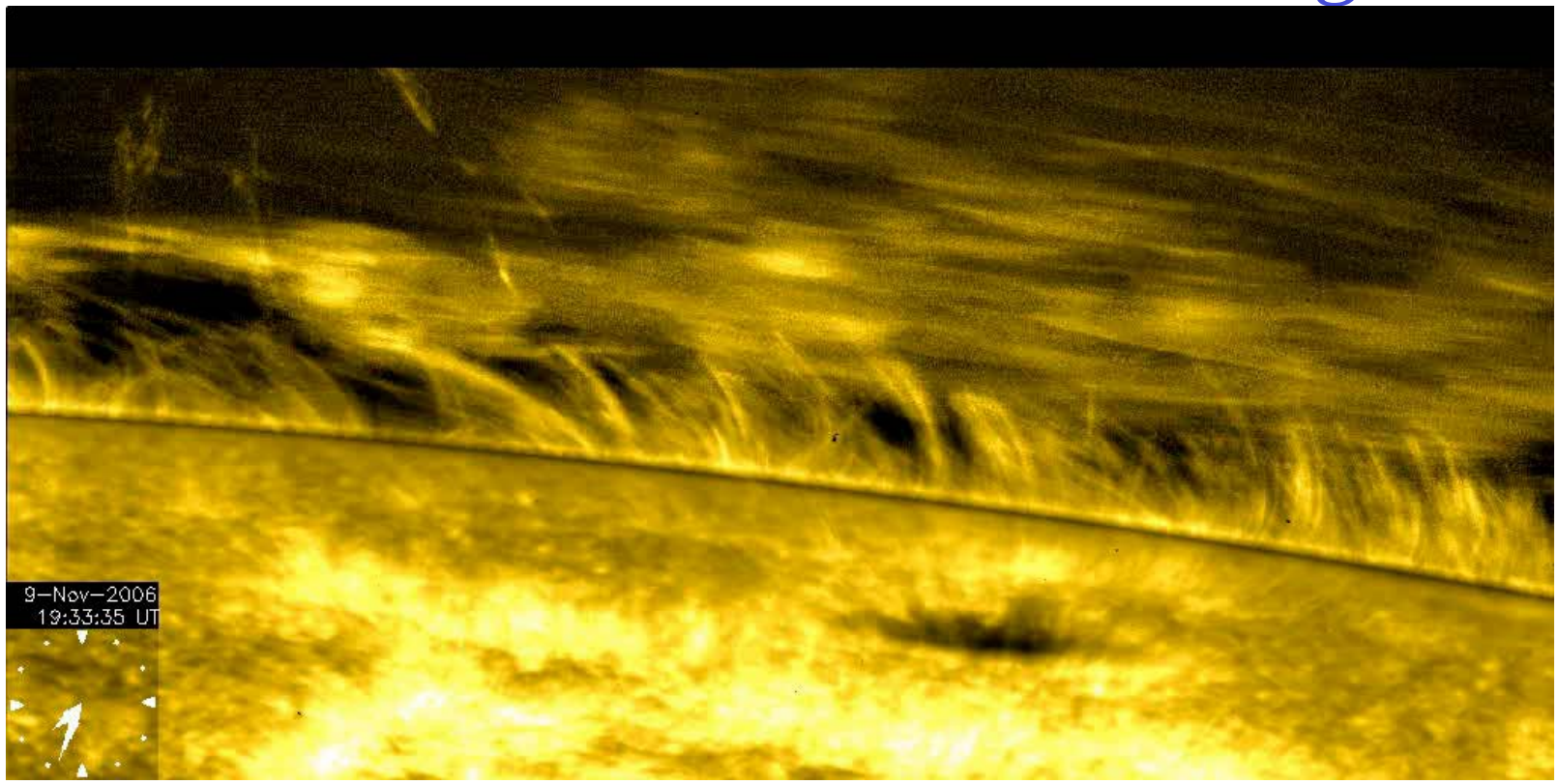
Cosmoclimatology

A new view on climate change



Henrik Svensmark,

Center for Sun Climate Research

Space DTU

Do Earth's clouds have their origin in deep space?

- Cosmic rays and climate
  - Definitions
  - Empirical evidence
- Experimental efforts and results
- Does is work in the real atmosphere?

Evolution of SN1993J

SN 1993J VLBI. III. The Evolution of the Radio Shell

M. F. Bietenholz , N. Bartel , and M. P. Rupen

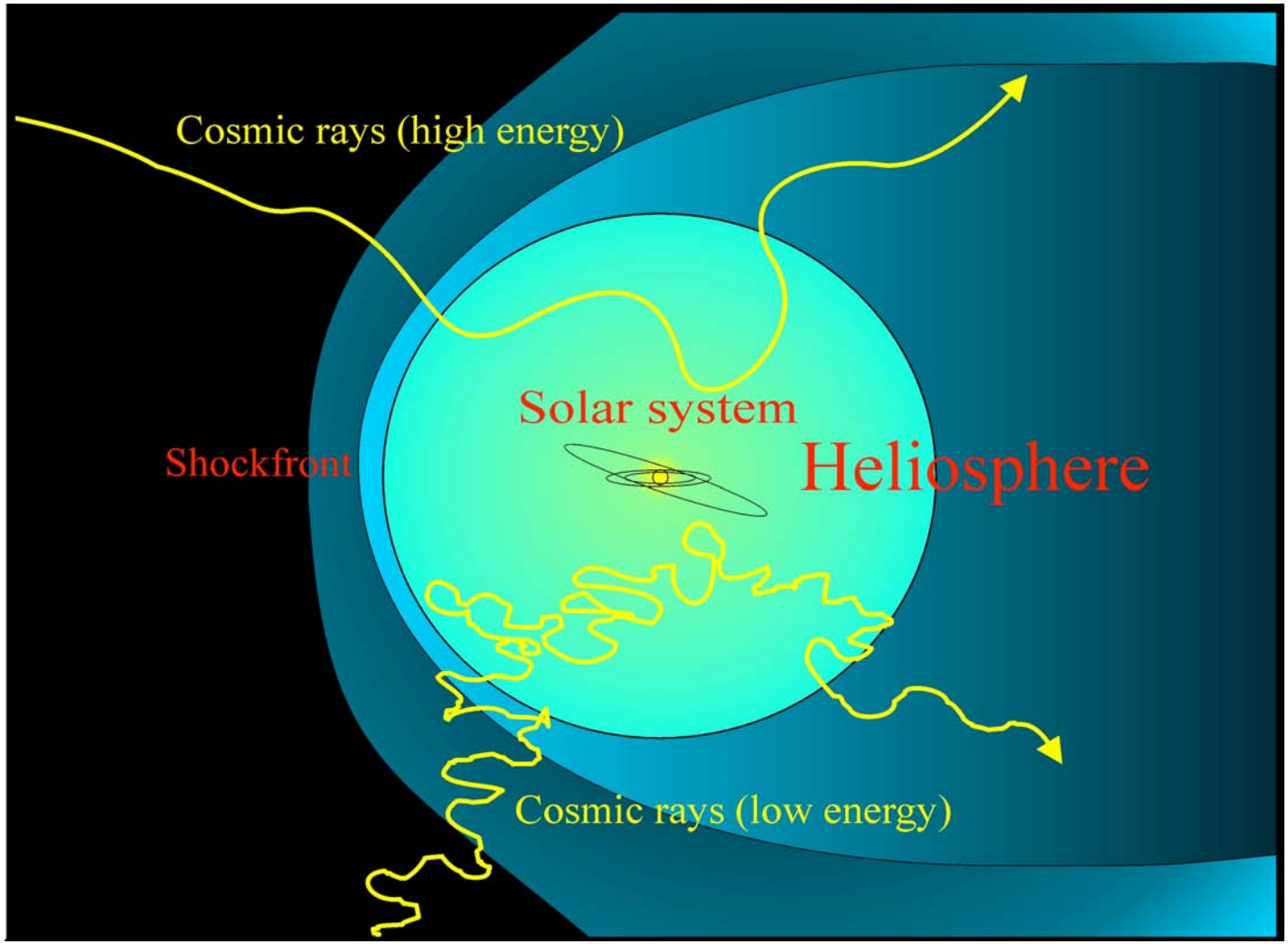
The Astrophysical Journal, 597:374-398, 2003

5000 AU

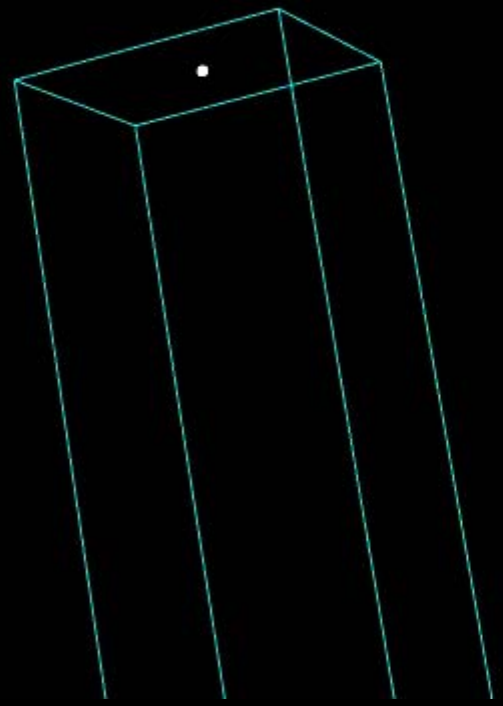
8.4 GHz, from *t* = 50d to *t* = 2787d

What are Cosmic Rays?

Heliosphere, Cosmic Rays and Solar Activity



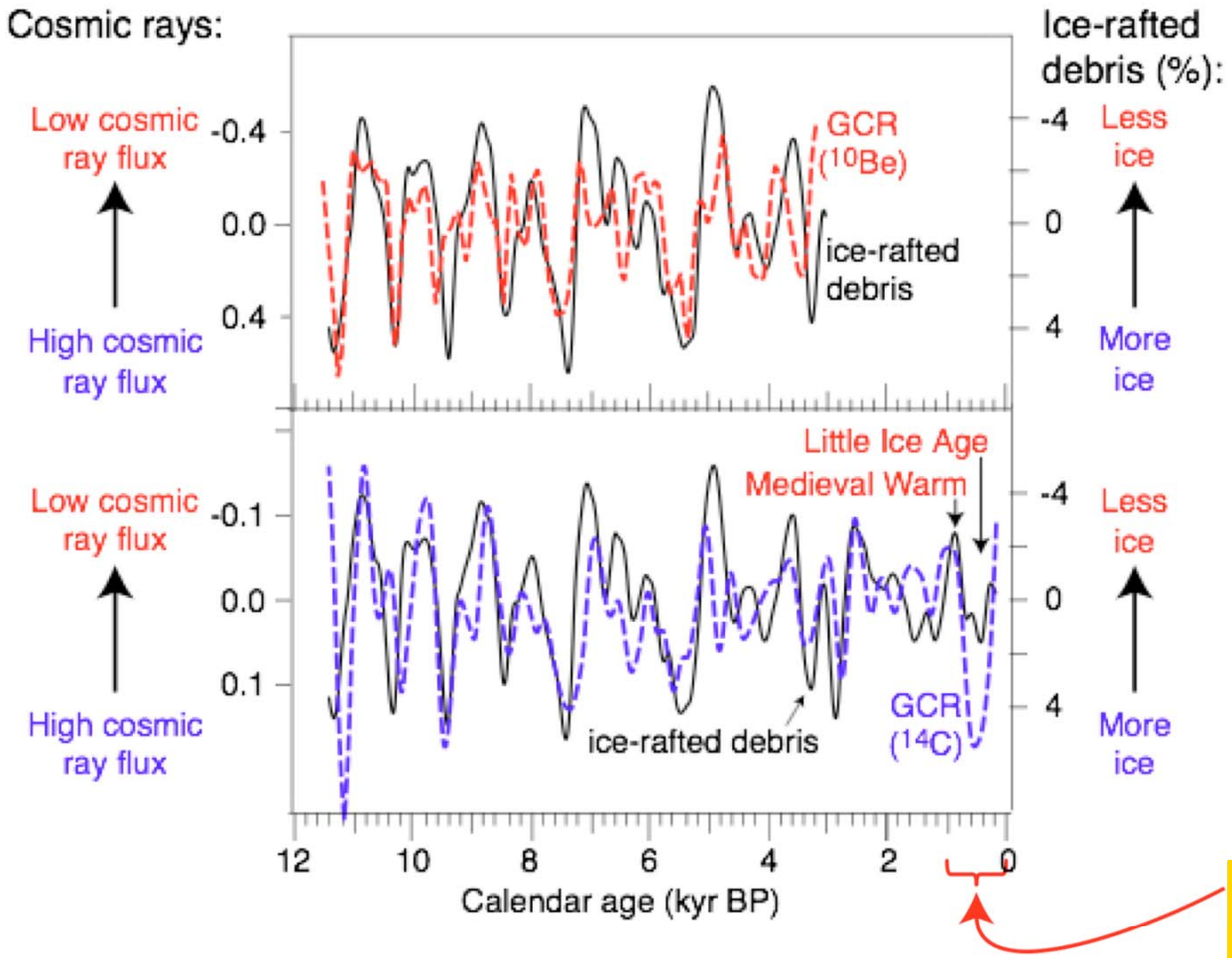
Cosmic ray shower (Movie)

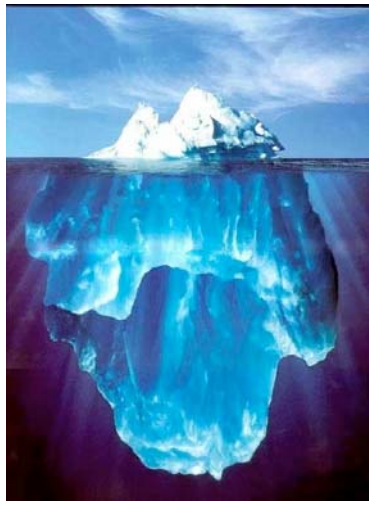


About 70 muons/s /m^2 at the Earths surface
In 24 hours about 12 million muons goes through a human body

Cosmic rays and climate over the last 10.000 years

Bond et al, Science 294, 2001





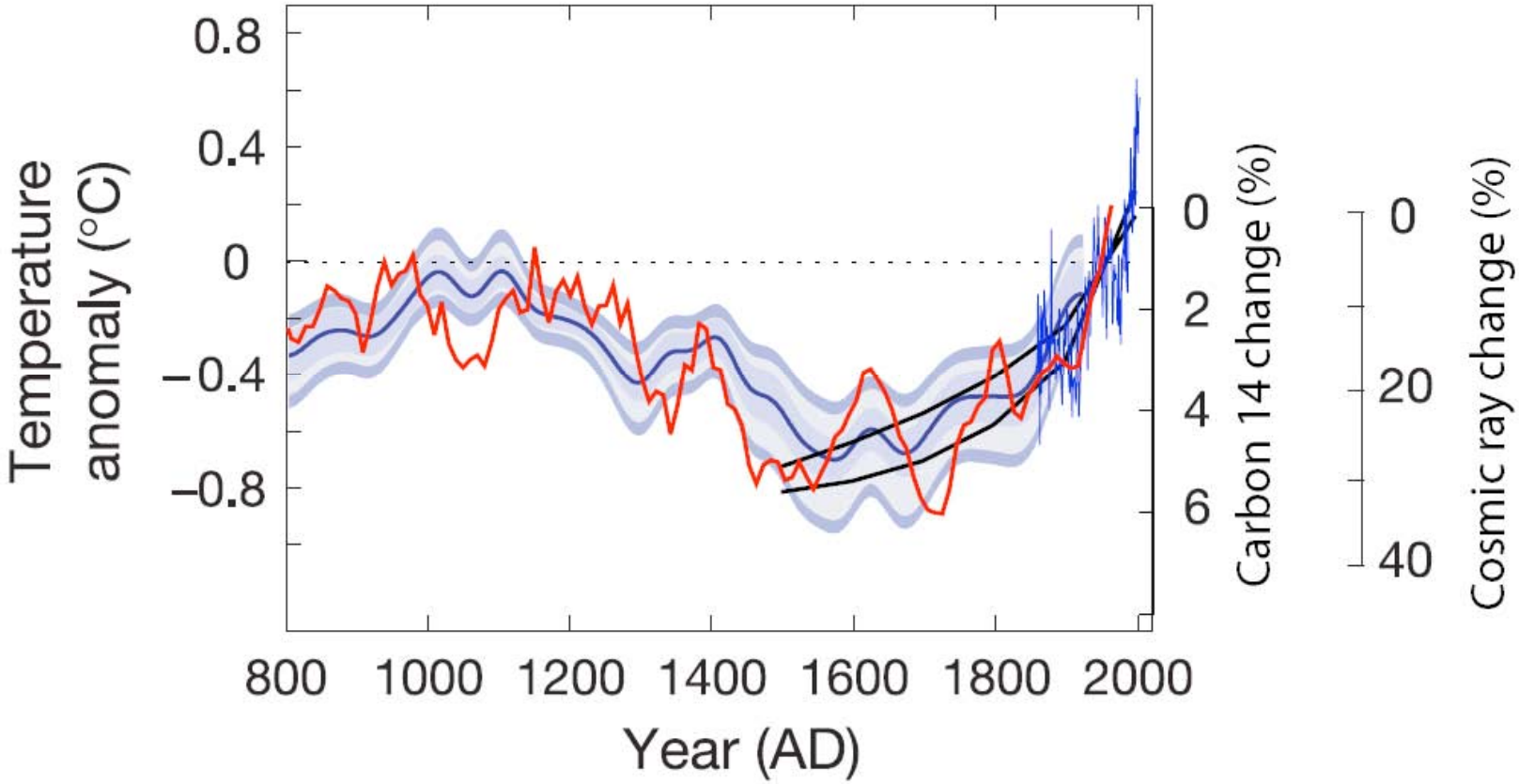
According to icecores CO_2 levels has been constant ~280 ppm

Last 1000 years
Little Ice Age

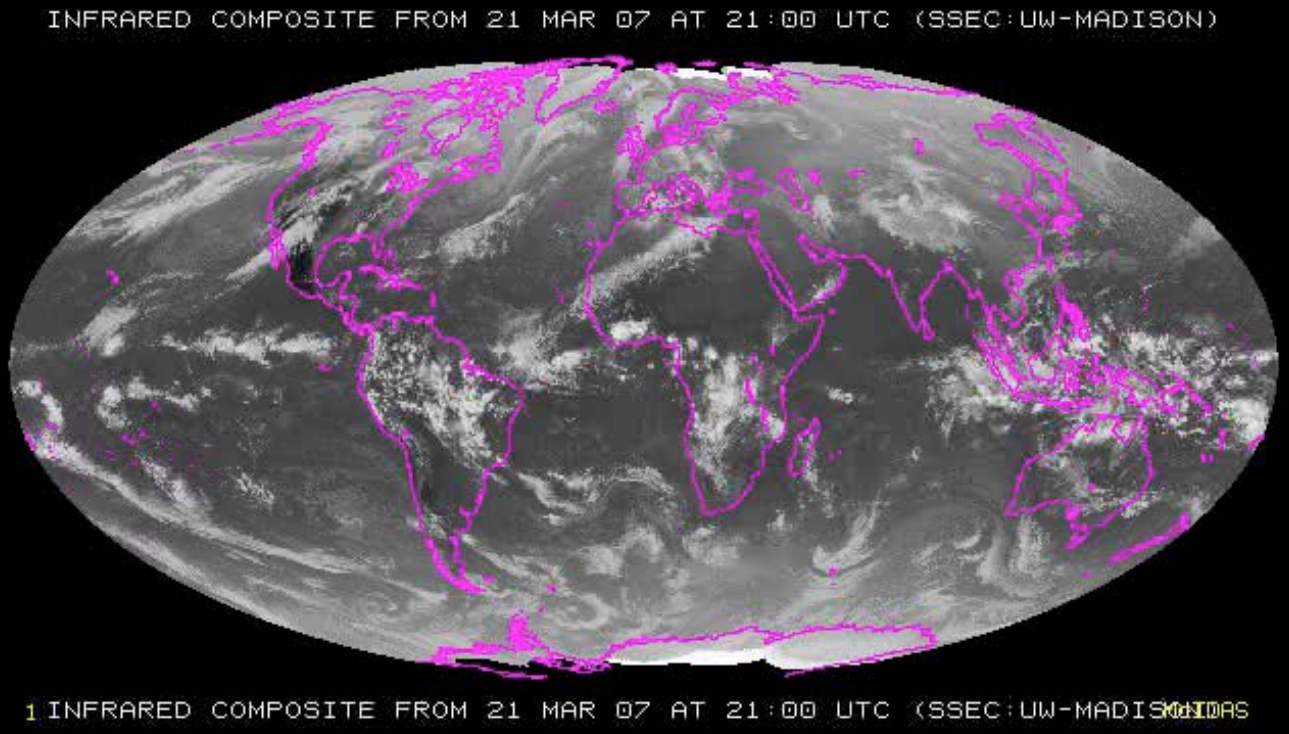
- Little Ice Age is merely the most recent of a dozen such events during the last 10.000 years

Adapted from Kirkby

Cosmic rays and climate over the last millennium

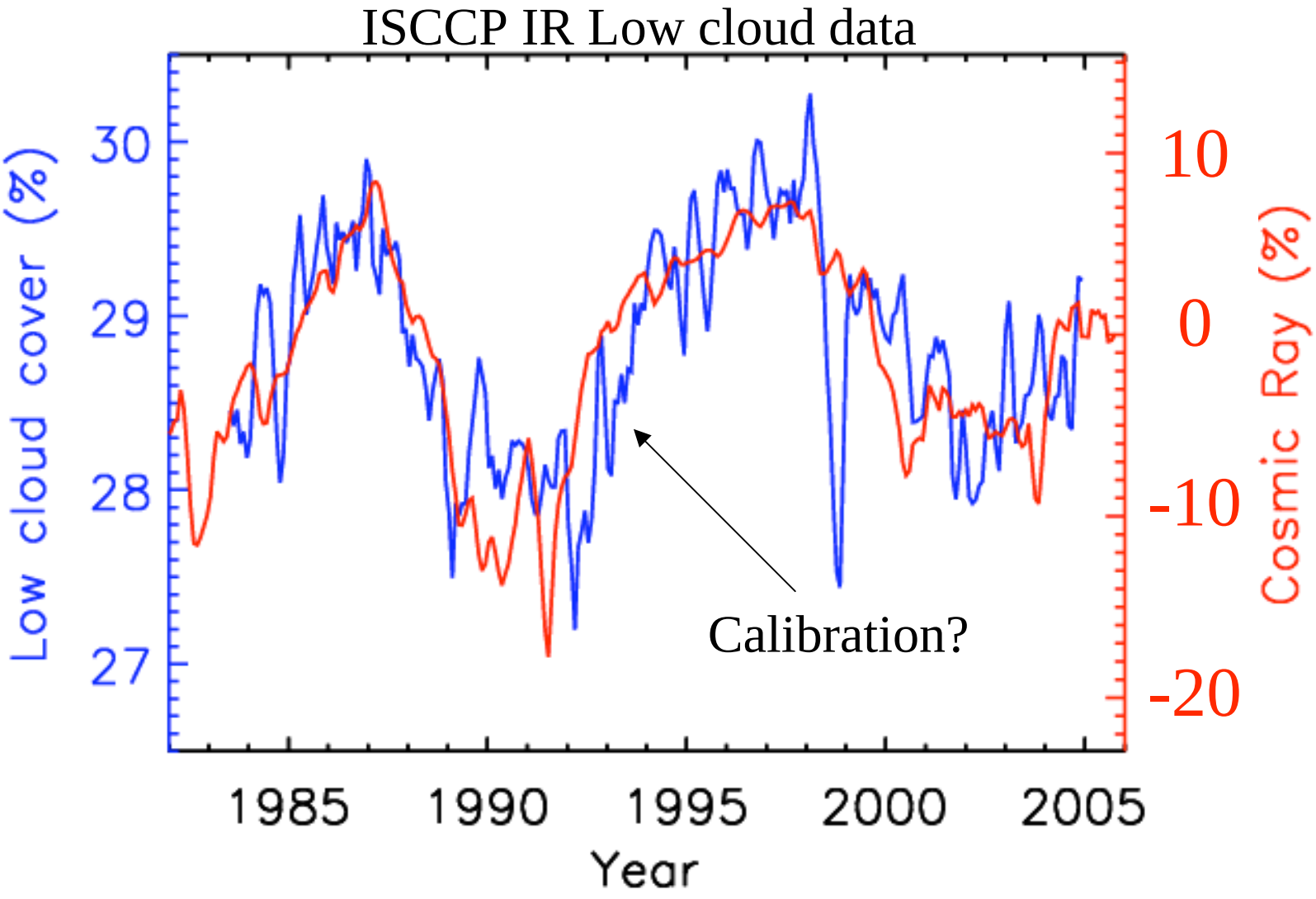


How can STARS influence Climate?

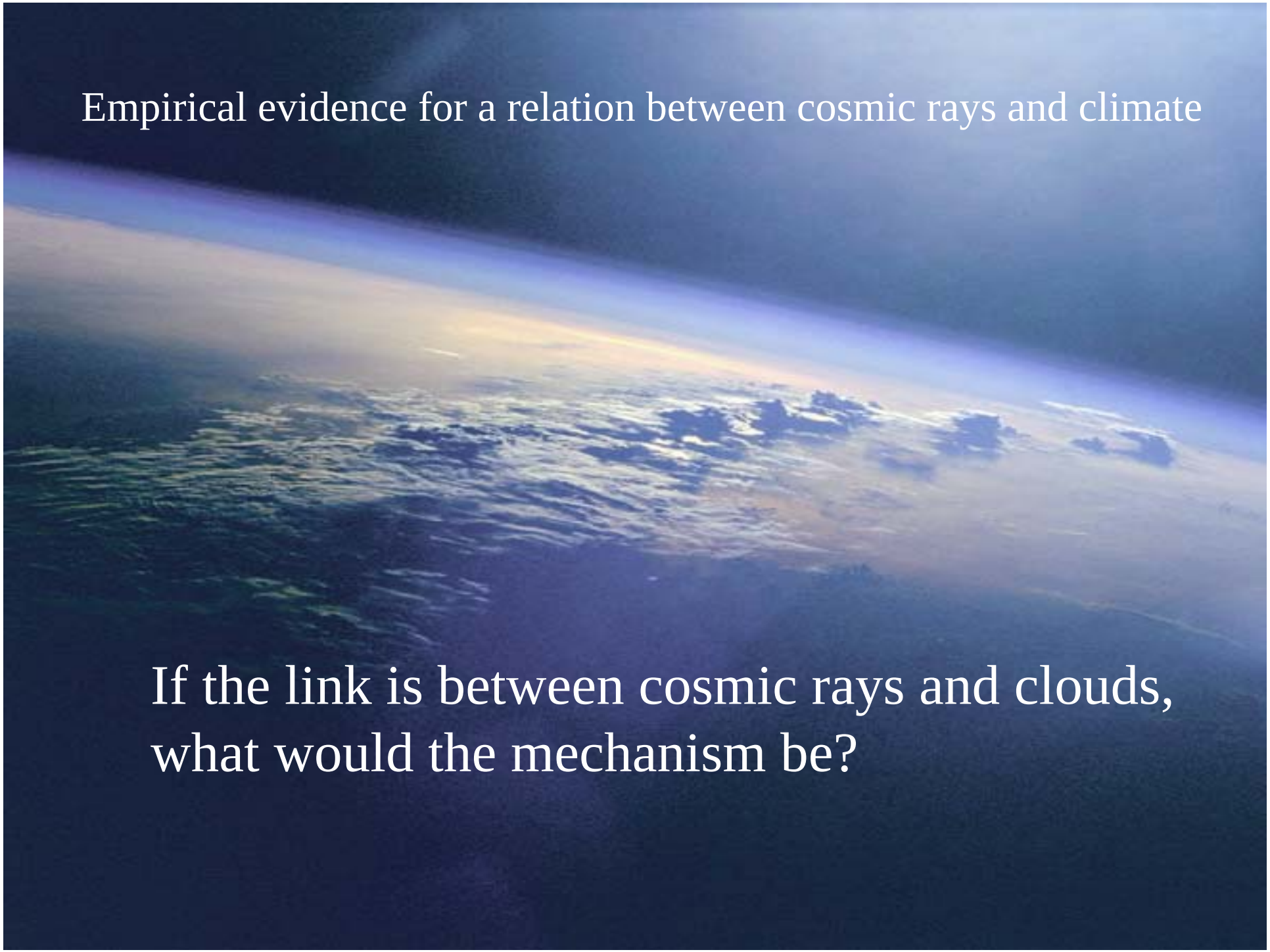


Net effect of clouds is to cool the Earth by about 30 W/m^2

Link between Low Cloud Cover and Galactic Cosmic Rays? Solar cycle variation

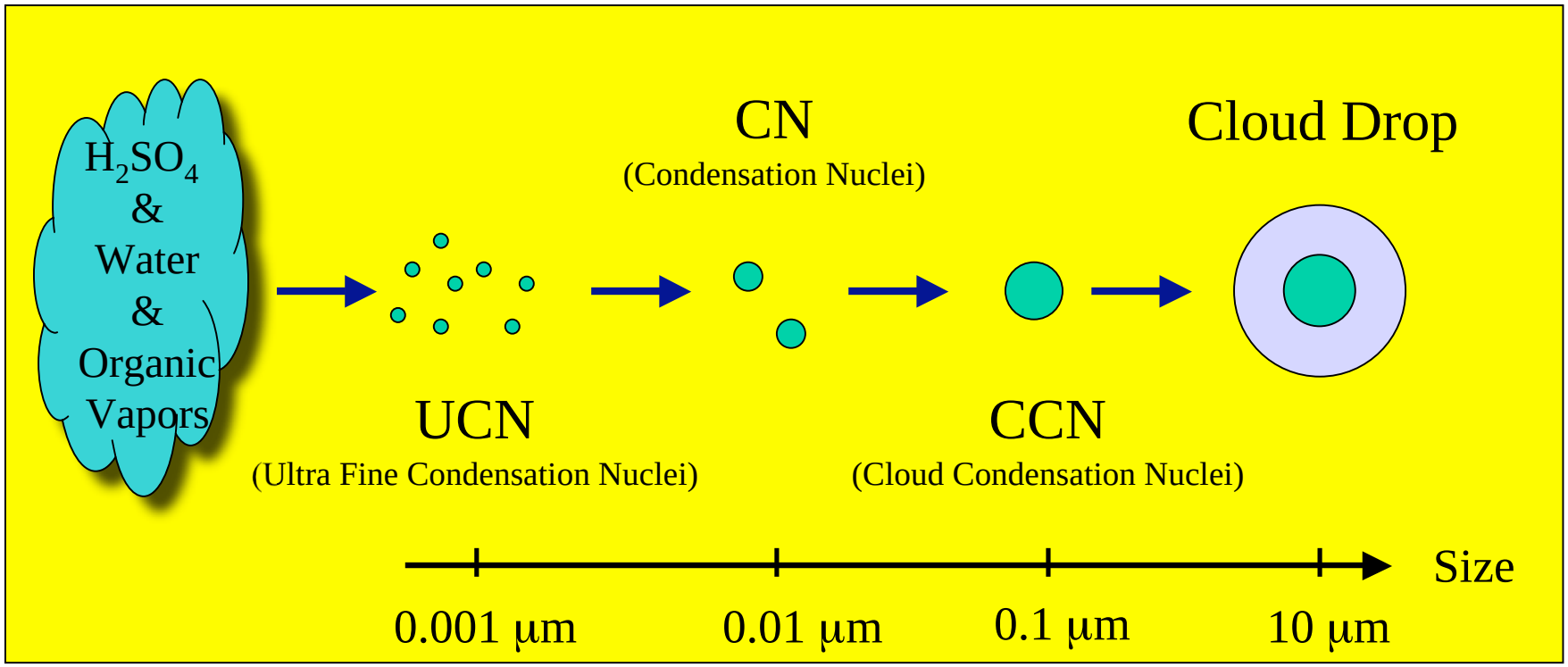


Svensmark & Friis-Christensen, JASTP 1997, Svensmark, PRL 1998, Marsh & Svensmark, PRL, 2000. (update 2005)


Empirical evidence for a relation between cosmic rays and climate
If the link is between cosmic rays and clouds, what would the mechanism be?

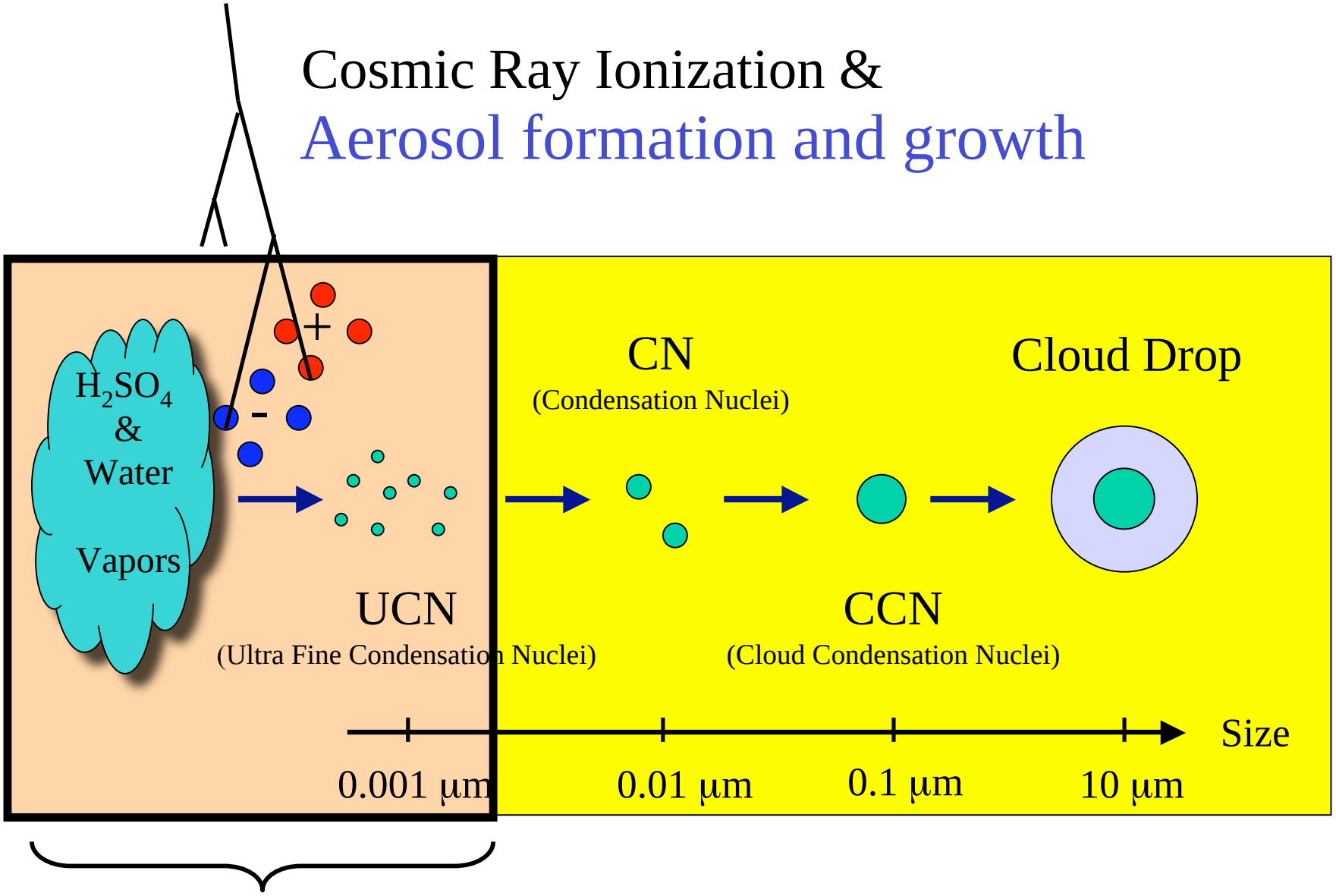
Aerosol formation and growth

Possible link between clouds and cosmic rays



Nucleation process
is unsolved

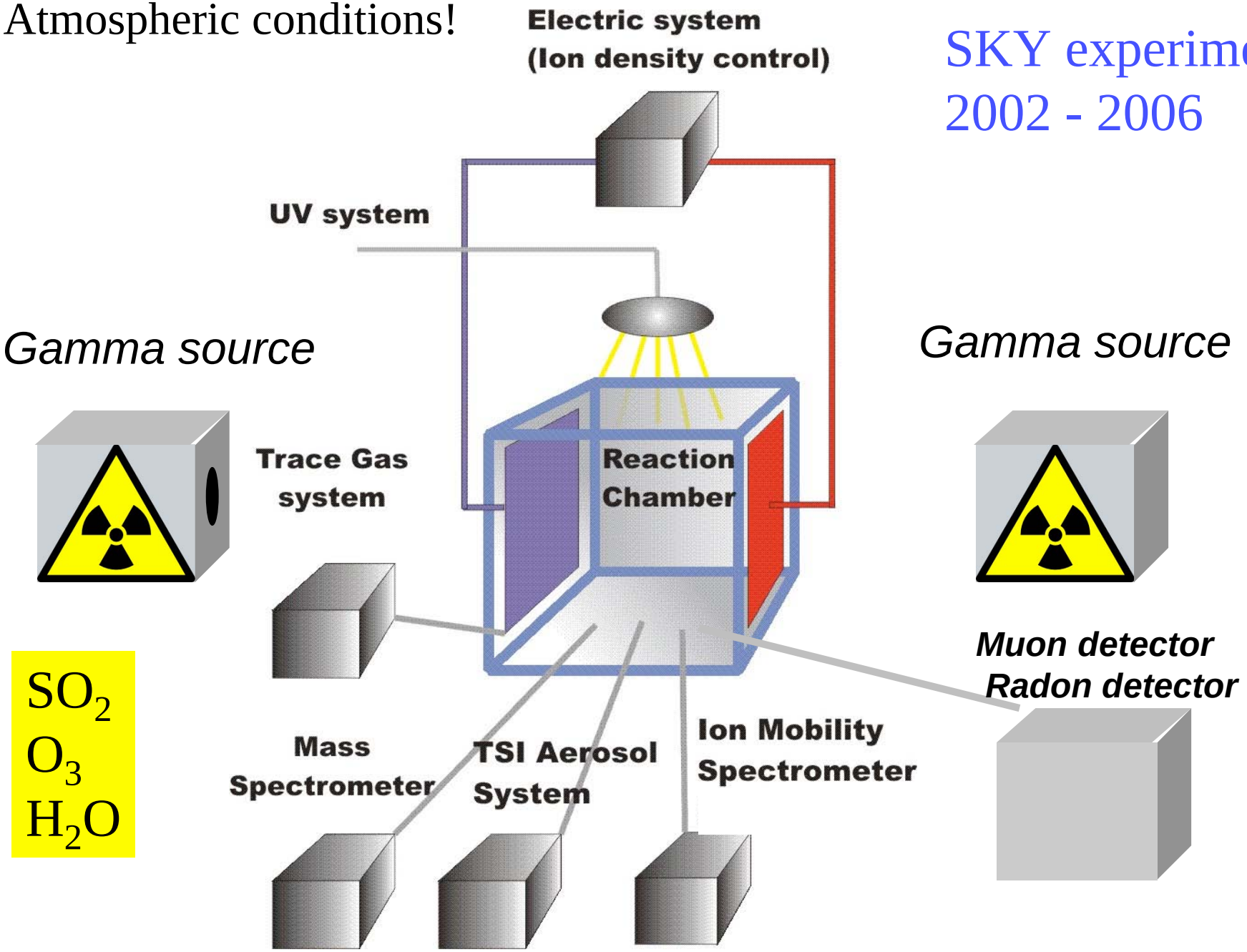
Cosmic Ray Ionization &
Aerosol formation and growth



What is the importance of IONS ?

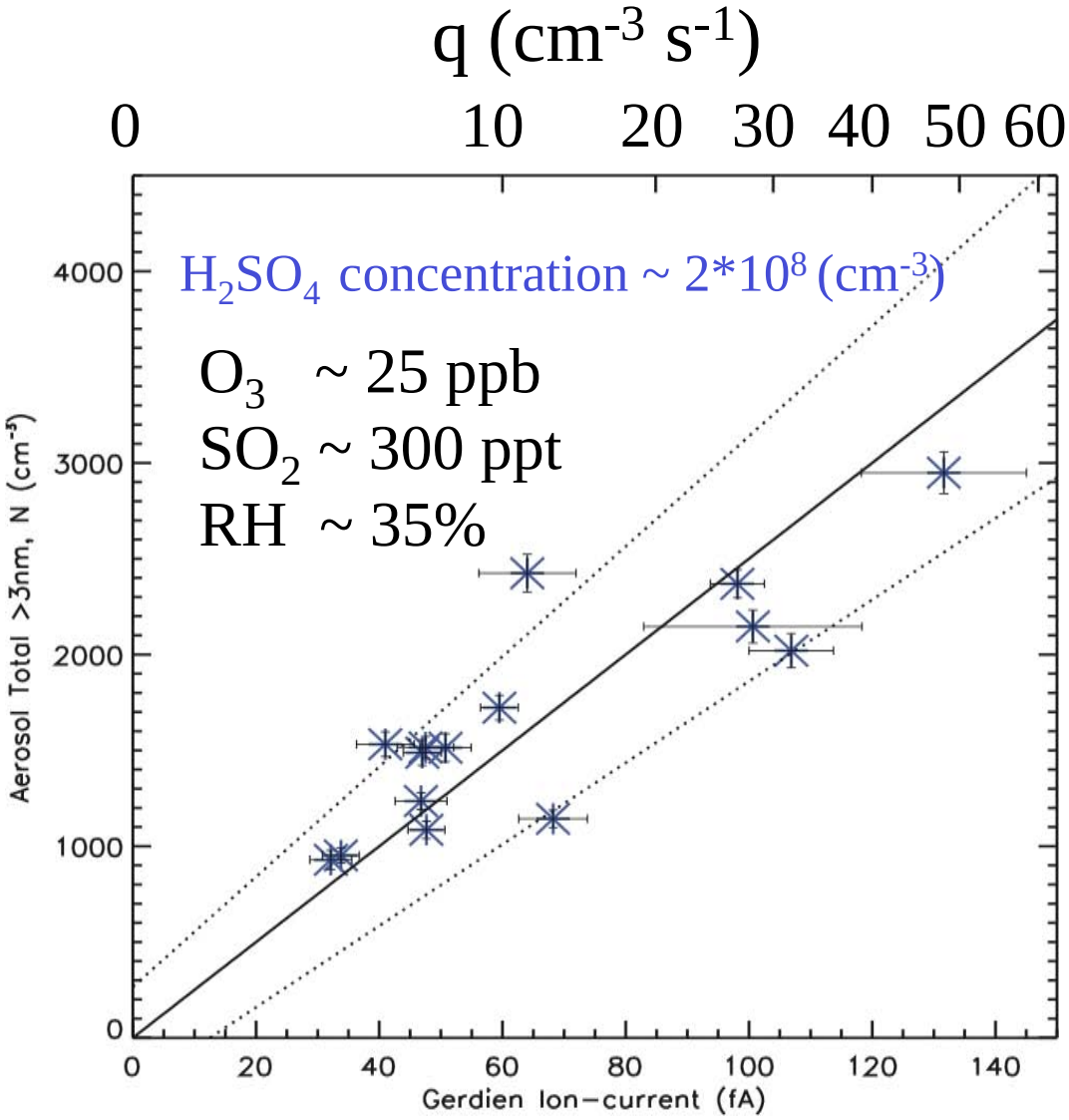
Atmospheric conditions!

SKY experiment
2002 - 2006

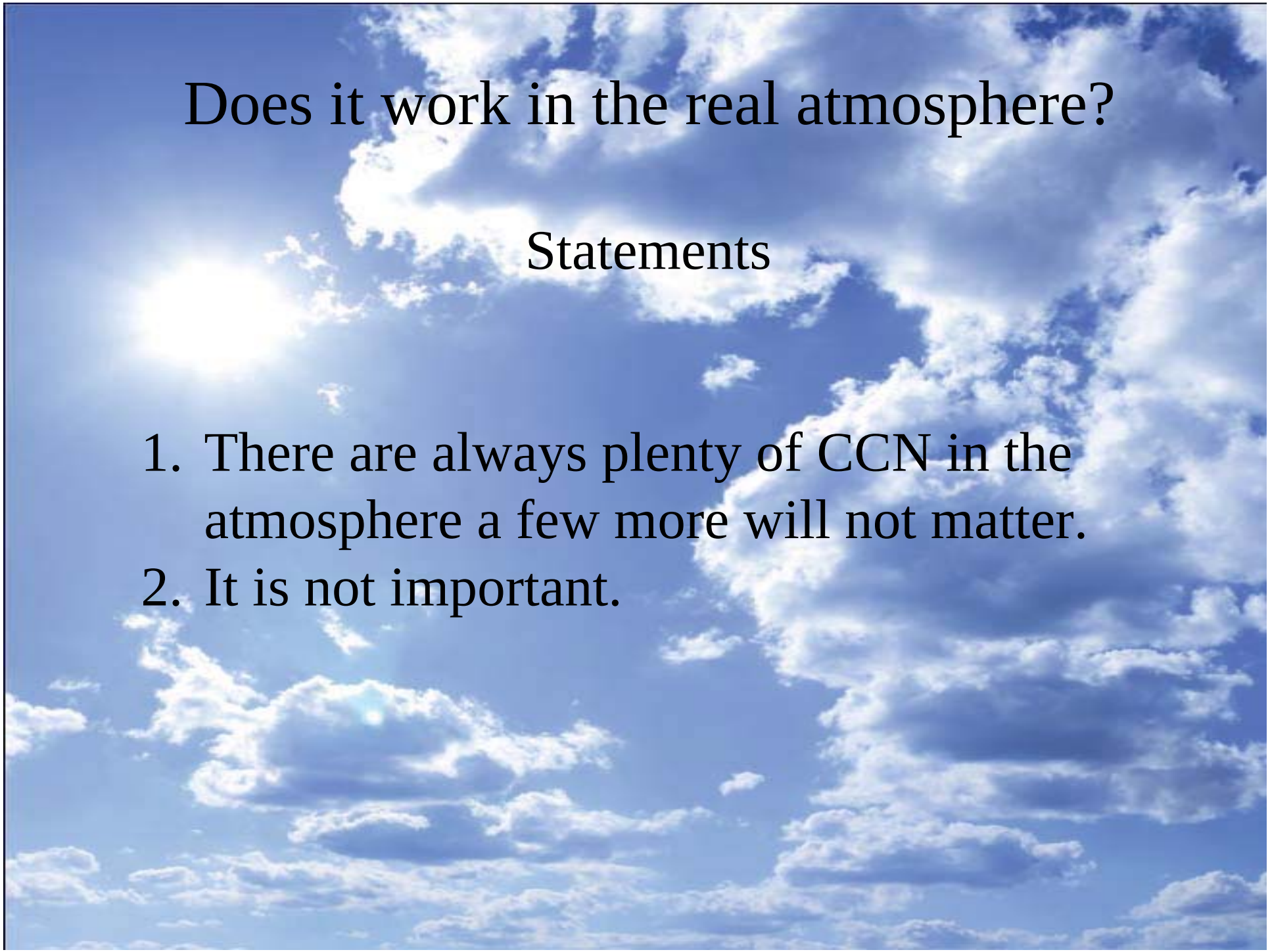


SO_2
O_3
H_2O

Steady state experiment

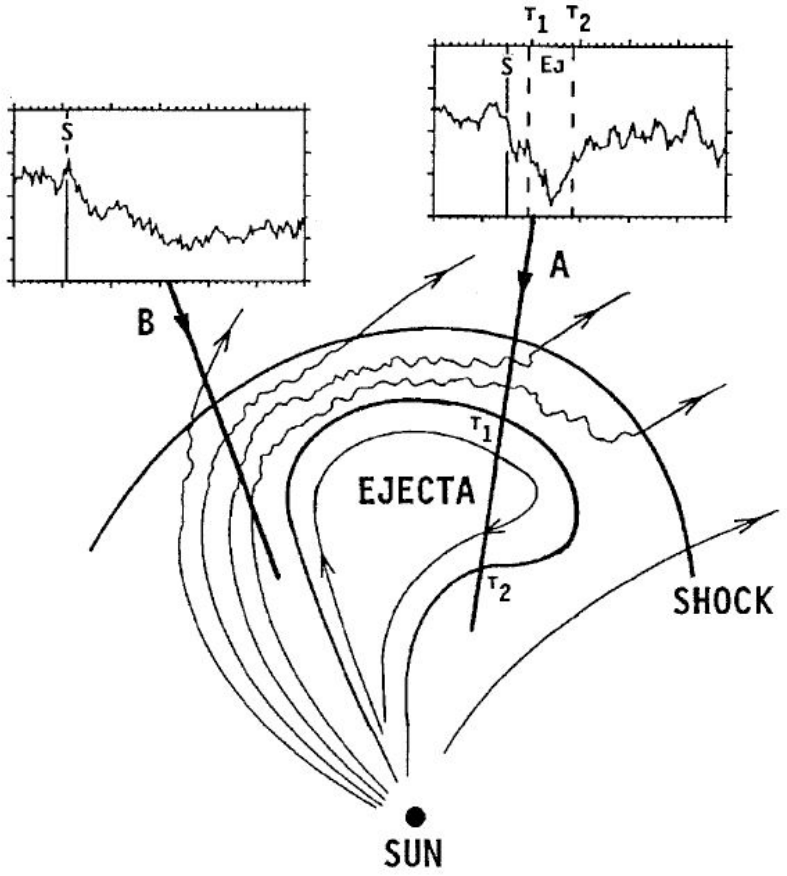


Svensmark et al. Proc. R. Soc. A (2007) 463, 385–396

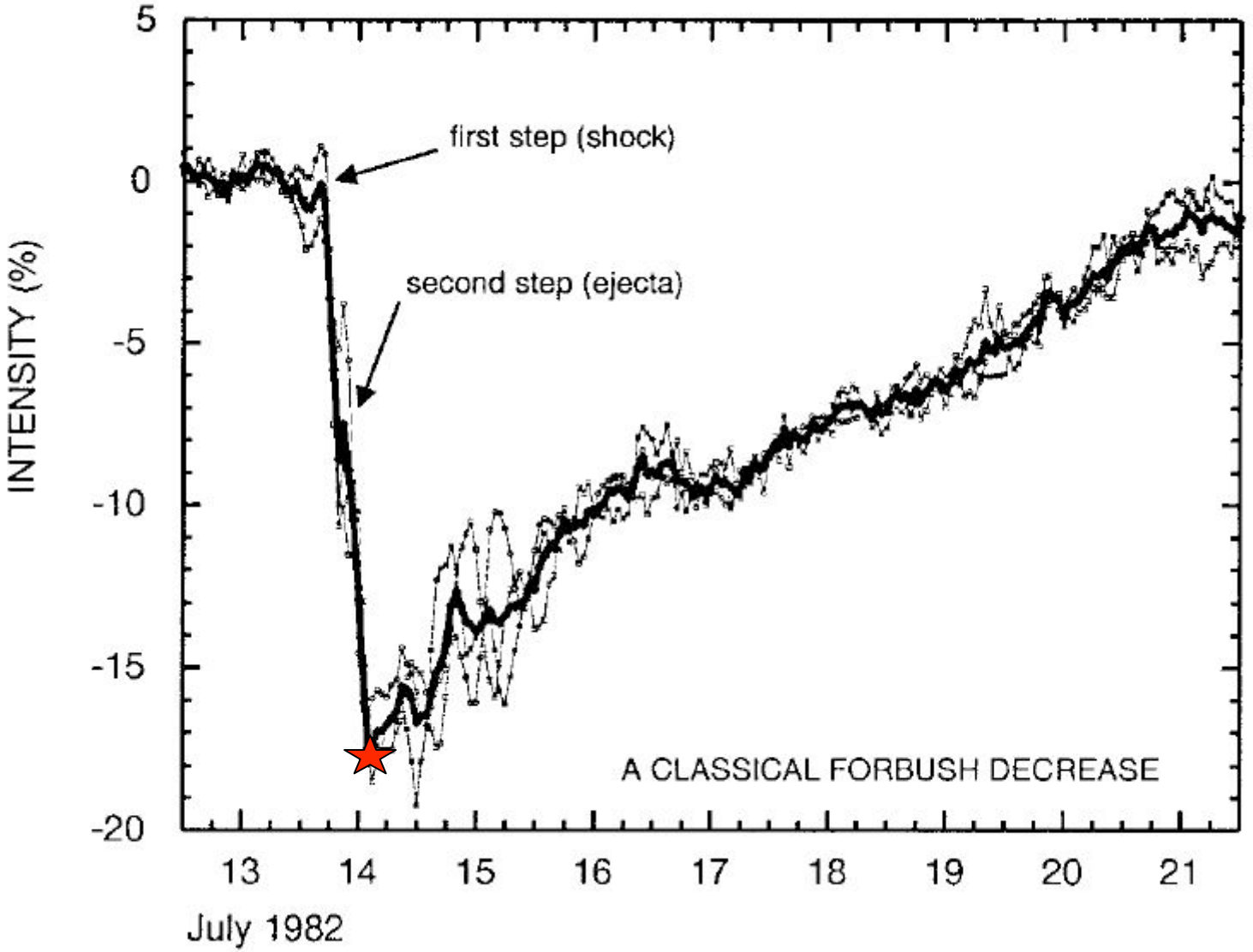

Does it work in the real atmosphere?
Statements
1. There are always plenty of CCN in the atmosphere a few more will not matter.
2. It is not important.

Coronal Mass Ejections

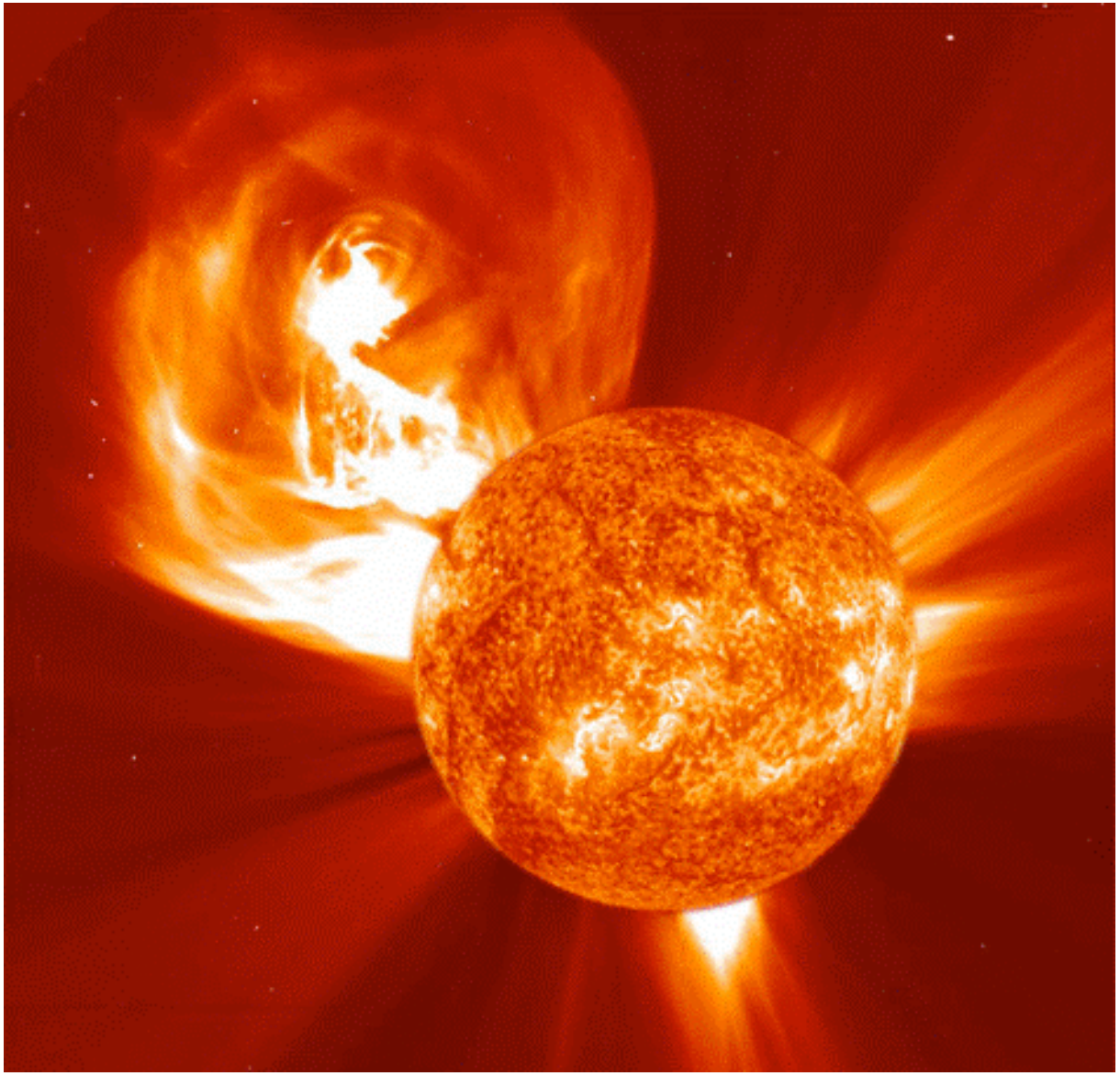
Natural experiments for testing the GCR-atmosphere link



A Classic Forbush Decrease



Cloud Killer?



CME January 4, 2002

5 strongest Forbush decreases: SSM/I data

Liquid water content of clouds over oceans

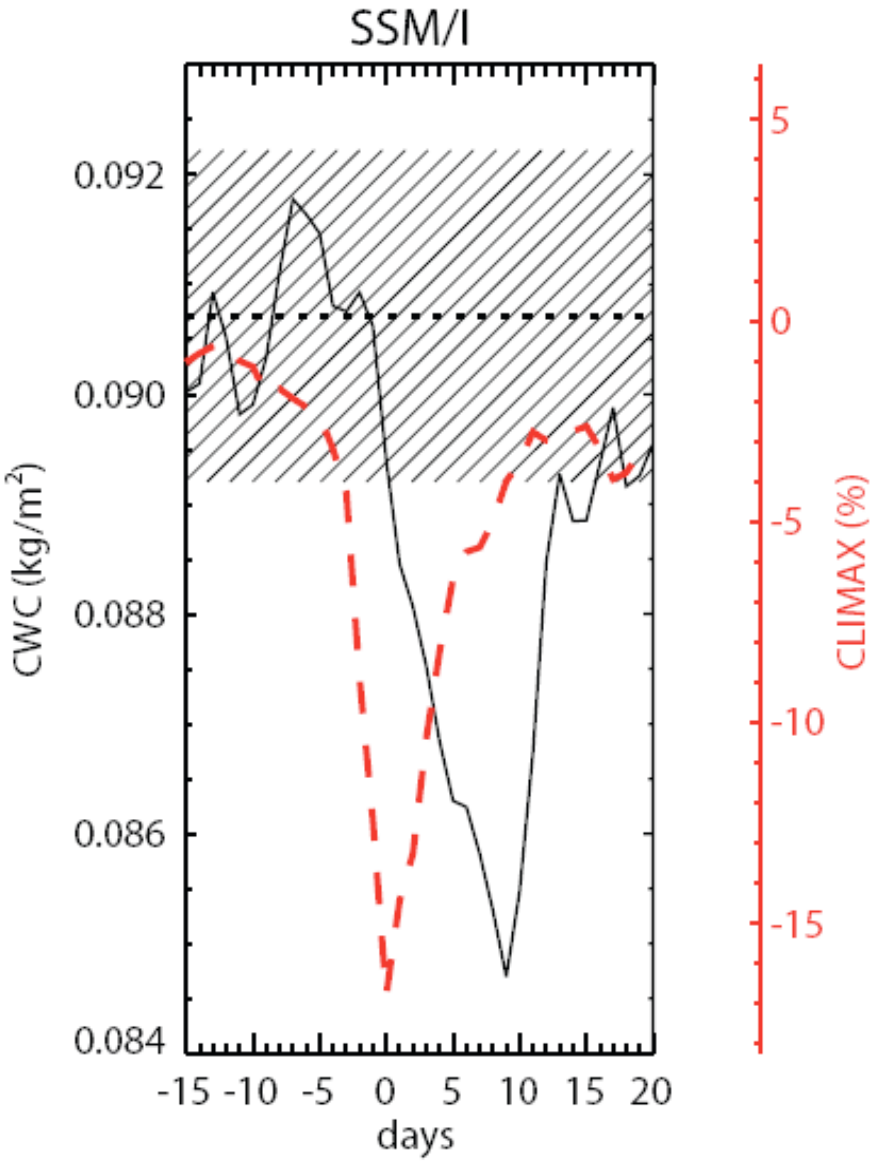
NOTE: SSM/I data

Ionization change ~ 10%

Liquid water change ~ 6%

Suggest that a large fraction of clouds are influenced by ionization

δM ~ 3 Gton

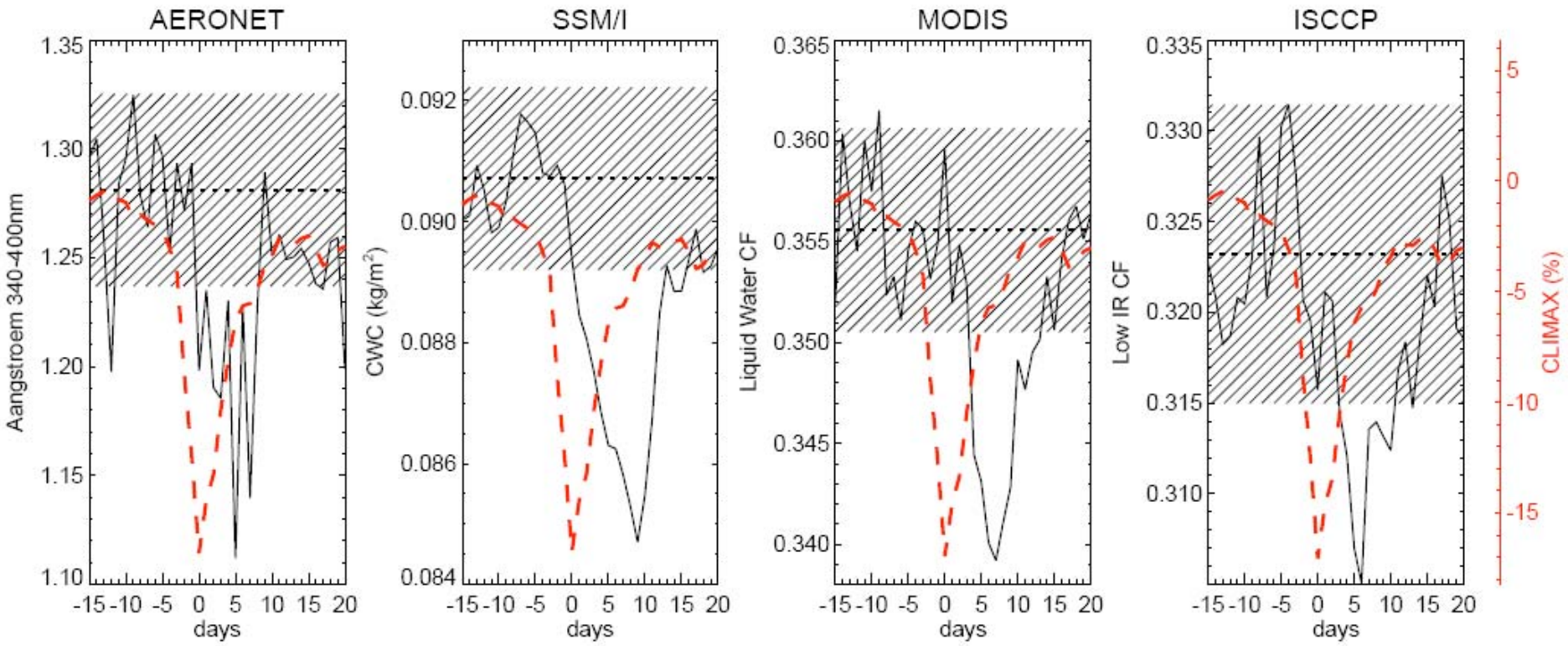


AERONET, SSM/I, MODIS and ISCCP data for 5 strongest Forbush decreases

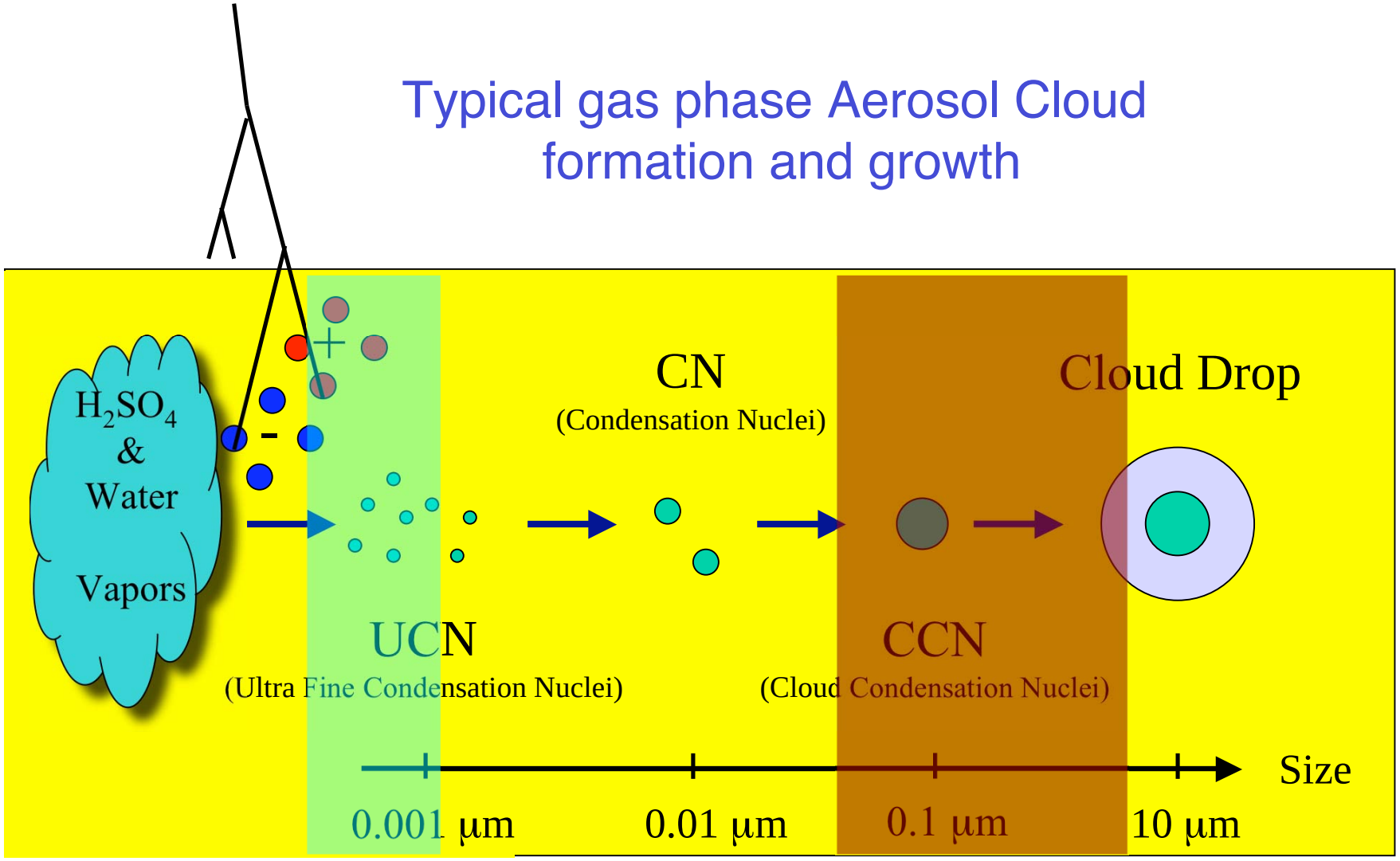
Aerosols

Clouds

Liquid water | Liquid cloud fraction | Low Clouds

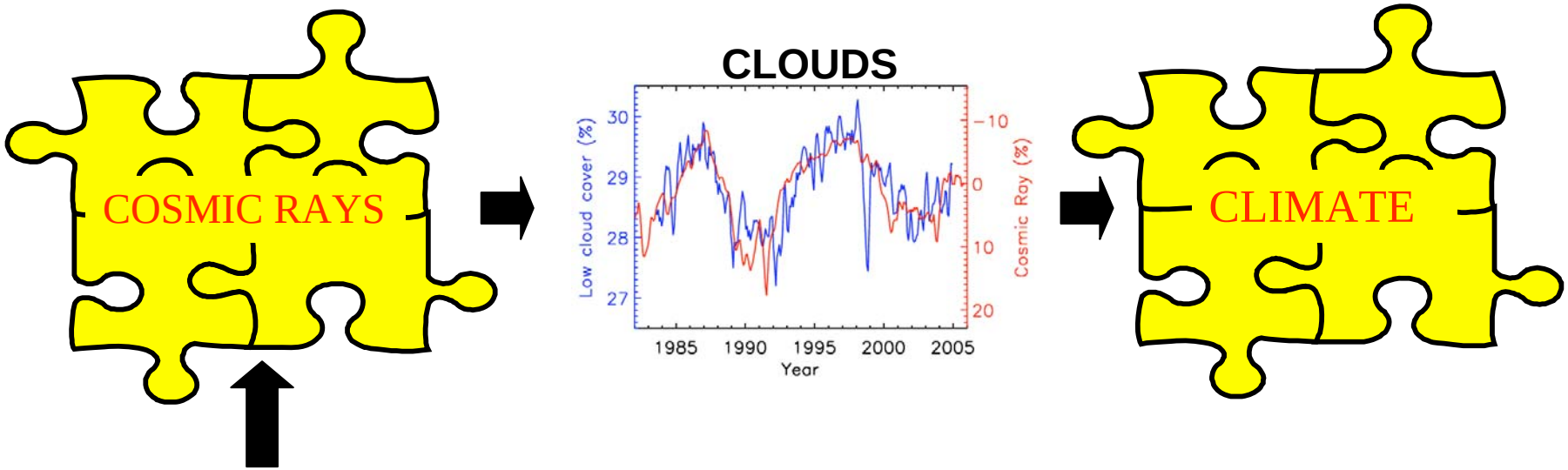


Typical gas phase Aerosol Cloud formation and growth



Ion induced formation of aerosols

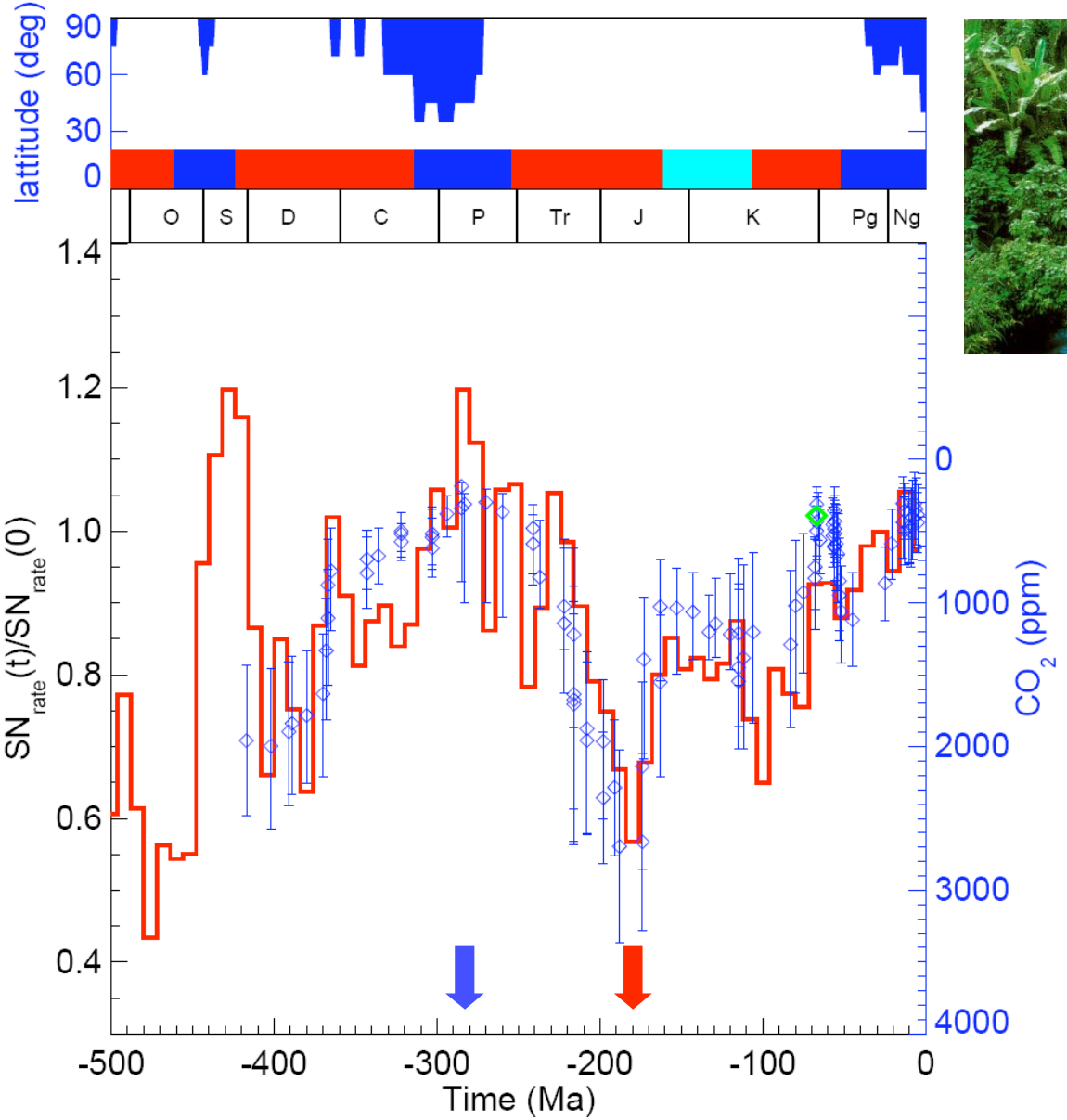
Cosmic Rays and Climate



Supported by empirical, observational, and experimental evidence

Variations in Cosmic Ray Flux Cause Variations in Earths Climate.

SN variations and Earths Climate

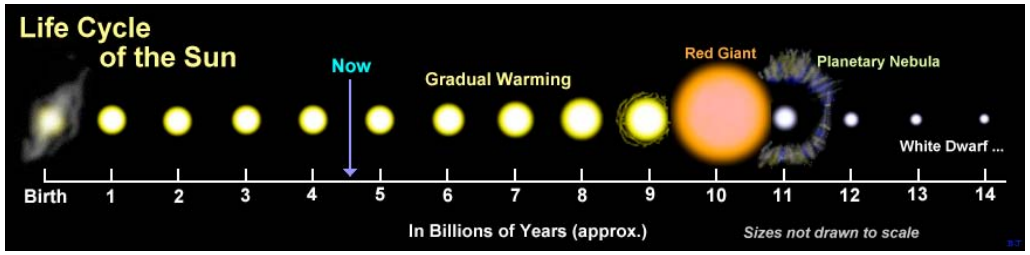


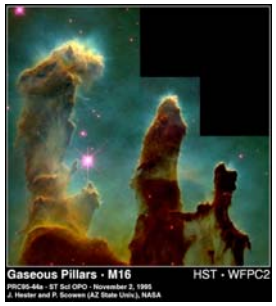
Svensmark 2008

What about longer time scales, i.e over the history of the Earth 4.6 Billion years?

Although Cosmic ray fluxes are not known so far back in time, they can be constructed from knowledge of

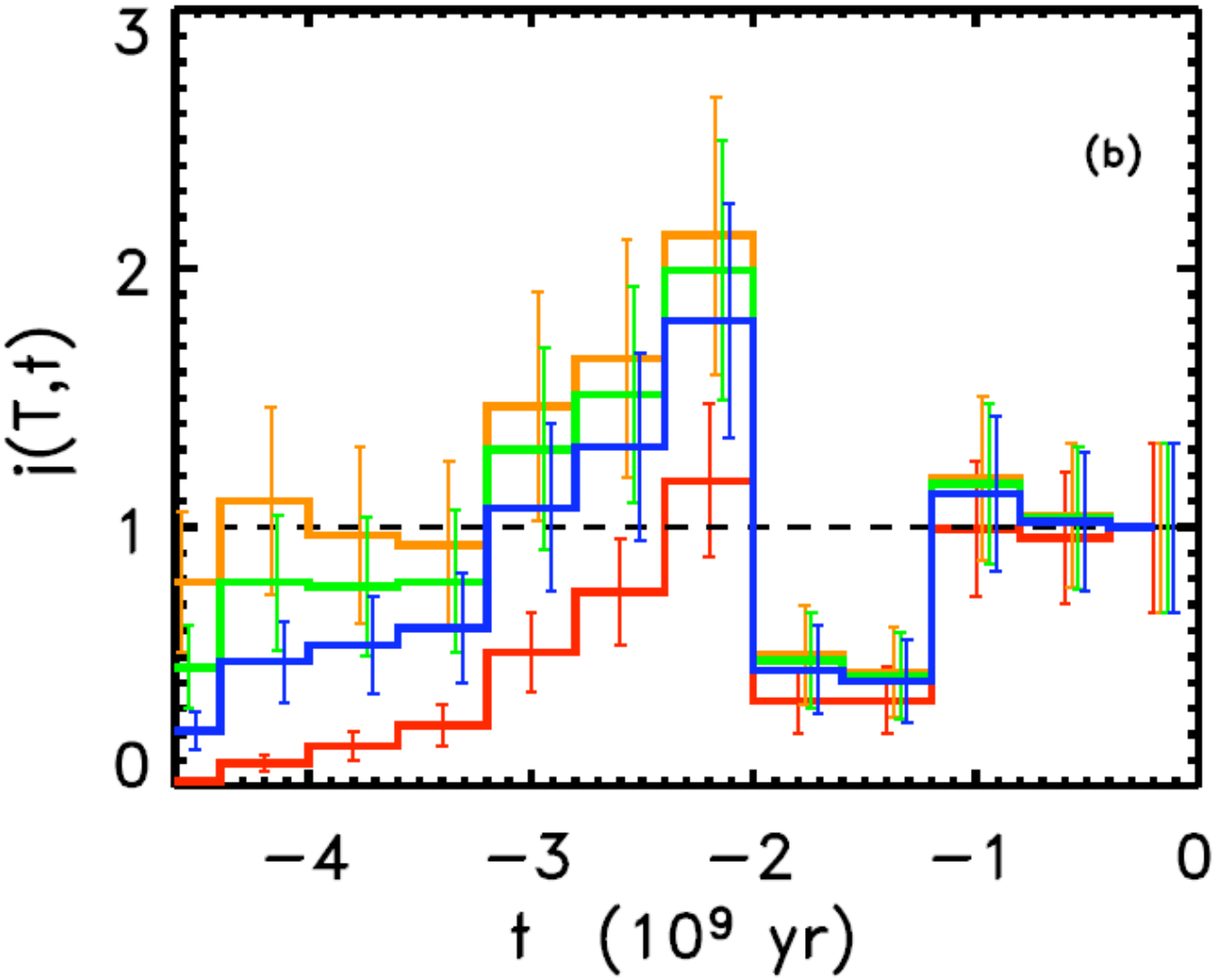
1) Solar Evolution





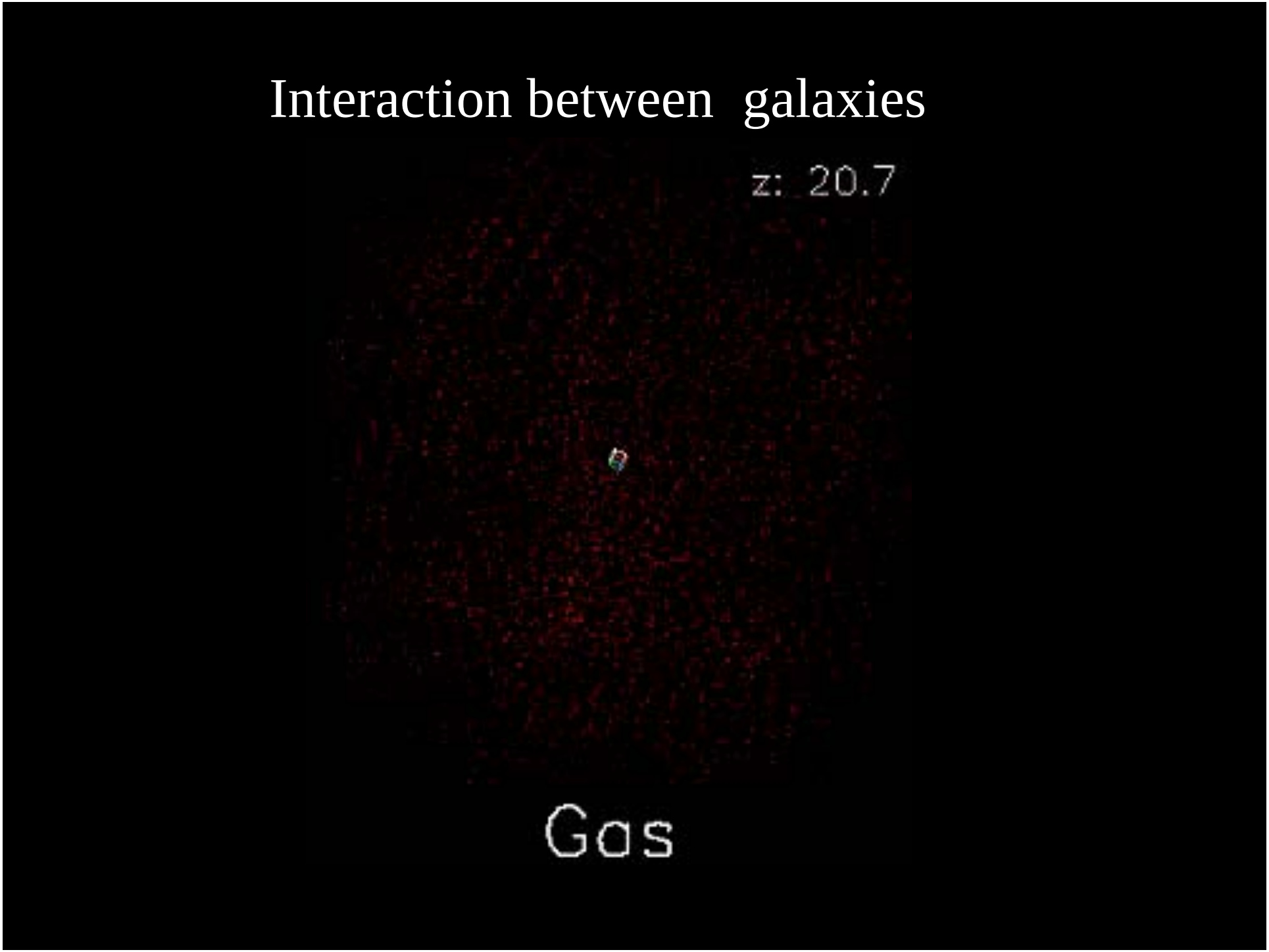
2) History of Star Formation Rate in the Milky Way

Solar Evolution, Star Rate Formation and Cosmic Rays

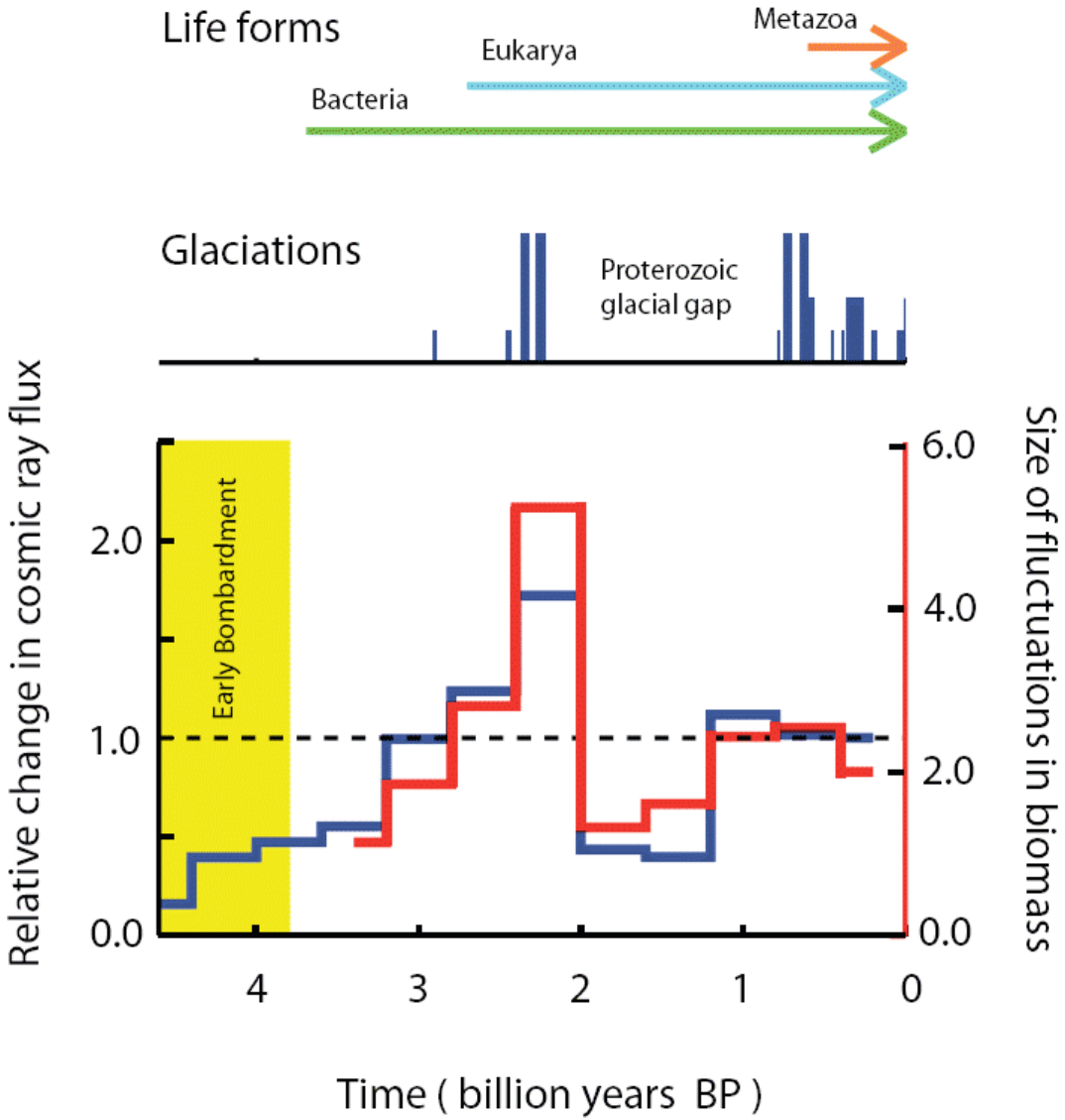


Svensmark, Astronomical Notes 2006

Interaction between galaxies

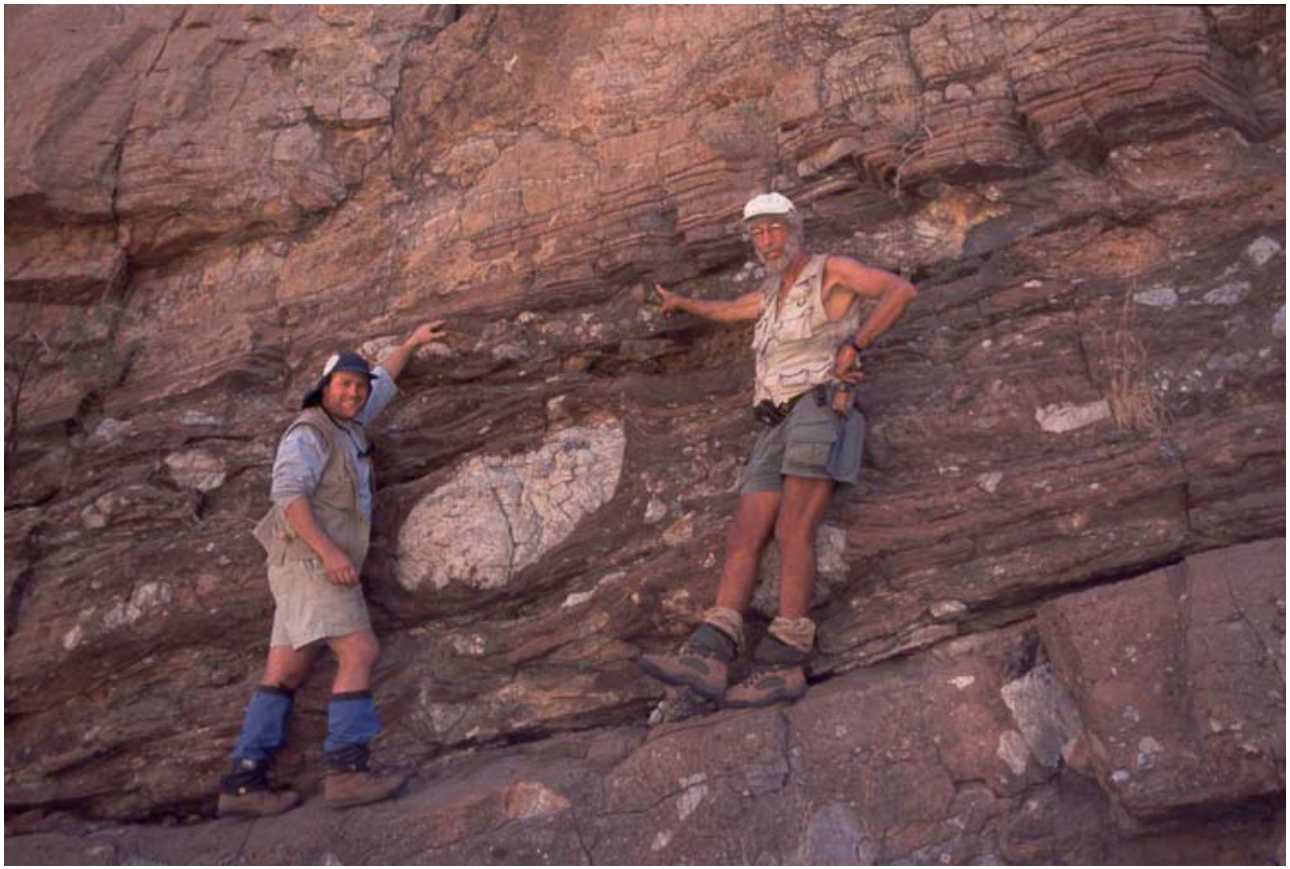


Cosmic Rays and the Biosphere in 4 Billion Years



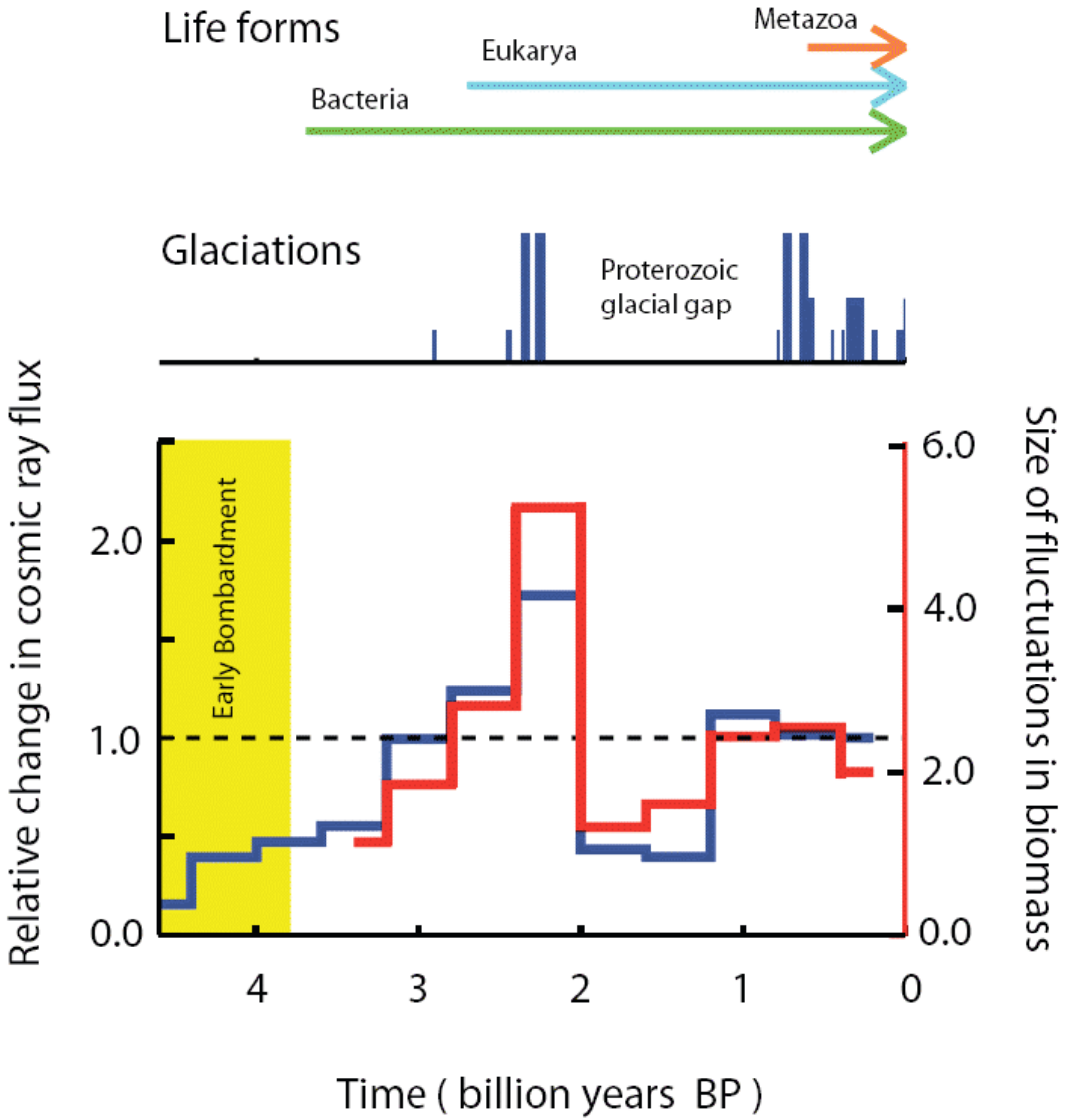
Svensmark, Astronomical Notes 2006

Snowball Earth



Hofman and Schrag point to glaciomarine dropstone

Cosmic Rays and the Biosphere in 4 Billion Years



Svensmark, Astronomical Notes 2006

Conclusion

Variation in cosmic rays are associated with changes in Earths climate. Strong empirical evidence. (not discussed: long time scales e.g. million of years)

Evidence suggest that clouds are the key player.

New insight to the physical mechanism has been demonstrated experimentally and observationally

- Involving ions and aerosol formation
- Linking to clouds and thereby the energy budget of the Earth
- Observations further suggest that a large fraction of clouds are influenced by ionization. (6% change in liquid water for a 10 % change in ionization)

Understanding the cosmic ray climate link could have large implications in our understanding of climate changes.

The theory ”Cosmic rays and climate” is alive and strong

Thanks:

Torsten Bondo

Jacob Svensmark

Martin Enghoff

Nigel D. Marsh

Nigel Calder

Jens Olaf Pedersen

Ulrik I. Uggerhøj

Sean Paling

DTU-space

Center for Sun-Climate Research

Scientists agree that over the last century the Earth has become warmer. But do we really know why this has happened?

A deftly written and enjoyable read, *The Chilling Stars* outlines a brilliant, daring and undoubtedly controversial new theory that will provoke fresh thinking about global warming.

As prize-winning science writer Nigel Calder and climate physicist Henrik Svensmark explain, an interplay of the clouds, the Sun and cosmic rays – sub-atomic particles from exploded stars – seems to have more effect on the climate than man-made carbon dioxide.

This conclusion stems from Svensmark's research at the Danish National Space Center which has recently shown that cosmic rays play an unsuspected role in making our everyday clouds. And during the last 100 years cosmic rays became scarcer because unusually vigorous action by the Sun batted many of them away. Fewer cosmic rays meant fewer clouds and a warmer world.

The theory, simply put here but explained in fascinating detail in the book, emerges at a time of intense public and political debate about climate change. Motivated only by their concern that science must be trustworthy, Svensmark and Calder invite their readers to put aside their preconceptions about man-made global warming and look afresh at the role of Nature in this hottest of world issues.

ISBN10:1-84046-815-7
ISBN13:978-1840468-15-1
9 781840 468151

Icon Books UK £9.99
Canada $20.00
www.iconbooks.co.uk

Earth image courtesy of NASA, background courtesy of Pekka Parvialnen / Science Photo Library

Cover design by Ghost

THE CHILLING STARS

Henrik Svensmark & Nigel Calder

THE CHILLING STARS

A New Theory of Climate Change

Henrik Svensmark & Nigel Calder

Response in aerosols and clouds as function of strength of all the Forbush decreases.

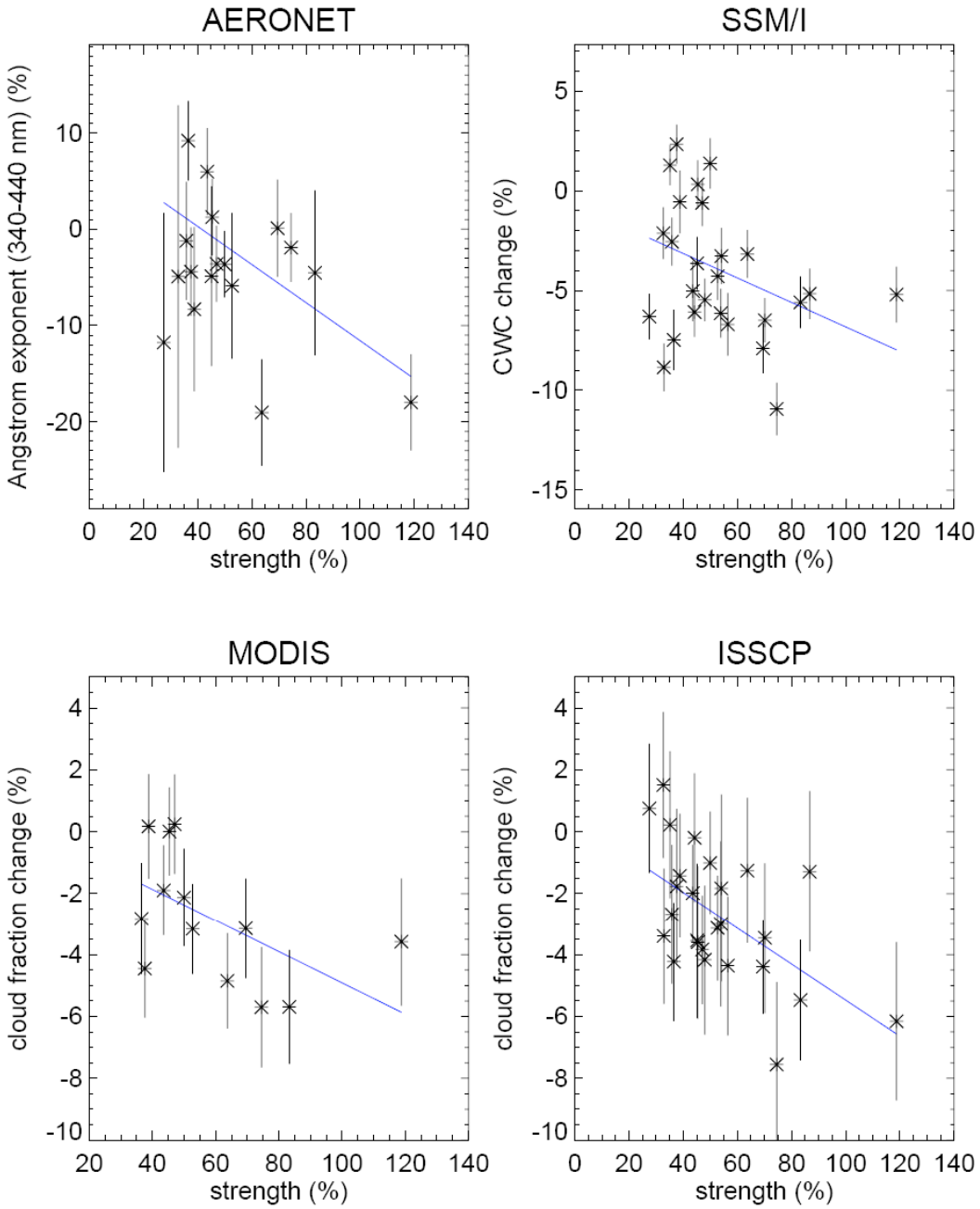
NOTE: SSM/I data

Ionization change ~ 10%

Liquid water change ~ 6%

Suggest that a large fraction of clouds are influenced by ionization

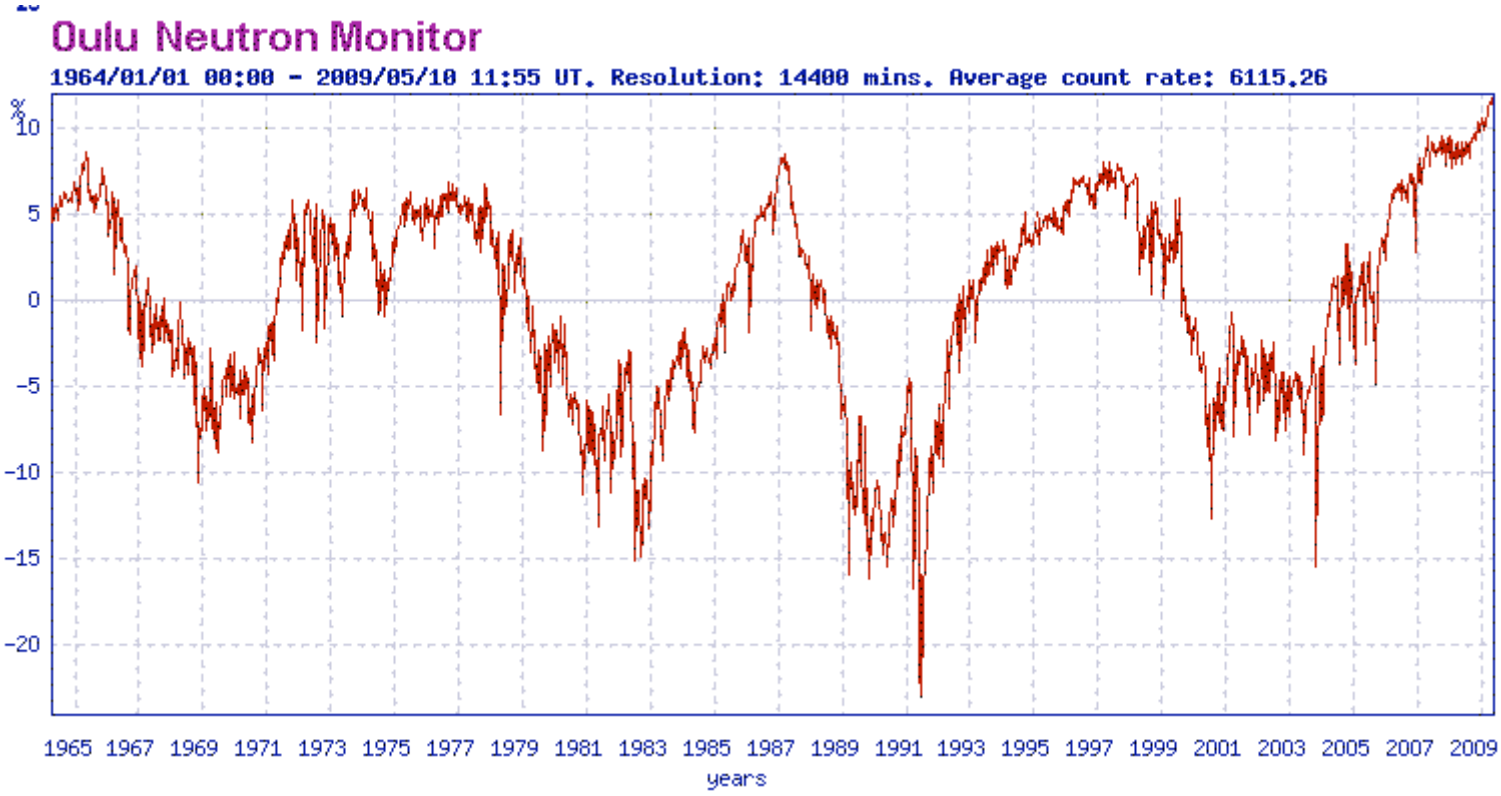
δM ~ 3 Gton



Prediction

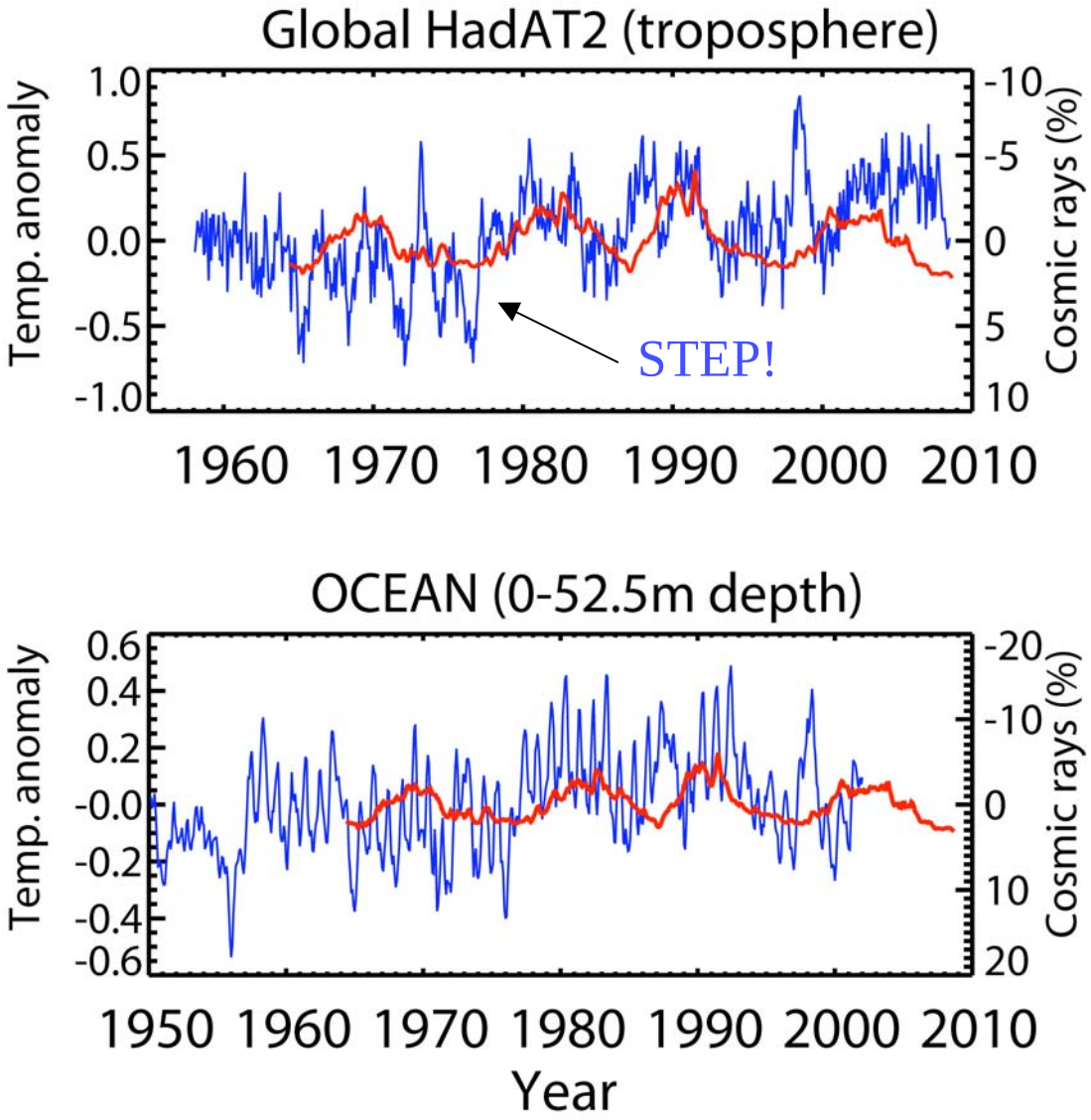
The near future: Cooling

The sun will show how important it is



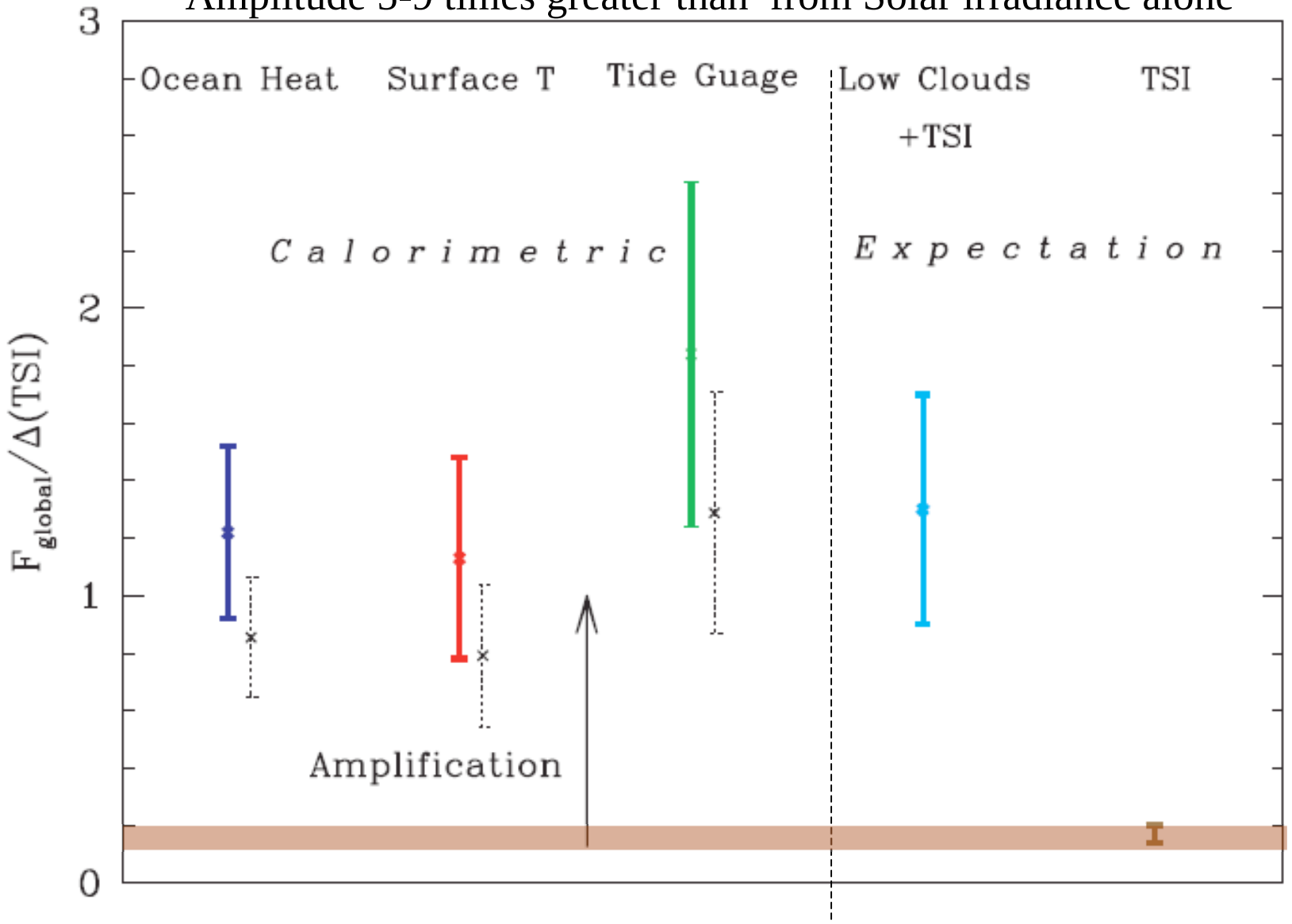
Cosmic Rays and 1960 -2008 tropospheric temperatures

Average temperature between 0-10 km



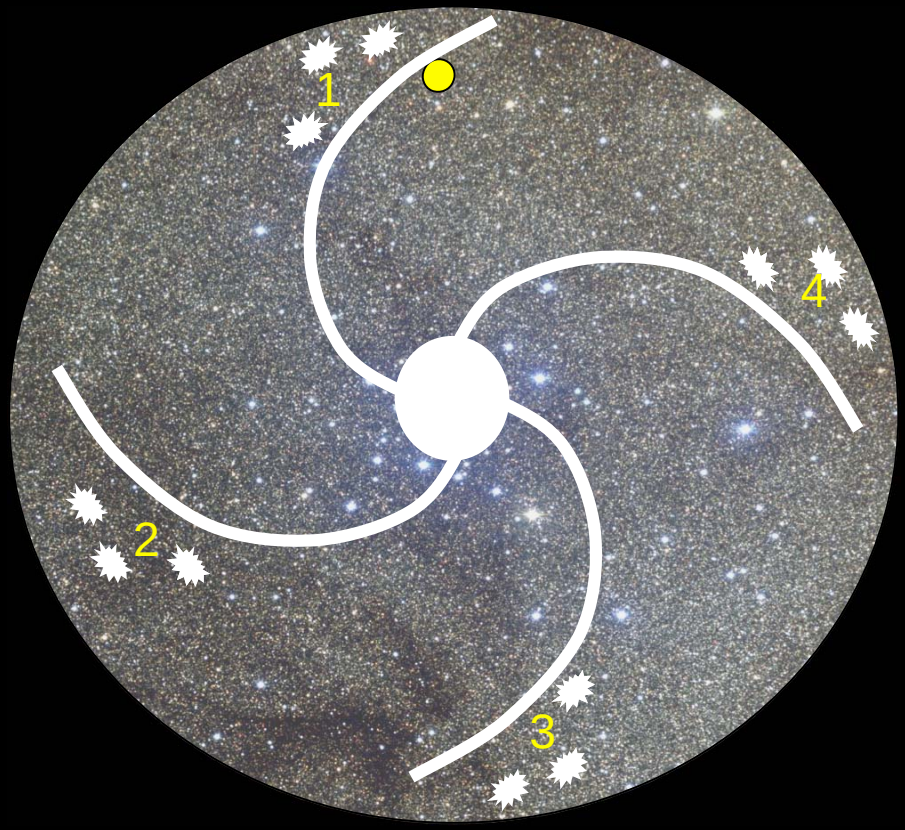
Using the oceans as a calorimeter to quantify the solar radiative forcing

Amplitude 5-9 times greater than from Solar irradiance alone



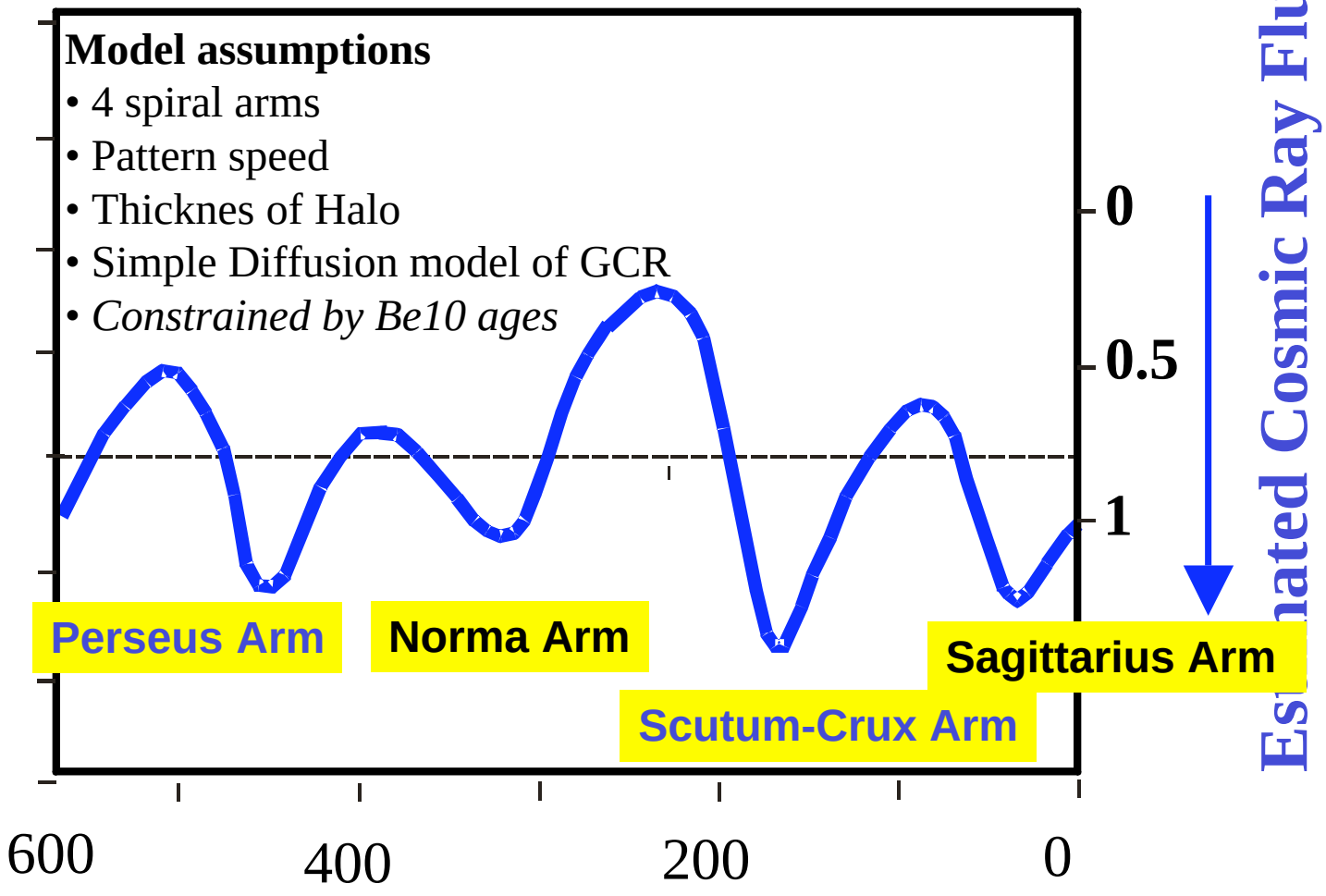
Nir J. Shaviv JGR 2009

Milky Way, Soler System, Spiral Arms



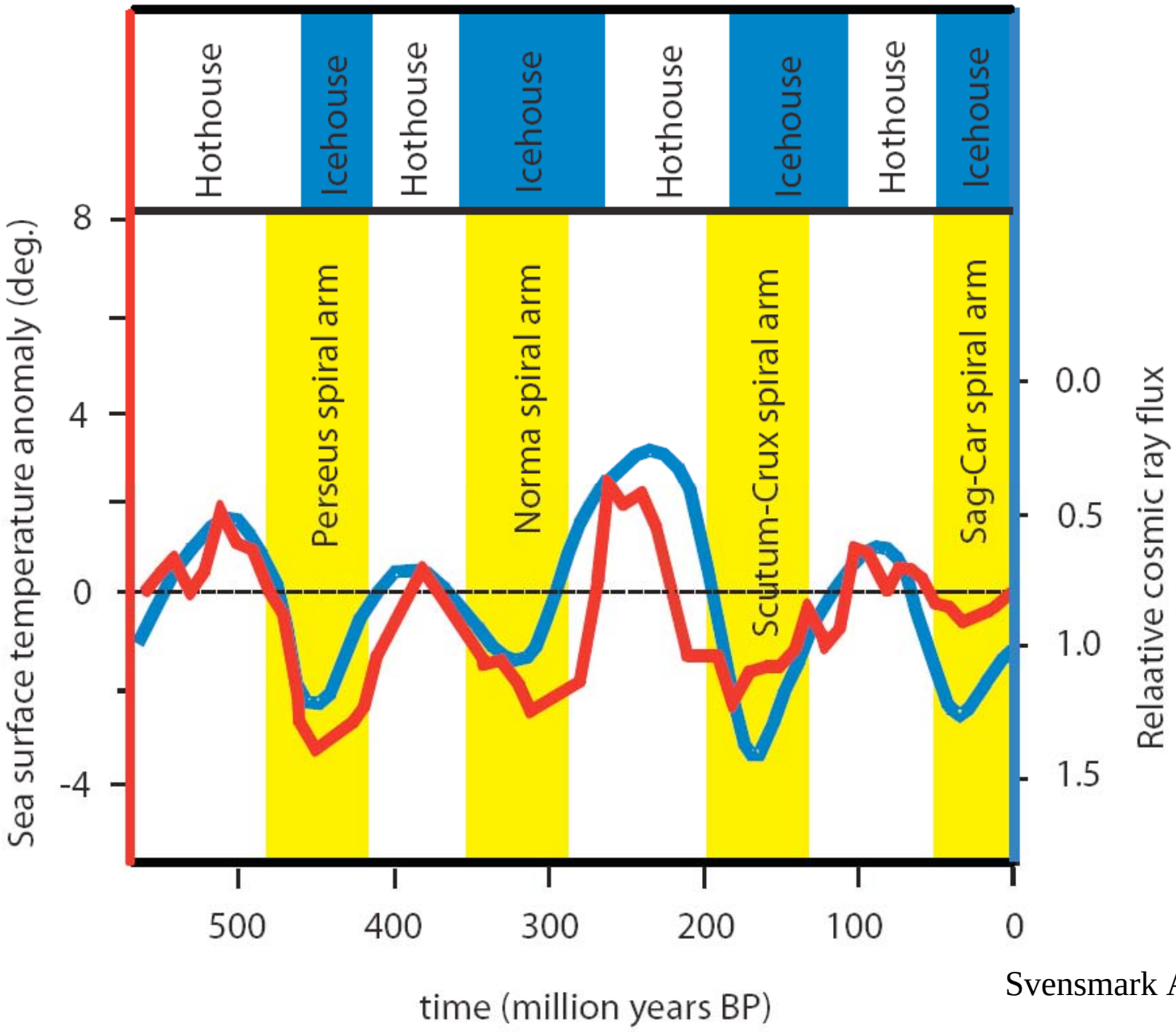
Galactic year ~ 250 myr
Pattern speed ~ 0.5 stellar speed
Overtakes spiral arm 140 myr

Cosmic rays and spiral arm crossing



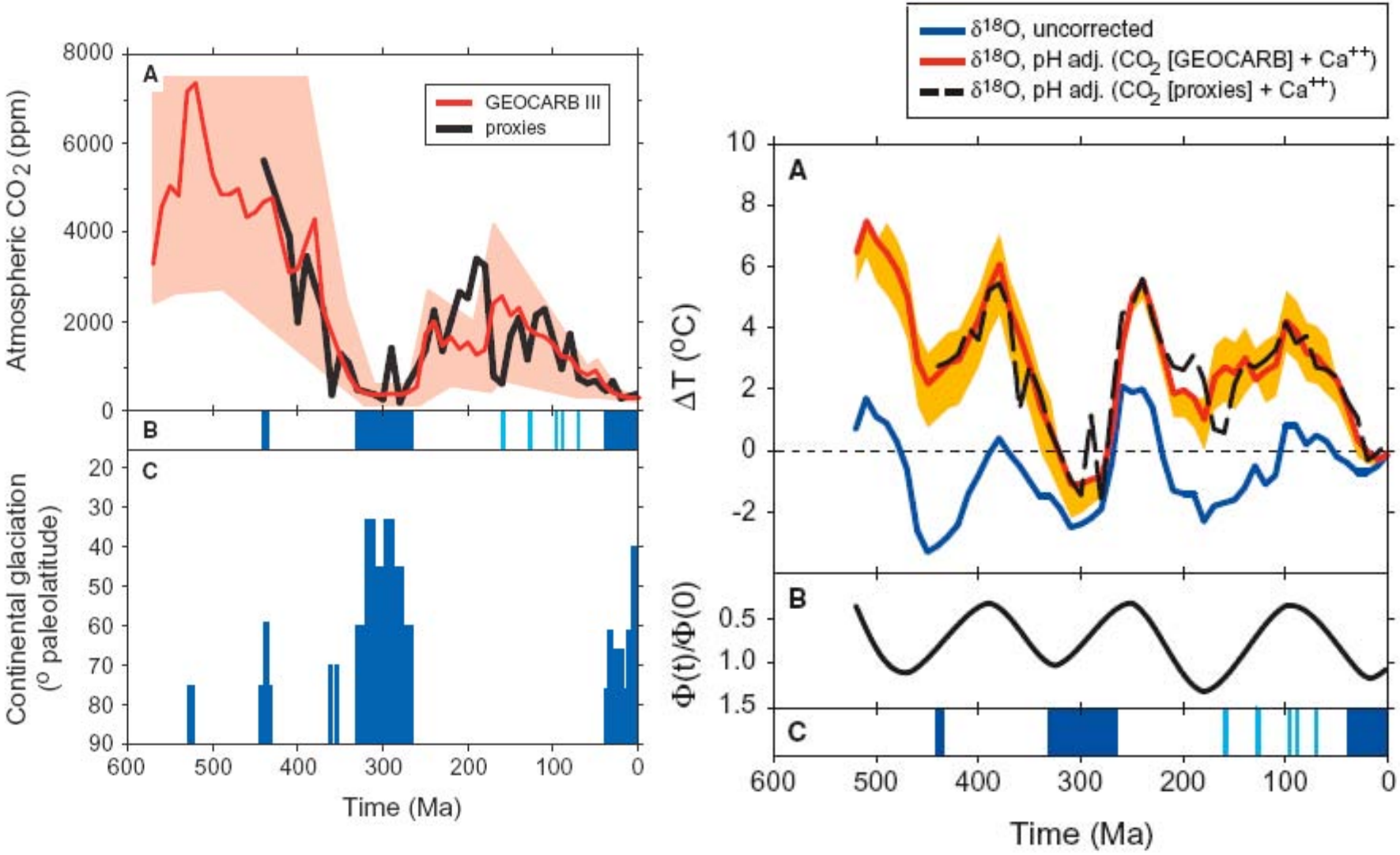
Shaviv, PRL (2002)

Shaviv & Veizer



Svensmark A&G 2007

CO_2 as a primary driver of Phanerozoic climate



summing up

- Super Nova variations for the past 500 myr have be constructed from the number and age of stellar clusters with in 1 kpc of the Sun.
- No prior assumptions about the Milky Way structure.

- The variations show a remarkable agreement with changes in the climate
  1. Geological evidence of glaciations in Earths History
  2. CO2 variations follow the SN with a correlation coefficient of -0.86
- Solves a serious critique of a link between GCR and climate.

- Implications are for example:
  1. Climate on Earth is close linked to the Galactic neighborhood of the solar system
  2. CO2 can not be the driver of climate, if SN are driving climate variations.
  3. Climate sensitivity of CO2 is smaller than estimates from climate models (< 1.5 K)

Sloan & Wolfendale

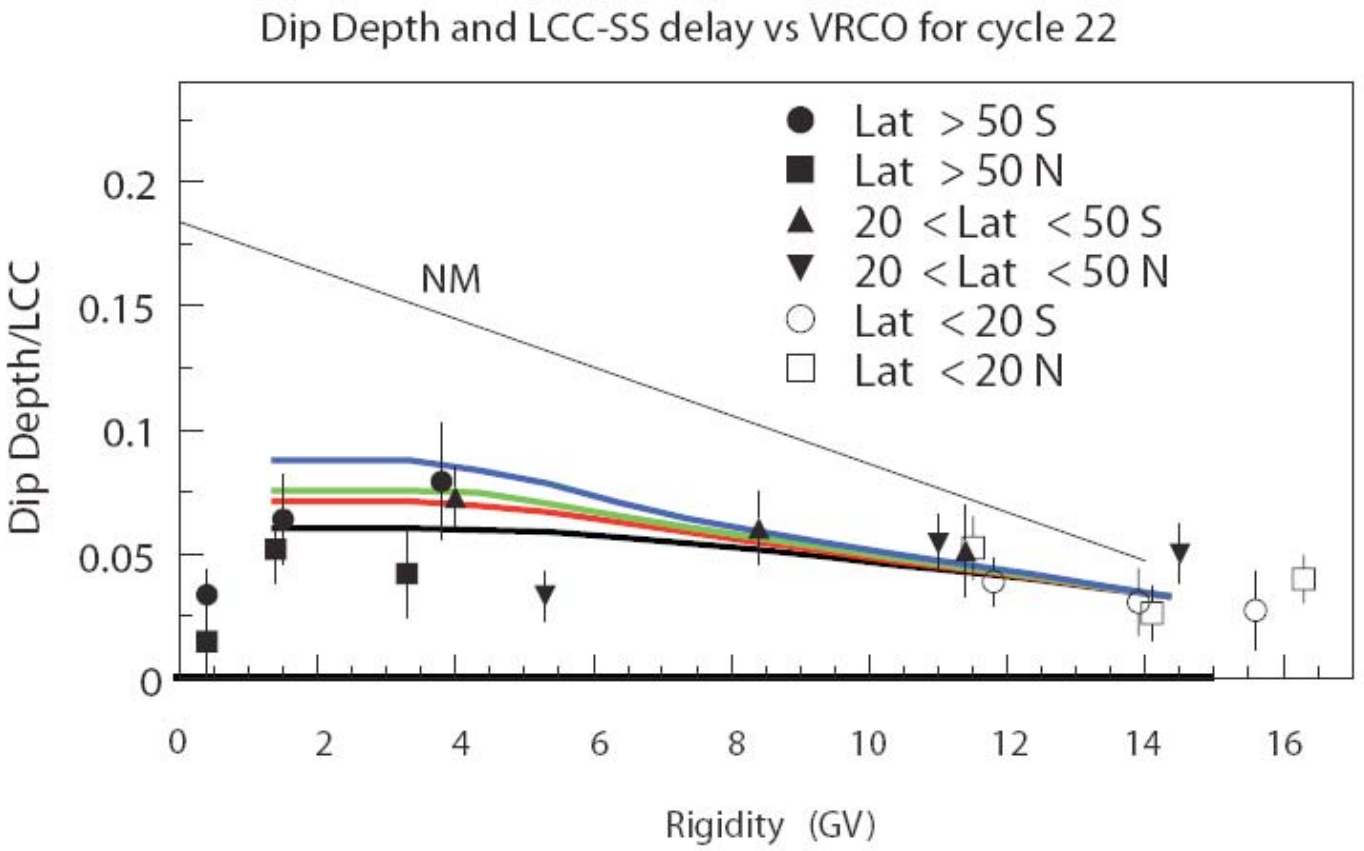
CLAIMS

1. No effect of Forbush decreases"lattitude" variation
2. Variations show no lattitude effect

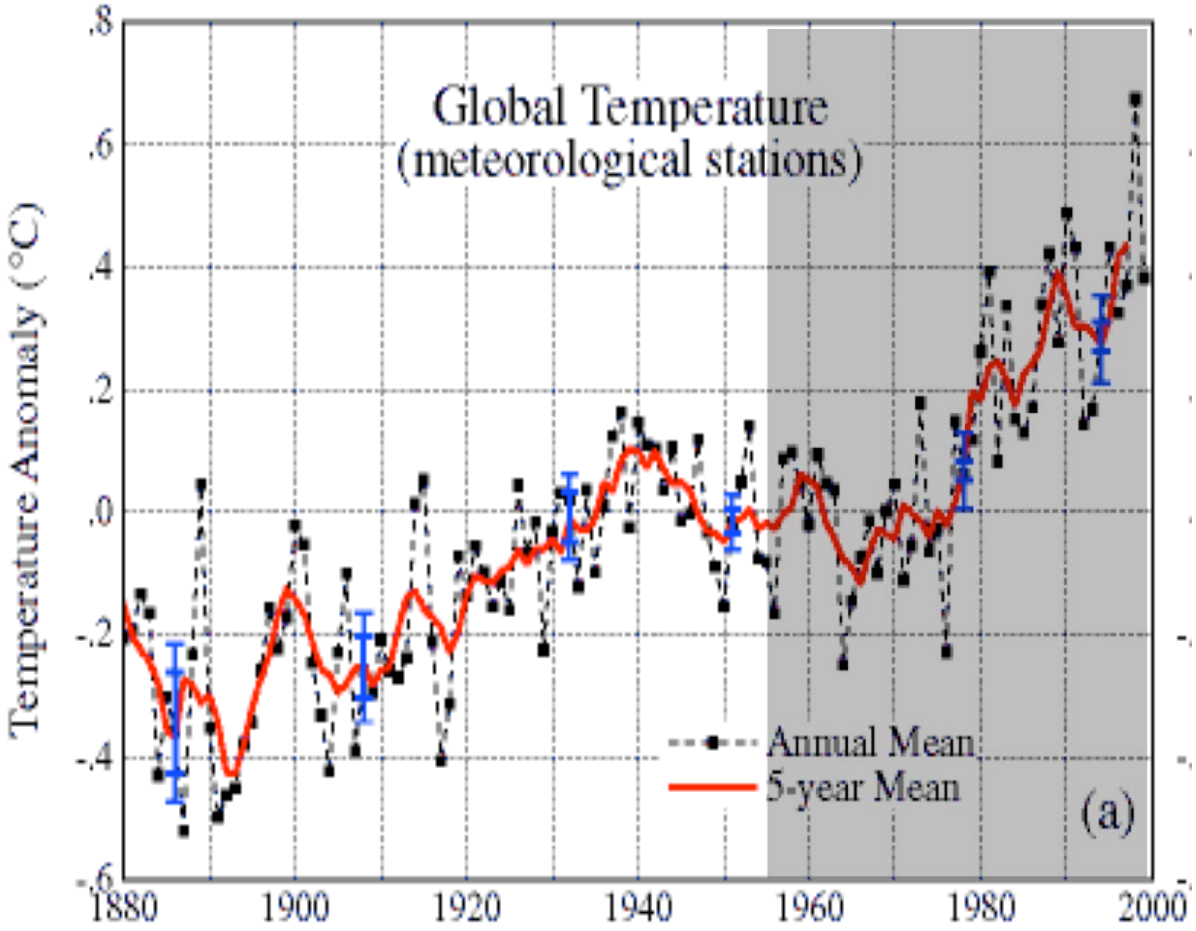
3. Wrong sign phaseshift for solar cycle and clouds

ANSWER

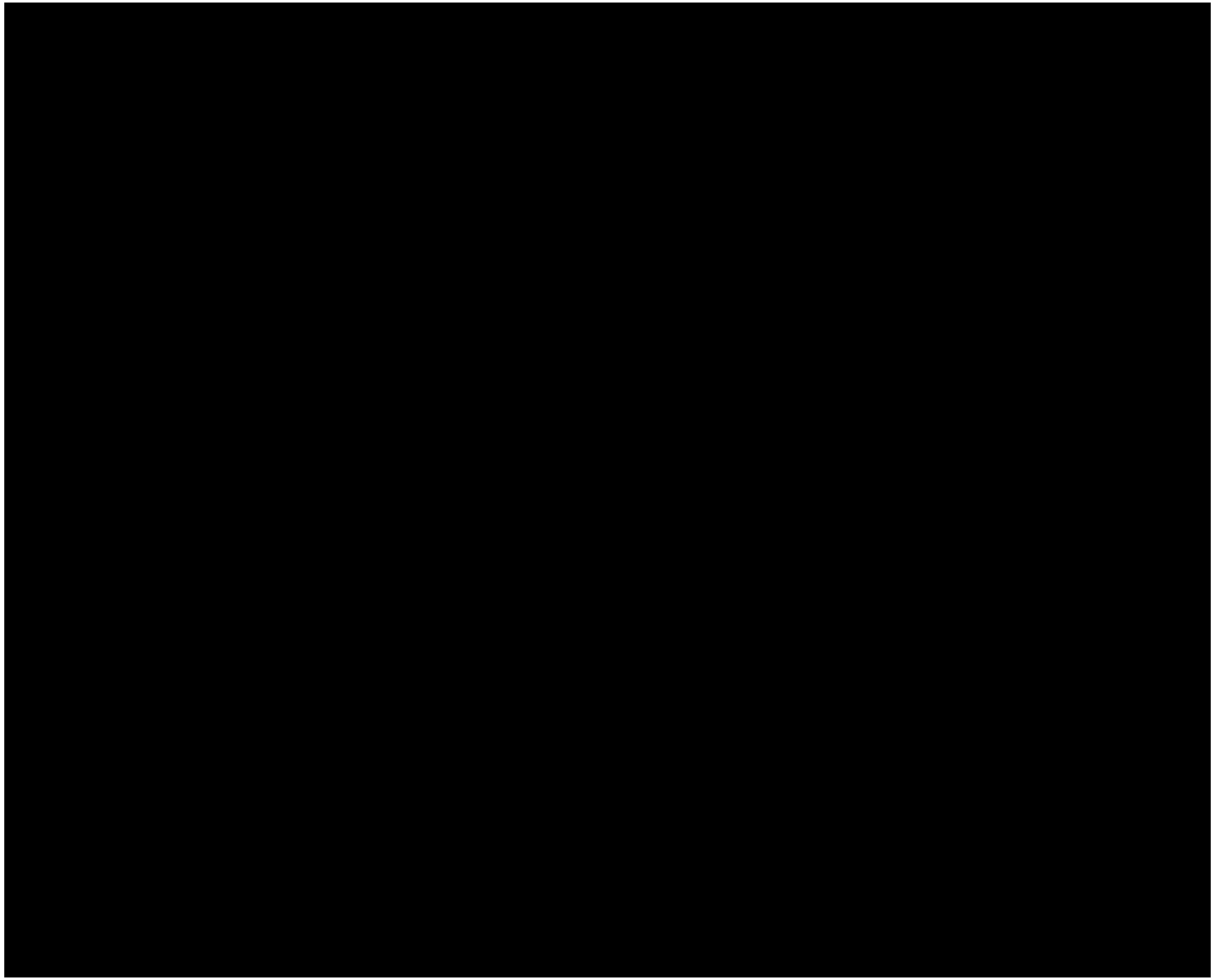
1:Wrong: A clear effect
2:Wrong: Effect in agreement with observations
3:Wrong: Effect as expected



Global surface temperature

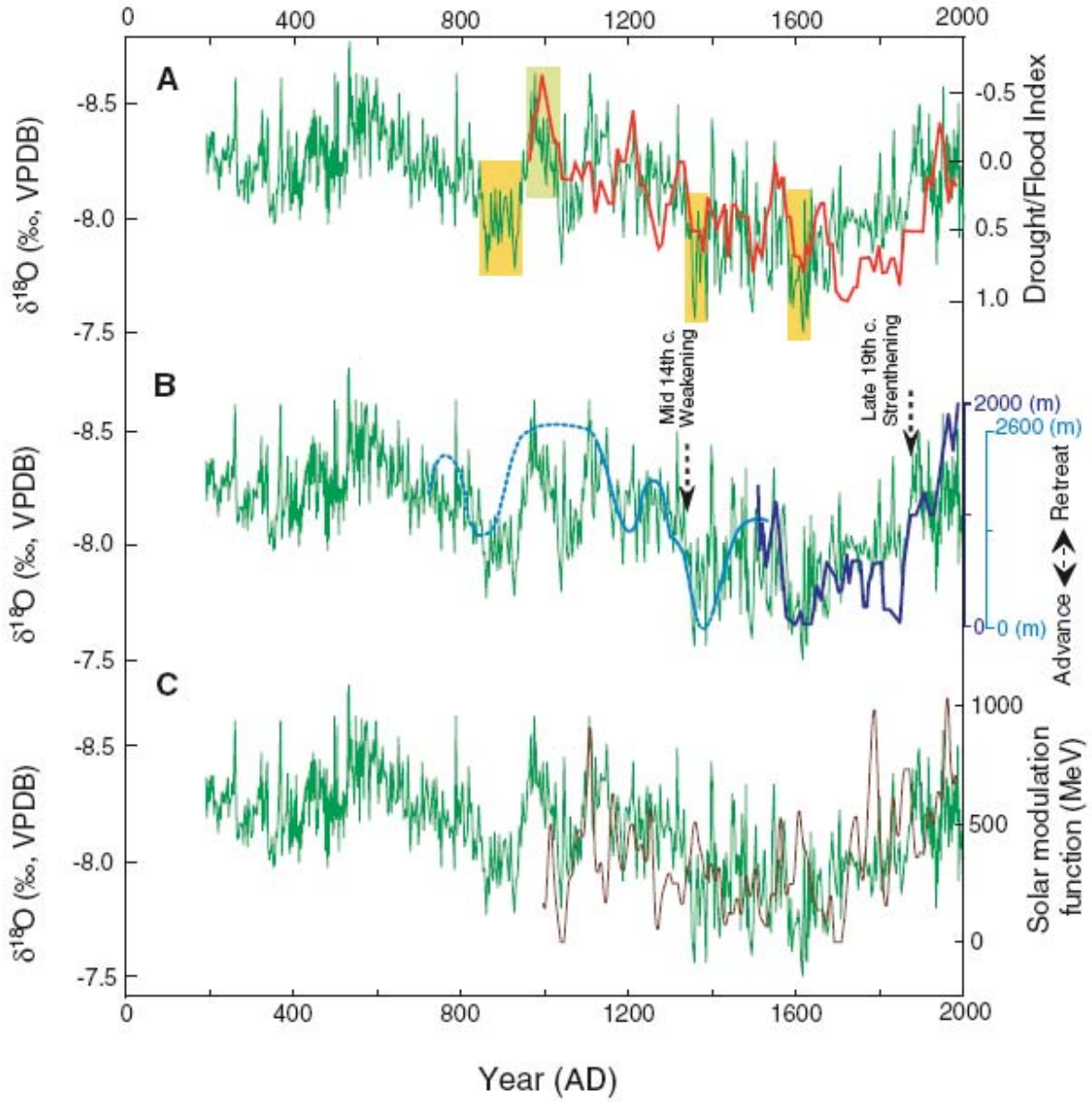


Change in Cosmic ray flux through 300 years



Clouds must respond to the changing COSMIC RAY FLUX

There is evidence from boreholes suggesting that clouds have been forcing the Earth over the last 6000 years.


A
B
C
δ18O (‰, VPDB)
Drought/Flood Index
Mid 14th c. Weakening
Late 19th c. Strenthening
2000 (m)
2600 (m)
0 (m)
Retreat
Advance
Solar modulation function (MeV)
Year (AD)

A Test of Climate, Sun, and Culture Relationships from an 1810-Year Chinese Cave Record

Pingzhong Zhang,[1] Hai Cheng,[2*] R. Lawrence Edwards,[2] Fahu Chen,[1] Yongjin Wang,[3] Xunlin Yang,[1] Jian Liu,[4] Ming Tan,[5] Xianfeng Wang,[2] Jinghua Liu,[1] Chunlei An,[1] Zhibo Dai,[1] Jing Zhou,[1] Dezhong Zhang,[1] Jihong Jia,[1] Liya Jin,[1] Kathleen R. Johnson[6]

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