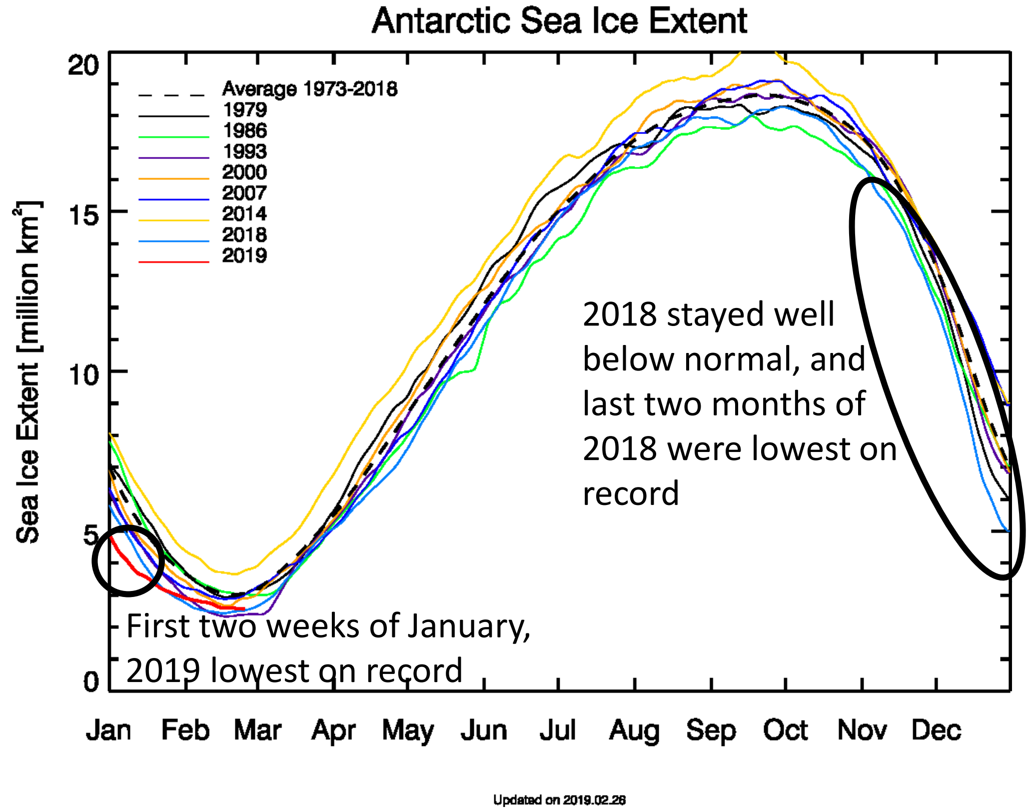
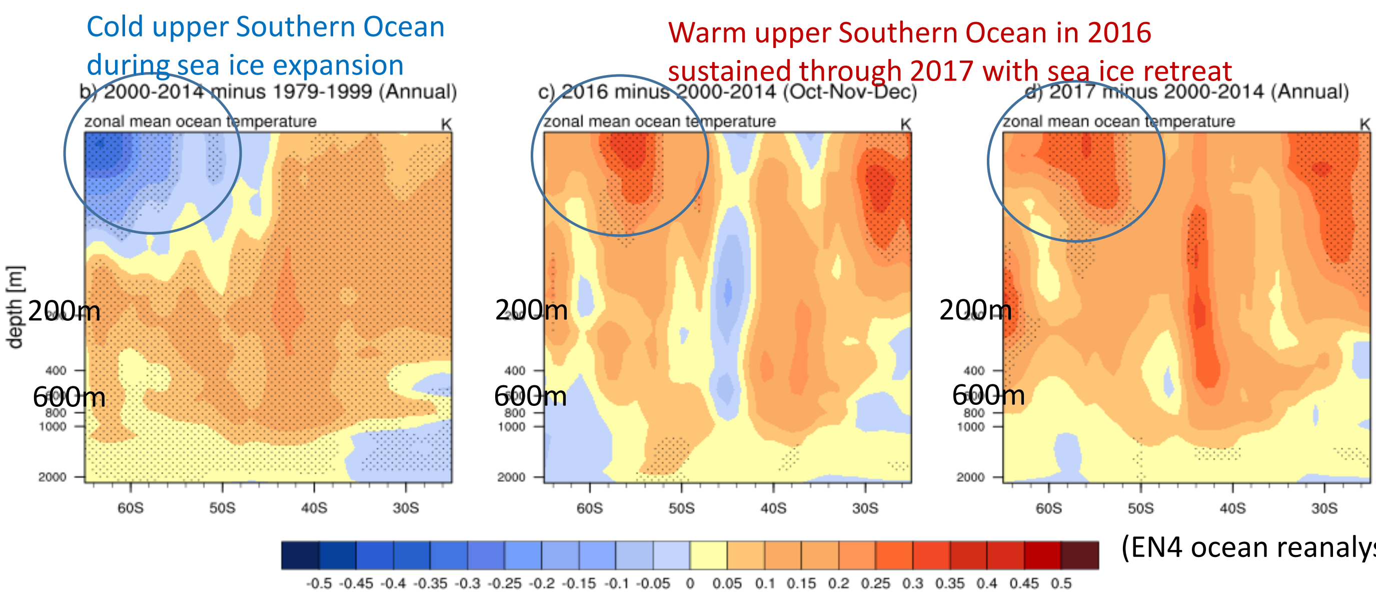
**The sudden and dramatic *decrease* of Antarctic sea ice extent that started in late 2016 was sustained at least into early 2019**




(ftp://sidads.colorado.edu/DATASETS/NOAA/G02135/)




https://seaice.uni-bremen.de/sea-ice-concentration/time-series/




(EN4 ocean reanalysis data)

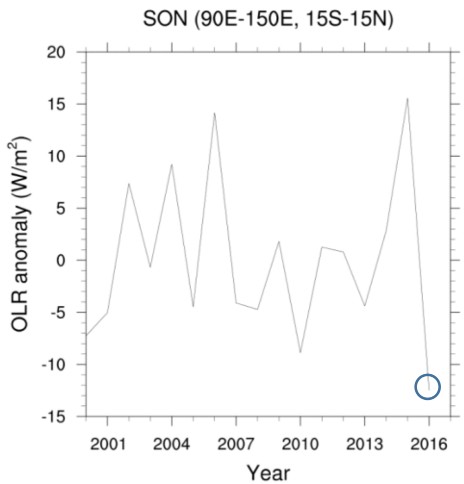
# The sudden and dramatic *decrease* of Antarctic sea ice extent that started in late 2016 was sustained at least into early 2019

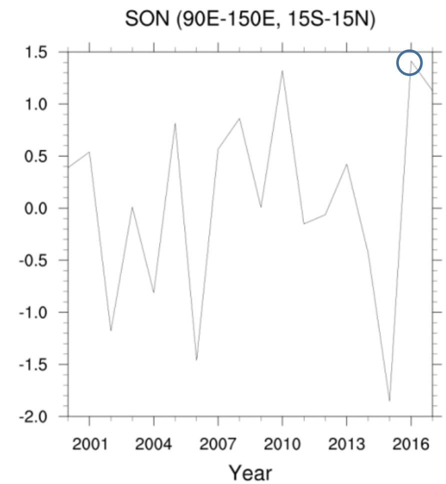
Possible causes:

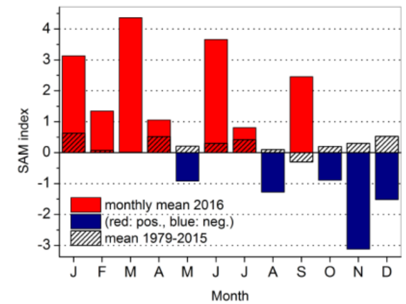
1. Atmospheric surface wind forcing associated with teleconnections from tropics (late 2016 changes documented in observations, Wang et al., 2019)

2. Changes in Southern Ocean associated with decadal variability of IPO and SAM

# In late 2016, there were a lot of record anomalies that could have contributed




Negative SAM index (Schlosser et al 2017)

http://www.nerc-bas.ac.uk/icd/gjma/sam.html

SAM negative Jan-Mar 2017; then positive April 2017-Feb 2018 with only Oct. 2017 and Mar 2018 negative

**Records in the 2000s for SON:**

--OLR in E. Indian

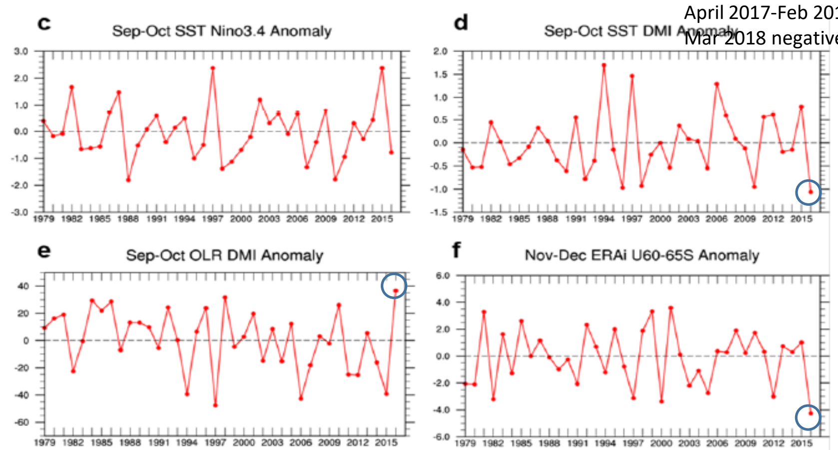
--precip in E. Indian

--negative DMI

--positive OLR-DMI

--negative SAM

--easterly anomaly 850 hPa u winds at 60-65S




(Wang et al., 2018)

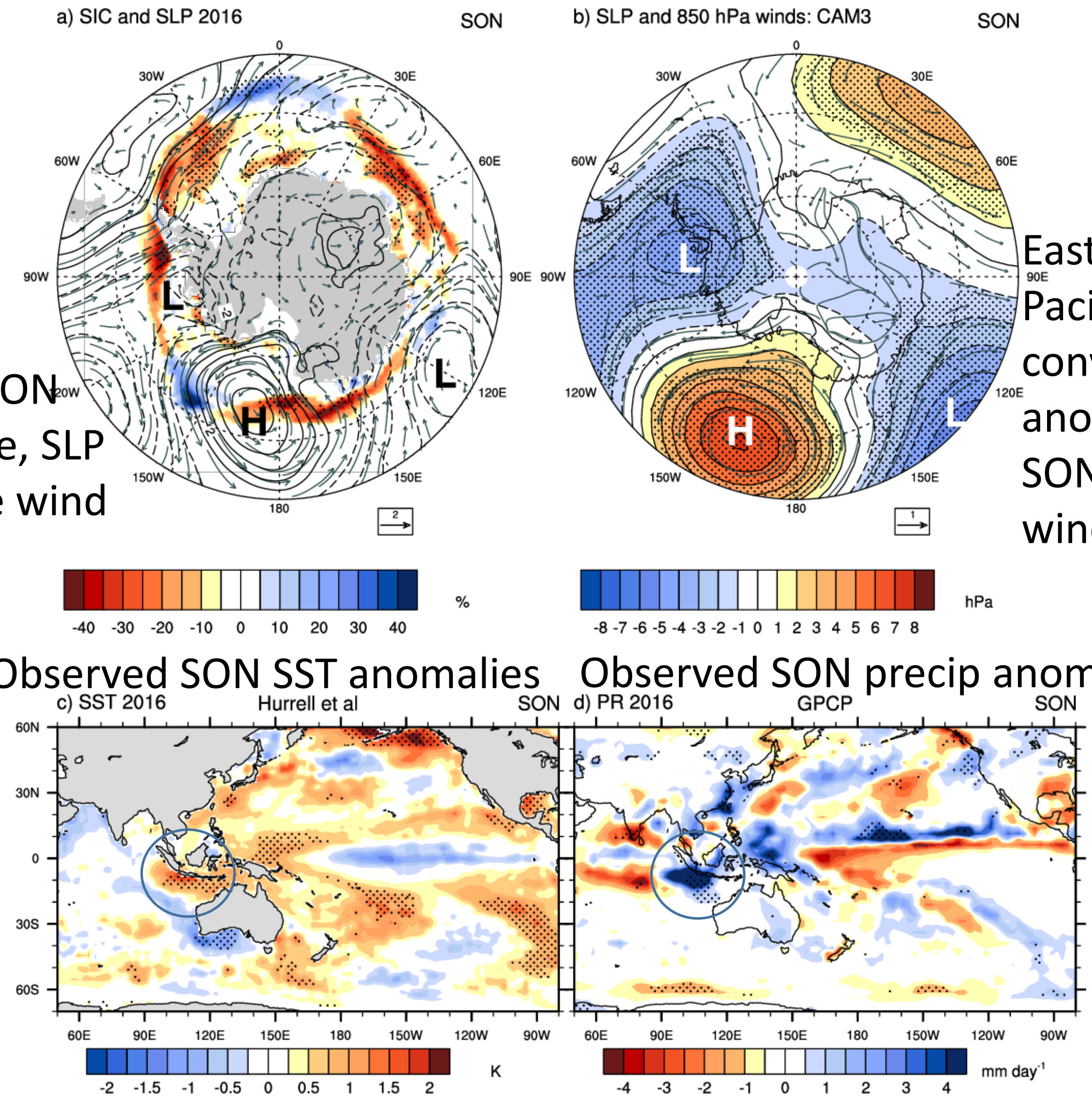
# Evidence that mid- and high latitude teleconnections with southward surface winds, which reduced sea ice extent, were driven from the tropics

Observed SON 2016 sea ice, SLP and surface wind anomalies

Eastern Indian/western Pacific 120E,Eq positive convective heating anomaly experiment, SON SLP and surface wind anomalies

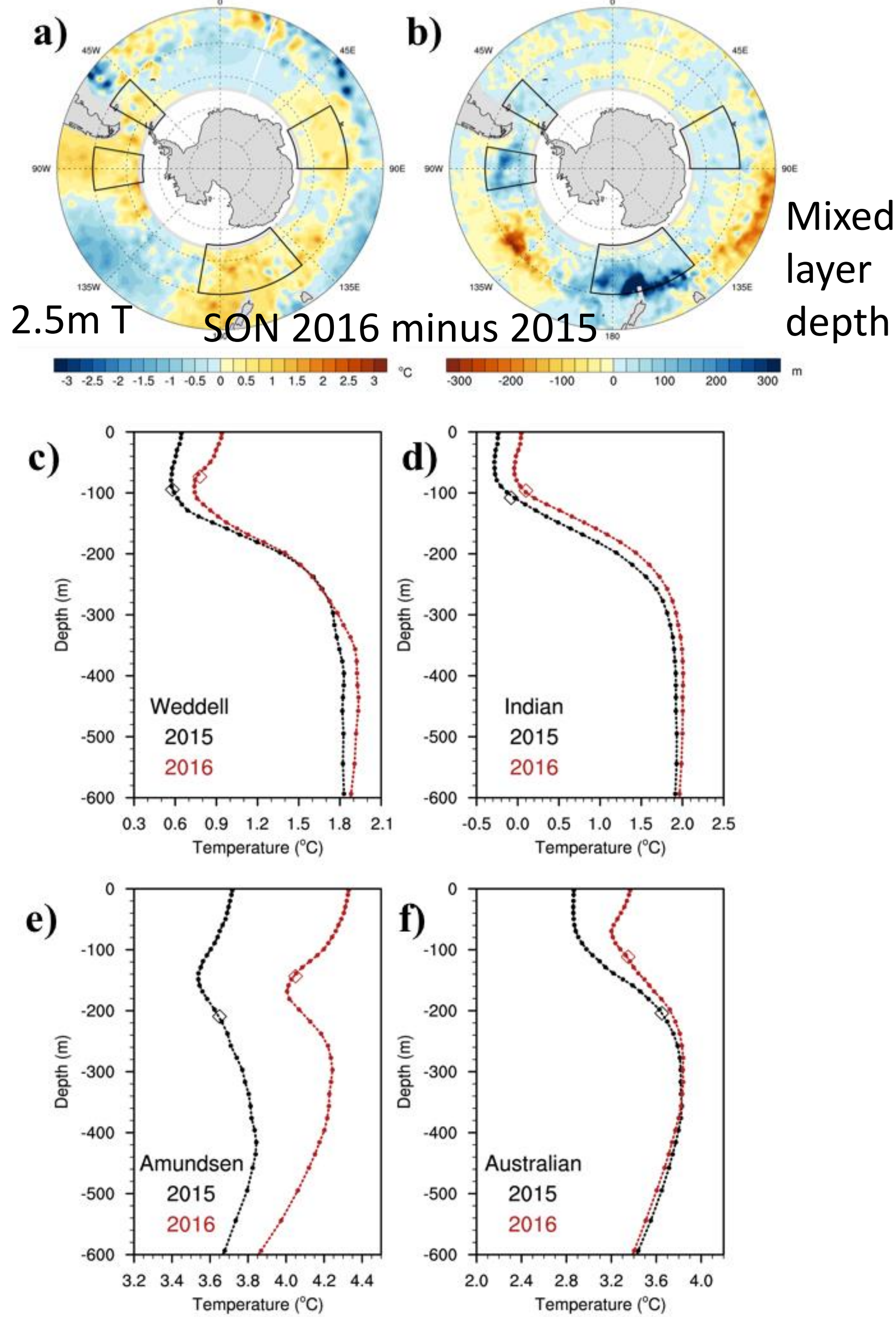
Observed SON SST anomalies

Observed SON precip anomalies



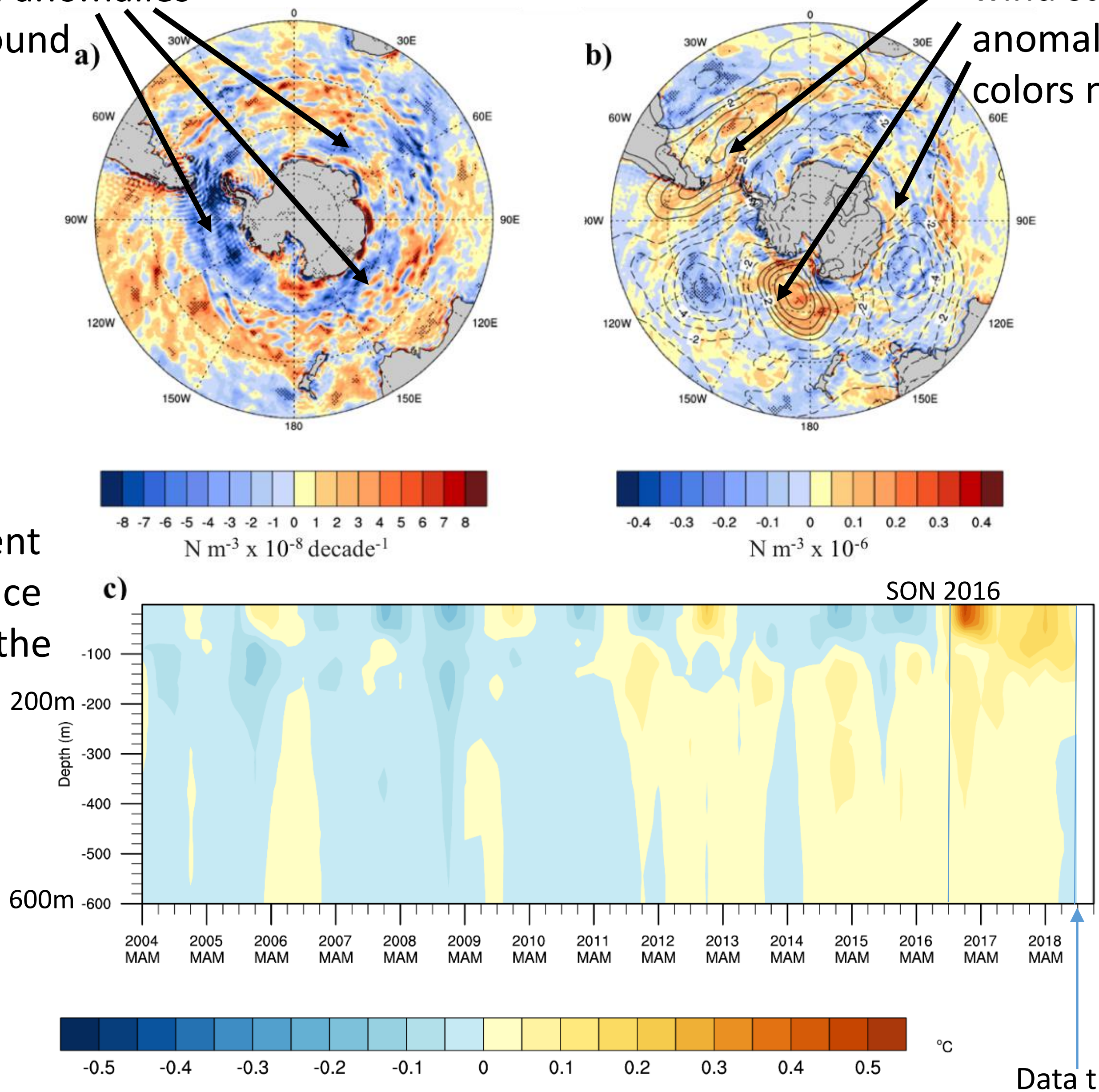
## In SON 2016, SSTs over much over much of the Southern Ocean warmed and mixed layer depth shallowed

(gridded Argo float data)



2000-2014 trend of negative wind stress curl anomalies (blue colors around Antarctica)

SON 2016 positive wind stress curl anomalies (orange colors near Antarctica)



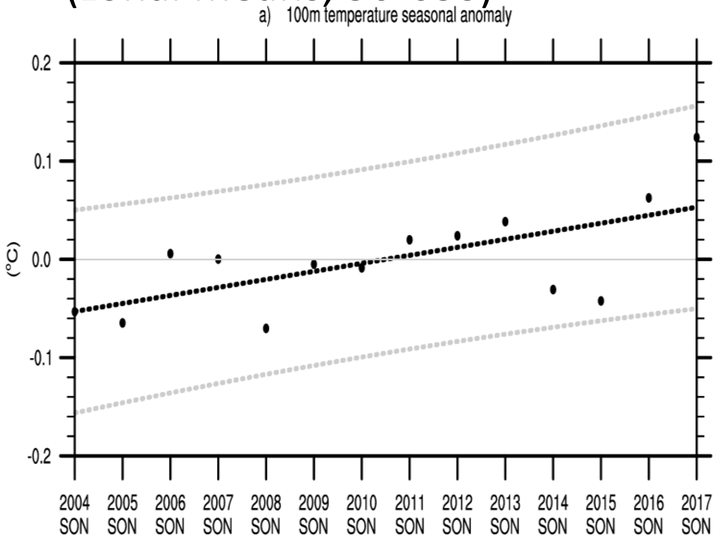

Episodic movement of warm subsurface water upward in the water column (zonal mean temperature 50-65S)

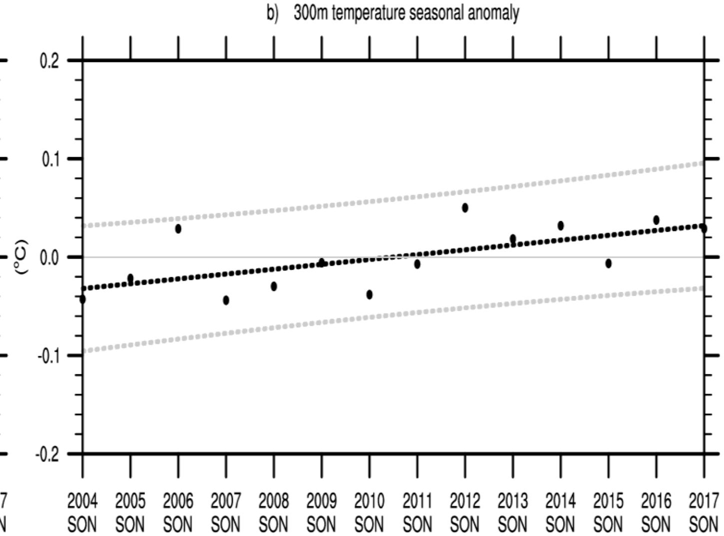
In SON 2016, entire zonal mean water column in upper 600m had positive temperature anomalies

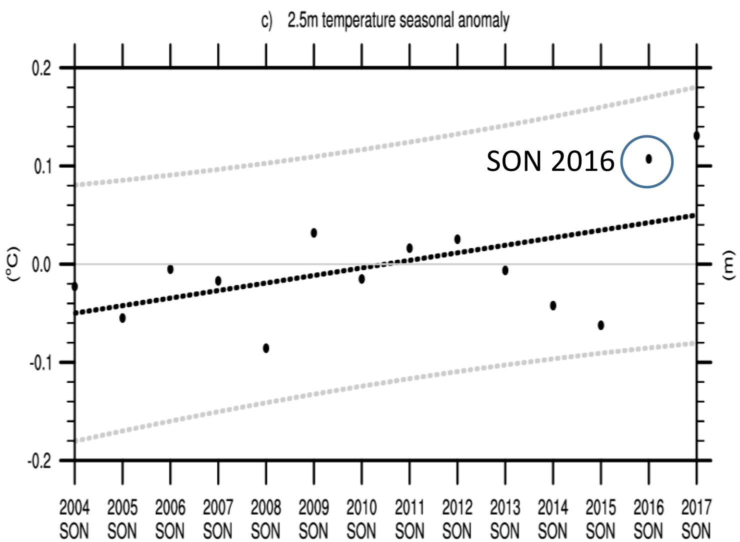
Data through SON 2018

**Examples of statistically significant warming trends at 100m and 300m**

(zonal means, 50-65S)




**Little warming trend at 2.5m until sudden jump in SON 2016**

(most of trend from 2004-2016 due to warming step function in SON 2016)

# What would it take to move warmer subsurface water upward?

**Surface wind stress forcing can produce vertical motion in the water column (upward is "Ekman suction"):**

$w_e = \frac{1}{\rho f} \nabla \times \tau \cdot \hat{k}$

**$w_e$ (Ekman suction) proportional to curl of the wind stress**

wind stress curl trend near 60˚S for the 2000s about $1 \times 10^{-7}$ N $m^{-3}$ $yr^{-1}$,

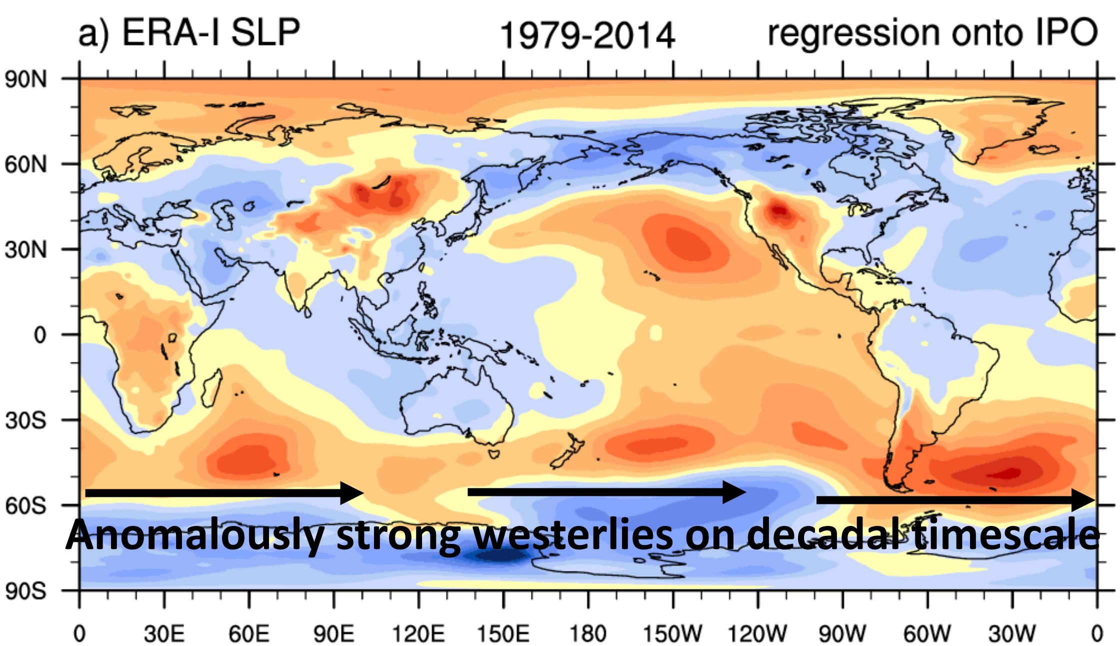
average change of $w_e$ over the last decade is about $0.5 \times 10^{-6}$ m $sec^{-1}$.

-- about 15 m per year of upward vertical motion driven by the wind

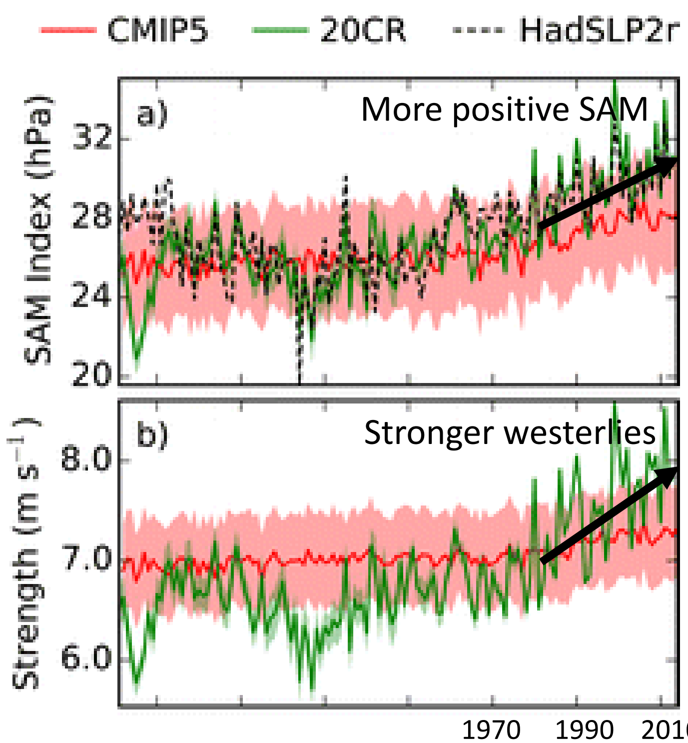
## about 150 m of upward vertical motion if applied over 10 years.

# What could produce anomalously strong westerlies on the decadal timescale?

## Negative IPO (shown here regressed onto sea level pressure)

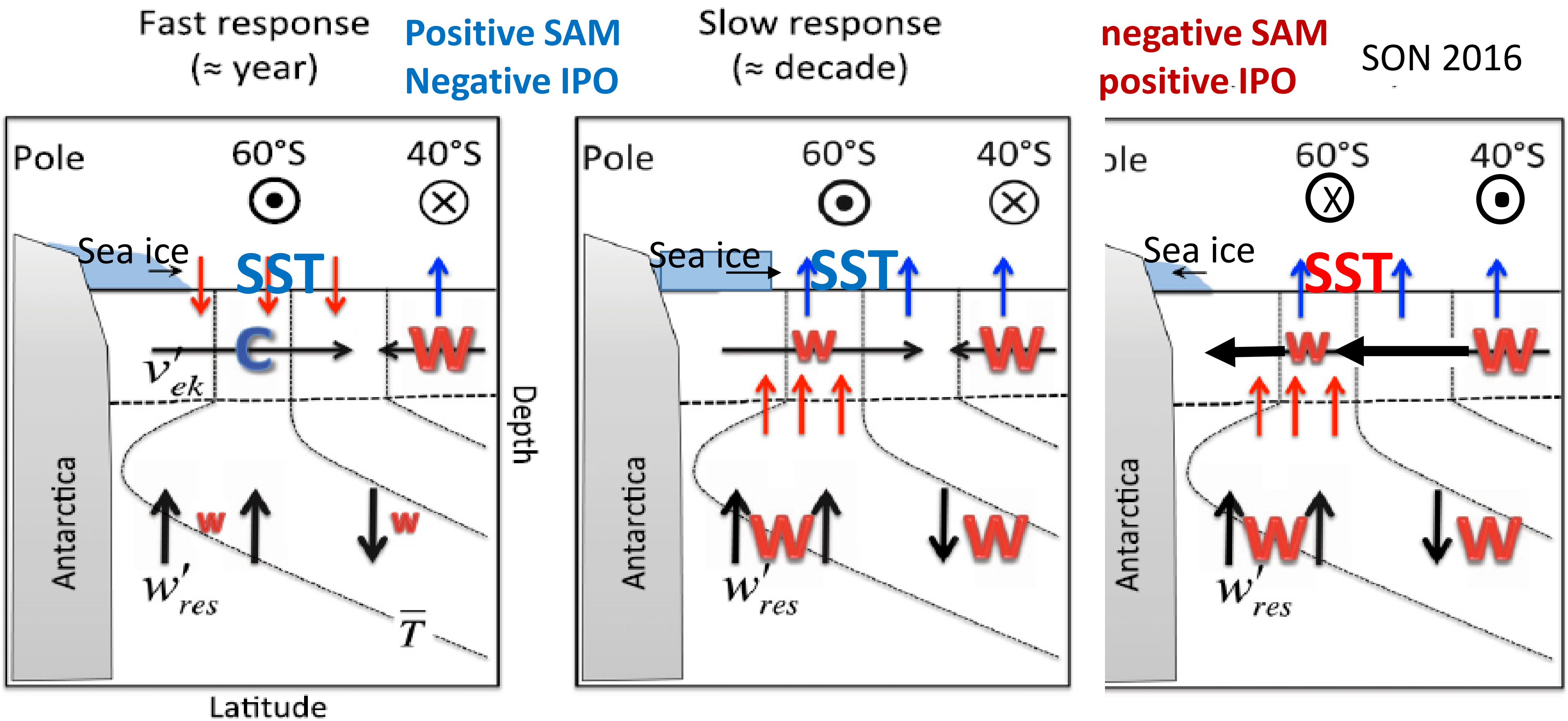



## ... and/or positive SAM




(Swart et al., 2015, J. Clim)

# A modified "two timescale response" to wind forcing over the Southern Ocean, leading to a sudden SST and sea ice transition




(modified from Ferreira et al., 2015, J. Clim.)

## What caused the sudden (and subsequently sustained) retreat of Antarctic sea ice starting in late 2016?

--Anomalous mid- and high latitude southward surface winds forced from the tropics

--A warmer upper Southern Ocean that was the culmination of a negative decadal trend of wind stress curl with positive Southern Annular Mode and negative Interdecadal Pacific Oscillation resulting in Ekman suction that moved warmer water upward in the column closer to the surface, a transition to positive Interdecadal Pacific Oscillation around 2014-2016, and negative Southern Annular Mode in late 2016.

(Meehl et al., 2019: Recent sudden Antarctic sea ice retreat caused by connections to the tropics and sustained ocean changes around Antarctica, *Nature Comms*., **10**:14, https://doi.org/10.1038/s41467-018-07865-9)

Key outstanding questions for your research area and how being part of CLEX could help those to be answered:

1. The changes we've studied relate mainly to internally generated variability, but how does that relate to climate system response to increasing GHGs?
2. How do the connections between timescales work? (e.g. seasonal negative SAM in SON2016 connected to decadal timescale variability of SAM and IPO)
3. How do decadal timescale changes of SAM and IPO relate to each other?

CLEX enables connections to others working on similar problems and leverages those efforts through enhanced communication and collaboration