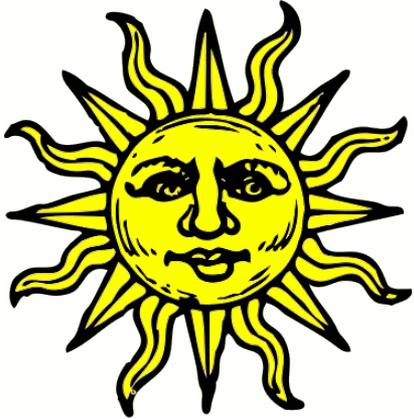


# **The sun, cosmic rays, clouds, and climate - the model perspective**

**Jan Kazil**

**CIRES**

**University of Colorado / NOAA Earth System Research Laboratory**



Solar radiative flux at distance to Earth: **1366 W/m<sup>2</sup>**

Global cloud fraction: ~ 0.72

Cloud albedo: 0.1-0.9

Ocean albedo: ~ 0.06

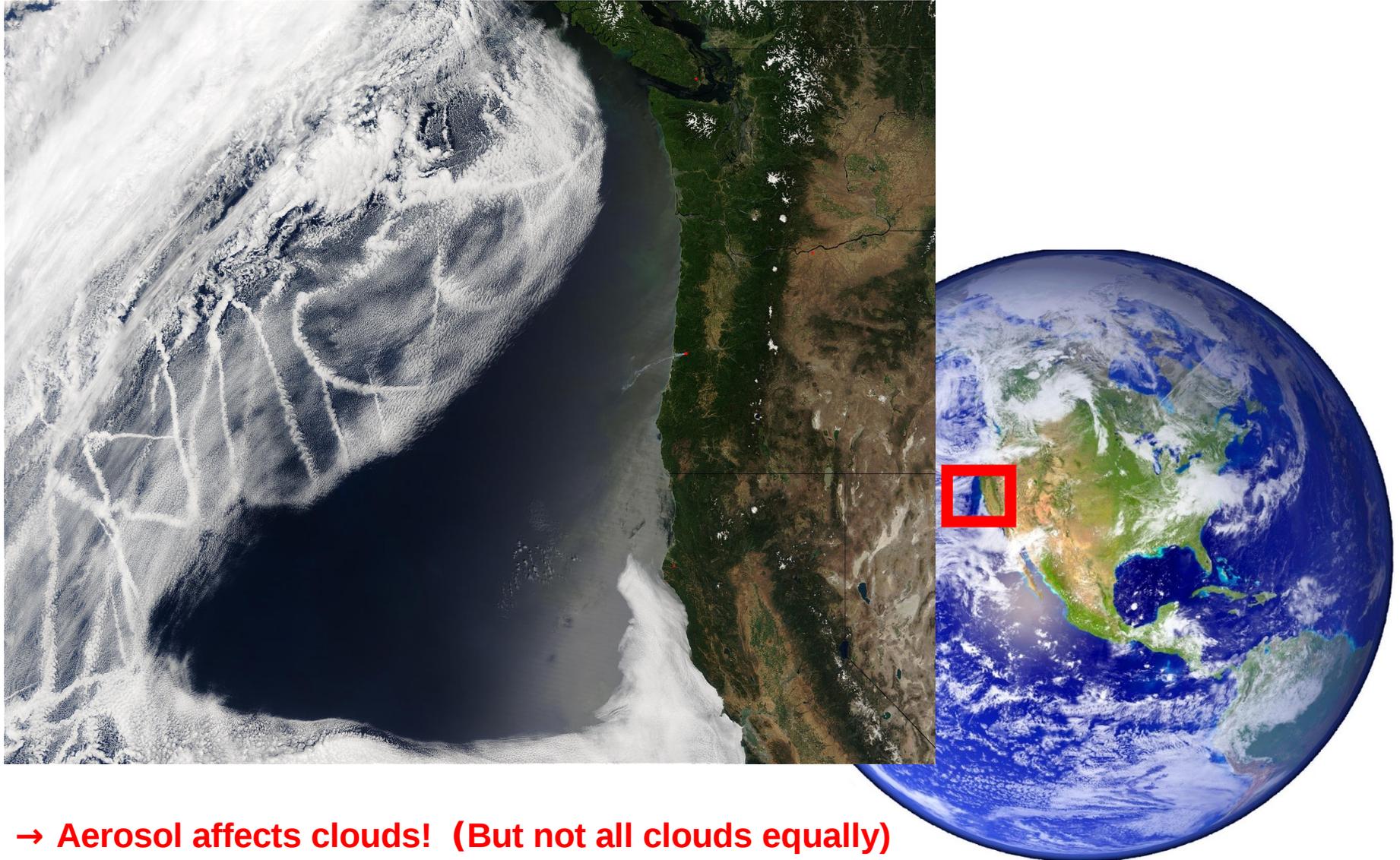
Land albedo: ~ 0.1 (forest)  
~ 0.4 (sand)  
~ 0.85 (snow)

Global albedo: **0.3**

(Earth absorbs 70 % of solar radiation)

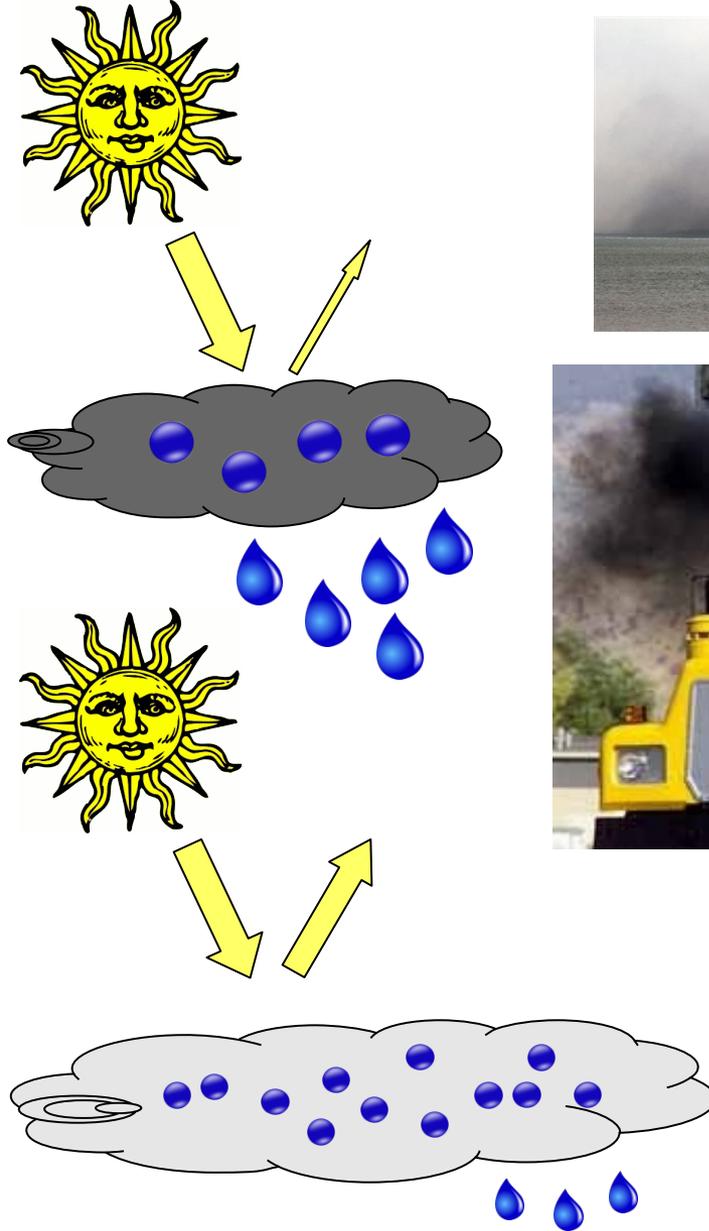
Total absorbed solar energy: **239 W/m<sup>2</sup>**

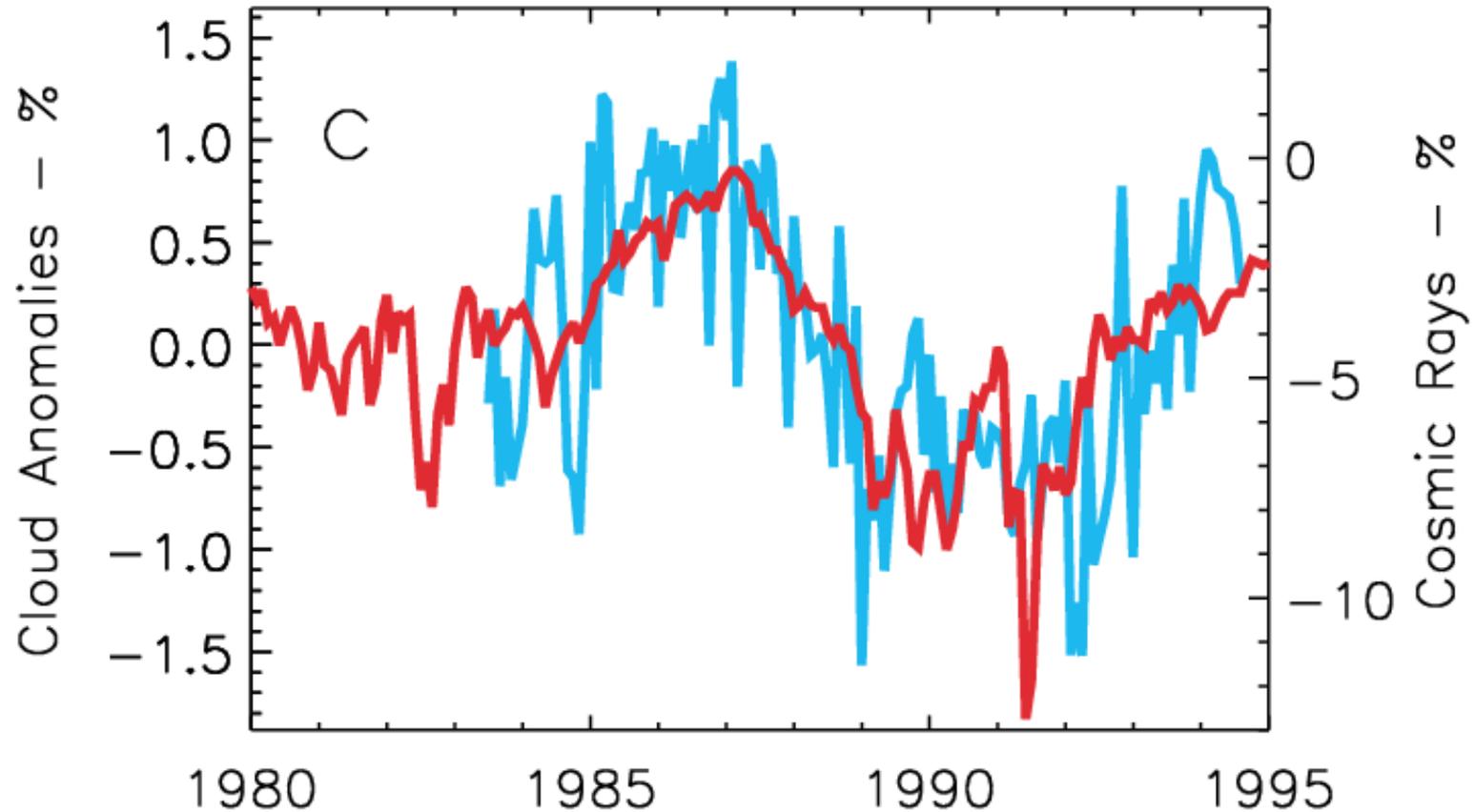




**→ Aerosol affects clouds! (But not all clouds equally)**

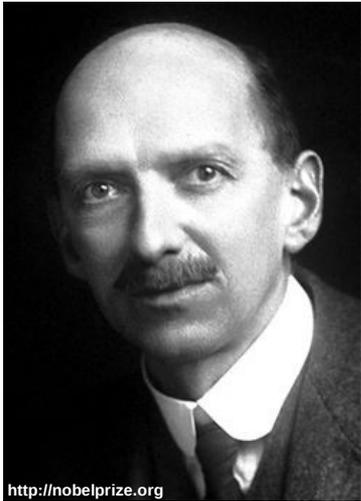
# Aerosol and clouds





Svensmark, H., and Friis-Christensen, E., JASTP, 1997  
Marsh, N. D., and Svensmark, H., PRL, 2000

1899 ...



**C. T. R. Wilson**

**When the gas was exposed to even weak Röntgen radiation, comparatively dense fogs were obtained ...**

**Thus, exposure to Röntgen rays causes nuclei to be produced ... water may condense upon them.**

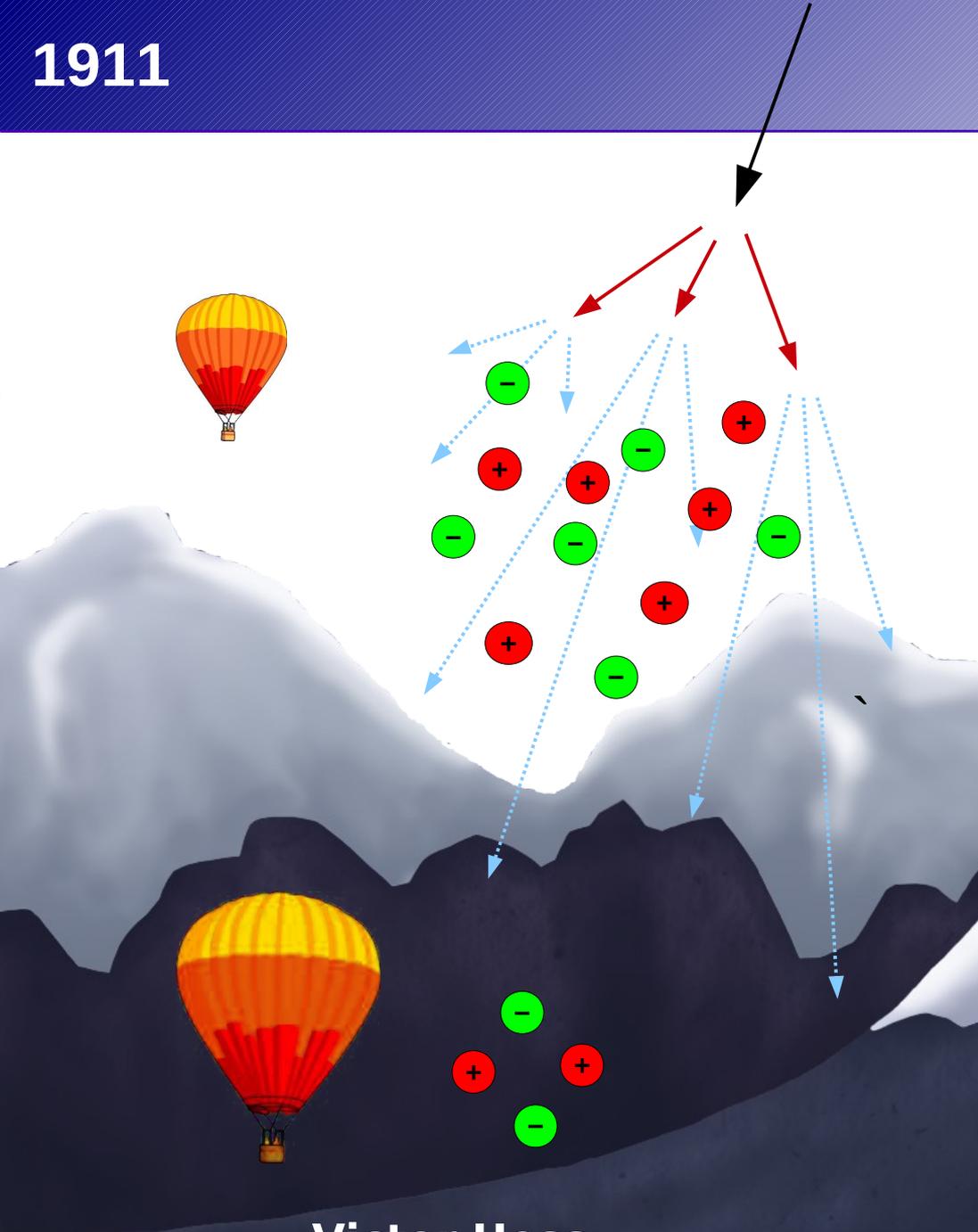
**These nuclei are to be identified with the “ions”...**

**→ Cloud chamber → Nobel Prize 1927**

Museum at the Cavendish Laboratory, Cambridge, UK



1911

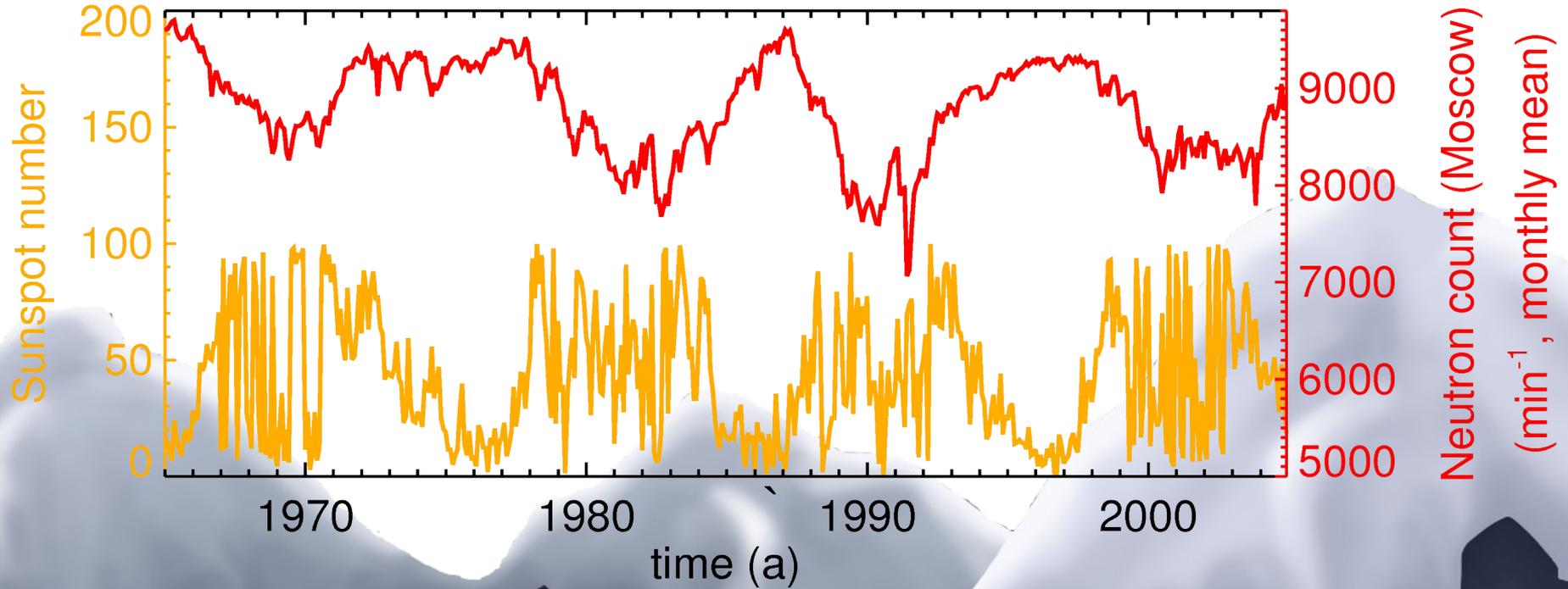


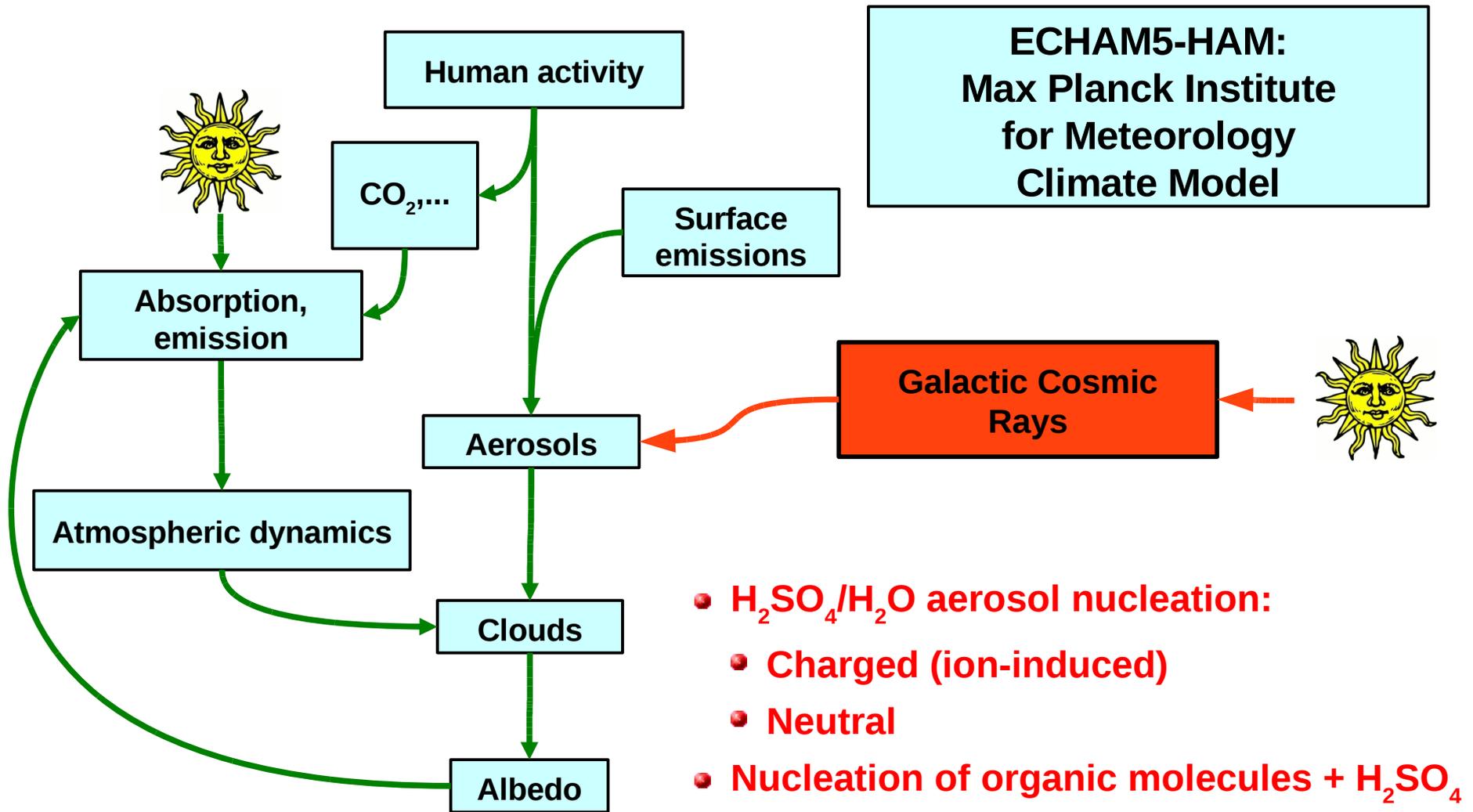
[http://faculty.washington.edu/wilkes/saltan\\_ess.gif](http://faculty.washington.edu/wilkes/saltan_ess.gif)

**Victor Hess**

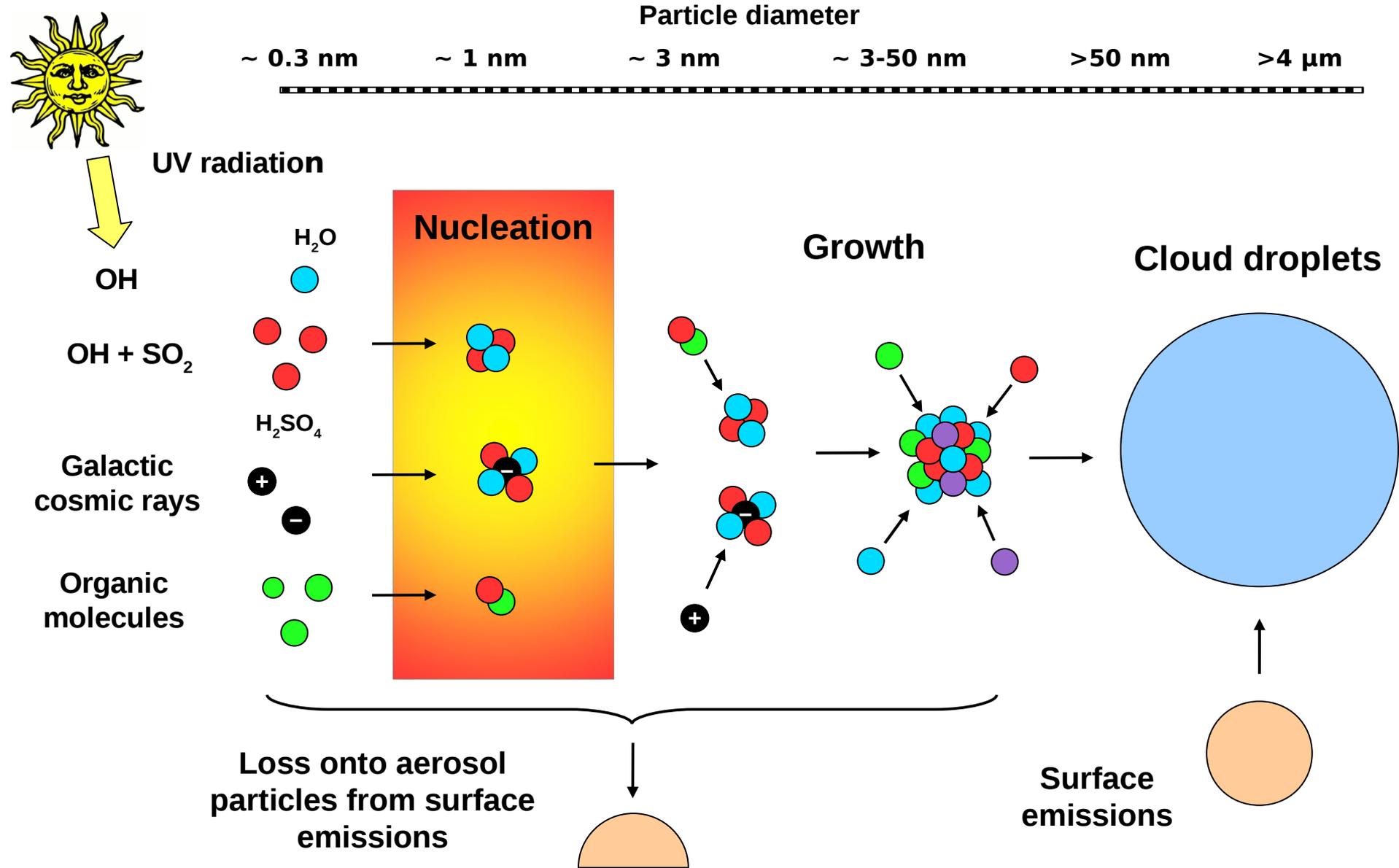
**→ Nobel Prize 1936**

# Solar cycle and galactic cosmic rays

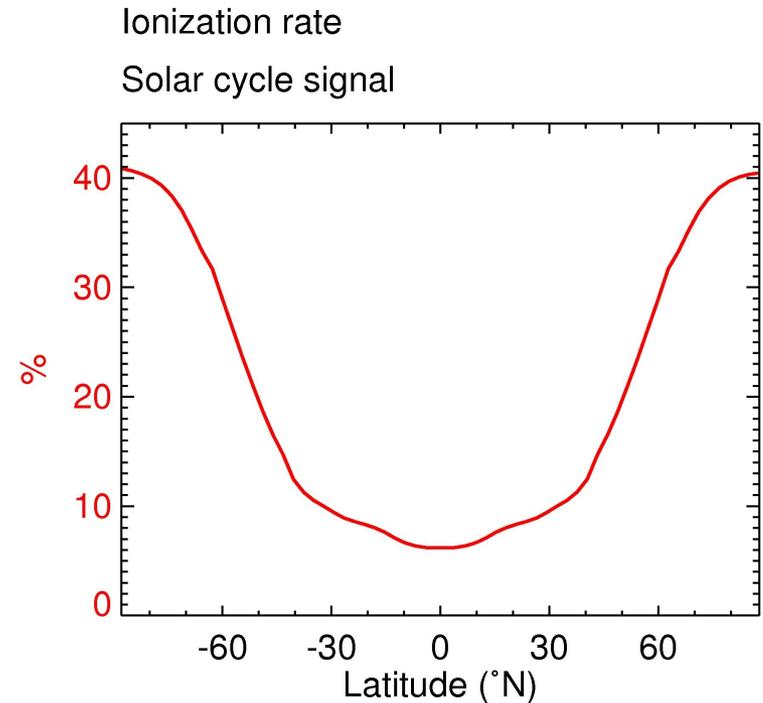
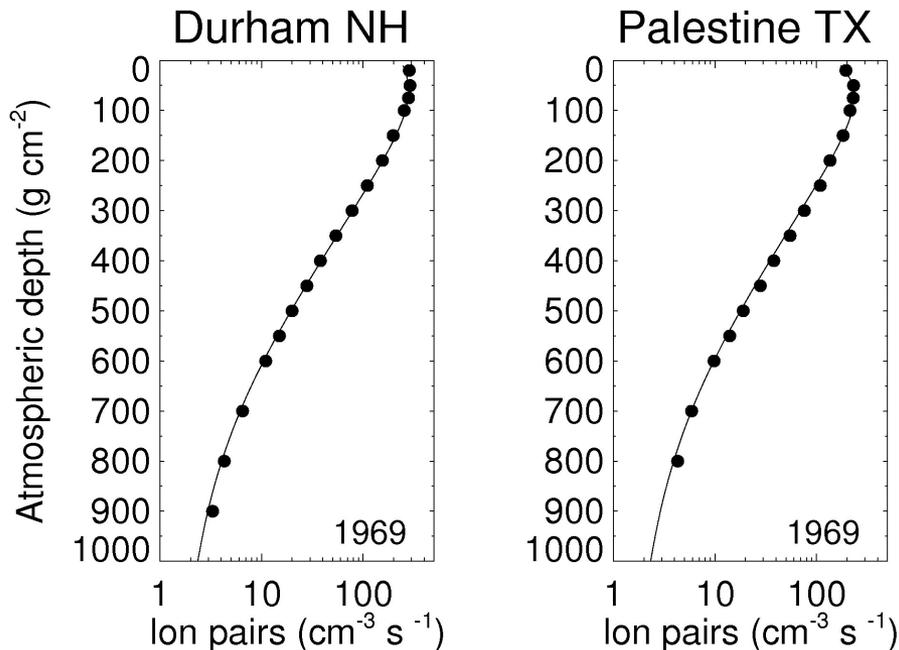




# Aerosol nucleation



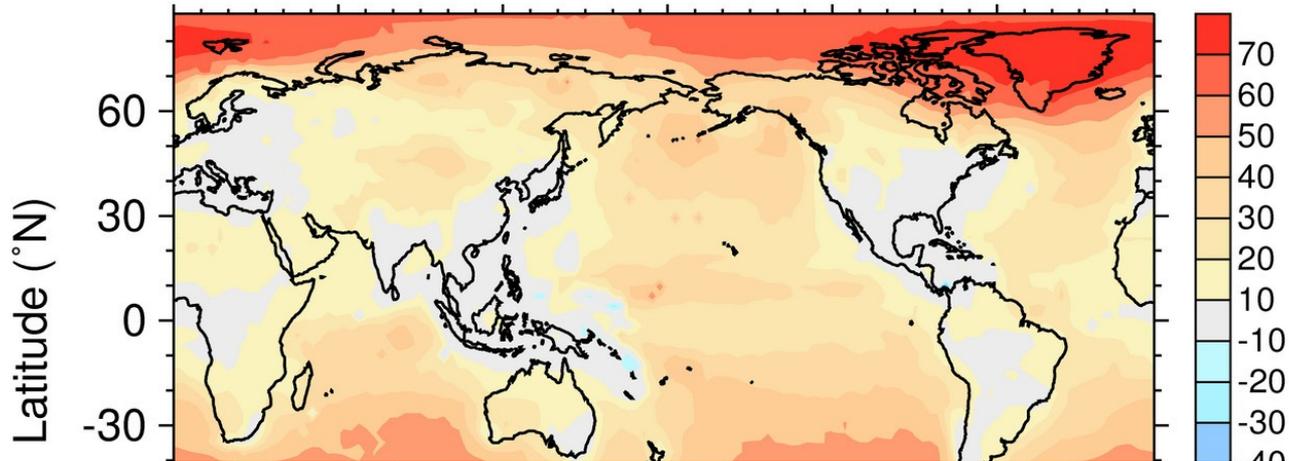
## Model of energetic particle transport in the heliosphere (K. O'Brian, NAU):



## Galactic cosmic rays → Earth's radiative forcing?

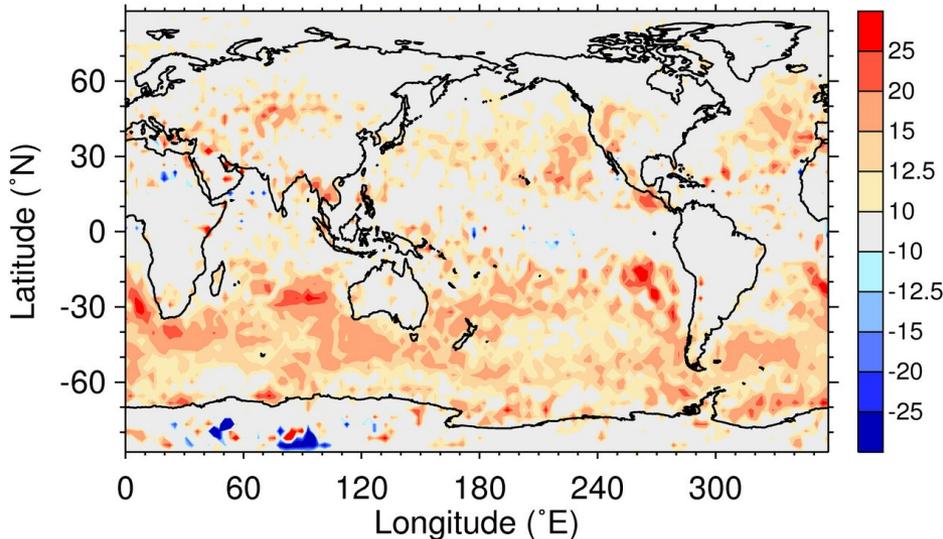
- Simulations:
  - ◆ GCR ionization **ON**
  - ◆ GCR ionization **OFF**
  
- Calculate the difference in:
  - ◆ Aerosol concentration
  - ◆ Cloud drop number
  - ◆ Absorbed radiation
  
- **This is the contribution of GCR**

Aerosol larger than 3 nm in diameter (boundary layer)  
(contribution of GCR ionization in %)



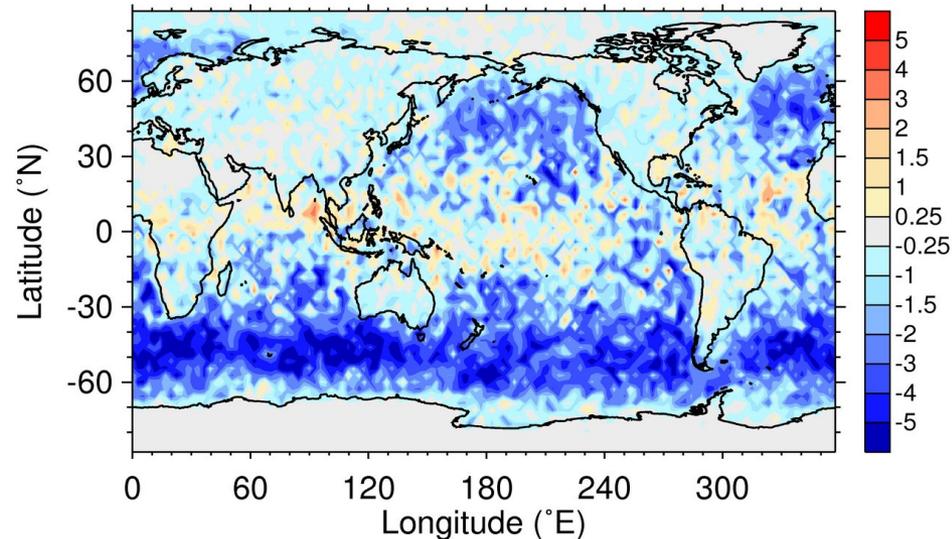
Cloud droplet burden

(contribution of GCR ionization in %)

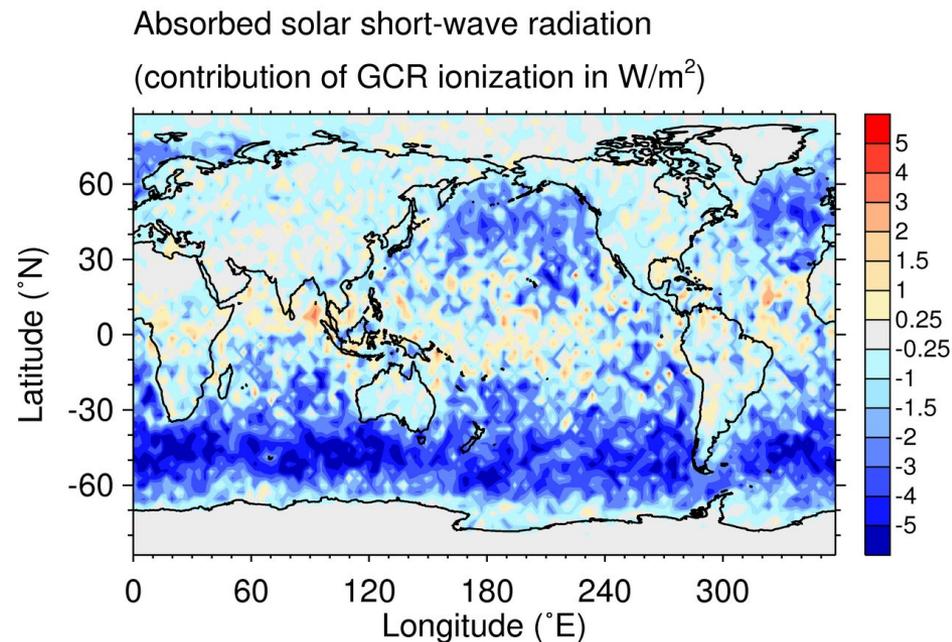


Absorbed solar short-wave radiation

(contribution of GCR ionization in  $W/m^2$ )



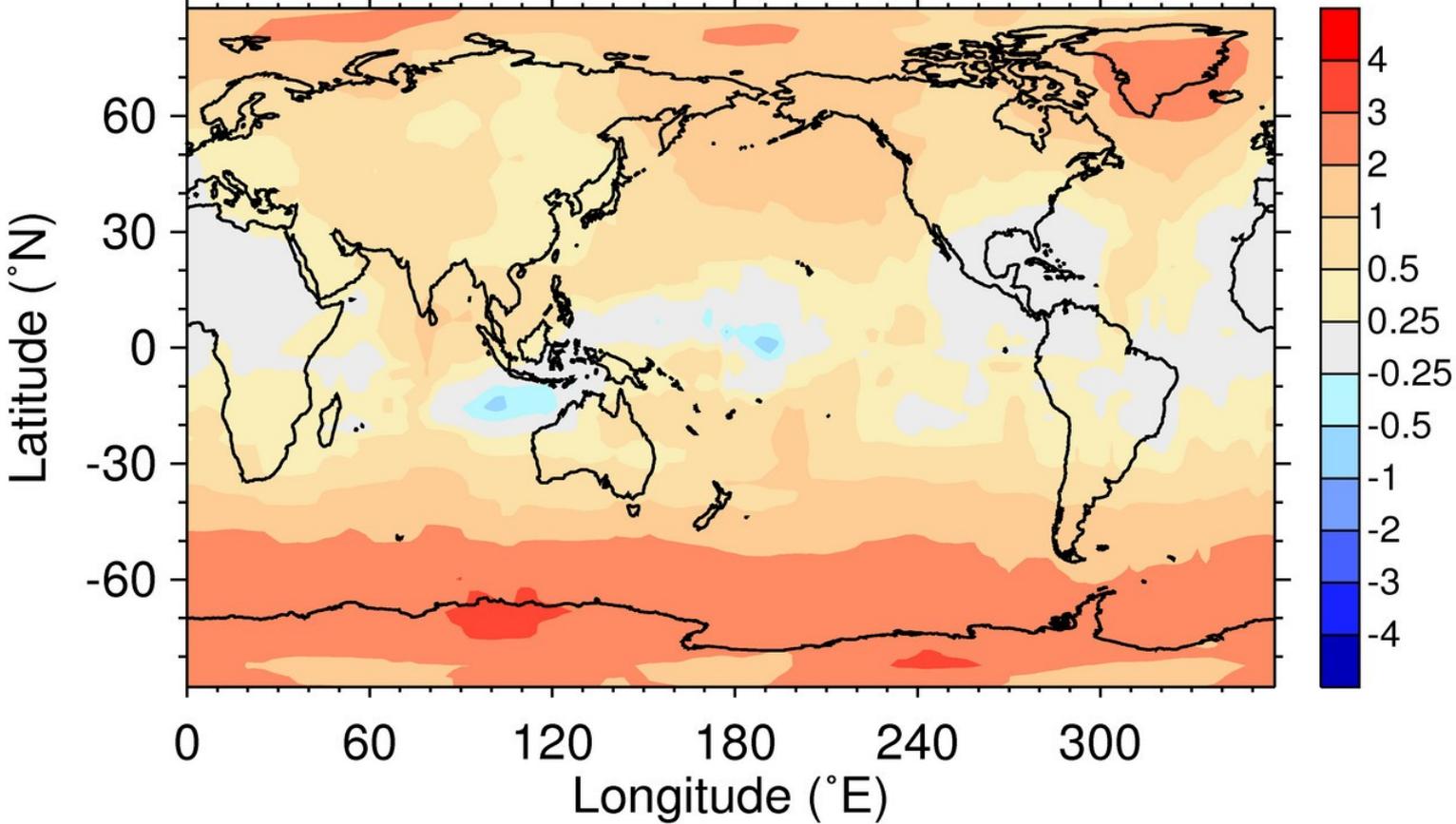
**Global average:  $-1.15 \text{ W/m}^2$**   
**(This has nothing to do with global warming!)**



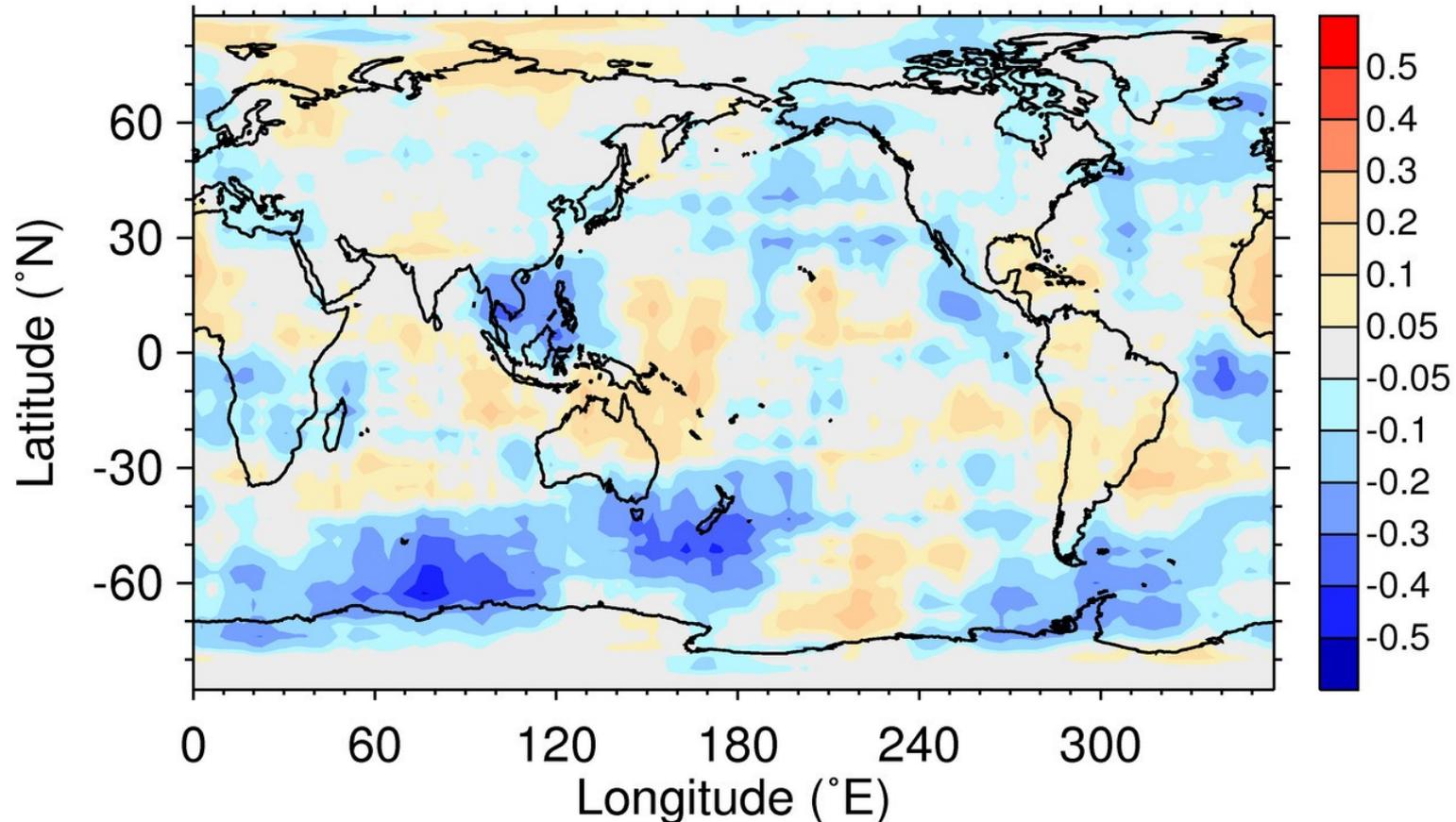
## 11-year solar cycle (decadal solar variability)

- Simulations:
  - ◆ Solar maximum (**low** GCR ionization)
  - ◆ Solar minimum (**high** GCR ionization)
  
- Calculate the difference in:
  - ◆ Ionization rate
  - ◆ Aerosol concentration
  - ◆ Cloud drop number
  - ◆ Absorbed radiation
  
- Look for solar cycle signal

Aerosol larger than 3 nm in diameter (boundary layer)  
(change from solar maximum to minimum in %)

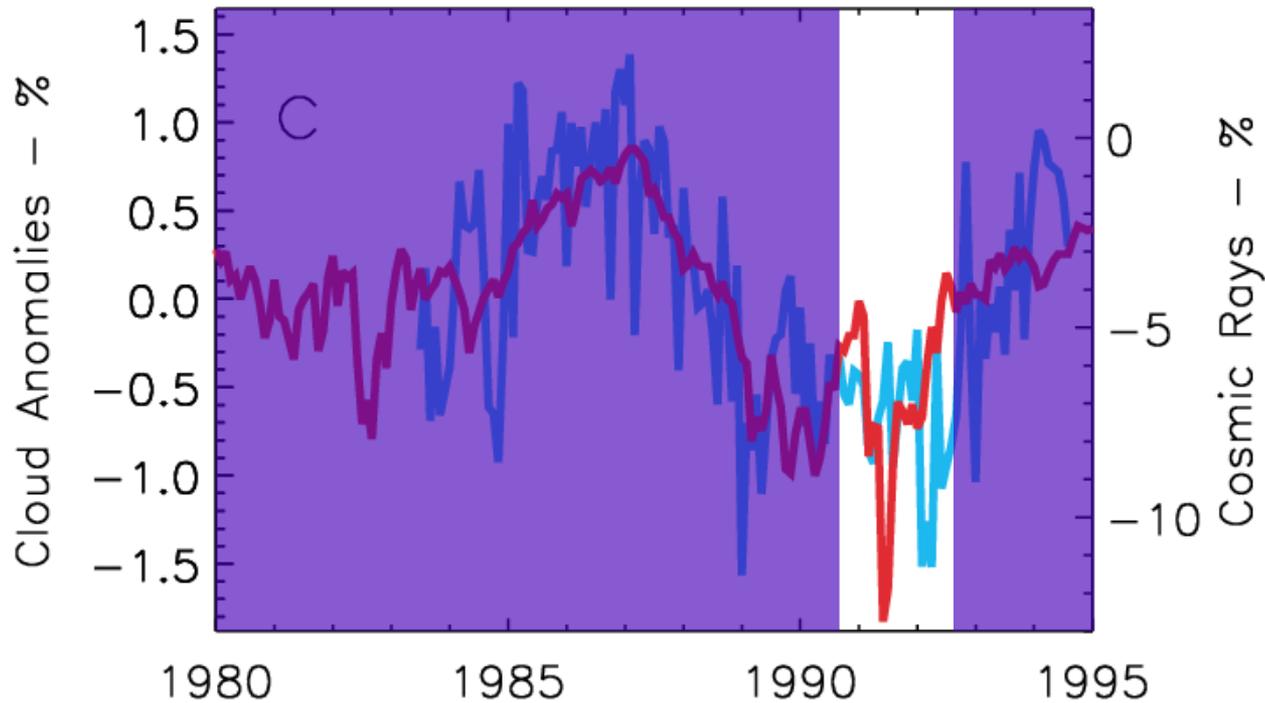


Absorbed solar short-wave radiation  
(change from solar maximum to minimum in  $\text{W/m}^2$ )



**Global average: -0.028  $\text{W/m}^2$       Very small!**

- **Galactic cosmic rays have a cooling impact:**
  - **Reduce Earth's radiative forcing by about – 1.15 W/m<sup>2</sup>**
- **This effect arises via ...**
  - **the growth of ions to aerosol particles**
  - **and a subsequent response of clouds**
- **This has nothing to do with global warming**
- **Solar cycle modulation very weak**
- **Is that it ???**

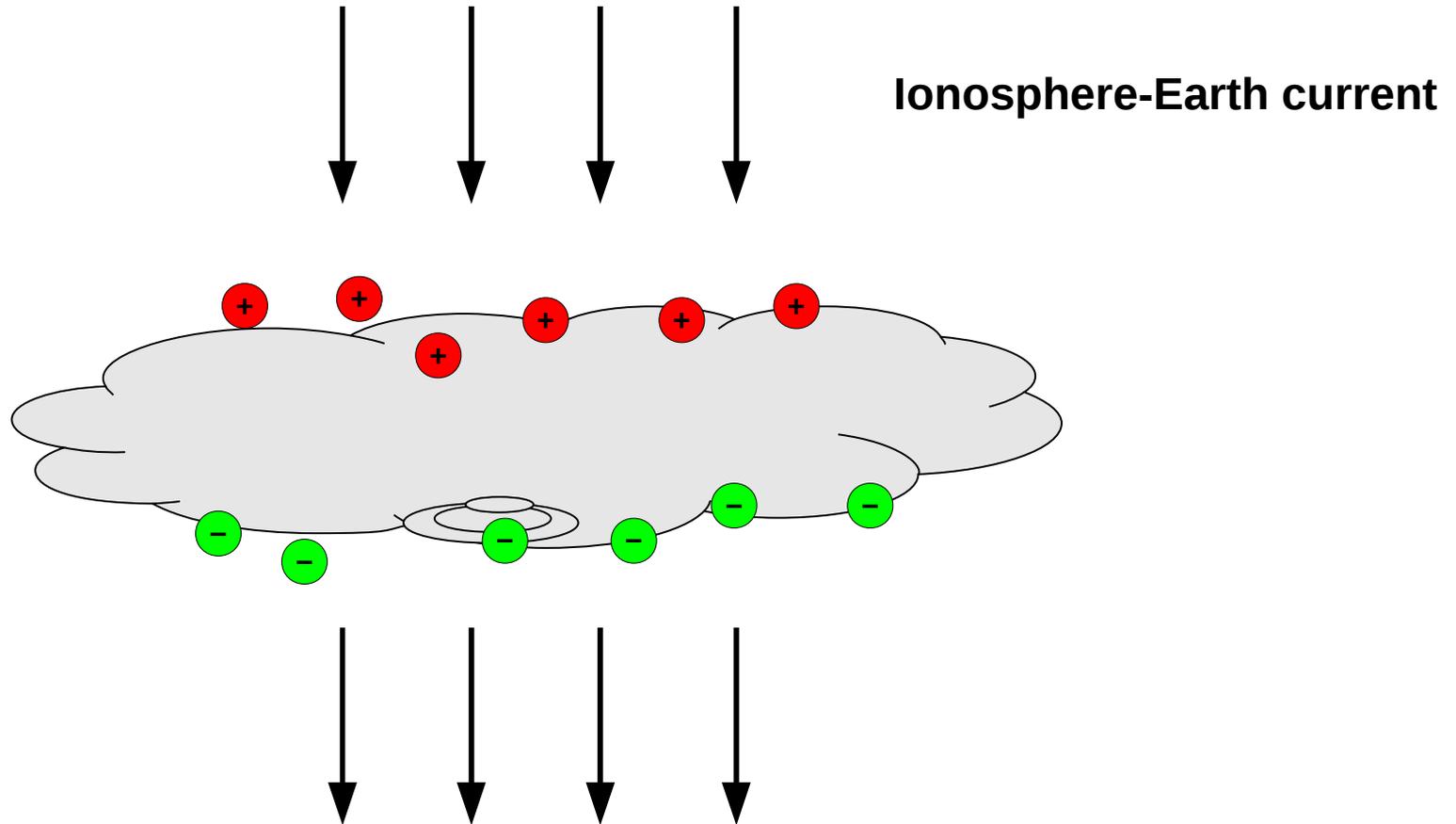


Can we expect a signal in the model due to Forbush decreases?

**Sudden cosmic ray decreases: No change of global cloud cover**  
(Calogovic, J., et al., GRL, 2010)

**What about the doubling of the Sun's magnetic field in the past 100 years?**  
(Lockwood, M., et al., Nature 1999 )

## GCR, atmospheric electricity, and clouds



→ Brian Tinsley, UT Dallas

- **High Altitude Observatory**
- **NCAR Advanced Study Program**
  
- **Edward R. Lovejoy (NOAA)**
- **Keran O'Brian (NAU)**
- **Johann Feichter (MPI for Meteorology)**
- **Ulrike Lohmann (ETH Zürich)**
- **Philip Stier (Oxford University)**
- **Graham Feingold (NOAA)**