

# **The Sun's role in climate change**

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Calgary, June 2015

Collaborators:

HU – Shlomi Ziskin, Naftali Smith, Daniel Howard

DTU – Henrik Svensmark, Martin A. B. Enghoff, Jens Olaf P. Pedersen

U. Ottawa – Ján Veizer, Andreas Prokoph,

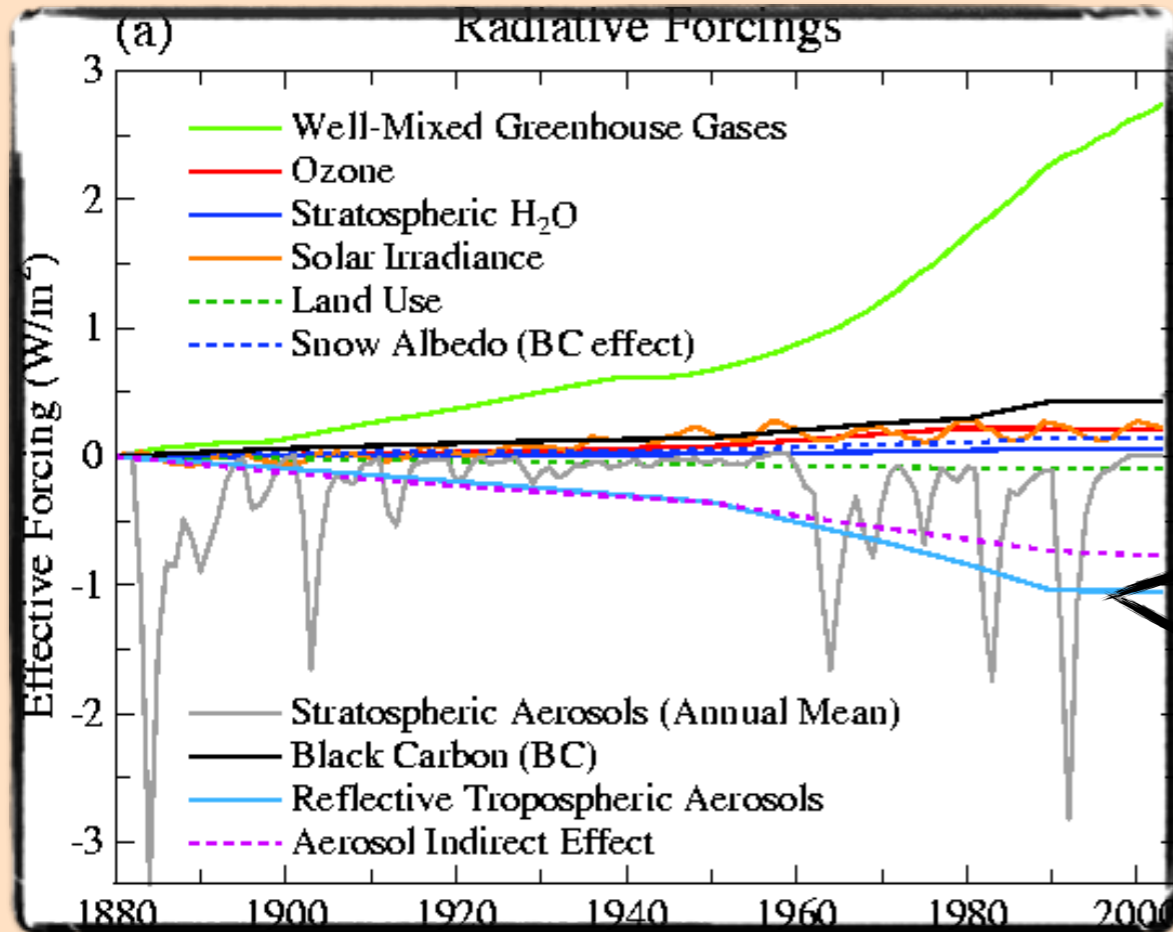
# What will I talk about?

- The “standard” lore - Why is solar activity shunned?
- (Some) Evidence for problems with the standard picture.
- Quantifying the solar forcing - It is large!
- Solar forcing and climate change.
- Cosmic Rays, the link between solar activity and climate

It is commonly believed that...



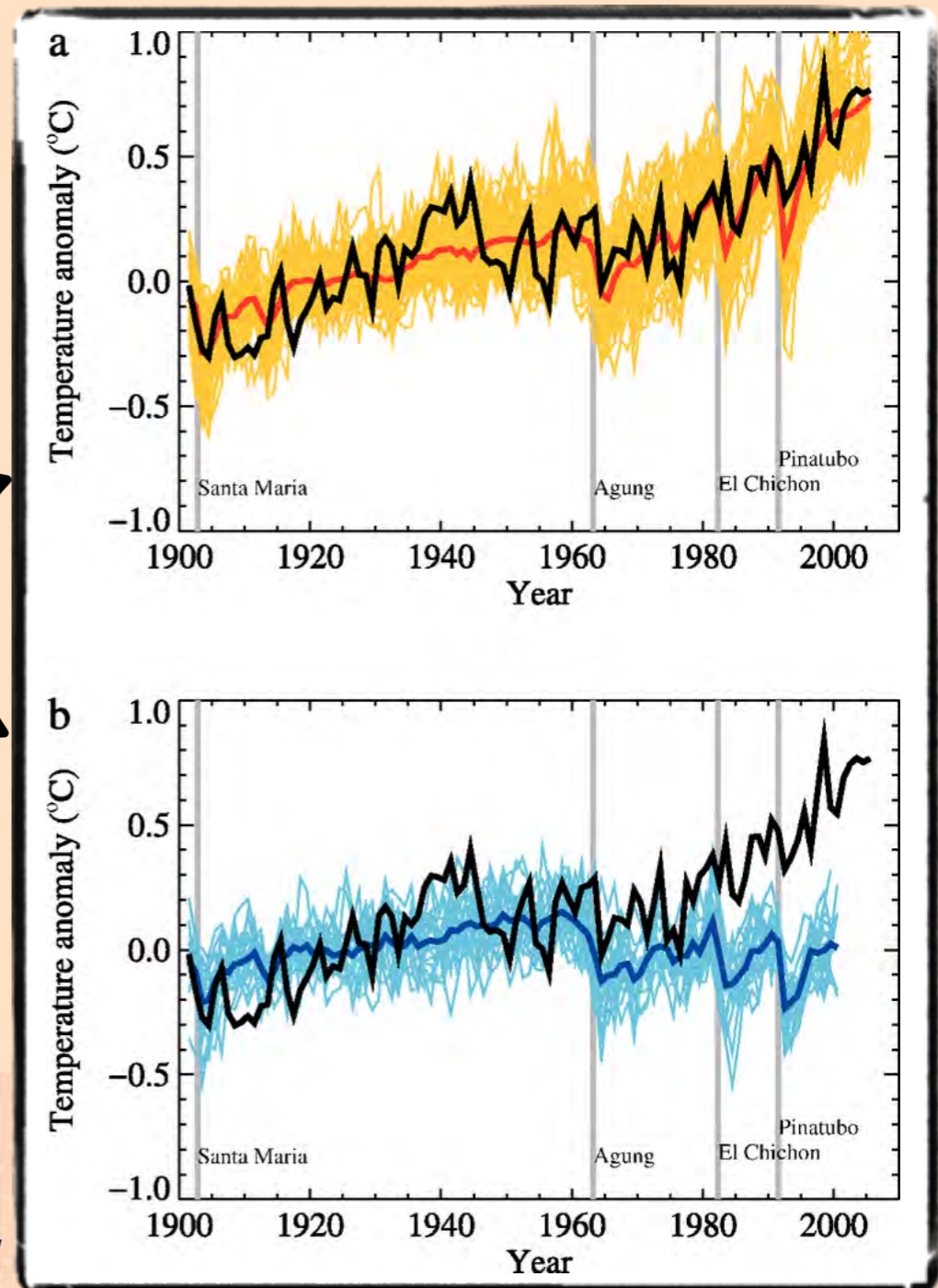
# 20<sup>th</sup> century warming is Anthropogenic



With Anthropogenic Forcings

Without Anthropogenic Forcings

IPCC AR4

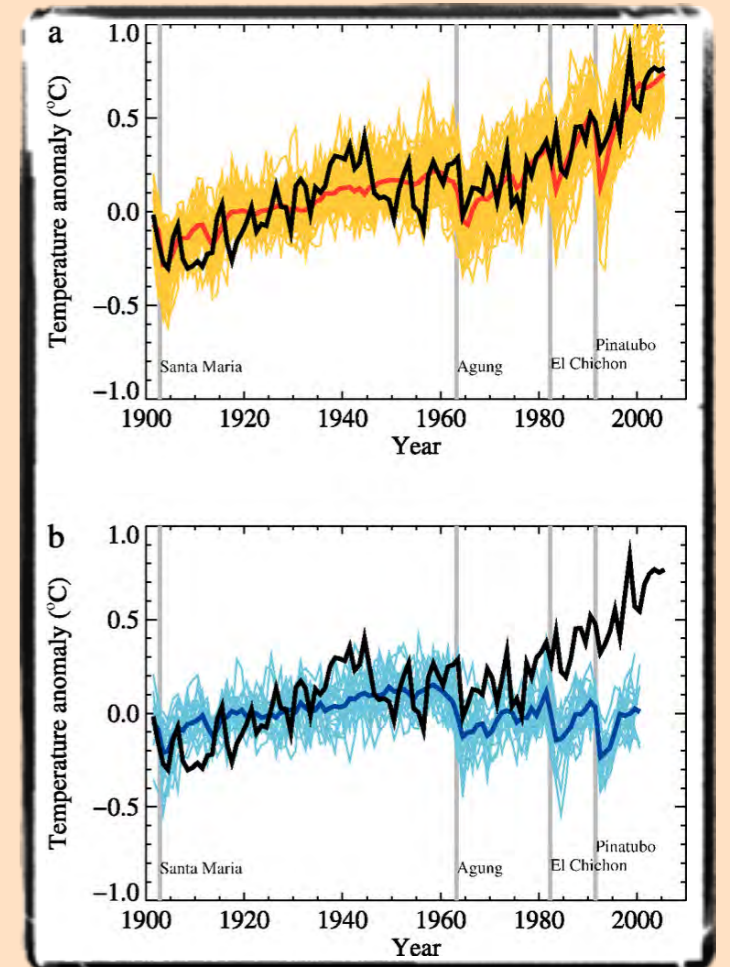


# The trinity

Climate Sensitivity is high  
(increases in the  $\text{CO}_2$  will  
cause a large change in T)  
**21<sup>st</sup> century  $\Delta T$  will be large**

There are no large  
“natural” climate drivers. In  
particular, **sun is  
unimportant**

**Most of the 20<sup>th</sup> century  
warming is  
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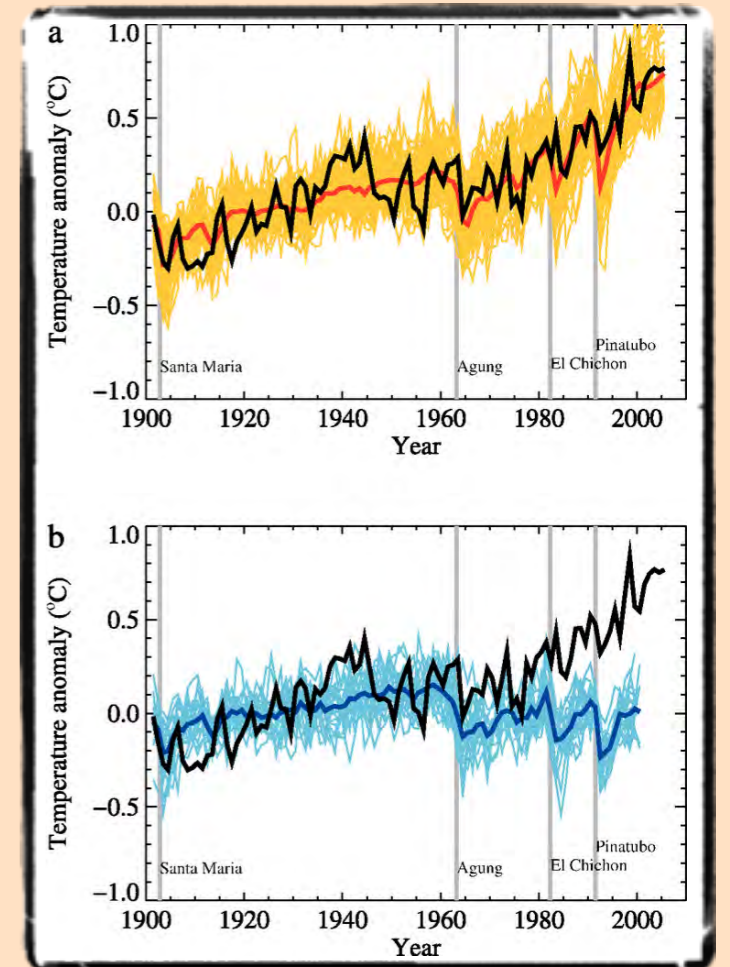


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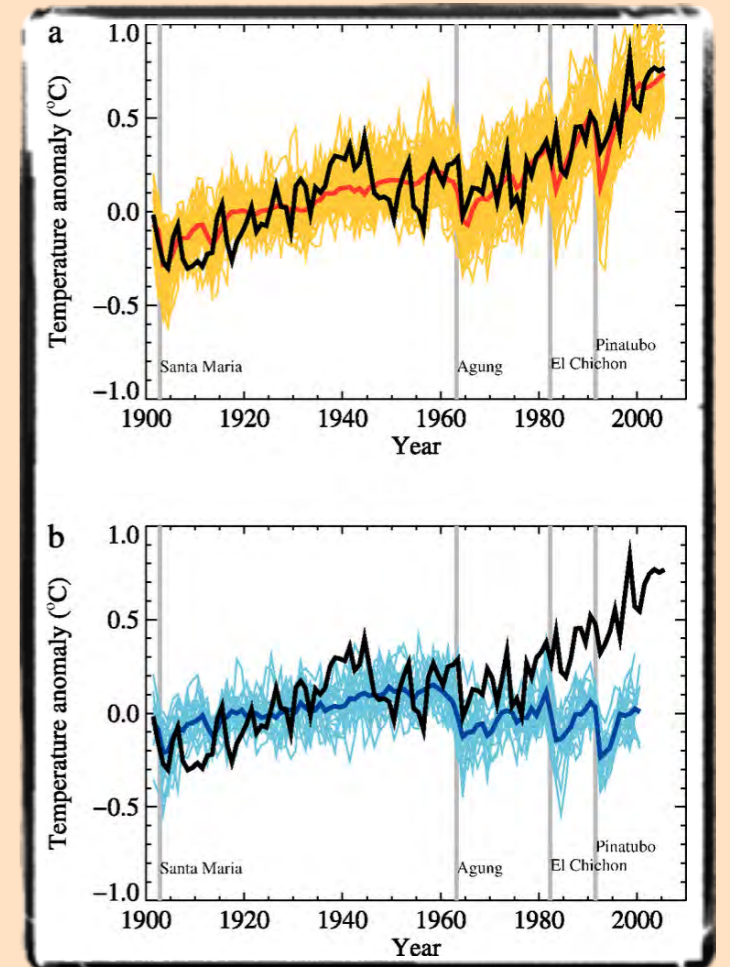


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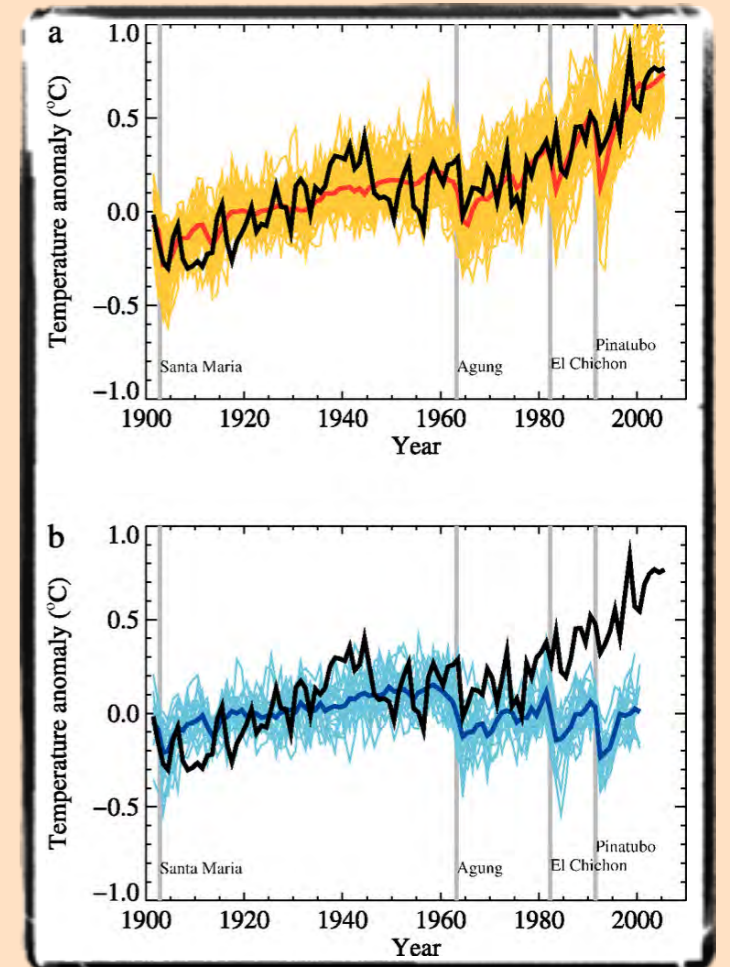
*The Sun is very important!*

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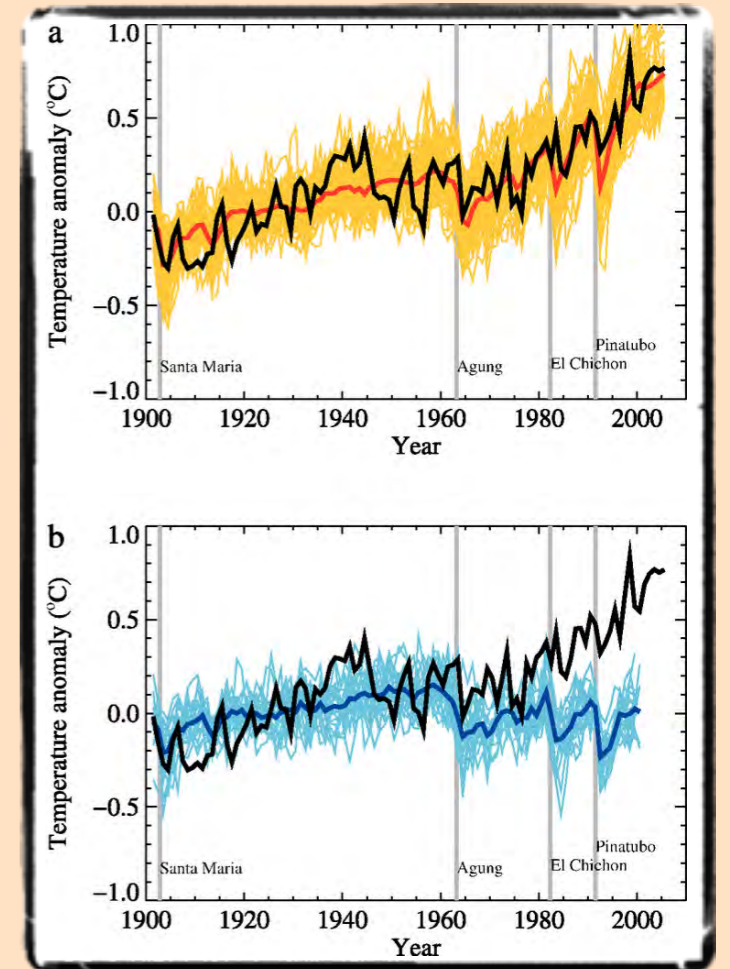
*Typically 1/2-2/3 solar 1/3-1/2 anthropogenic*



# The trinity

*Climate sensitivity is low*

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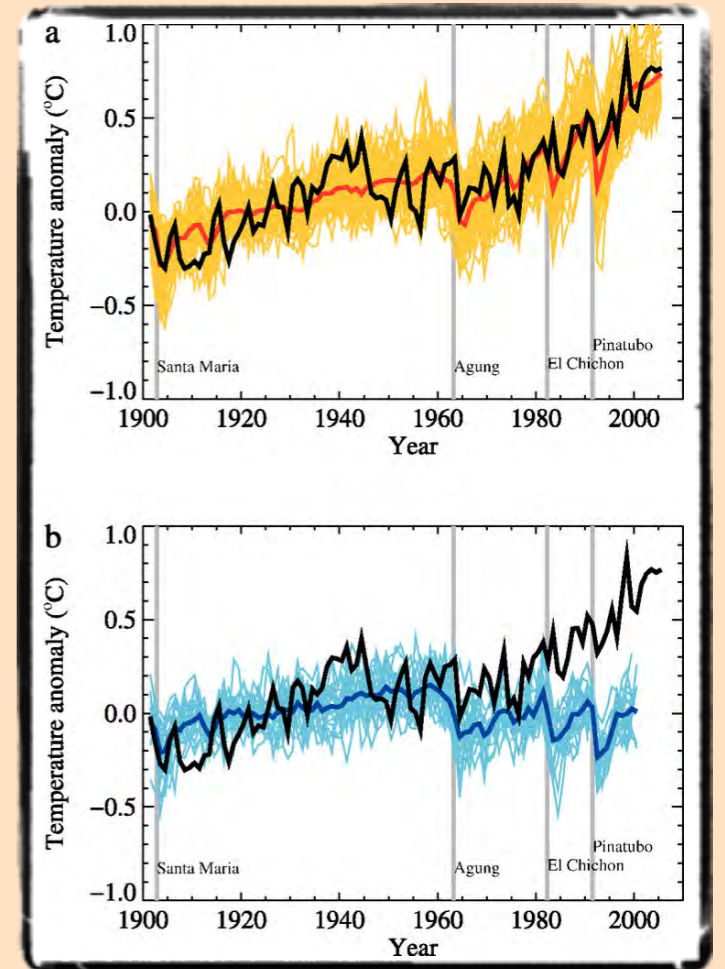
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# The trinity

*We will meet IPCC's 2°C in a "business as usual" scenario*

*Climate sensitivity is low*

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**21<sup>st</sup> century ΔT will be large**



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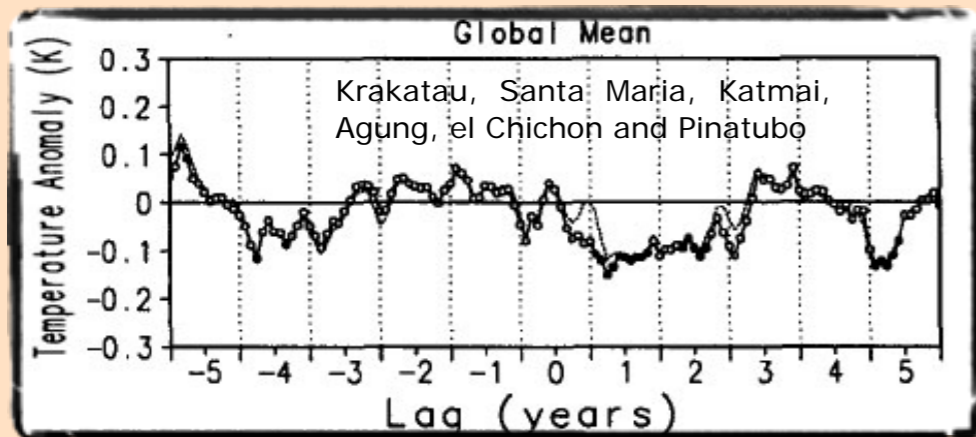
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Sensitivity is low

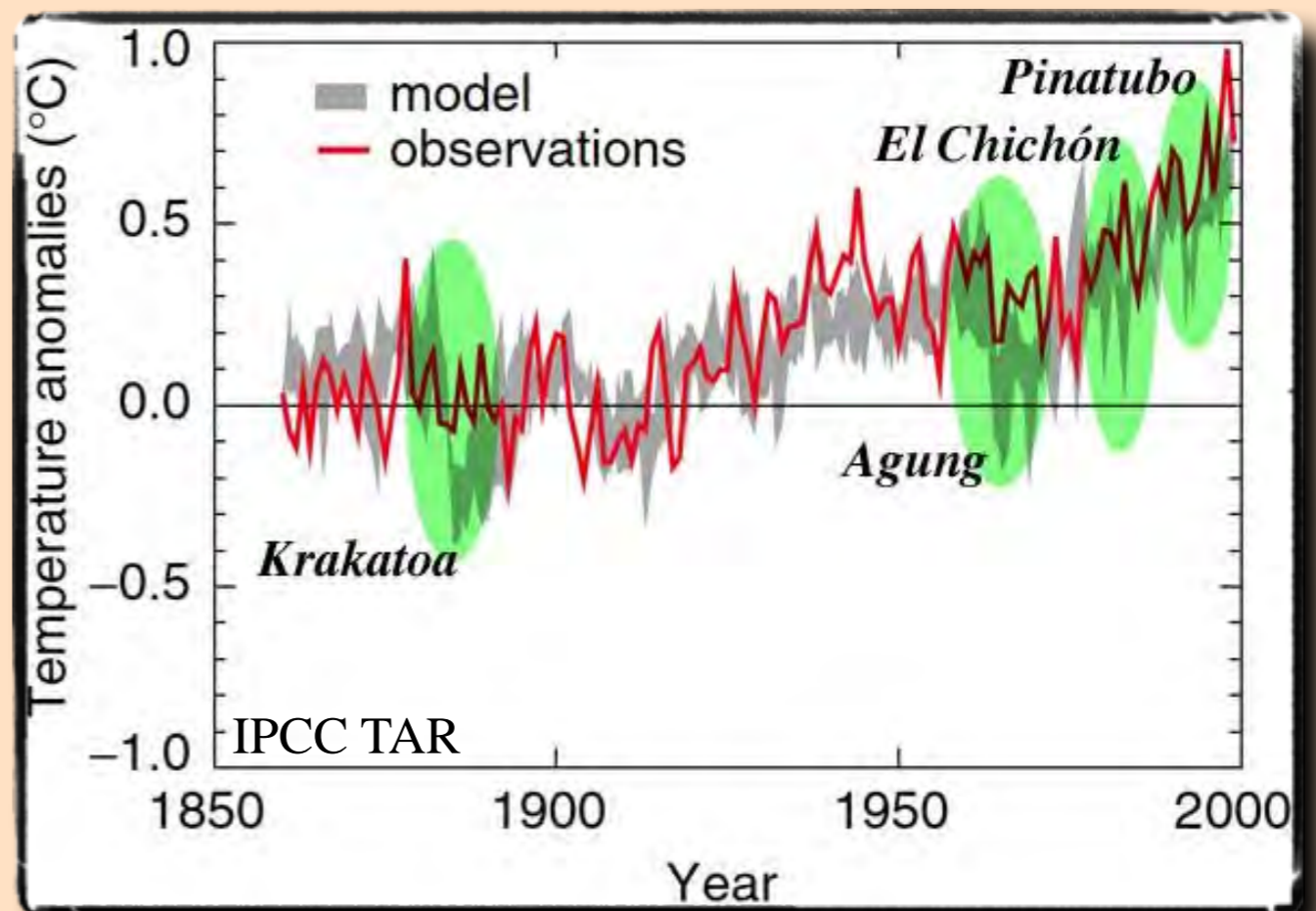
# Climate response to volcanoes is small



Robock and Mau 1995



Model predictions: Decrease of 0.3-0.5°C.  
Reality: Decrease of 0.1°C on average

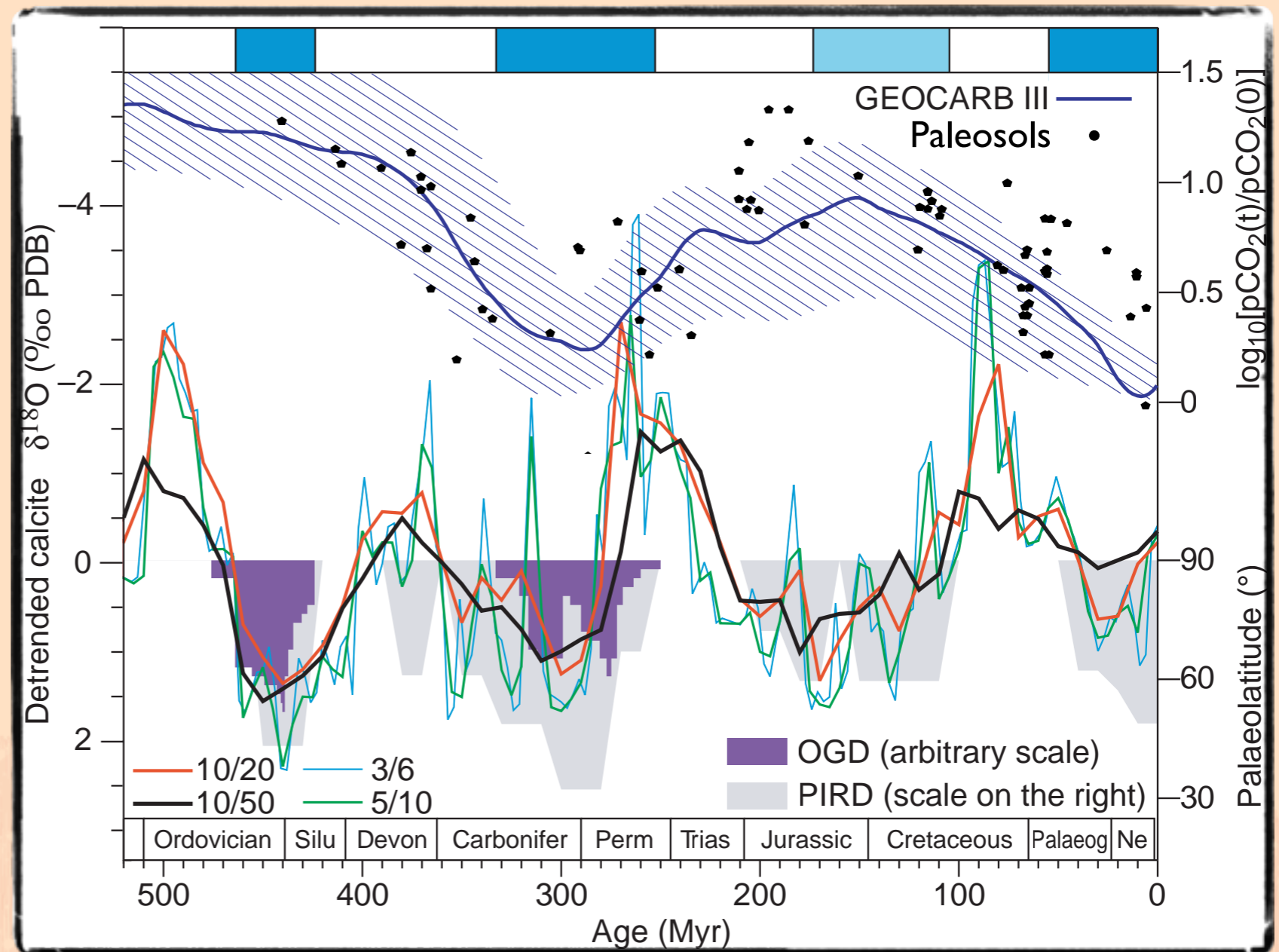


Lindzen & Giannitis (1998):  
 $\Delta T_{x2} \approx 1^\circ\text{C}$

# Climate response to CO<sub>2</sub> is small

- *Over geological time scales: Large intrinsic variations in CO<sub>2</sub> do not cause large temperature changes.*

Based on the lack of correlation:  
 $1^{\circ}\text{C} \approx \Delta T_{x2} \approx 1.5^{\circ}\text{C}$   
(Shaviv 2005)



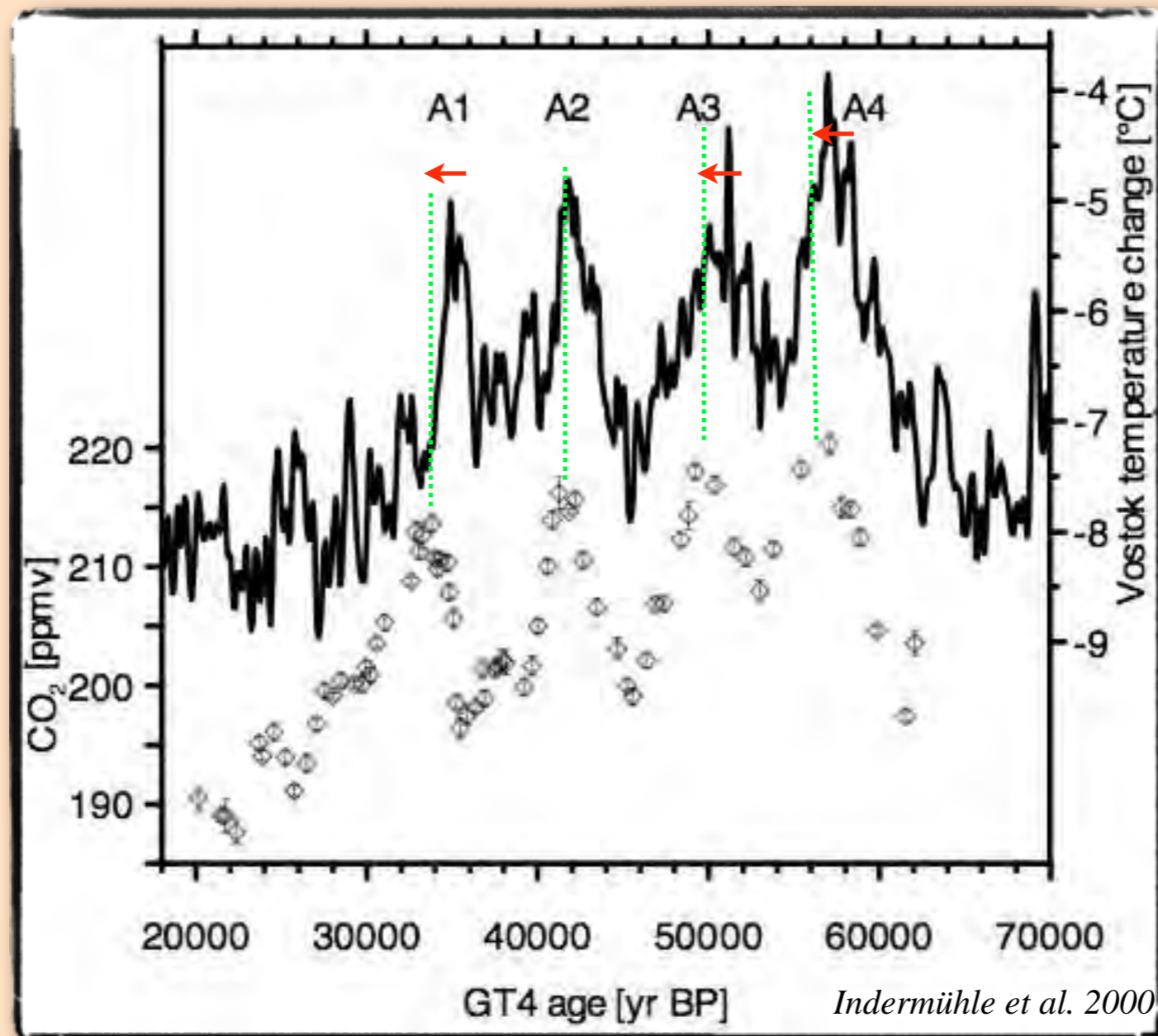
Veizer et al. (2000), Shaviv & Veizer (2003)

*But what about Al Gore and his ice cores?*



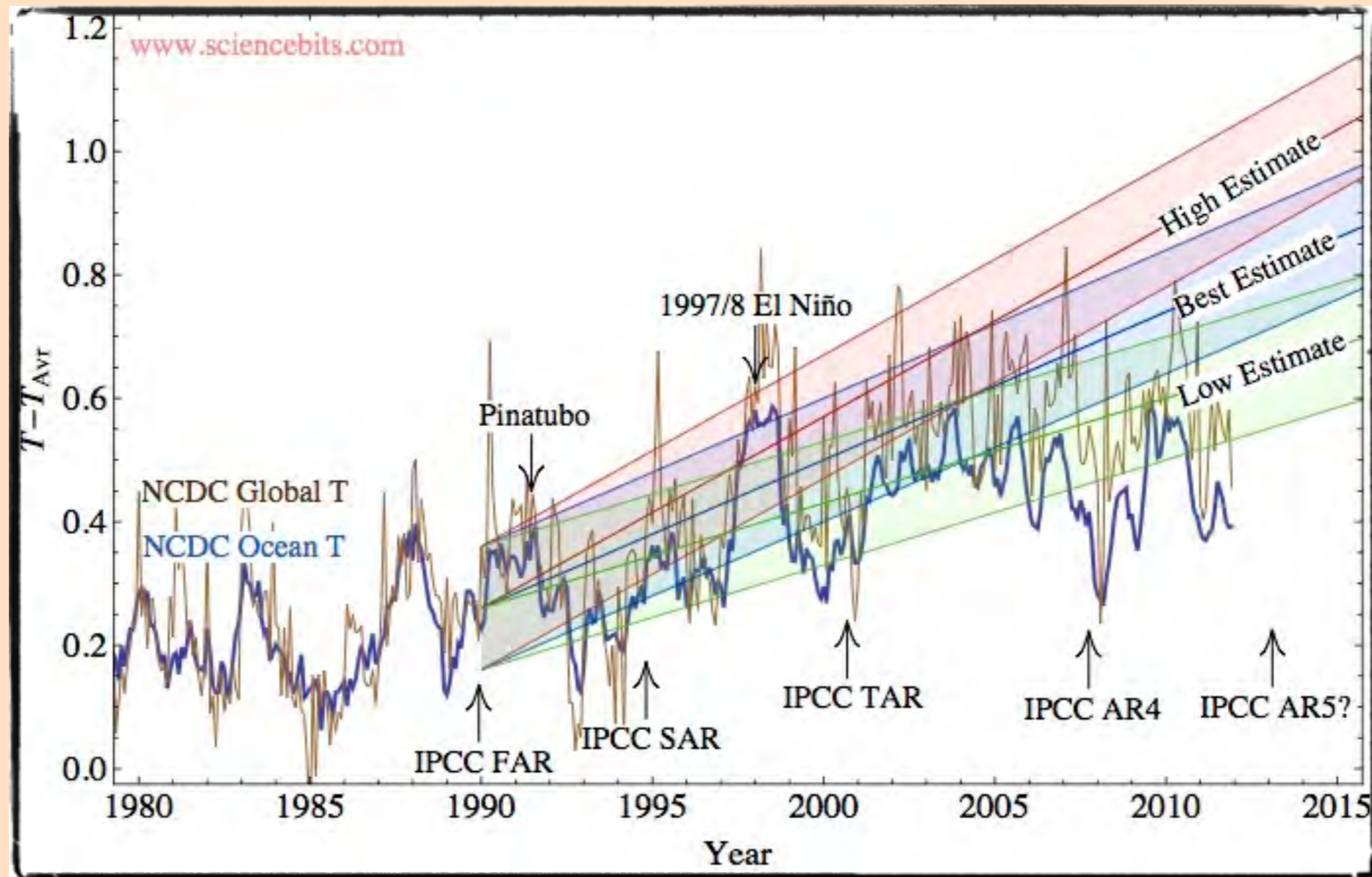
*But what about Al Gore and his ice cores?*

- *CO<sub>2</sub> lags temperature!*



# Global Warming “hiatus”

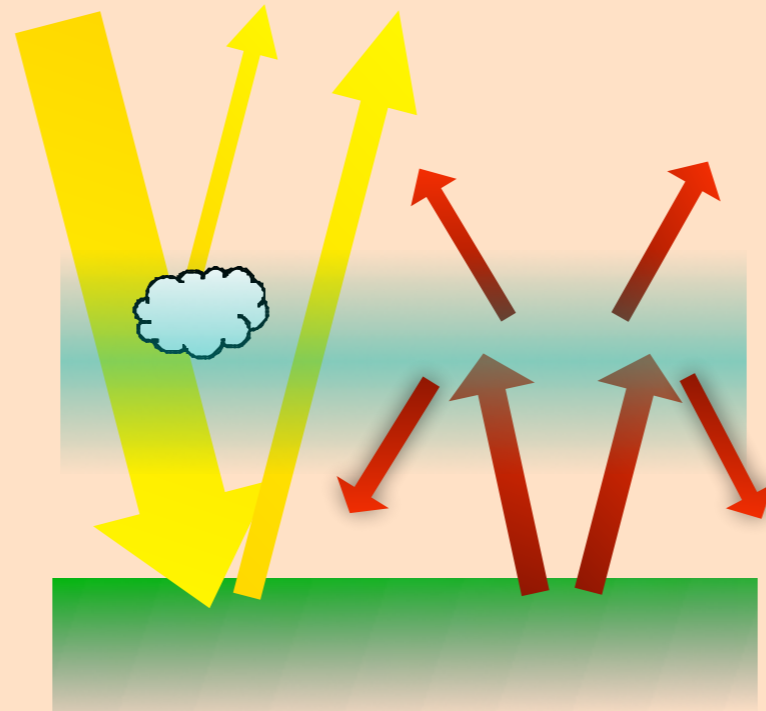
- Heating over the past 20 years running below the low estimate of the IPCC



Sensitivity below IPCC 1.5-4.5°C range, i.e.,  $\Delta T_{x2} \approx 1.5^\circ\text{C}$

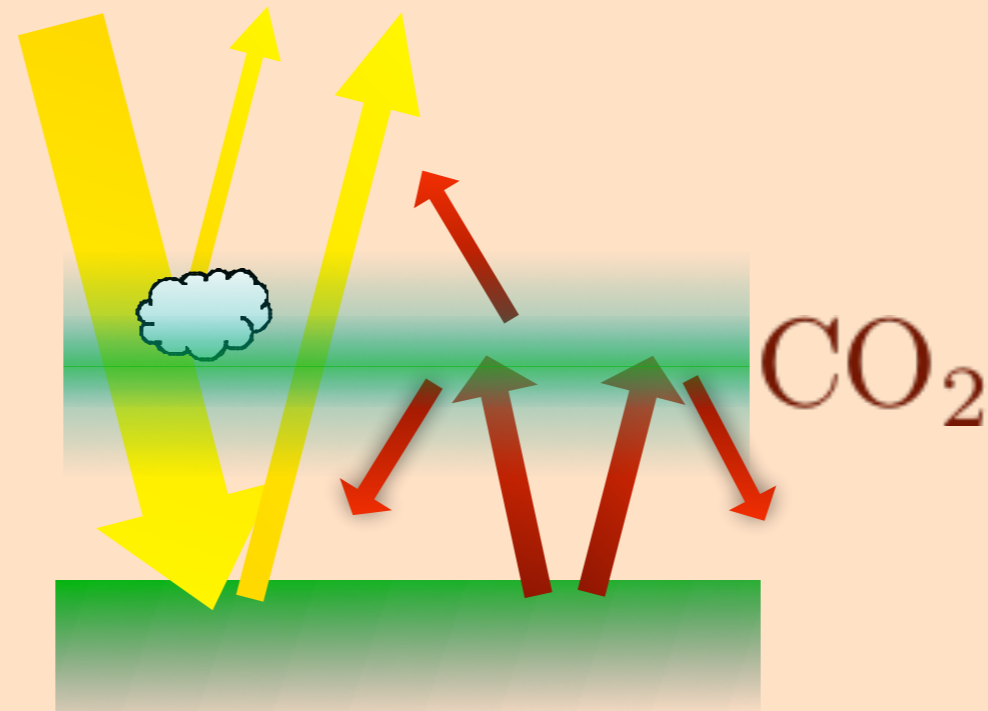


Why can't models predict climate sensitivity?



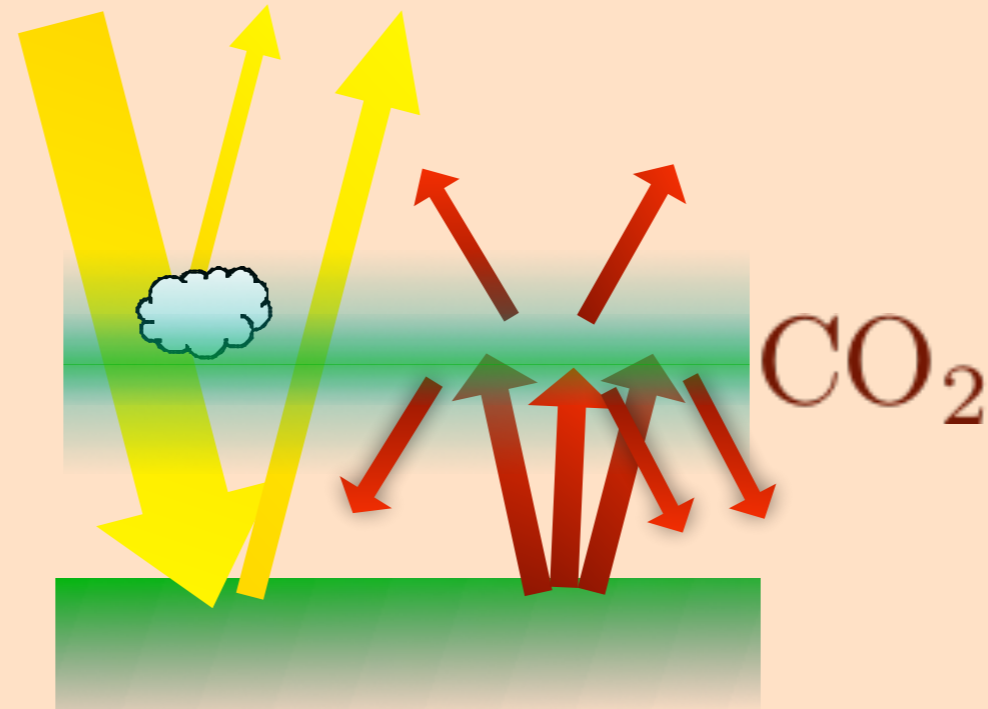
*The Greenhouse effect*

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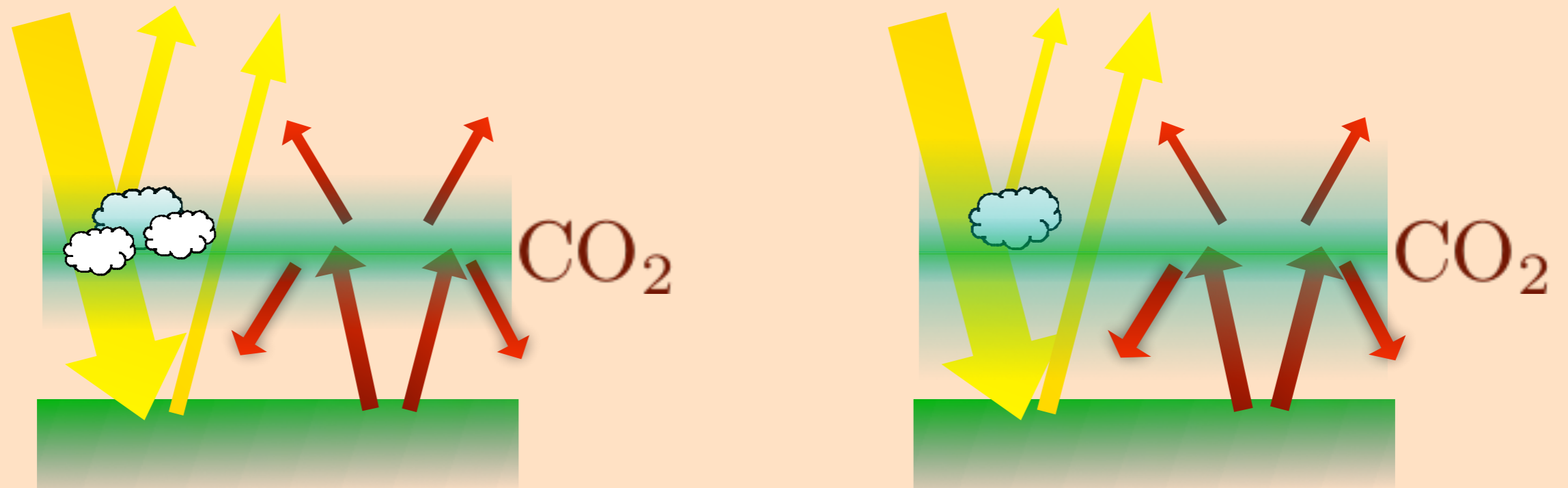
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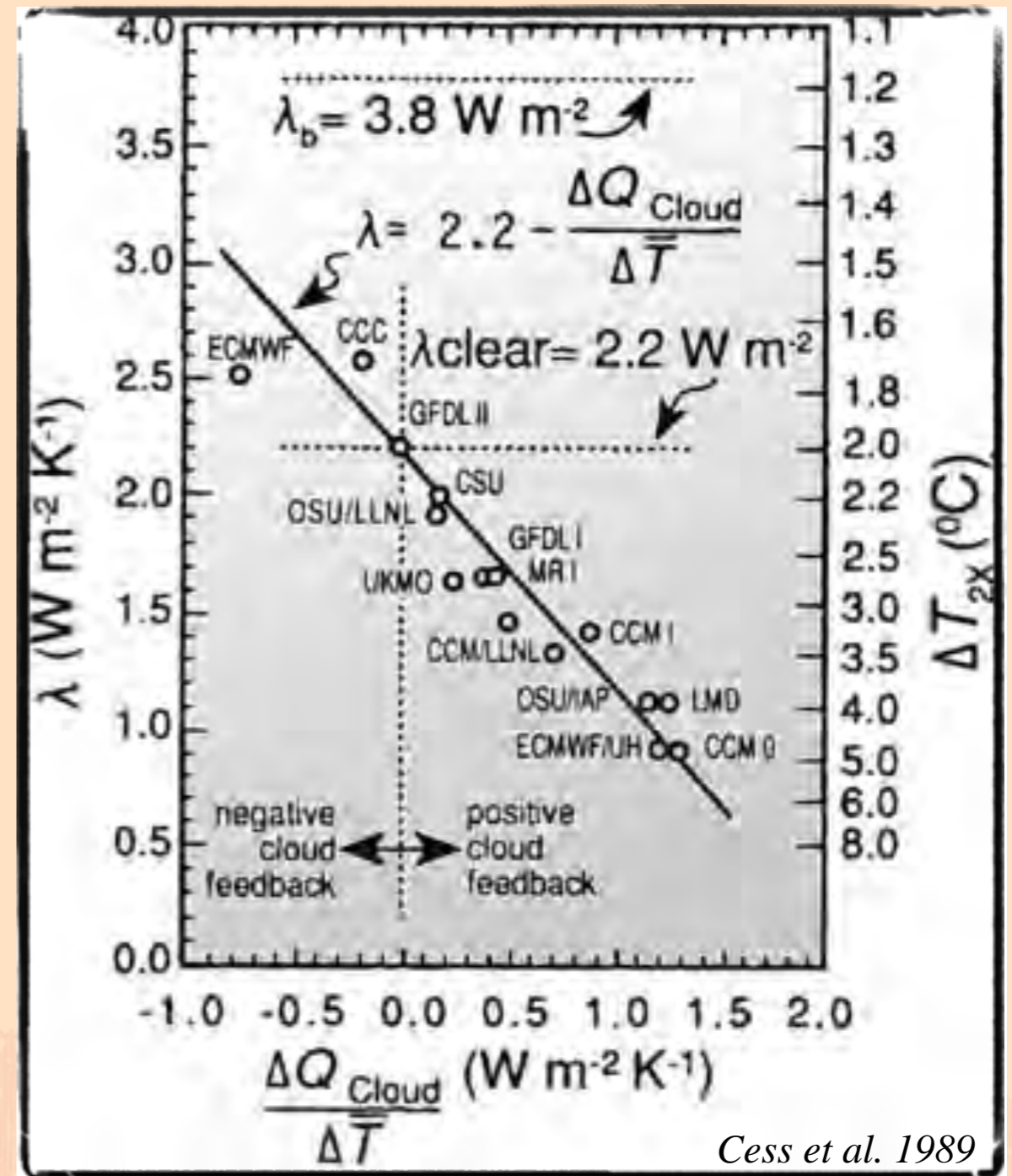
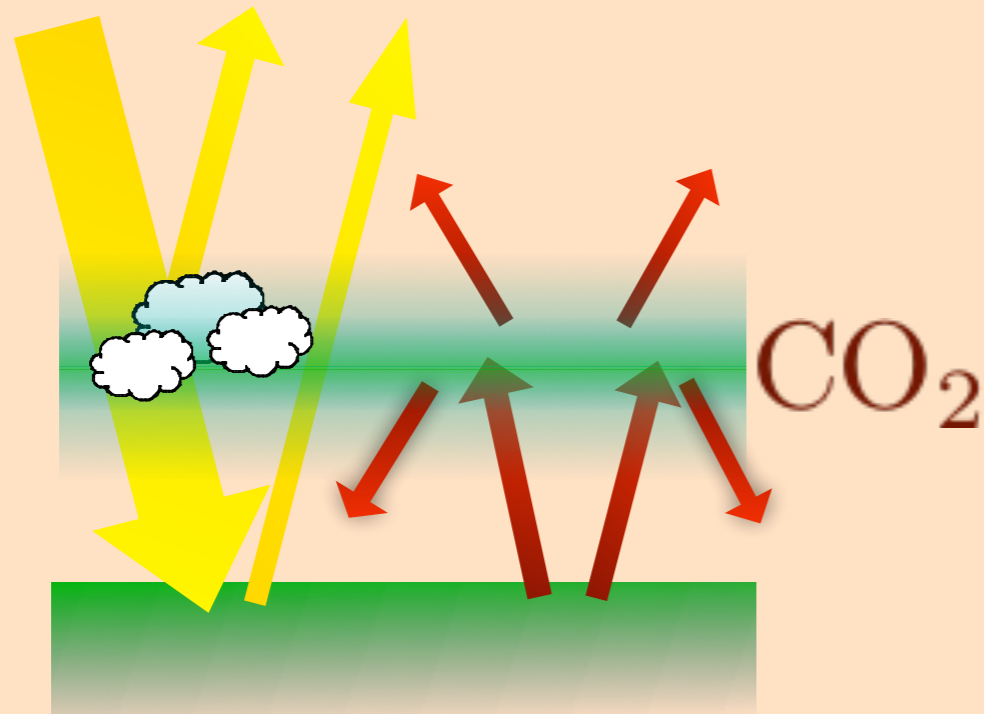
*The Greenhouse effect*

# Why can't models predict climate sensitivity?



Different “recipes” for the cloud cover produce different sensitivities: Increase of 1.5 to 5°C per CO<sub>2</sub> doubling.

# Why can't models predict climate sensitivity?



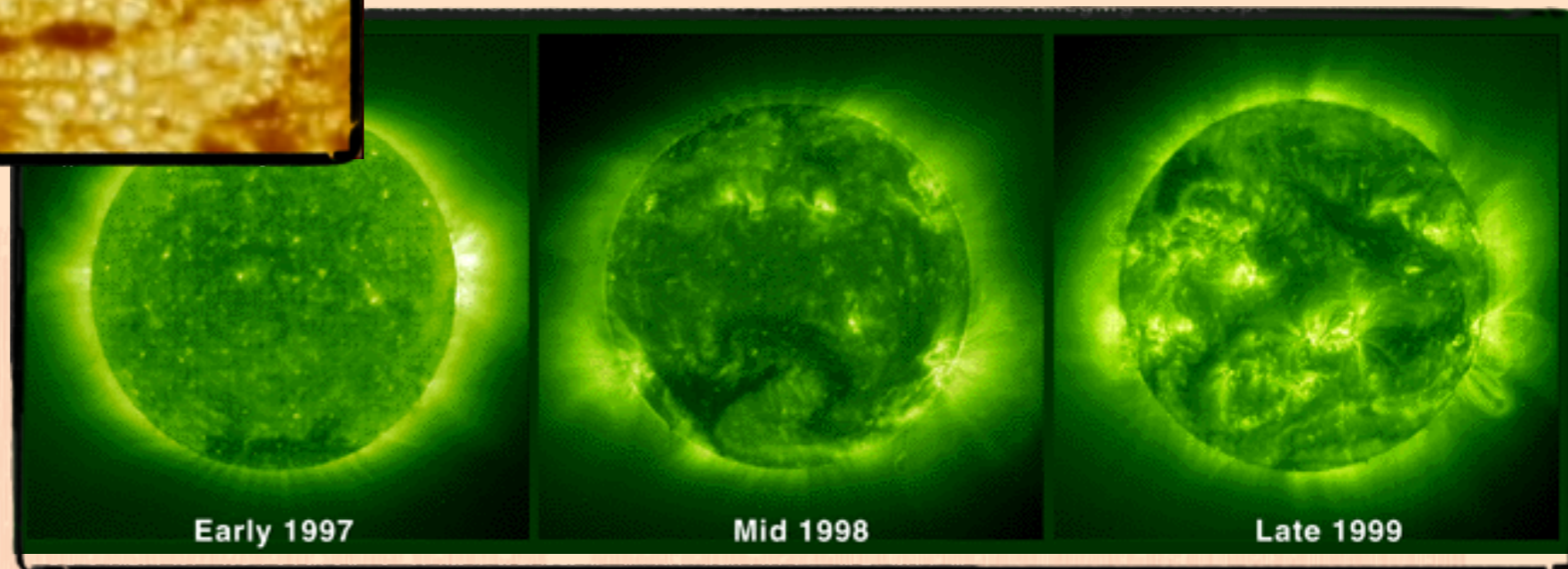
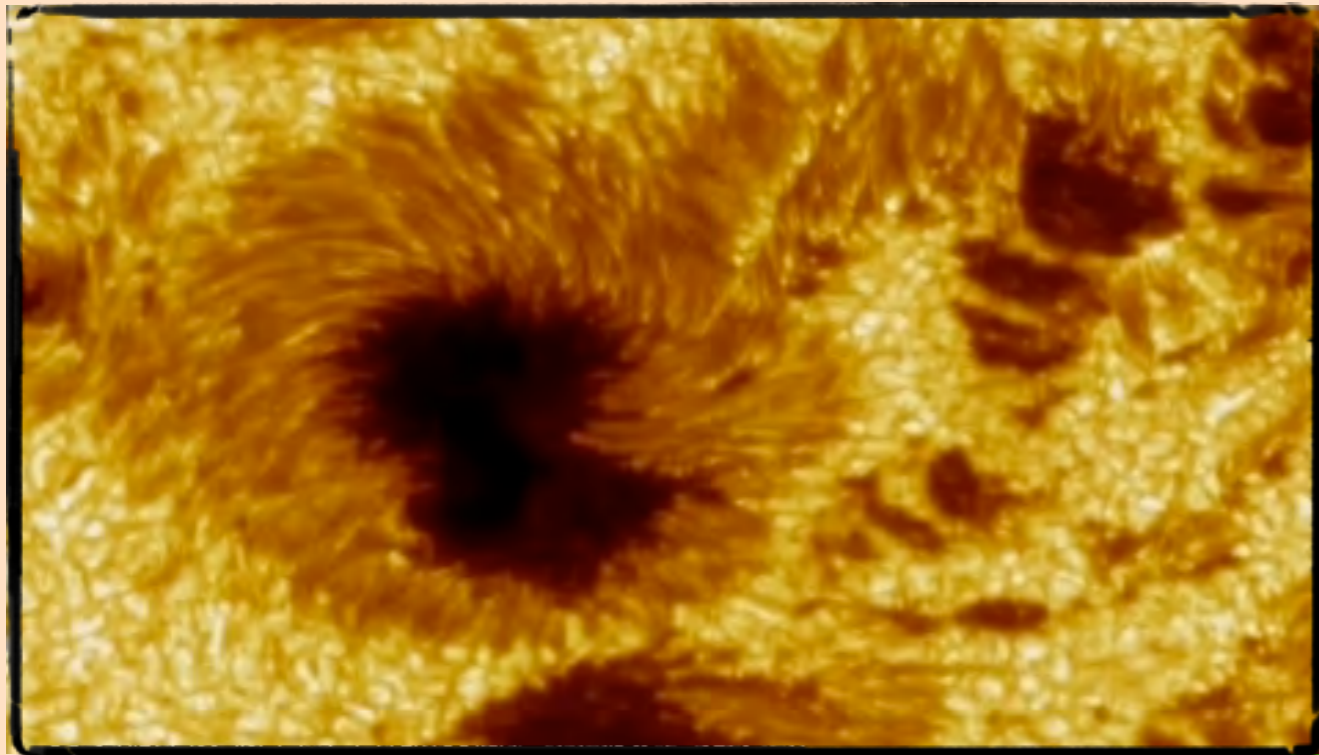


# The Sun's role in Climate Change



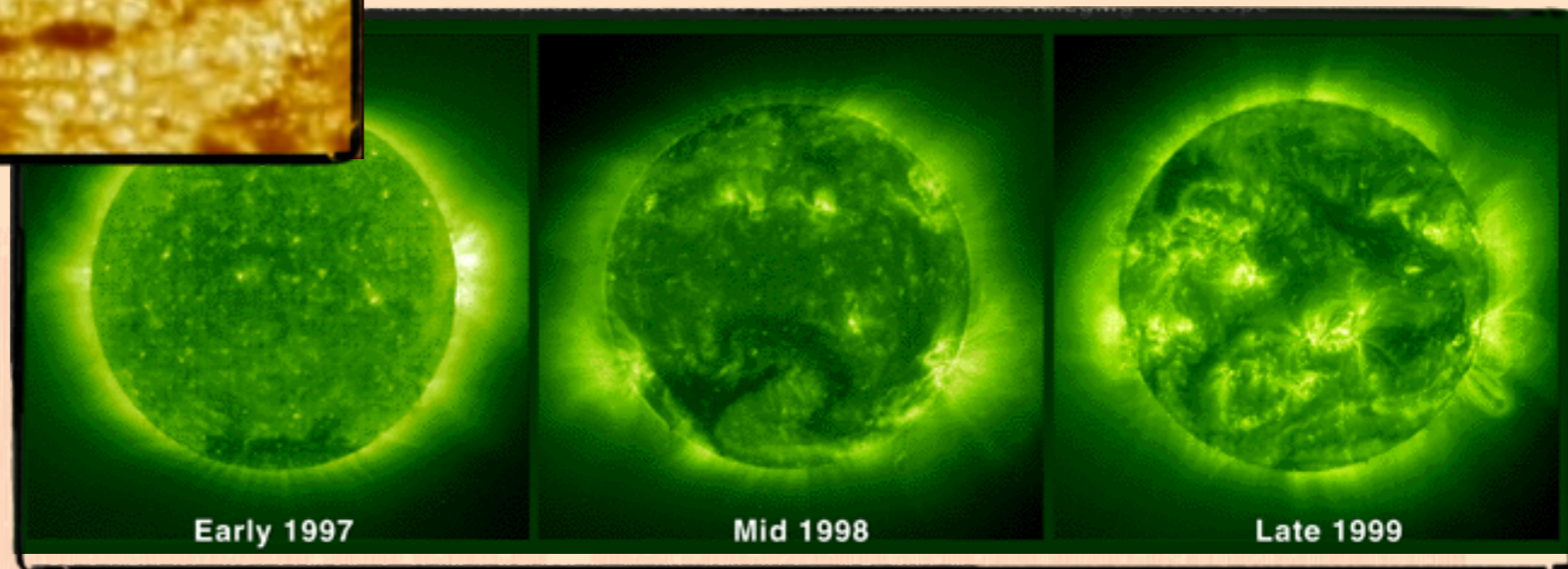
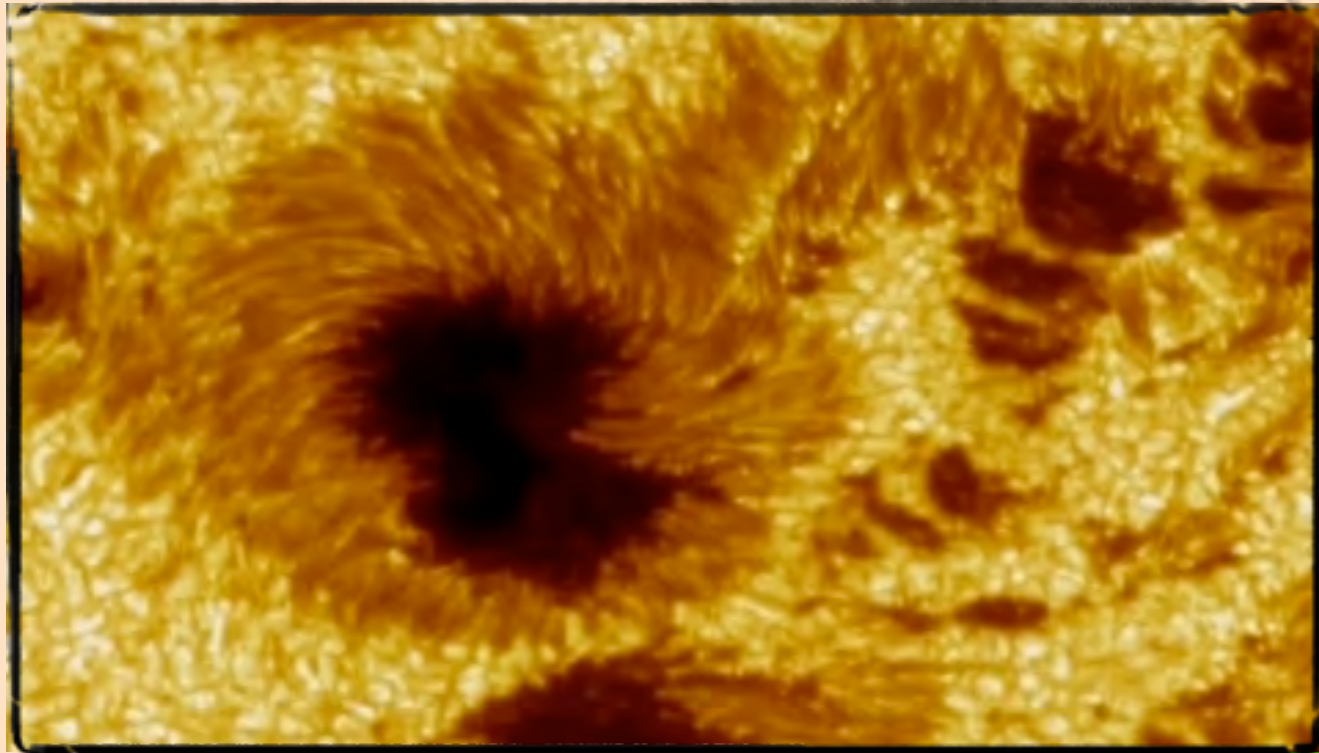
# Solar Activity

- *The claim that there isn't any other explanation, and therefore the warming must be primarily human, is wrong. There is another explanation: **Solar Activity**.*



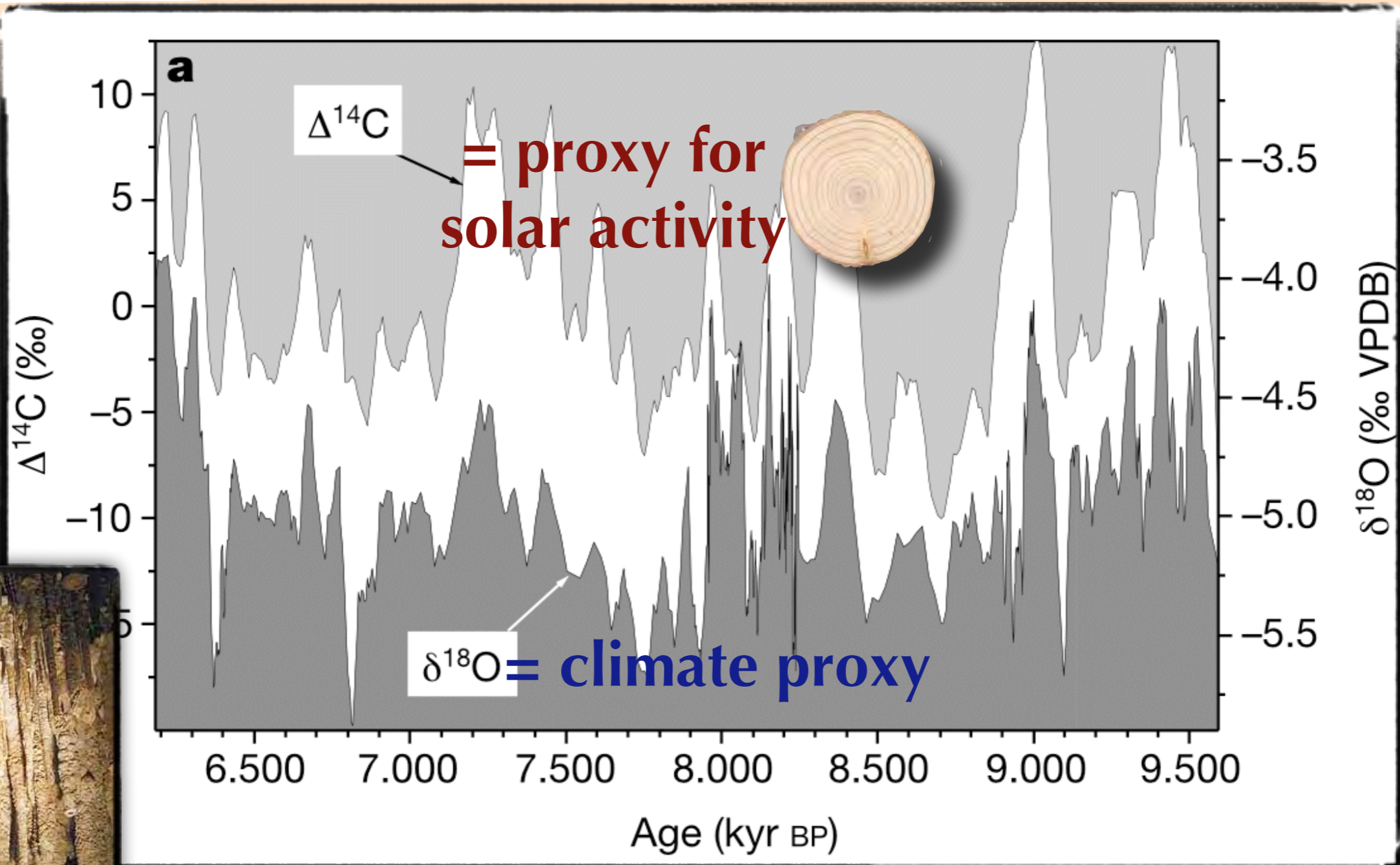
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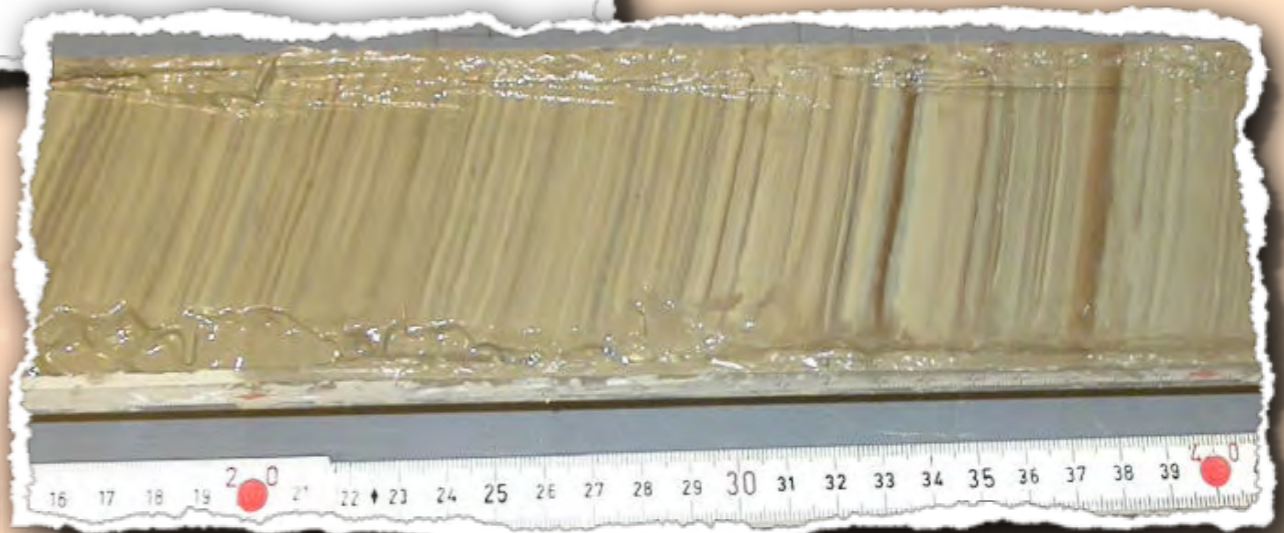
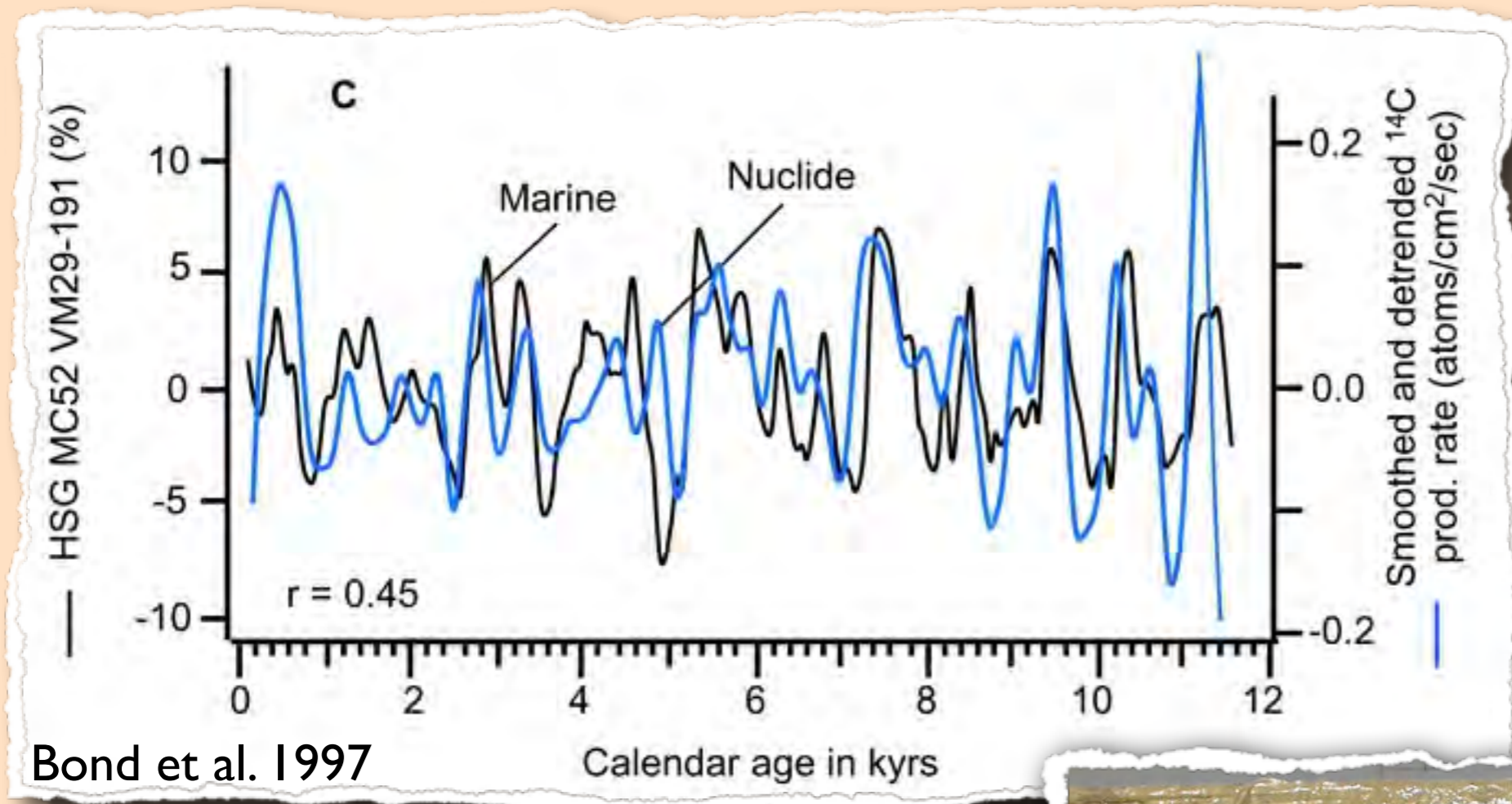




# The link over several millennia

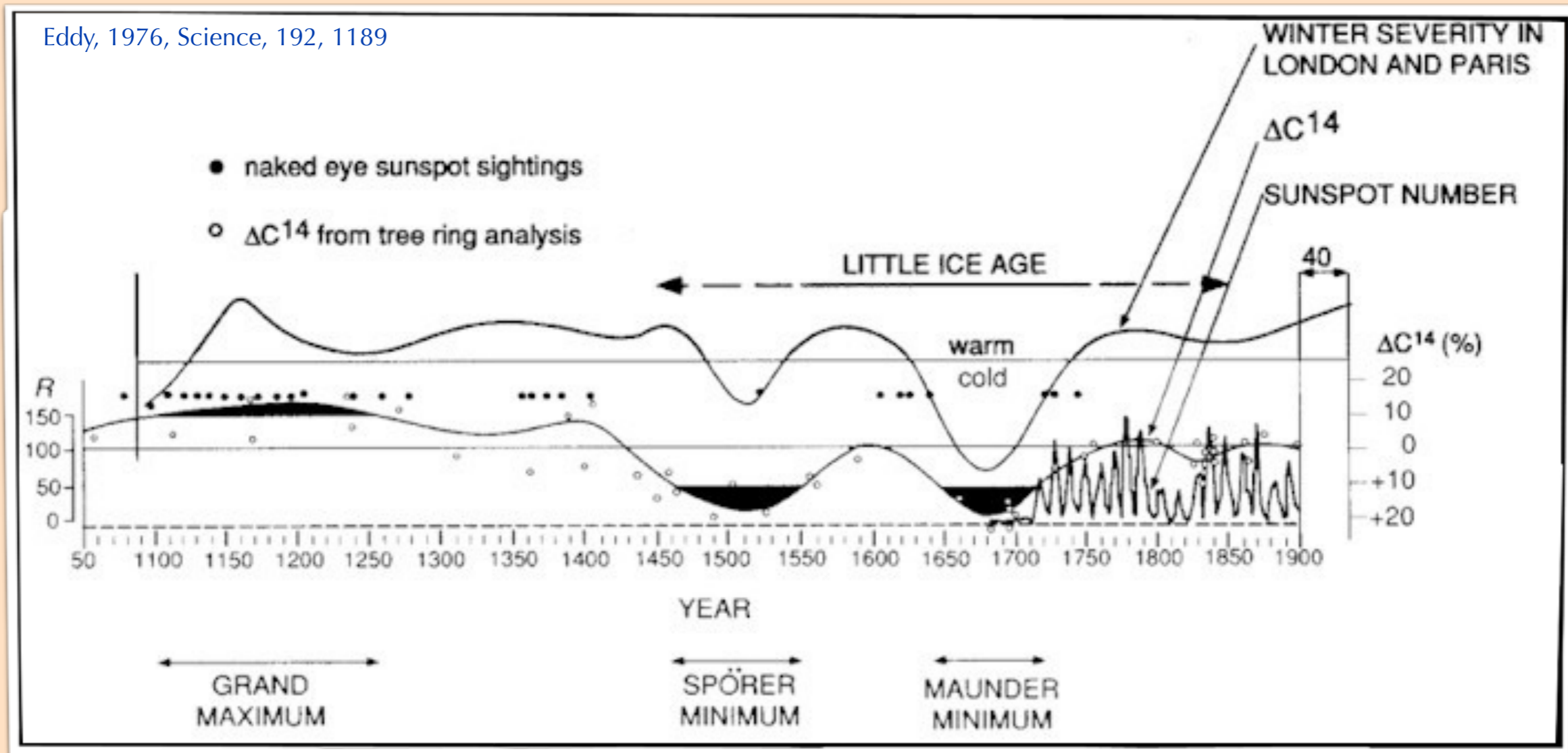


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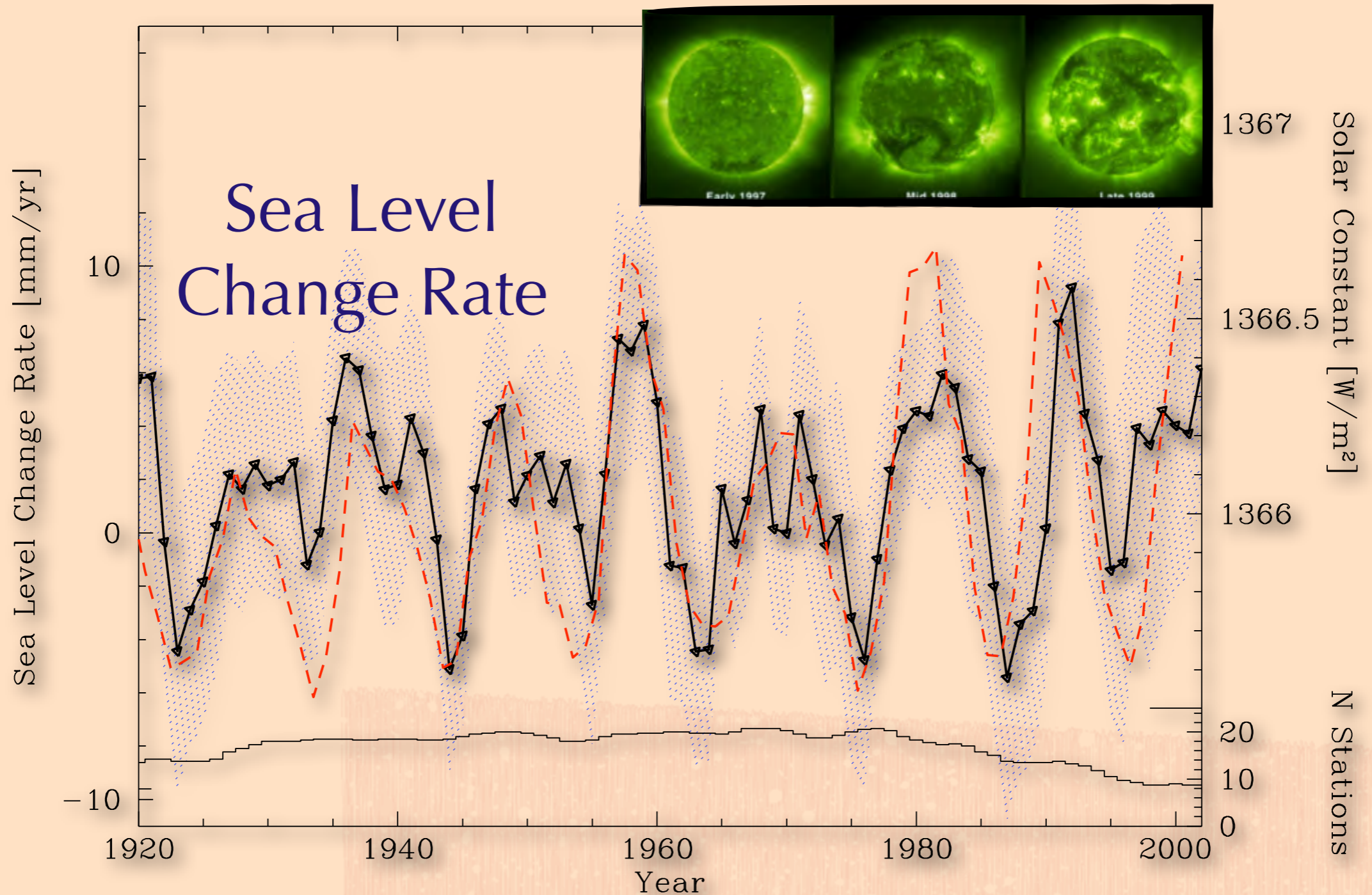
# The Link over the past Millennium

Eddy, 1976, Science, 192, 1189

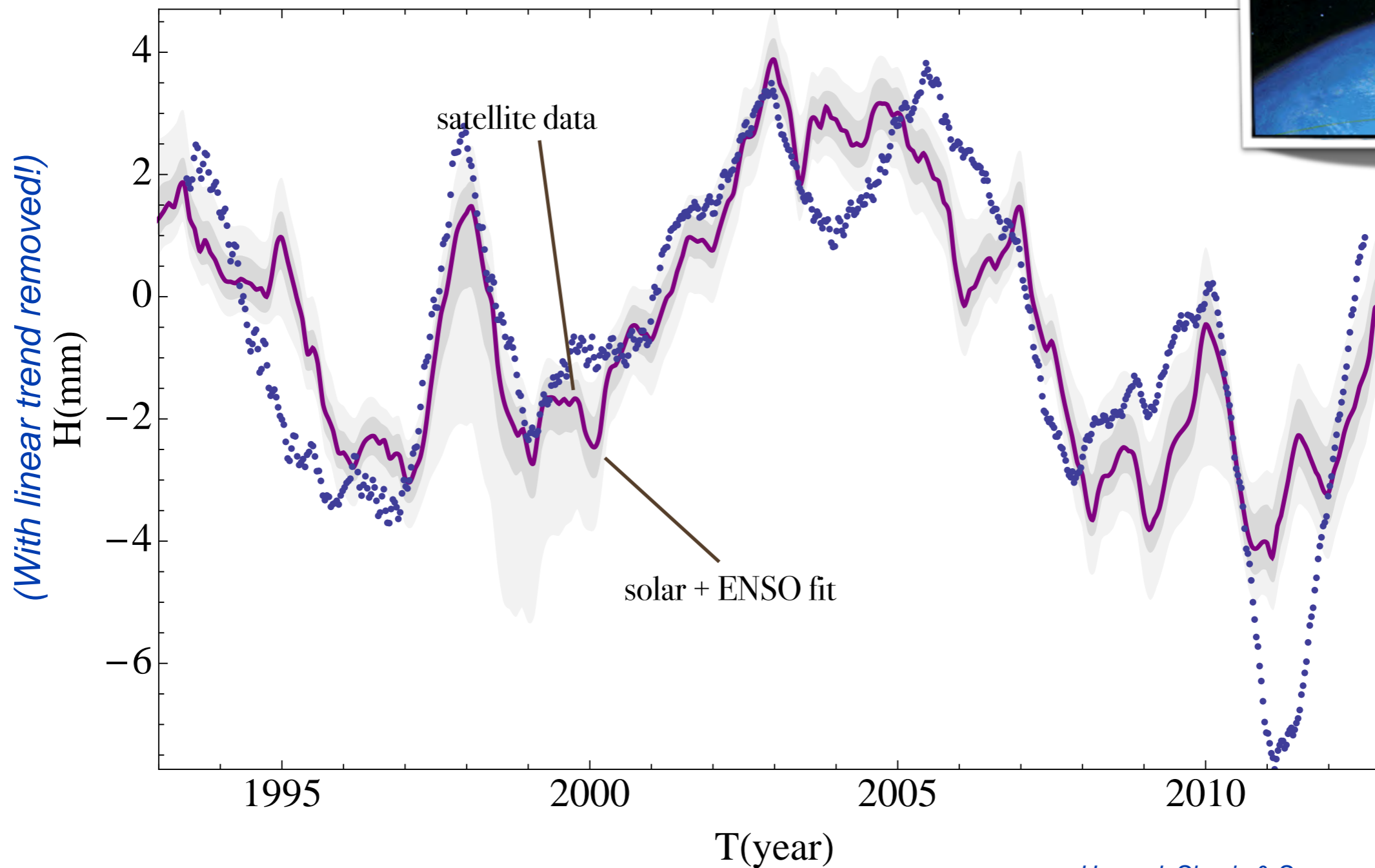
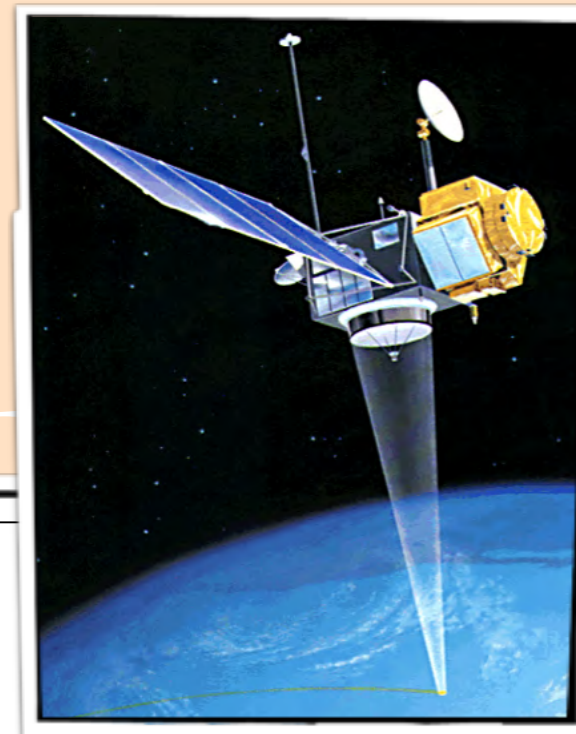


# Link over the 11-year Cycle

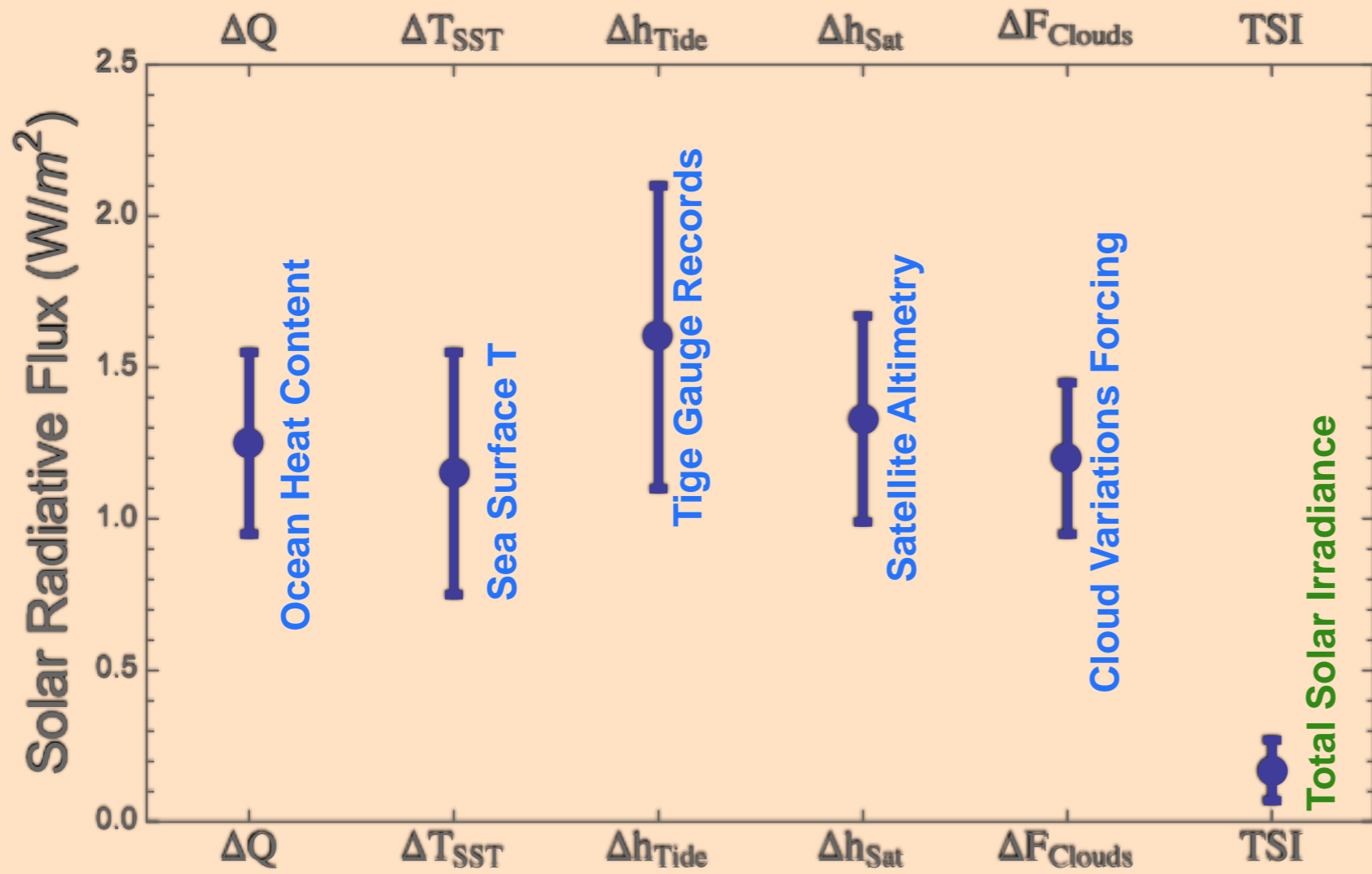
Sun



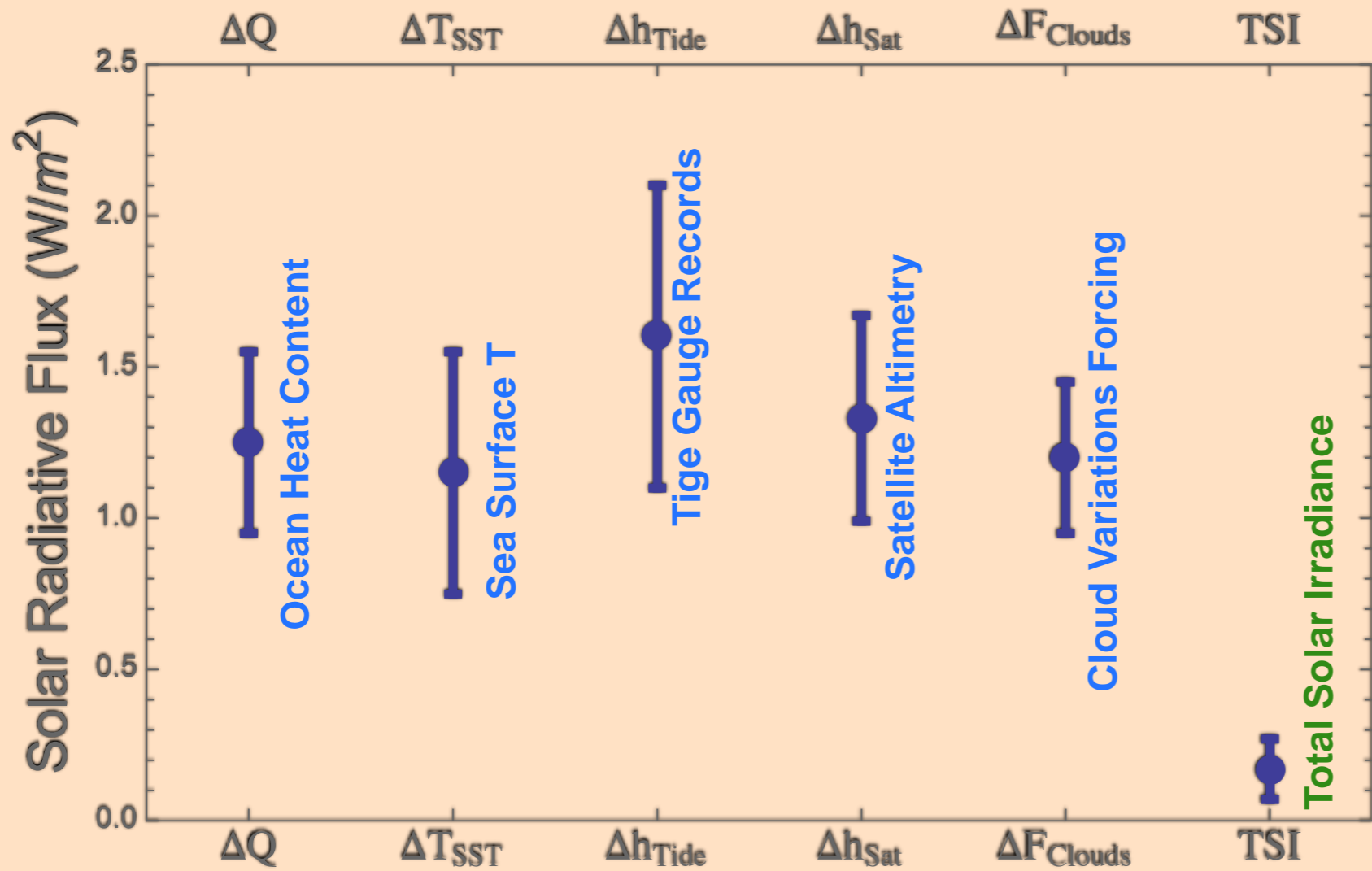
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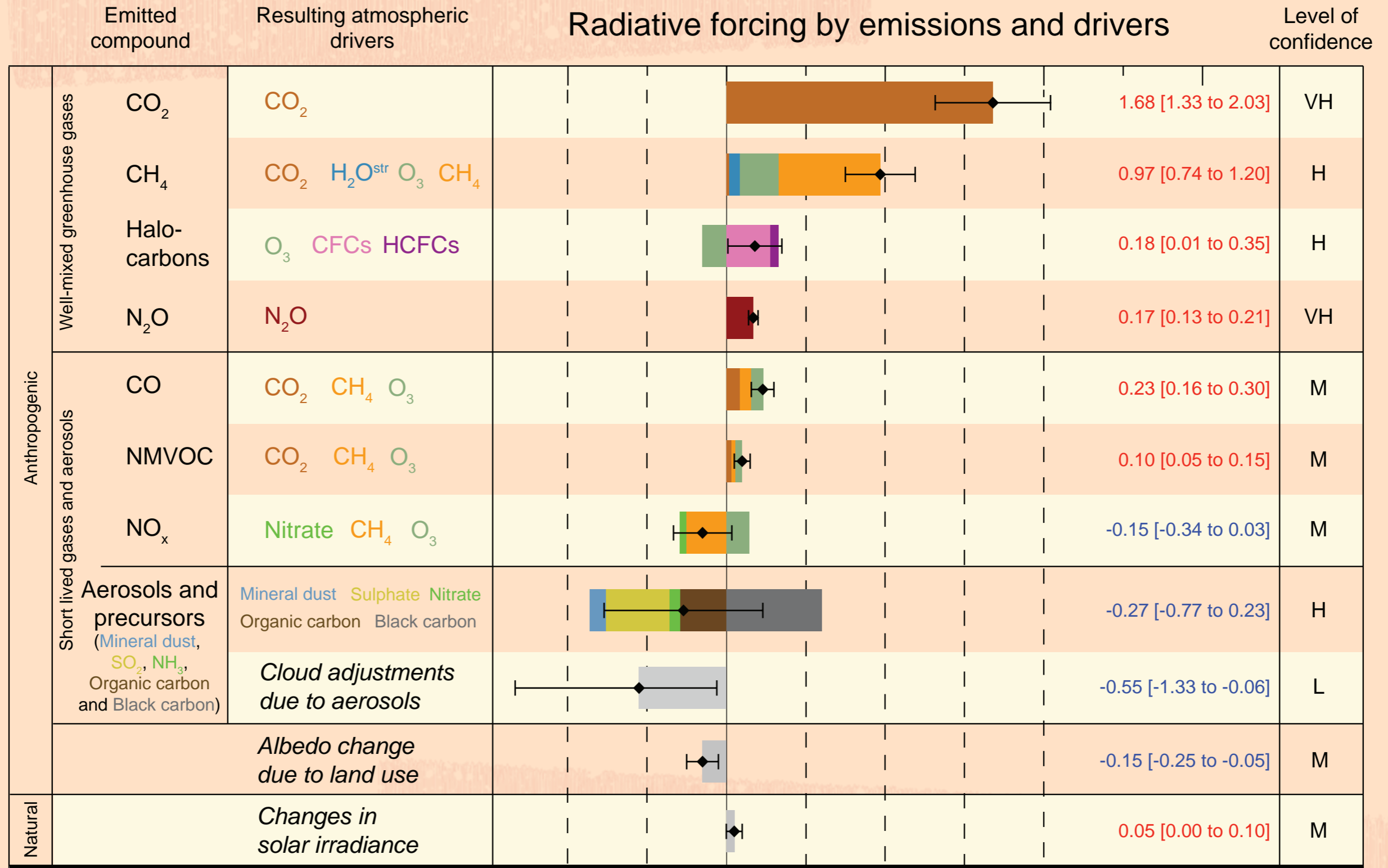


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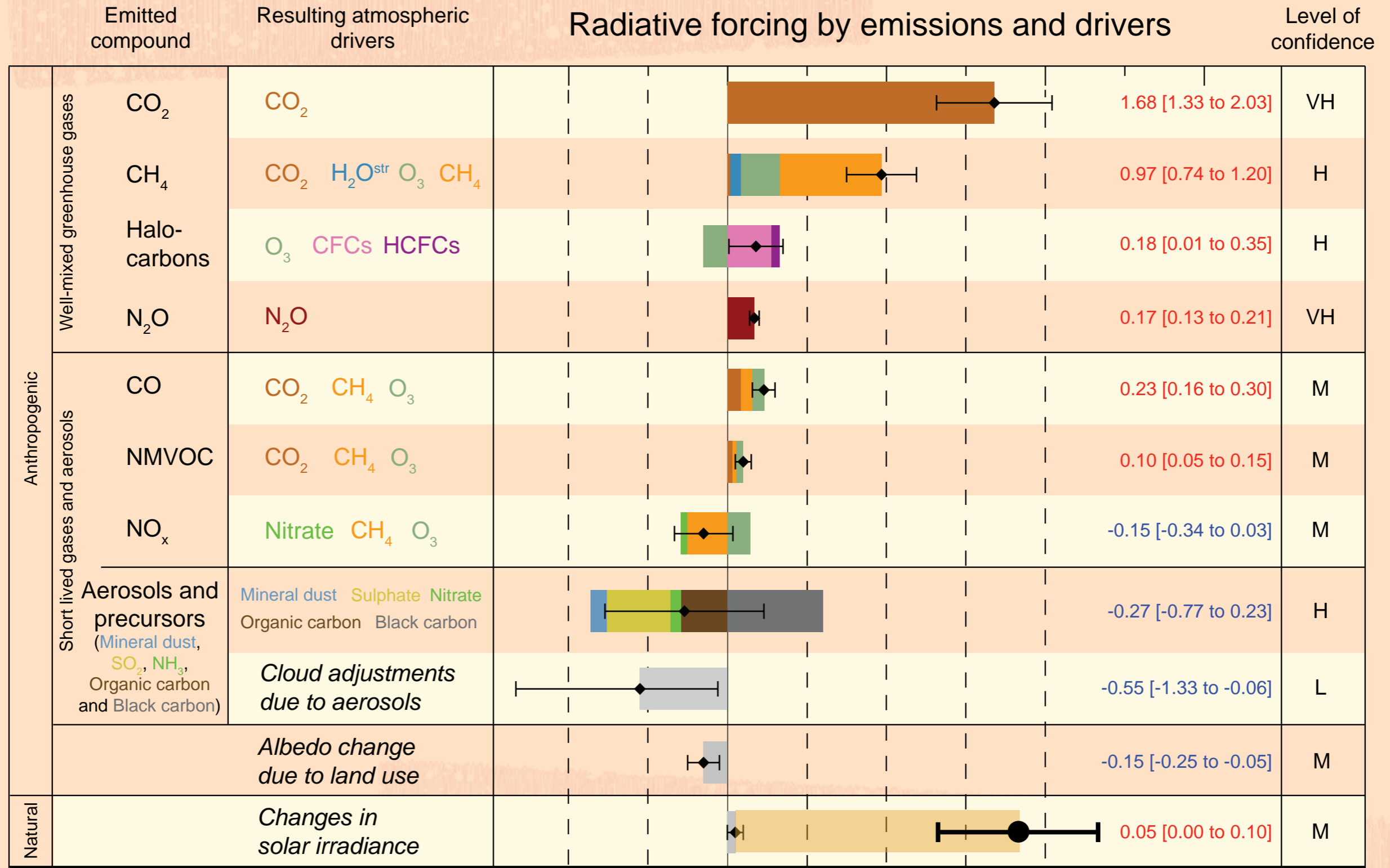
Require  
an amplification  
mechanism

# IPCC 5AR forcing graph





# IPCC 5AR forcing graph



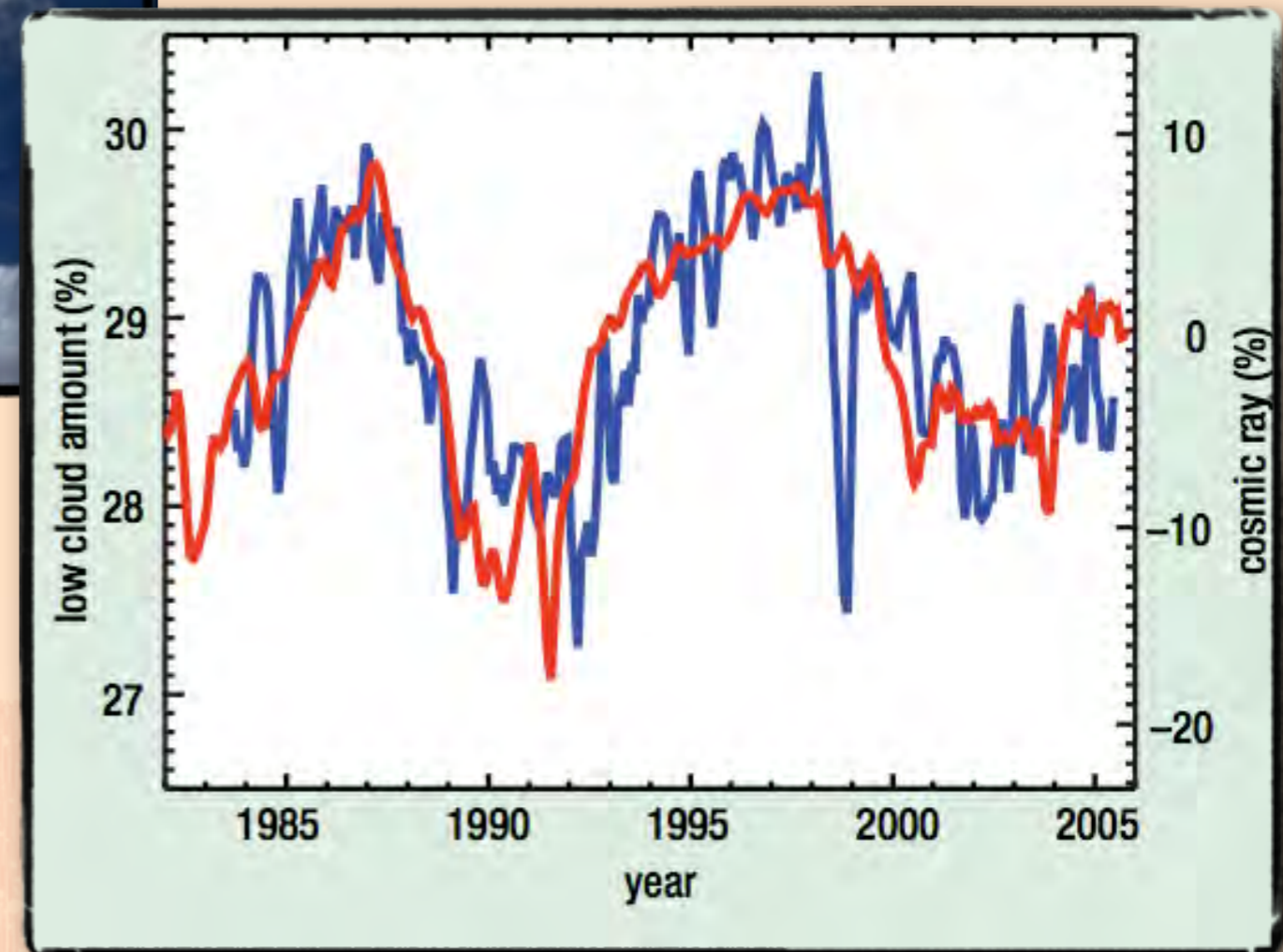
Since Maunder Minimum



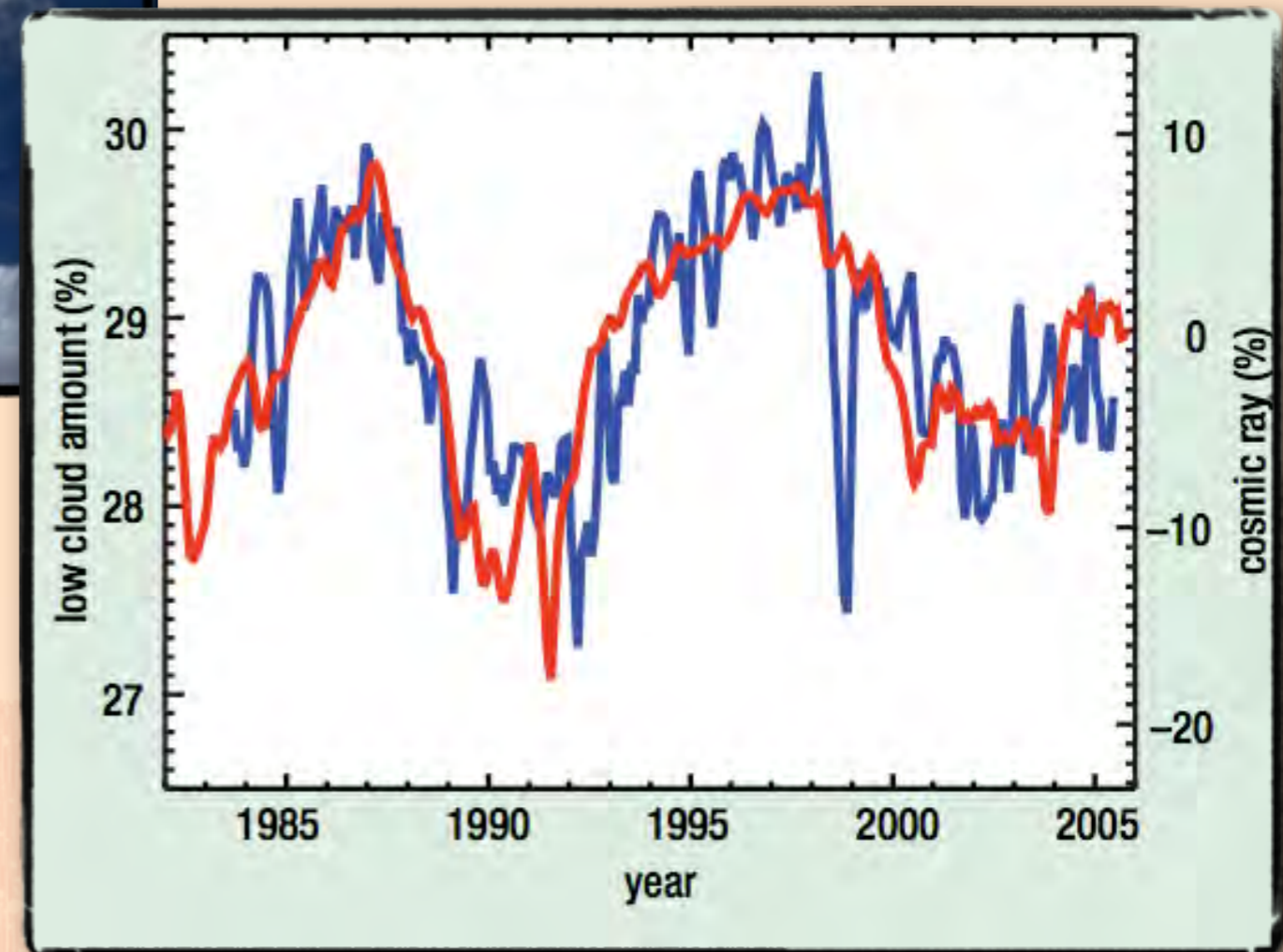
# Cosmic Rays: Linking Solar Activity to Climate

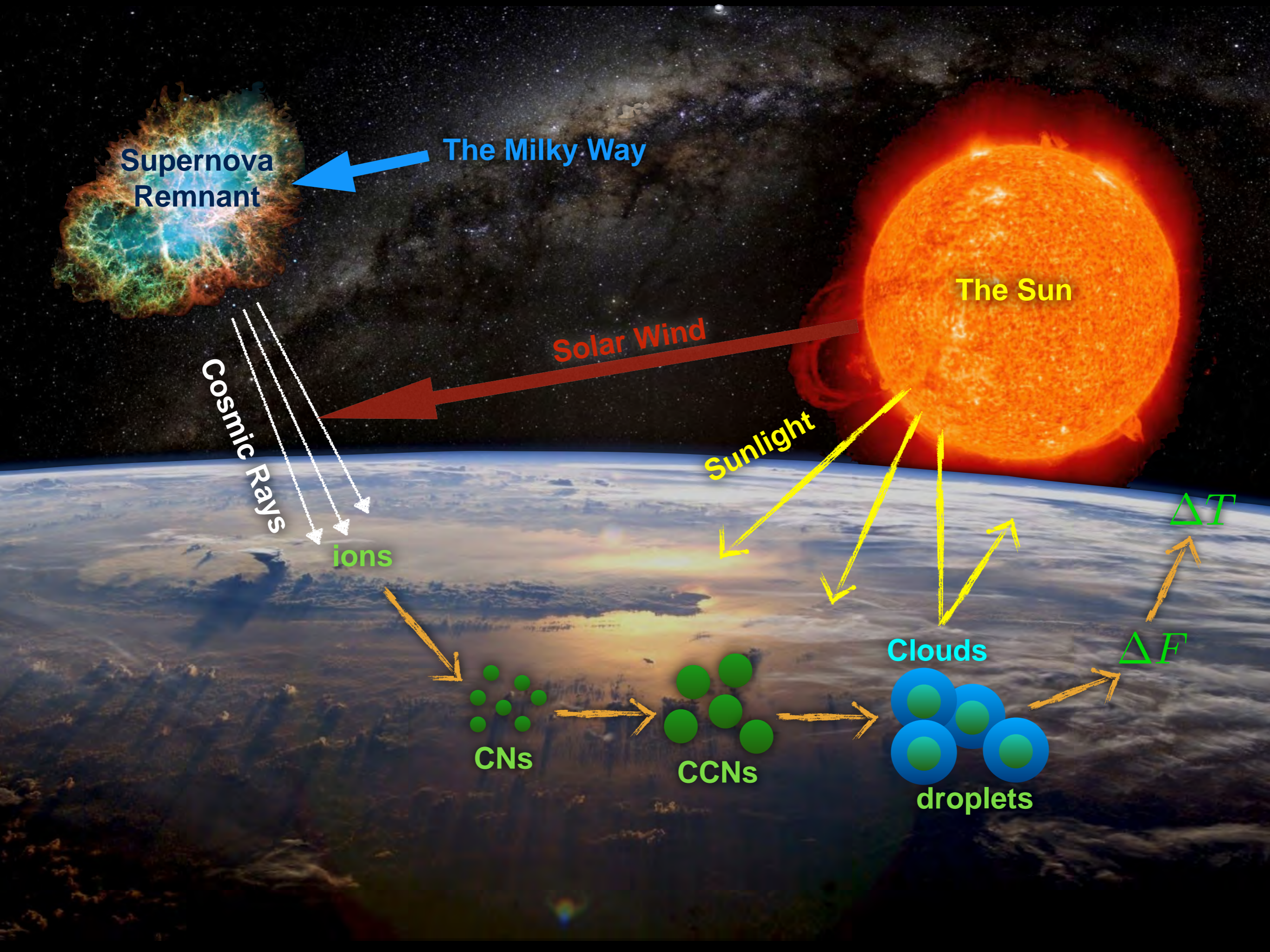


# Clouds over the 11-yr cycle



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Supernova Remnant

The Milky Way

The Sun

Solar Wind

Sunlight

Cosmic Rays

ions

$\Delta T$

$\Delta F$

Clouds

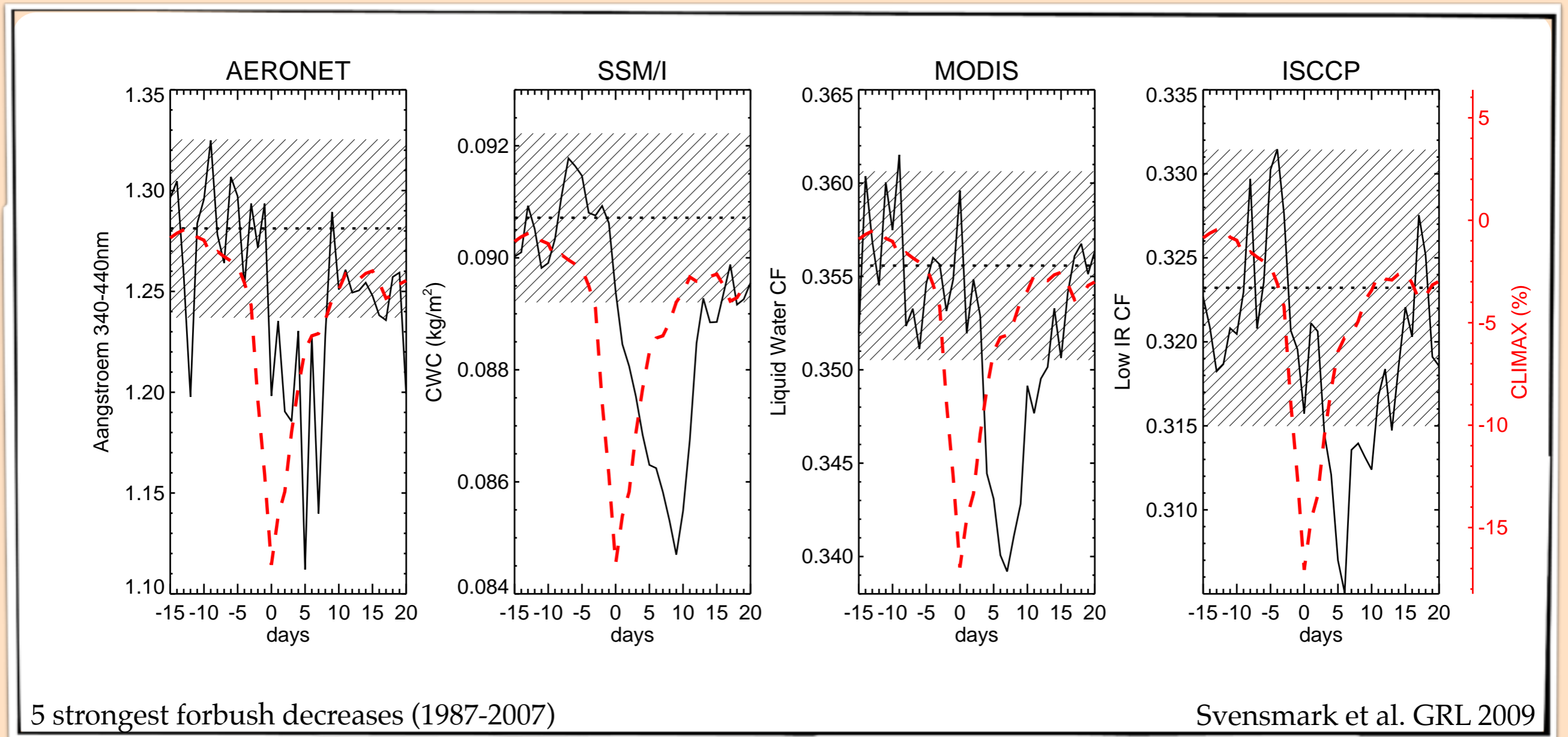
CNs

CCNs

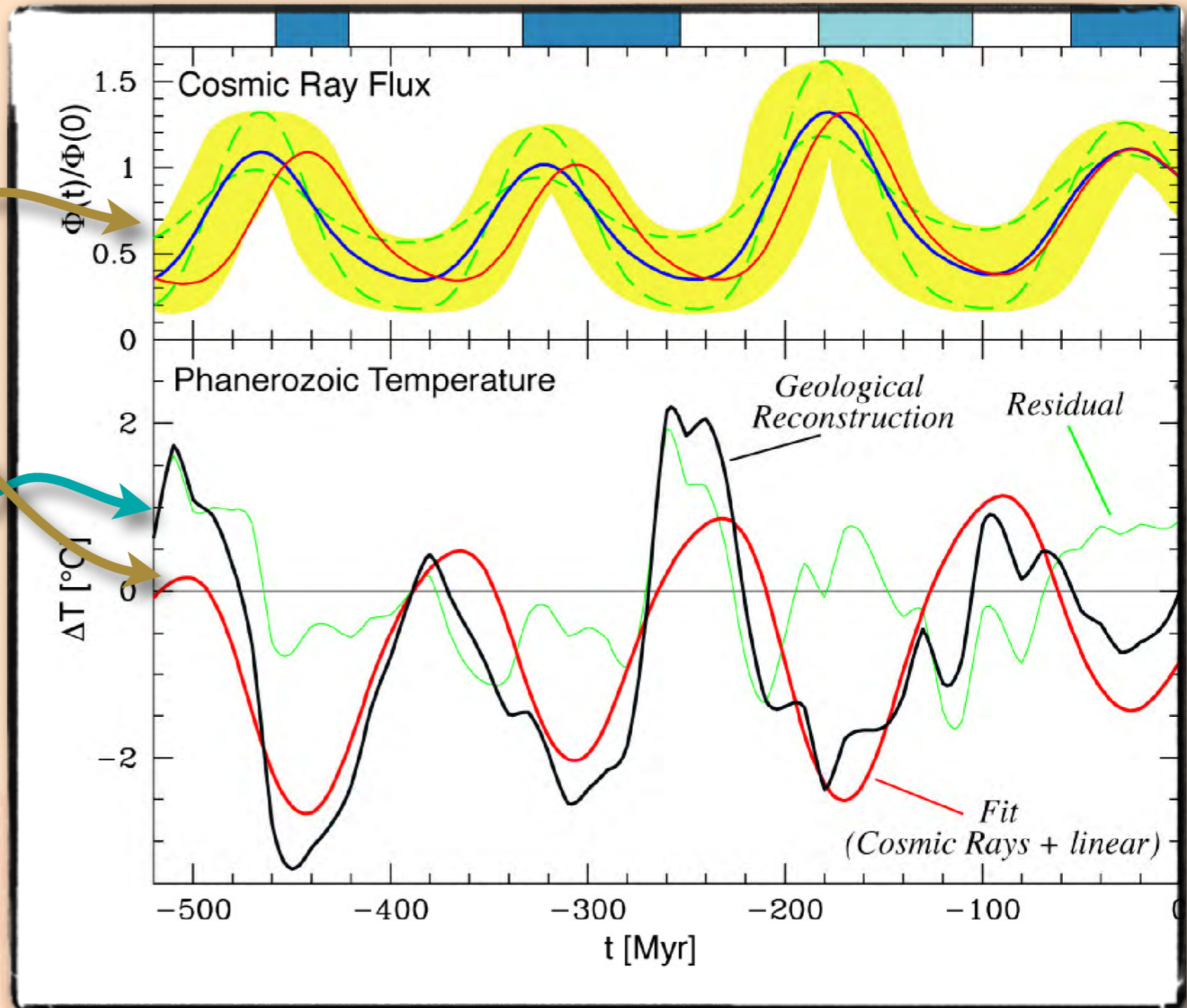
droplets

# Forbush decreases

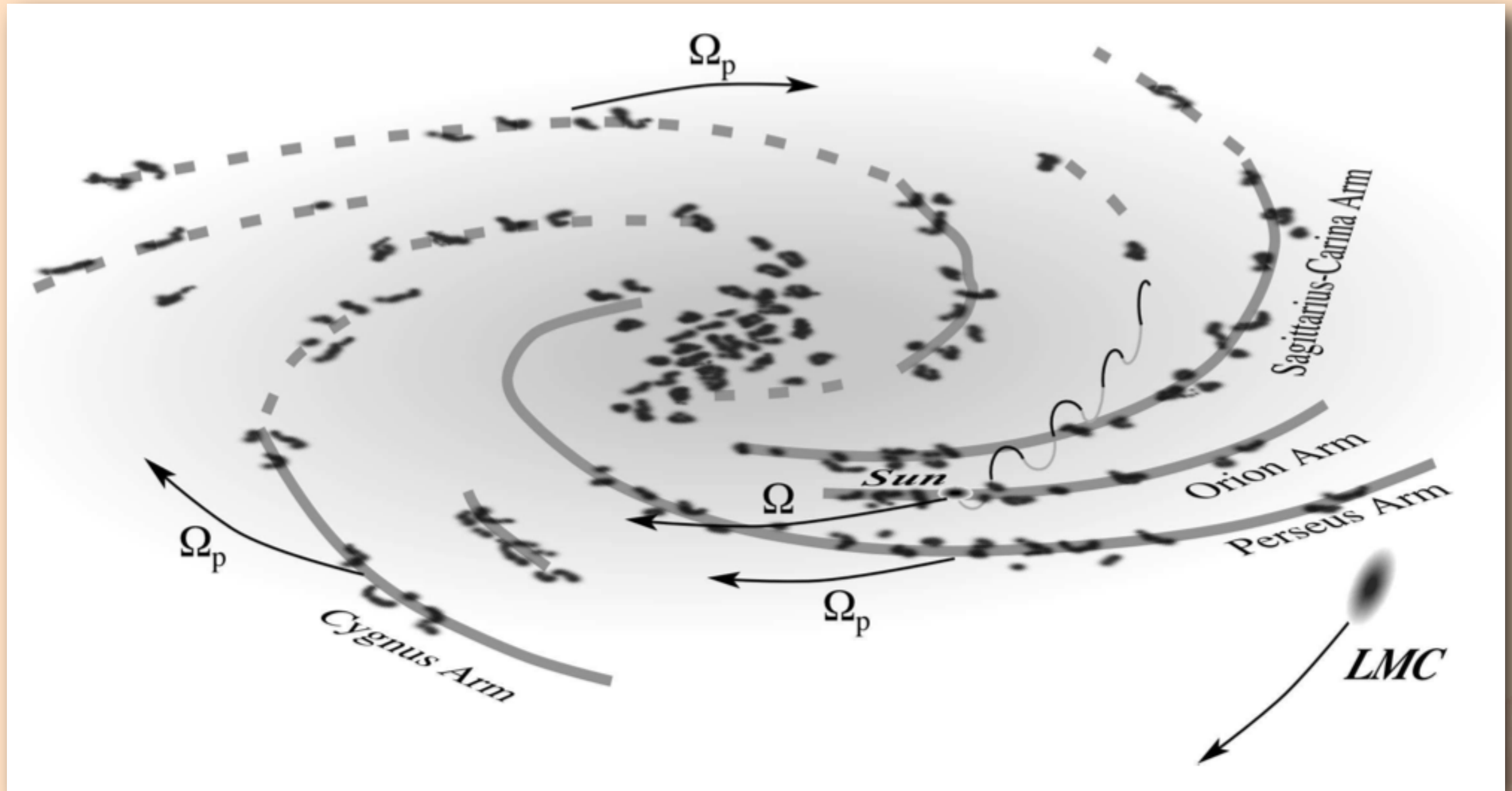
- ◆ Forbush decreases of the cosmic ray flux induce a large apparent effect on clouds



# Evidence over Geological Time Scales

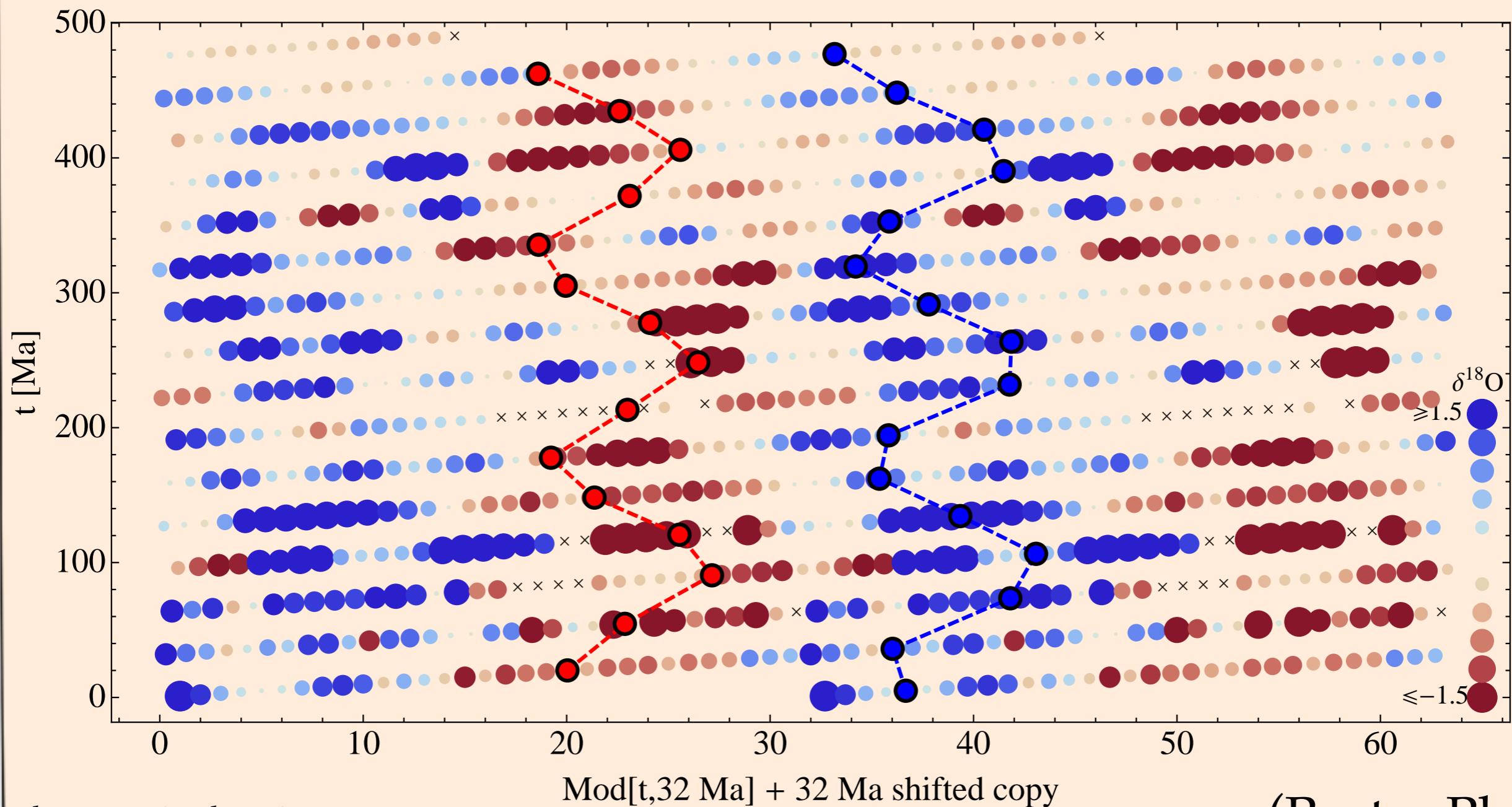


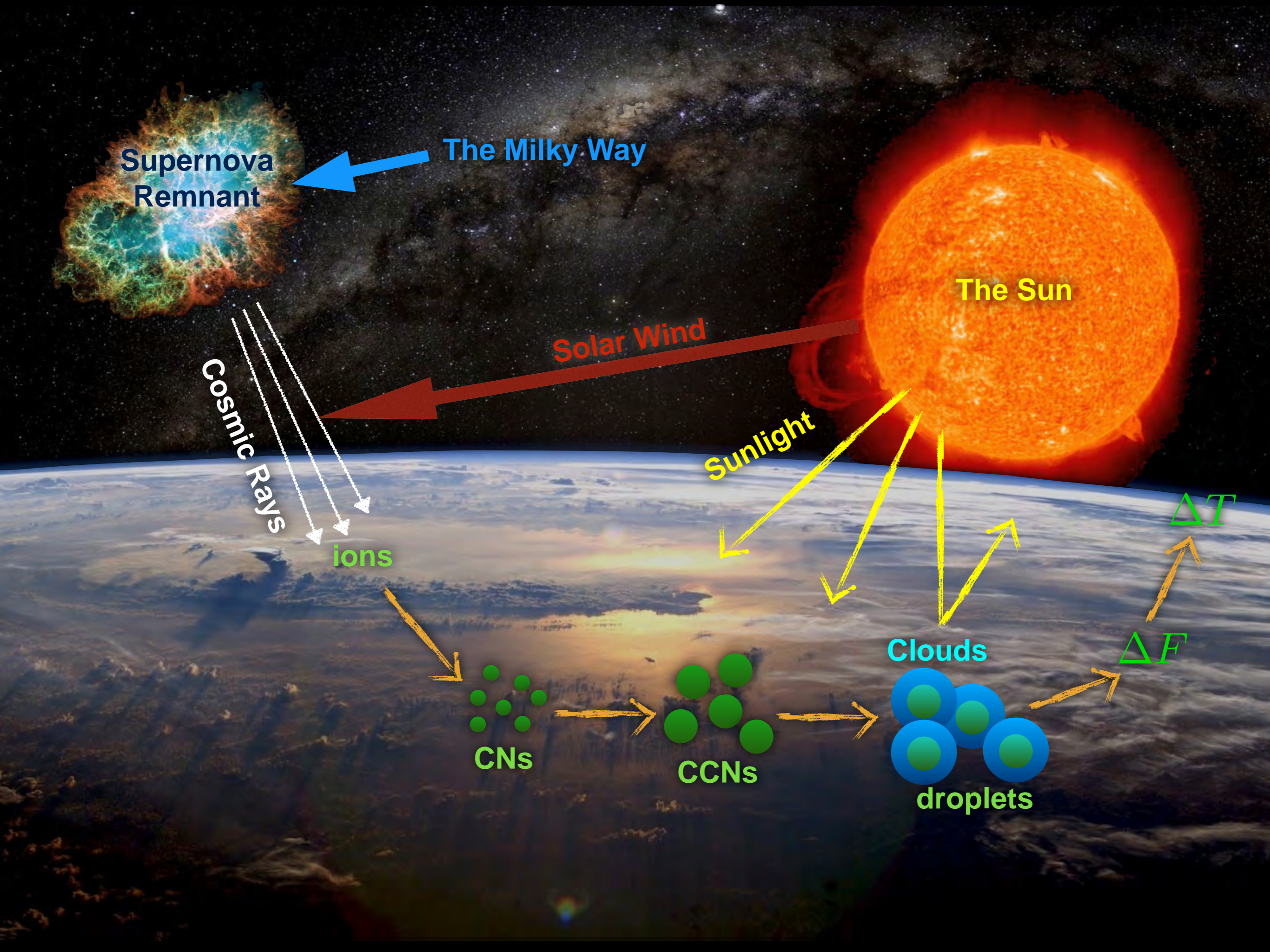
# Full Motion in the Milky Way





# Secondary Oscillation





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$\Delta T$

$\Delta F$

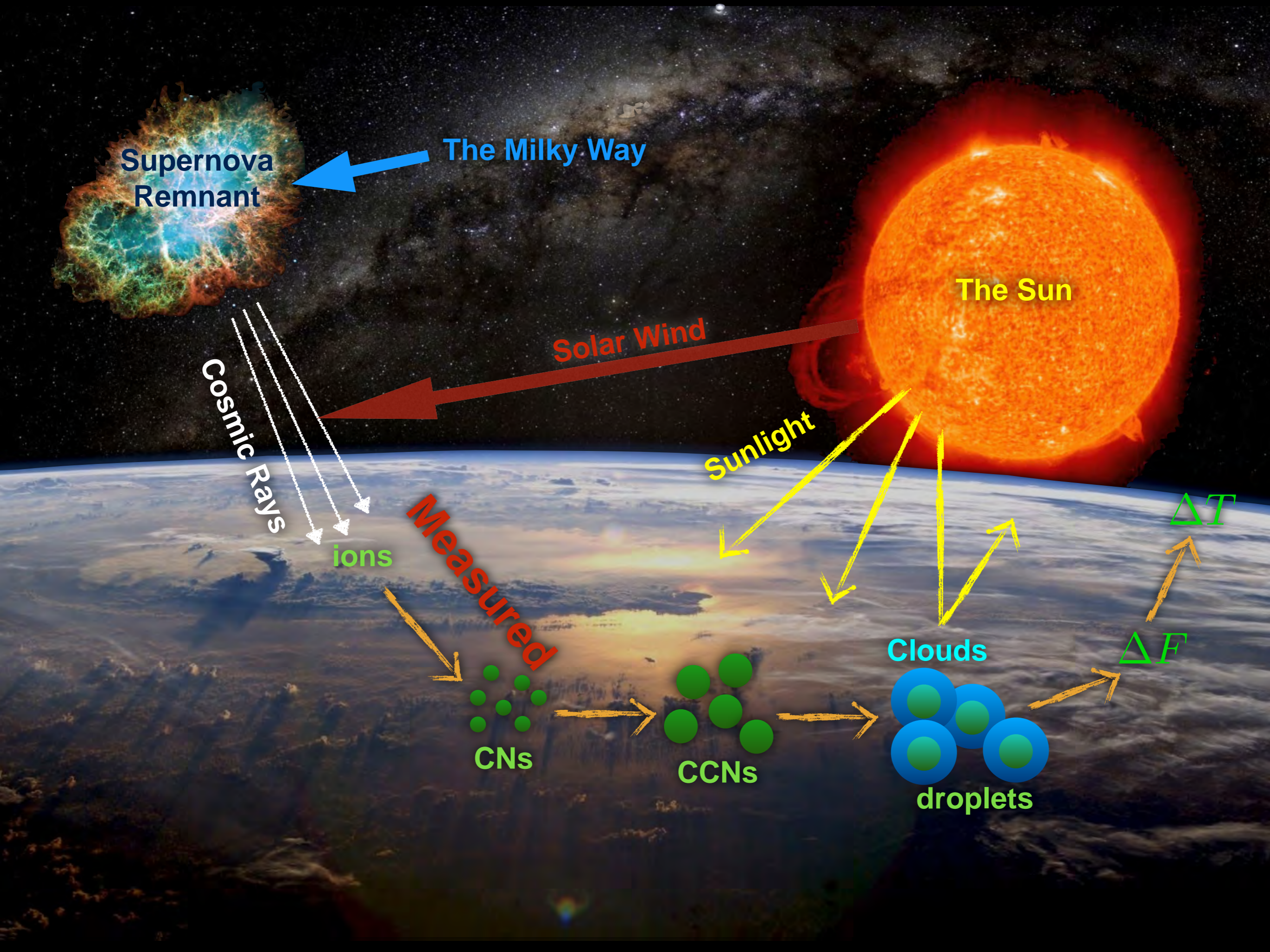
Clouds

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Measured

CNs

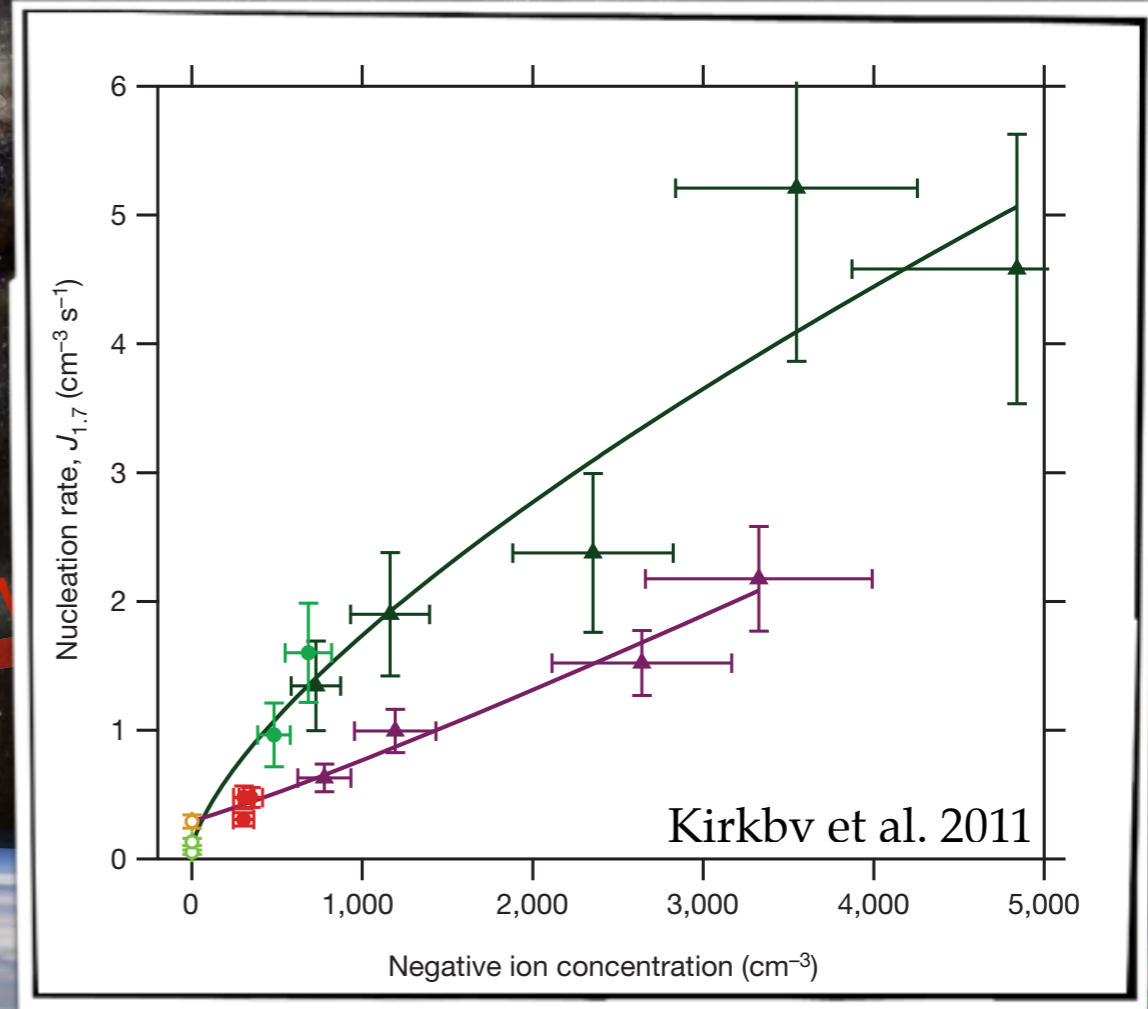
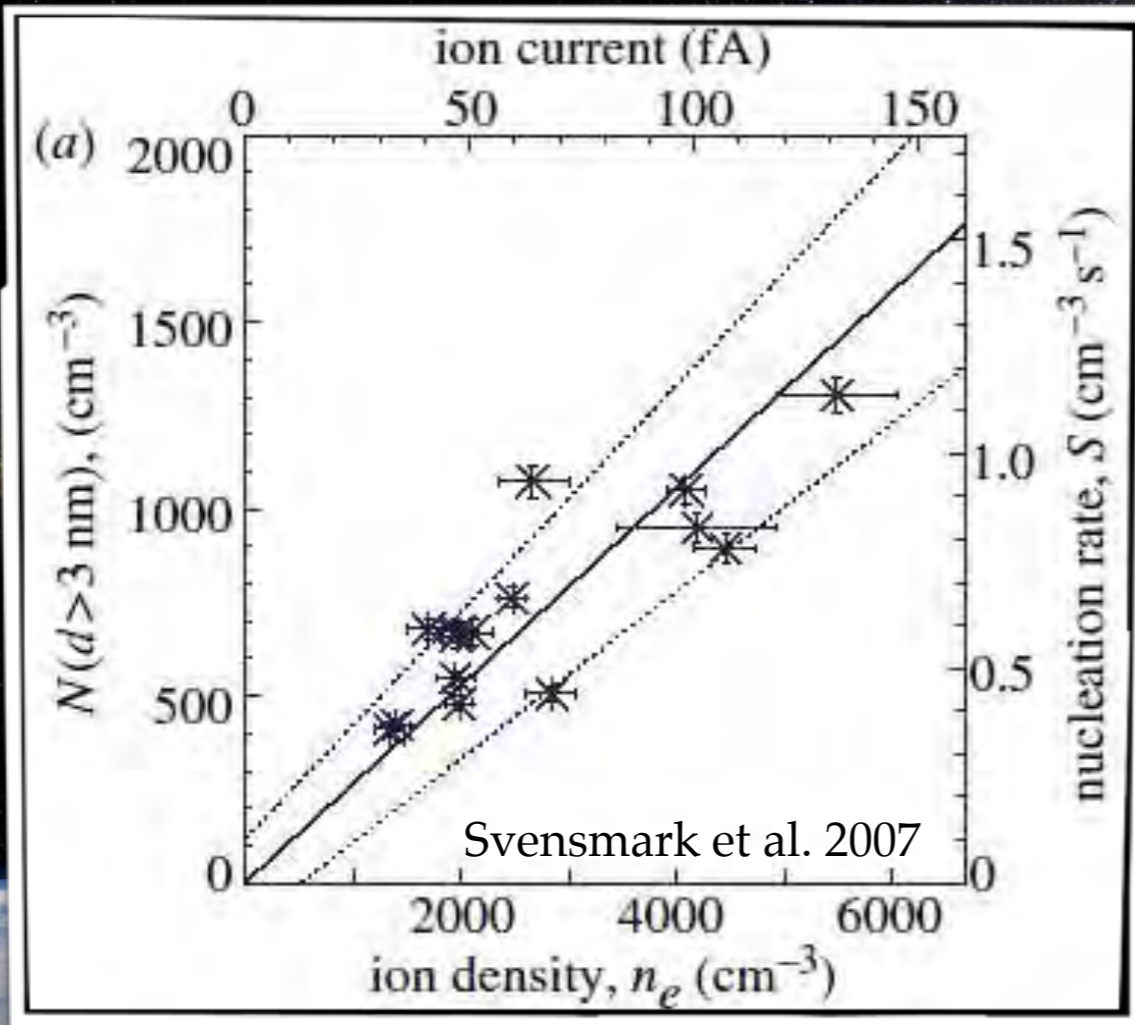
CCNs

Clouds

droplets

$\Delta F$

$\Delta T$



ions

measured

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CCNs

Clouds

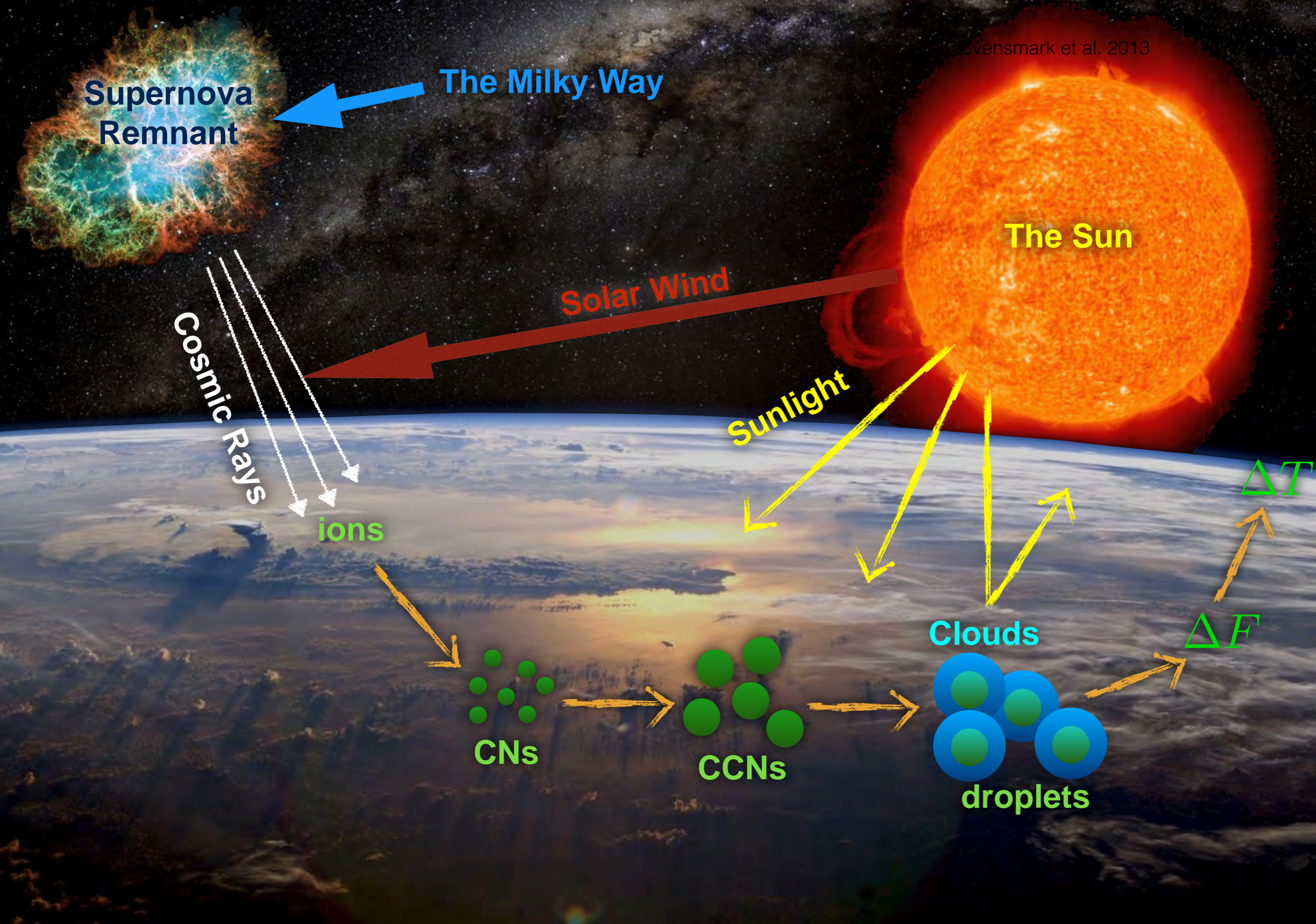
droplets

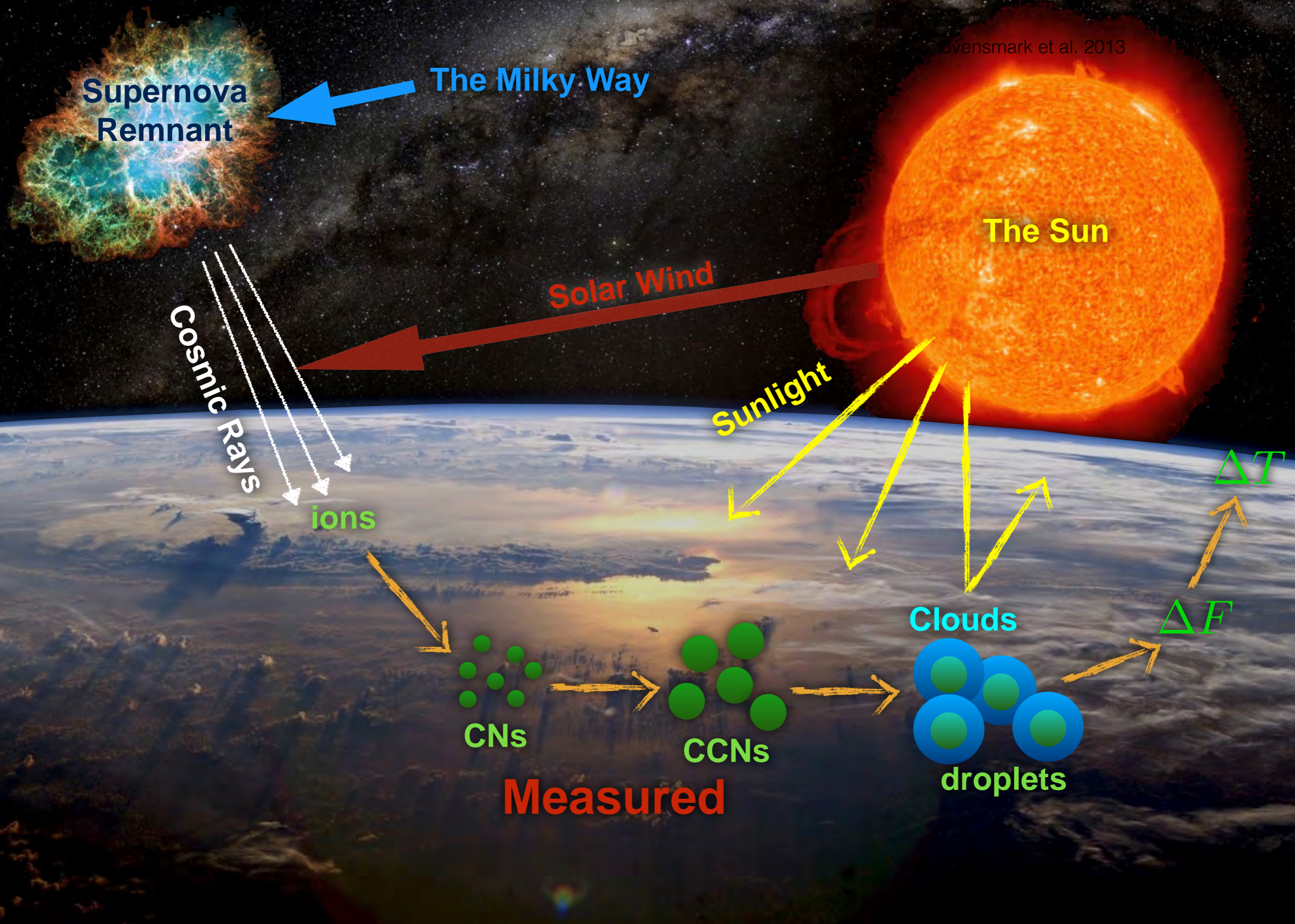
$\Delta F$

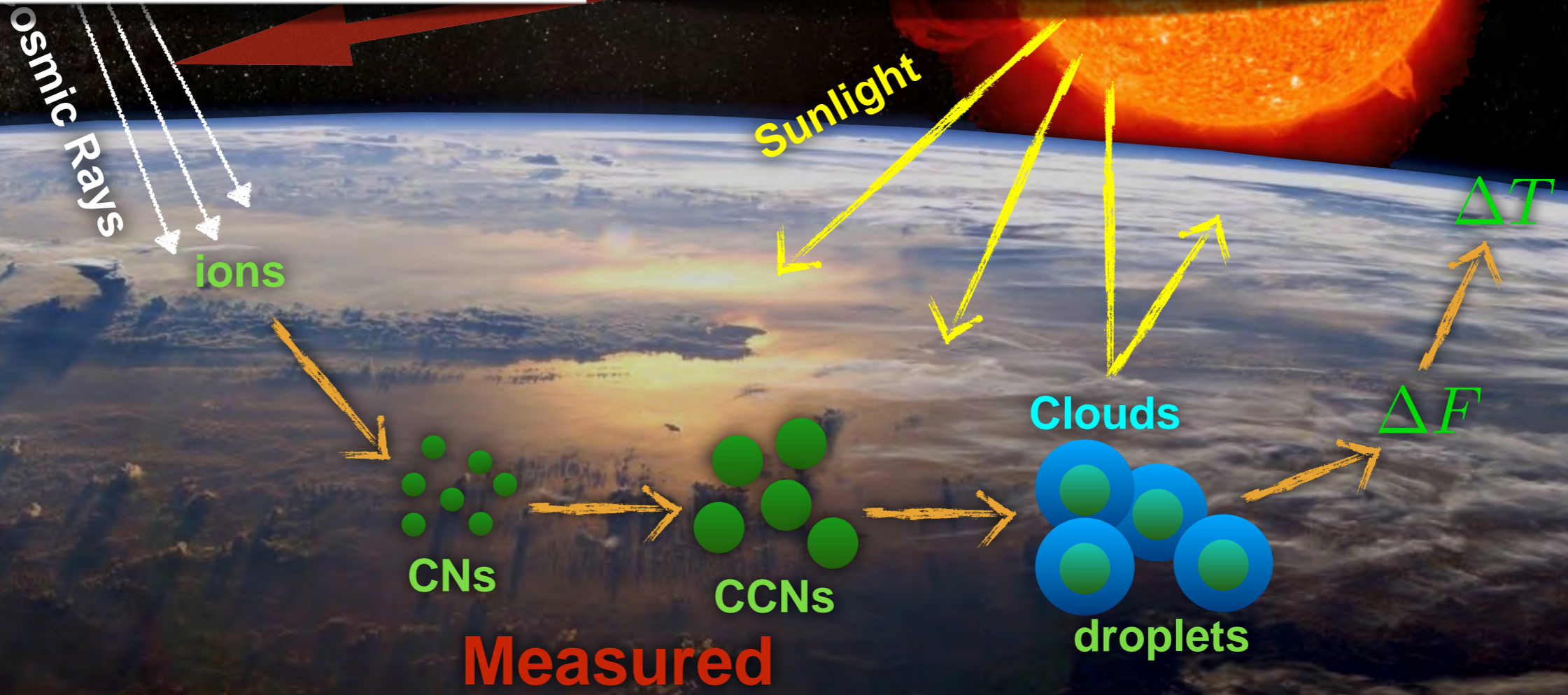
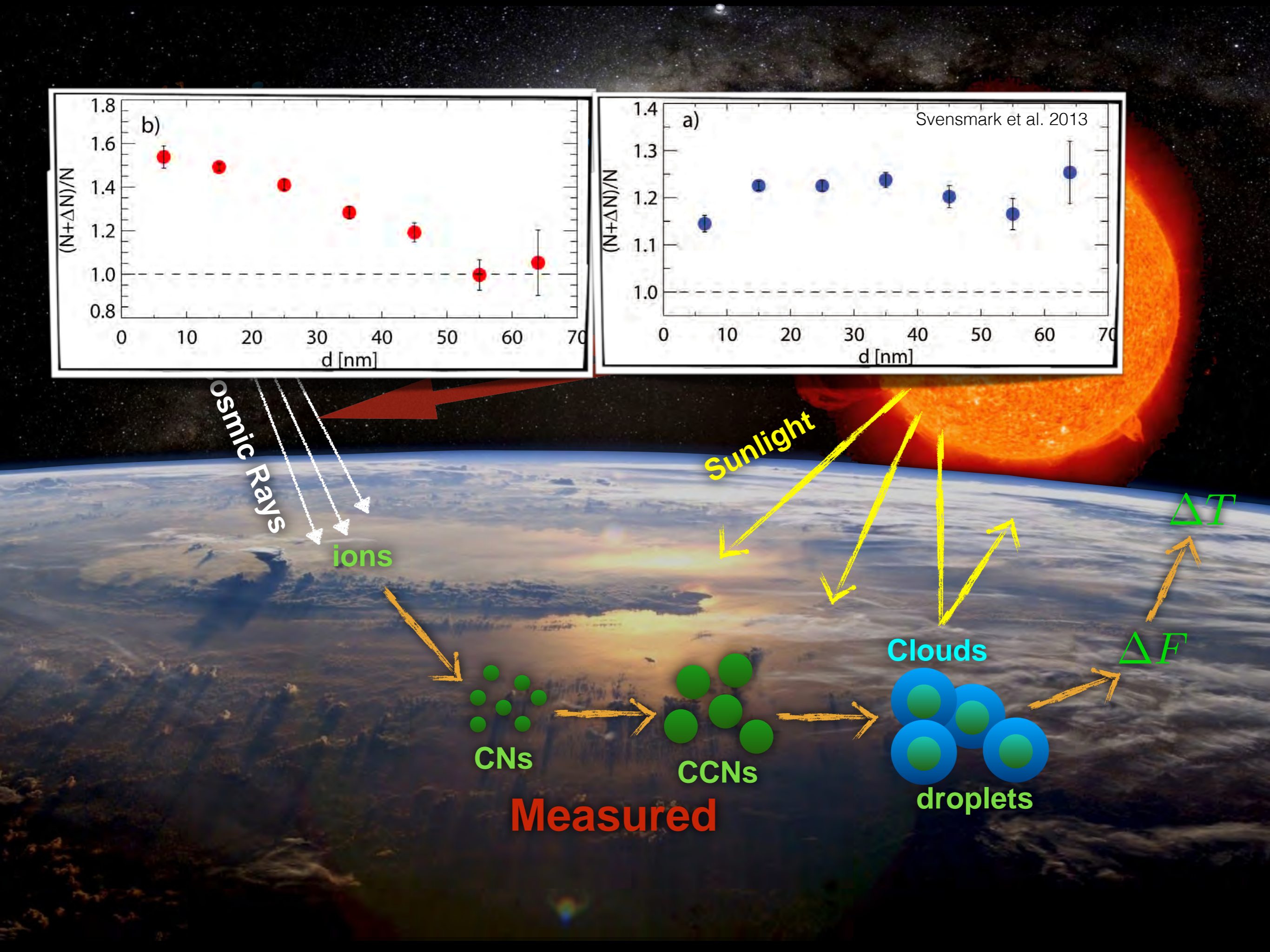
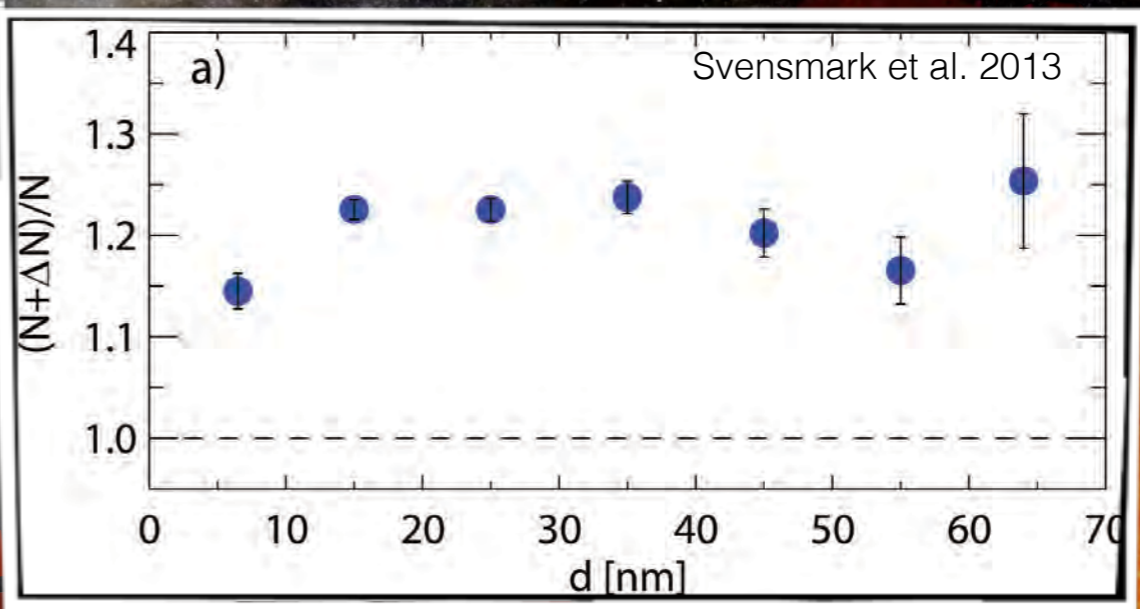
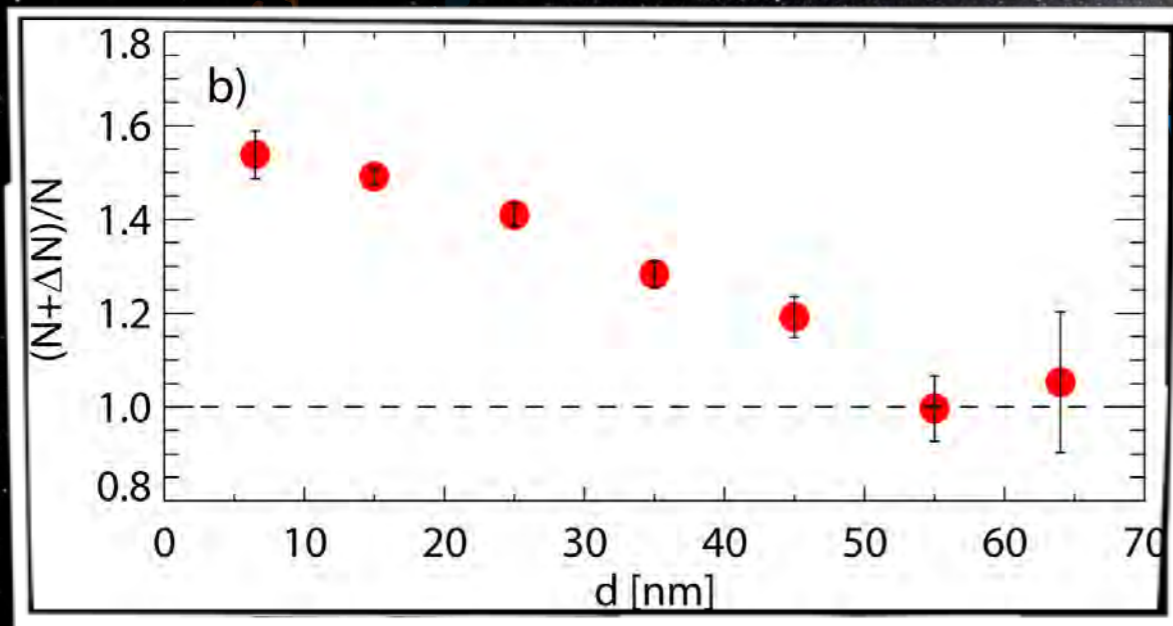
Way

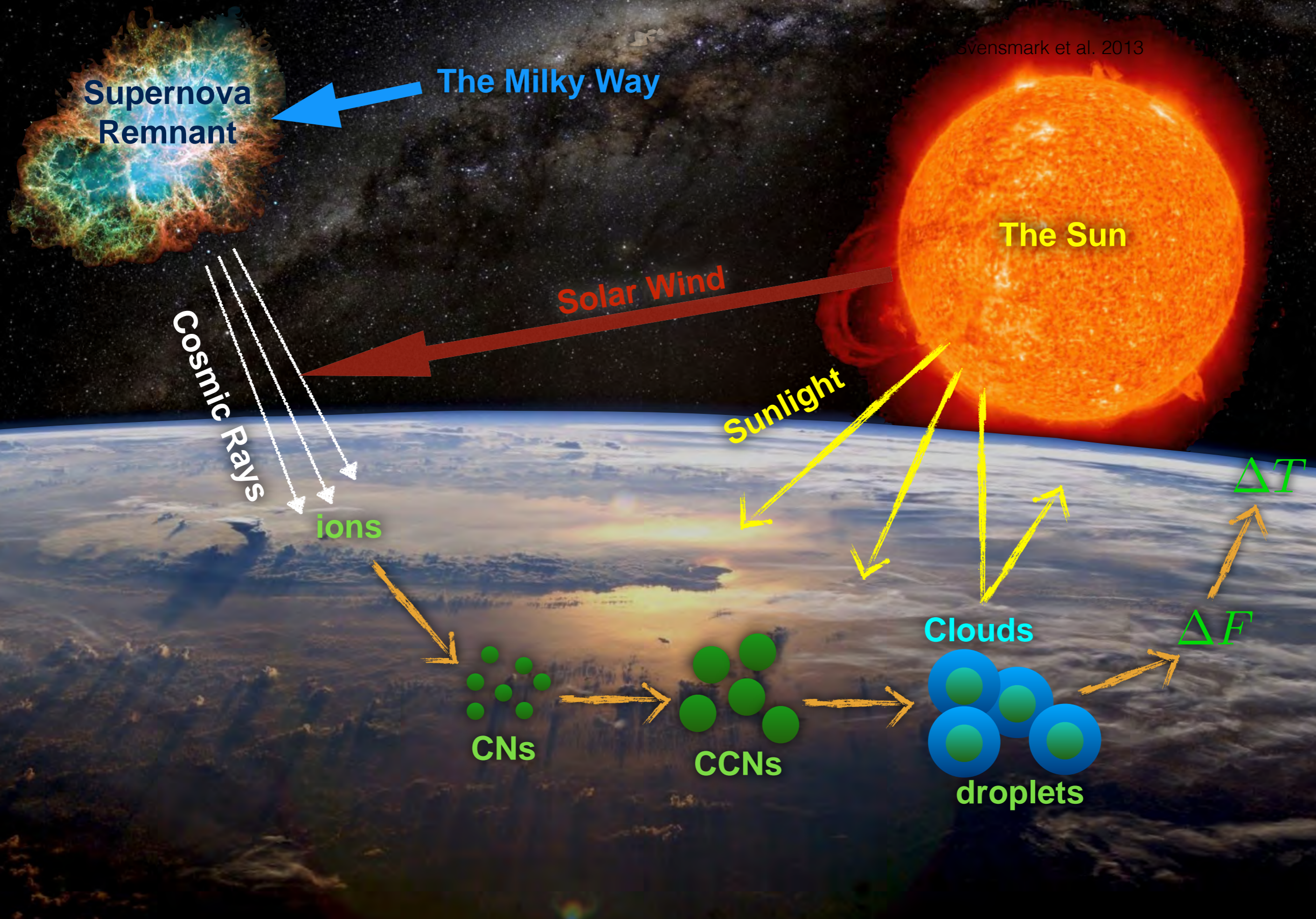
lar W

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$\Delta T$

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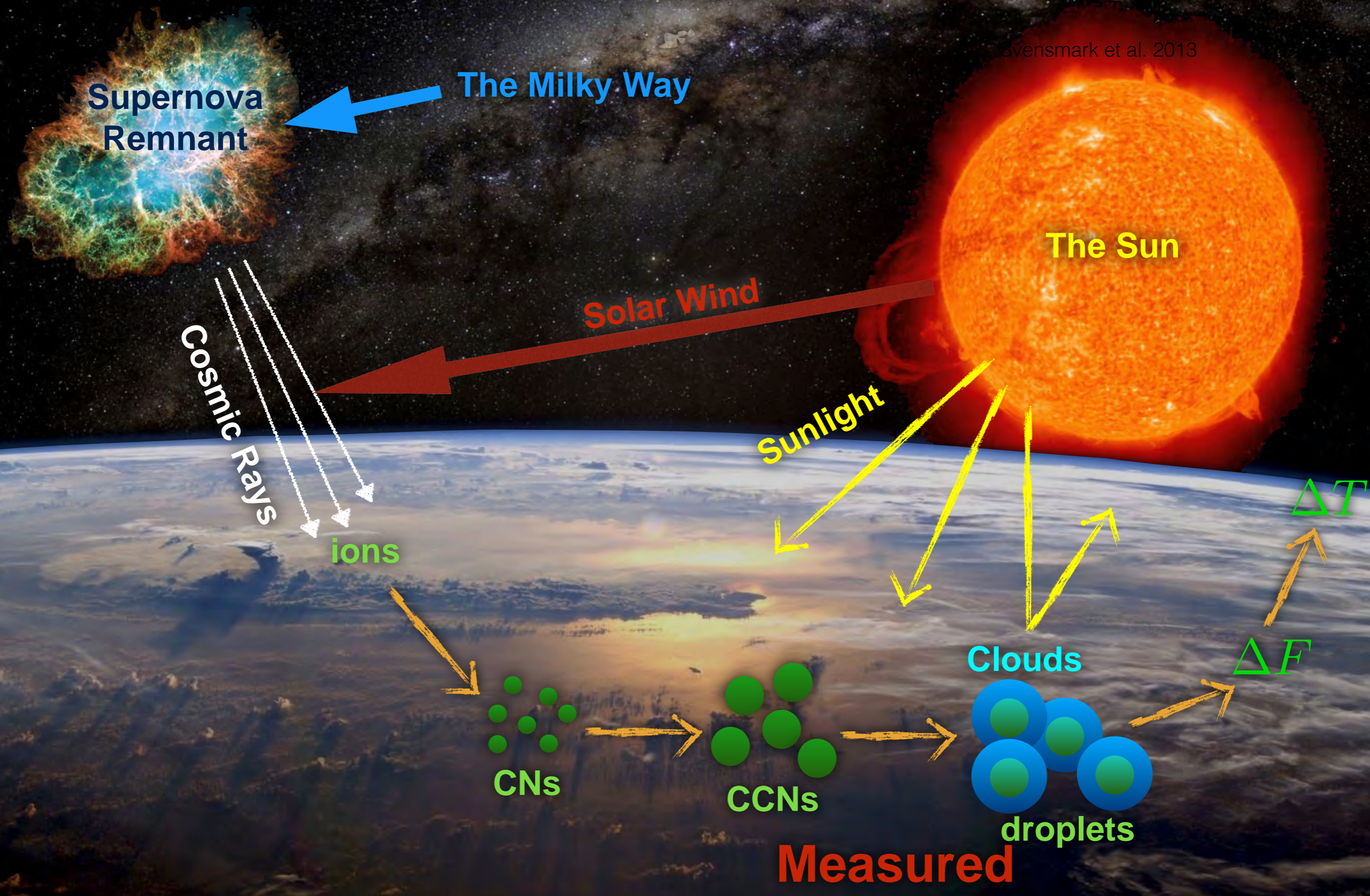
Clouds

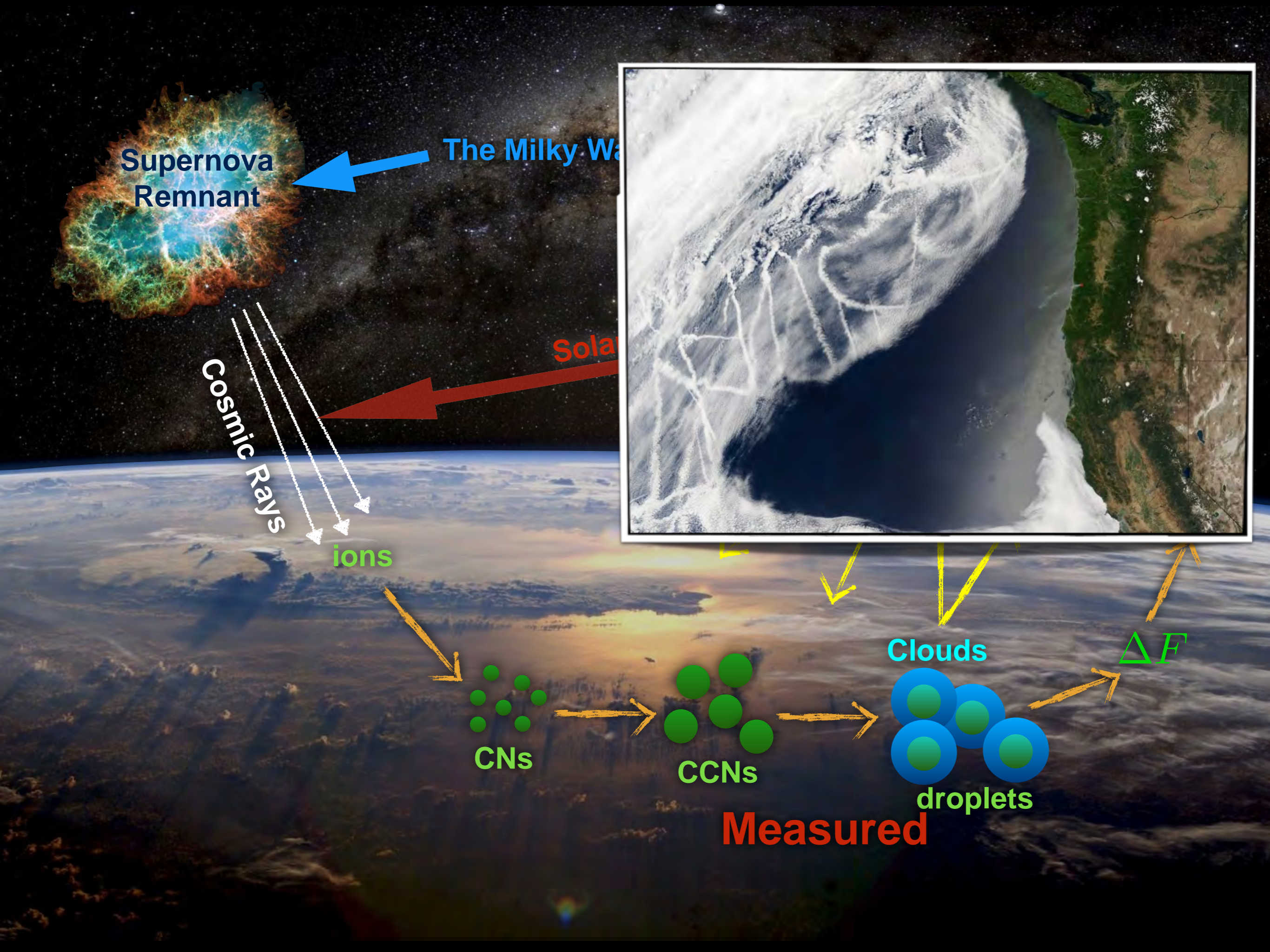
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Supernova Remnant

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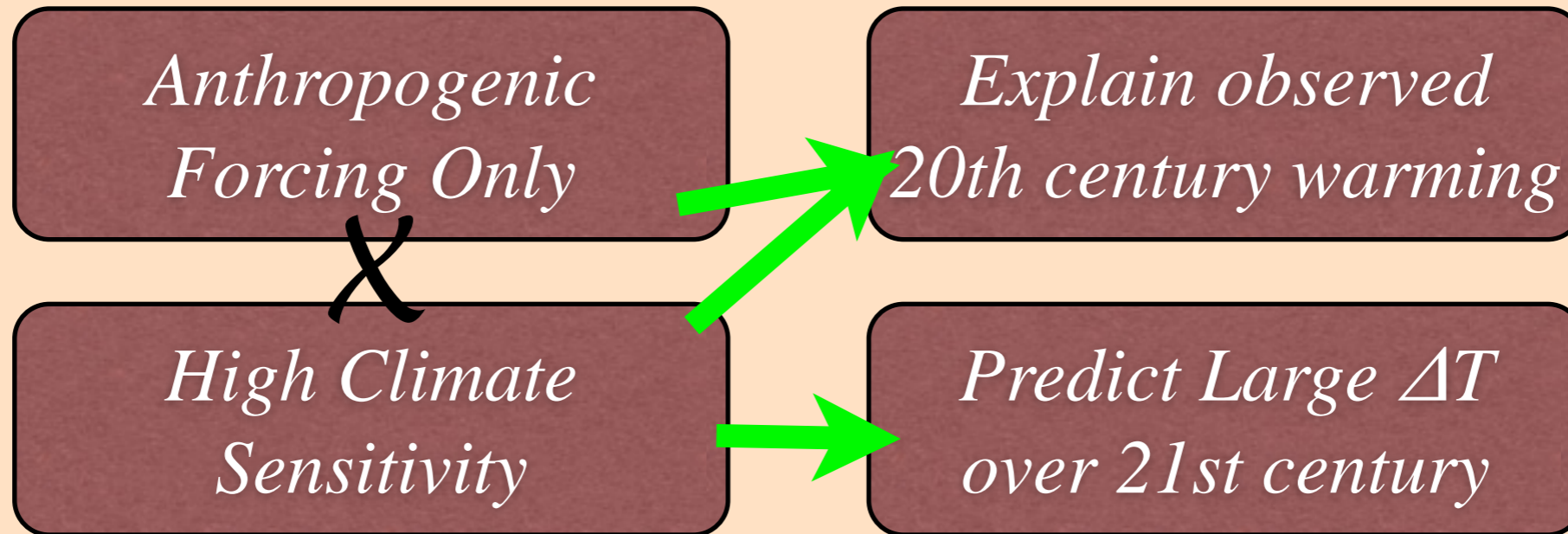
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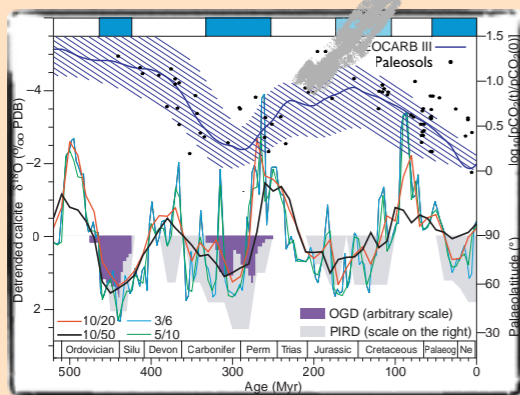
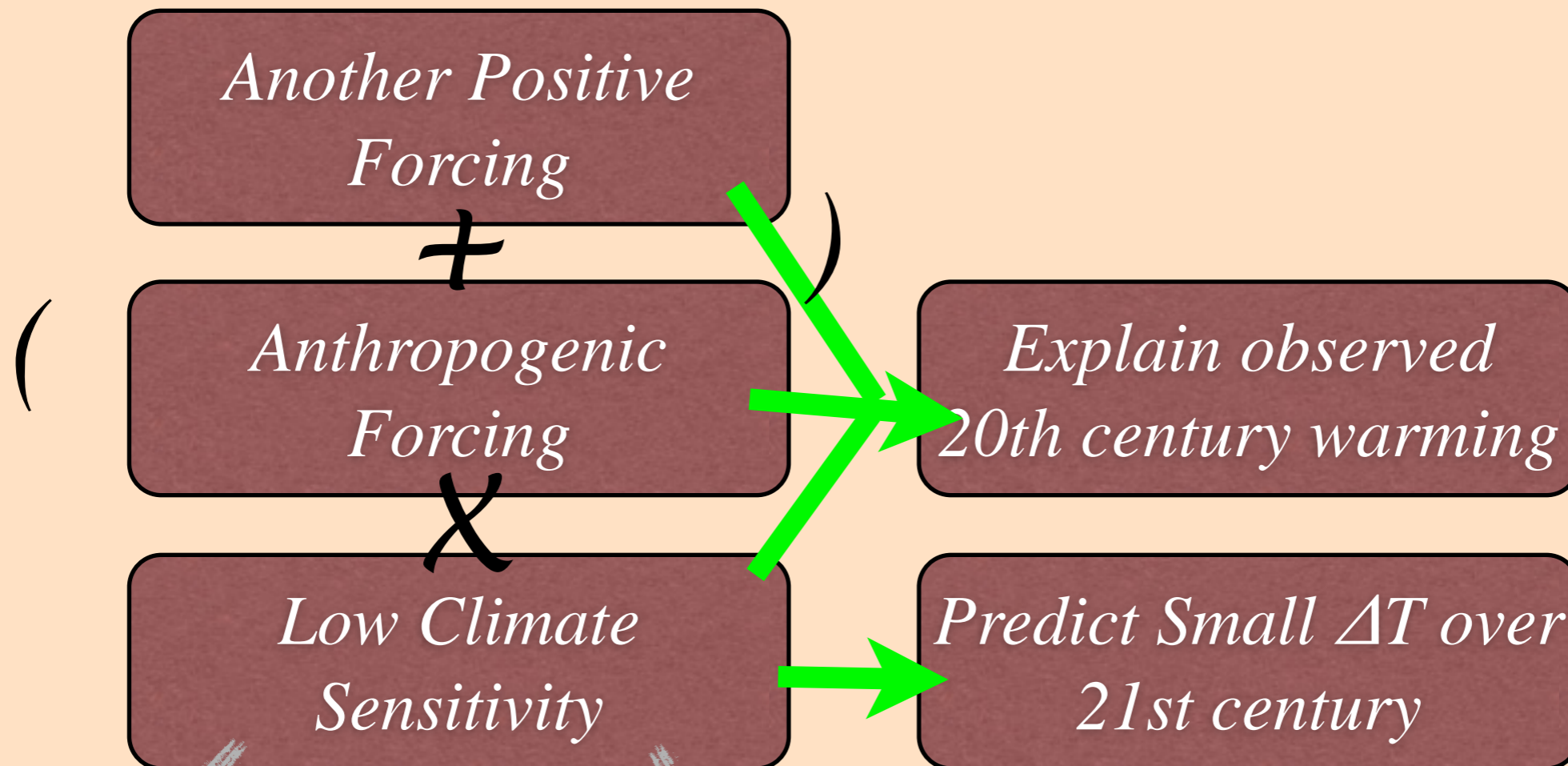
$\Delta F$

Measured

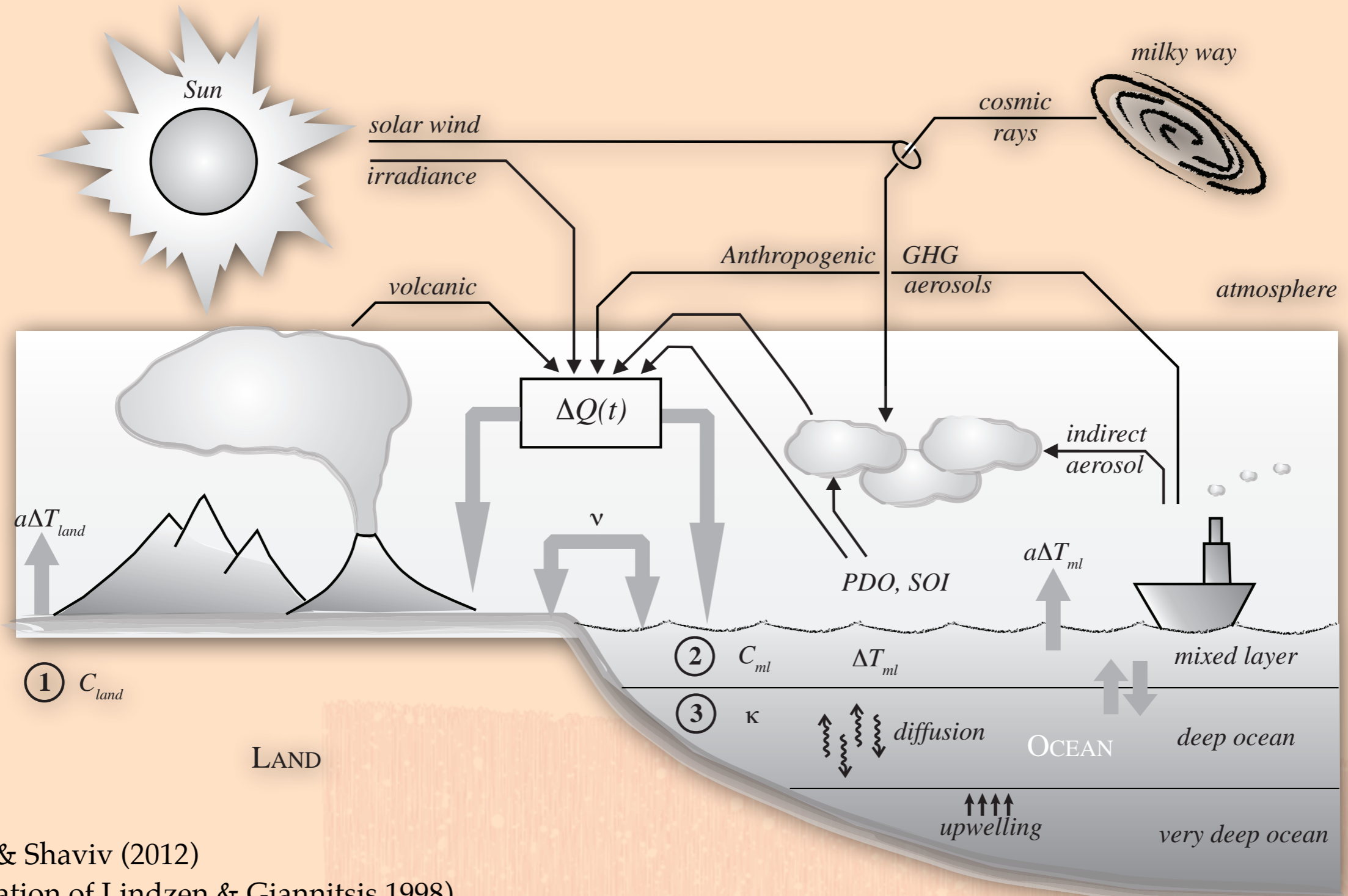
# Standard Explanation to 20<sup>th</sup> century



# And if there is another explanation?



# Basic Climate Model

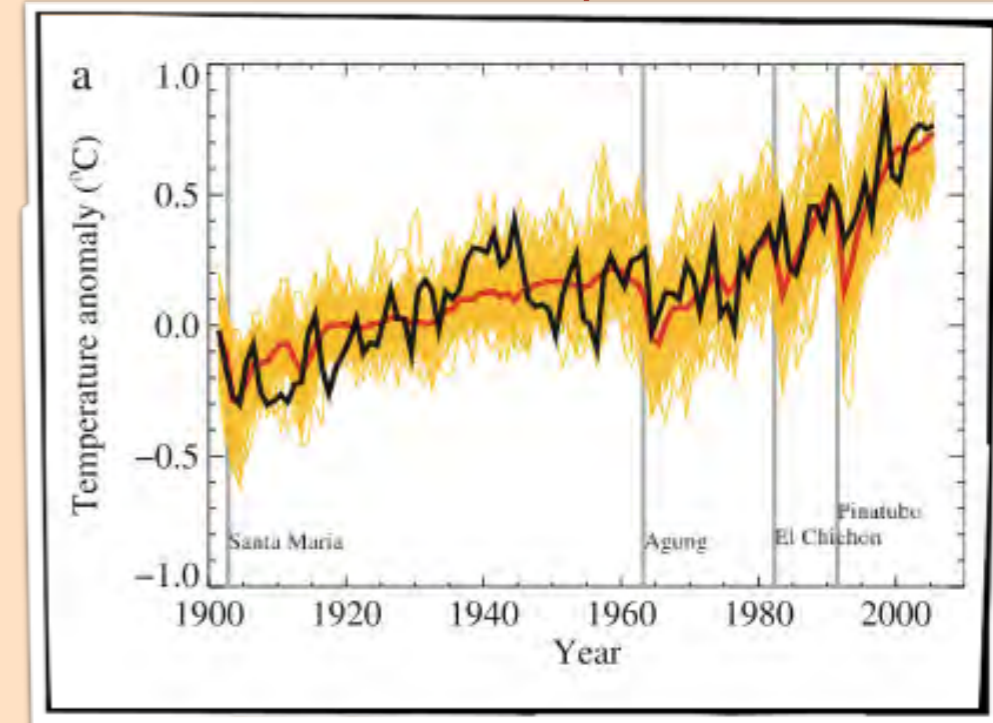
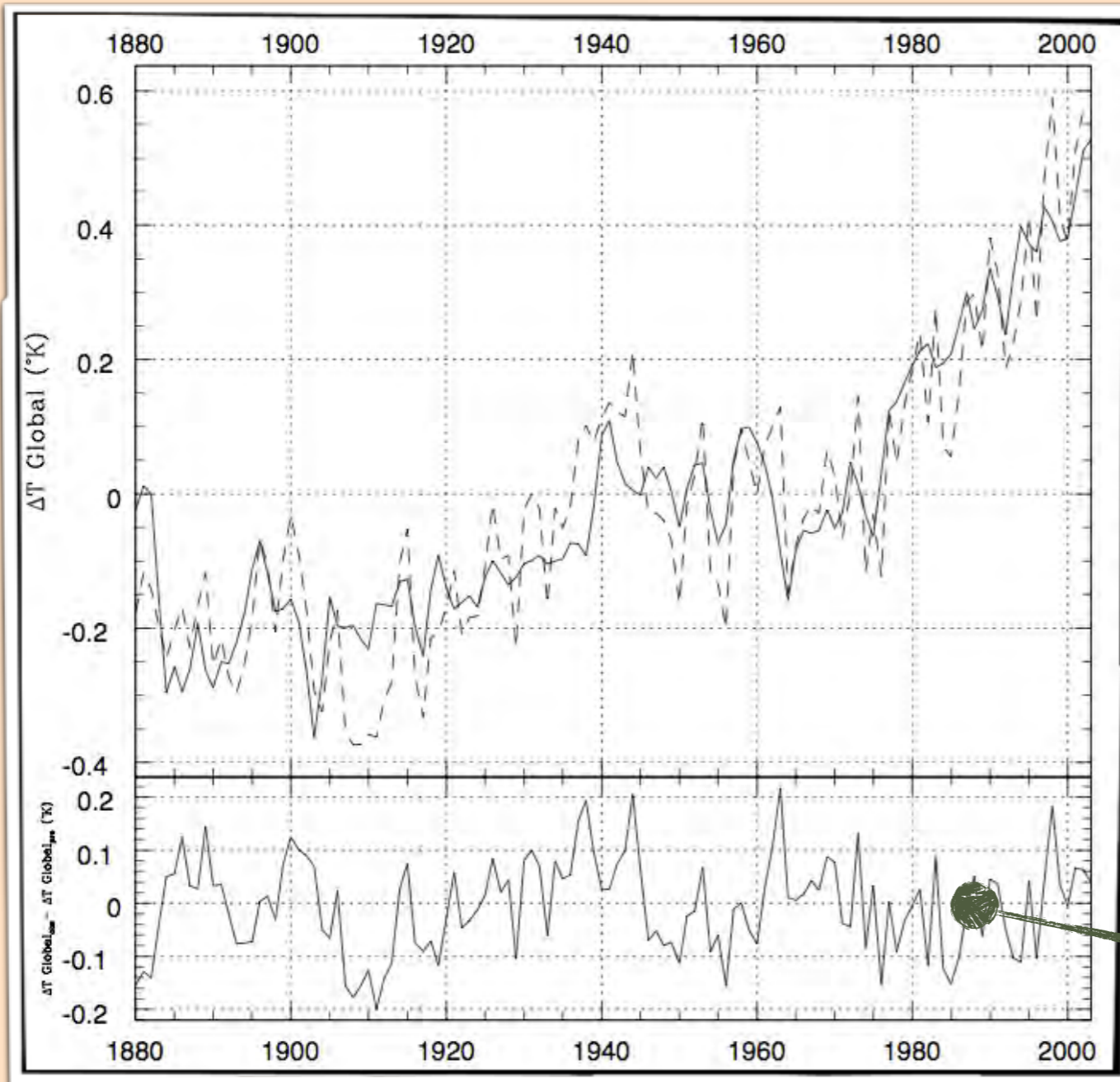


Ziskin & Shaviv (2012)  
 (elaboration of Lindzen & Giannitsis, 1998)

# 20th century warming

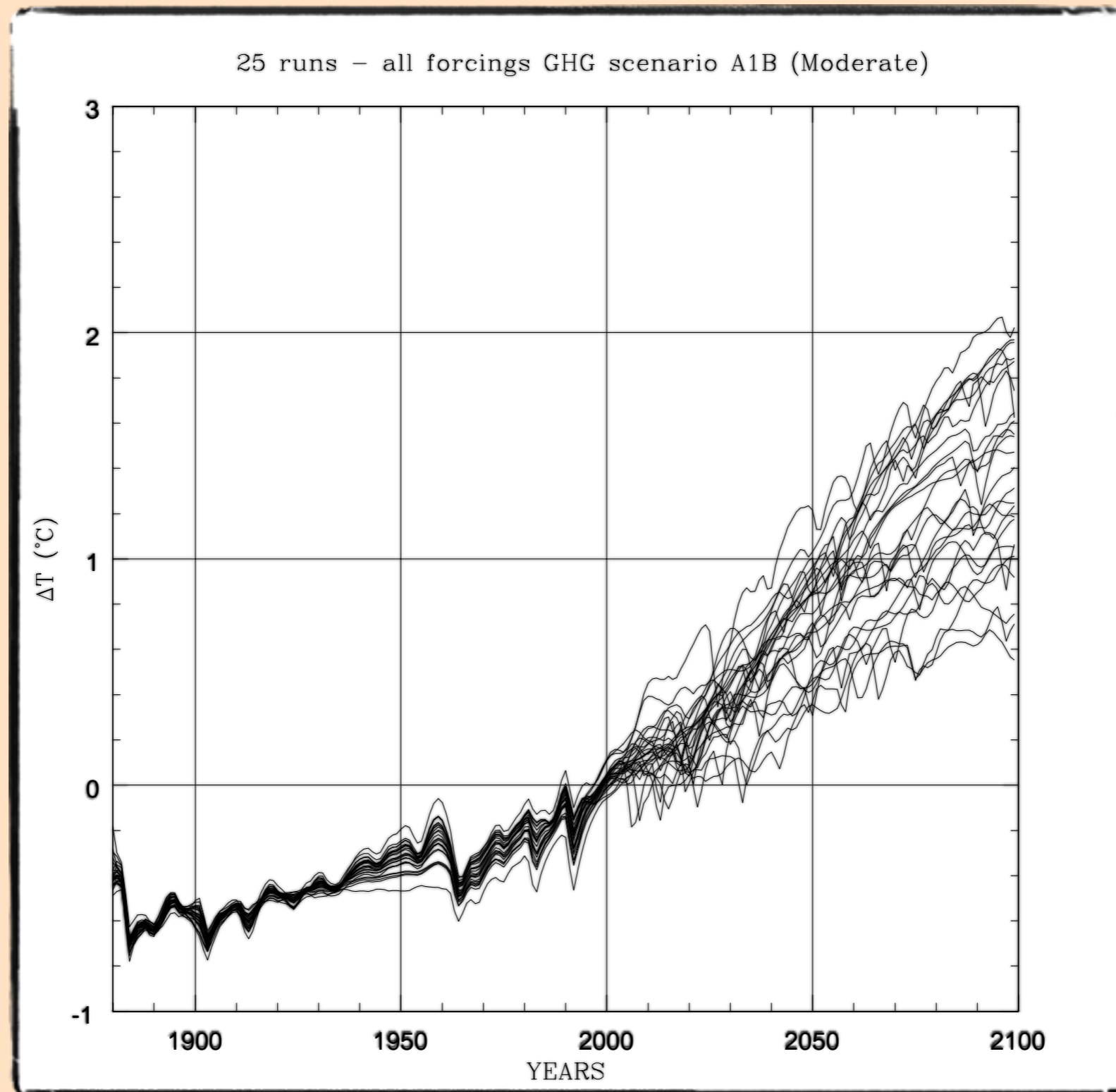
◆ Best fit (i.e., after parameter optimization)

Comparison: IPCC-AR4

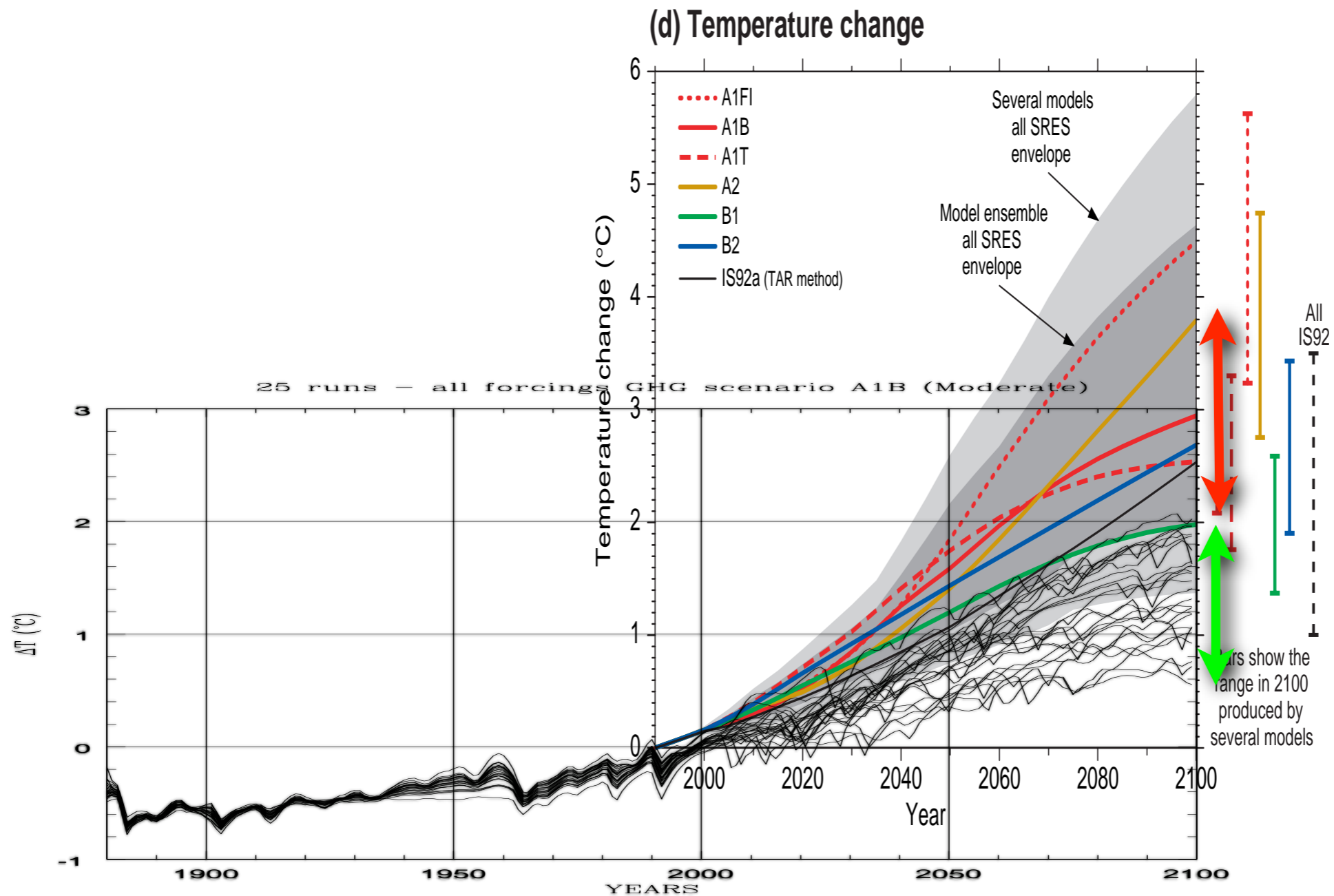


Residual more than twice smaller than with GCMs (without solar amplification)

# 21<sup>st</sup> century temperature increase (from fitting the 20<sup>th</sup> century)



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# Summary



Climate Sensitivity is high  
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And thanks to my collaborators!

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**The link is through cosmic rays!**

And thanks to my collaborators!

HU – Shlomi Ziskin, Naftali Smith, Daniel Howard

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