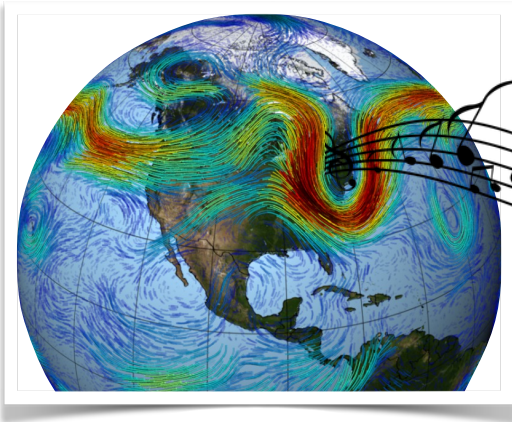
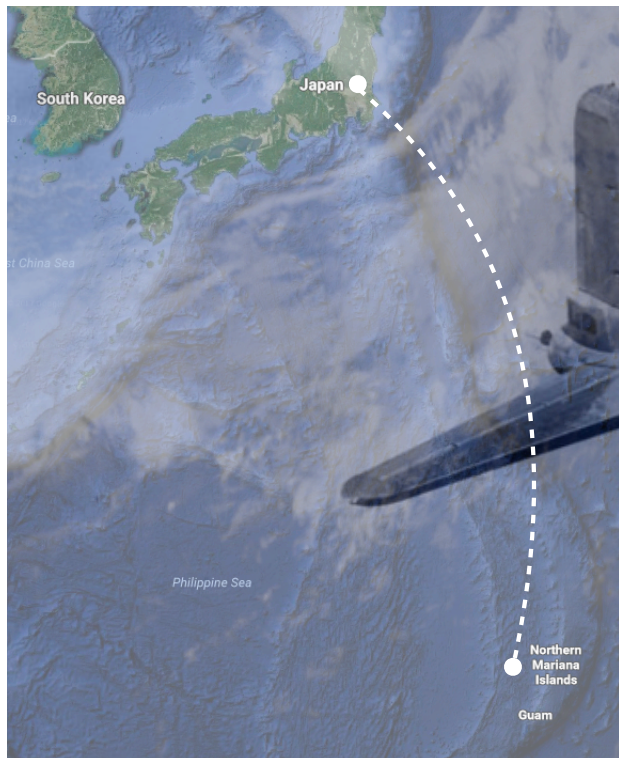




The Music in the Noise: Identifying the Jet-stream Response to Human Activity

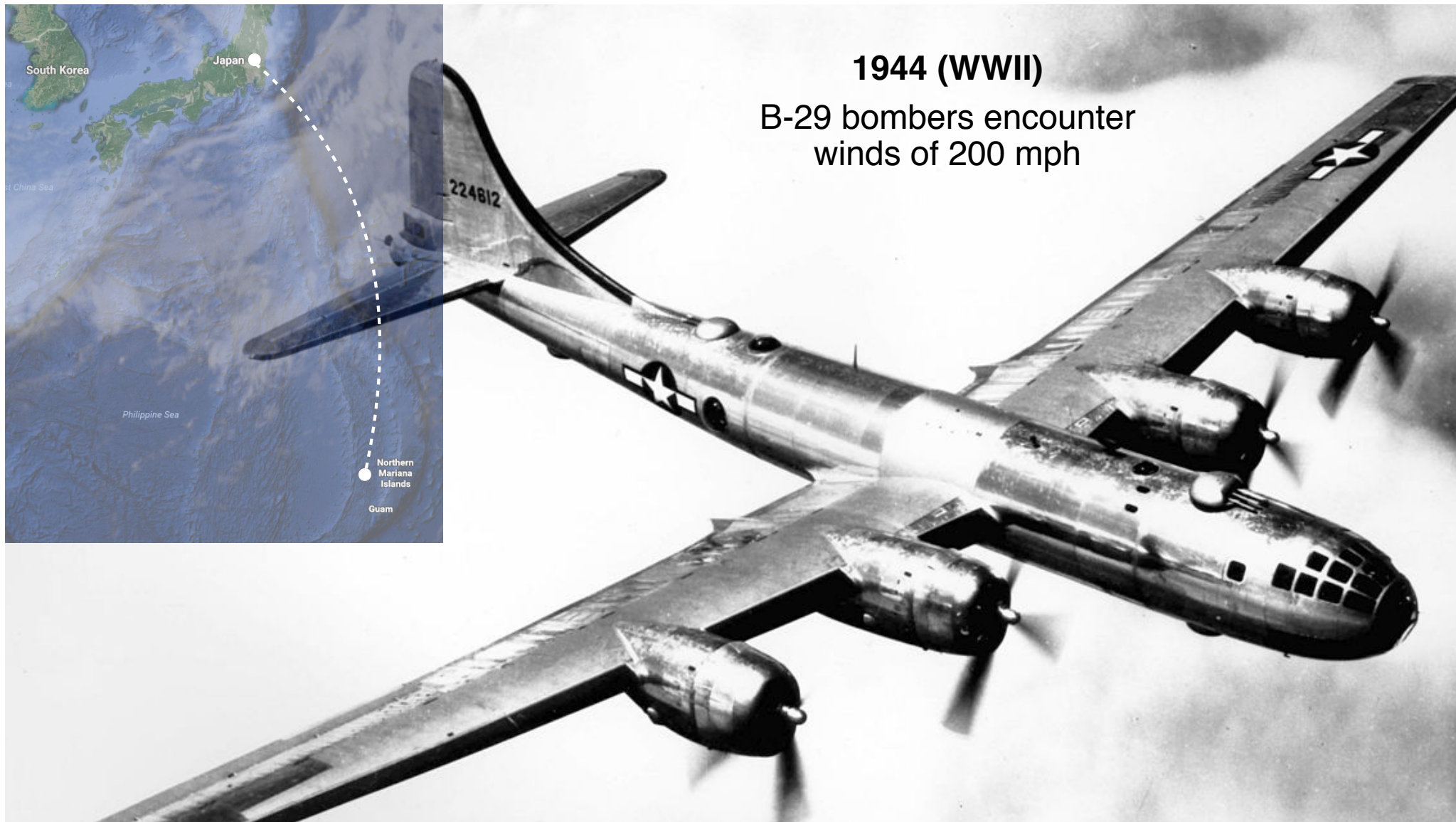
Elizabeth Barnes
Assistant Professor
Colorado State University





1944 (WWII)

B-29 bombers encounter
winds of 200 mph



Discovery of the Jet-stream

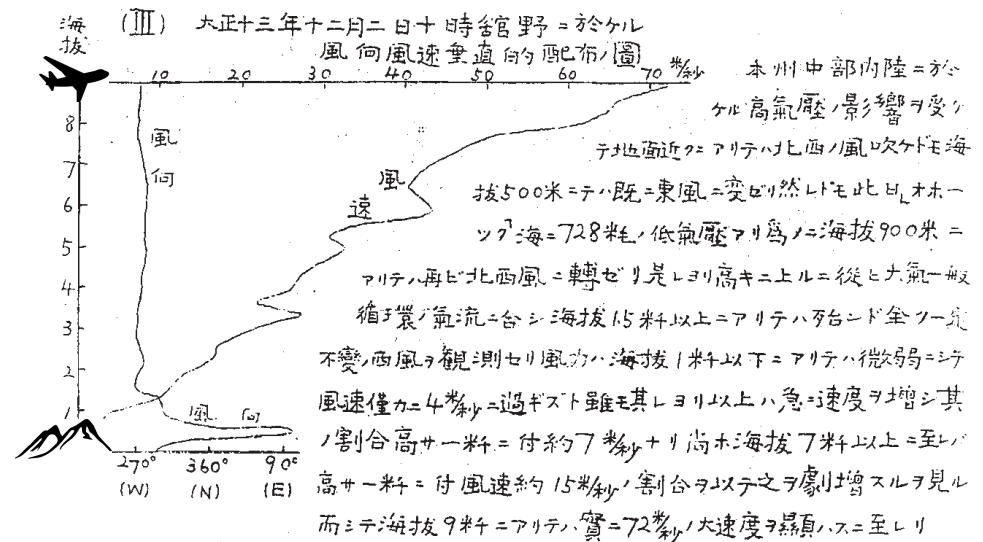


Wasaburo Ooishi
1874-1950

Lewis (2003; BAMS)

Discovery of the Jet-stream

Dec. 2, 1924: measurements at Japan's upper-air observatory in Tateno; 60 km NE of Tokyo



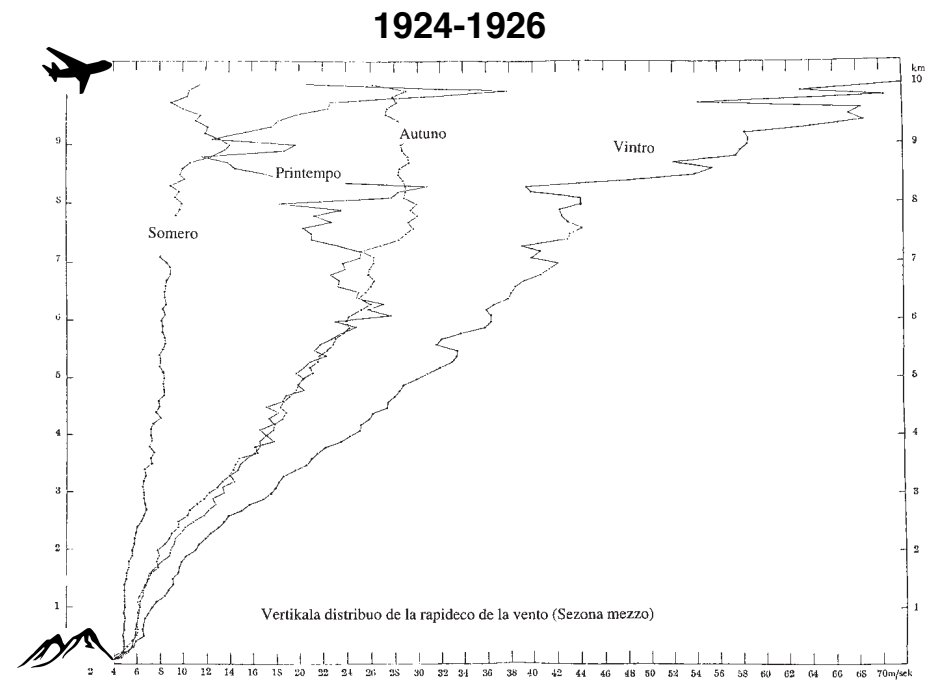
Wasaburo Ooishi
1874-1950

Lewis (2003; BAMS)

Discovery of the Jet-stream



Wasaburo Ooishi
1874-1950

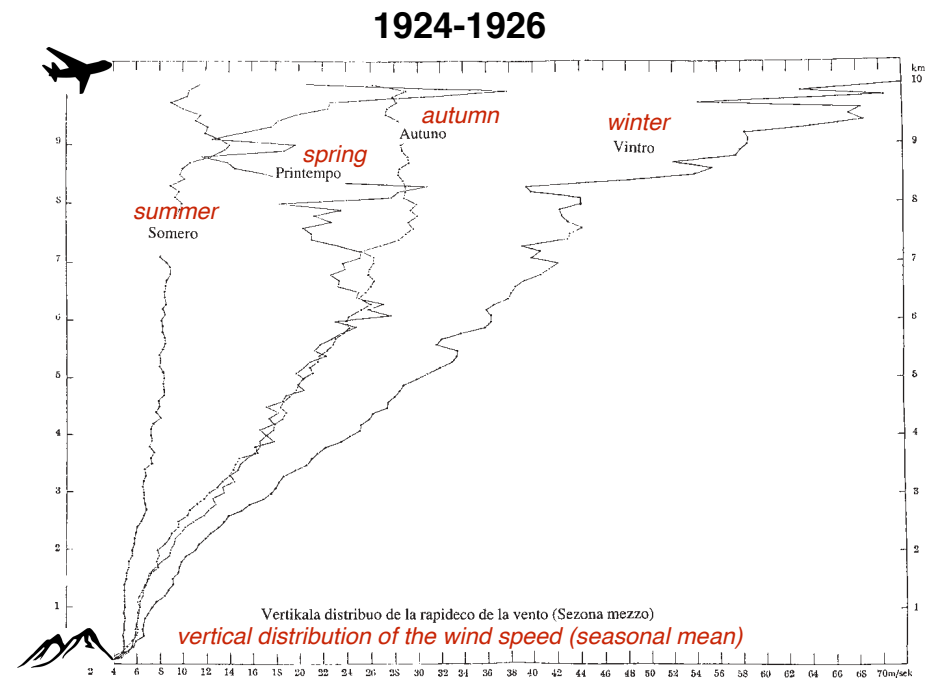


Lewis (2003; BAMS)

Discovery of the Jet-stream



Wasaburo Ooishi
1874-1950

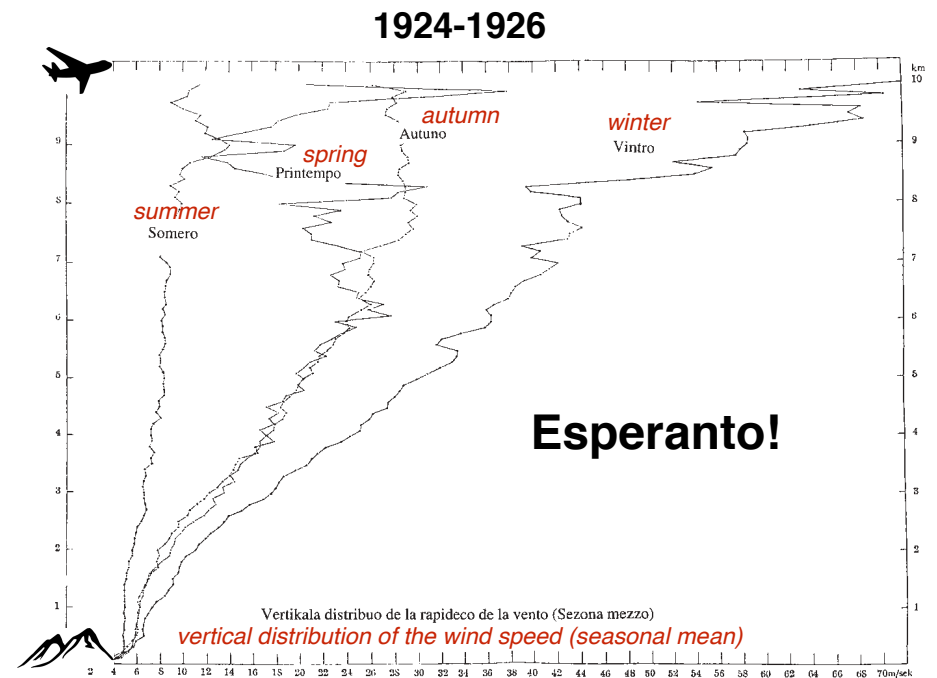


Lewis (2003; BAMS)

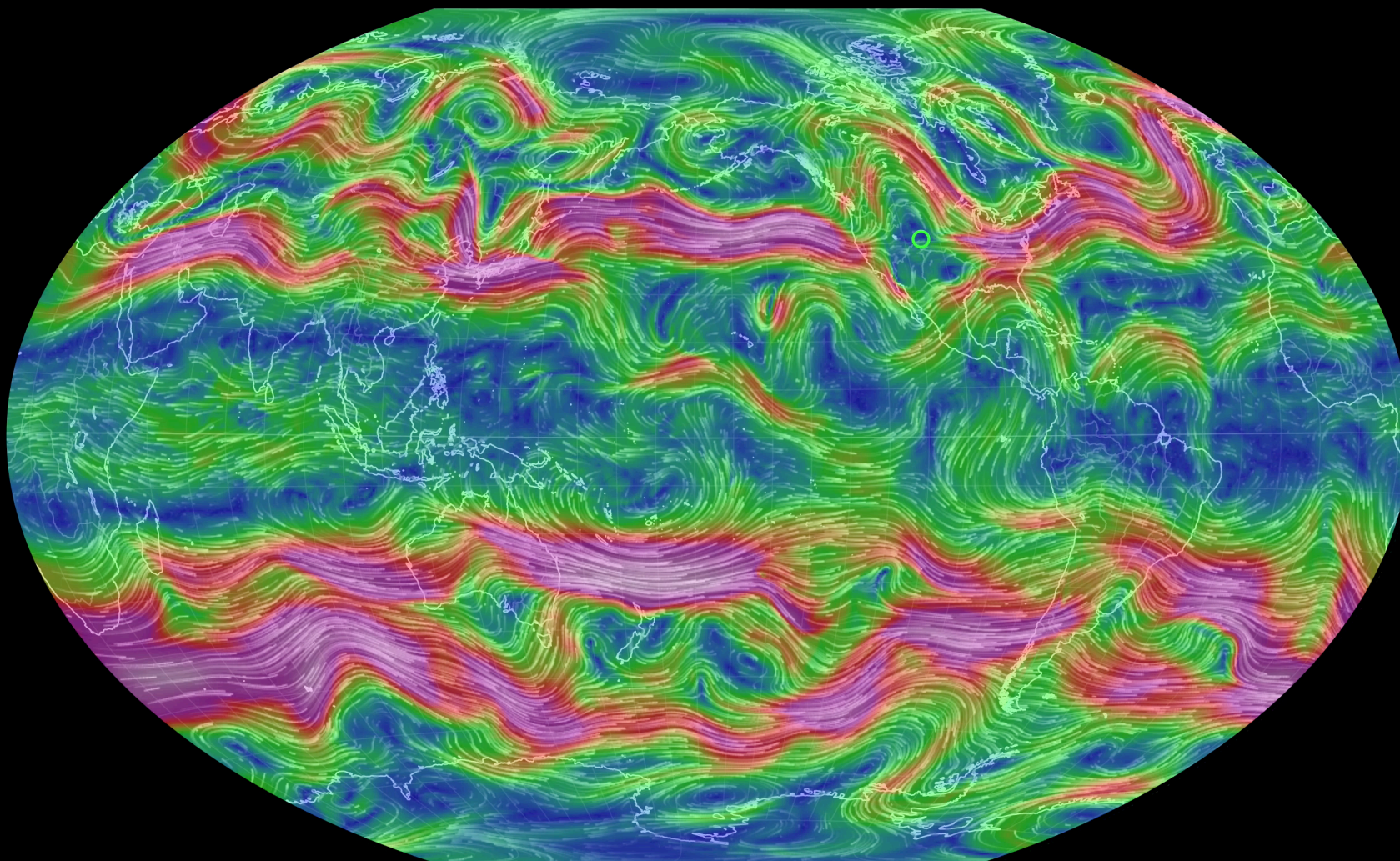
Discovery of the Jet-stream

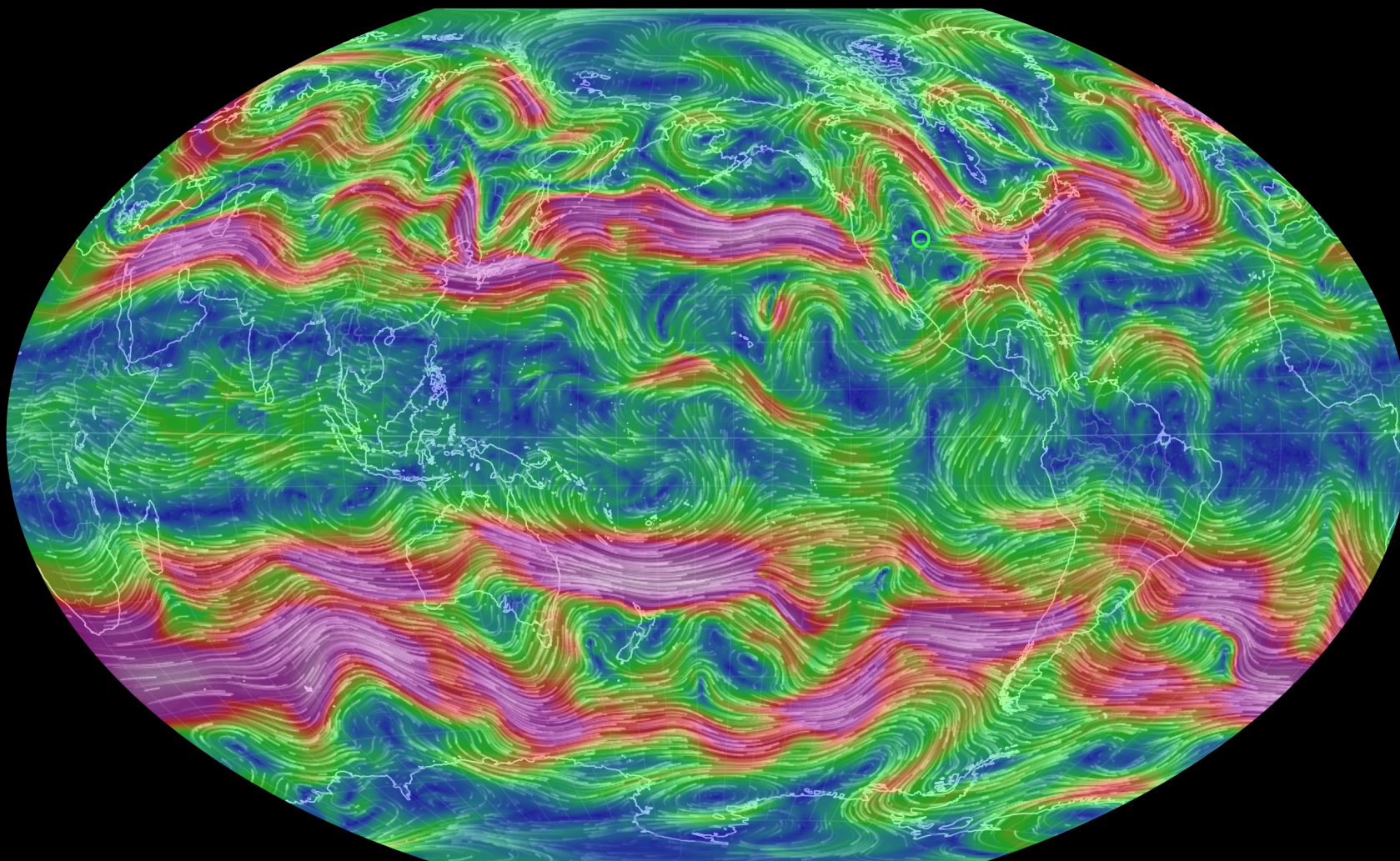


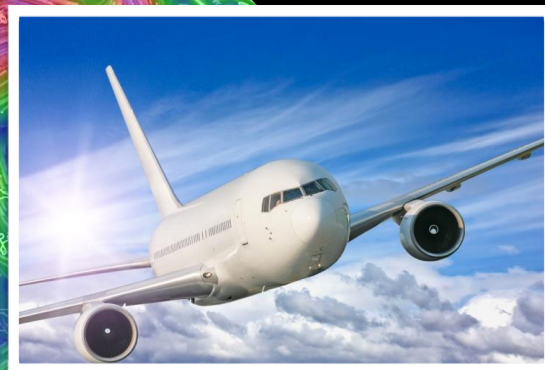
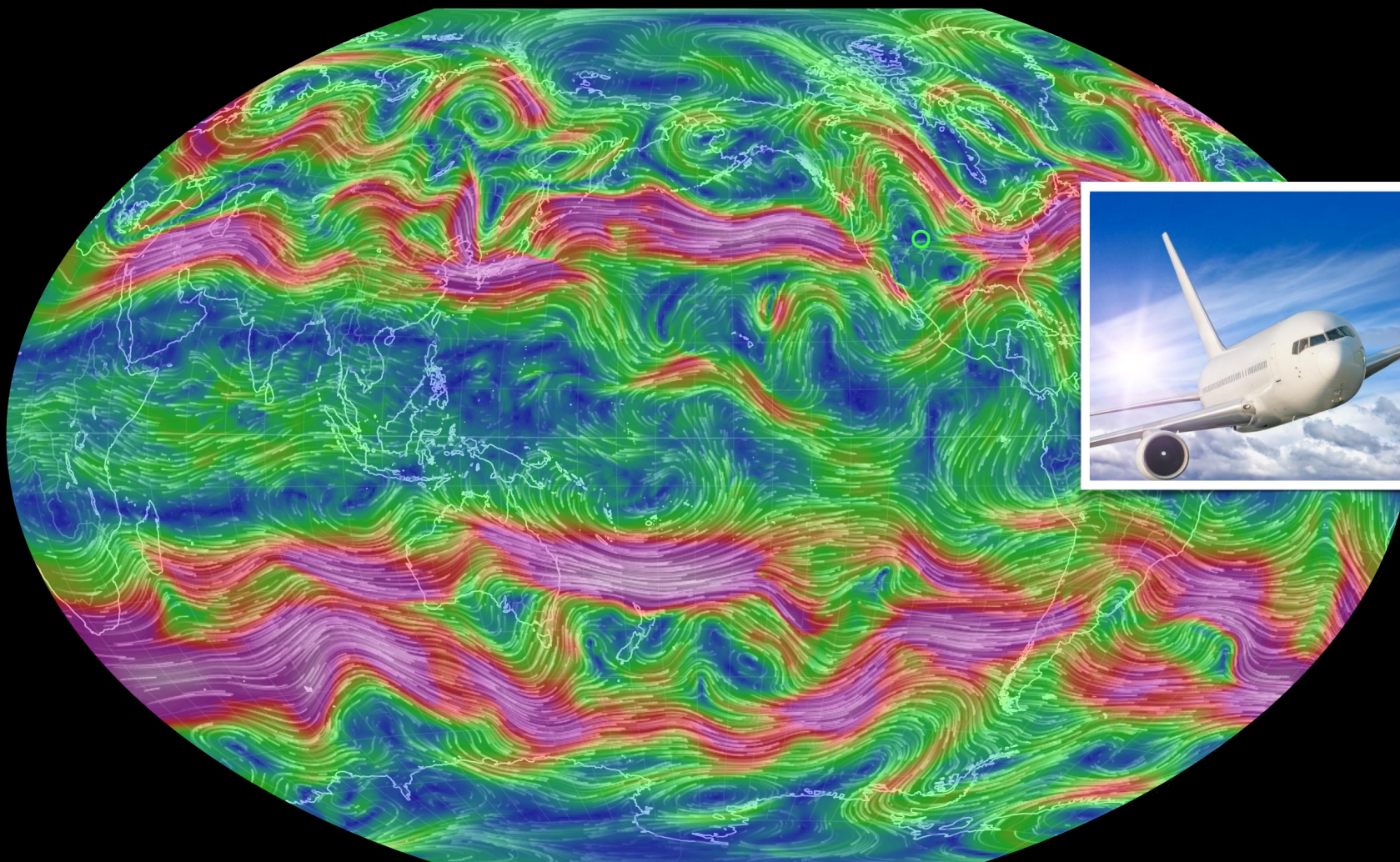
Wasaburo Ooishi
1874-1950

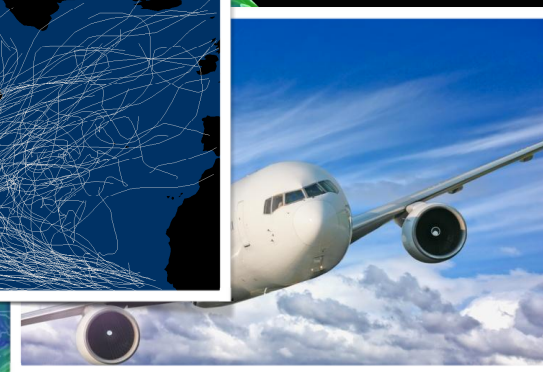
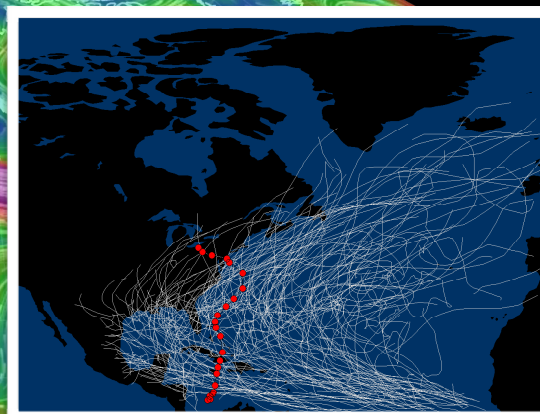
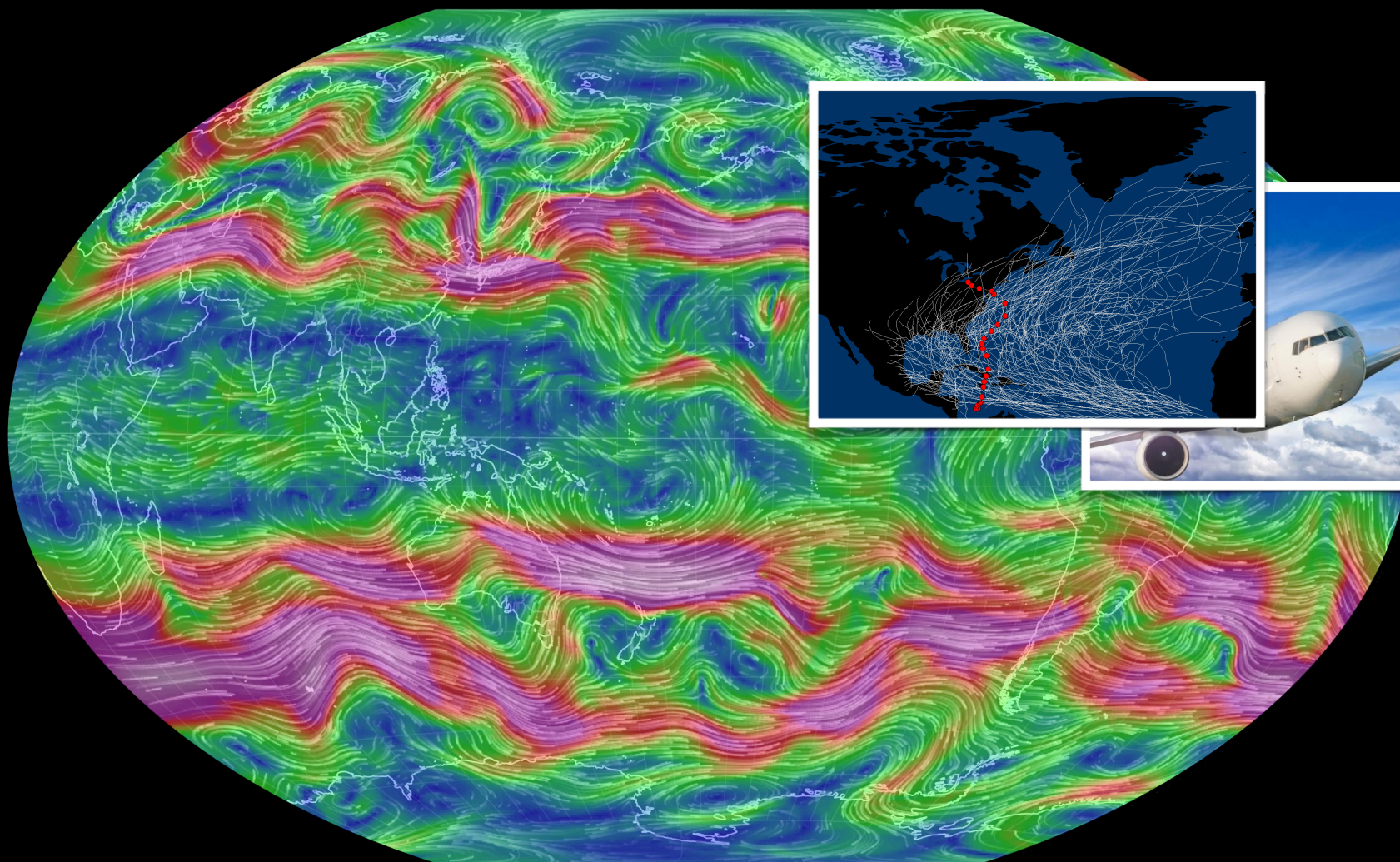


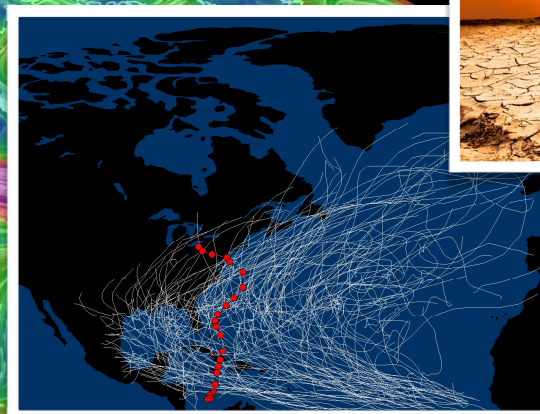
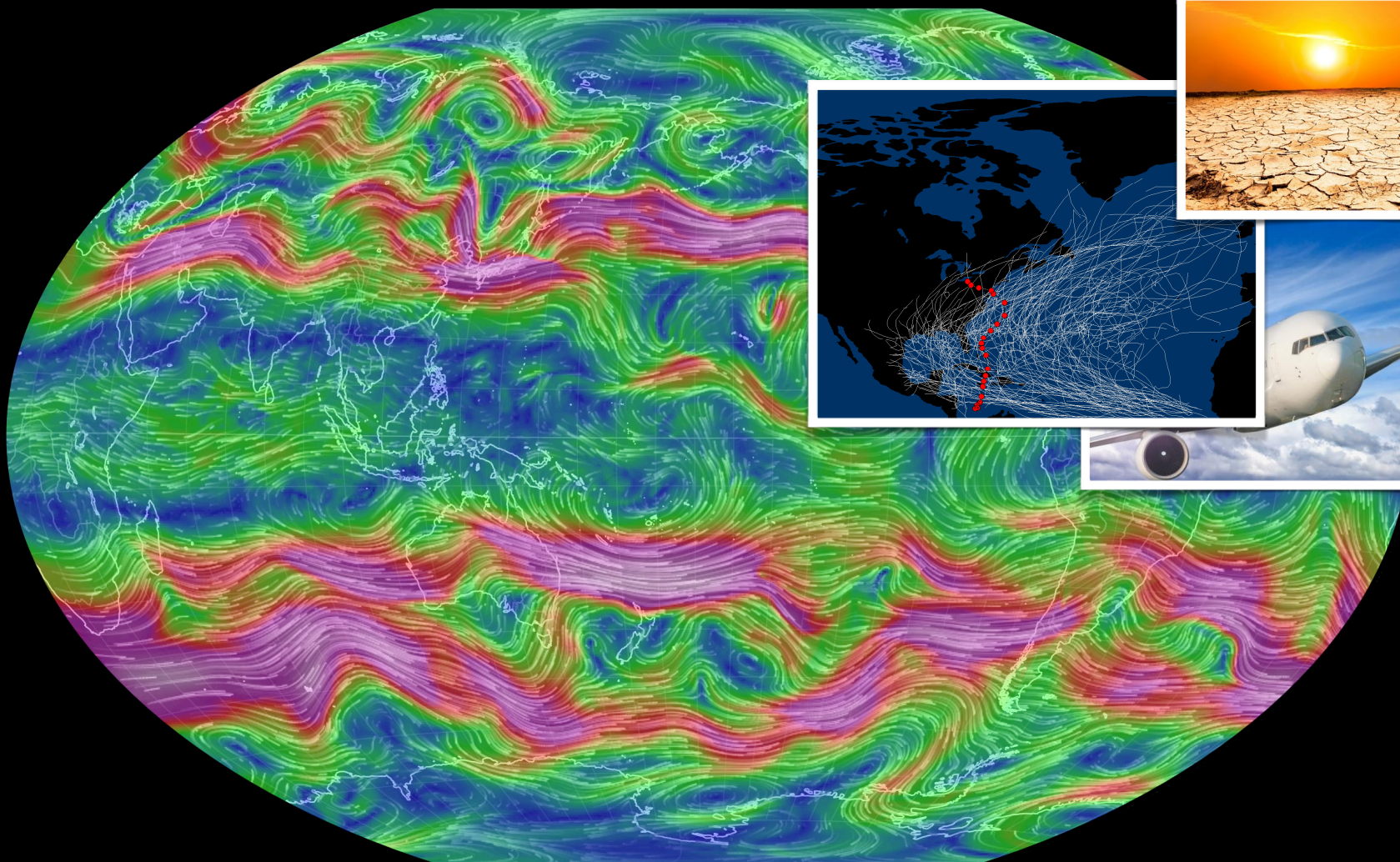
Lewis (2003; BAMS)

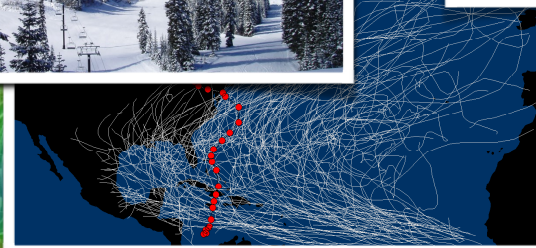
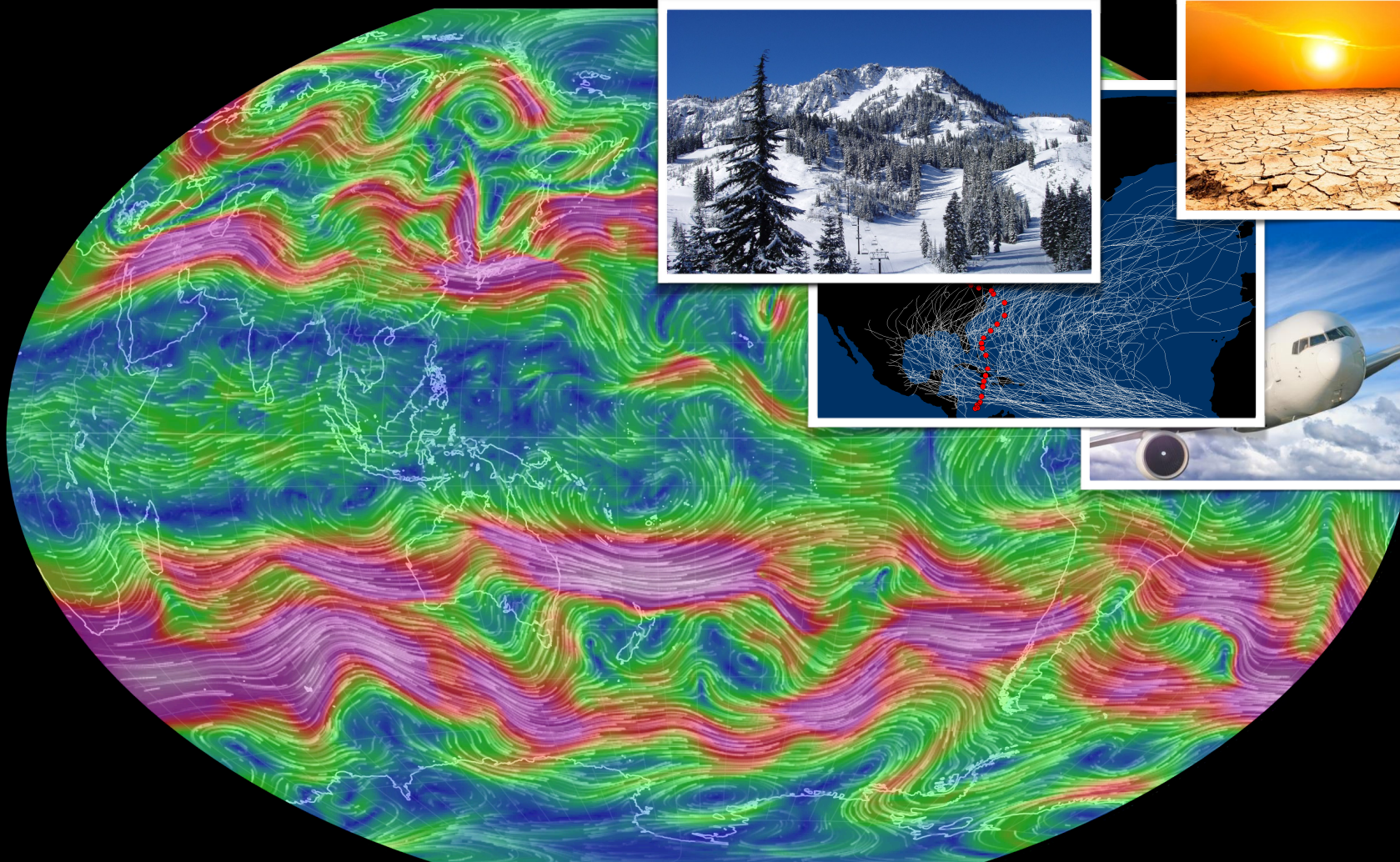


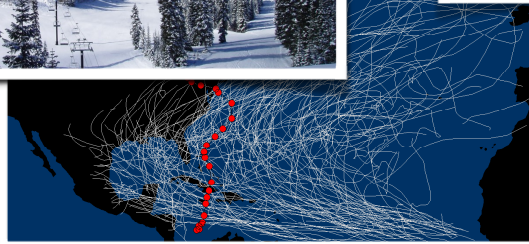
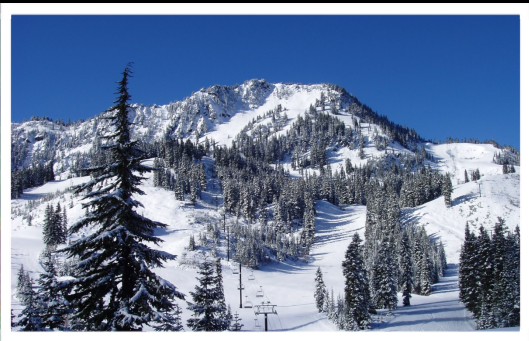
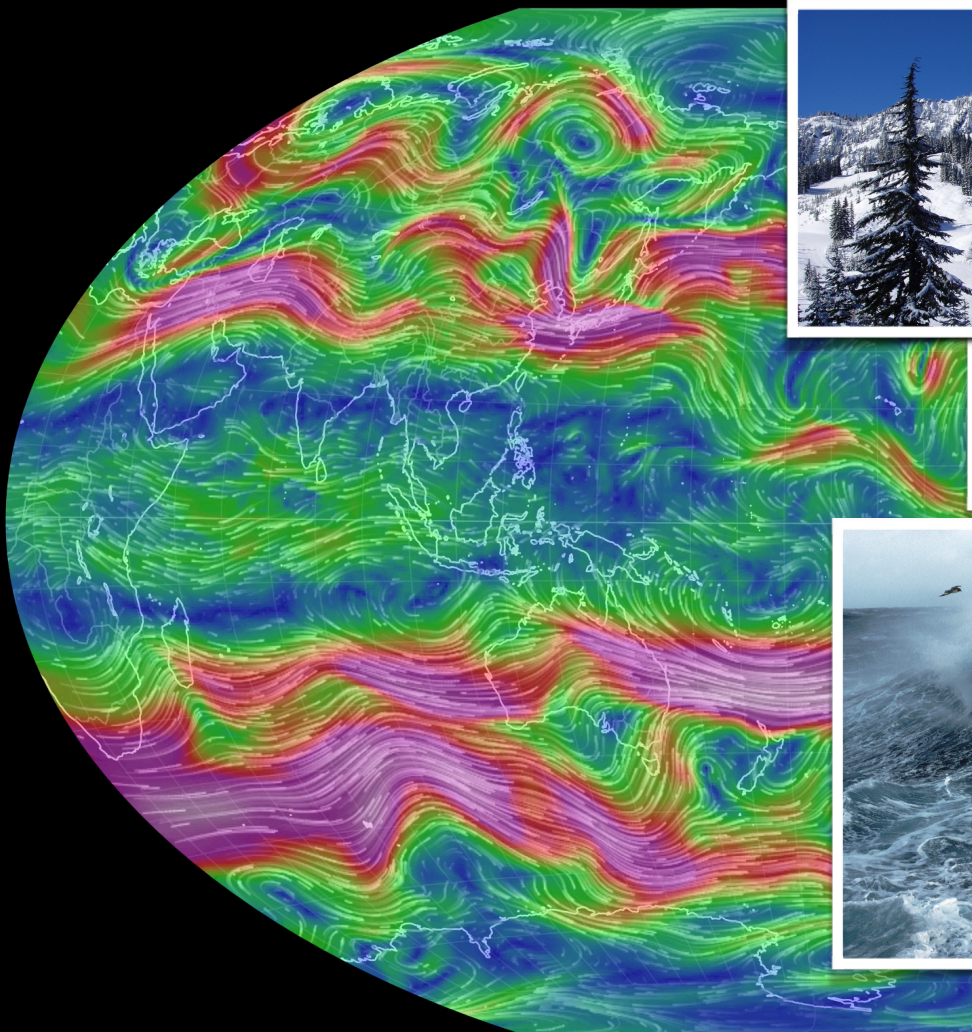


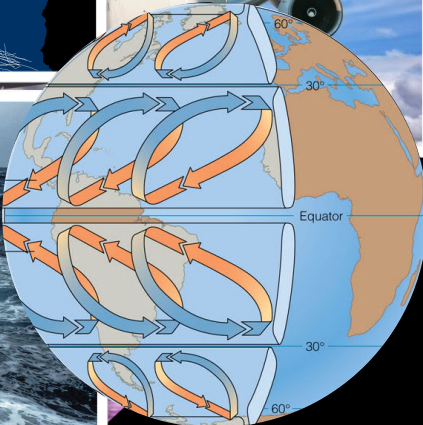
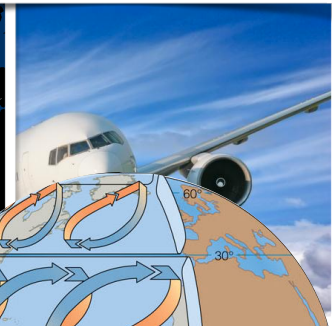
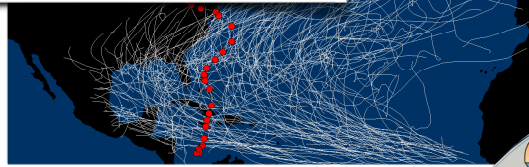
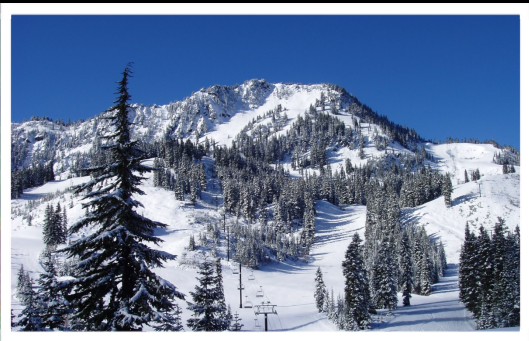
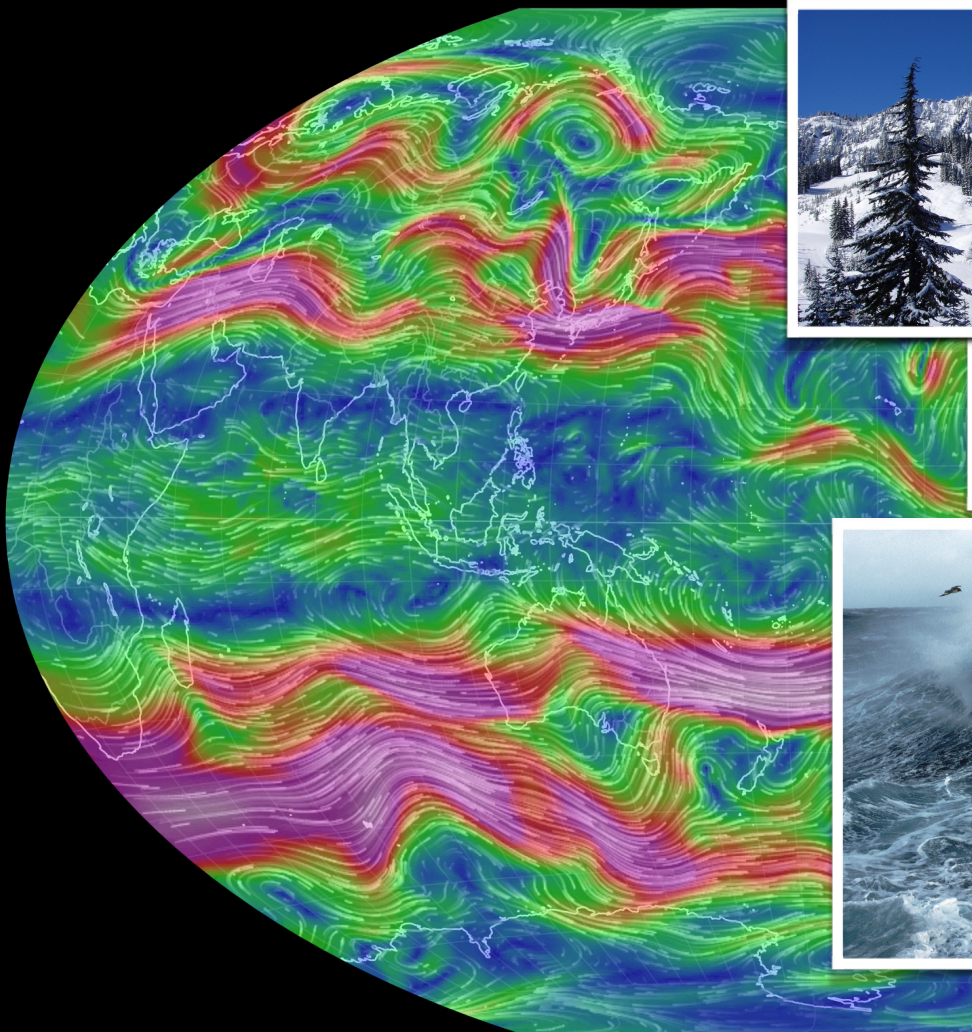


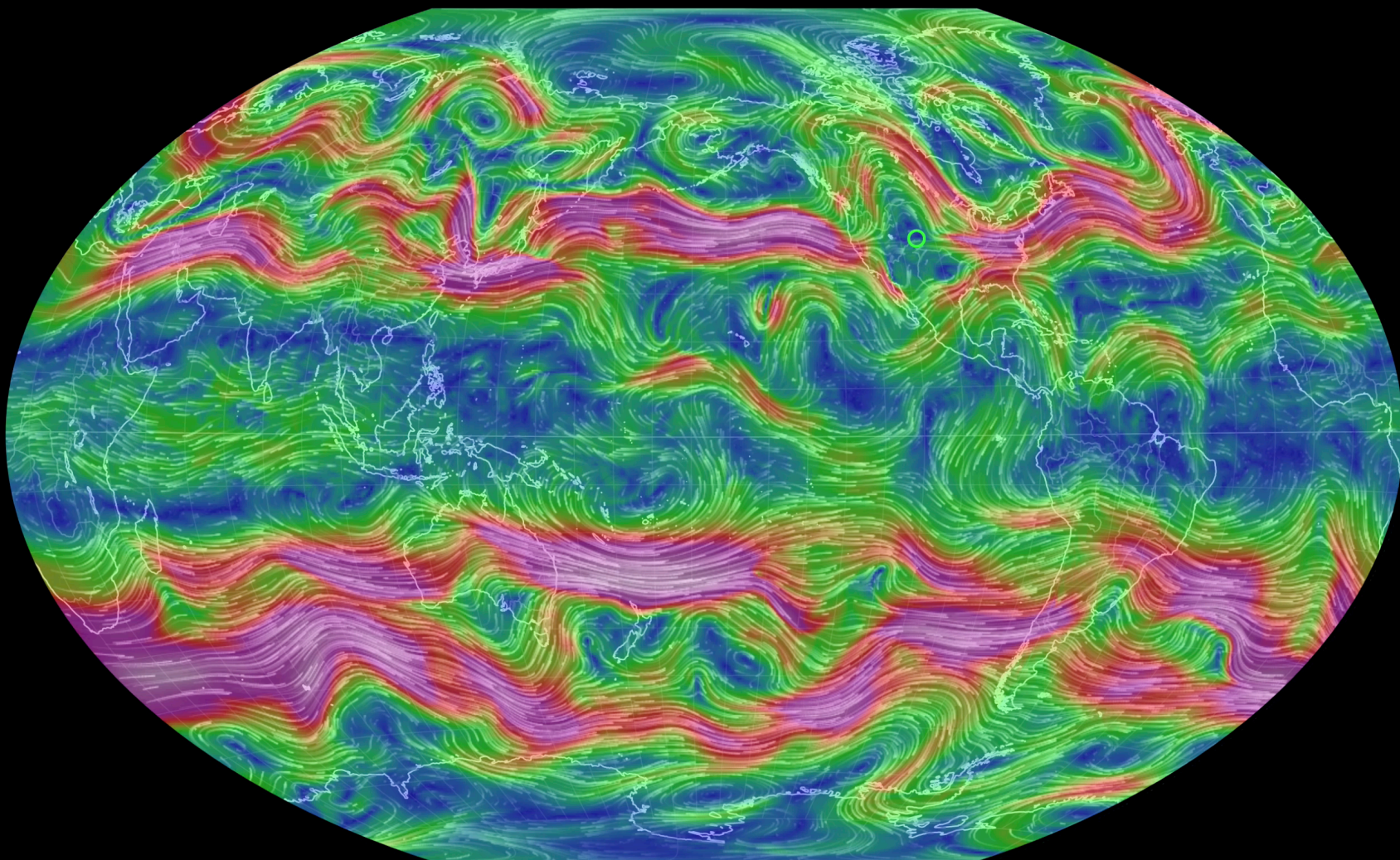


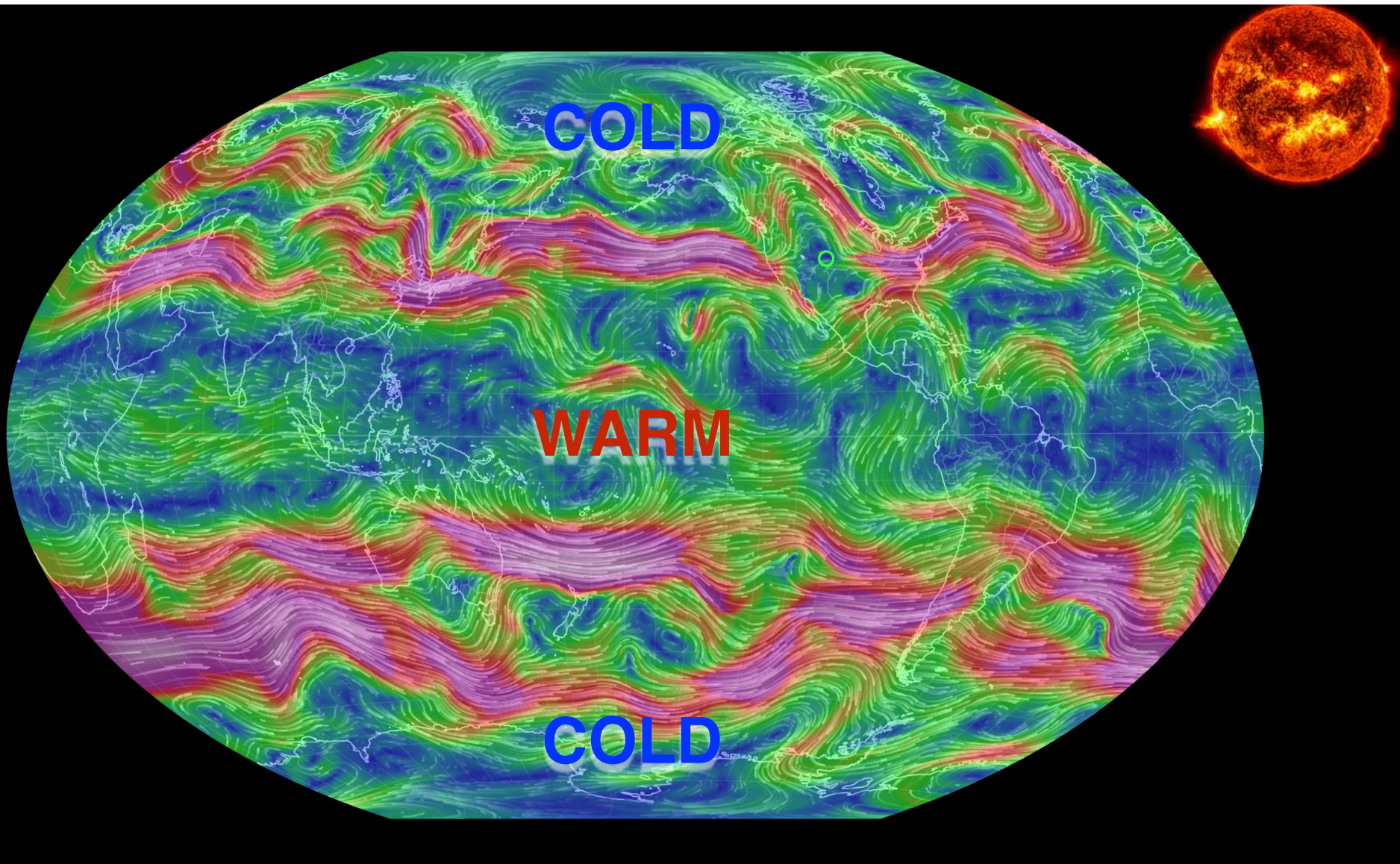


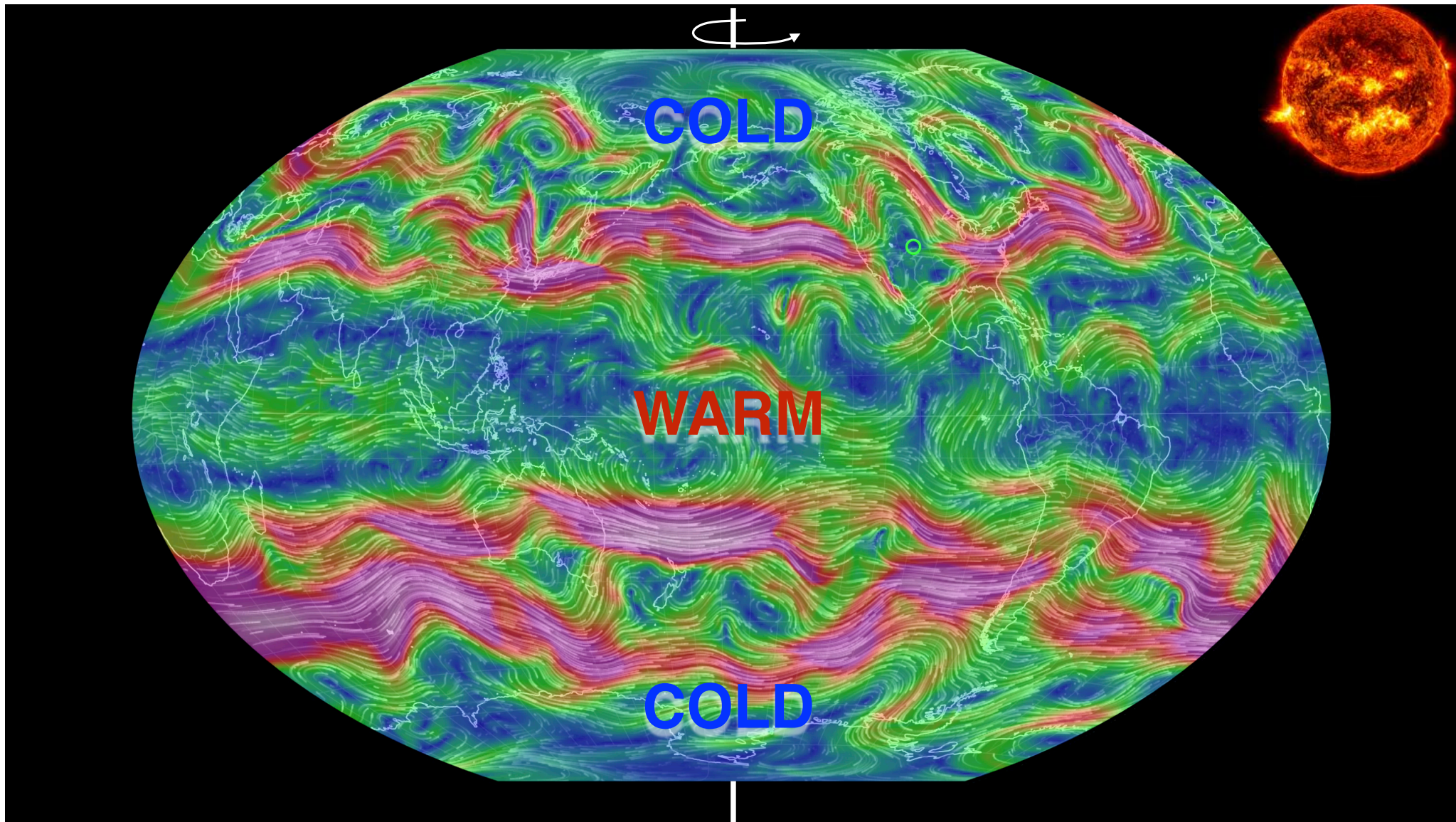




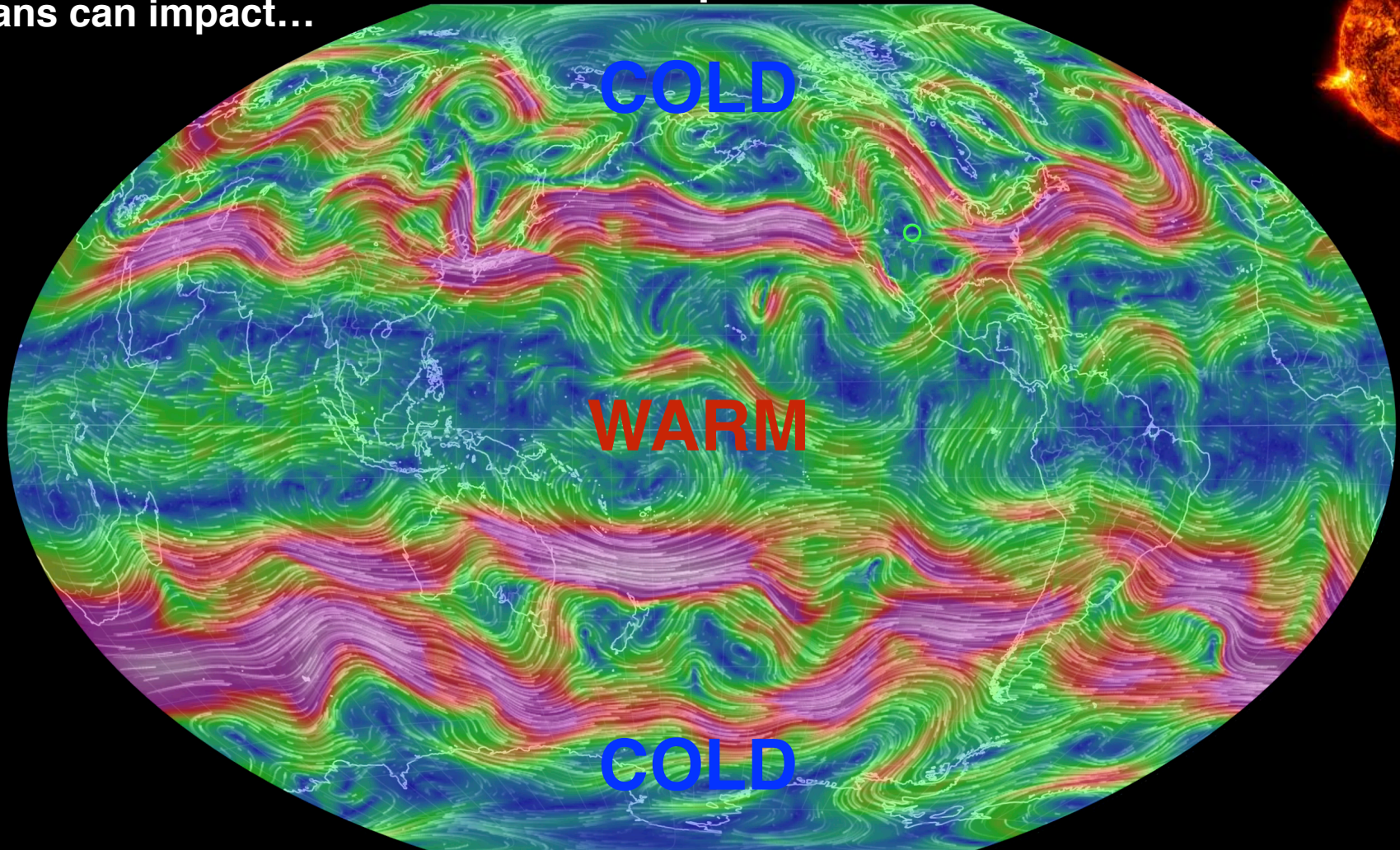
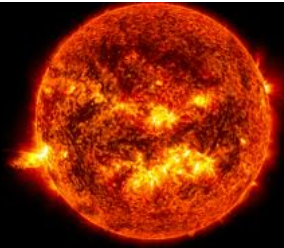




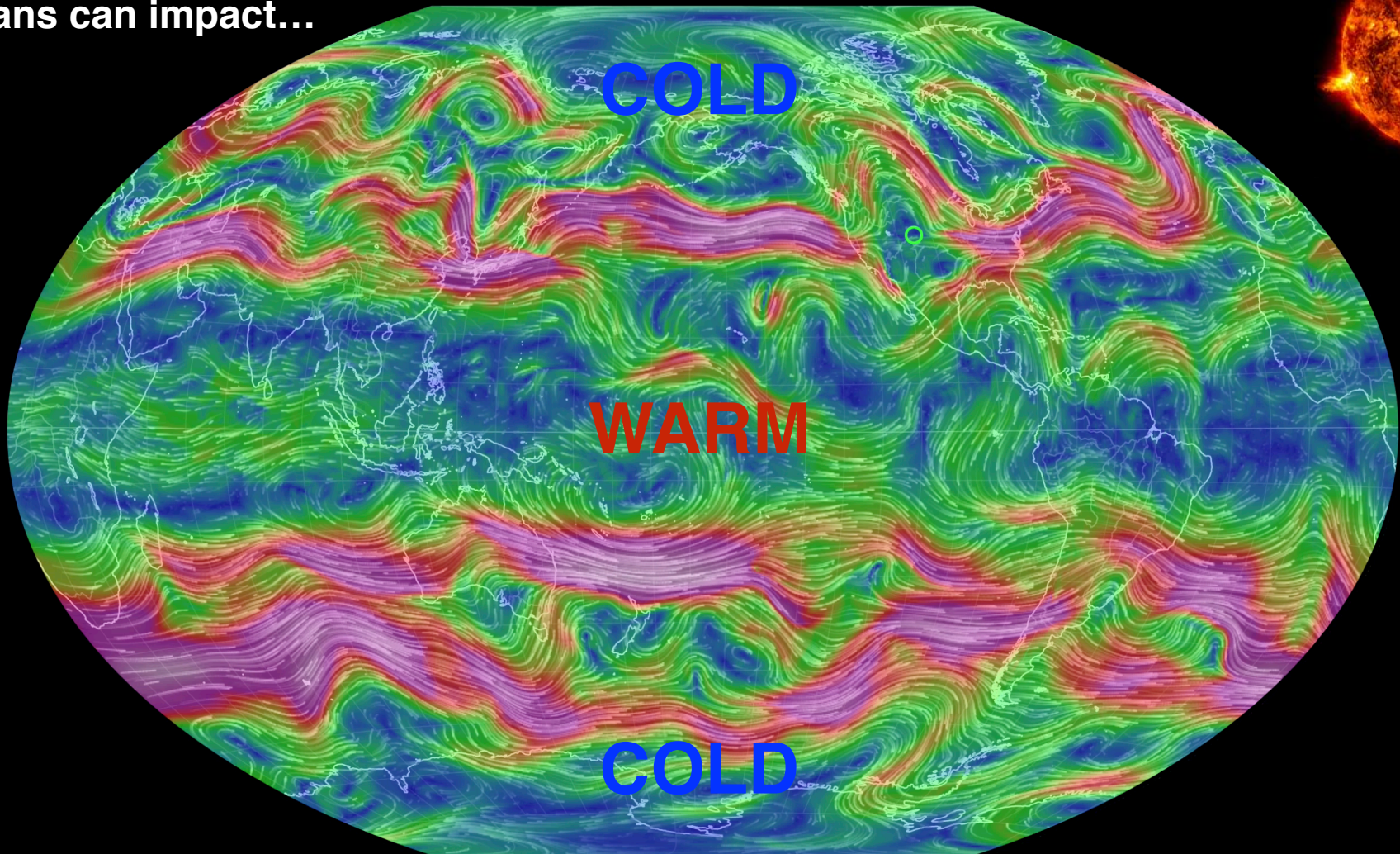




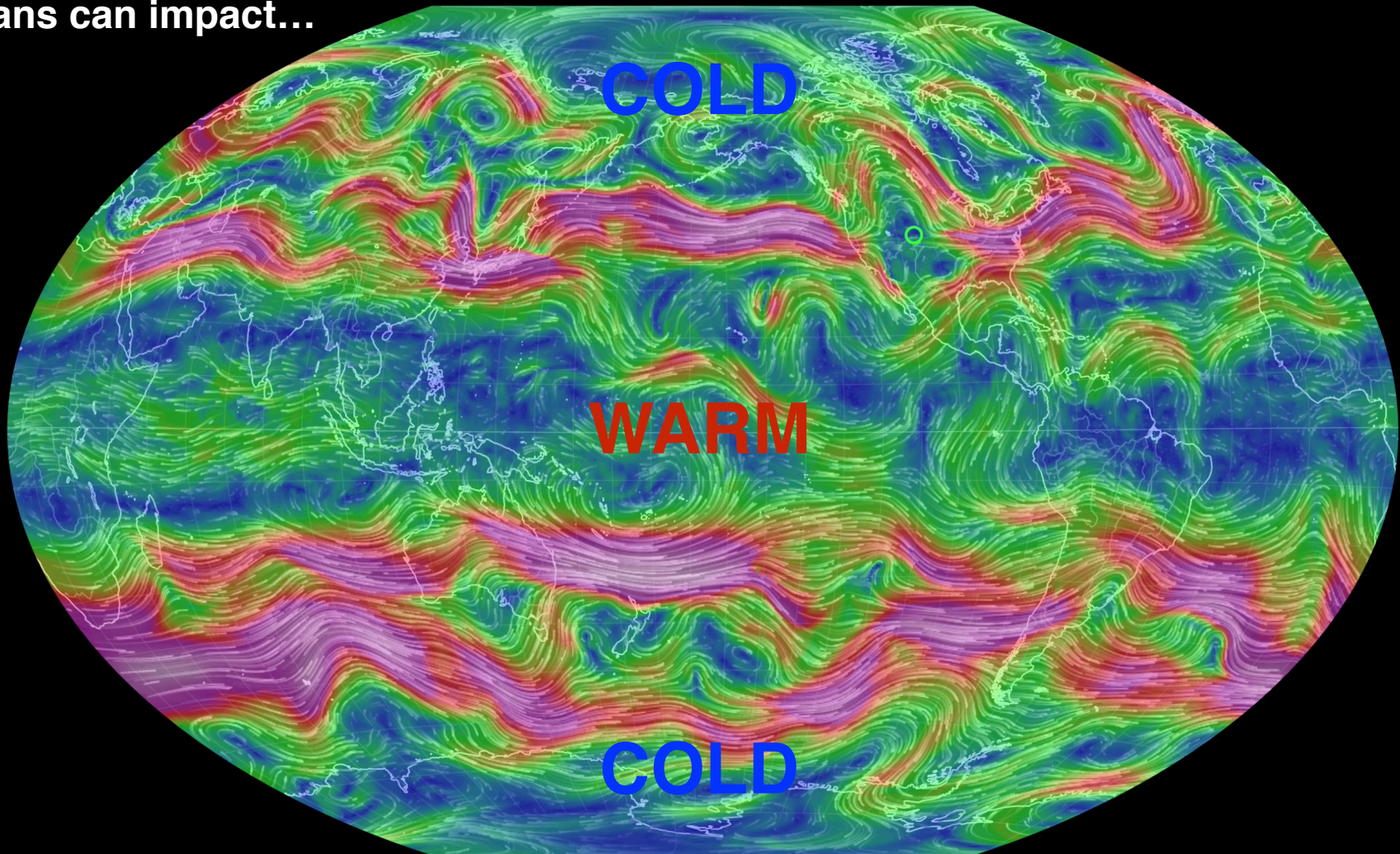
Humans can impact...

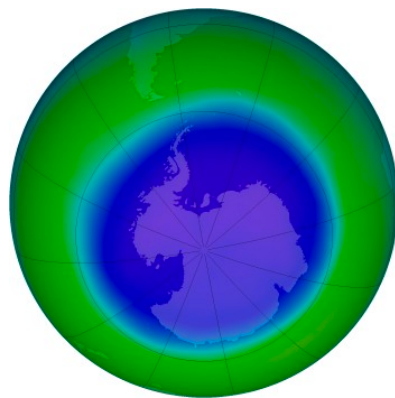


Humans can impact...

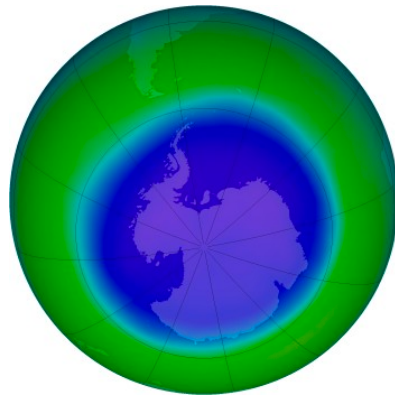


Humans can impact...

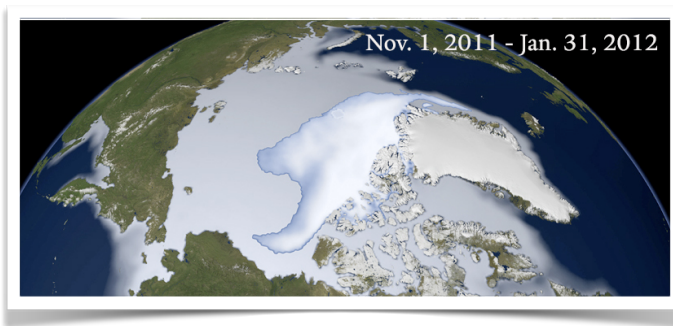




Southern Hemisphere Ozone Hole



Southern Hemisphere Ozone Hole



Arctic Sea Ice Loss

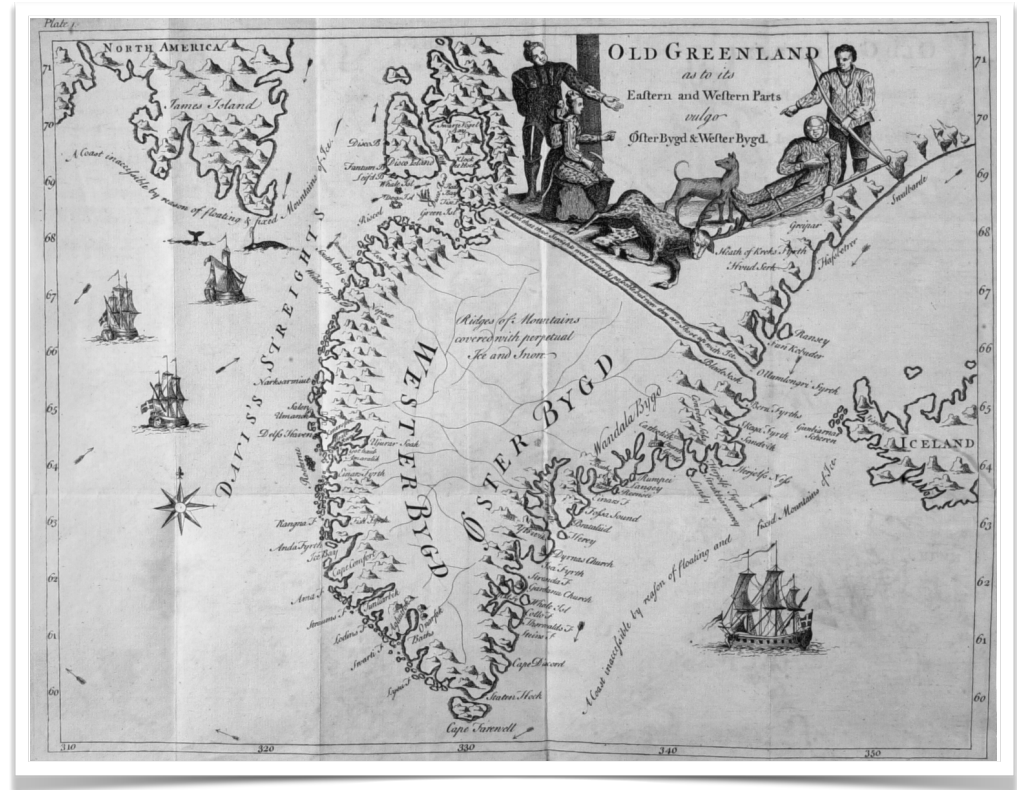
What's So Hard About This?

#1 There is a lot of noise.

#1 There is a lot of noise.

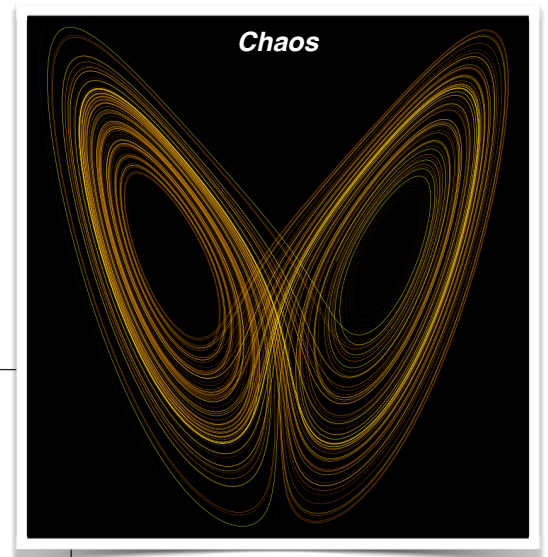
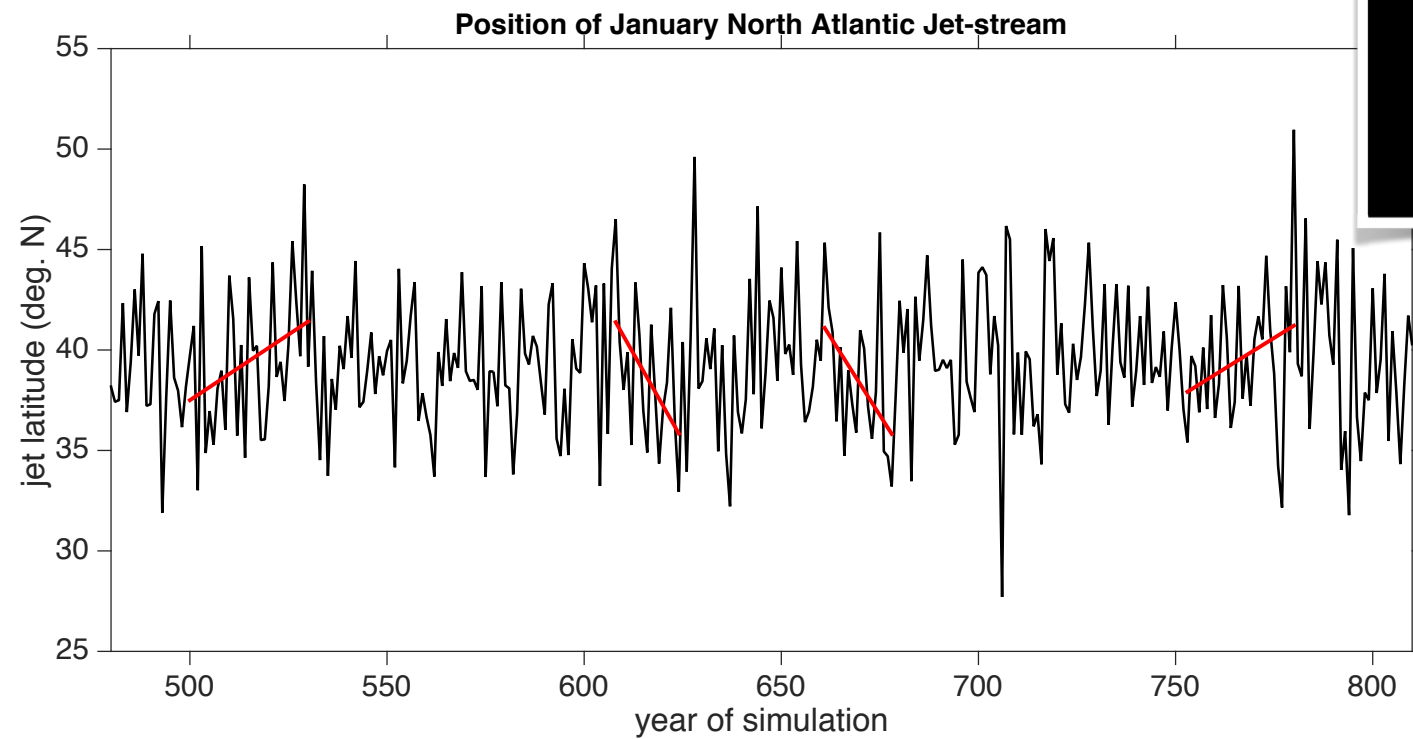
Konungs skuggsjá, King's Mirror
Norway, 1230 AD

“...it is in the nature of the glacier to emit a cold and continuous breath which drives the storm clouds away...But the neighboring lands often have to suffer...inasmuch as all the storms the glacier drives away from itself come upon others with keen blasts.”



Stephenson et al. (2003)

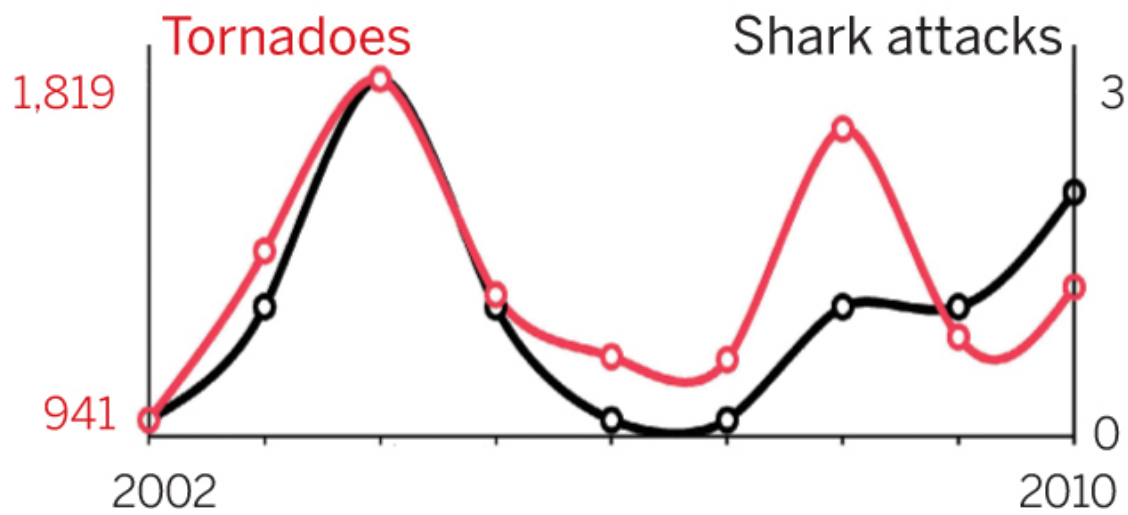
#1 There is a lot of noise.



*1850 climate model simulation
of CESM; Kay et al. (2015; BAMS)*

#2 Correlation \neq causation.

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Spurious Correlations; Tyler Vigen

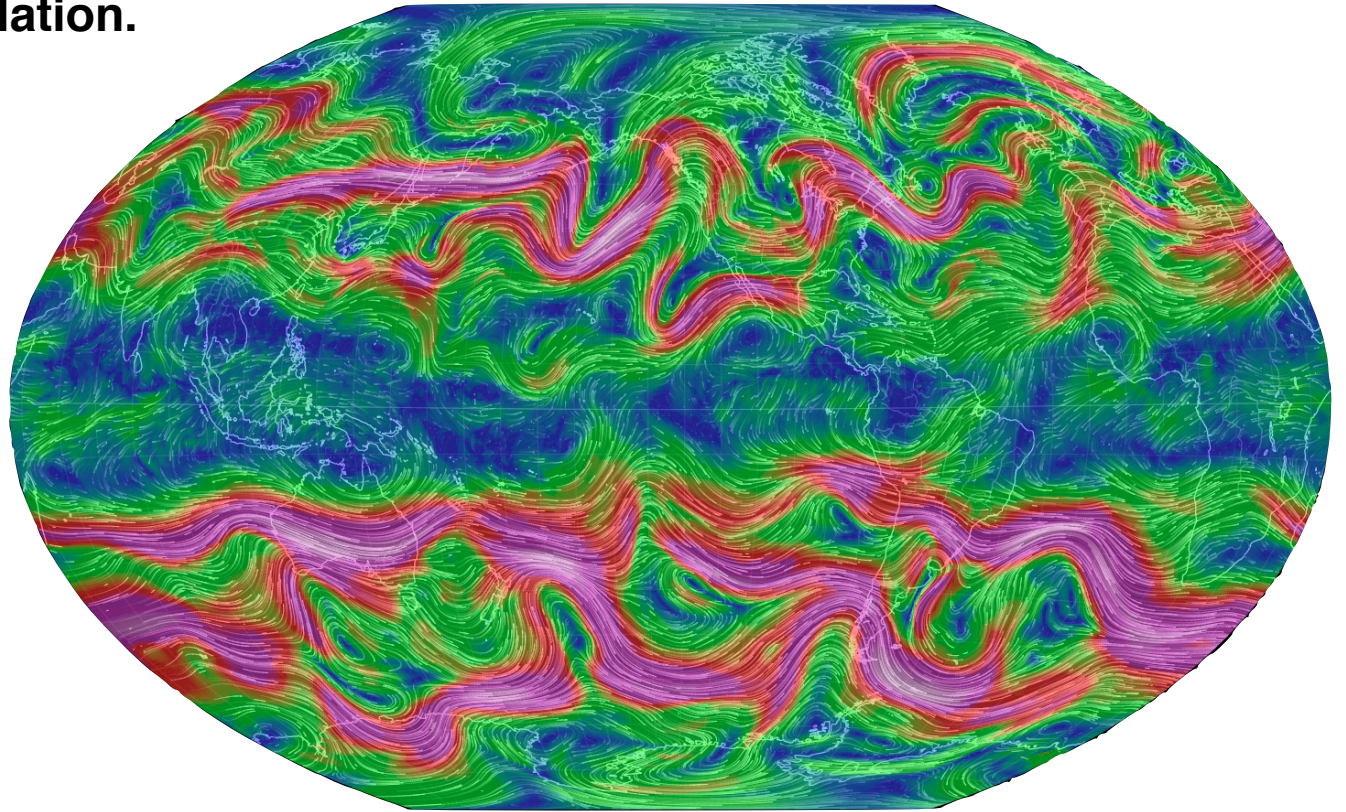
#2 Correlation \neq causation.



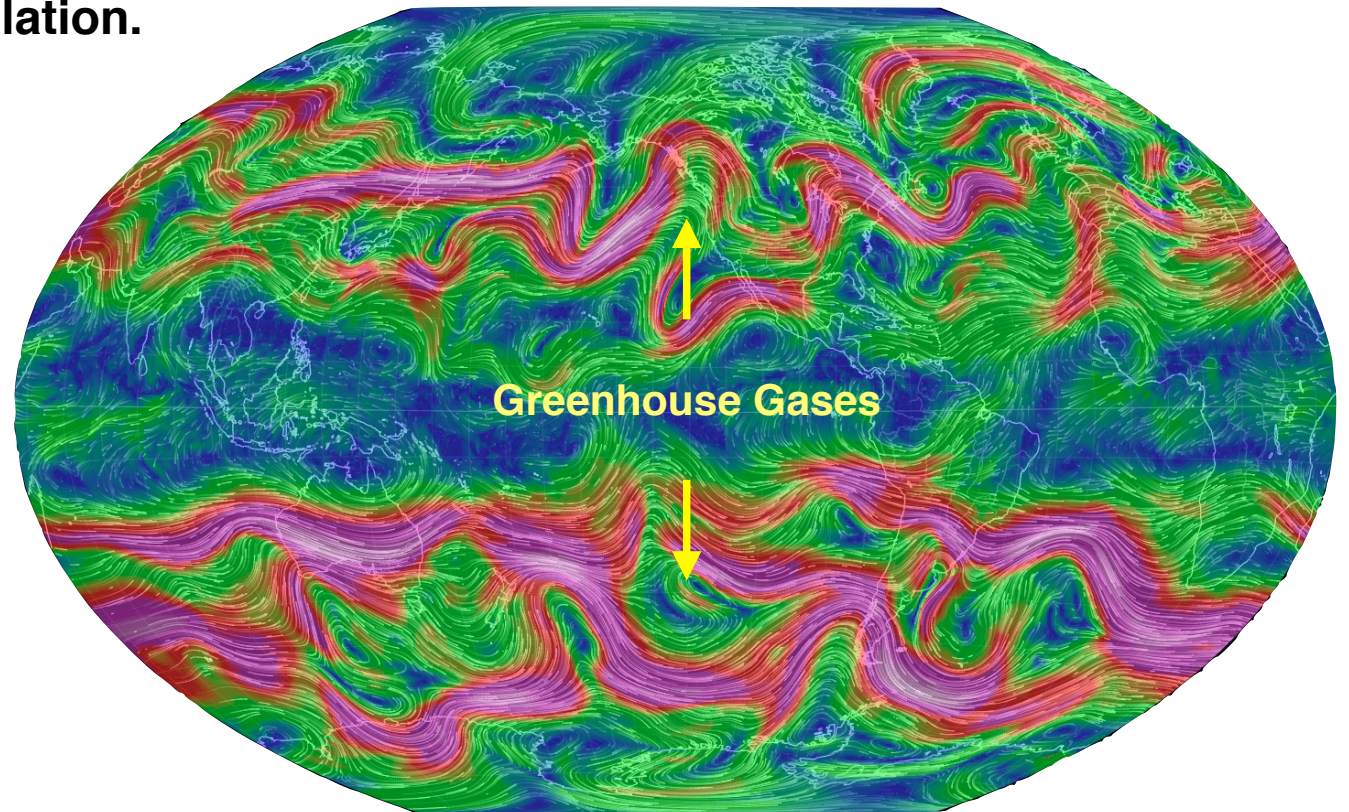
Family Circus

#3 Drivers don't act in isolation.

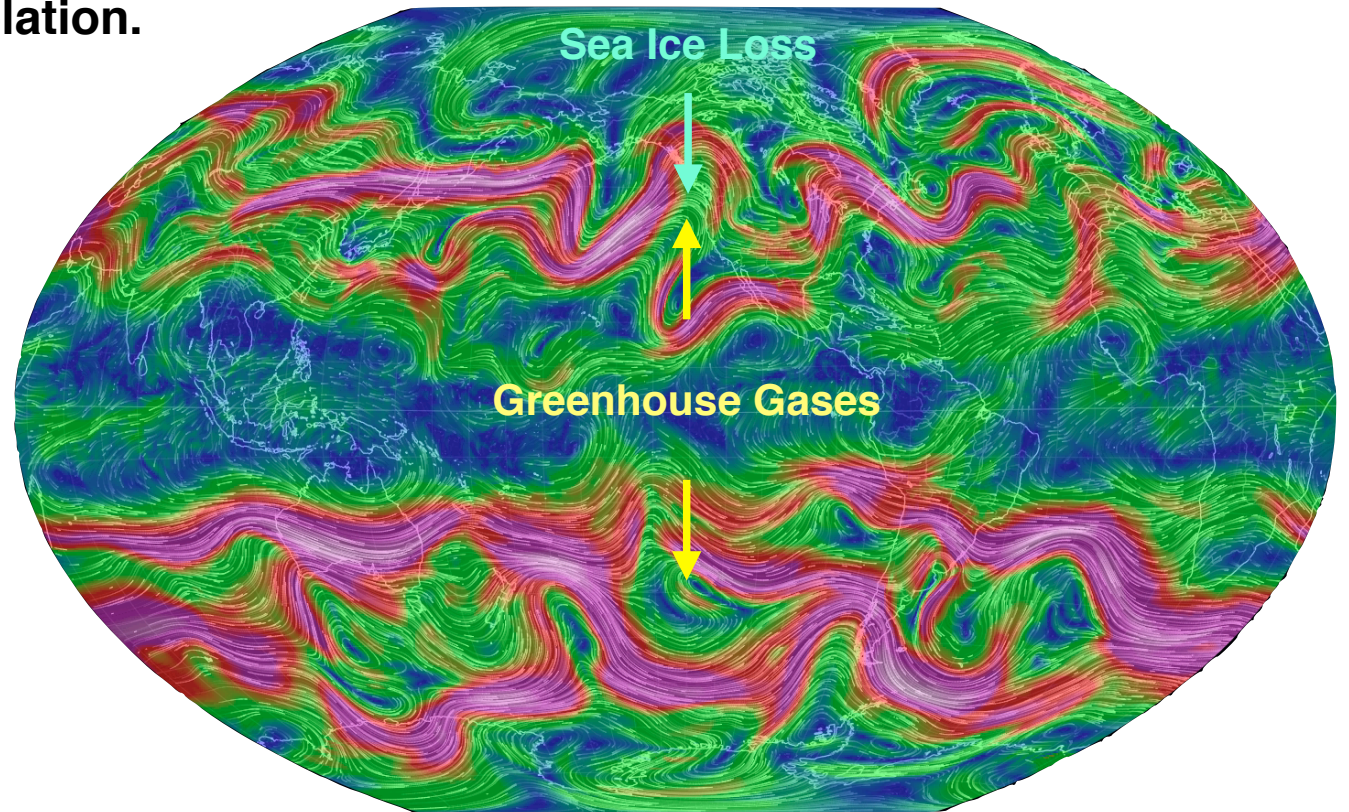
#3 Drivers don't act in isolation.



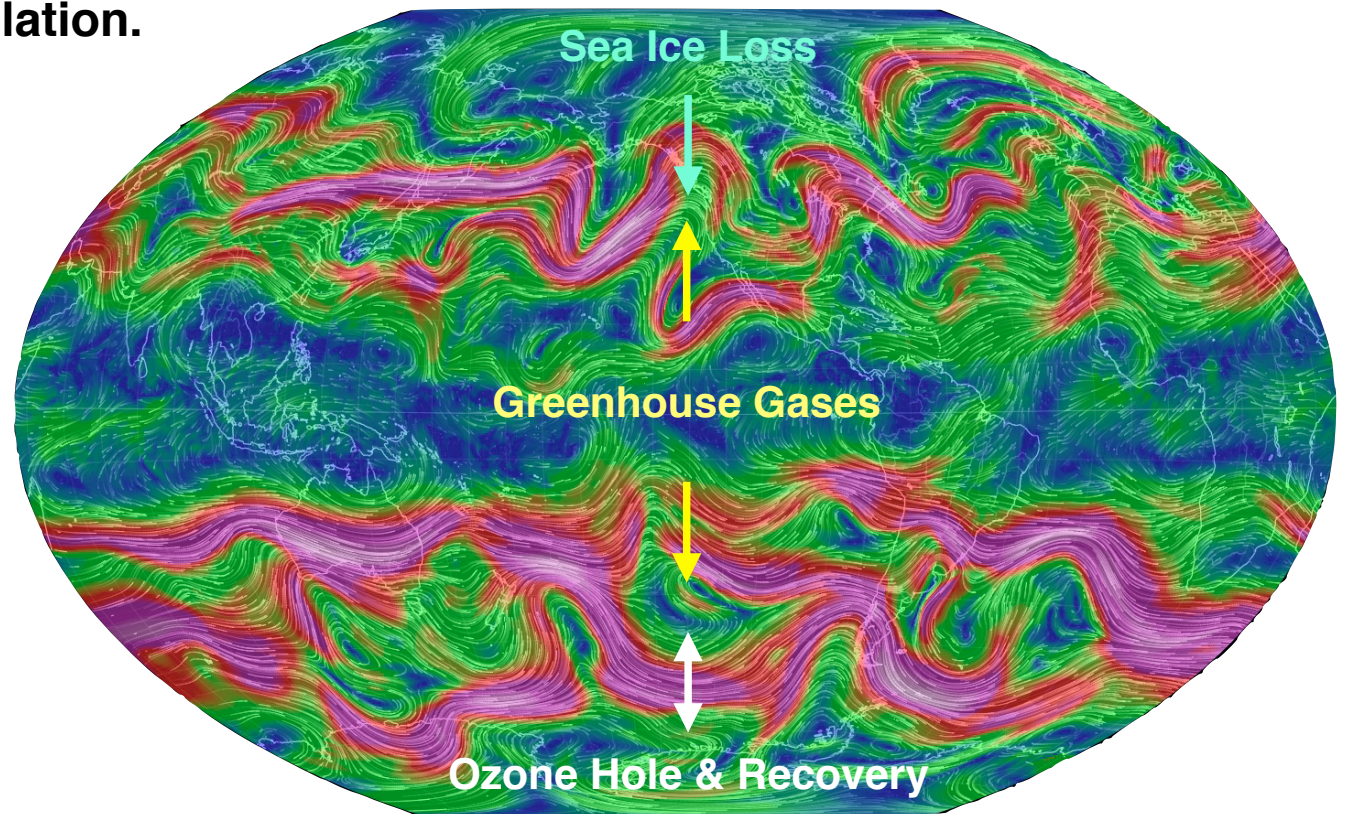
#3 Drivers don't act in isolation.



#3 Drivers don't act in isolation.



#3 Drivers don't act in isolation.



Three Questions

Three Questions

Can it?

Three Questions

Can it?

Has it?

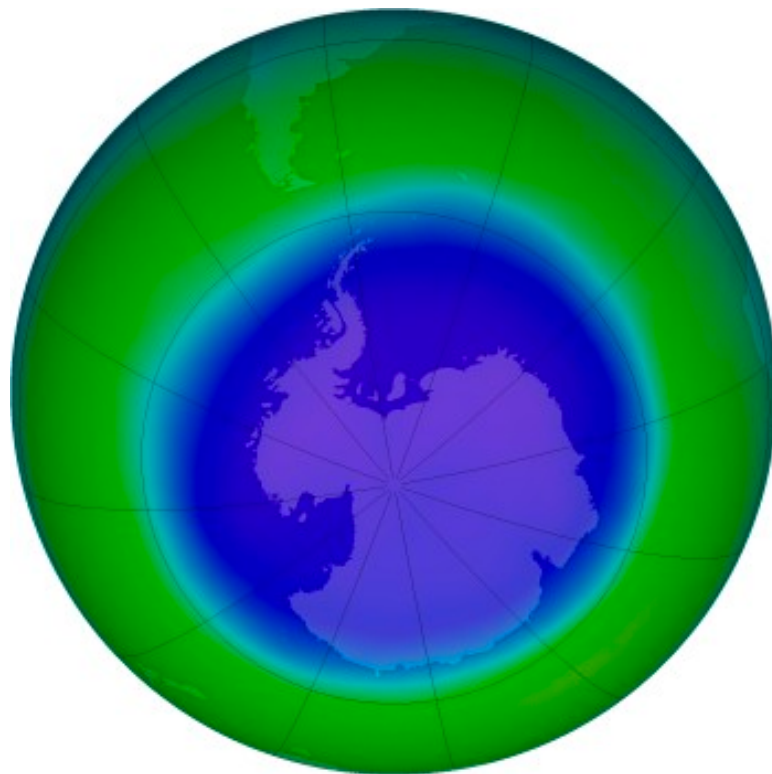
Three Questions

Can it?

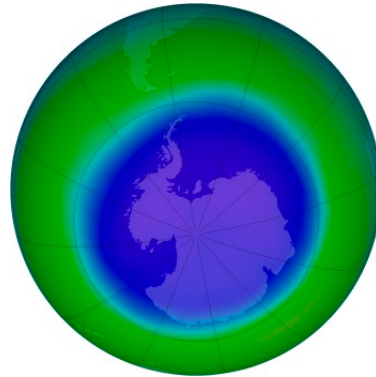
Has it?

Will it?

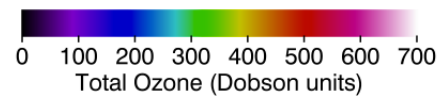
The Ozone Hole



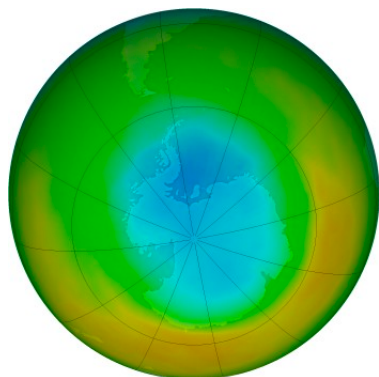
The Ozone Hole



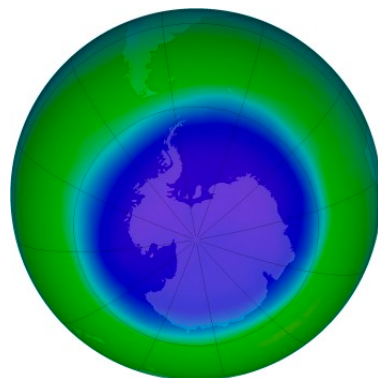
Sep. 2006



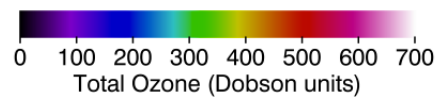
The Ozone Hole



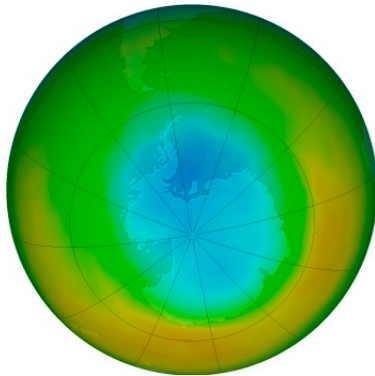
Sep. 1979



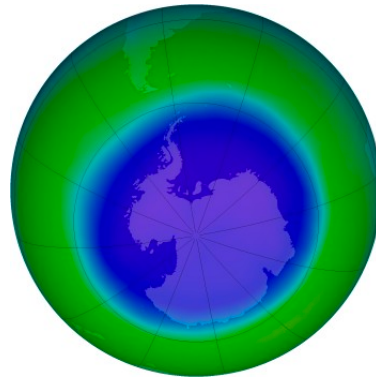
Sep. 2006



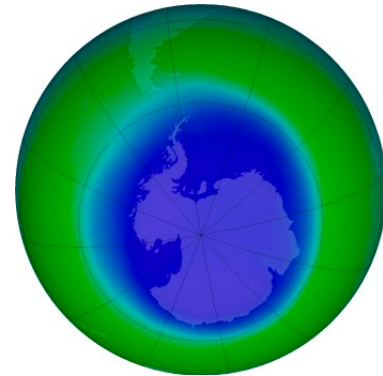
The Ozone Hole



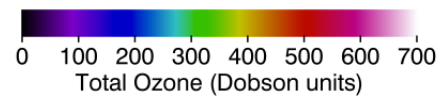
Sep. 1979



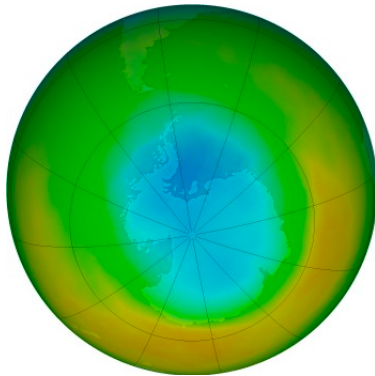
Sep. 2006



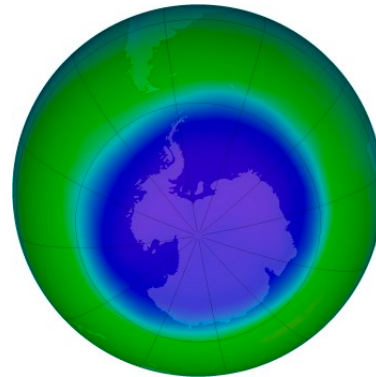
Sep. 2015



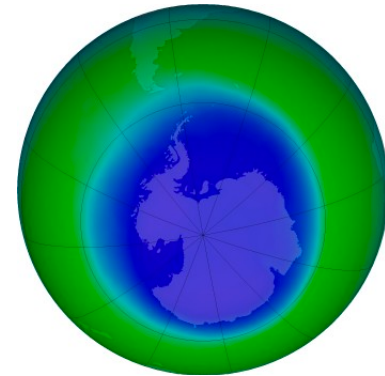
The Ozone Hole



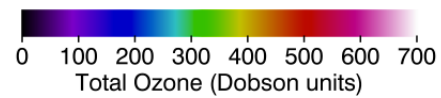
Sep. 1979



Sep. 2006

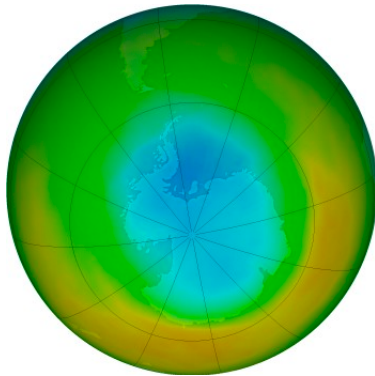


Sep. 2015

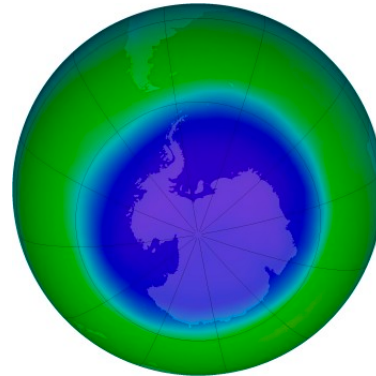


The Ozone Hole

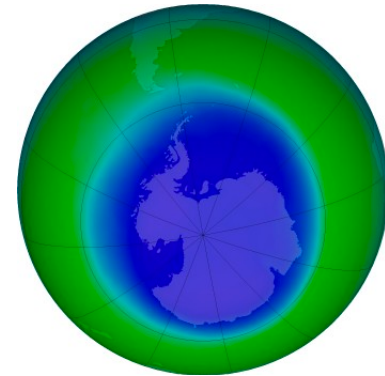
1988 Montreal Protocol
(signed by 40+ countries including the U.S.)



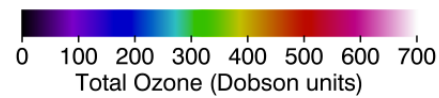
Sep. 1979



Sep. 2006

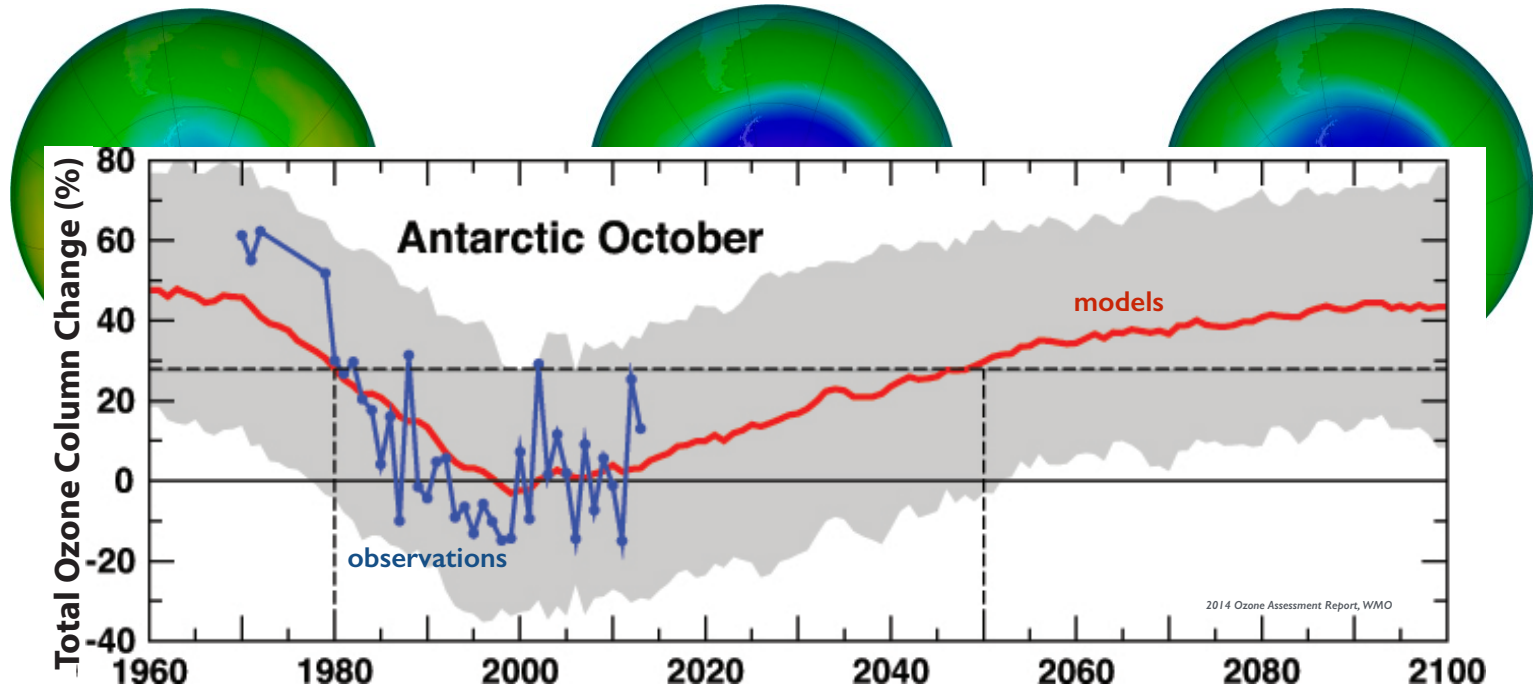


Sep. 2015



The Ozone Hole

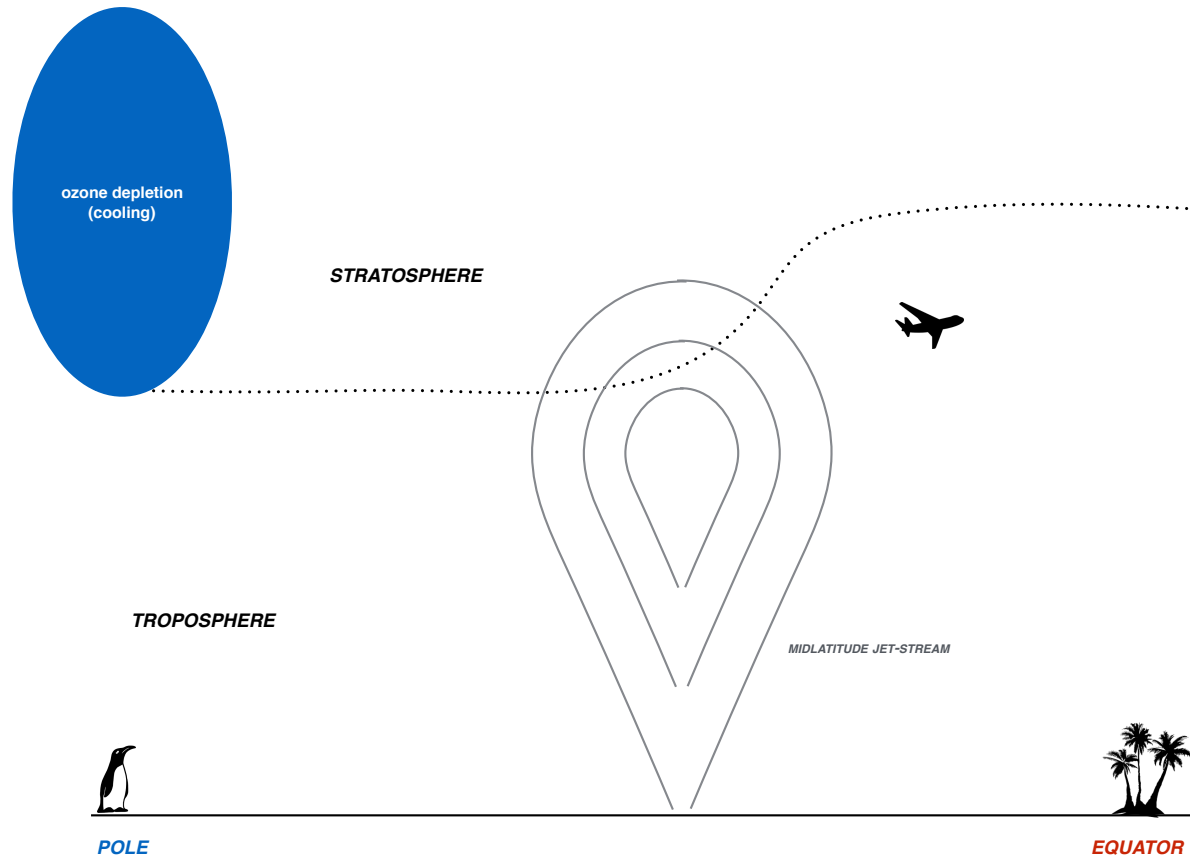
1988 Montreal Protocol
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images from NASA Ozone Hole Watch

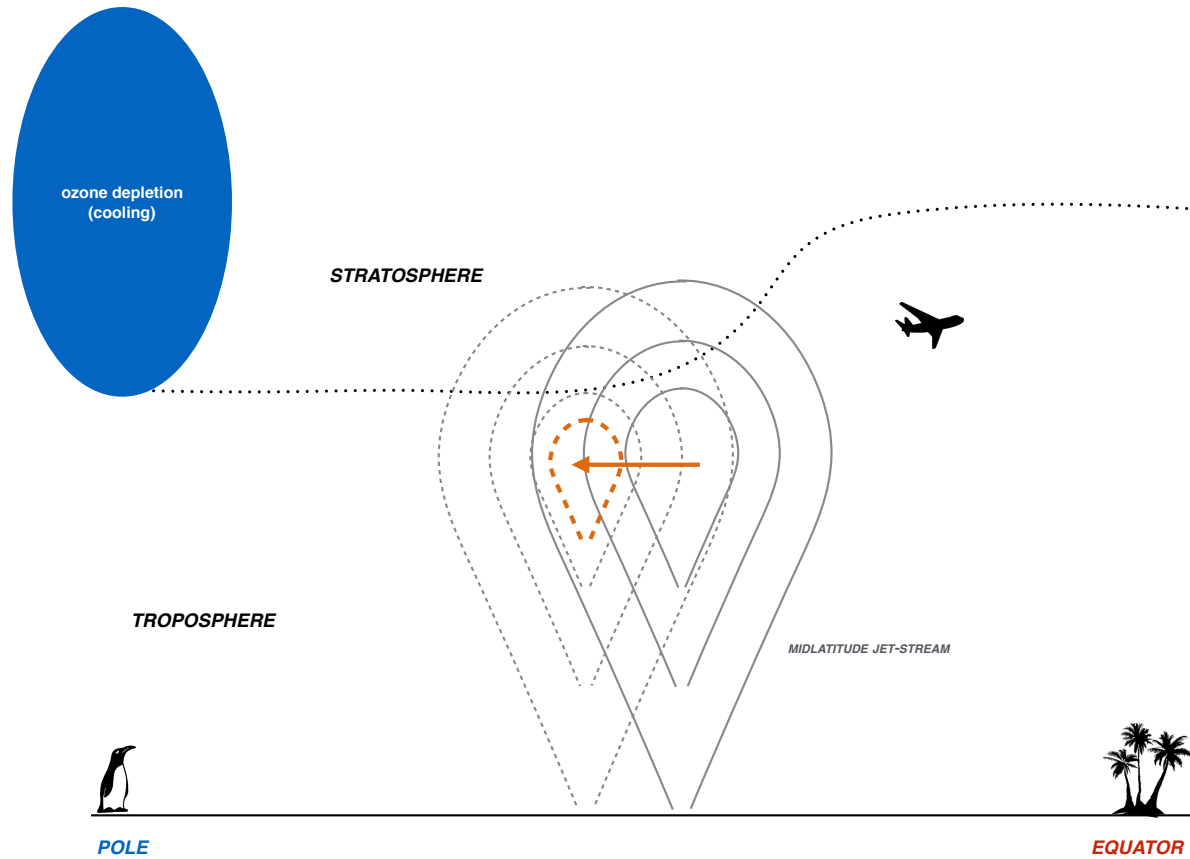
Can it?

Can ozone depletion impact the jet-streams?



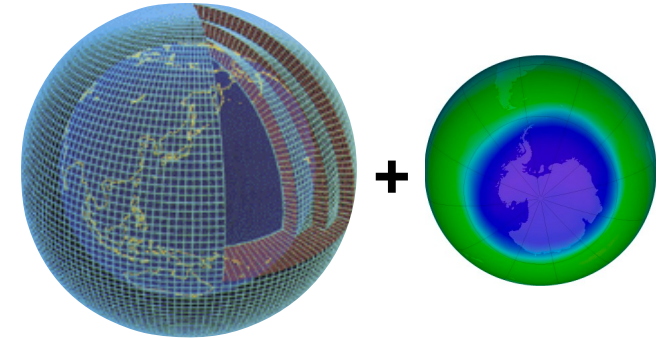
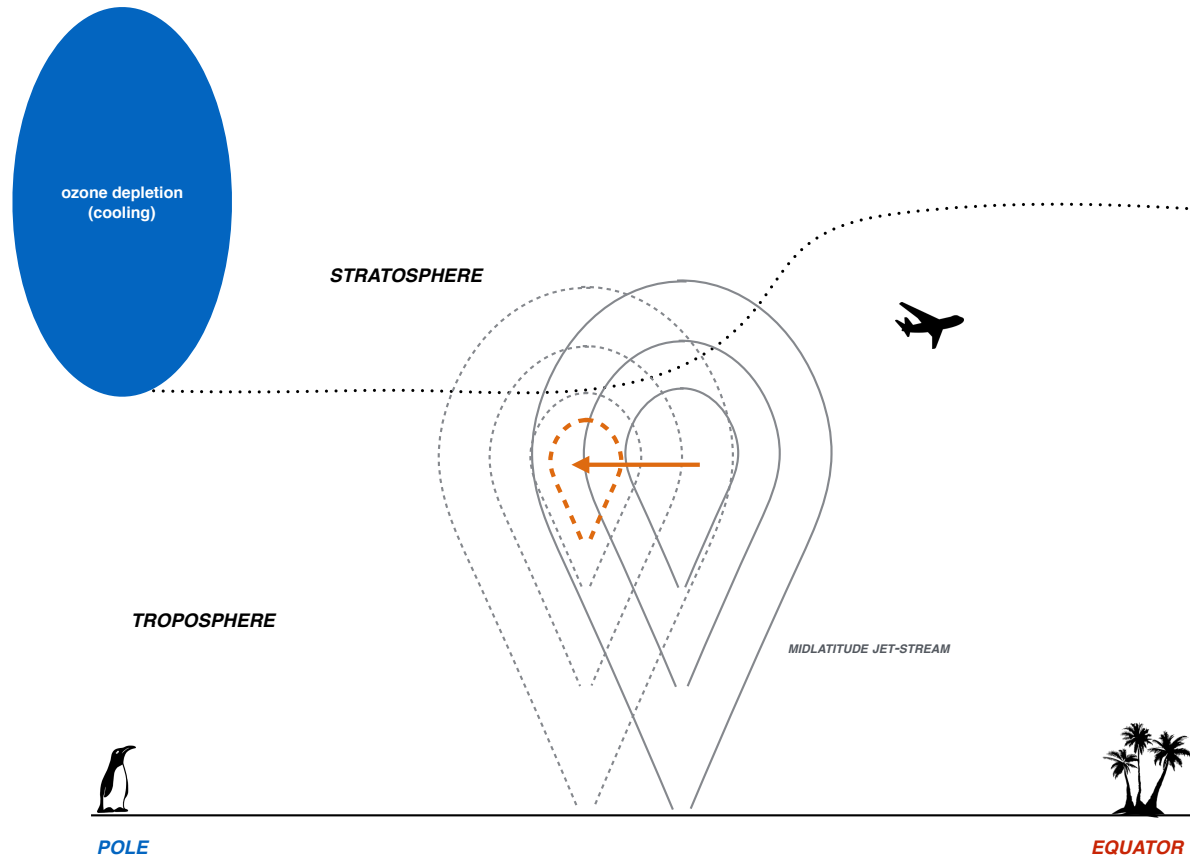
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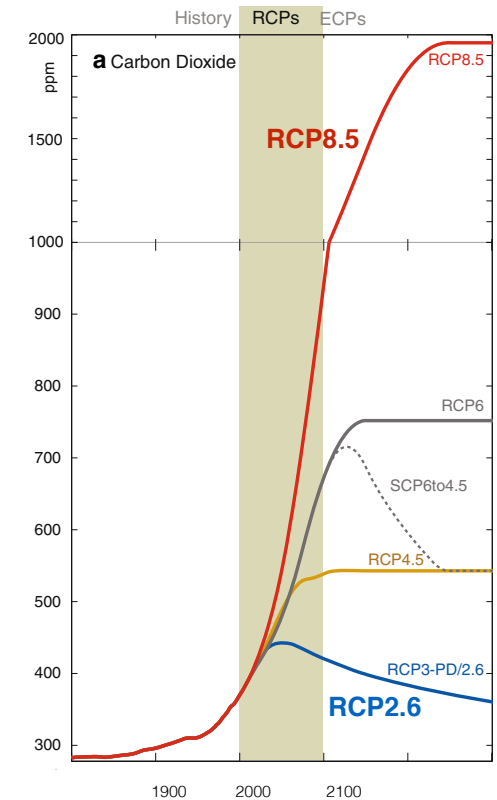
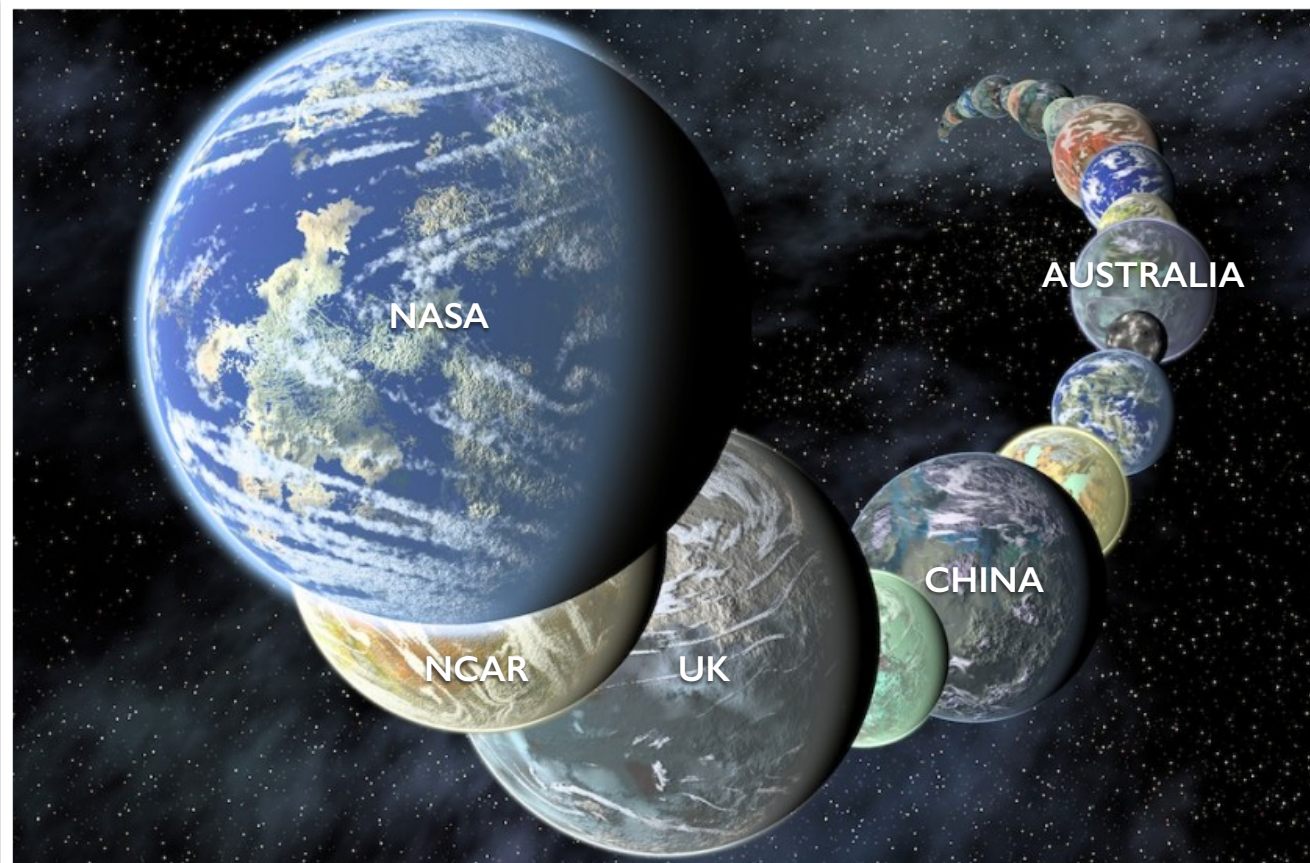
Can it?

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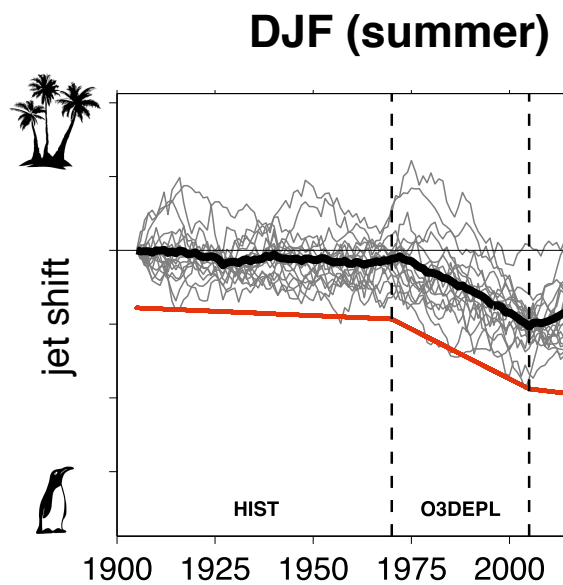
Has it?

Has ozone depletion impacted the jet-streams?



Has it?

Has ozone depletion impacted the jet-streams?

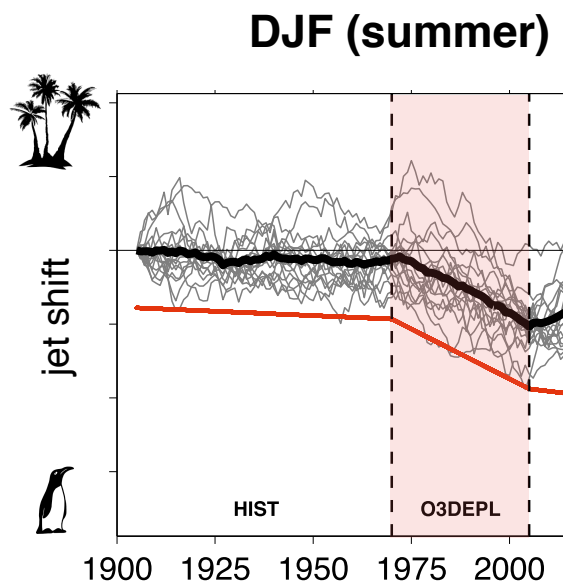


Barnes, Barnes et. al, 2014; Journal of Climate

images from NASA Ozone Hole Watch

Has it?

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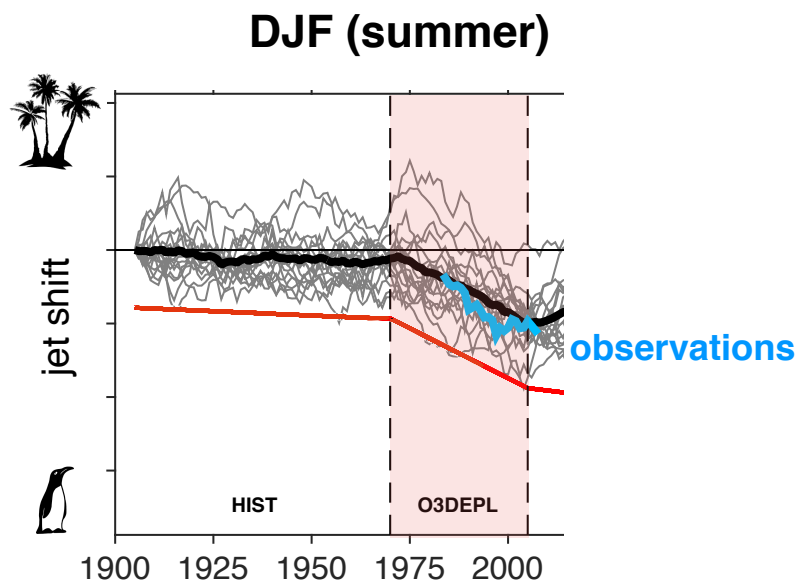


Barnes, Barnes et. al, 2014; Journal of Climate

images from NASA Ozone Hole Watch

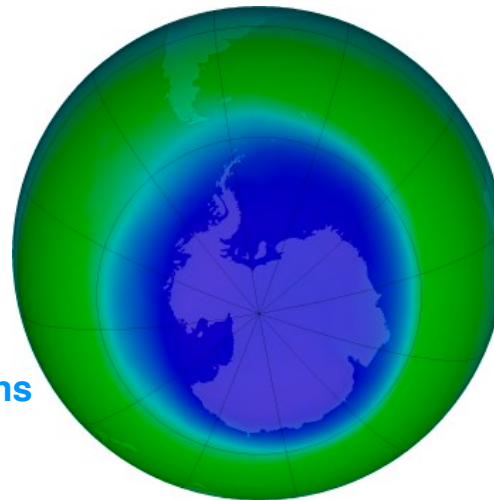
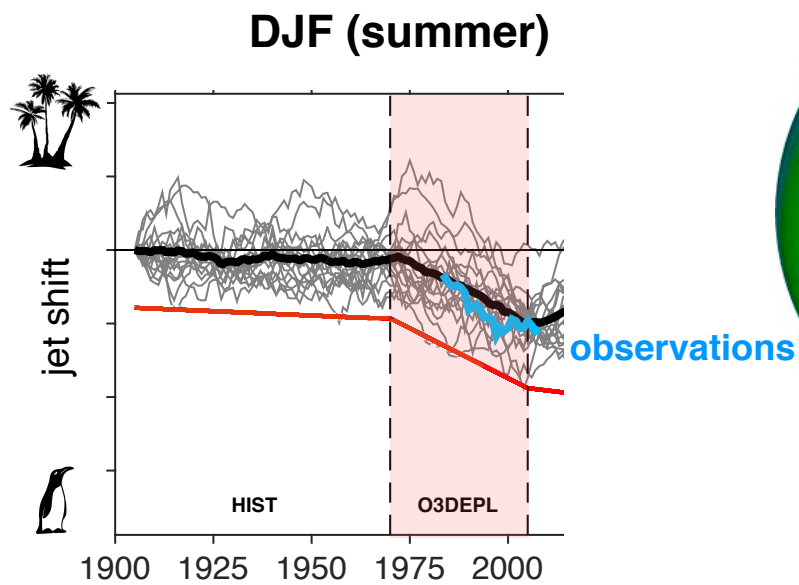
Has it?

Has ozone depletion impacted the jet-streams?

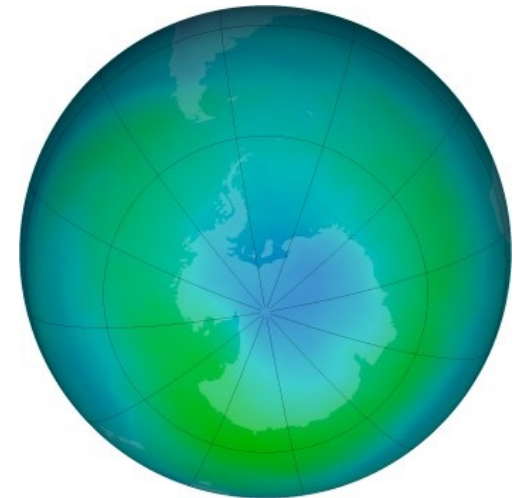


Has it?

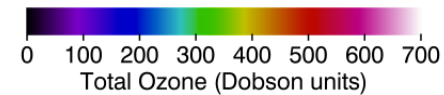
Has ozone depletion impacted the jet-streams?



Sep. 2015



Mar. 2015

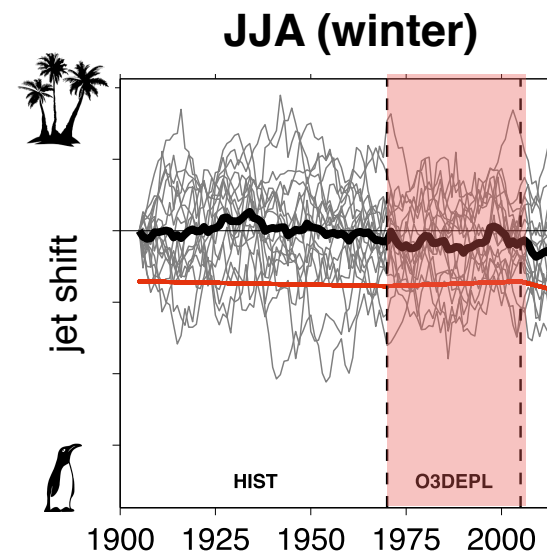
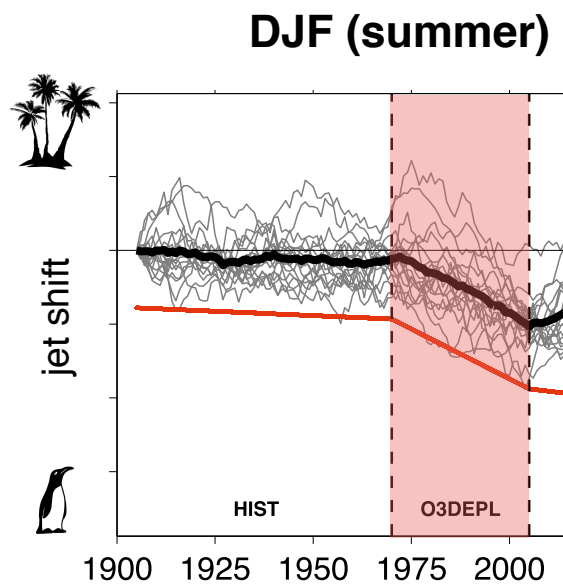


Barnes, Barnes et. al, 2014; Journal of Climate

images from NASA Ozone Hole Watch

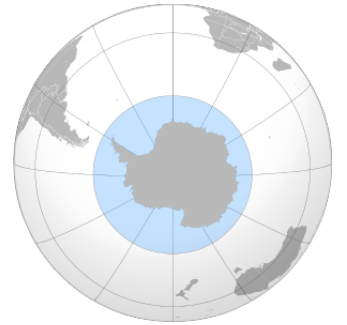
Has it?

Has ozone depletion impacted the jet-streams?



Has it?

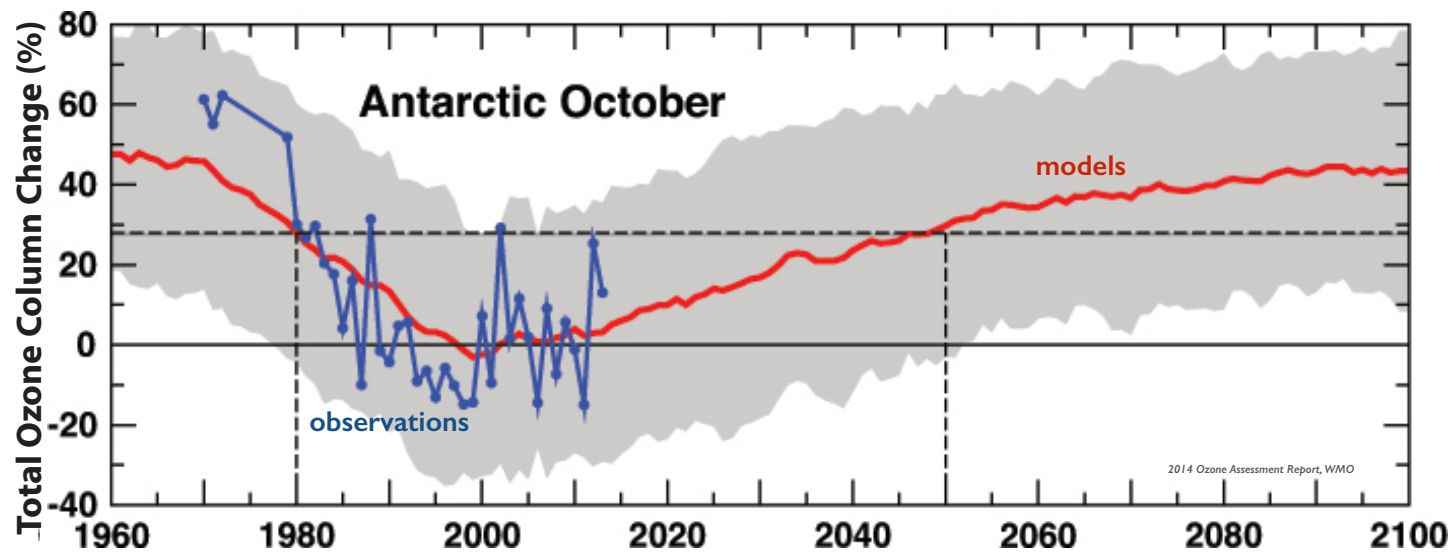
Has ozone depletion impacted the jet-streams?



wind changes over the
Southern Ocean may have
led to changes in ocean
circulation

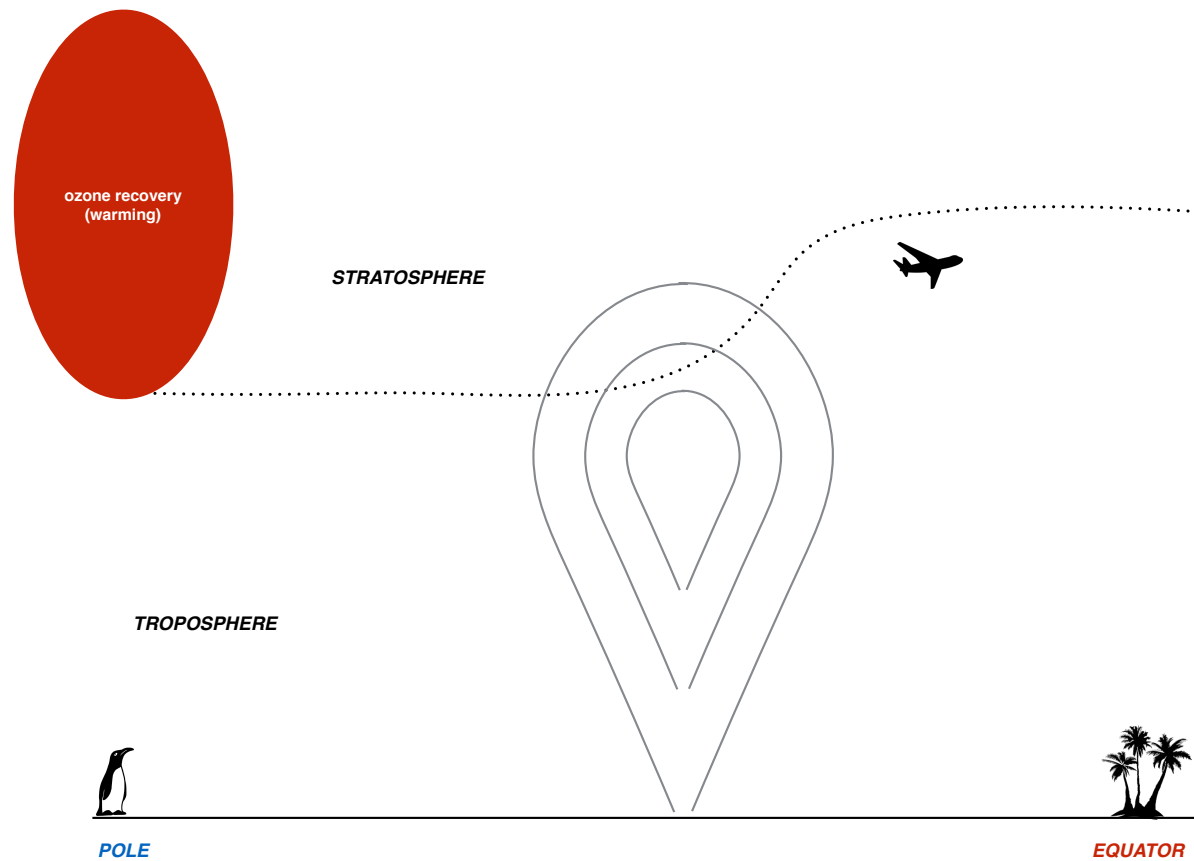
Will it?

Will ozone depletion impact the jet-streams?



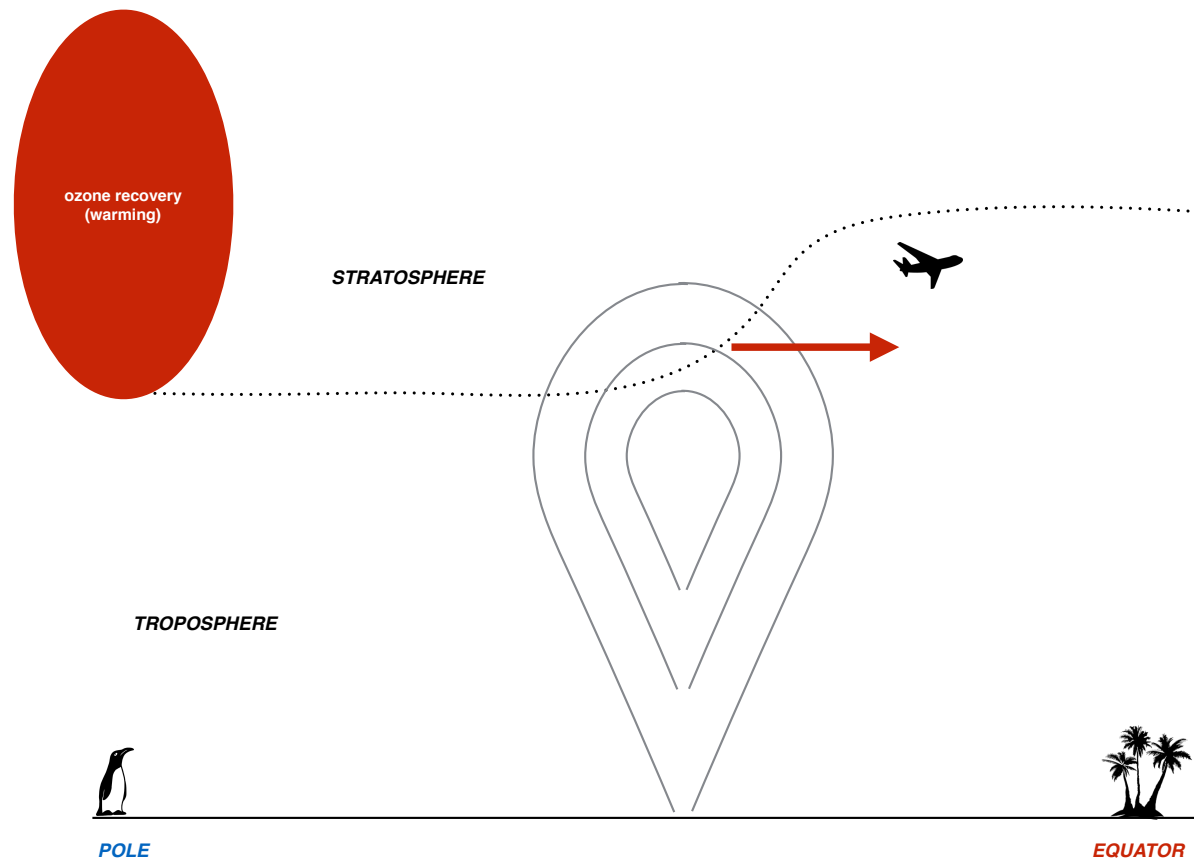
Will it?

Will ozone depletion impact the jet-streams?



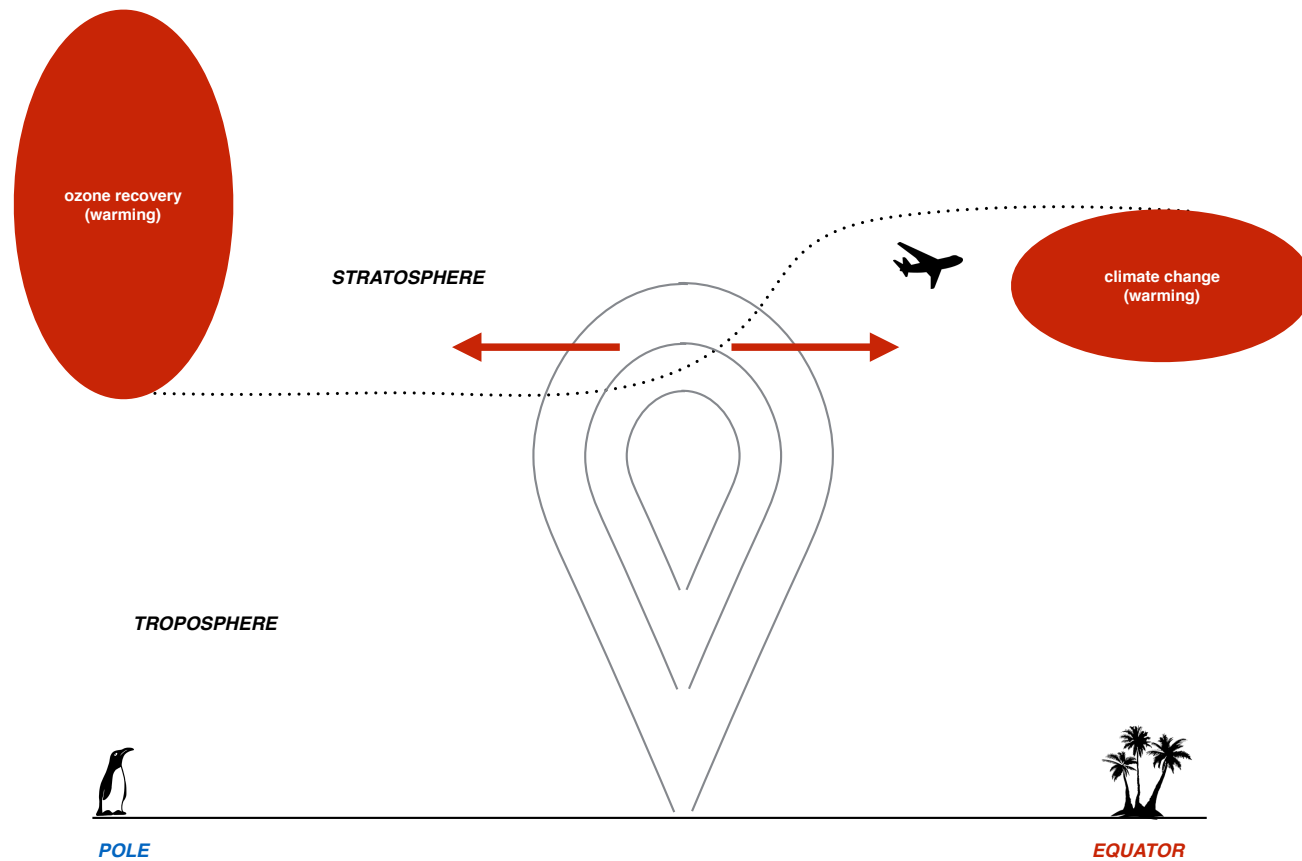
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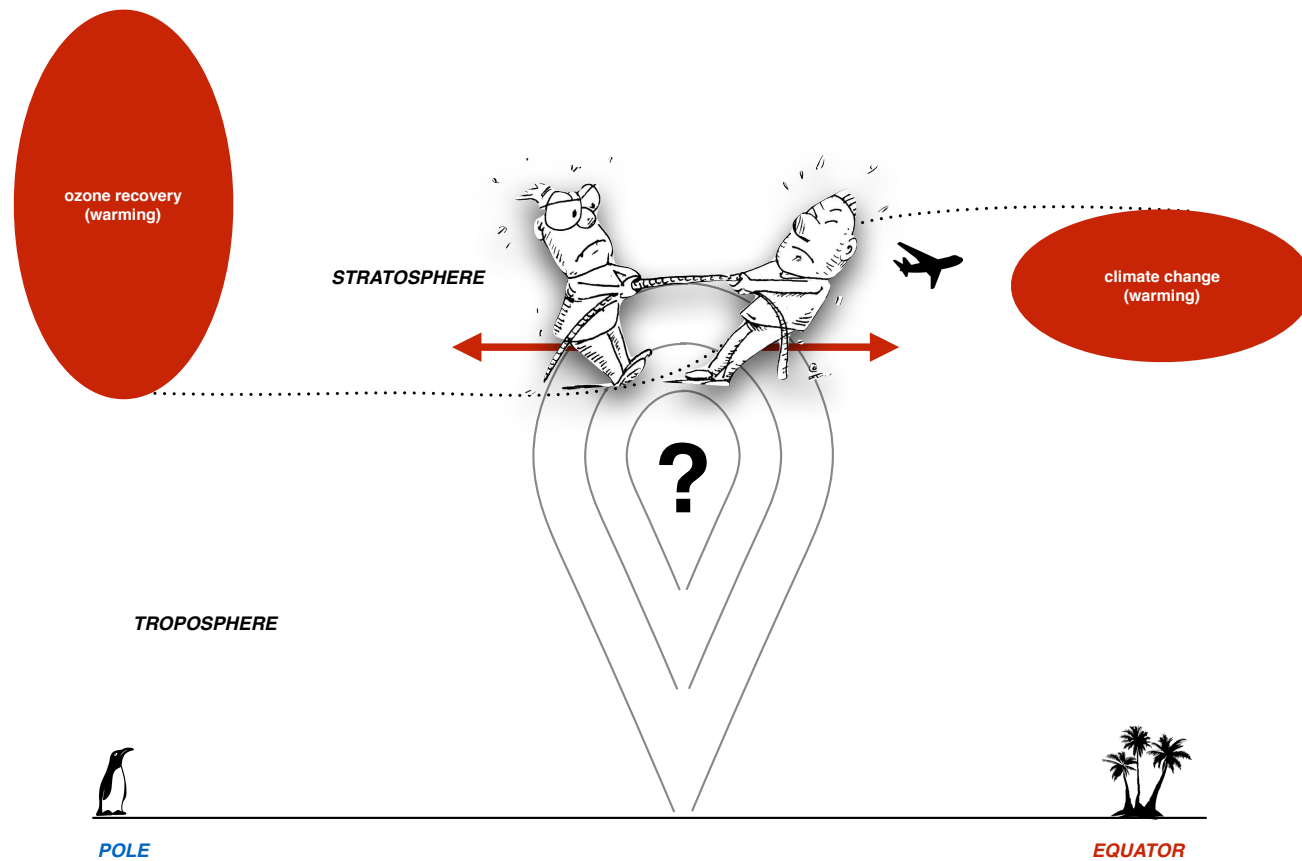
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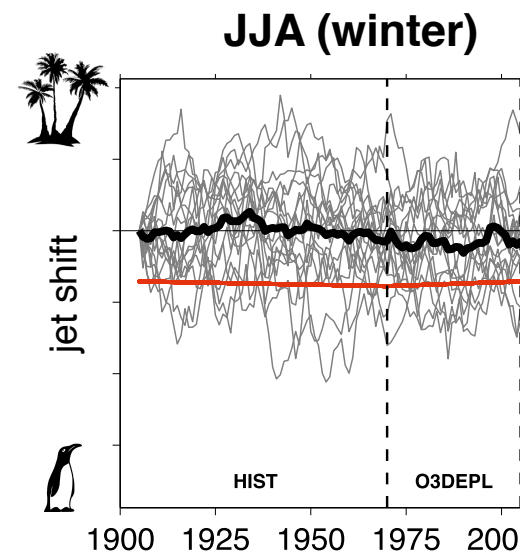
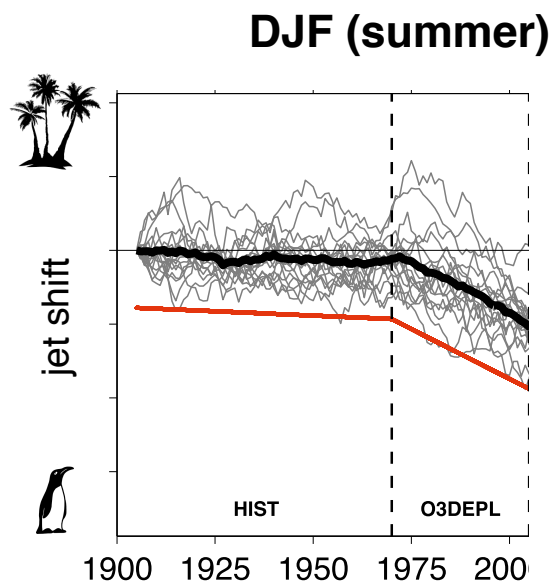
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Will ozone depletion impact the jet-streams?



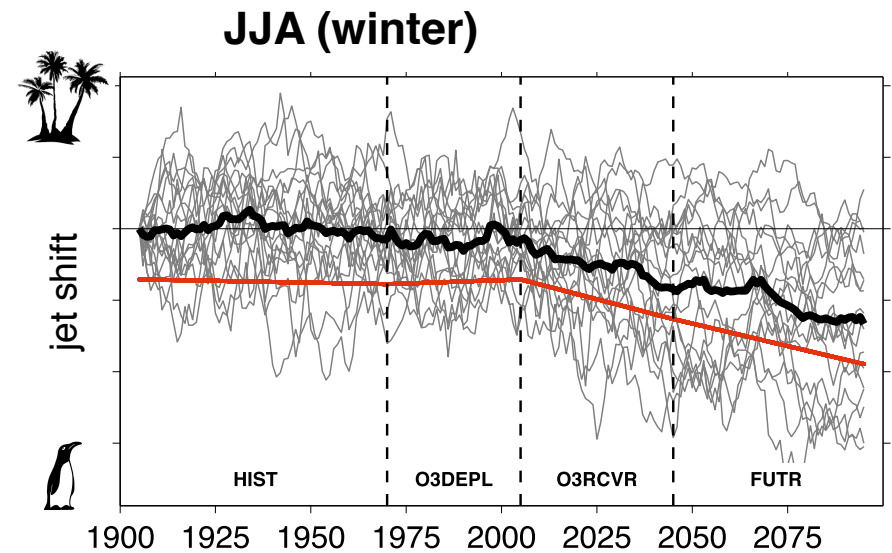
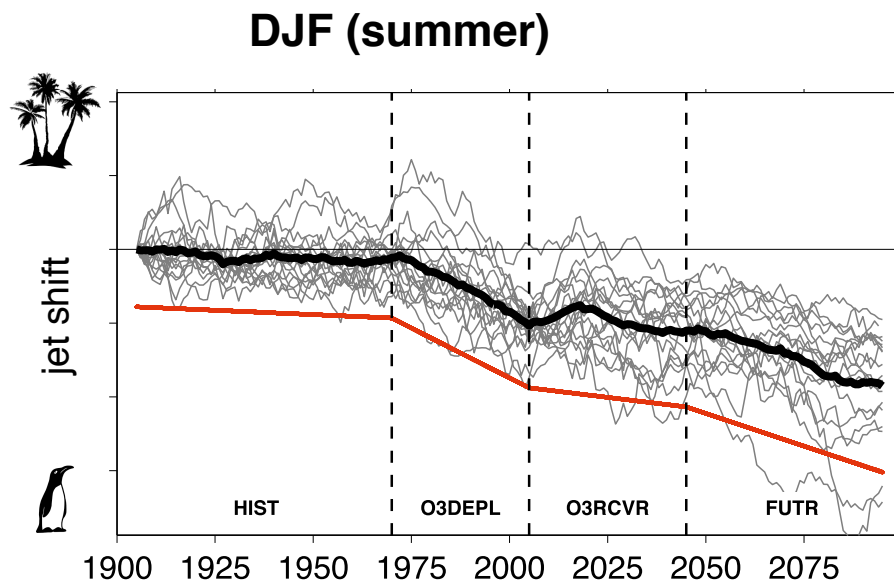
Will it?

Will ozone depletion impact the jet-streams?



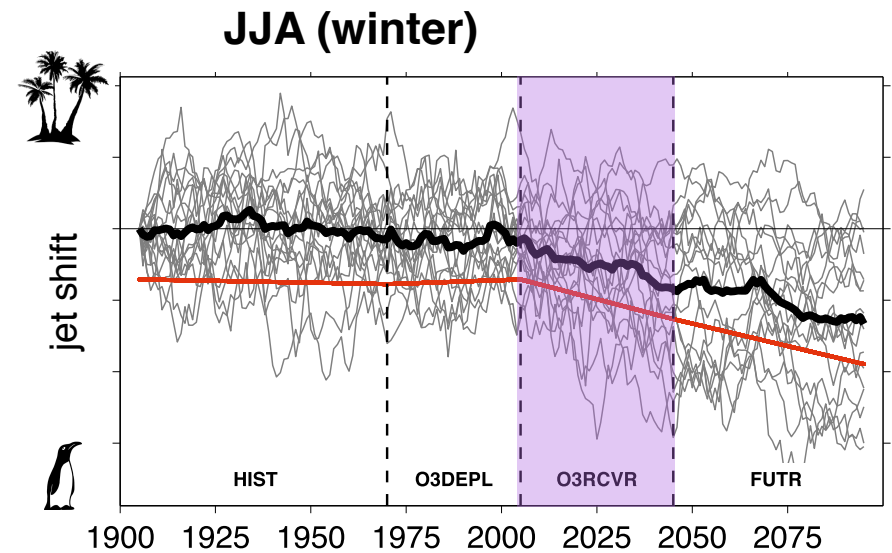
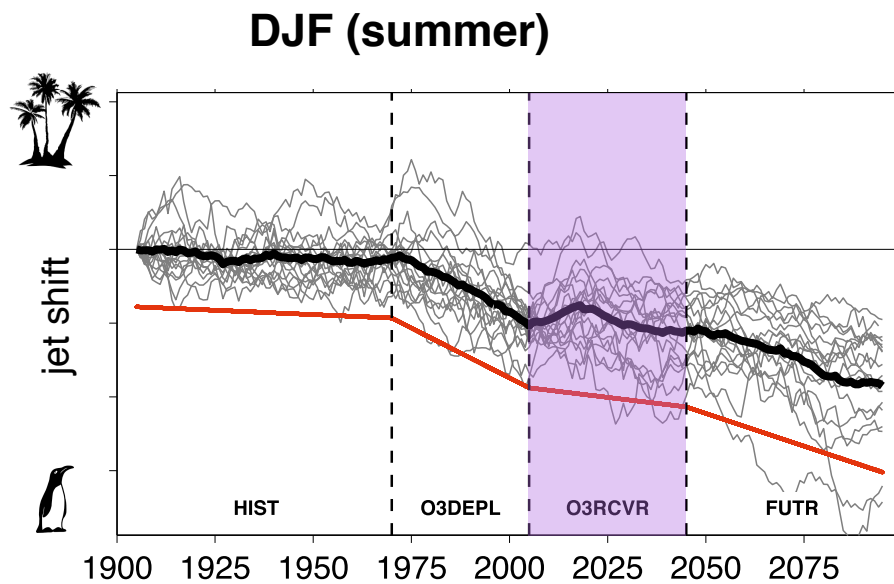
Will it?

Will ozone depletion impact the jet-streams?



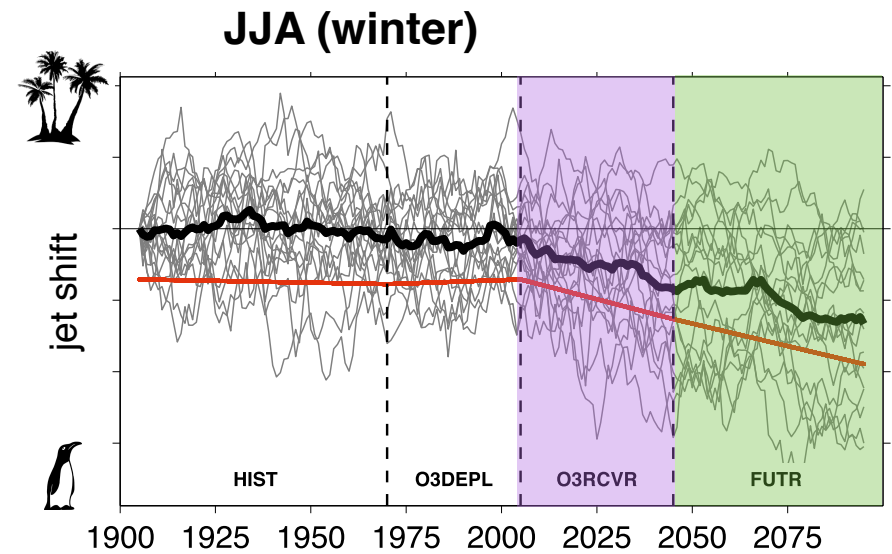
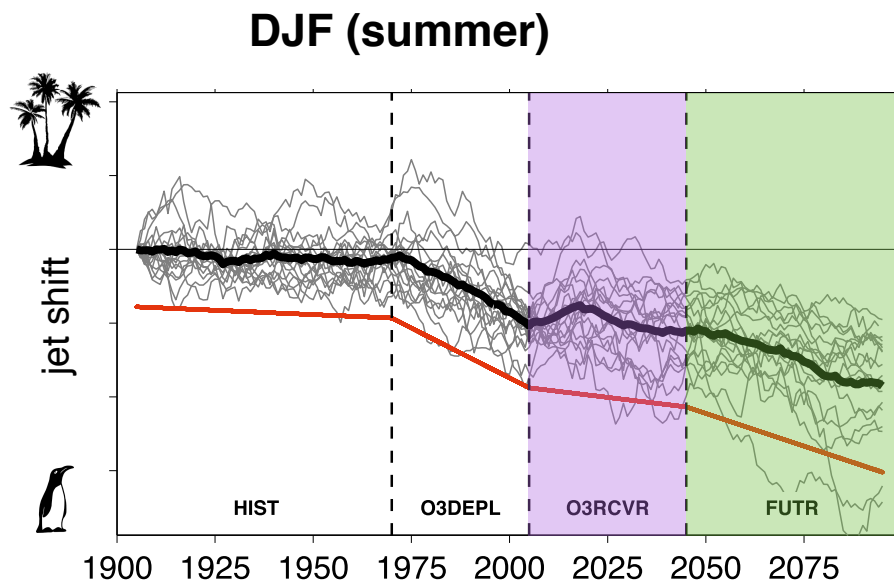
Will it?

Will ozone depletion impact the jet-streams?

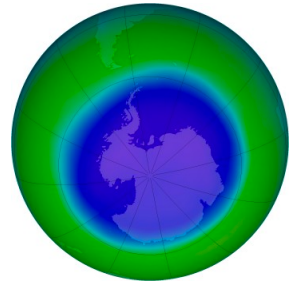


Will it?

Will ozone depletion impact the jet-streams?



Ozone Hole



Can it?

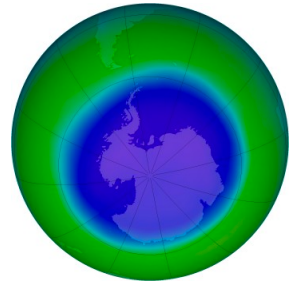
Has it?

Will it?

Can it?

Ozone Hole

yes.



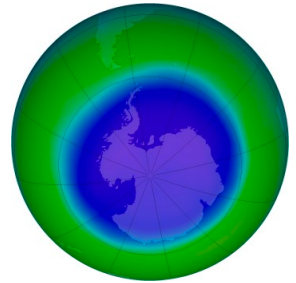
Has it?

Will it?

Can it?

Ozone Hole

yes.

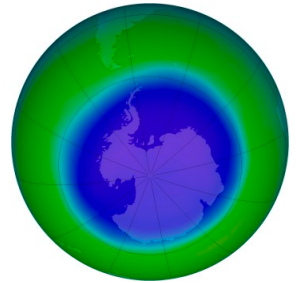


Has it?

yes. dominant driver of Southern Hemisphere jet-stream trends over the past 30 years

Will it?

Ozone Hole



Can it?

yes.

Has it?

yes. dominant driver of Southern Hemisphere jet-stream trends over the past 30 years

Will it?

yes. will likely oppose the climate change signal in the coming decades.

Arctic Sea Ice Loss

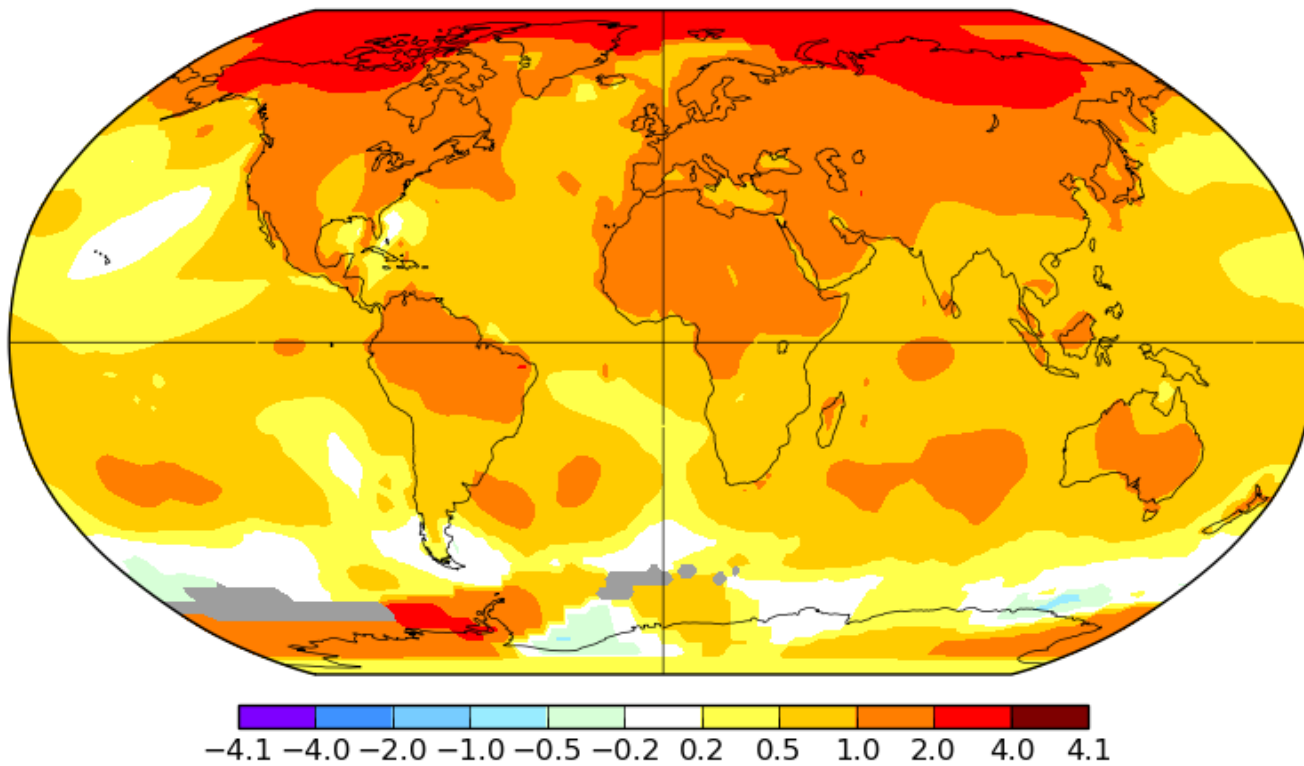


The Earth is warming. The Arctic is warming even faster.

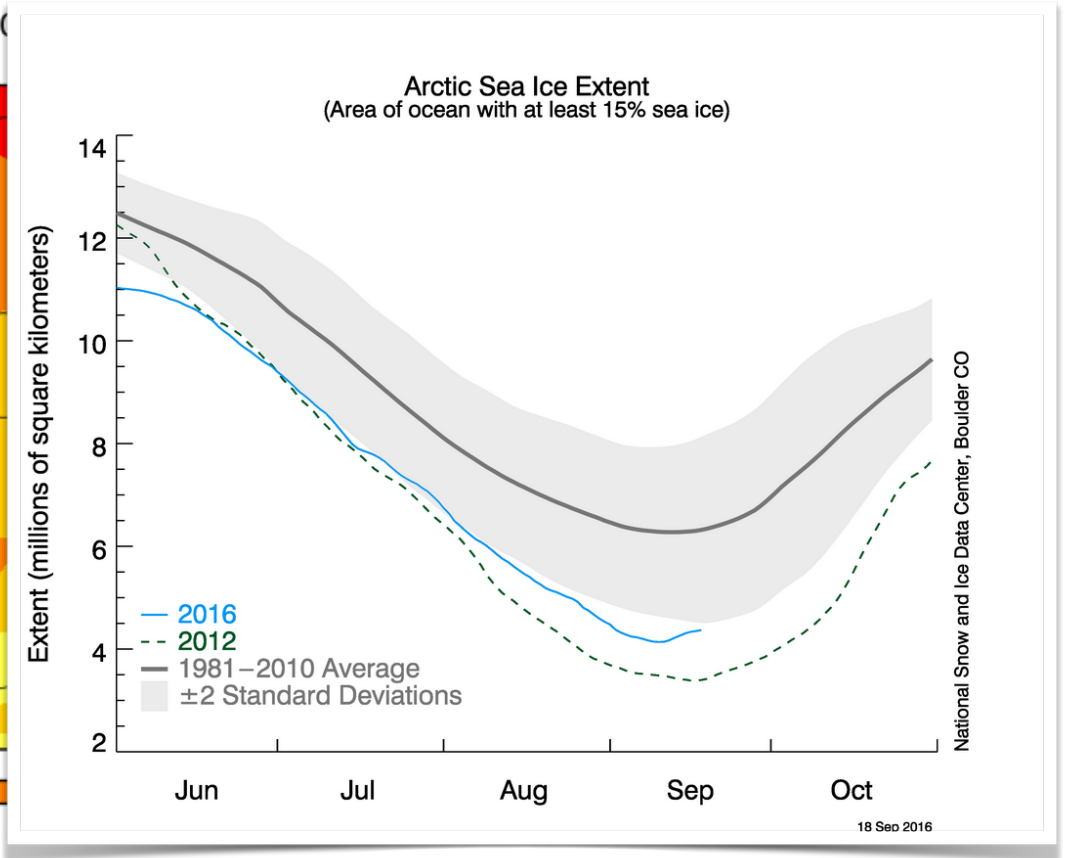
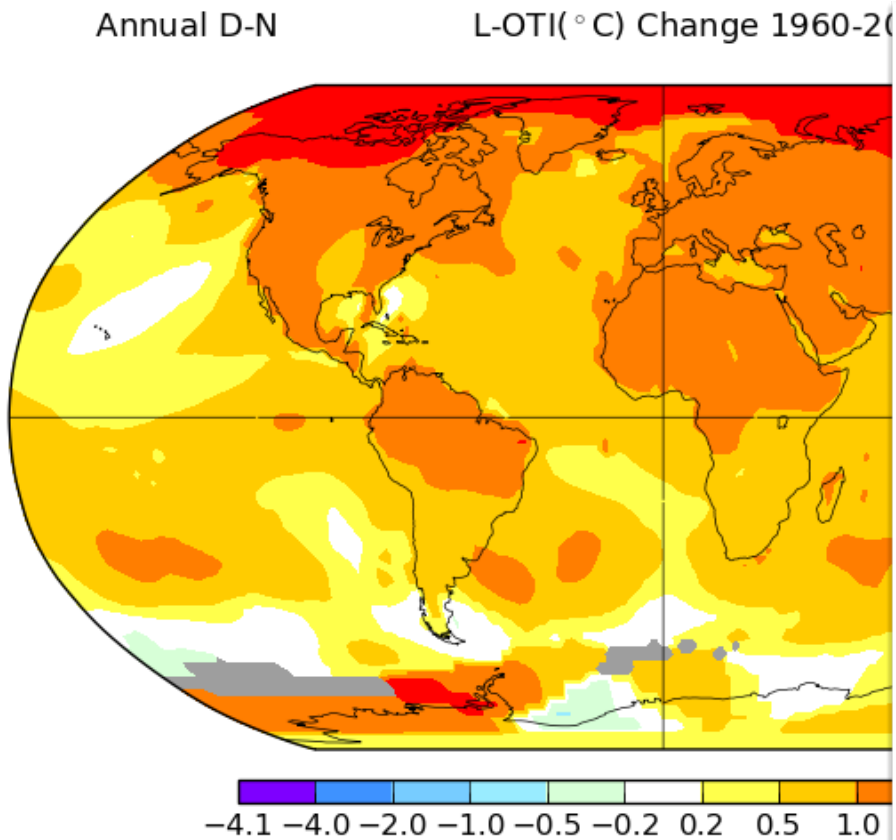
Annual D-N

L-OTI(°C) Change 1960-2015

0.87



The Earth is warming. The Arctic is warming even faster.



Capital Weather Gang

**It's about 50 degrees warmer than normal
near the North Pole, yet again**

Capital Weather Gang

It's about 50 degrees warmer than normal near the North Pole, yet again

**Climate
change**
The warming
Arctic

Arctic ice melt 'already affecting weather patterns where you live right now'

Soaring Arctic temperatures 'strongly linked' to recent extreme weather events, say scientists at cutting edge of climate change research

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The Arctic Is Getting Crazy

Feedback loops between record Arctic temperatures and the jet stream may be altering our weather

By Mark Fischetti on January 5, 2017 [Véalo en español](#)

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Wind contributing to Arctic sea ice loss, study finds

New research does not question climate change is also melting ice in the Arctic, but finds wind patterns explain steep decline

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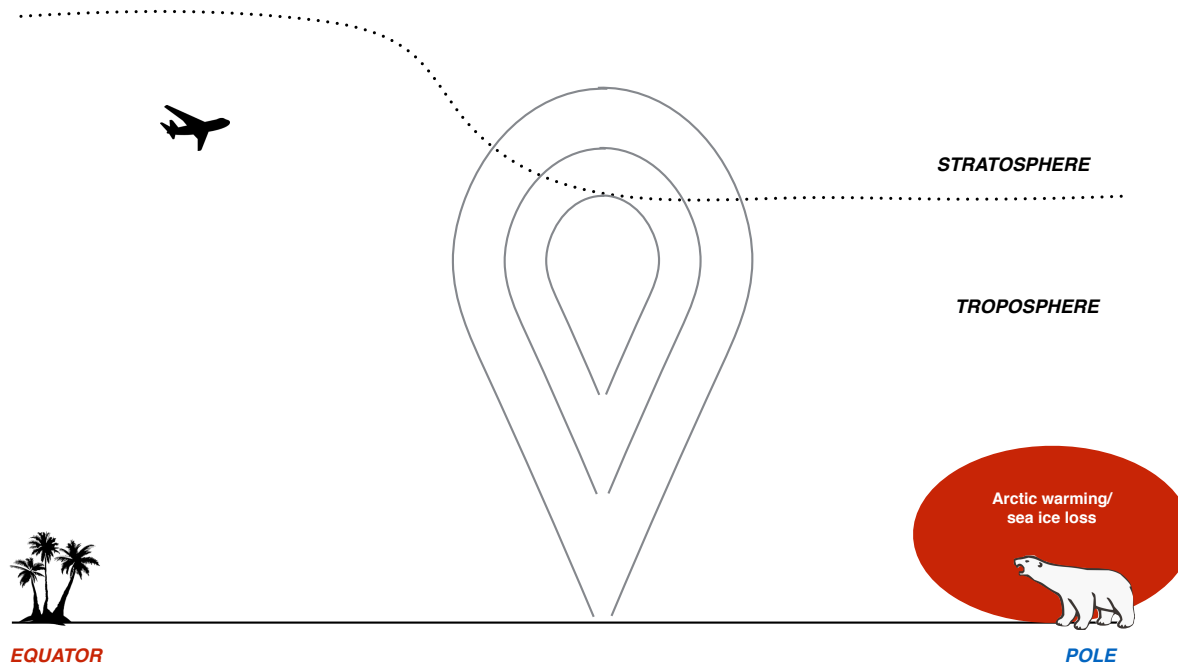
Energy and Environment

One of the most troubling ideas about climate change just found new evidence in its favor

By [Chris Mooney](#) March 27 at 12:06 PM 

Can it?

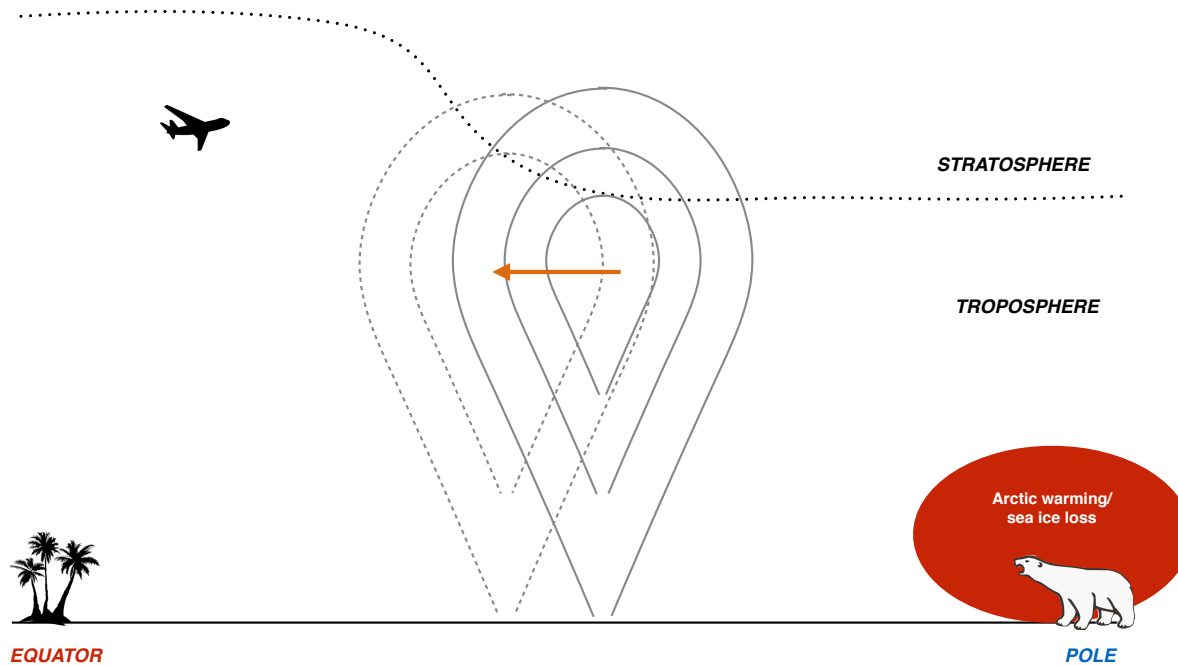
Can Arctic sea ice loss impact the jet-streams?



atmosphere-only CAM3 simulations
Deser, Tomas, et al. (2010; JCLI)

Can it?

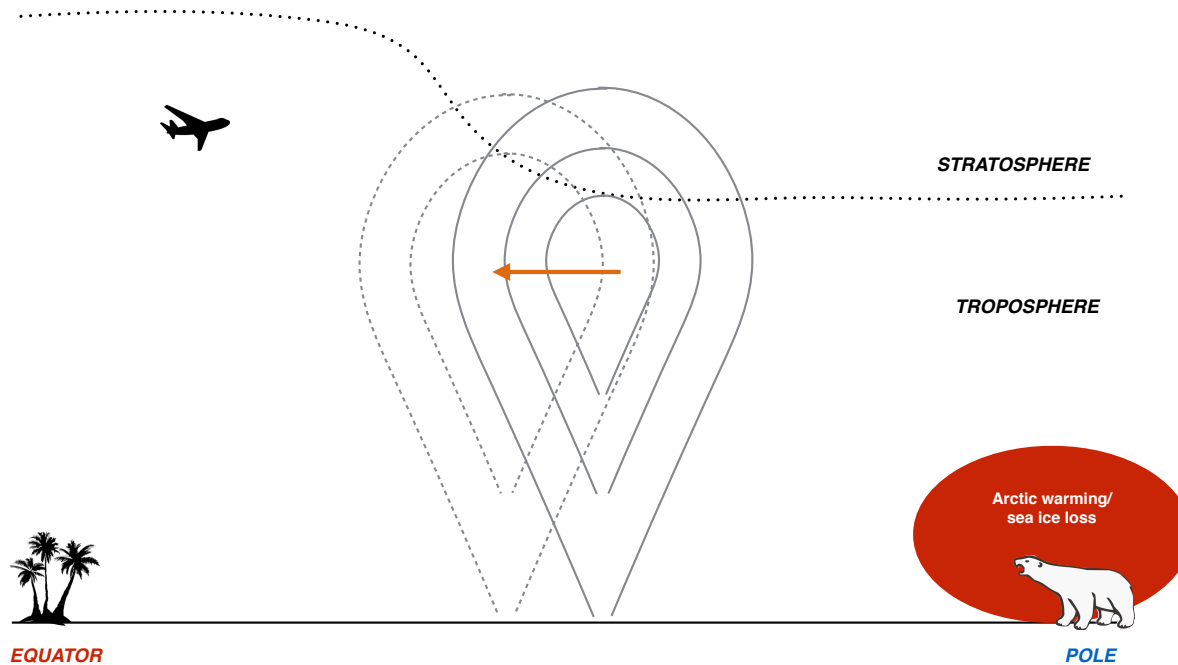
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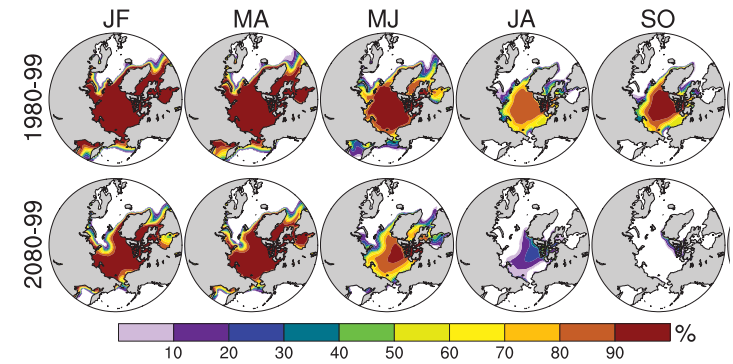
atmosphere-only CAM3 simulations
Deser, Tomas, et al. (2010; JCLI)

Can it?

Can Arctic sea ice loss impact the jet-streams?



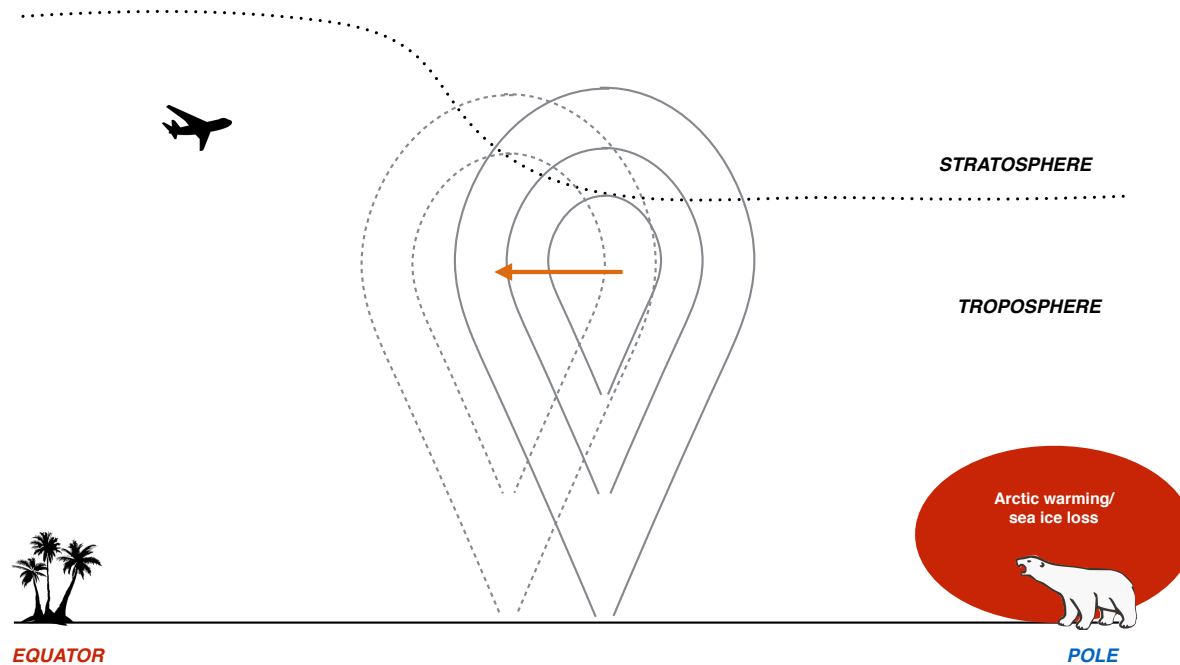
a) Sea Ice Concentration



atmosphere-only CAM3 simulations
Deser, Tomas, et al. (2010; JCLI)

Can it?

Can Arctic sea ice loss impact the jet-streams?



But How?

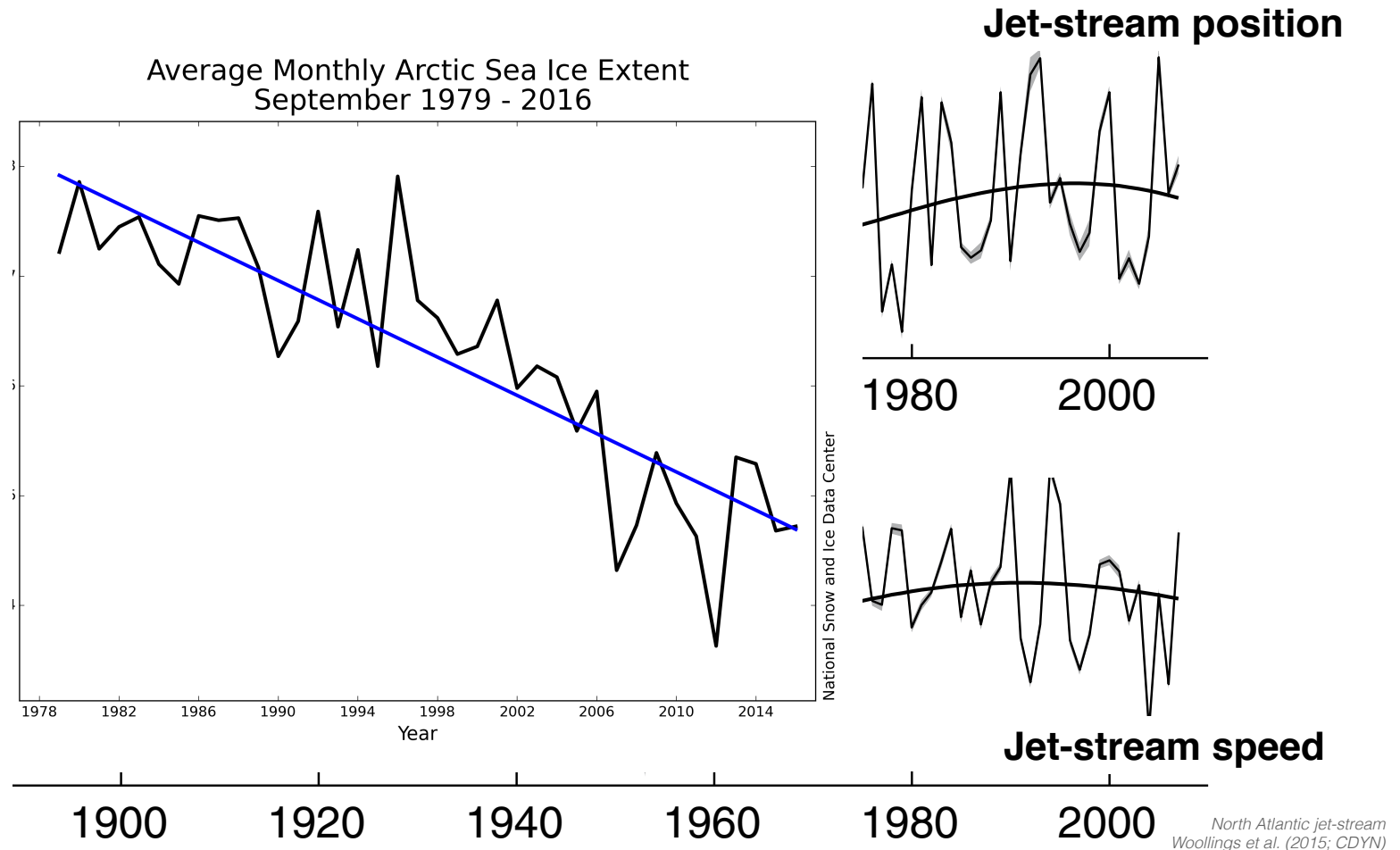
*many hypotheses are
being explored and tested*

WAIT!

That the Arctic **can** influence the jet-stream does not
imply that it **has** in a significant way,
nor does it imply that it **will** in the future.

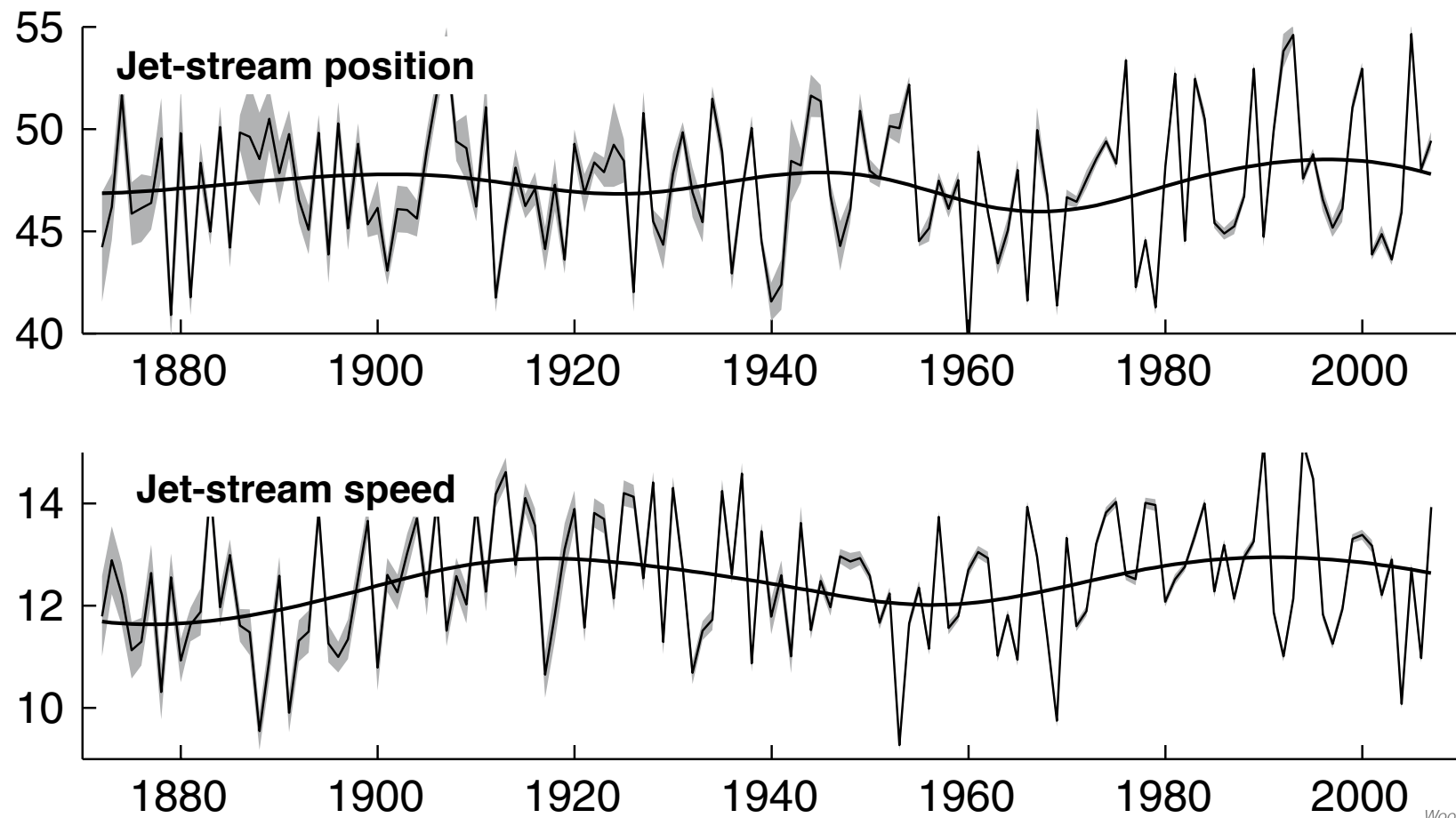
Has it?

Has Arctic sea ice loss impacted the jet-stream?



Has it?

Has Arctic sea ice loss impacted the jet-stream?



Has it?

Has Arctic sea ice loss impacted the jet-streams?

Has it?

Has Arctic sea ice loss impacted the jet-streams?

Option A

Arctic warming
& ice loss

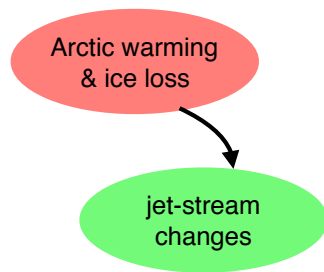


jet-stream
changes

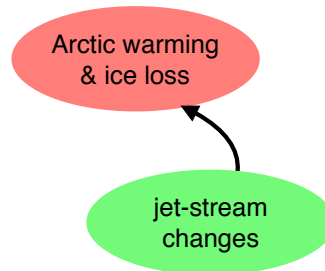
Has it?

Has Arctic sea ice loss impacted the jet-streams?

Option A



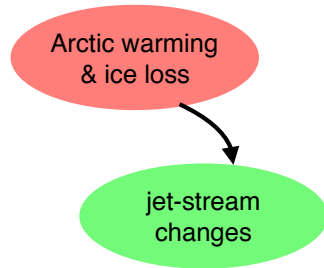
Option B



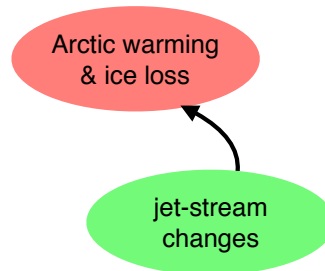
Has it?

Has Arctic sea ice loss impacted the jet-streams?

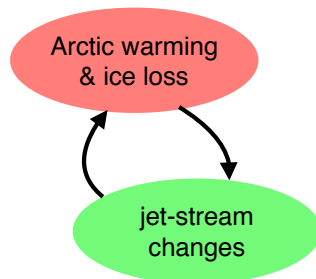
Option A



Option B

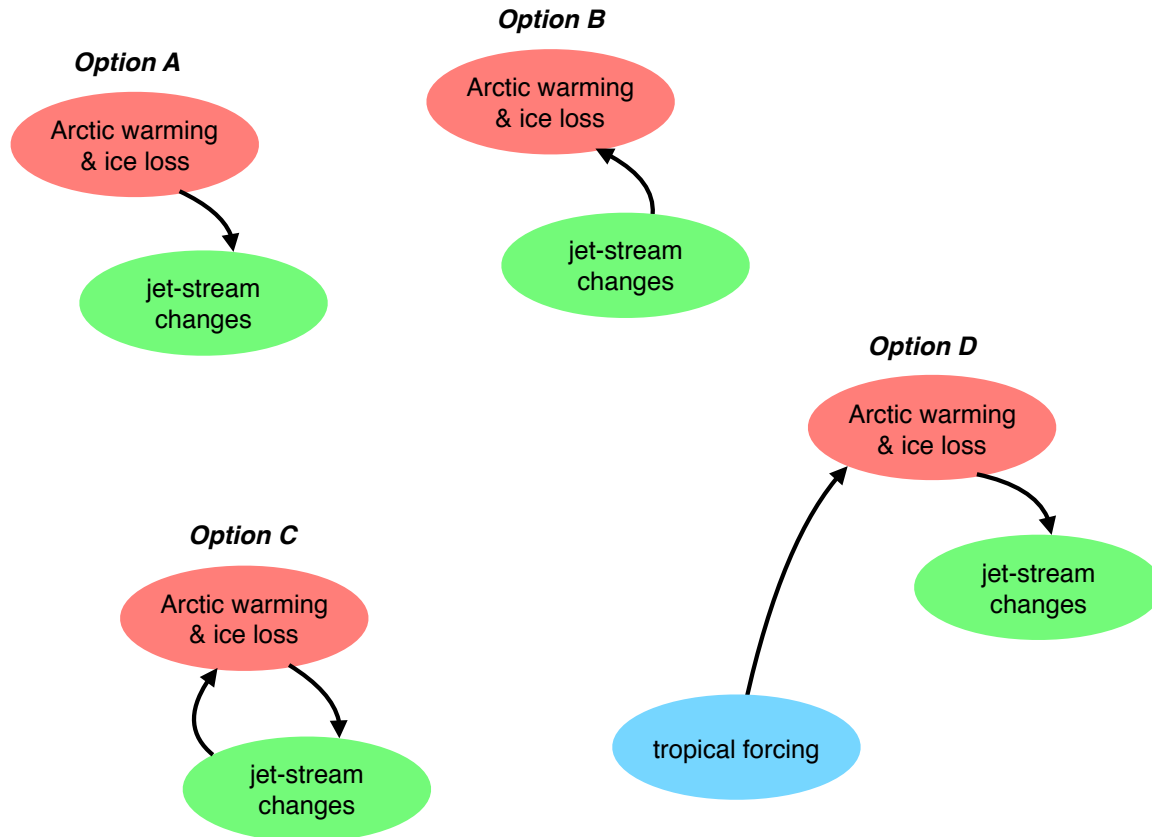


Option C



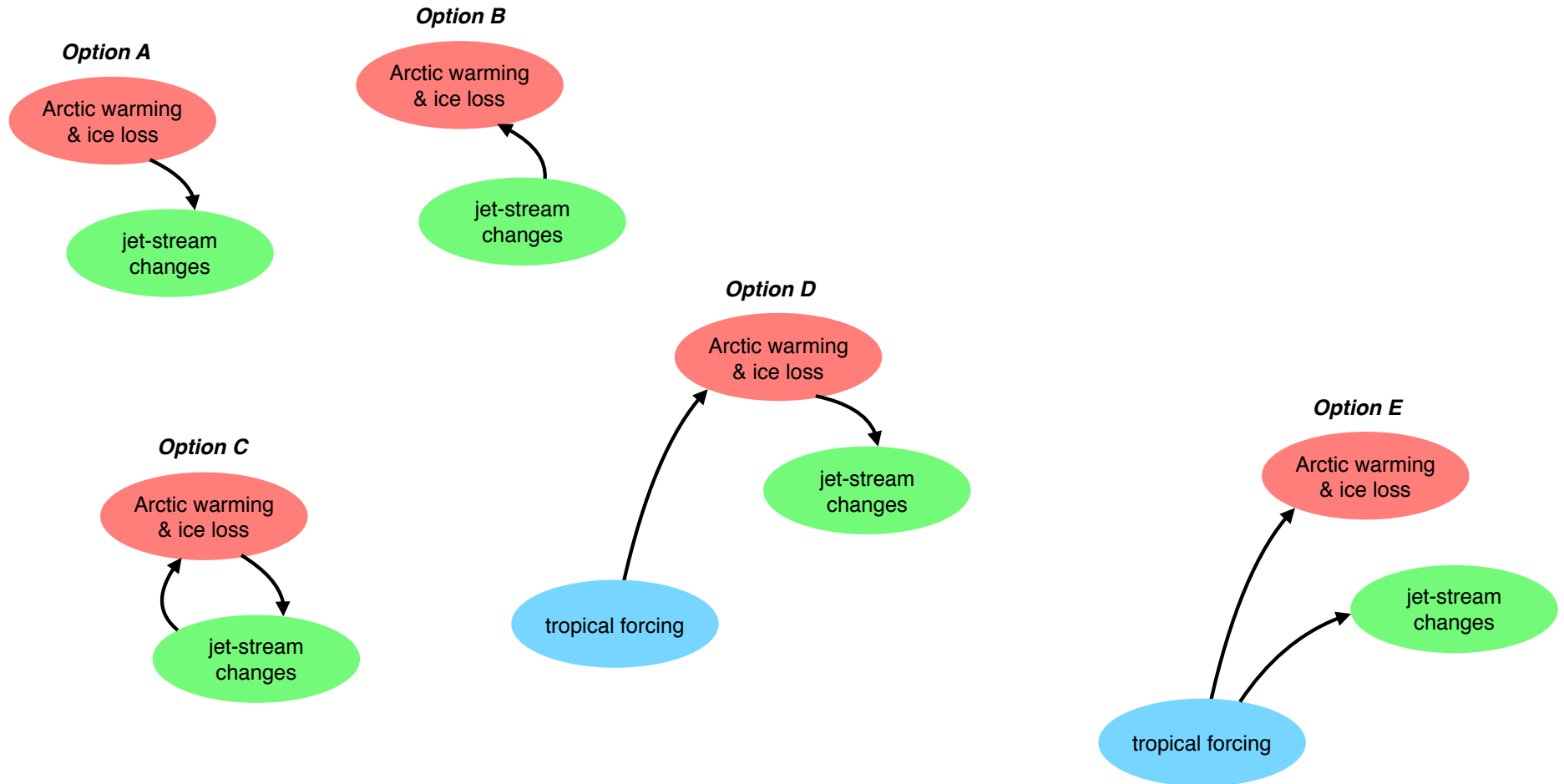
Has it?

Has Arctic sea ice loss impacted the jet-streams?



Has it?

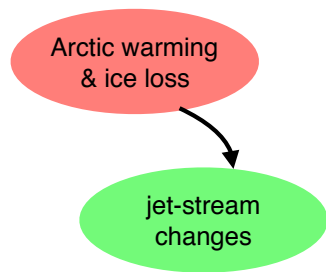
Has Arctic sea ice loss impacted the jet-streams?



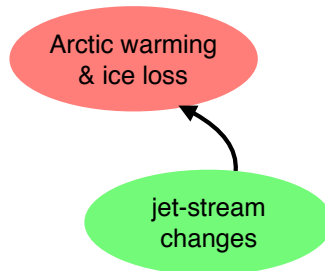
Has it?

Has Arctic sea ice loss impacted the jet-streams?

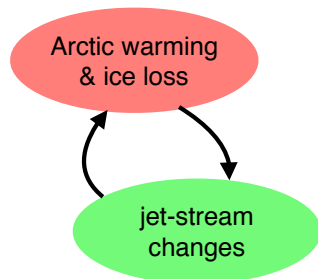
Option A



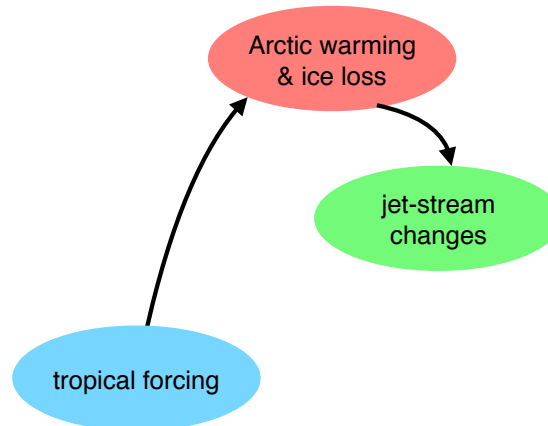
Option B



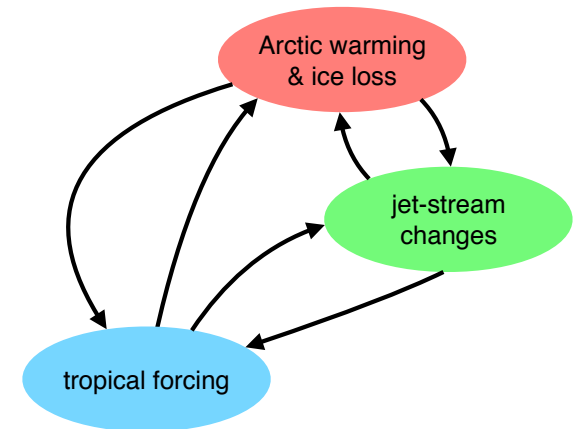
Option C



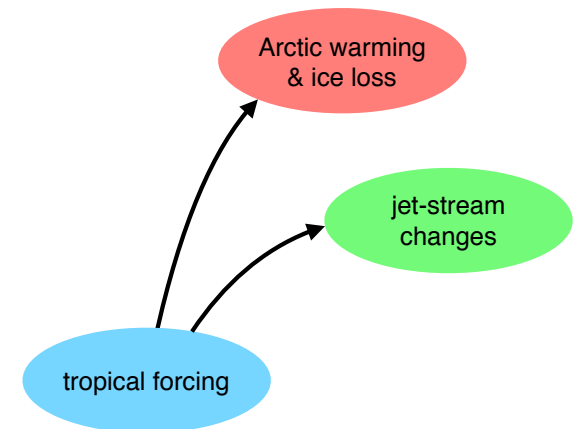
Option D



The Real World...

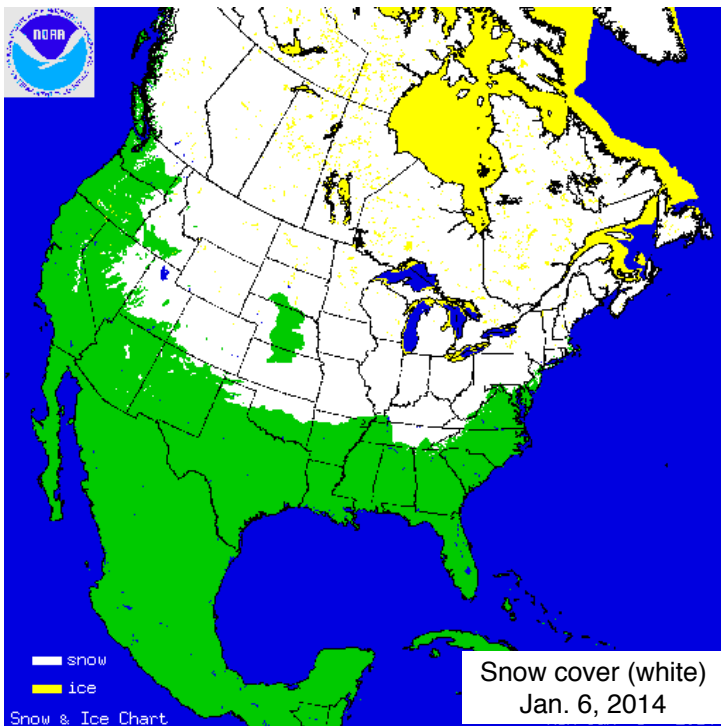


Option E

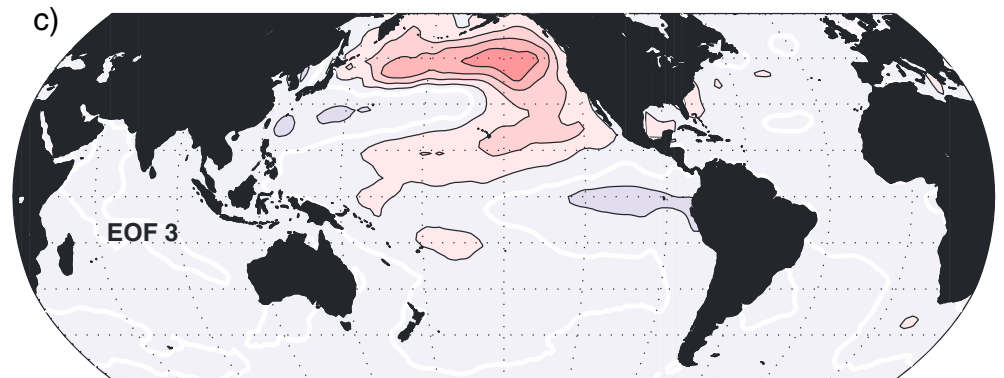


Has it? *Has Arctic sea ice loss impacted the jet-streams?*

Winter of 2013-14 was unusually cold...



- Winter of 2013-14 was very cold over the US and Canada. It has been suggested that Arctic sea ice loss may have been responsible
- However, recent work suggests that the Pacific ocean variability was the cause



Has it?

Has Arctic sea ice loss impacted the jet-streams?

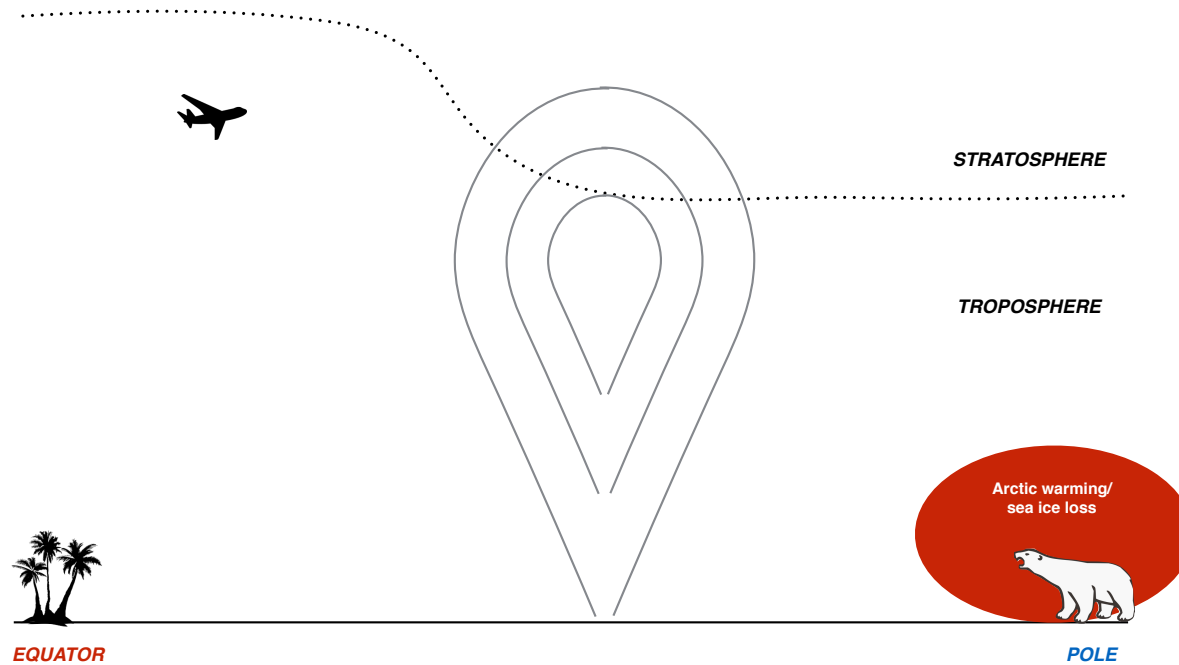
#1 There is a lot of noise.

#2 Correlation \neq causation.

#3 Drivers don't act in isolation.

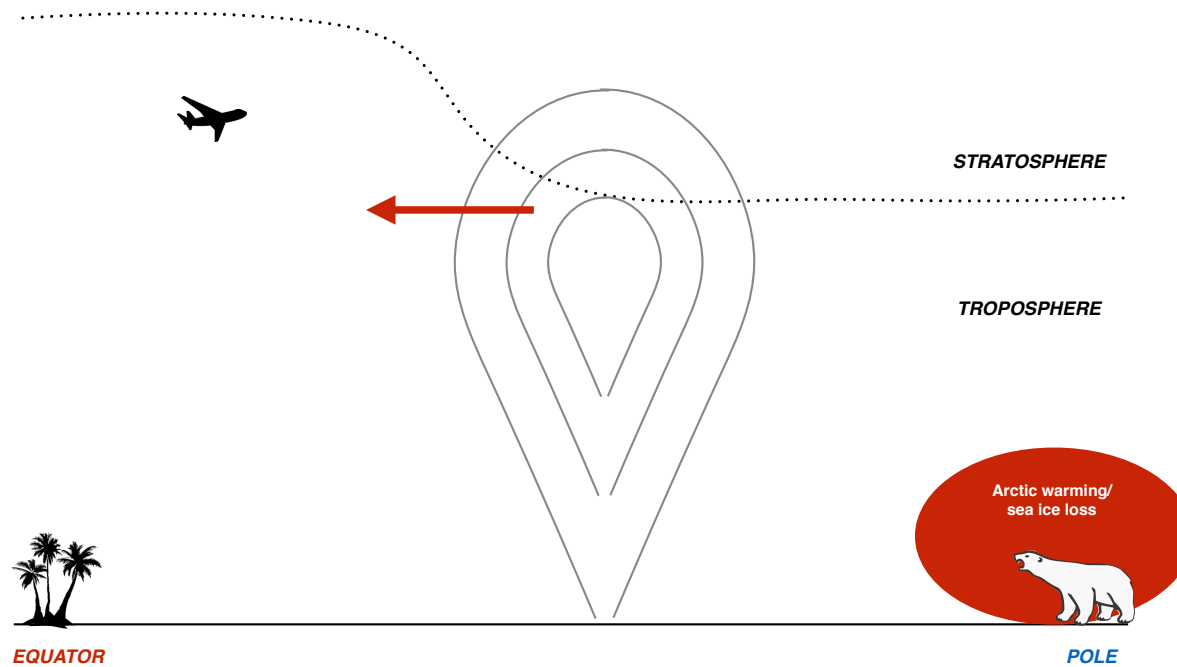
Will it?

Will Arctic sea ice loss impact the jet-streams?



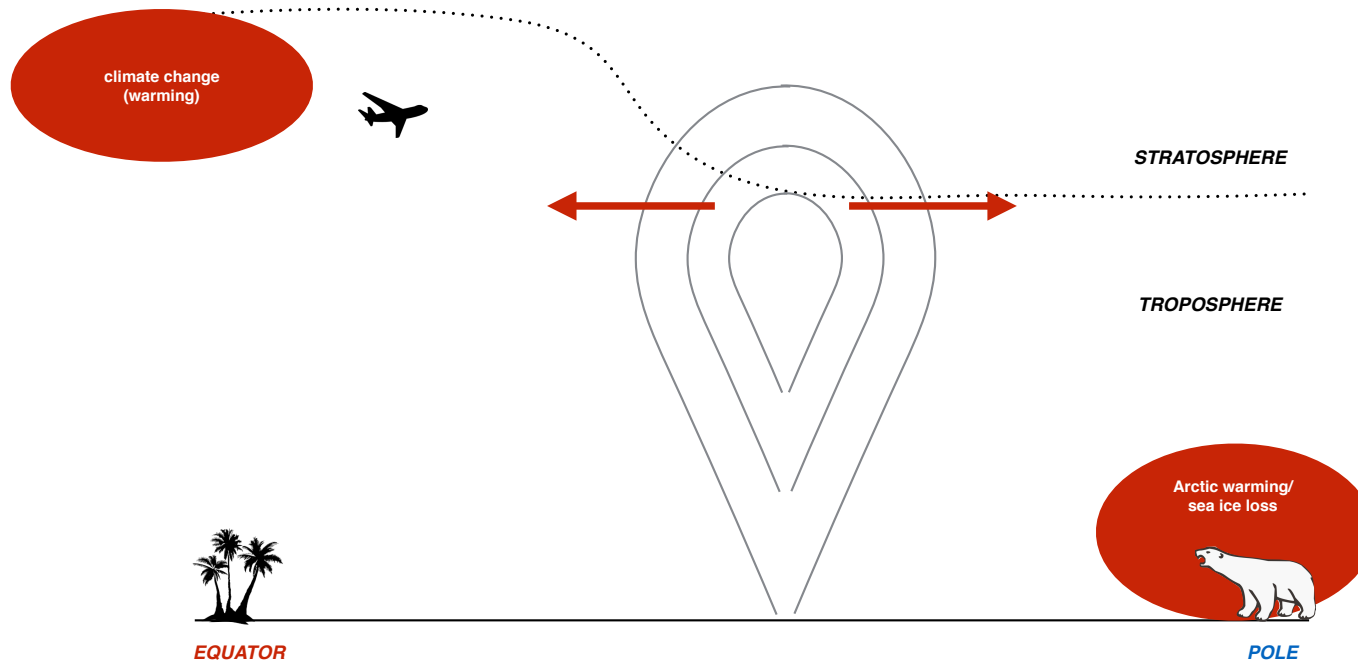
Will it?

Will Arctic sea ice loss impact the jet-streams?



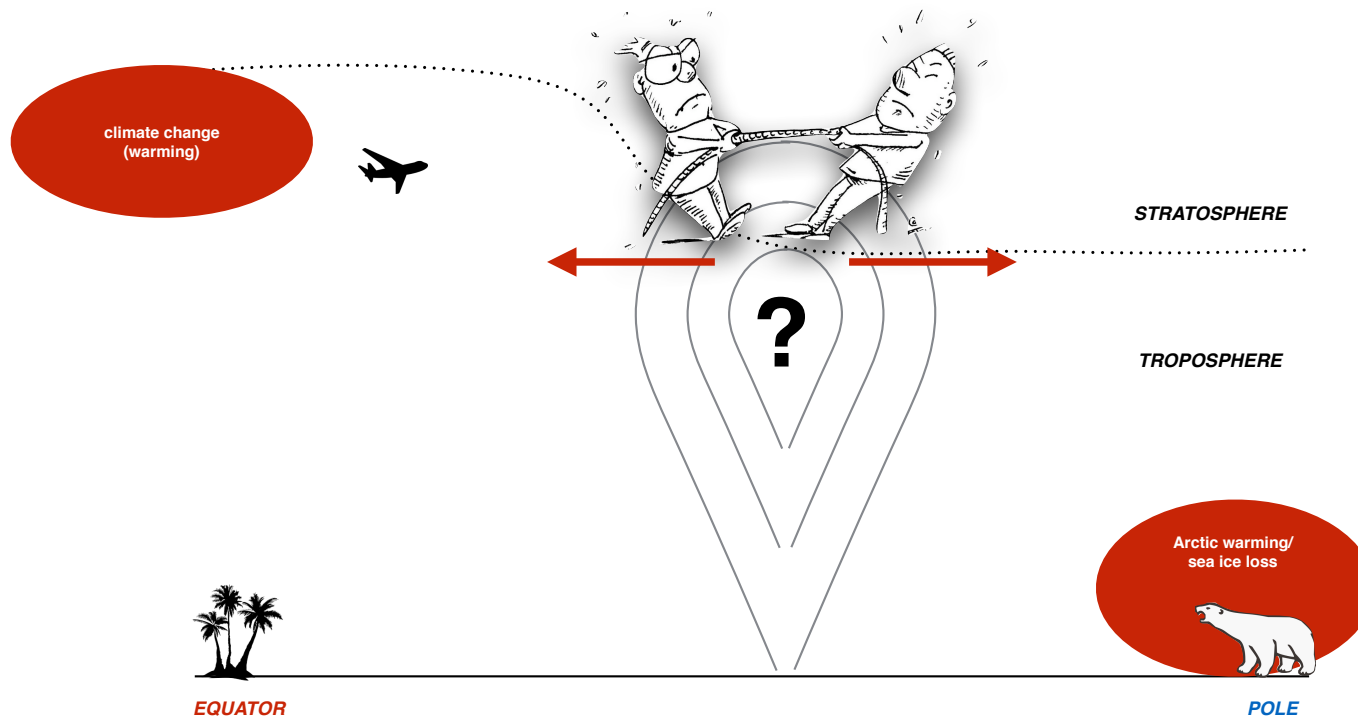
Will it?

Will Arctic sea ice loss impact the jet-streams?



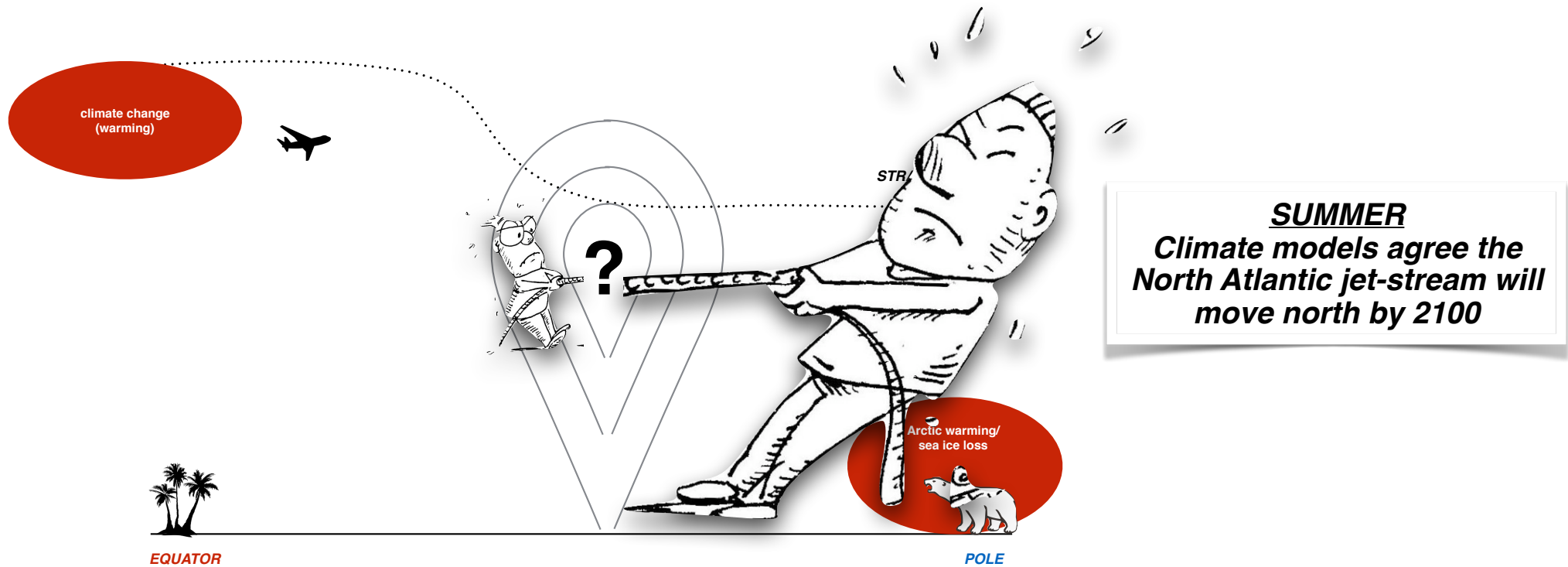
Will it?

Will Arctic sea ice loss impact the jet-streams?



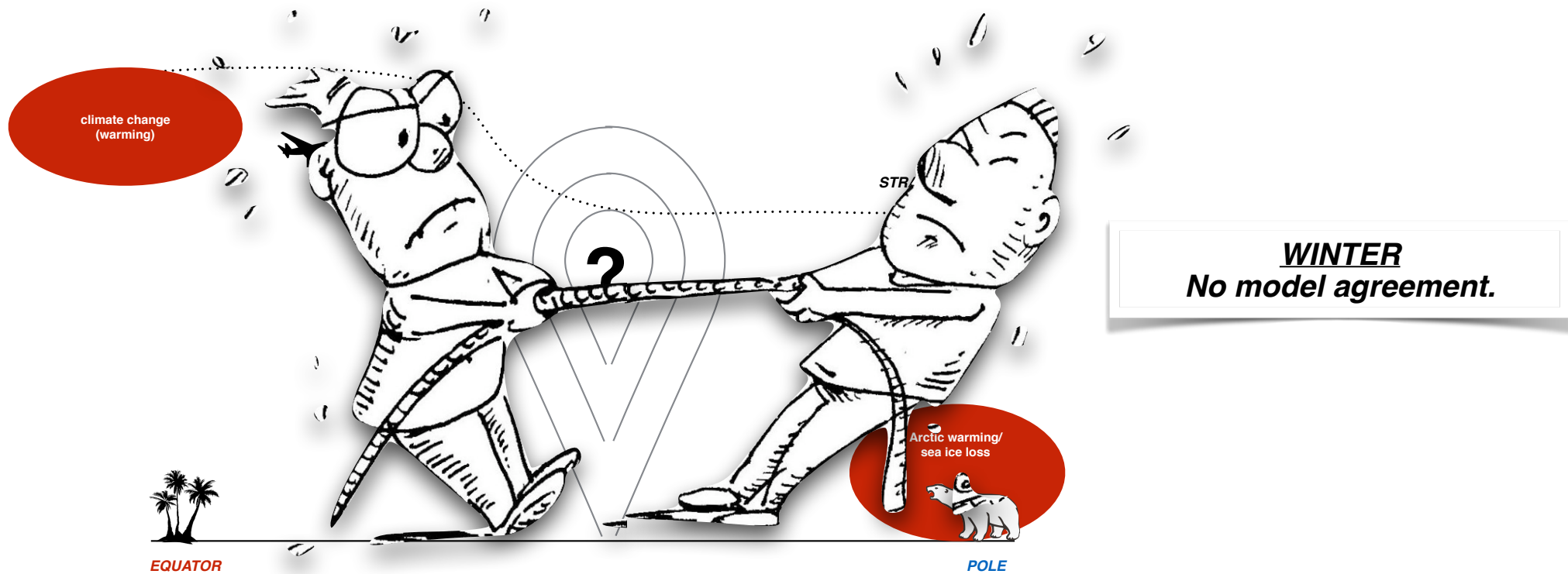
Will it?

Will Arctic sea ice loss impact the jet-streams?



Will it?

Will Arctic sea ice loss impact the jet-streams?

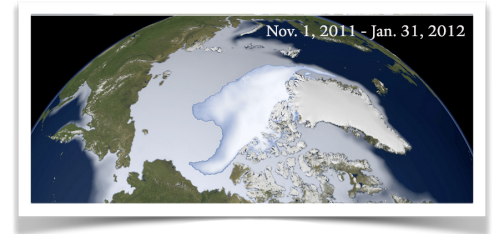


Arctic Sea Ice Loss

Can it?

Has it?

Will it?



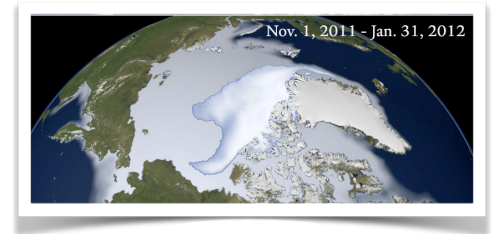
Can it?

Arctic Sea Ice Loss

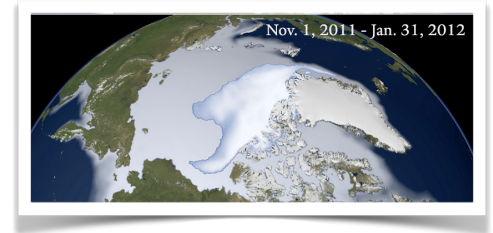
yes.

Has it?

Will it?



Arctic Sea Ice Loss



Can it?

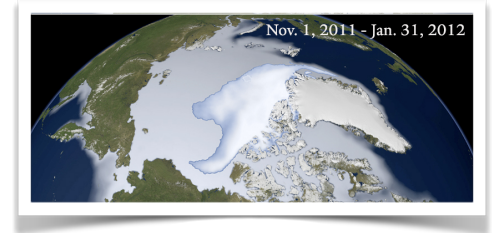
yes.

Has it?

maybe. but if so, the signal is very weak.

Will it?

Arctic Sea Ice Loss



Can it?

yes.

Has it?

maybe. but if so, the signal is very weak.

Will it?

yes. will likely oppose other climate change signals in the coming decades.

Human activity **can** influence the jet-stream.

Human activity **can** influence the jet-stream.

Detecting whether a signal **has** emerged from the noise is difficult.

Human activity **can** influence the jet-stream.

Detecting whether a signal **has** emerged from the noise is difficult.

A tug-of-war on the jet-streams **will** occur in the future...

Human activity **can** influence the jet-stream.

Detecting whether a signal **has** emerged from the noise is difficult.

A tug-of-war on the jet-streams **will** occur in the future...

But which side will win?

