Arctic Upper Ocean **warming**: The role of the atmosphere

**Michael Steele & real meteorologists**

*Polar Science Center, Applied Physics Lab, University of Washington*

*Seattle, WA USA*

Zhe Li  
*UCSB, Santa Barbara, CA*

& Q. Ding (UCSB), A. Schweiger (UW)

Anne Sledd  
*NOAA/CIRES, Boulder, CO*

& J. Kay (CU), T. L’Ecuyer (UWisc)
Ice Retreat

Sept. Arctic Sea Ice Extent
(1979-2021, NSIDC)
Ice Retreat

Ice loss even north of Greenland!
“Wandel Sea”

Moore et al. (GRL, 2018)

Sept. Arctic Sea Ice Extent (1979-2021, NSIDC)

Feb 25, 2018
Ice Retreat

Sept. Arctic Sea Ice Extent (1979-2021, NSIDC)

Ice loss even north of Greenland!
“Wandel Sea”

Feb 25, 2018
winter

Greenland

Moore et al. (GRL, 2018)

Aug 2020
summer

MOSAiC

NSTM & ice-α feedback

Schweiger et al. (Nature CE&E, 2021)

Sea Ice Concentration [%]
Ice Retreat

Sept. Arctic Sea Ice Extent (1979-2021, NSIDC)

Complicated 2D geometry

Median
(1981-2010)
Ocean surface warming

Sea Surface Temperature (SST)

UpTempO buoys

Sept 16, 2021

Sept 14, 2021

Complicated geometry

Complicated SST!

http://psc.apl.washington.edu/UpTempO/
Ocean surface warming

[SST map showing warm areas in the Arctic Ocean, with UpTempO buoys indicated]

http://psc.apl.washington.edu/UpTempO/
Where it all started

Arctic Ocean surface warming trends over the past 100 years
M. Steele, W. Ermold, J. Zhang
(GRL, 2008)

Sea ice

Max Anomaly ≤ 5°C

Sept. Arctic Sea Ice Extent
(1979-2021, NSIDC)
Where it all started

Arctic Ocean surface warming trends over the past 100 years
M. Steele, W. Ermold, J. Zhang
(GRL, 2008)

AGU talk Dec. 2007
My Climate Crank

Subject: Global Warming

The San Francisco Chronicle printed "New Alarm is Raised Over Melting Polar Ice." I quote, "Michael Steele, an oceanographer at the Polar Science Center, said his group's measurements ...have shown a warming trend for the past 100 years".

Since the Polar Science Center has only been in operation since 1978, how is that possible? It makes one wonder how many other articles written by such "scientists" are more political than scientifically factual.

I have also sent a letter to the Dean of the school asking for disciplinary action against you, Mr. Steele, for your obvious deception.

Mr. Steele’s comments will be brought to the attention of Fox News Network. Maybe Bill O’Reilly or Sean Hannity can sort it out with Mr. Steele.

Robert A. Casper, SR
64 Wallace Way
San Rafael, CA 94903
summer SST anomaly

Physics?
Atmos heating $\sim 5 \times$

Lateral ocean heat flux convergence

Heat Input (MJ/m²)

Steele et al. (JGR, 2010)
- using PIOMAS model
Recently?

Warming

1982-2020 August linear SST trend (°C/yr)

Timmermans & Labe (NOAA, 2020)

40 years x 0.05-0.1°C/yr = 2-4°C
Recently?

Timmermans & Labe (NOAA, 2020)

1982-2020 August linear SST trend (°C/yr)

40 years x 0.05-0.1°C/yr = 2-4°C
(NOAA/OISST aka “Reynolds”)  
25 km global, gridded SST 1981-present  

SST ~ -1°C  
(too warm!)  

Banzon et al. (J Tech, 2020)  
Huang et al. (J Climate, 2021)
SST across the MIZ

- SST ~ -1°C (too warm!)

Banzon et al. (J Tech, 2020)
Huang et al. (J Climate, 2021)
NOAA/OISST aka “Reynolds”
25 km global, gridded SST 1981-present
iceSST: 15sep2012

SST ~ -1°C (too warm!)

OISSTv2.1:
- SST = T_f + c*SIC
- T_f (climo SSS)

Bazon et al. (J Tech, 2020)
Huang et al. (J Climate, 2021)
How much of this is due to:

• Global warming vs.

• Internal climate variability?
Background Question:
How much **Arctic sea ice loss** is due to:

Global *warming* vs. internal climate *variability*?

See Q. Ding’s poster

Sept. Arctic Sea Ice Extent
*(1979-2021, NSIDC)*
Atmos trends

Summer (JJA) Z700 trend

Incr. high pressure & AC winds

Ding et al. (Nature CC, 2017)
Atmos trends

Atmos is:
- **Warmer** (subsidence)
- **Wetter/cloudier @ surface**
  (incr. LW down)

[Ding et al. (Nature CC, 2017)]

**Summer (JJA)**

Z700 trend

Incr. high pressure & AC winds
Atmos trends

Internal climate variability + global warming

☞ Incr. high pressure & AC winds ☜

Ding et al. (Nature CC, 2017)
Atmos trends

CMIP5 (1979–2014)
climate model ensemble

Obs. (1979–2014)
ERA-I

Summer (JJA) Z700 trend

Global warming

☞ Incr. high pressure & AC winds ☞

Ding et al. (Nature CC, 2017)
- **Summer (JJA)**
- **Z700 trend**

~ 40% of sea ice loss is from internal climate variability

☞ **Incr. high pressure & AC winds**

*Ding et al. (Nature CC, 2017)*
Incr. high pressure & AC winds

~ 40% of sea ice loss is from internal climate variability

...ultimately forced by the tropical Pacific!

Ding et al. (Nature CC, 2017)
Michael Steele
Polar Science Center / APL
University of Washington

Incr. high pressure & AC winds

Ding et al. (Nature CC, 2017)

Clivar Arctic Ocean
Seattle, WA

Summer (JJA)
Z700 trend

~ 40% of sea ice loss is from internal climate variability

...ultimately forced by the tropical Pacific!

☞ Incr. high pressure & AC winds

→ OK SO WHAT ABOUT SST?
Upper Arctic Ocean warming (0-50 m depth)

Ocean reanalyses:
- ORAS5 (ECMWF)
- SODA3.4.2 (U of MD)
- GECCO3 (German ECCO)

Li et al. (Nature Comm, 2017)
Upper Arctic Ocean warming (0-50 m depth)

Meteorologists using ocean reanalyses as “truth!”

Li et al. (Nature Comm, 2017)

Is this even bad?!
Upper Arctic Ocean warming (0-50 m depth)

Ocean reanalyses:
- ORAS5 (ECMWF)
- SODA3.4.2 (U of MD)
- GECCO3 (German ECCO)

Li et al. (Nature Comm, 2017)

Sound familiar?!
Oceanographers using atmos reanalyses as “truth!”
Upper Arctic Ocean warming (0-50 m depth)

Li et al. (Nature Comm, 2017)

Ocean reanalyses:
- ORAS5 (ECMWF)
- SODA3.4.2 (U of MD)
- GECCO3 (German ECCO)

*UpTempO buoys*

“Arctic” region

Summer sea ice conc. (%)

ORAS5

late summer & fall

ORAS5

Late summer & fall (SON)
The role of global warming (incr. CO$_2$)

Li et al.
(Nature Comm, 2017)
The role of global warming ($\text{incr. CO}_2$)

Li et al. (Nature Comm, 2017)

Global warming: 
~ 50% of obs (1979-2018)

...only half!

ORAS5 ("obs")

CESM-LEN40 ("global warming")
The role of internal climate variability

Li et al. (Nature Comm, 2017)
The role of internal climate variability

Li et al. (Nature Comm, 2017)

~ forced ice-ocean run
(varying winds + fixed CO$_2$

ORAS5 ("obs")

Wind nudging + fixed CO$_2$
("internal climate var.")
The role of internal climate variability

Li et al. (Nature Comm, 2017)

**Int. Climate Var:**
~ 25% of obs (1979-2018)

ORAS5 (“obs”)

Wind nudging + fixed CO₂
(“internal climate var.”)
The role of internal climate variability

Li et al. (Nature Comm, 2017)

Int. Climate Var: ~ 25% of obs (1979-2018)

Int. Climate Var: ~ 60% of obs (2000-2018)

ORAS5 ("obs")

Wind nudging + fixed CO₂ ("internal climate var.")

Wow!
The role of internal climate variability

Li et al. (Nature Comm, 2017)

Int. Climate Var:
~ 25% of obs (1979-2018)

Int. Climate Var:
~ 60% of obs (2000-2018)

Wind nudging + fixed CO$_2$
("internal climate var.")

ORAS5 ("obs")

Wow!
Multi-year $\rightarrow$ *seasonal* Arctic Ocean SST warming
The seasonal $\text{SST}_{\text{max}}$: What controls it?

**Day Of Retreat (SIC < 15%)**

Satellite & atmos reanalysis

**Earlier ice retreat $\Rightarrow$ warmer $\text{SST}_{\text{max}}$**

Steele & Dickinson

(JGR, 2016)
The seasonal $\text{SST}_{\text{max}}$: What controls it?

Steele & Dickinson (JGR, 2016)

Earlier ice retreat $\rightarrow$ warmer $\text{SST}_{\text{max}}$
The seasonal $\text{SST}_{\text{max}}$: What controls it?

What about clouds?

Earlier ice retreat $\rightarrow$ warmer $\text{SST}_{\text{max}}$
Day of Retreat controls SST$_{\text{max}}$ especially in the north

“pre-industrial CO$_2$”

“present-day CO$_2$”

“4 x CO$_2$” (seasonal ice pack)

Weaker control with earlier DOR
The seasonal $\text{SST}_{\text{max}}$: The effect of clouds

Sledd et al. (GRL, 2022, in prep.)

Cloud Fraction influence is weak/moderate
- cools in the south
- warms in the north

Cloud Fraction influence is strong
- cools everywhere

CESM model runs

Cloud Fraction
- "pre-industrial CO$_2$"
- "present-day CO$_2$"
- "4 x CO$_2$" (seasonal ice pack)
The seasonal $\text{SST}_{\text{max}}$: The effect of clouds

Cloud Fraction

Correlation with $\text{SST}_{\text{max}}$

- "pre-industrial CO$_2$"
- "present-day CO$_2$"
- "4 x CO$_2$" (seasonal ice pack)

CESM model runs

Cloud Fraction influence is weak/moderate
- cools in the south
- warms in the north

Cloud Fraction influence is strong
- cools everywhere

As ice retreats earlier, clouds play a bigger role
Summary: **Clouds** & Arctic SST

**Early/mid summer:** cooling

\[ \text{decr SW down} \]

**The future:** Early sea ice retreat

\[ \rightarrow \text{a boring, “regular” ocean!} \]
Summary: **Clouds** & Arctic SST

**Early/mid summer:** cooling

- decr SW down

**Late summer / fall:** warming

- incr LW down

The future: Early sea ice retreat ➔ a boring, “regular” ocean!

Now & always: Arctic SST strongly influenced by the tropical Pacific!
Summary: **Clouds** & Arctic SST

Early/mid summer: **cooling**
- decr SW down

Late summer / fall: **warming**
- incr LW down

The future: Early sea ice retreat ➔ a boring, “regular” ocean!

Now: Arctic SST strongly influenced by the tropical Pacific!

Thank you