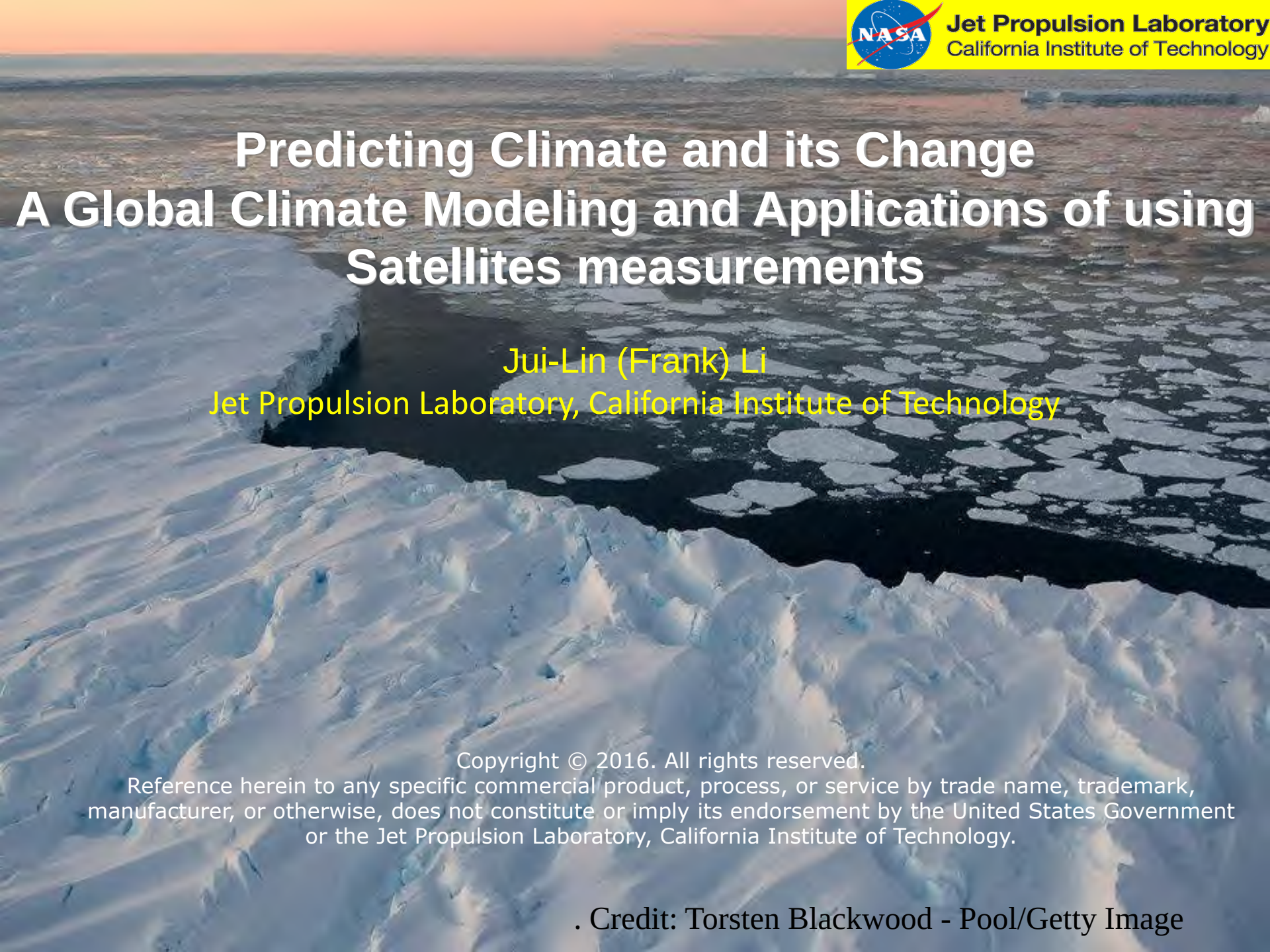


Jet Propulsion Laboratory
California Institute of Technology

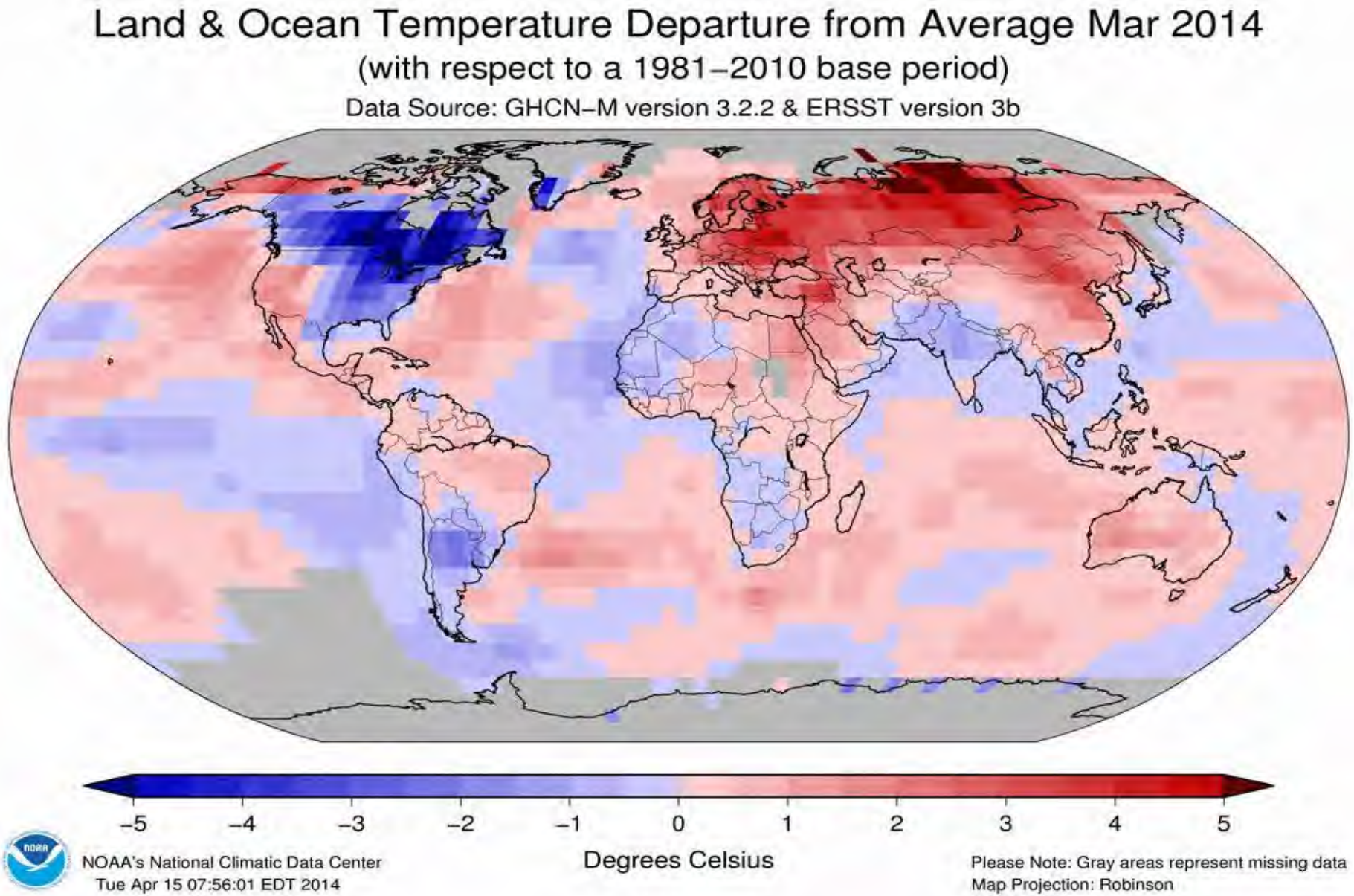
Predicting Climate and its Change
A Global Climate Modeling and Applications of using Satellites measurements

Jui-Lin (Frank) Li
Jet Propulsion Laboratory, California Institute of Technology

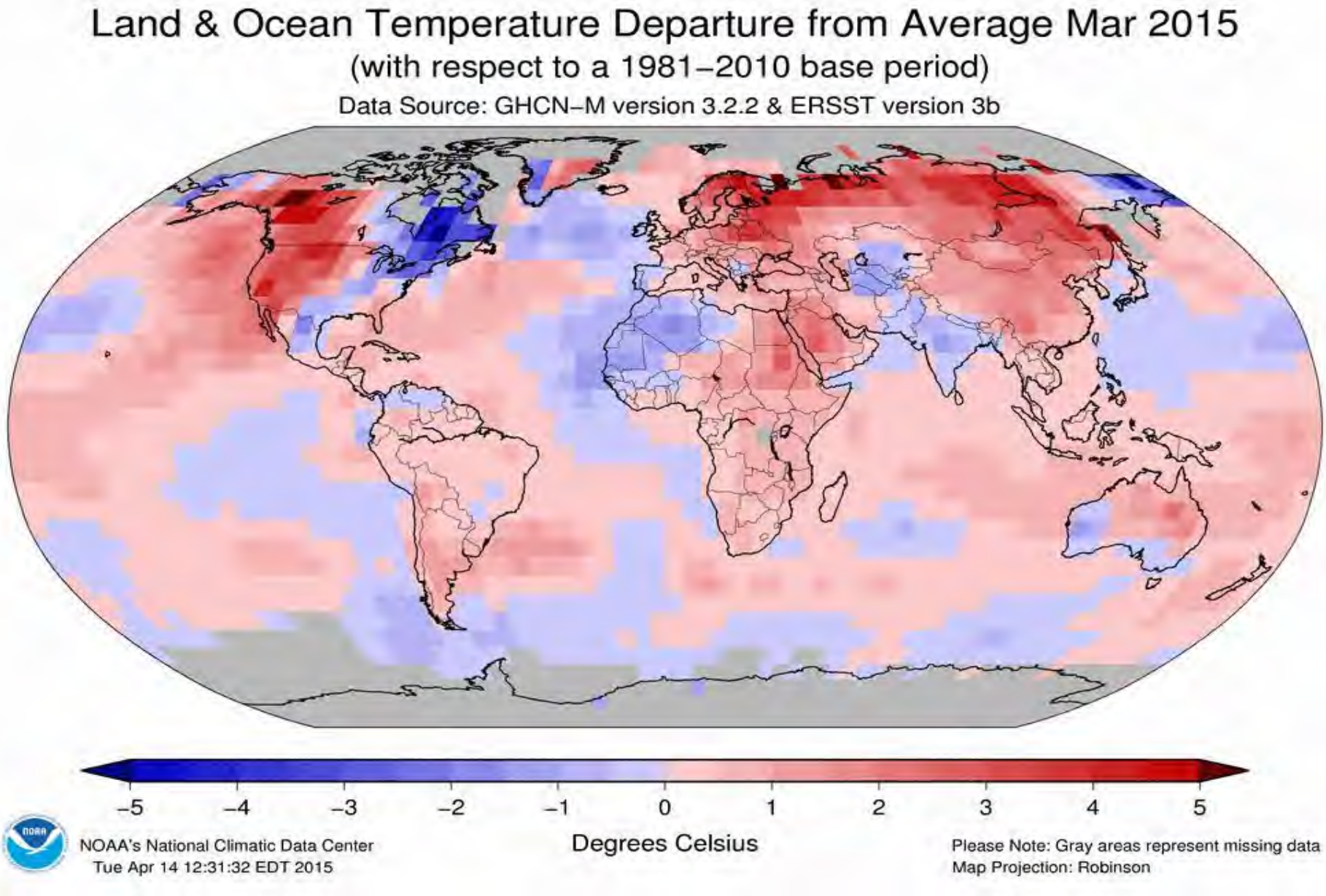
. Credit: Torsten Blackwood - Pool/Getty Image

Observations of climate change

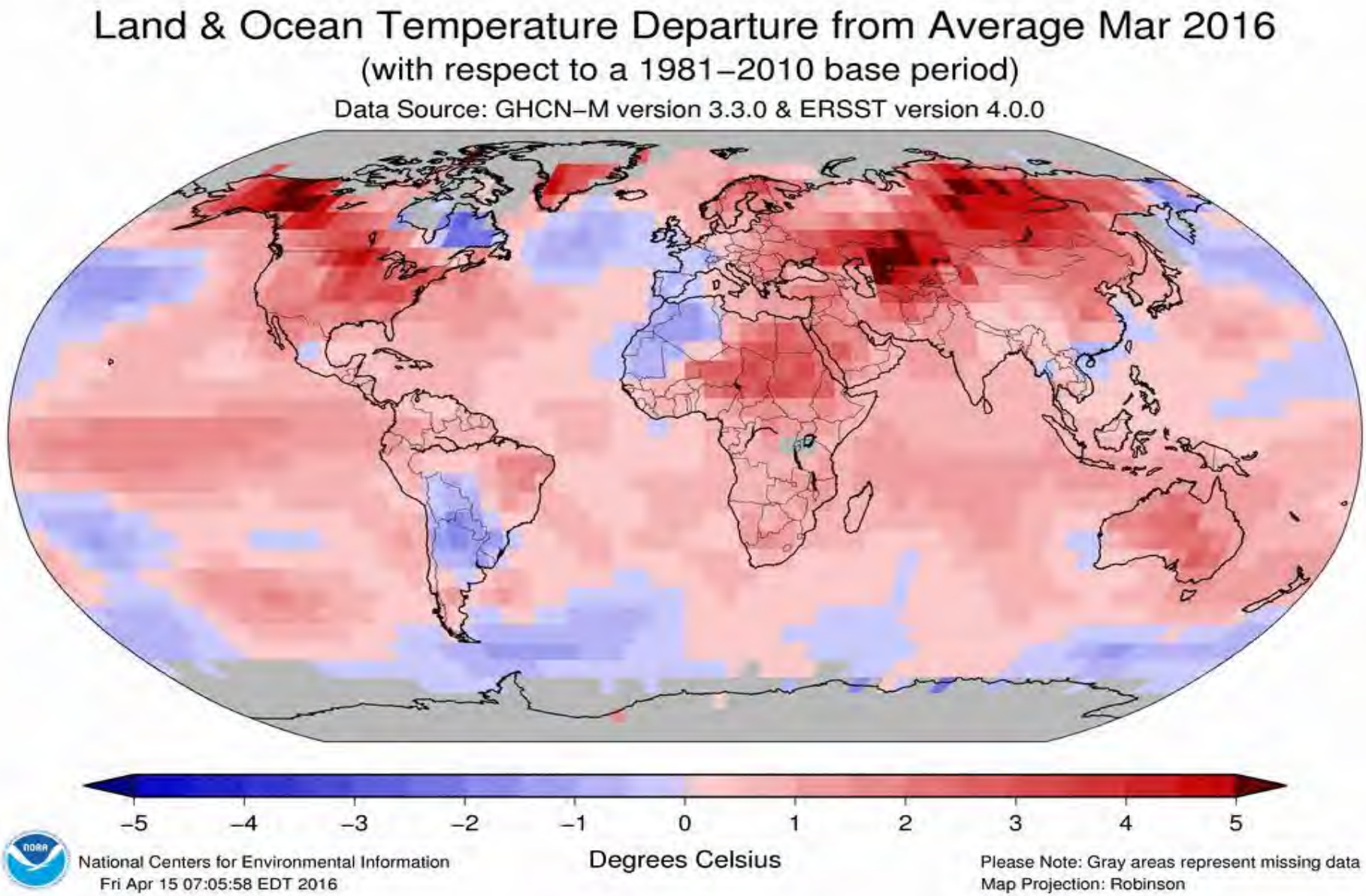
Present Day Global Mean Surface Temperature



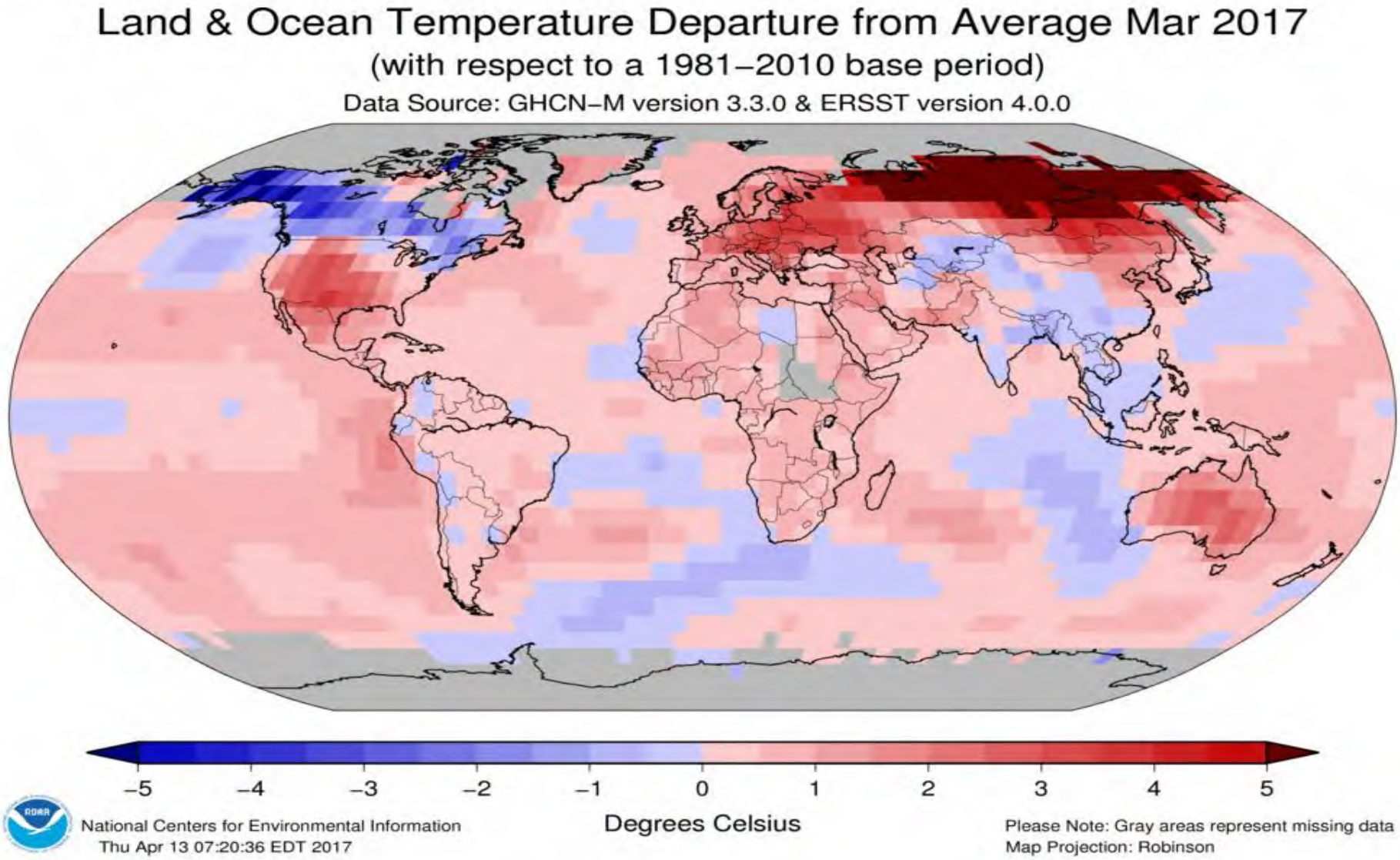
Present Day Global Mean Surface Temperature



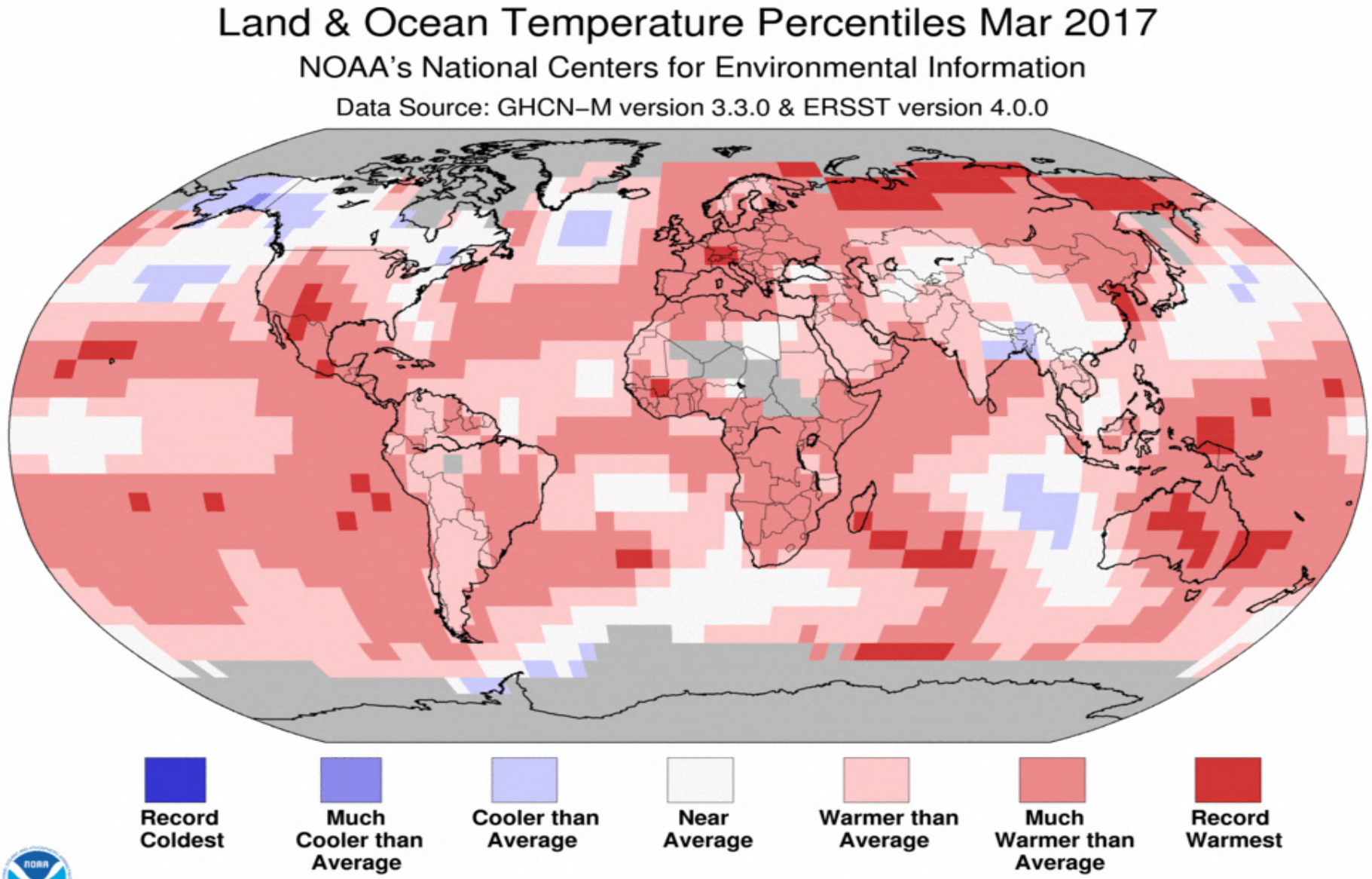
Present Day Global Mean Surface Temperature



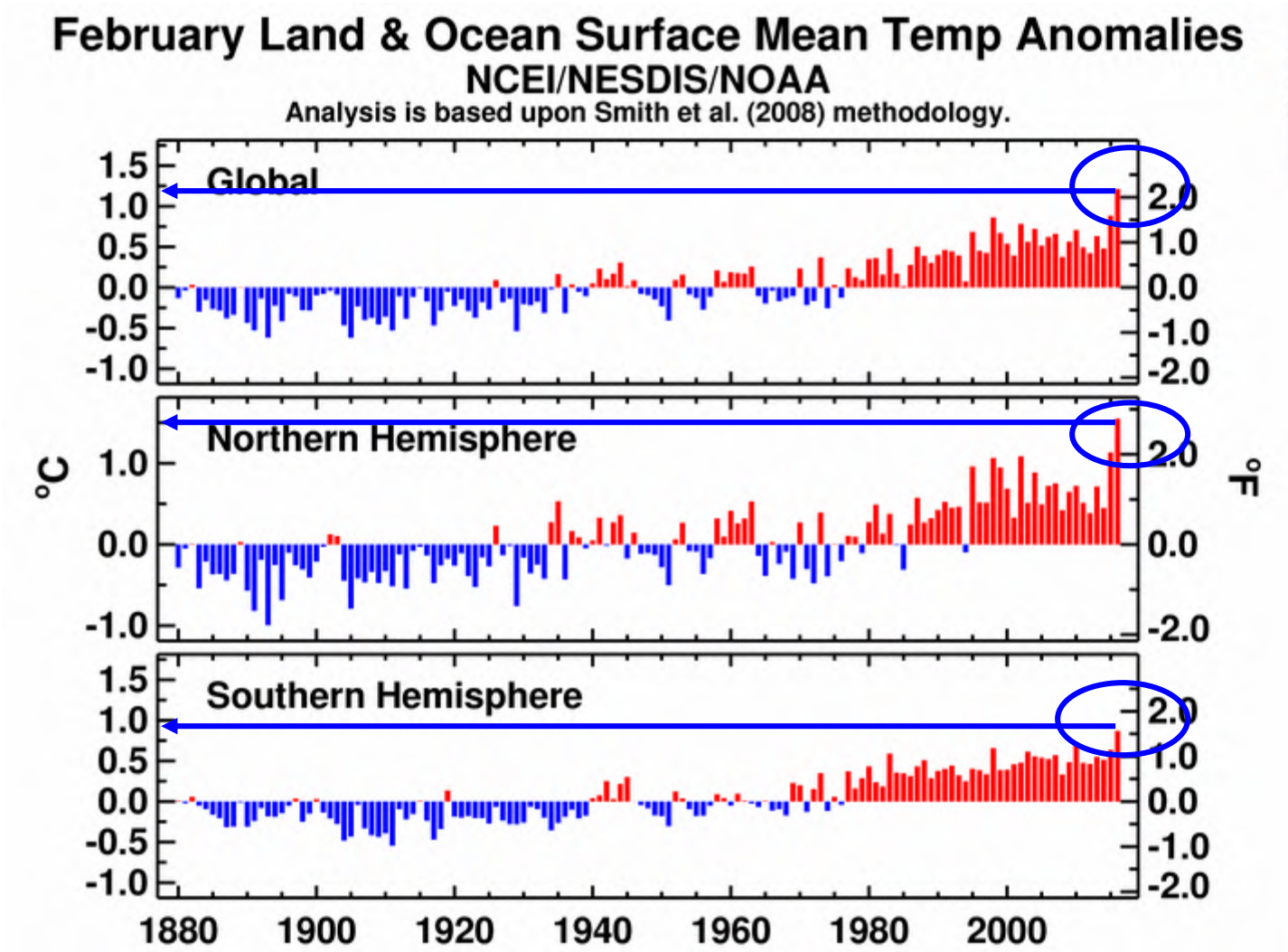
Present Day Global Mean Surface Temperature



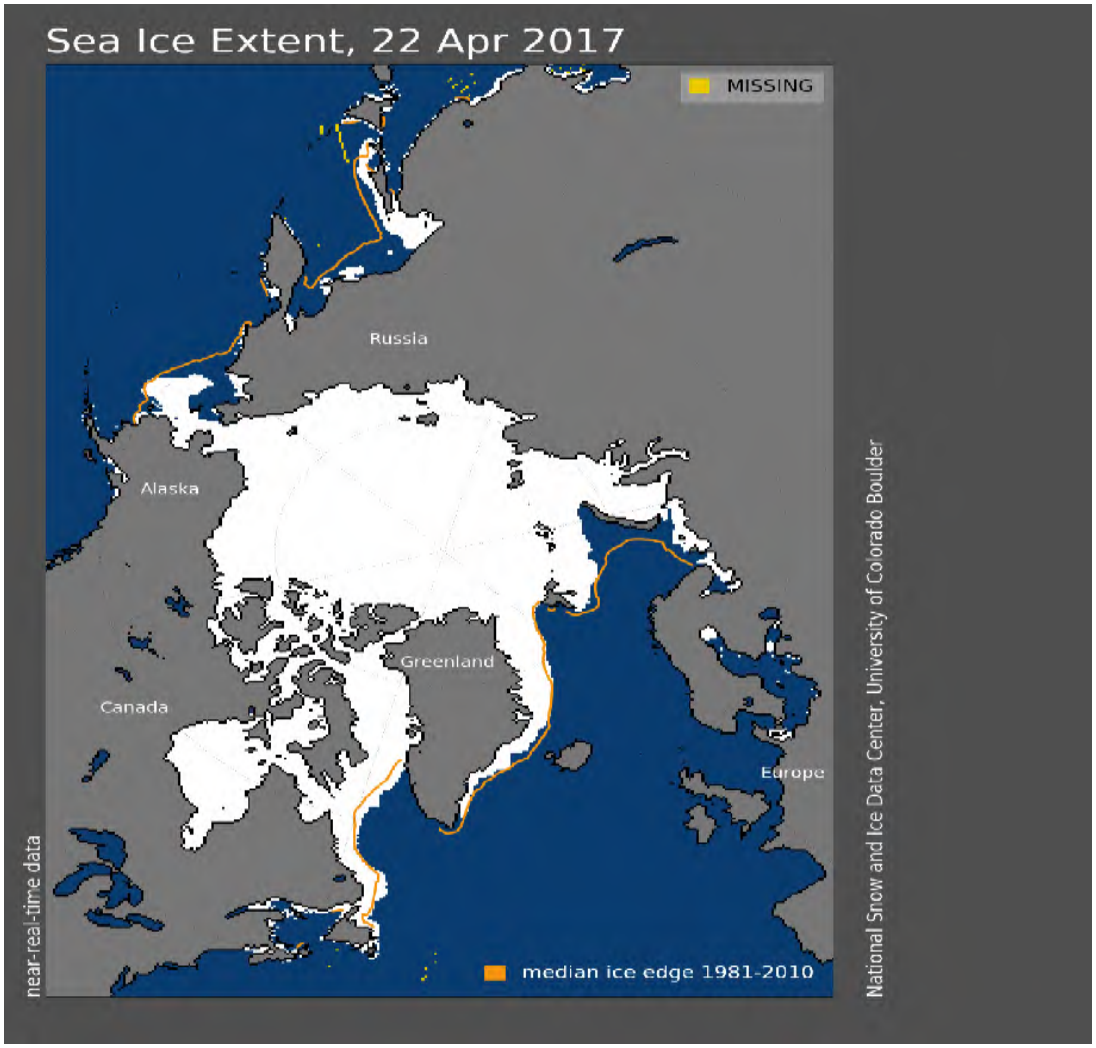
Present Day Global Mean Surface Temperature



Global Mean Surface Temperature



Current Arctic Sea Ice Extent Observations

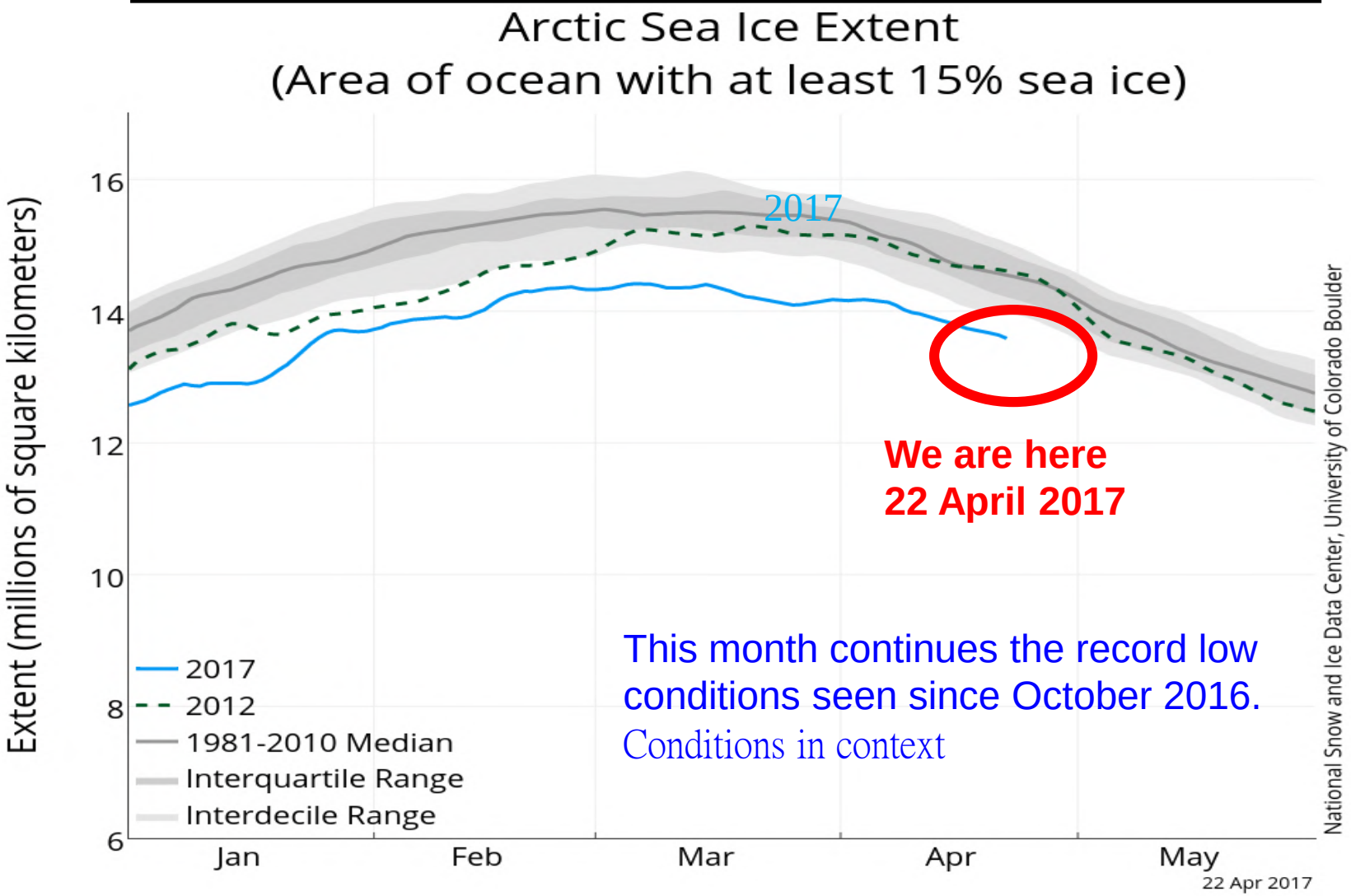


Arctic sea ice extent for March 2017 was the lowest record month.

The magenta line shows the 1981 to 2010 average extent for that month

Arctic sea ice extent for March 2017 was the lowest in the satellite record for the month.

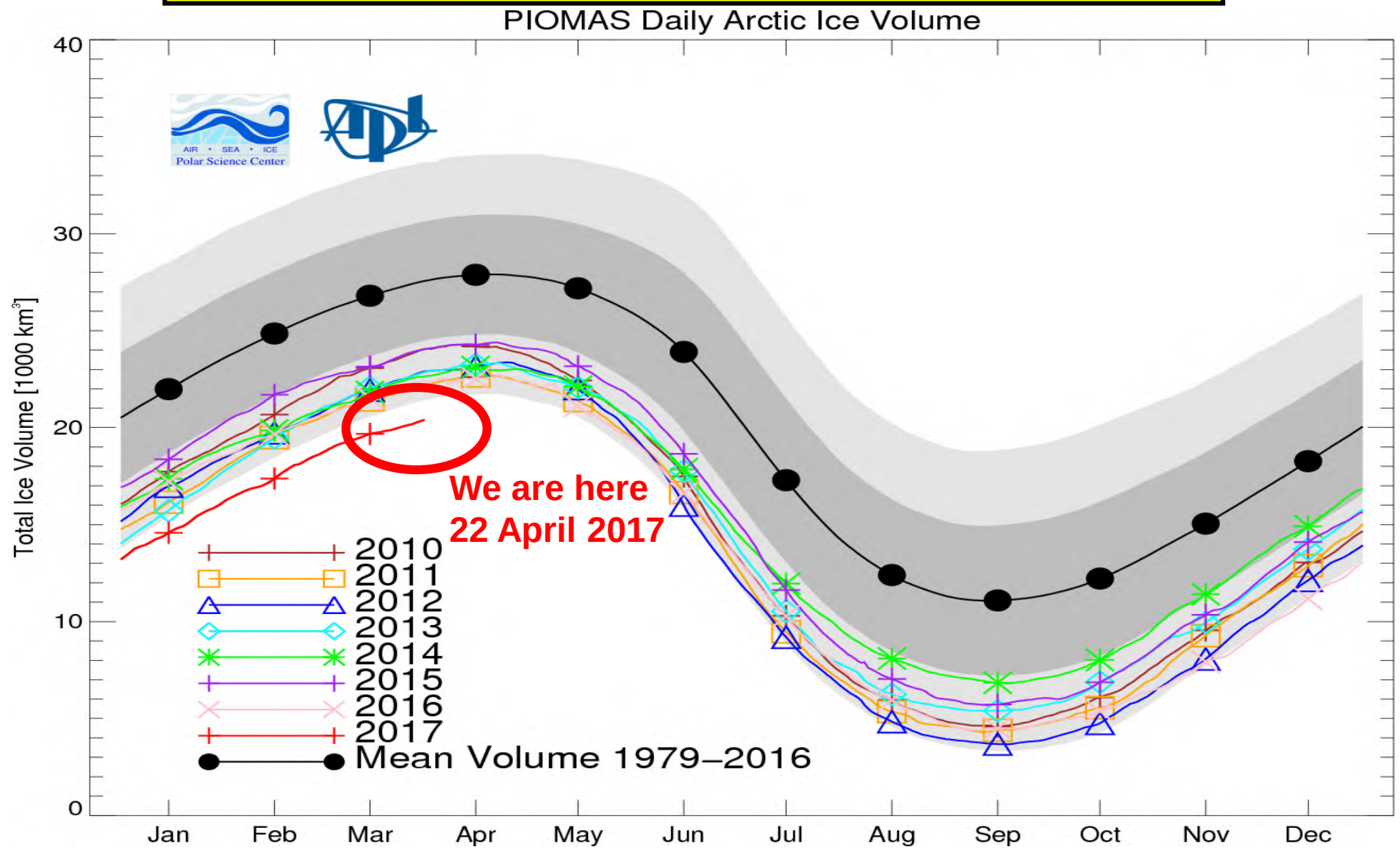
Arctic Sea Ice Extent Observations
Three days ago – 22 April 2017



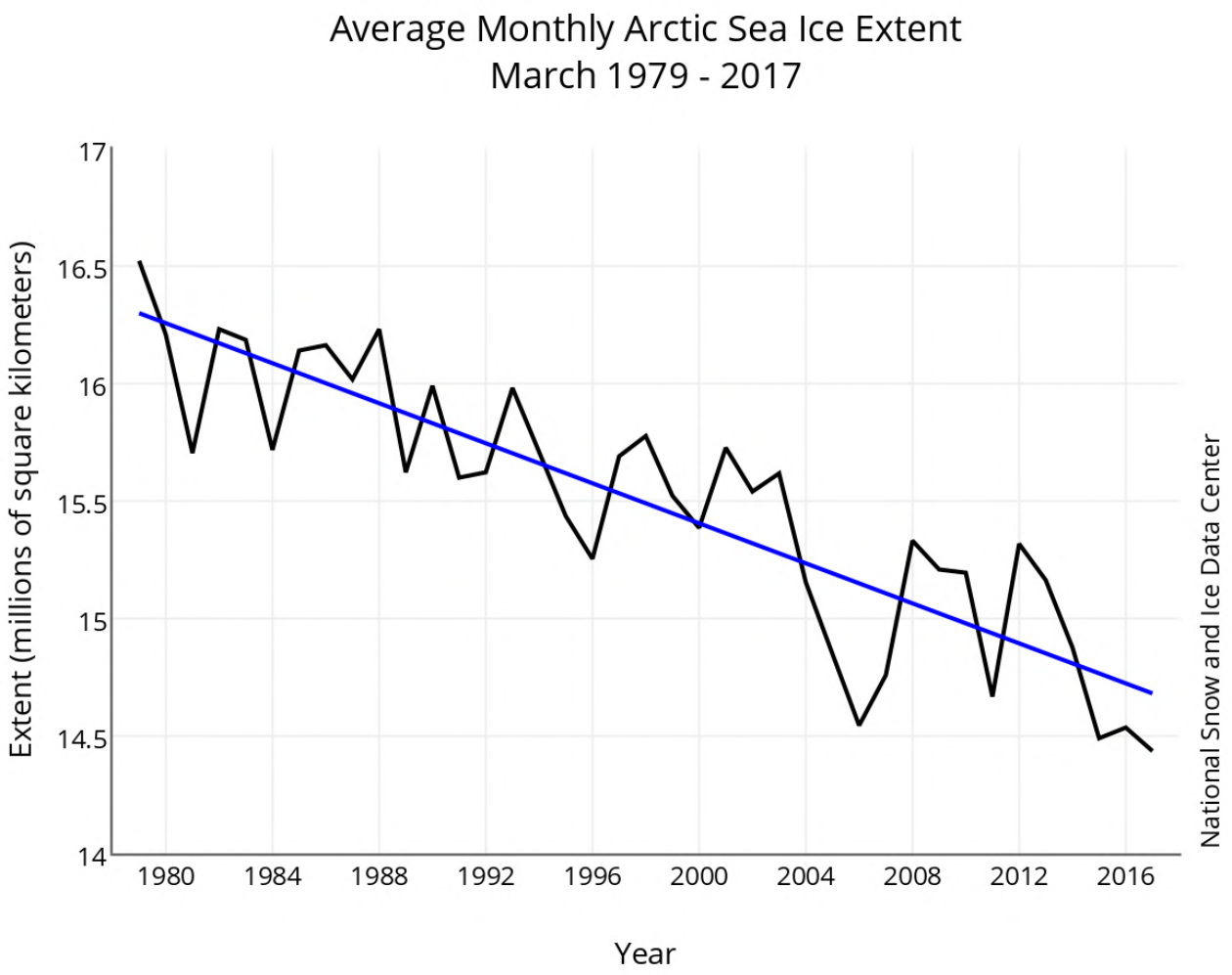
This month continues the record low conditions seen since October 2016.

Conditions in context

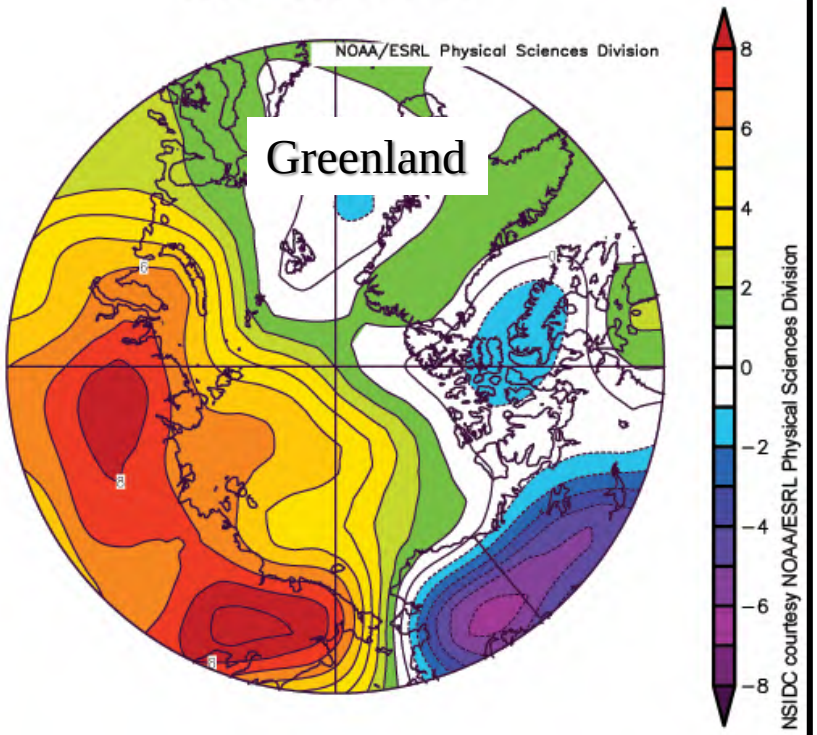
Arctic Sea Ice Volume
Three days ago – 22 April 2017



Arctic Sea Ice Extent Observations
Three days ago – 22 April 2017



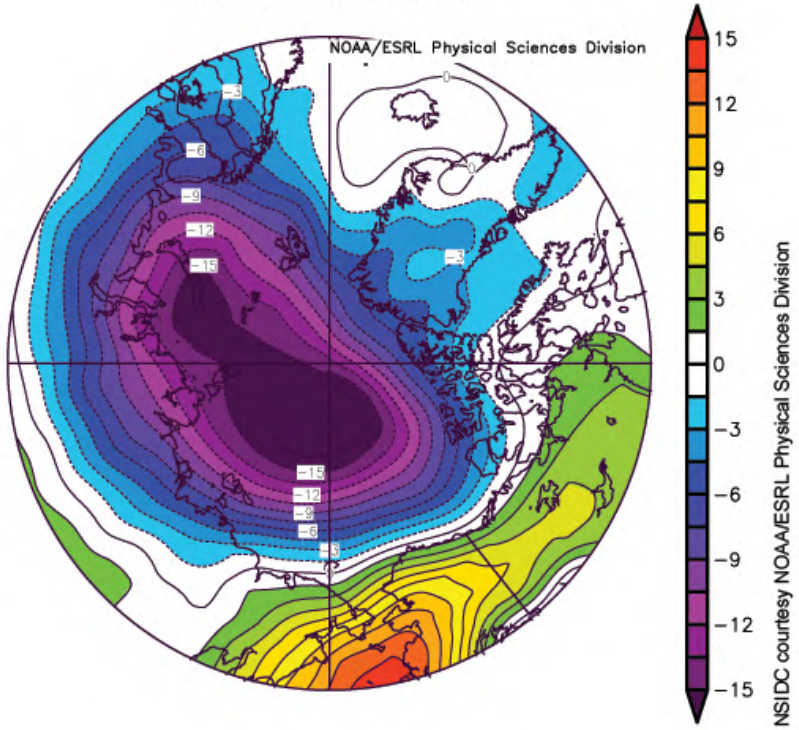
Arctic Air Temperature Difference March 2017



Arctic air temperature differences at the 925 hPa level in degrees Celsius for **March 2017**.

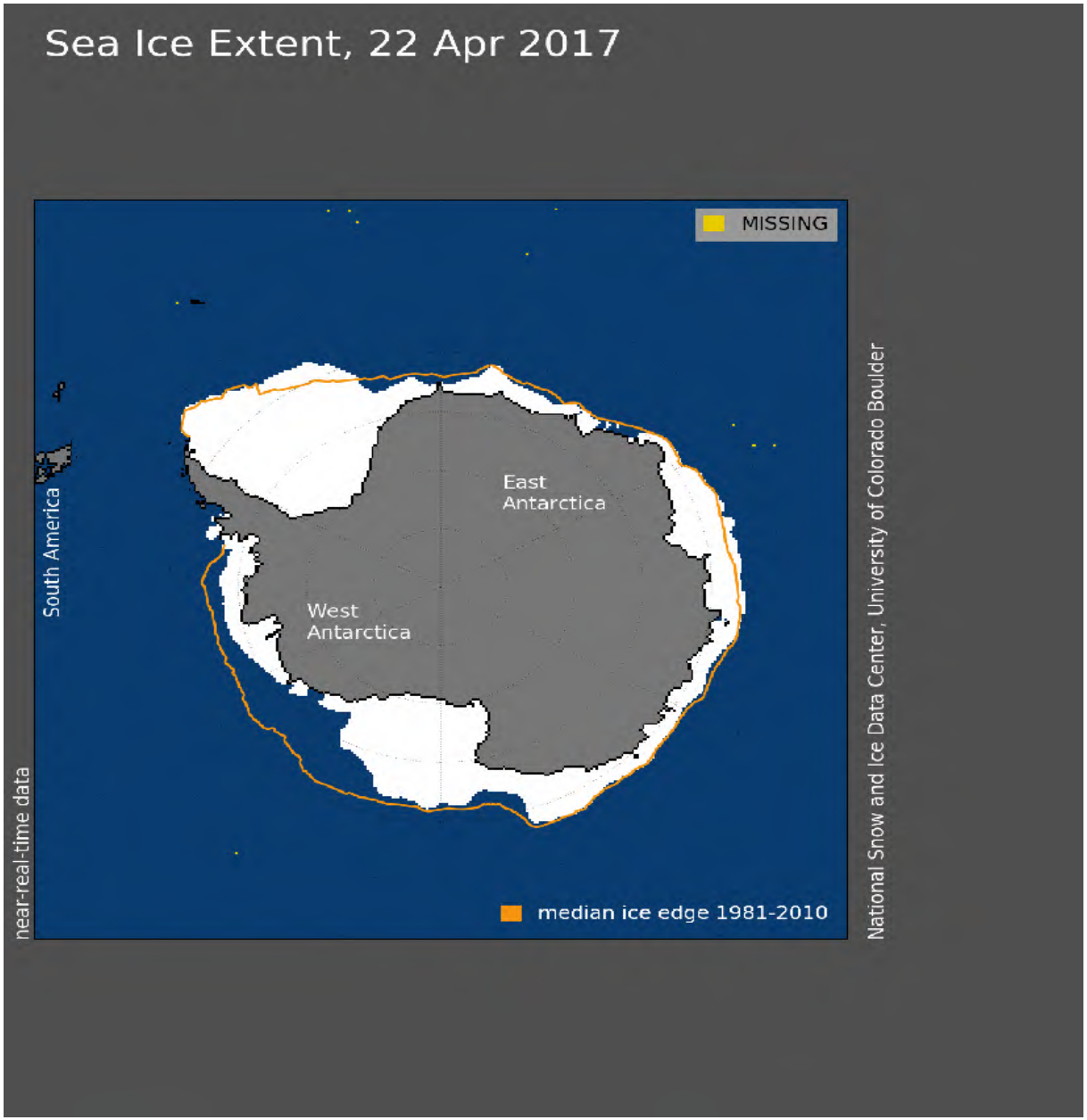
Yellows and reds indicate temperatures higher than the 1981 to 2010 average; blues and purples indicate temperatures lower than the 1981 to 2010 average.

Arctic Air Pressure Difference March 2017



The plot shows Arctic sea level pressure (in hPa) for **March 2017** expressed as departures from average conditions.
The dominant feature is a large area of below average pressure covering most of the Arctic Ocean.

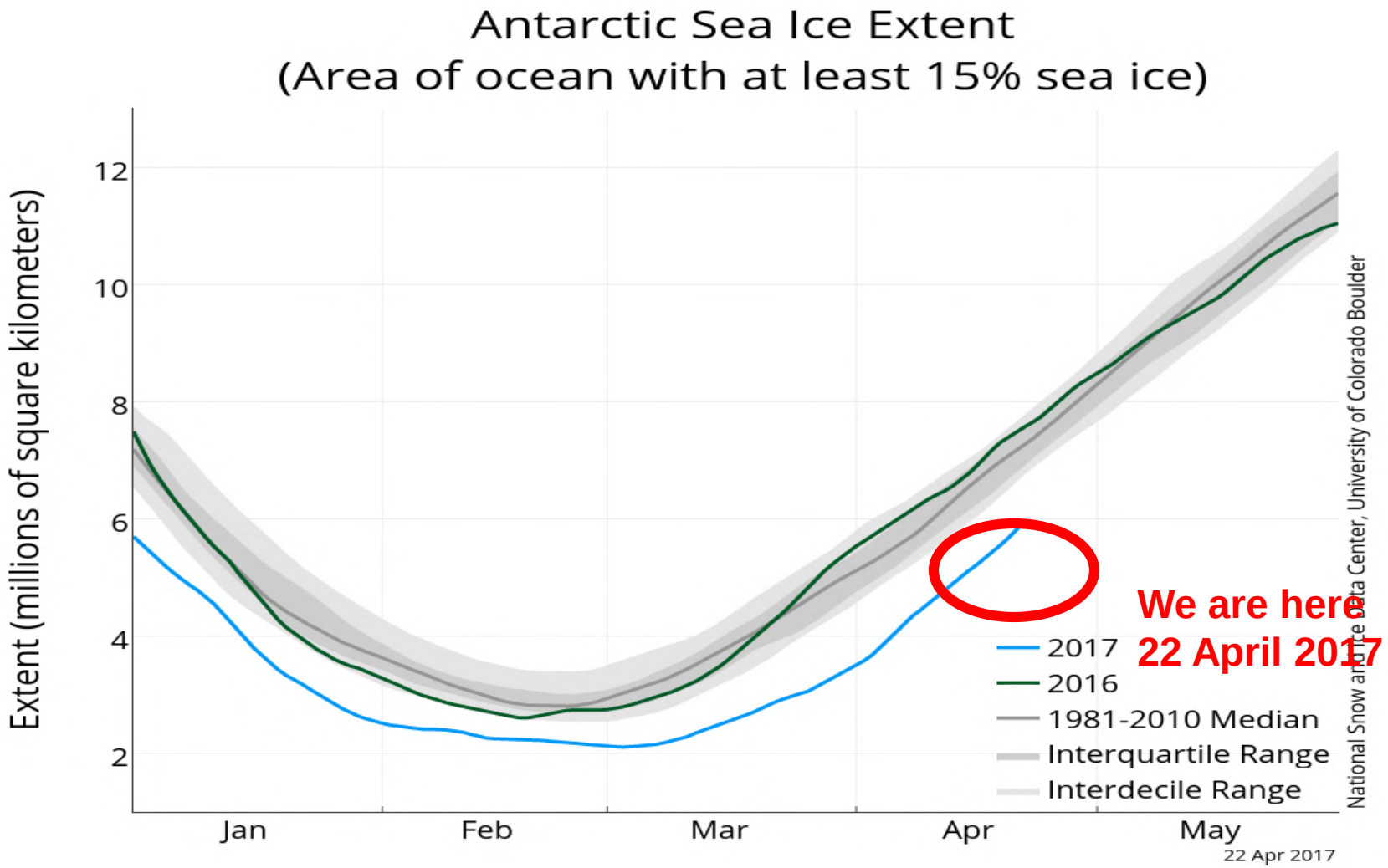
Current Arctic Sea Ice Extent Observations



Arctic sea ice extent for March 2017 was the lowest record month.

The magenta line shows the 1981 to 2010 average extent for that month

Antarctic Sea Ice Extent Observations
Three days ago – 22 April 2017



Arctic Sea Ice Extent Observations
Three days ago – 22 April 2017

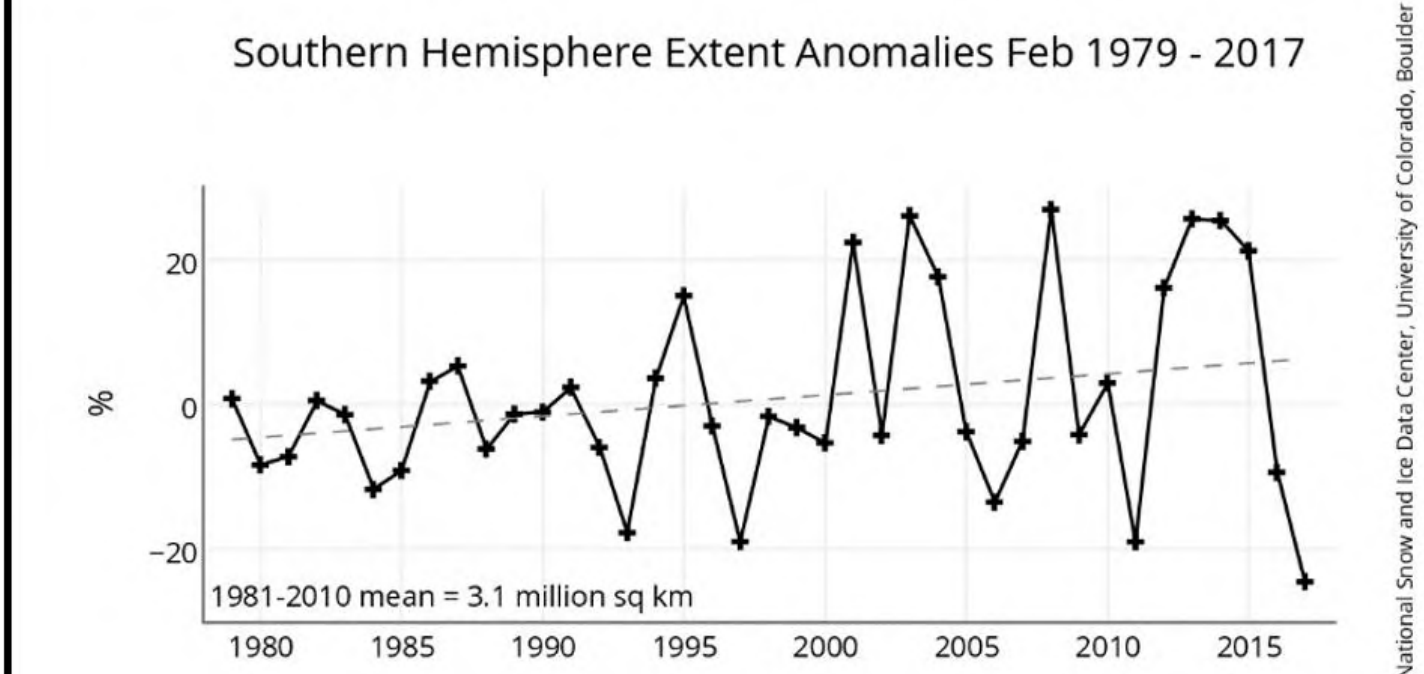
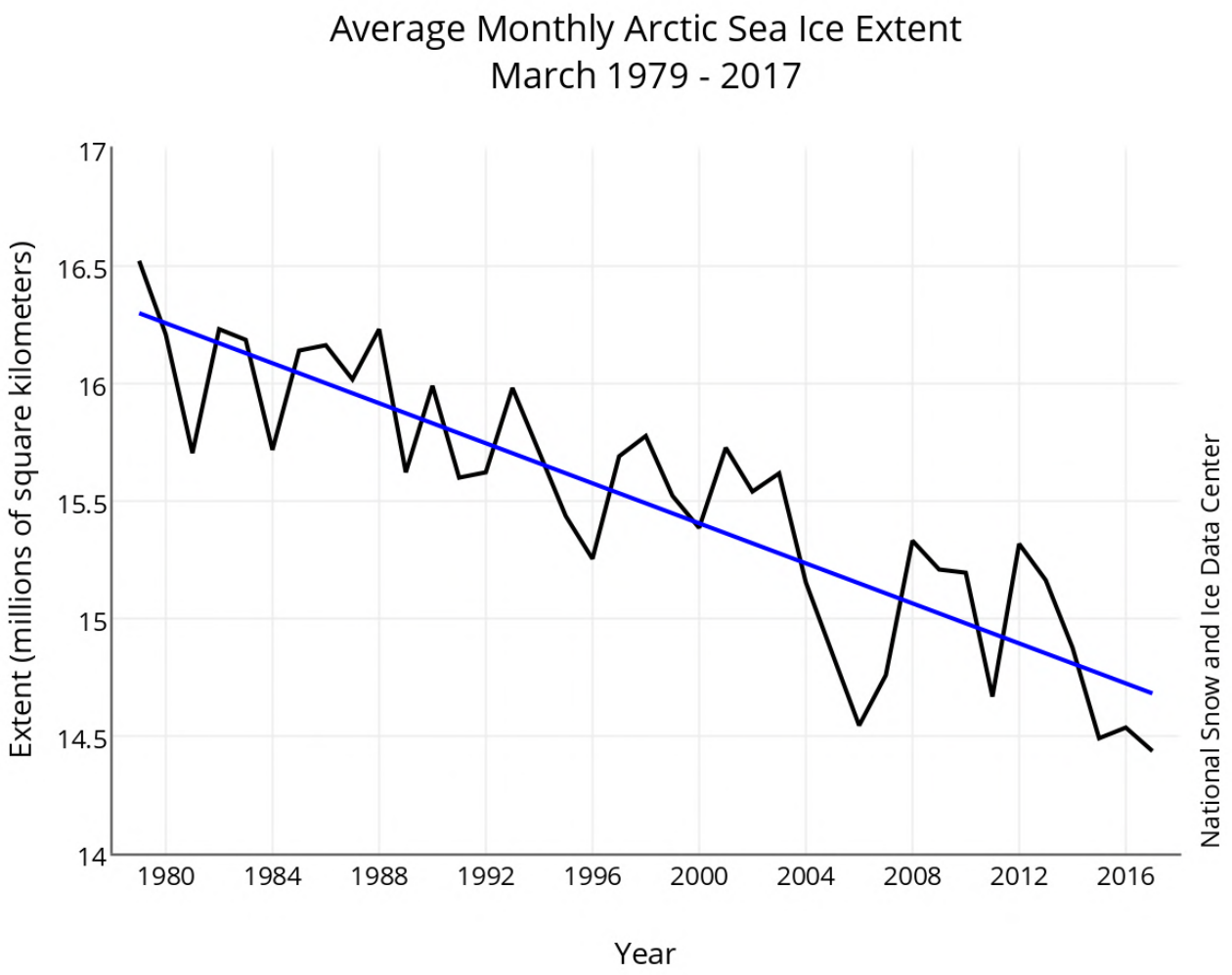


Figure A

Arctic Sea Ice Extent Observations
Three days ago – 22 April 2017



Assessing the Cloud, Radiation and Sea Ice Interaction using Observations

Jui-Lin (Frank) Li, Richard Mark, Wei-Liang Lee,
Jia-Yuh Yu, Yi-Hui Wang, K-M Hsu, E. Fetzer, G. Stephens, Y-H Liu,….

GOAL

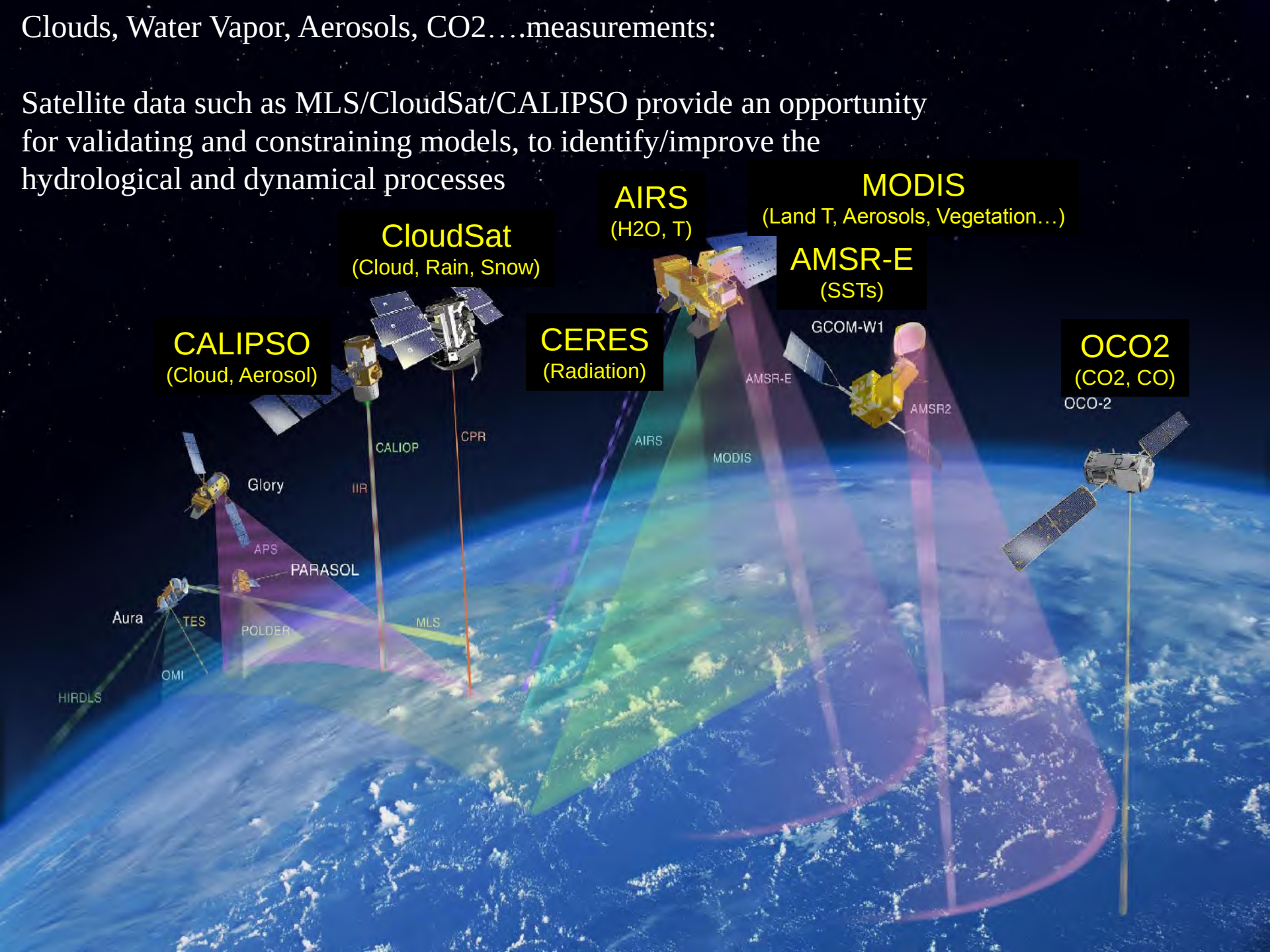
Using Satellites Observation and RA to Reveal the Impacts of Cloud and Radiation on the Radiation Budgets and Polar & Southern Ocean Sea Ice Variation and Seasonal Cycle and Interannual Cycle

NSIDC – Sea Ice
MODIS – Skin T
CloudSat-CALIPSO – Snow & cloud ice Mass & cloud cover & Radiative Flux
MODIS – IWP & LWP
CERES – Radiation
CALIPSO & MISR & MODIS – aerosol →Cloud & radiative impacts
ECMWF-I – Dynamics (u, v and w)

In Preparation

Clouds, Water Vapor, Aerosols, CO2….measurements:

Satellite data such as MLS/CloudSat/CALIPSO provide an opportunity for validating and constraining models, to identify/improve the hydrological and dynamical processes



The sea ice surface temperature (Ts), defined as radiative skin temperature, Ts, can be assumed directly determined by the surface energy budget for the gross, GCM grid-box scale as following:

Ts ~ *direct SW warming at the surface (RSDS)*

– albedo cooling effect (RSUS: over snow, land ice)

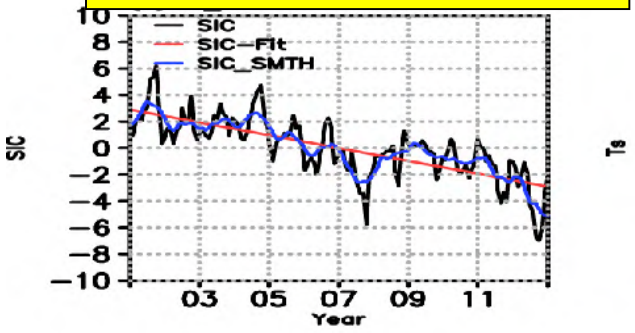
+ cloud longwave greenhouse warming (RLDS)

$\sim (1-\alpha)$*Downward SW* $+ \varepsilon$ *Downward LW*

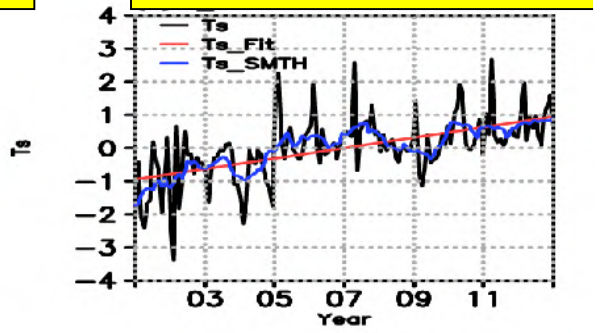
~ *Net surface SW + Downward LW*

Observed Sea Ice-Radiation-Skin T Trend over North Pole

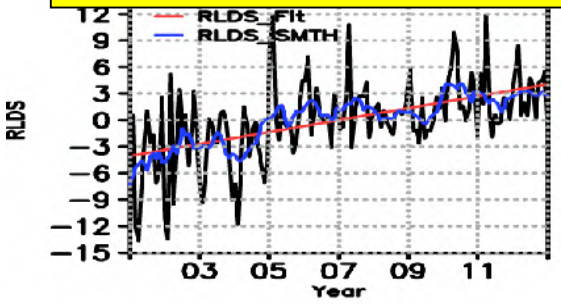
NSDIC Sea Ice Concentration (SIC)



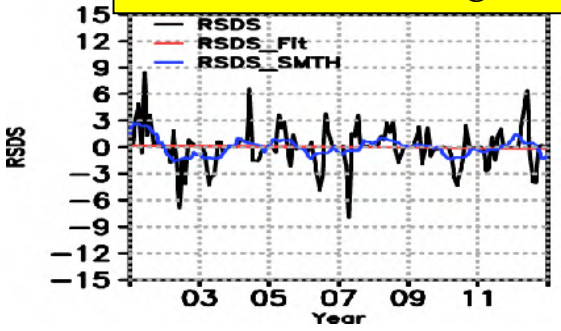
MODIS Skin Temperature (Ts)



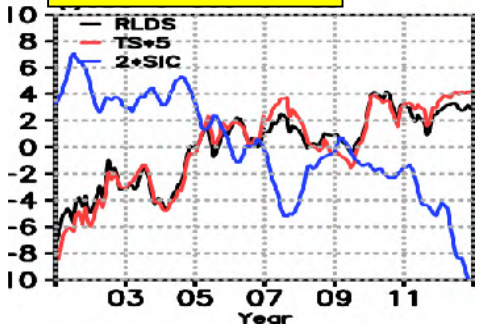
CERES Downward LW @ Surface (RLDS)



CERES Downward SW @ Surface (RSDS)

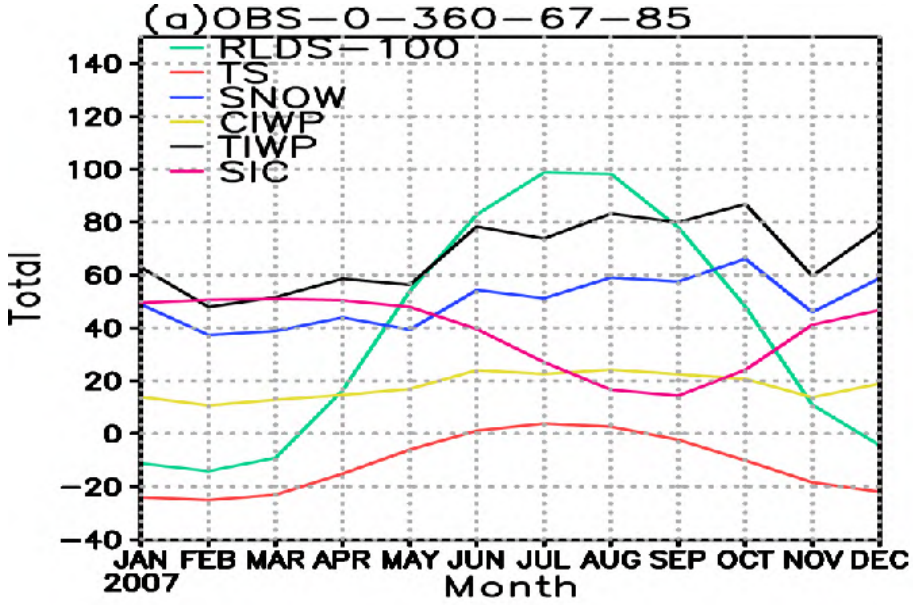


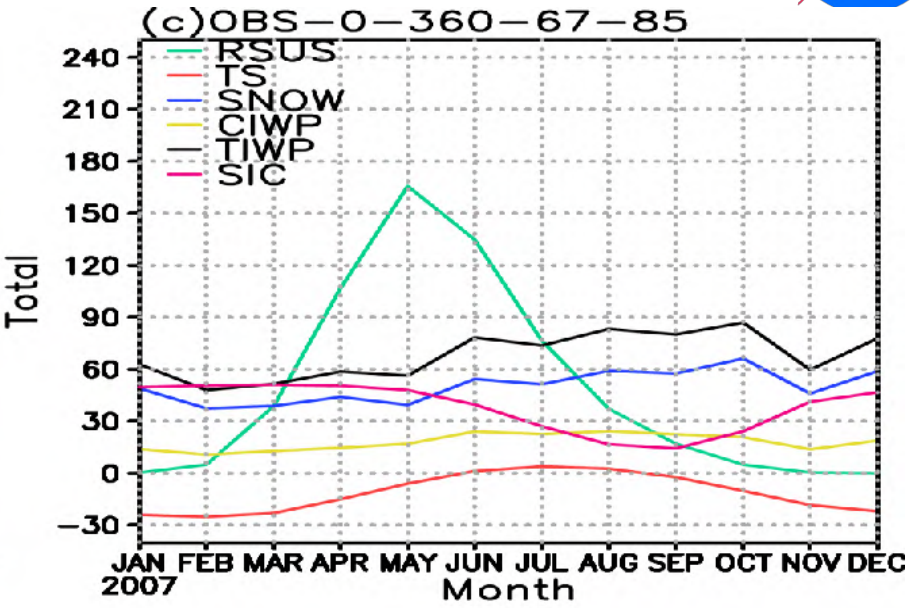
RLDS & Ts & SIC

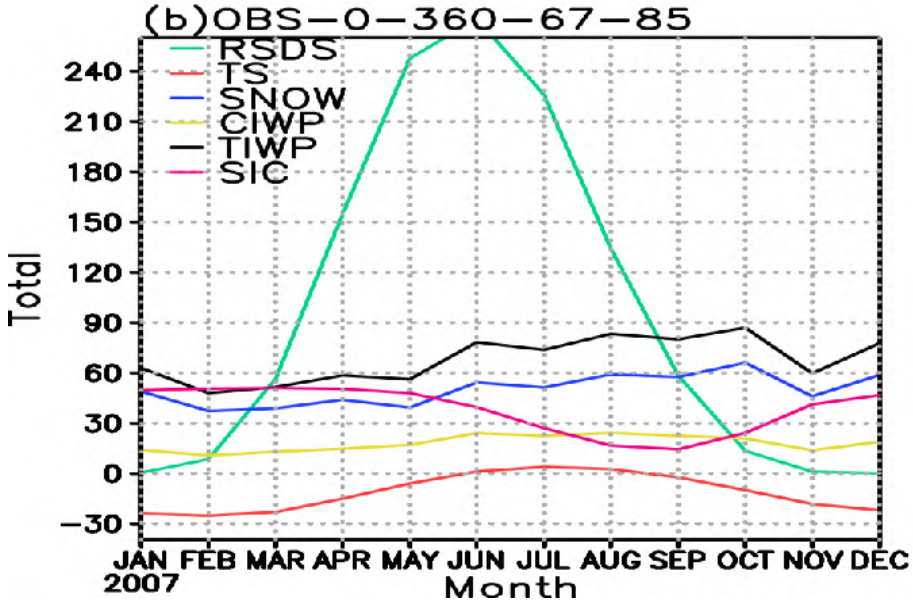


(Li, Richard, Lee, Wang and Stephens, in preparation)

Sea Ice-Radiation-Skin T over North Pole
2007-2010 Seasonal Cycle

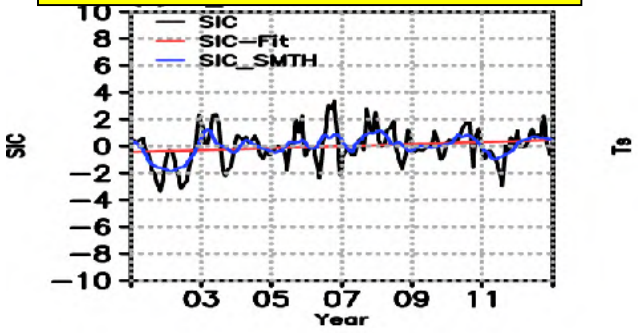




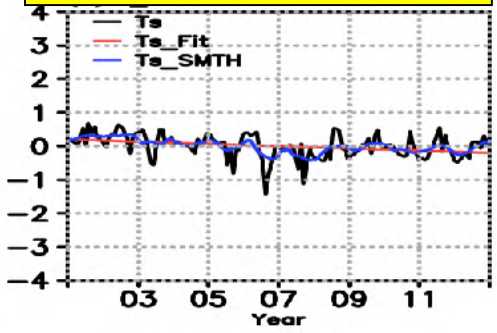


Observed Sea Ice-Radiation-Skin T Trend over Southern Oceans

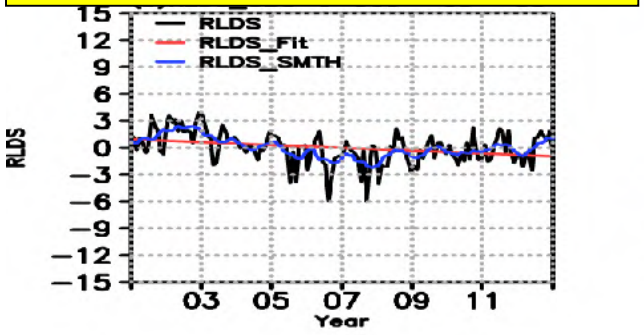
NSDIC Sea Ice Concentration (SIC)



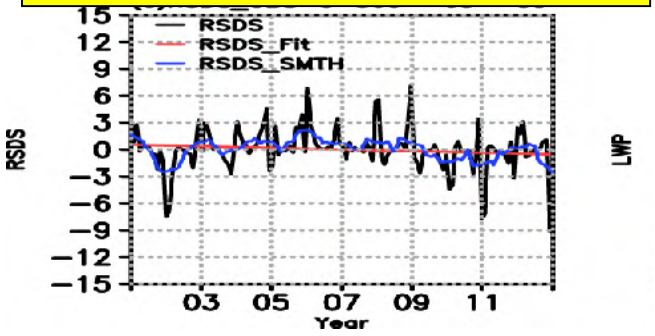
MODIS Skin Temperature (Ts)



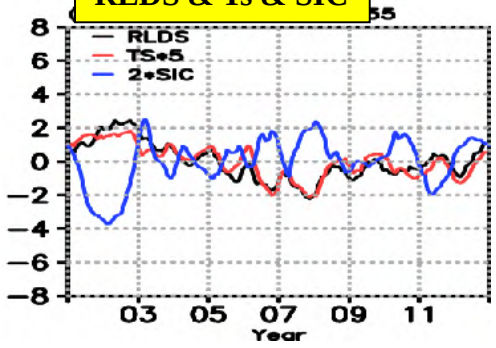
CERES Downward LW @ Surface (RLDS)



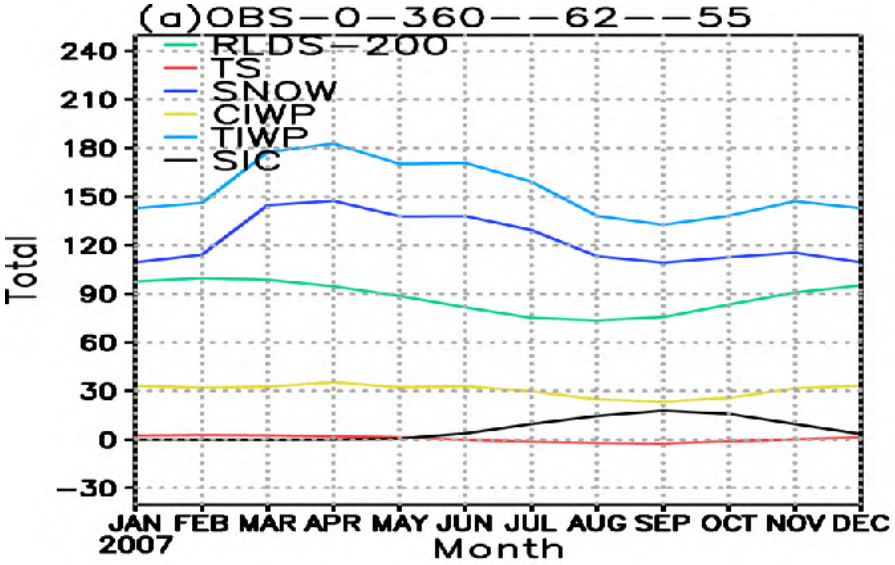
CERES Downward SW @ Surface (RSDS)

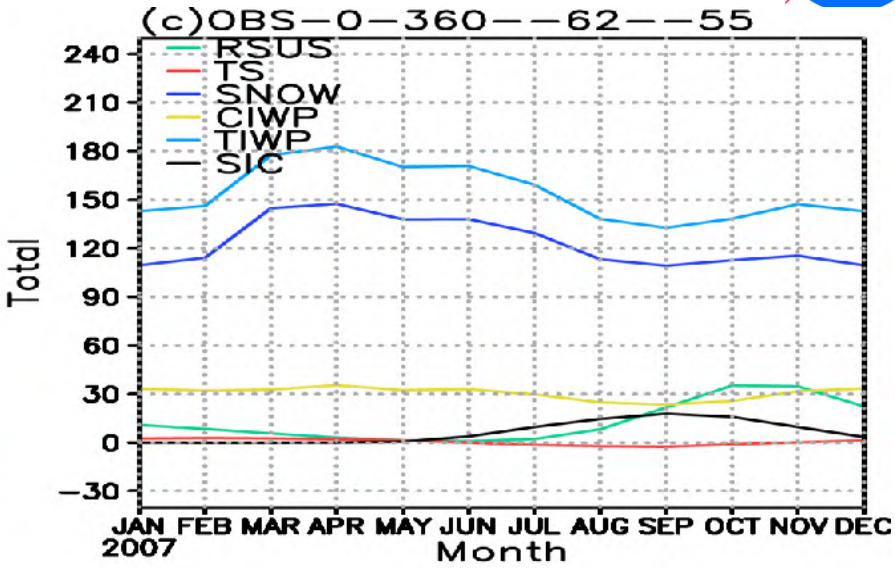


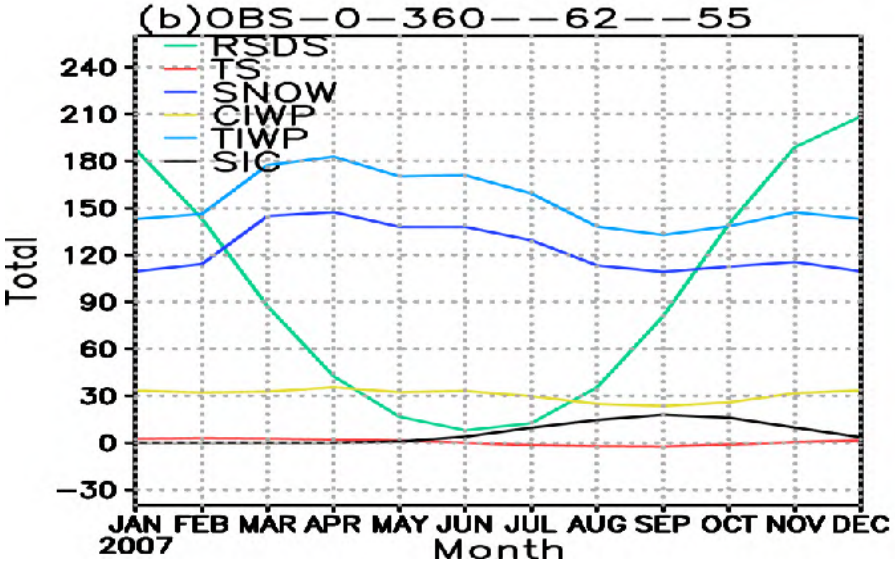
RLDS & Ts & SIC



Sea Ice-Radiation-Skin T over Southern Oceans
2007-2010 Seasonal Cycle







Arctic Sea Ice Extent Observations
Three days ago – 22 April 2017

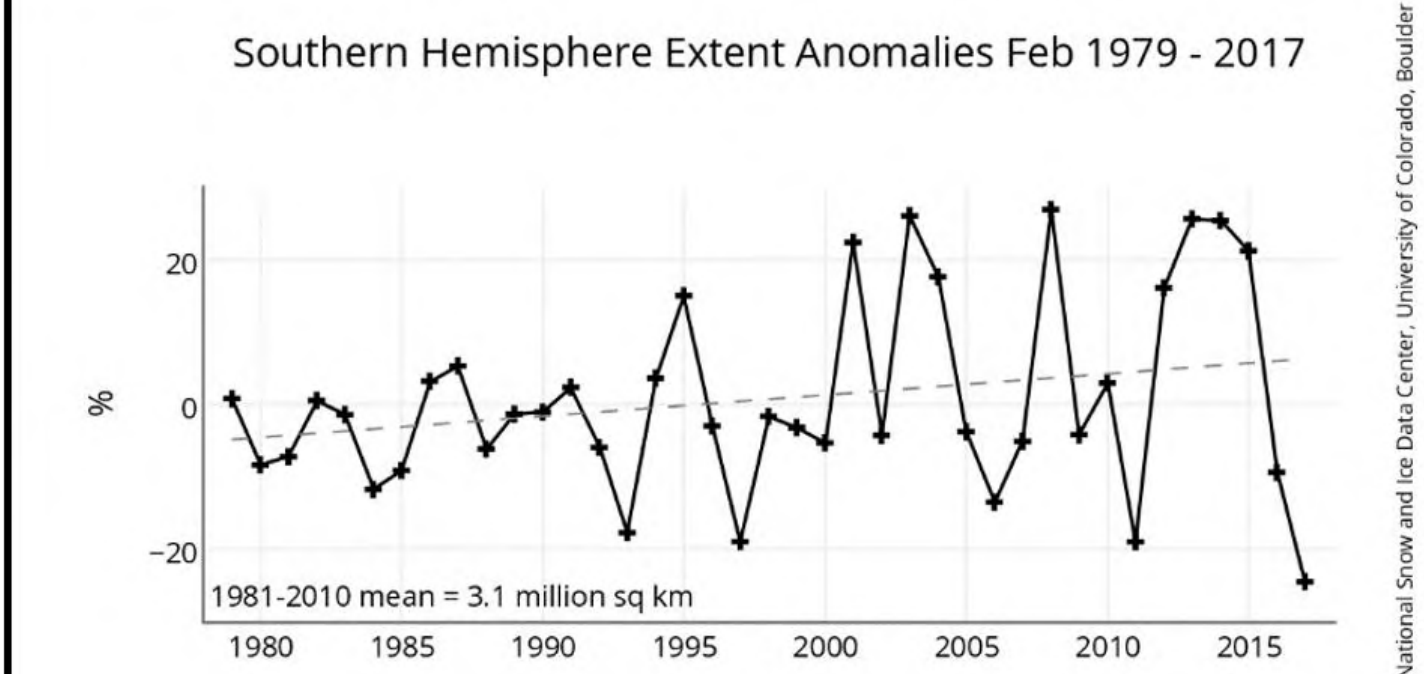
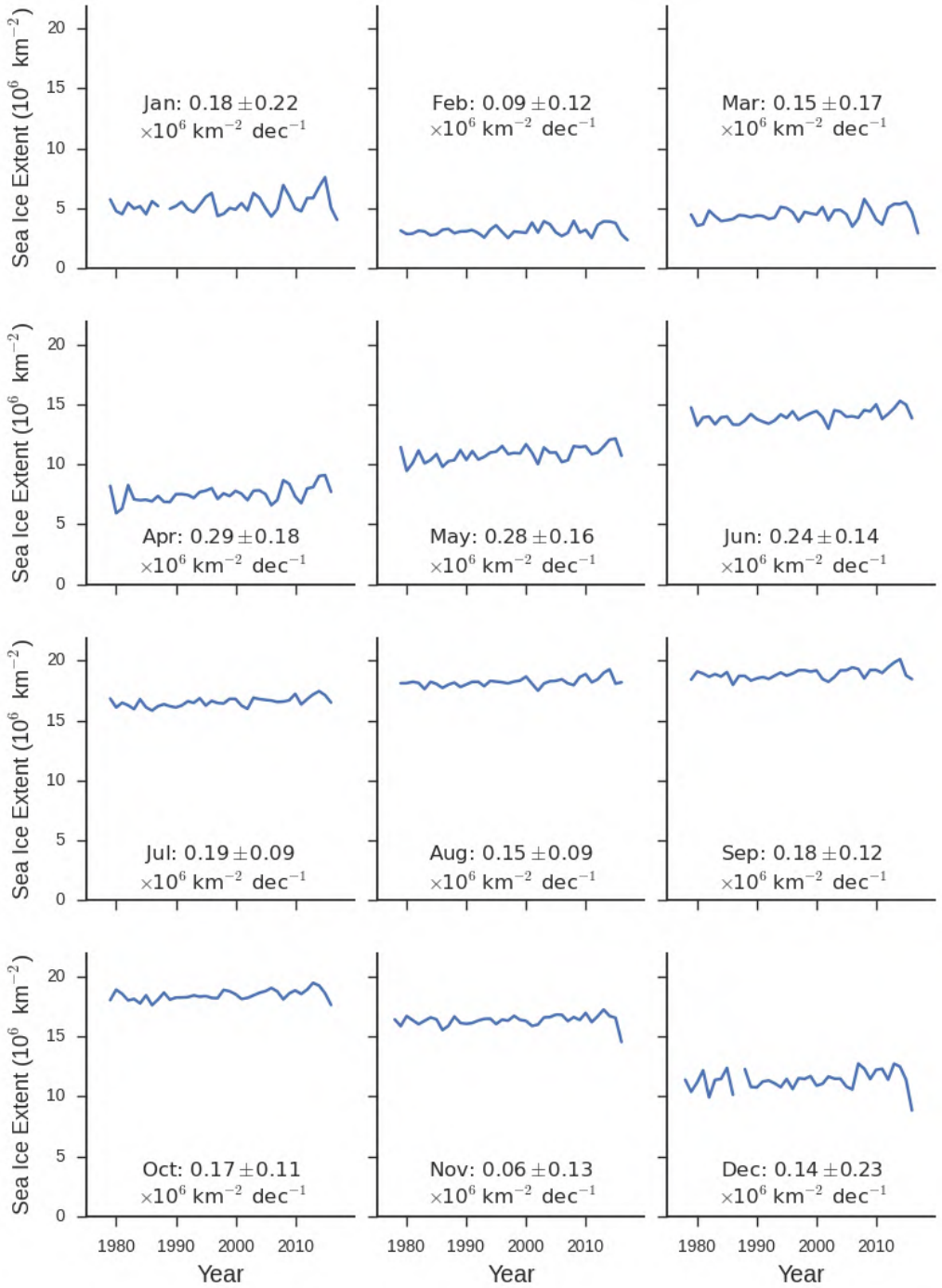
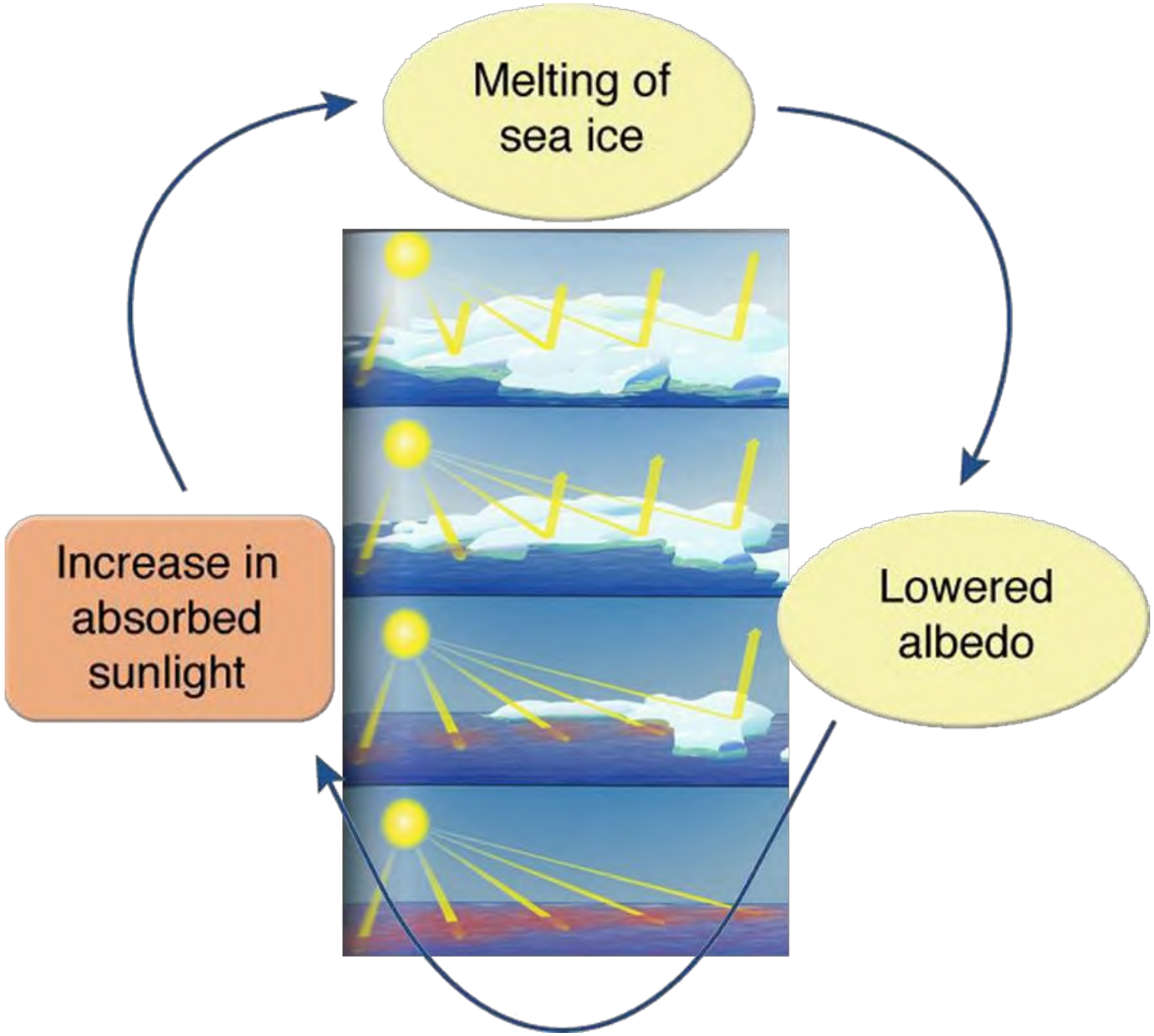
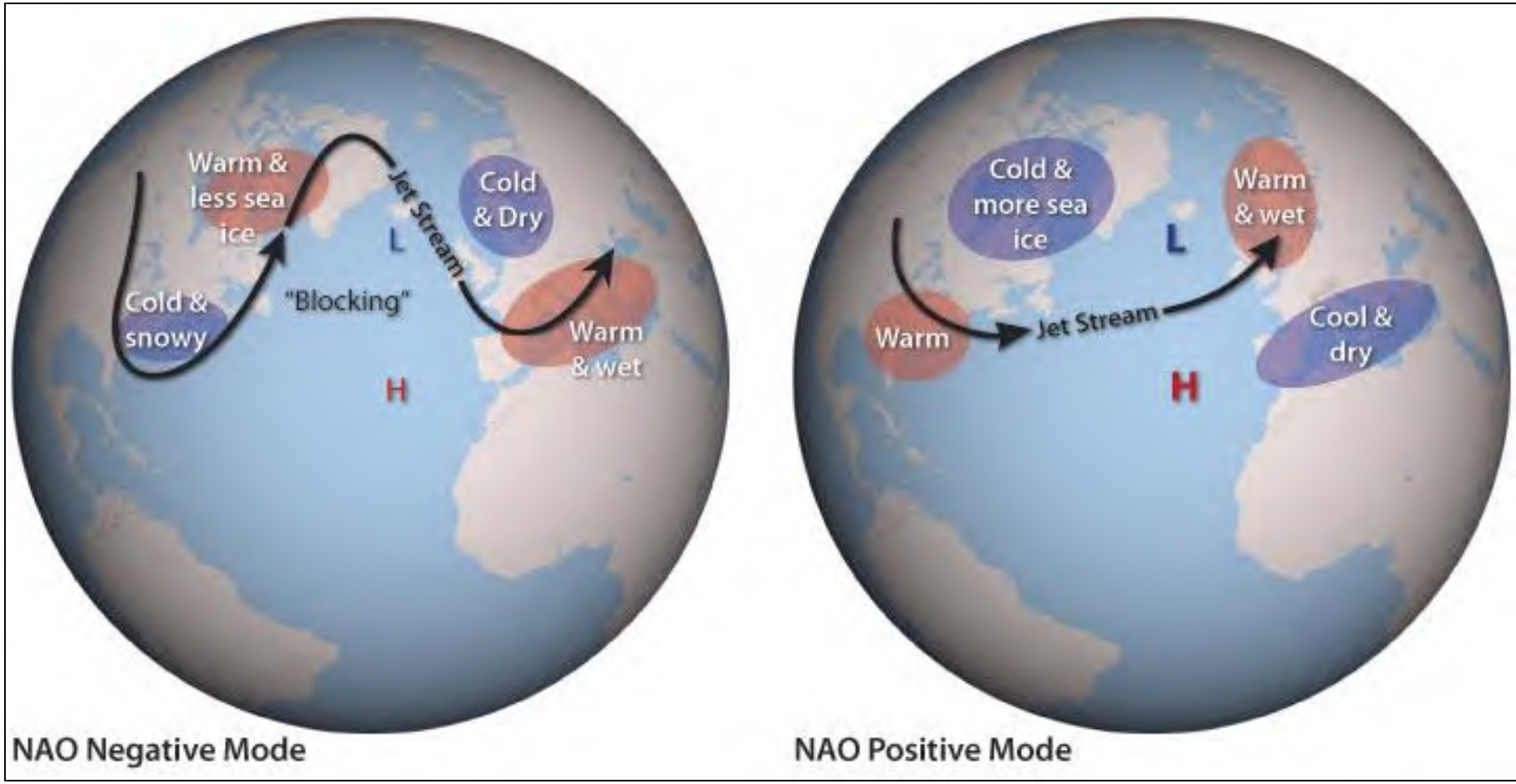


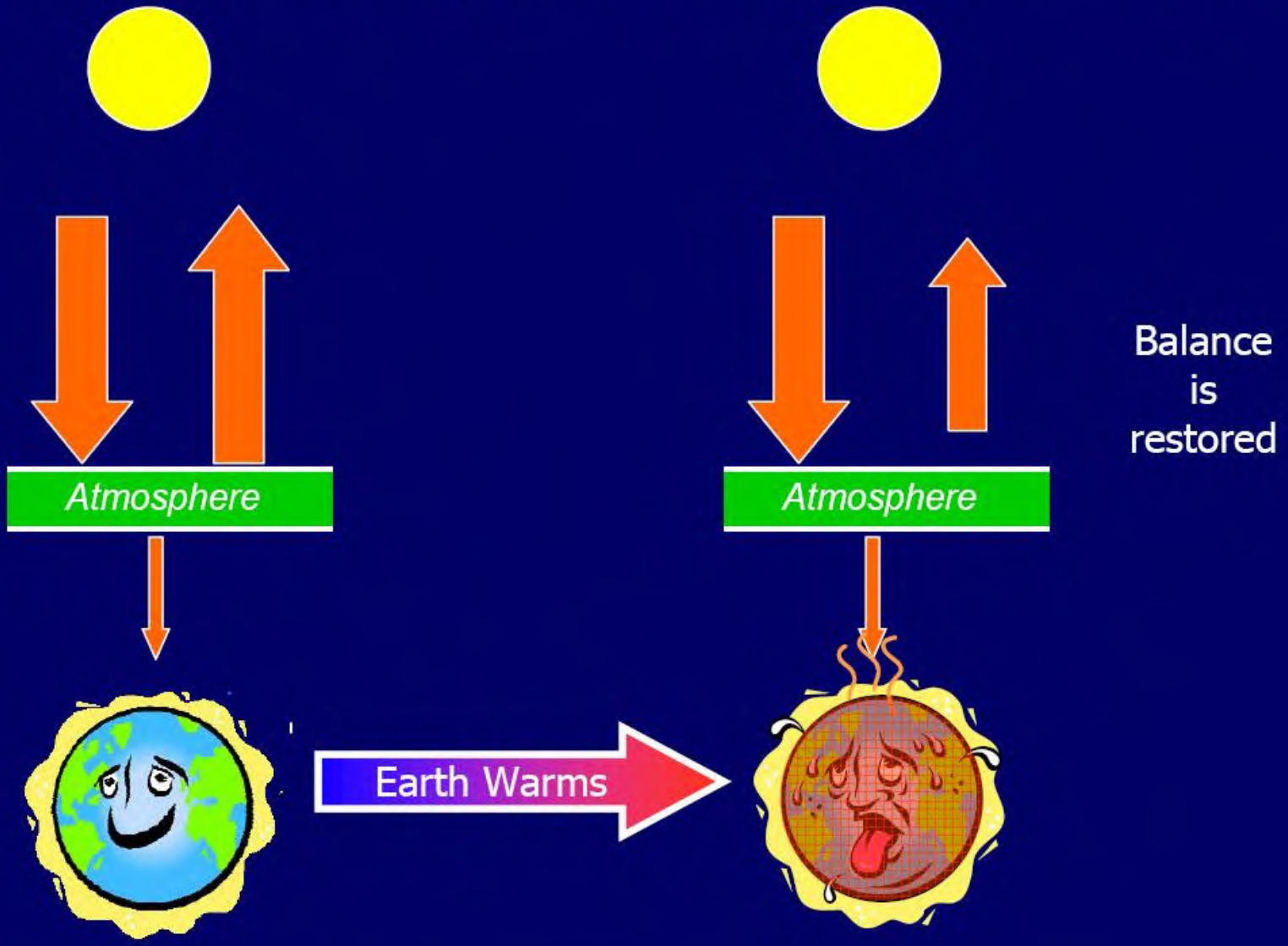
Figure A


Sea Ice Extent (10^6 km^{-2})
Jan: 0.18 ±0.22
×10^6 km^{-2} dec^{-1}
Feb: 0.09 ±0.12
×10^6 km^{-2} dec^{-1}
Mar: 0.15 ±0.17
×10^6 km^{-2} dec^{-1}
Apr: 0.29 ±0.18
×10^6 km^{-2} dec^{-1}
May: 0.28 ±0.16
×10^6 km^{-2} dec^{-1}
Jun: 0.24 ±0.14
×10^6 km^{-2} dec^{-1}
Jul: 0.19 ±0.09
×10^6 km^{-2} dec^{-1}
Aug: 0.15 ±0.09
×10^6 km^{-2} dec^{-1}
Sep: 0.18 ±0.12
×10^6 km^{-2} dec^{-1}
Oct: 0.17 ±0.11
×10^6 km^{-2} dec^{-1}
Nov: 0.06 ±0.13
×10^6 km^{-2} dec^{-1}
Dec: 0.14 ±0.23
×10^6 km^{-2} dec^{-1}
0
5
10
15
20
1980
1990
2000
2010
Year


Melting of sea ice
Lowered albedo
Increase in absorbed sunlight


Warm & less sea ice
Jet Stream
Cold & Dry
L
Cold & snowy
"Blocking"
Warm & wet
H
NAO Negative Mode
Cold & more sea ice
L
Warm & wet
Warm
Jet Stream
Cool & dry
H
NAO Positive Mode

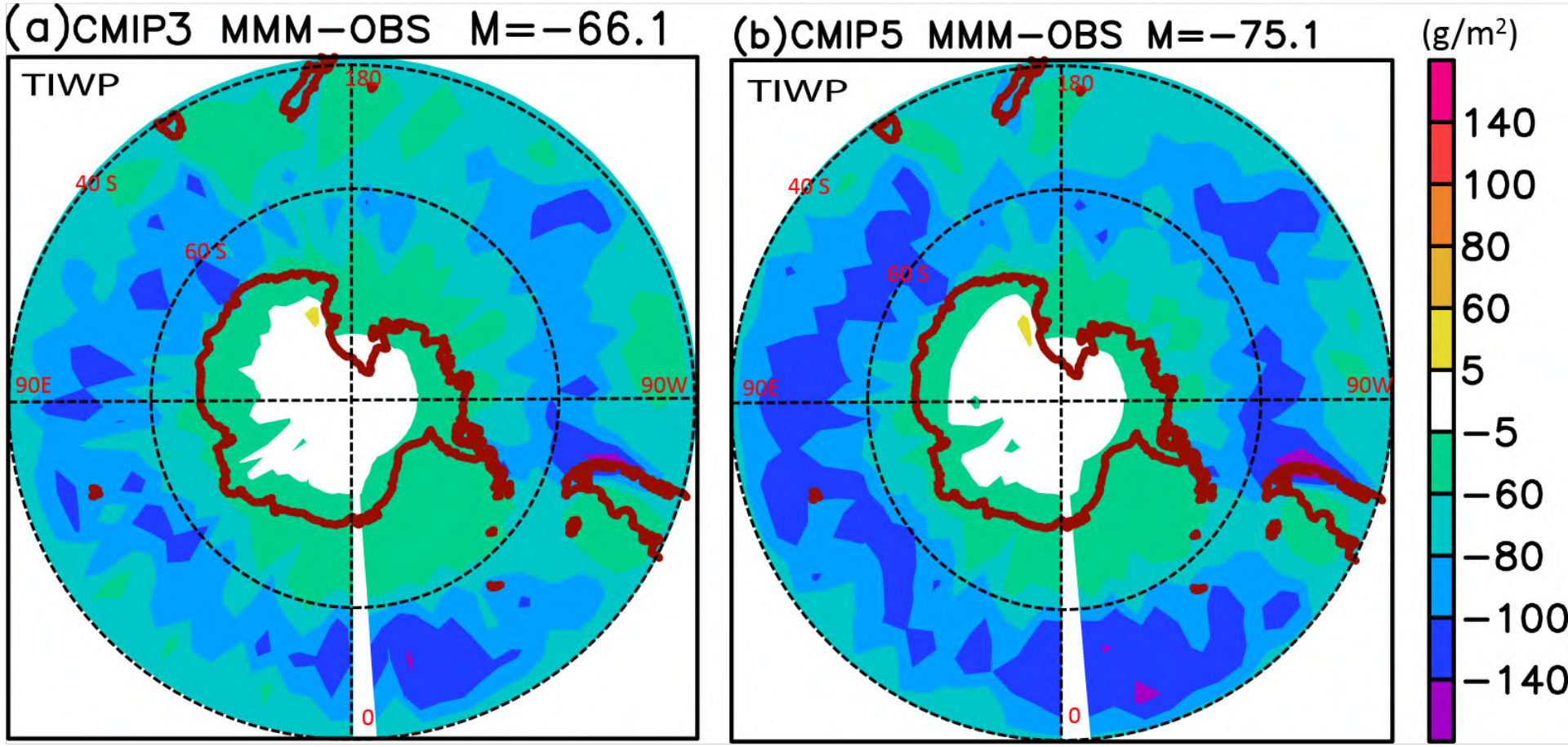
Thermal Inertia: Energy Balance

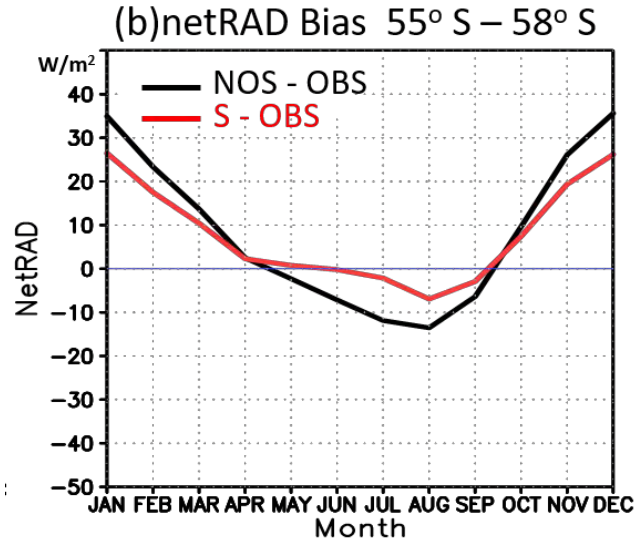


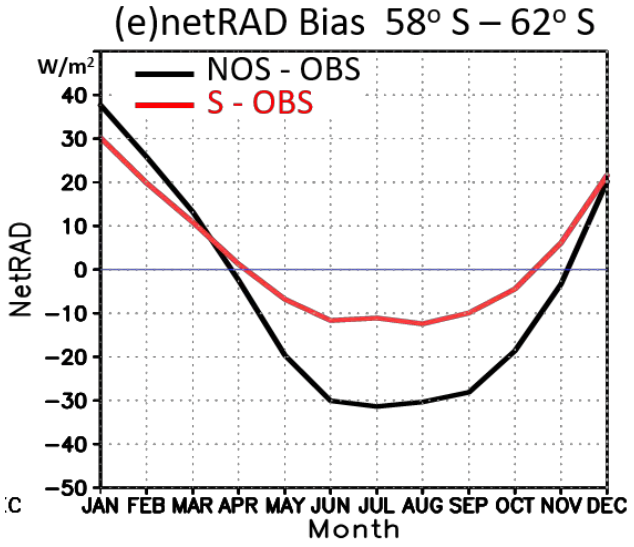
Improved simulation of Antarctic sea ice due to the radiative effects of falling snow

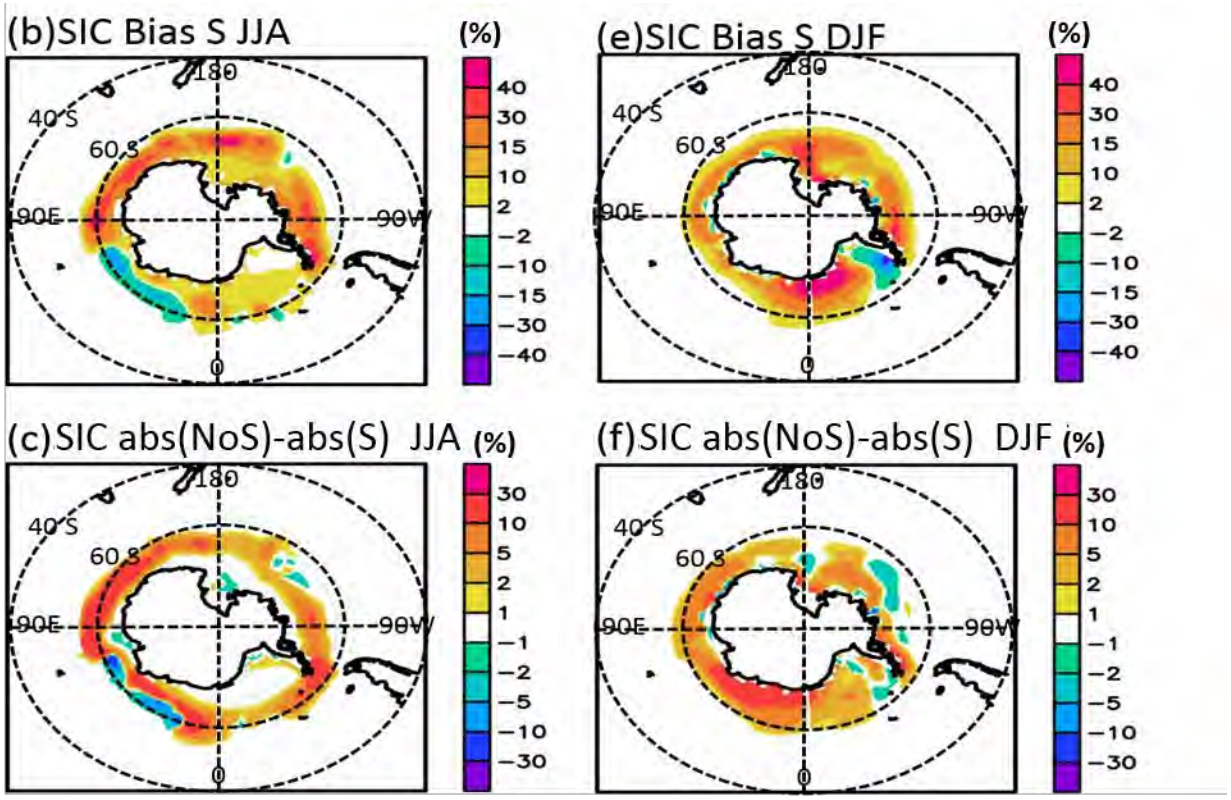
Li, J.-L. F., Mark Richardson[1], Yulan Hong[4], Wei-Liang Lee[2], Yi-Hui Wang[1], Jia-Yuh Yu[3], Eric Fetzer[1], Graeme Stephens[1], Yinghui Liu

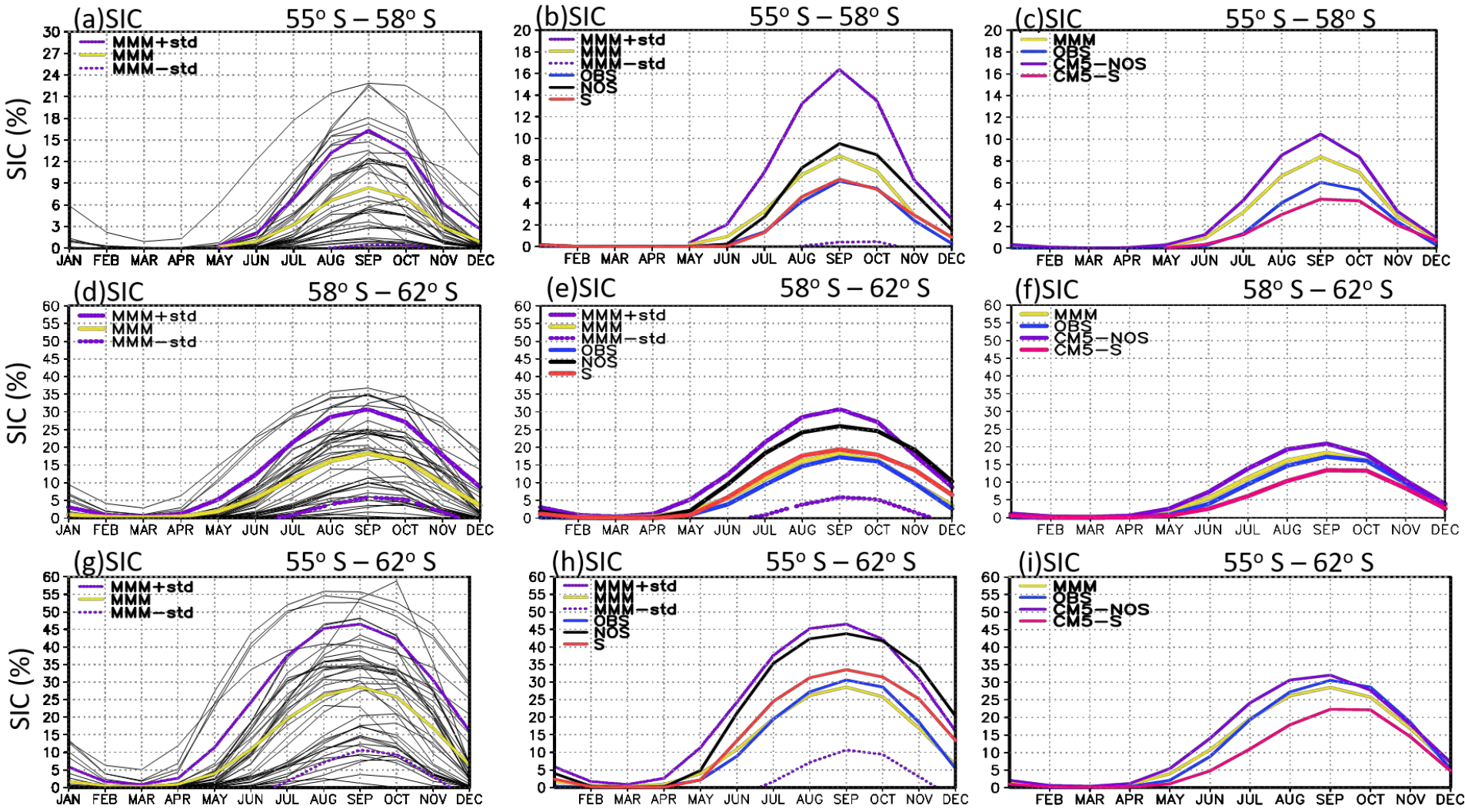
Submitted to ERL, under revision

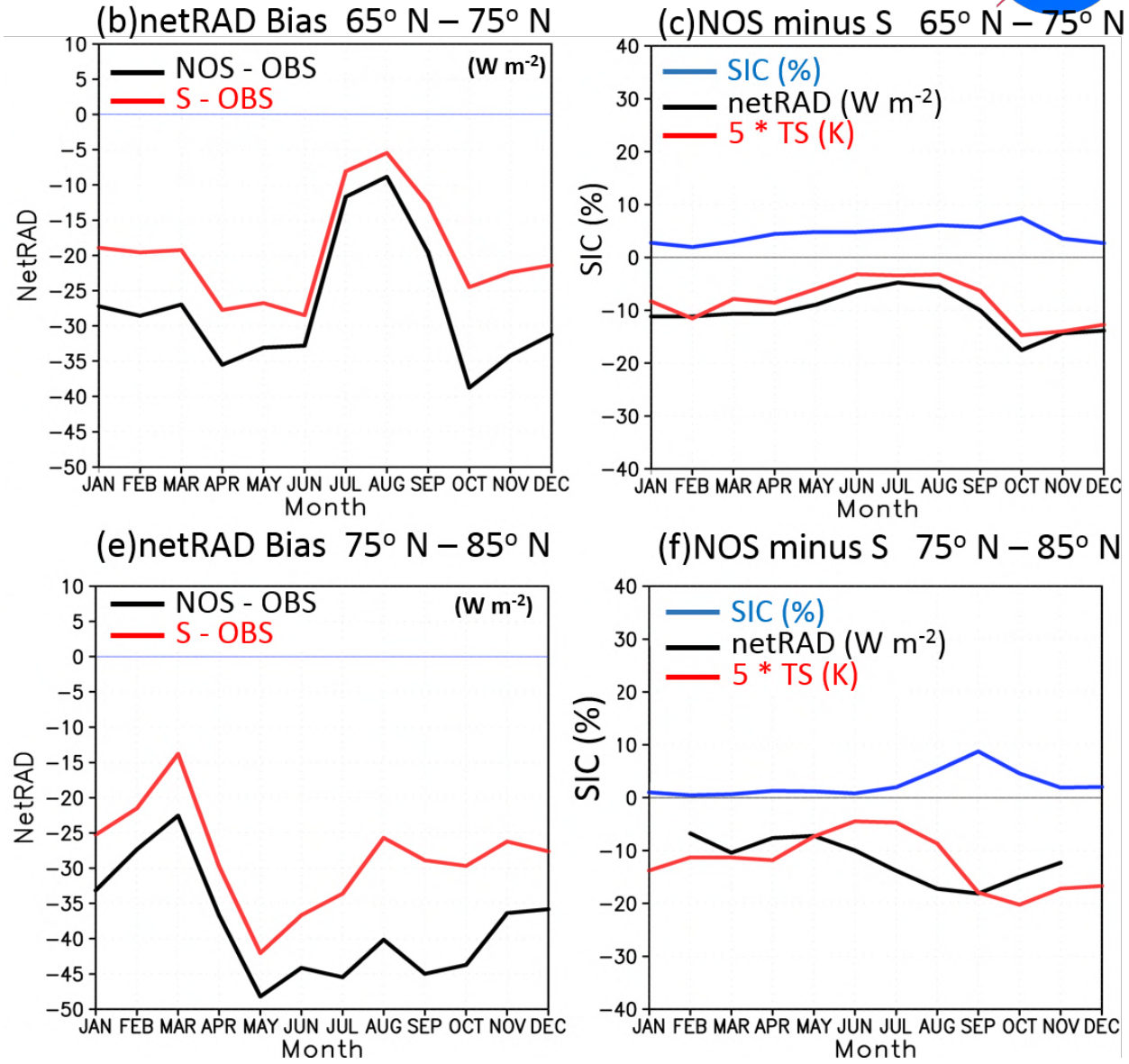

(a)CMIP3 MMM−OBS M=−66.1
TIWP
180
40 S
60 S
90E
90W
0
(b)CMIP5 MMM−OBS M=−75.1
TIWP
180
40 S
60 S
90E
90W
0
(g/m²)
140
100
80
60
5
−5
−60
−80
−100
−140


(b)netRAD Bias 55° S – 58° S
W/m²
NOS - OBS
S - OBS
NetRAD
40
30
20
10
0
−10
−20
−30
−40
−50
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
Month

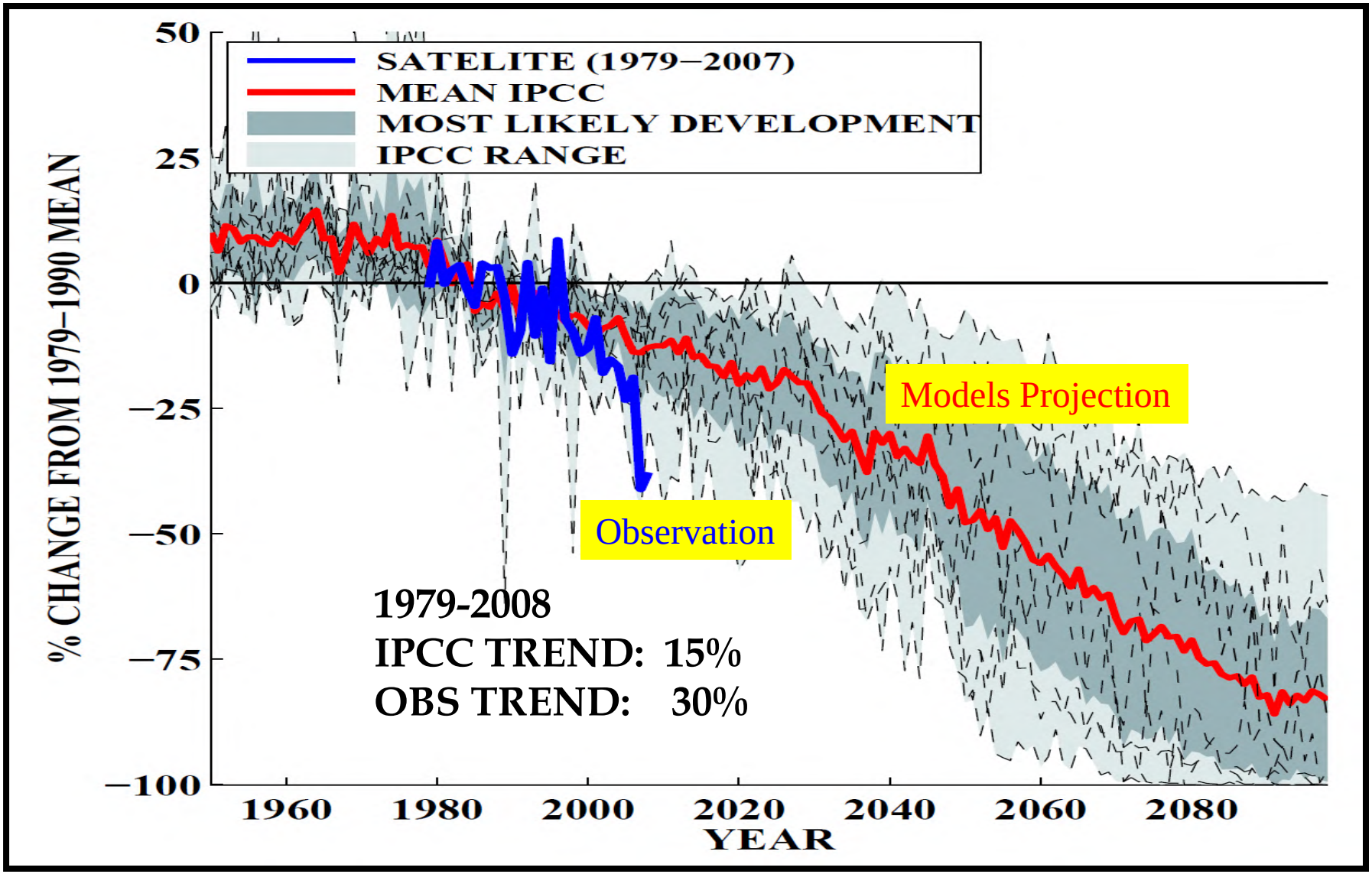

(e)netRAD Bias 58° S – 62° S
W/m²
NOS - OBS
S - OBS
NetRAD
40
30
20
10
0
−10
−20
−30
−40
−50
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
Month


(b)SIC Bias S JJA
(%)
40
30
15
10
2
−2
−10
−15
−30
−40
180
40 S
60 S
90E
90W
0
(e)SIC Bias S DJF
(%)
40
30
15
10
2
−2
−10
−15
−30
−40
180
40 S
60 S
90E
90W
0
(c)SIC abs(NoS)-abs(S) JJA (%)
30
10
5
2
1
−1
−2
−5
−10
−30
180
40 S
60 S
90E
90W
0
(f)SIC abs(NoS)-abs(S) DJF (%)
30
10
5
2
1
−1
−2
−5
−10
−30
180
40 S
60 S
90E
90W
0


(a)SIC
55° S – 58° S
(b)SIC
55° S – 58° S
(c)SIC
55° S – 58° S
(d)SIC
58° S – 62° S
(e)SIC
58° S – 62° S
(f)SIC
58° S – 62° S
(g)SIC
55° S – 62° S
(h)SIC
55° S – 62° S
(i)SIC
55° S – 62° S
SIC (%)
MMM+std
MMM
MMM−std
OBS
NOS
S
CM5−NOS
CM5−S
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC

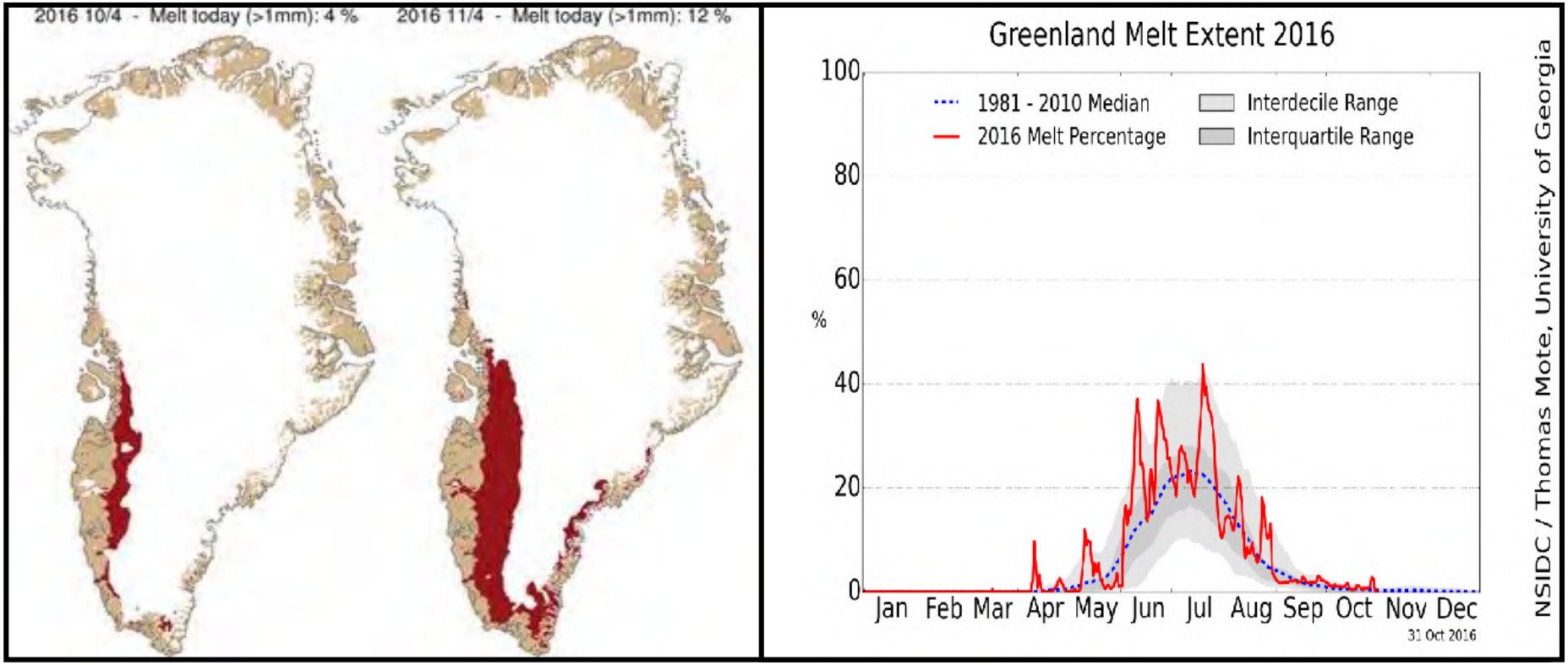

(b)netRAD Bias 65° N – 75° N
NOS - OBS
S - OBS
(W m-2)
NetRAD
Month
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
(c)NOS minus S 65° N – 75° N
SIC (%)
netRAD (W m-2)
5 * TS (K)
SIC (%)
(e)netRAD Bias 75° N – 85° N
(f)NOS minus S 75° N – 85° N

SEA ICE EXTENT
Present Days and Projection by Global Climate Models



Greenland's usual melt season runs from early June to September. "Too much, too early," tweeted the World Meteorological Organization!!!

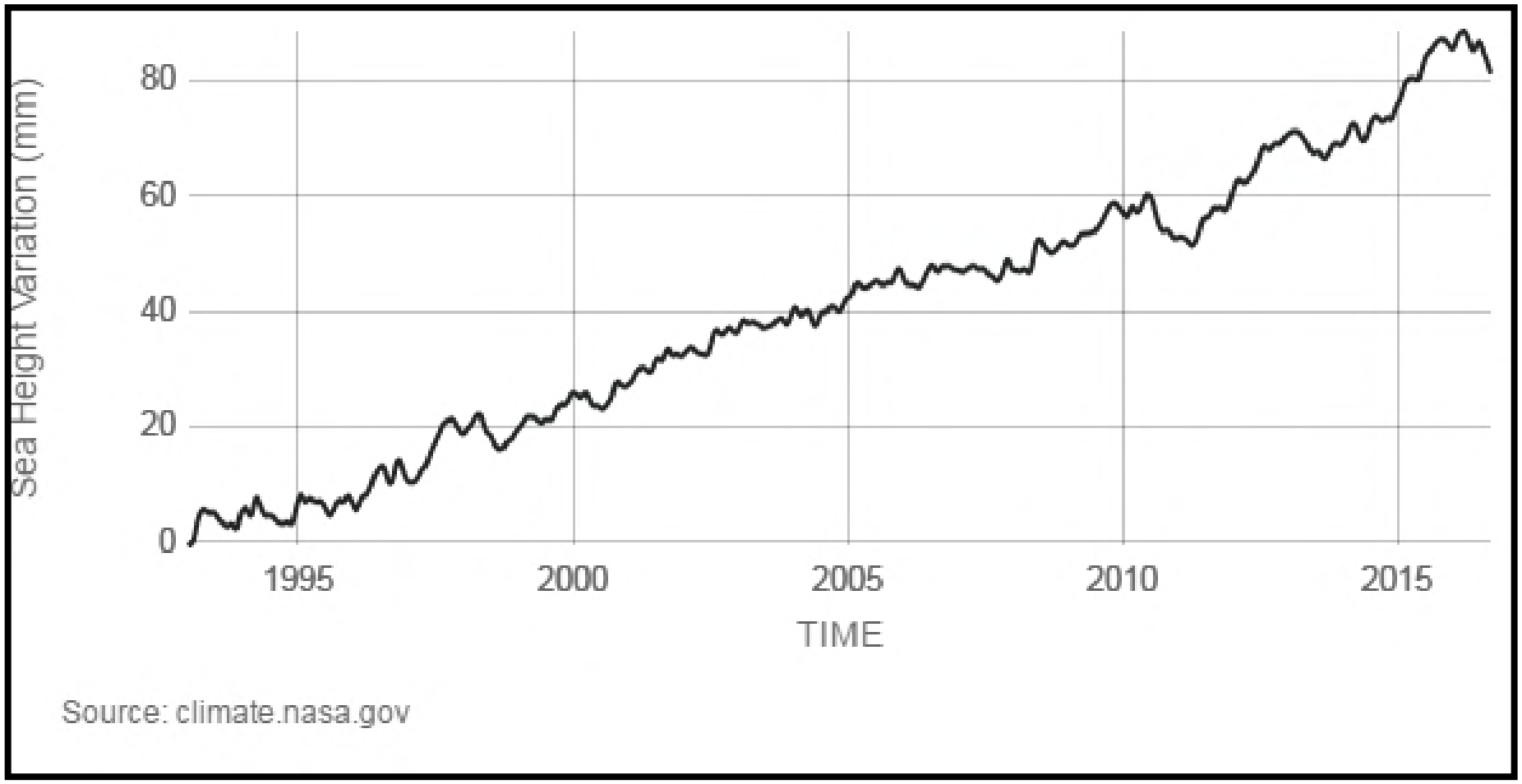
- Temperature readings exceeding 10 degree C in some places.
- Peak melt extent occurred on July 19, melting on 43 percent of the ice sheet.



Left: Maps showing areas where melting has taken place within the last two days. Right: The percentage of the total area of the ice where the melting occurred from 1 January until 11 May (in blue). The dark grey curve represents the 1990-2013 average.
(Source: Polar Portal/Danish Meteorological Institute)

Satellite sea level observations
Historical Sea Level Rise

SATELLITE DATA: 1993-PRESENT



Credit: NASA Goddard Space Flight Center

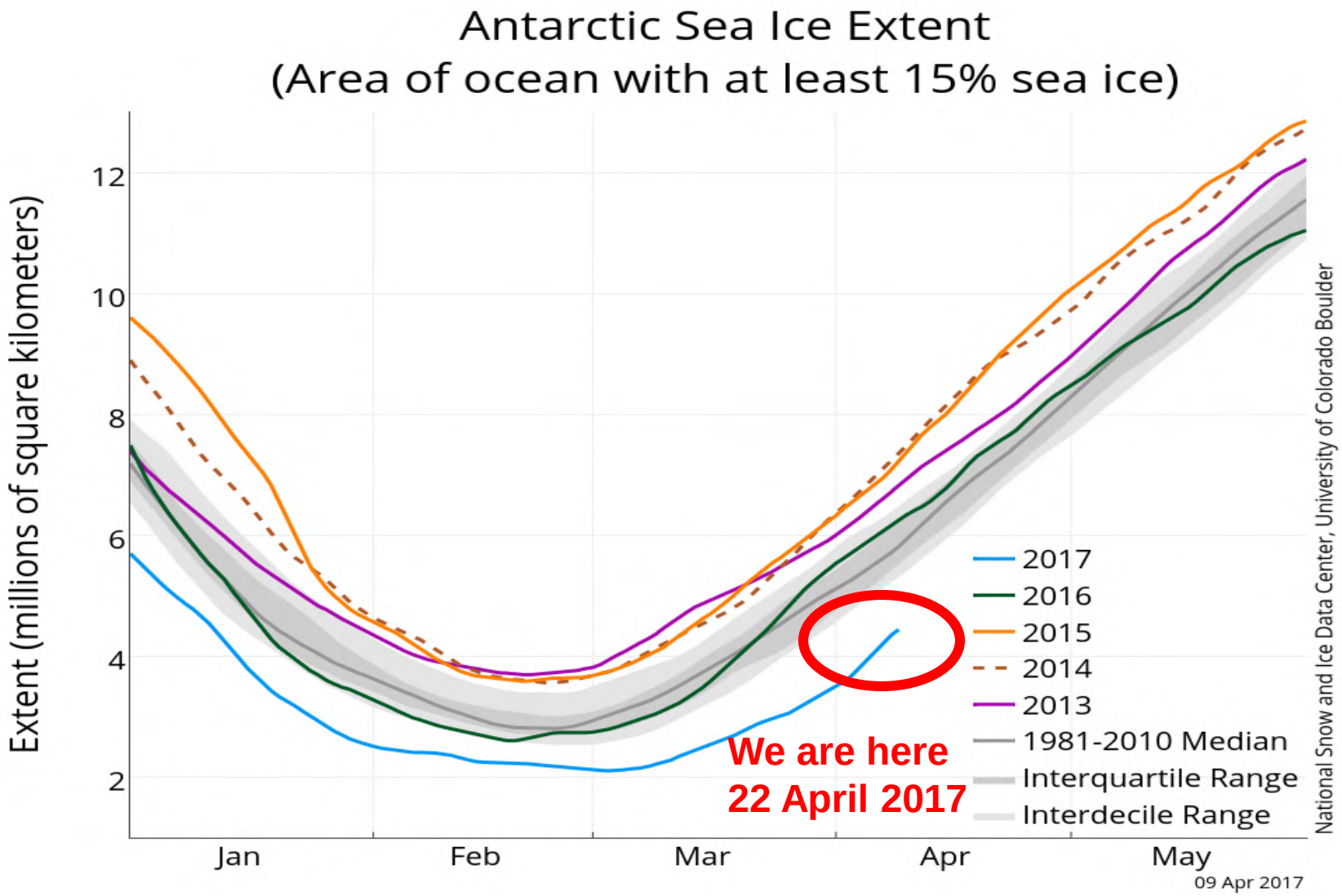
San Diego, 5-feet-under sea level rise

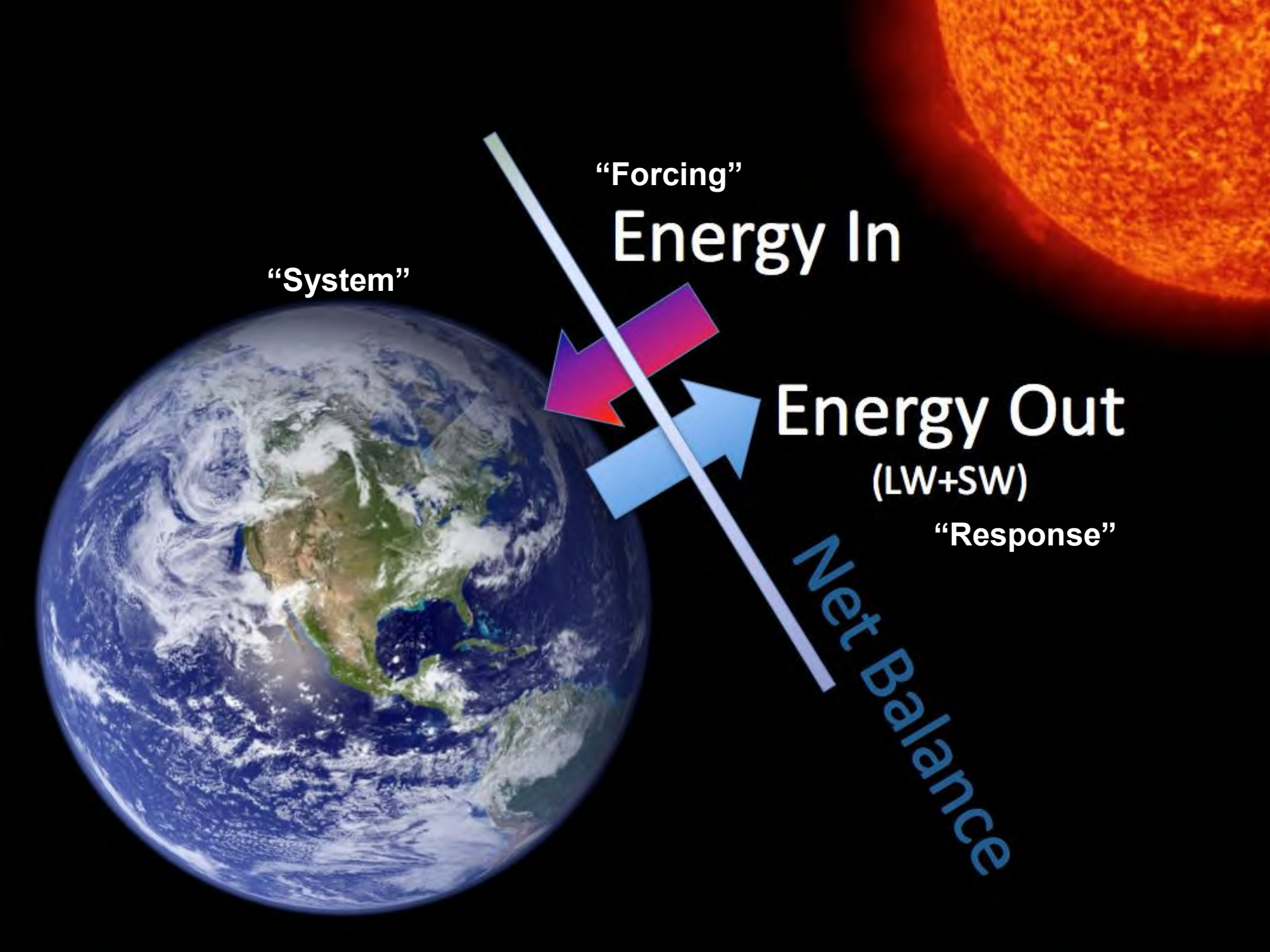
San Diego, 25-feet-under: Nickolay Lamm used sea level rise maps from Climate Central to create a formula to calculate how much water there would be on the ground in a specific location


NiNi:
Should We Buy a Boat!!
Thanks for Listening!!!

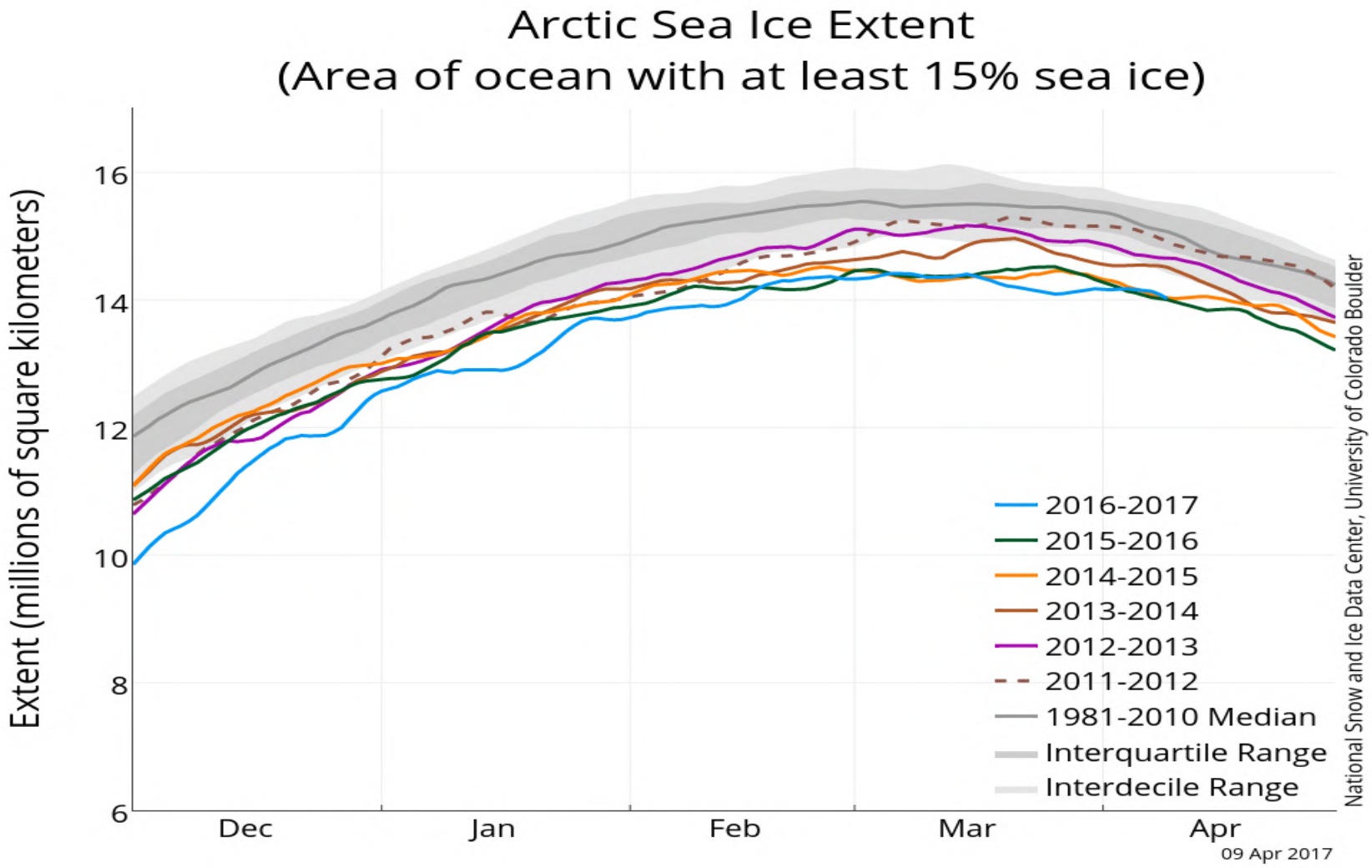
Back up

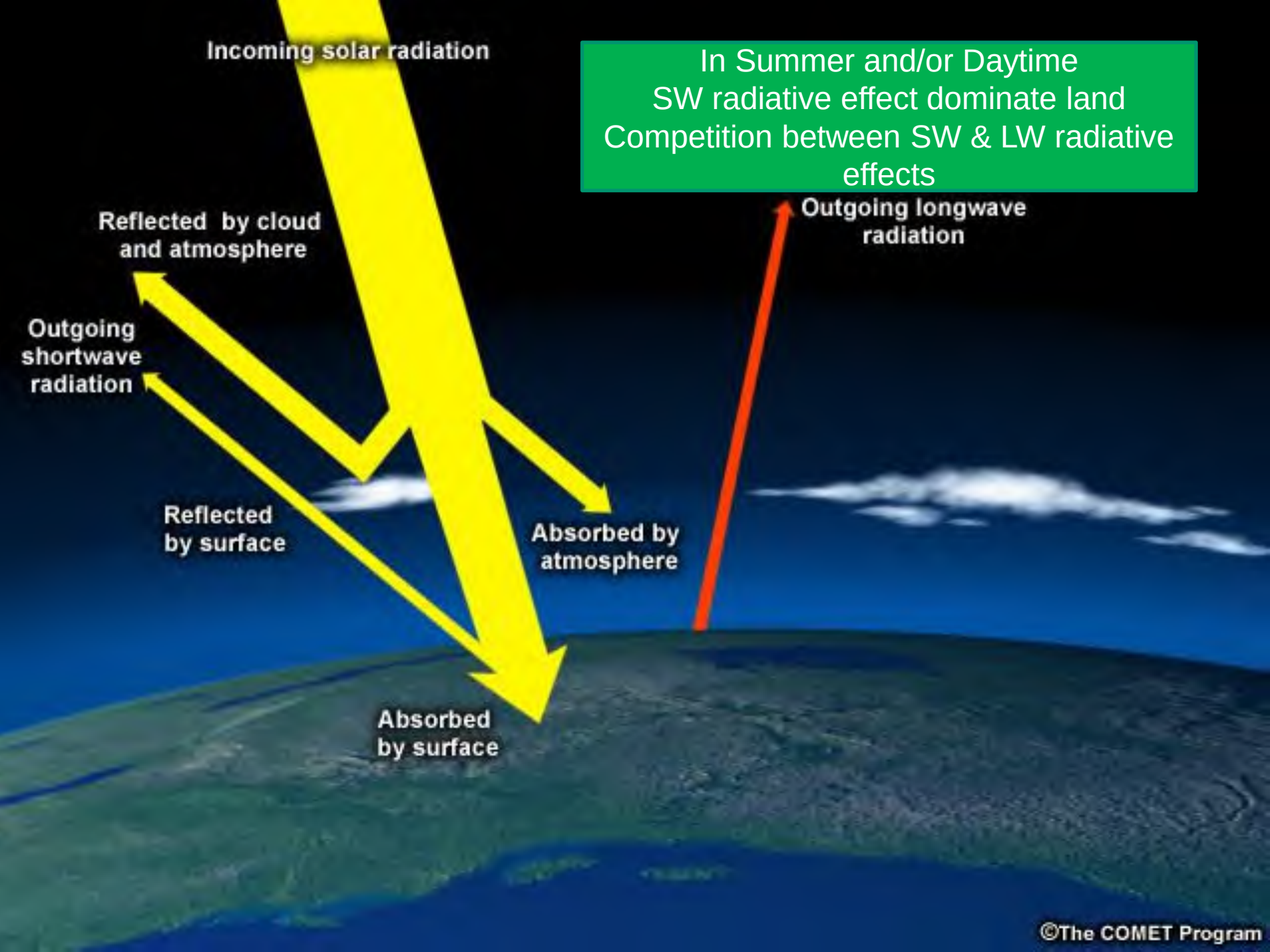
Antarctic Sea Ice Extent Observations
Three days ago – 22 April 2017



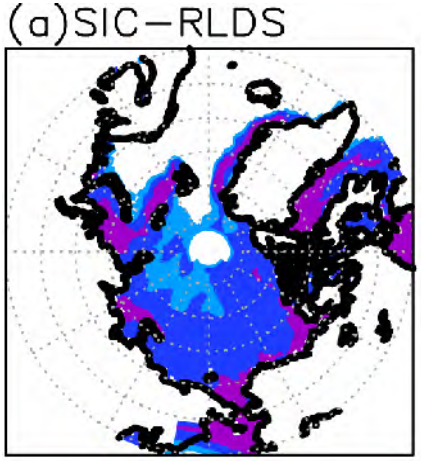

"Forcing"
Energy In
"System"
Energy Out
(LW+SW)
"Response"
Net Balance

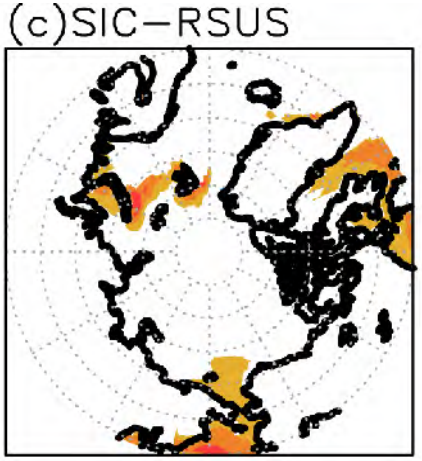
Arctic Sea Ice Extent Observations
Three days ago – 22 April 2017

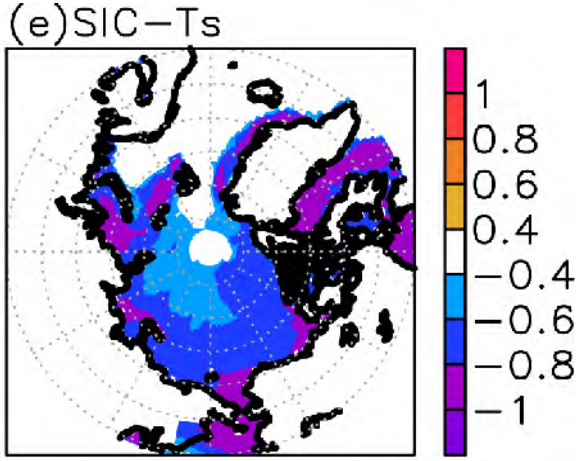


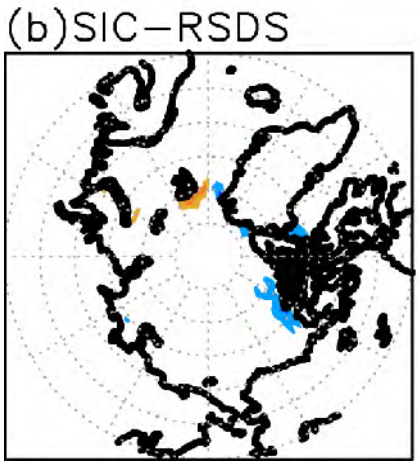

Incoming solar radiation
In Summer and/or Daytime
SW radiative effect dominate land
Competition between SW & LW radiative effects
Reflected by cloud and atmosphere
Outgoing longwave radiation
Outgoing shortwave radiation
Reflected by surface
Absorbed by atmosphere
Absorbed by surface
©The COMET Program

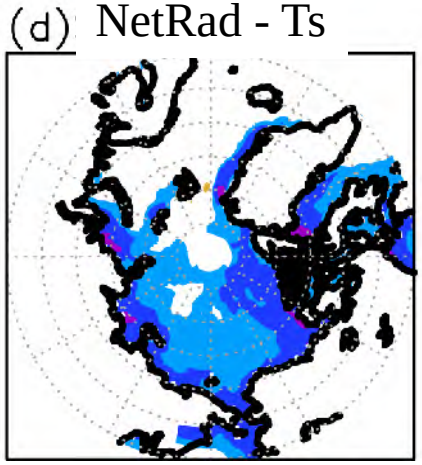
Observational Temporal & Spatial Correlation 2002-2013
Arctic Oceans

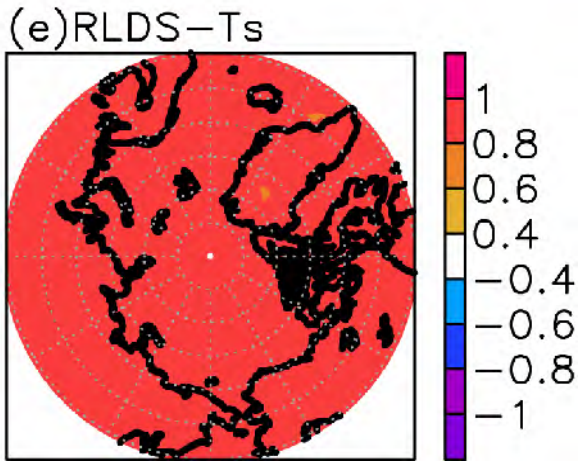




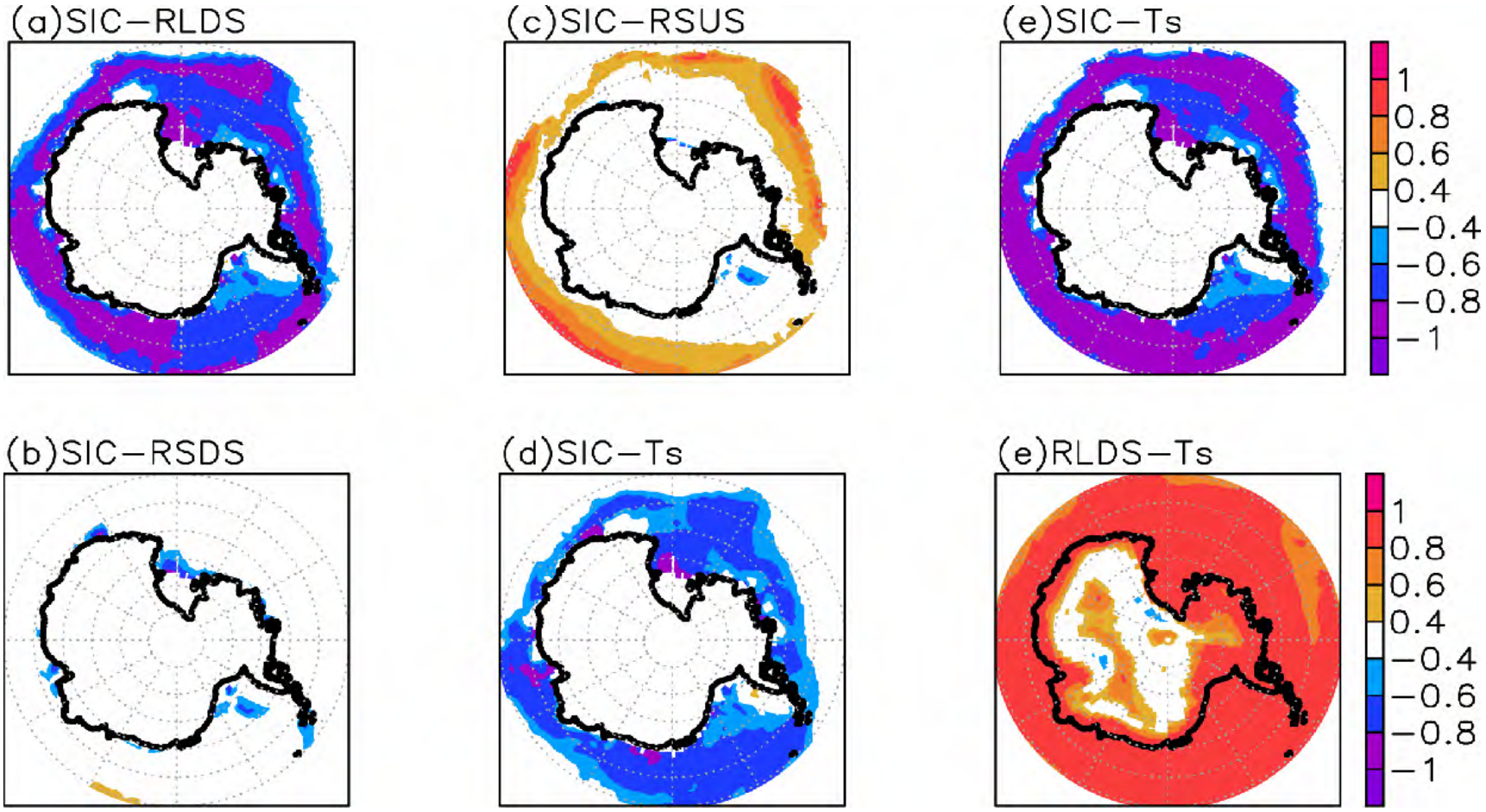








Observational Temporal & Spatial Correlation 2002-2013
Southern Oceans

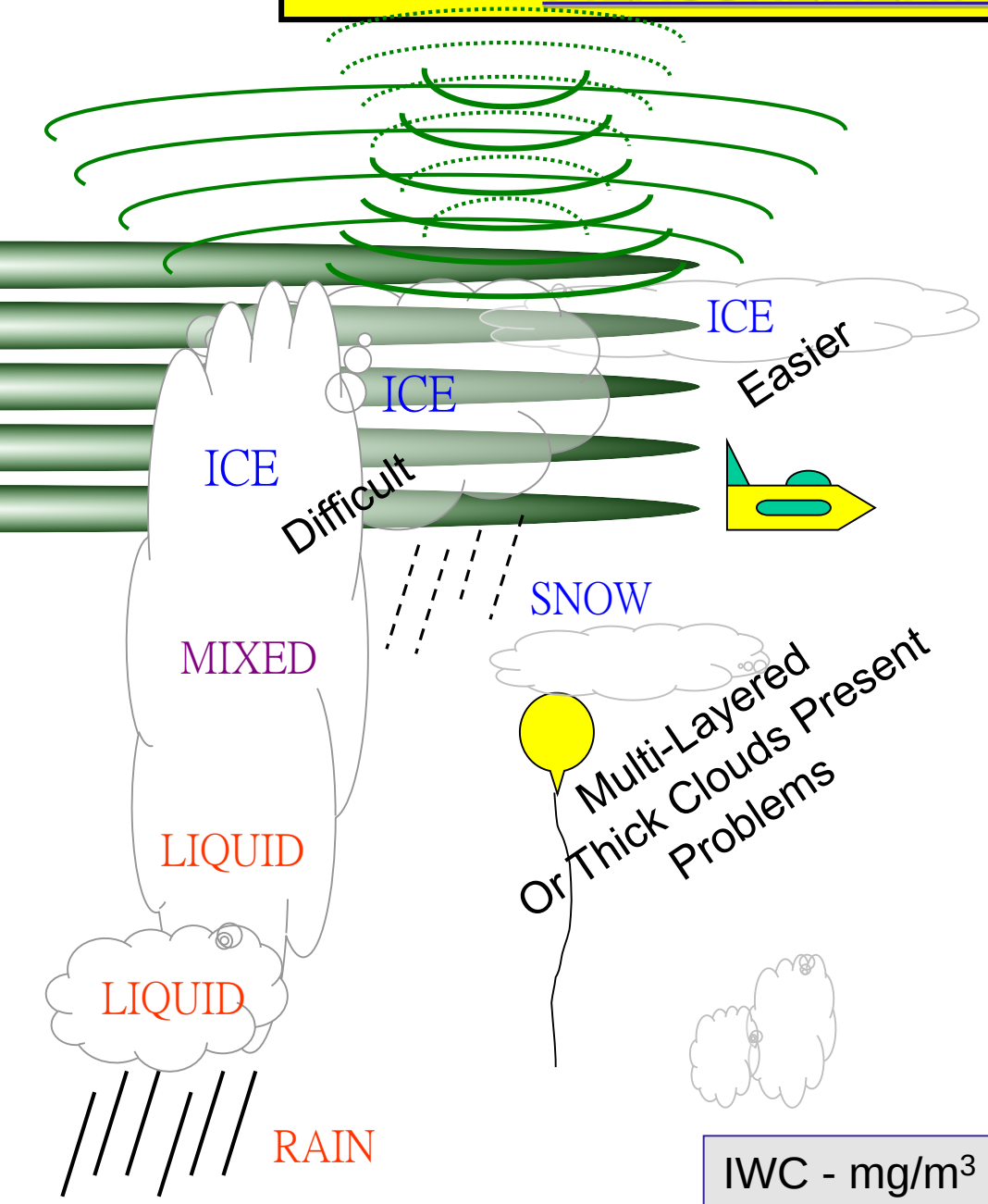


In winter and/or nighttime
LW radiative effect dominate over land

Climate Changes Found from Observations

- Global surface temperatures have risen by about 0.87°C up to May 2016 since 1880
- Sea level has risen by about 20 cm, ocean heat content has increased,
  - Almost all mountain glaciers have retreated
- The levels of CO_2 and other greenhouse' gases have dramatically increased coincidently with the mentioned global climate changed

Measurement Strategies



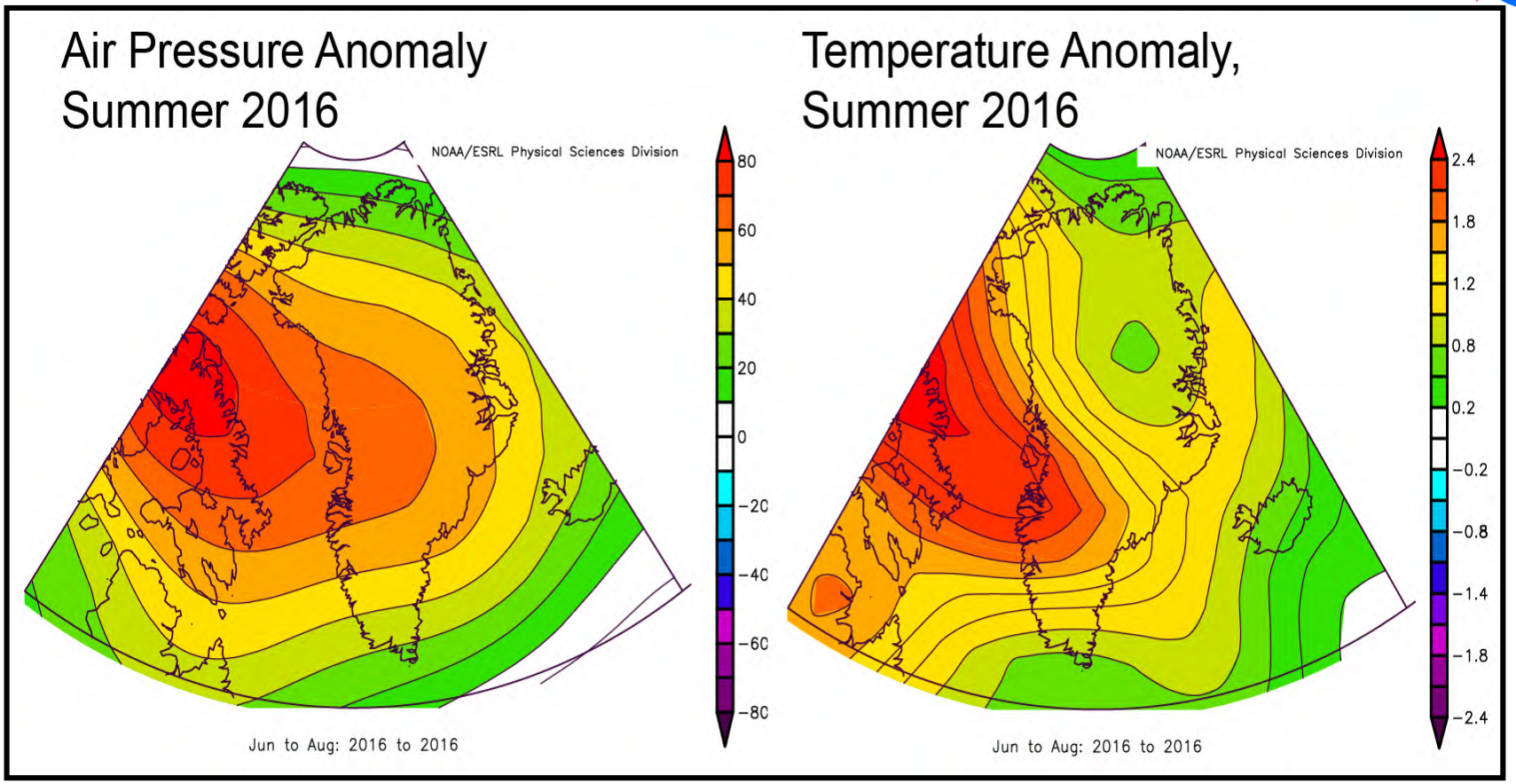
Passive Techniques such as those used in the CERES/MODIS, ISCCP, MODIS, and NOAA/MW products only provide Total IWP estimates - challenging in multi-layer, mixed and thick clouds.

MLS - a limb sounder - can probe the upper troposphere to estimate IWC (but not Total IWP)

CloudSat (cloud radar) and Calipso (lidar) can probe the cloud structure and provide estimates of IWC.
CloudSat also provides IWP.

IWC - mg/m^3
IWP - mg/m^2

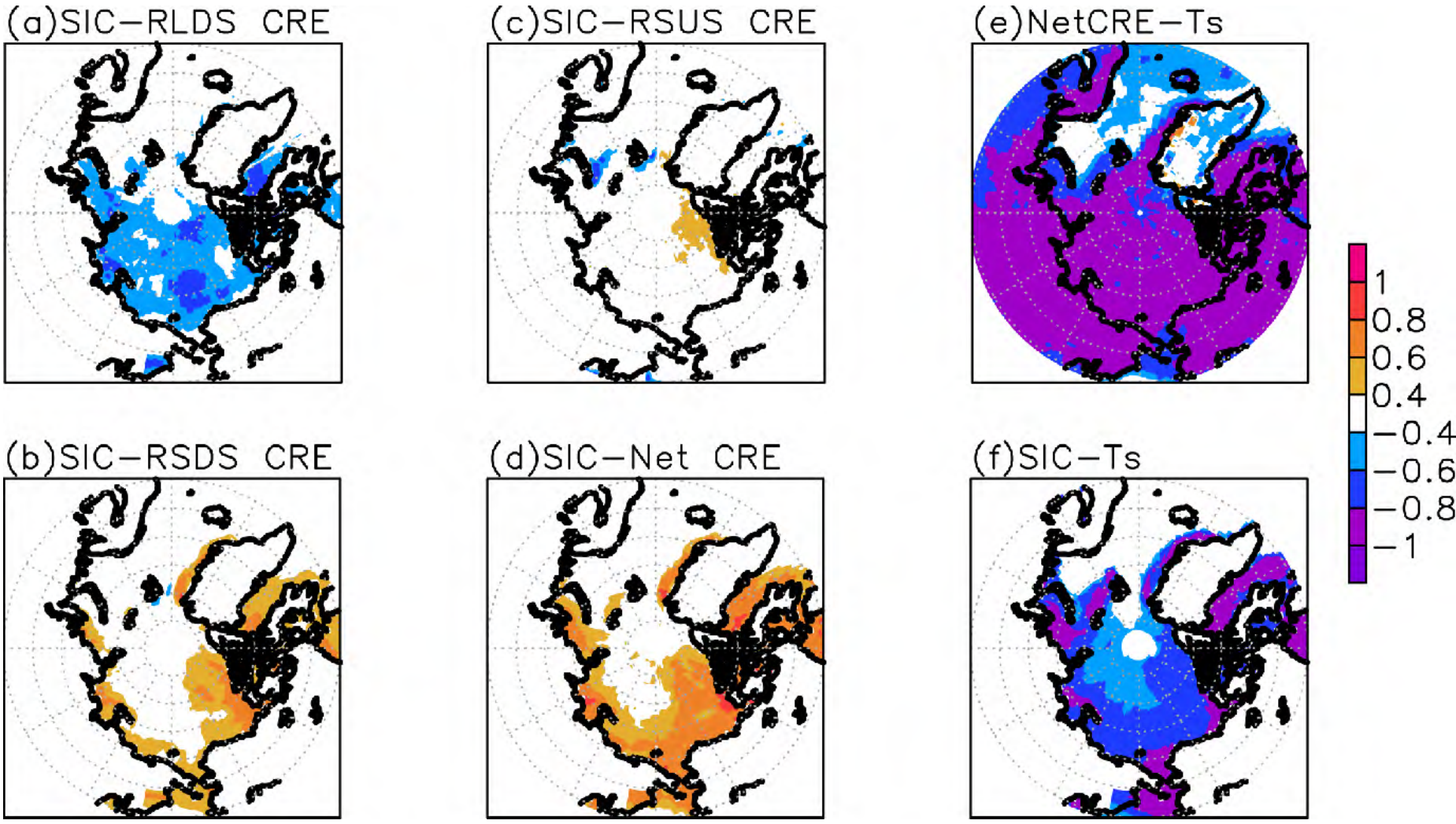
Greenland's Present Day Temperature Anomaly – Summer 2016



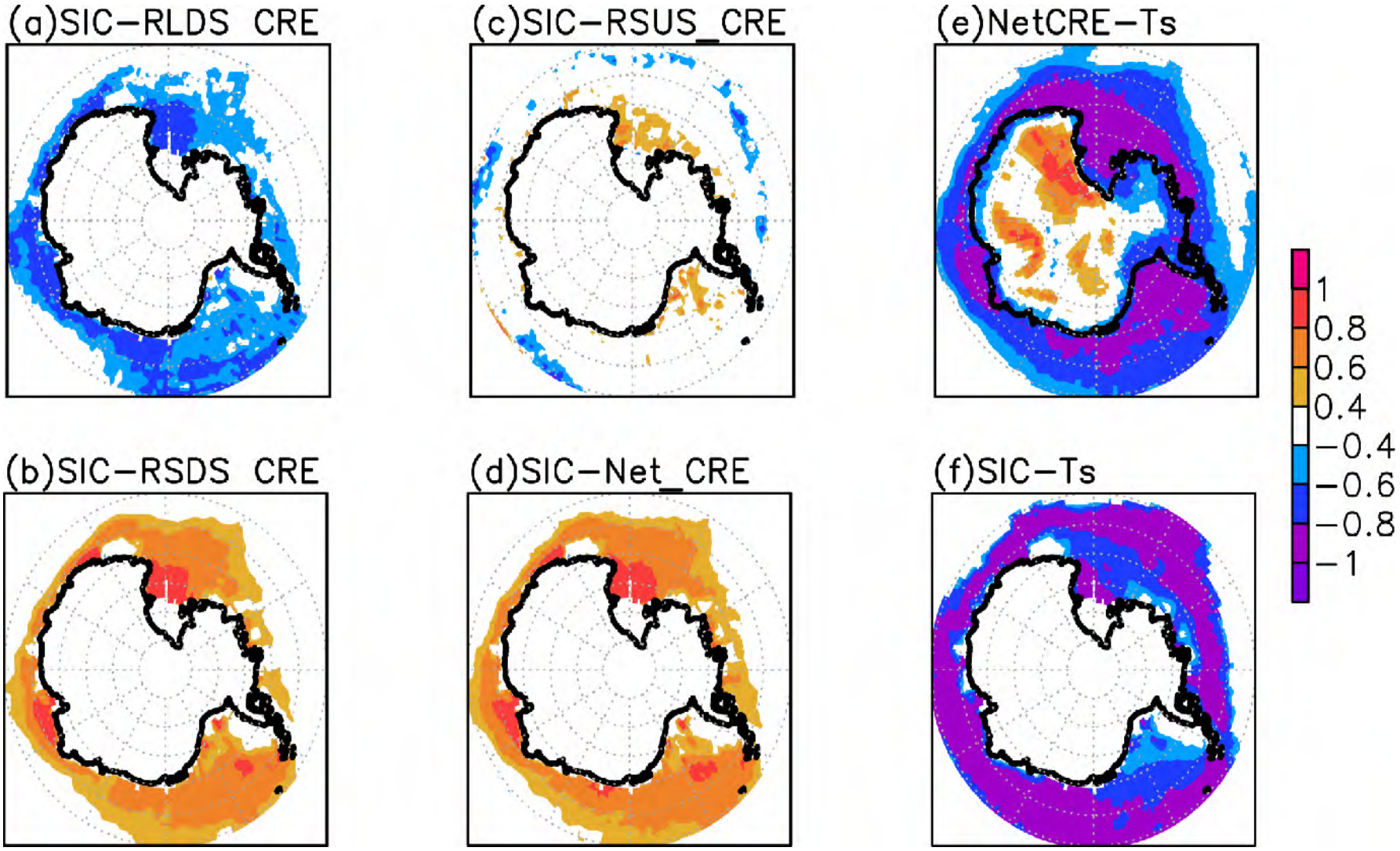
The left plot shows air pressure anomaly (height anomaly of the 500 mbar pressure level, in meters) and the right plot shows air temperature anomaly (in degrees Celsius) for June, July, and August 2016 combined, relative to the 1981 to 2010 average.

Credit: NSIDC courtesy, NOAA ESRL Physical Sciences Division

Observational Temporal & Spatial Correlation 2002-2013
Arctic Oceans



Observational Temporal & Spatial Correlation 2002-2013
Southern Oceans



What is Climate Change?

- **Weather is change from day to day to weeks…**
- **Climate is the "average weather" over a longer period, typically over tens of years and longer, and expected to remain relatively constant.**
- **If the climate has a significant change underlying a level of climate variability, we call it is a climate change.**

SUMMARY:

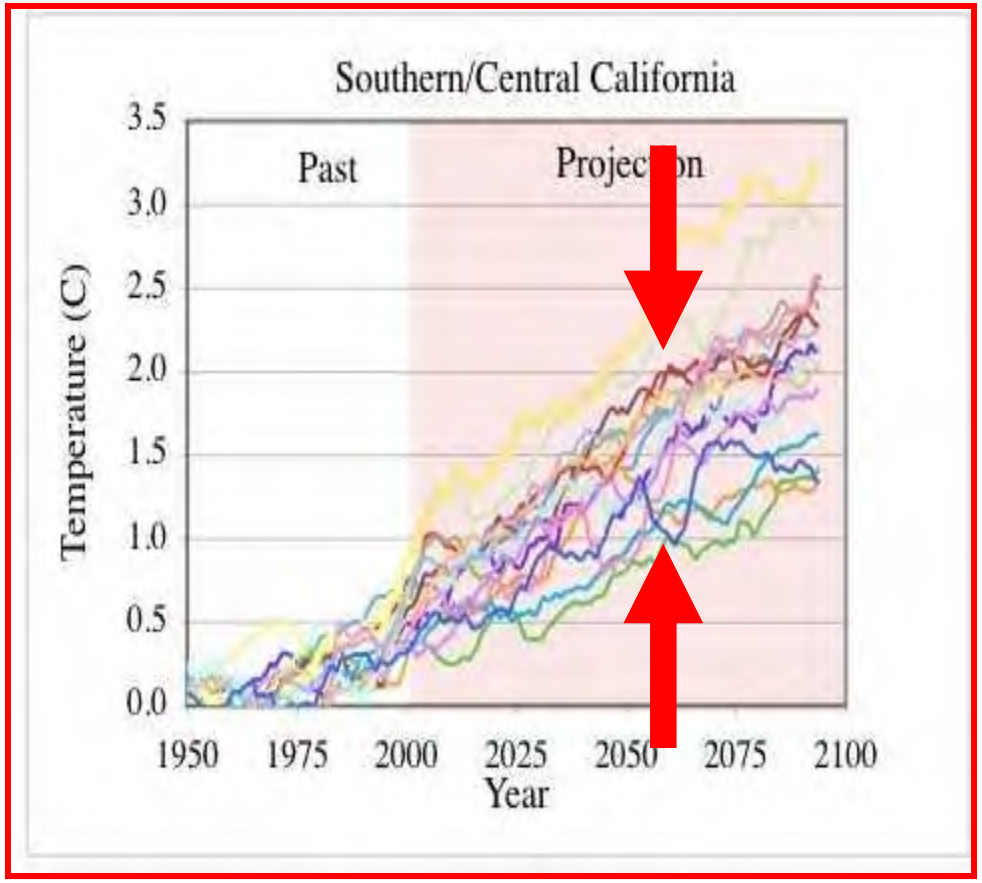
•OBSERVATIONS – Satellite Measurements etc

• UNDERSTANDING OF THE PROCESSES - Modeling

•CLIMATE PROJECTION STUDY - Modeling

•WILL THE CLIMATE CHANGES CONTINUE?

Global Climate Modeling Efforts: Using Observations To Reduce Uncertainties



- Better/More Measurements
- Faster/Better Computers & Infrastructure

•Continued Dedication & Focus