A critical look at cosmic ray-cloud relationships

Jaša Čalogović

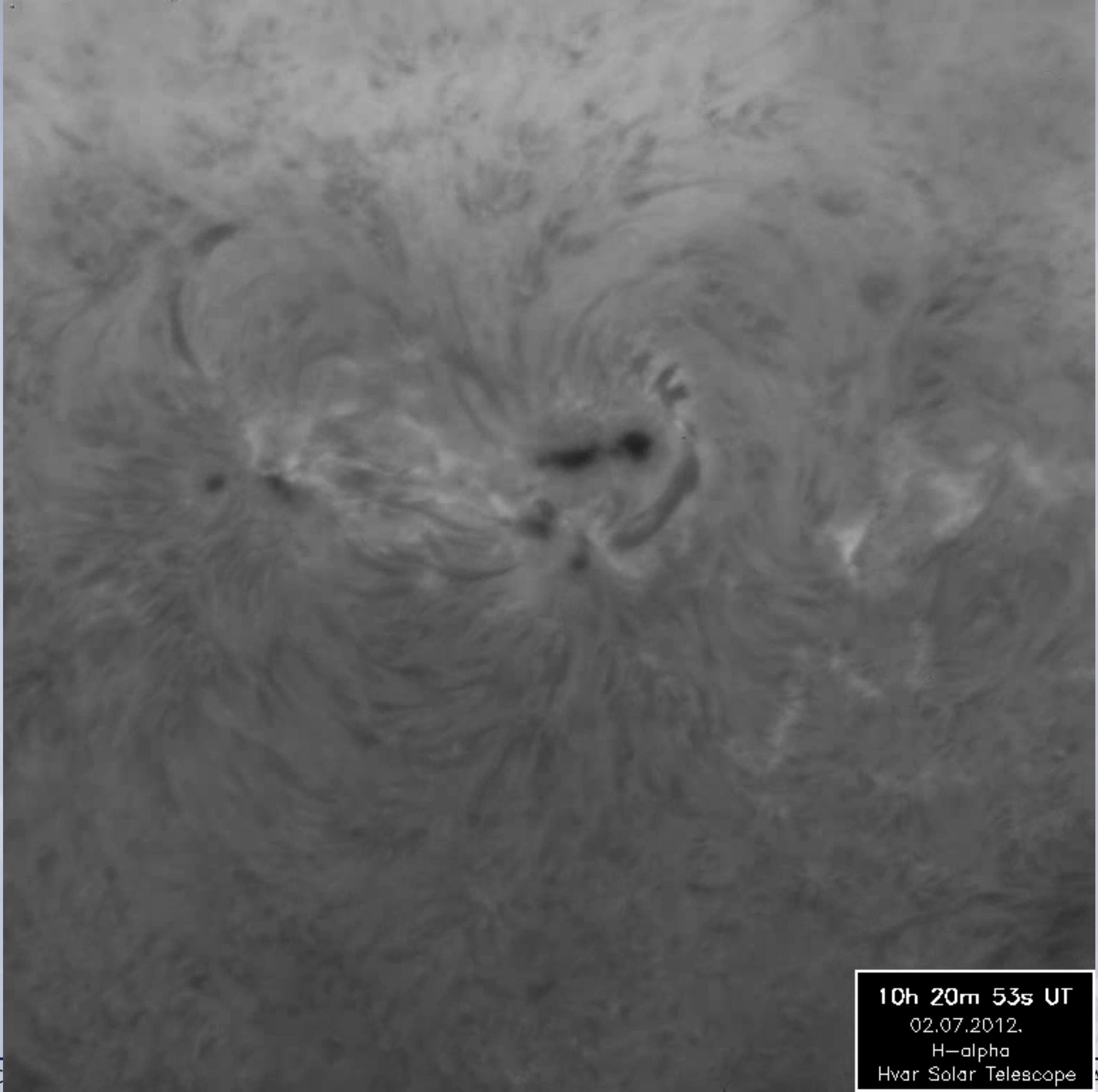
Hvar Observatory
Faculty of Geodesy
Zagreb, Croatia

Hvar Observatory

Photosphere and Chromosphere observations

- Group for Solar Physics (6 people):
  - space weather, eruptive processes
  - activity cycle, diff. rotation, convection
  - solar activity & climate

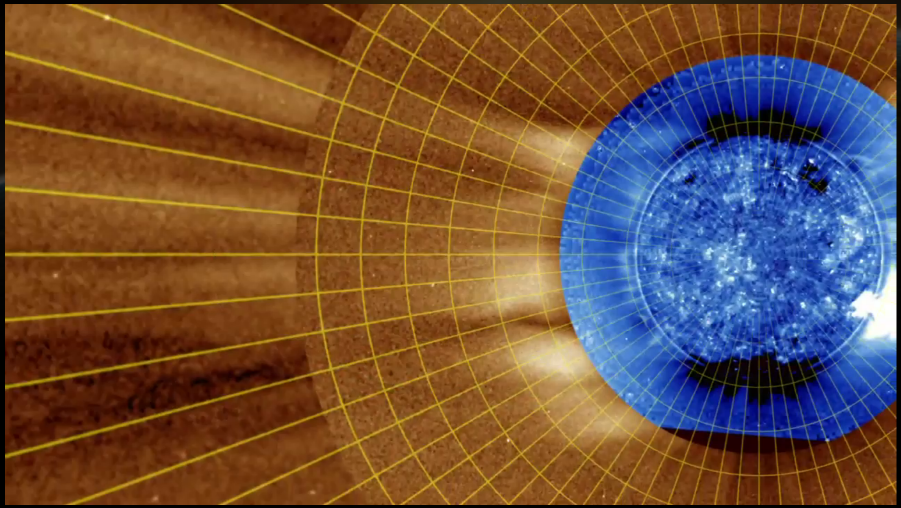
- Group for Stellar Physics (3 people):

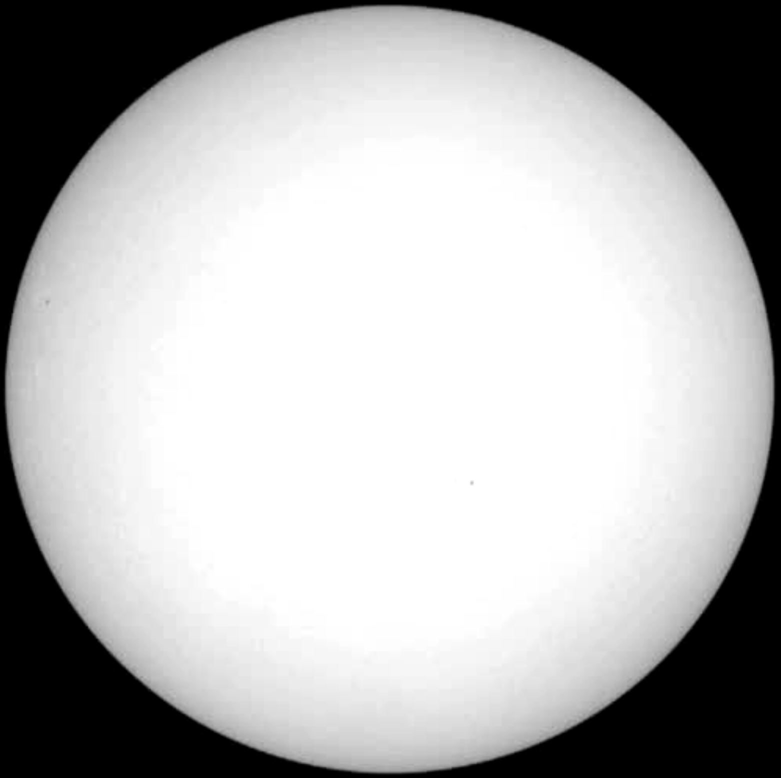

10h 20m 53s UT
02.07.2012.
H–alpha
Hvar Solar Telescope

Influence of solar variability on the Earth's climate requires knowledge of

1. Short- and long-term solar variability
2. Solar-terrestrial interactions
3. Mechanisms determining the response of the Earth's climate system to these interactions

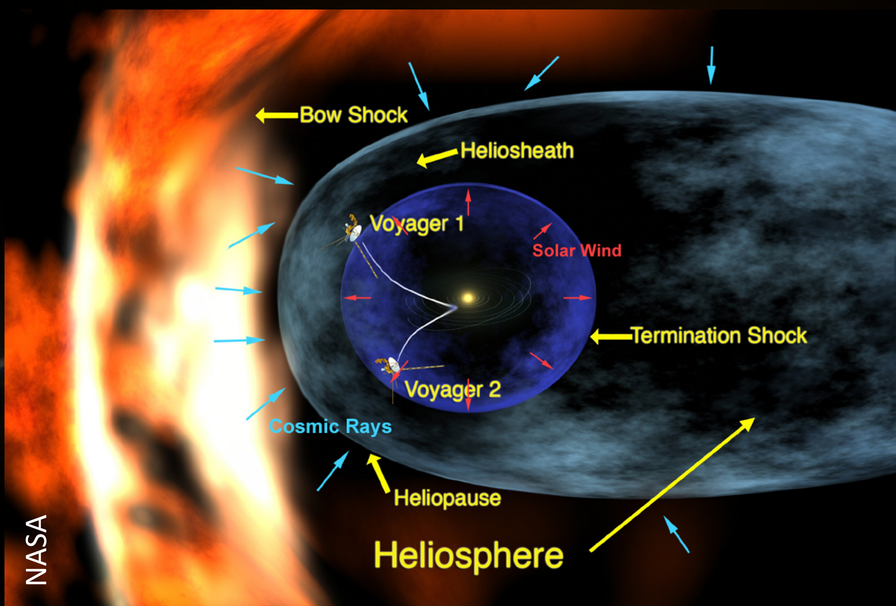
Rind, 2002

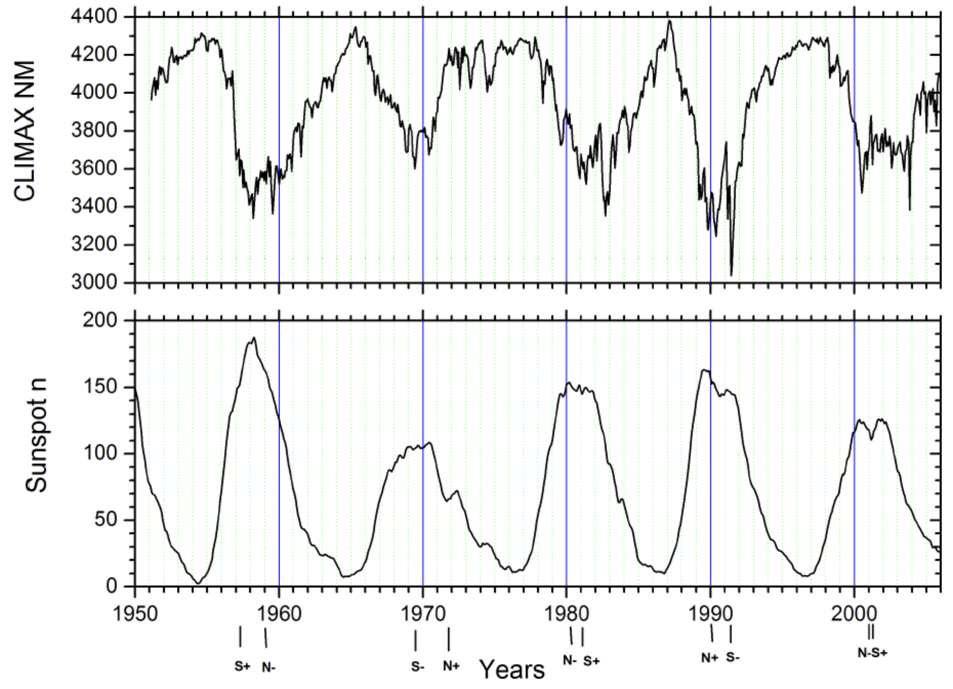




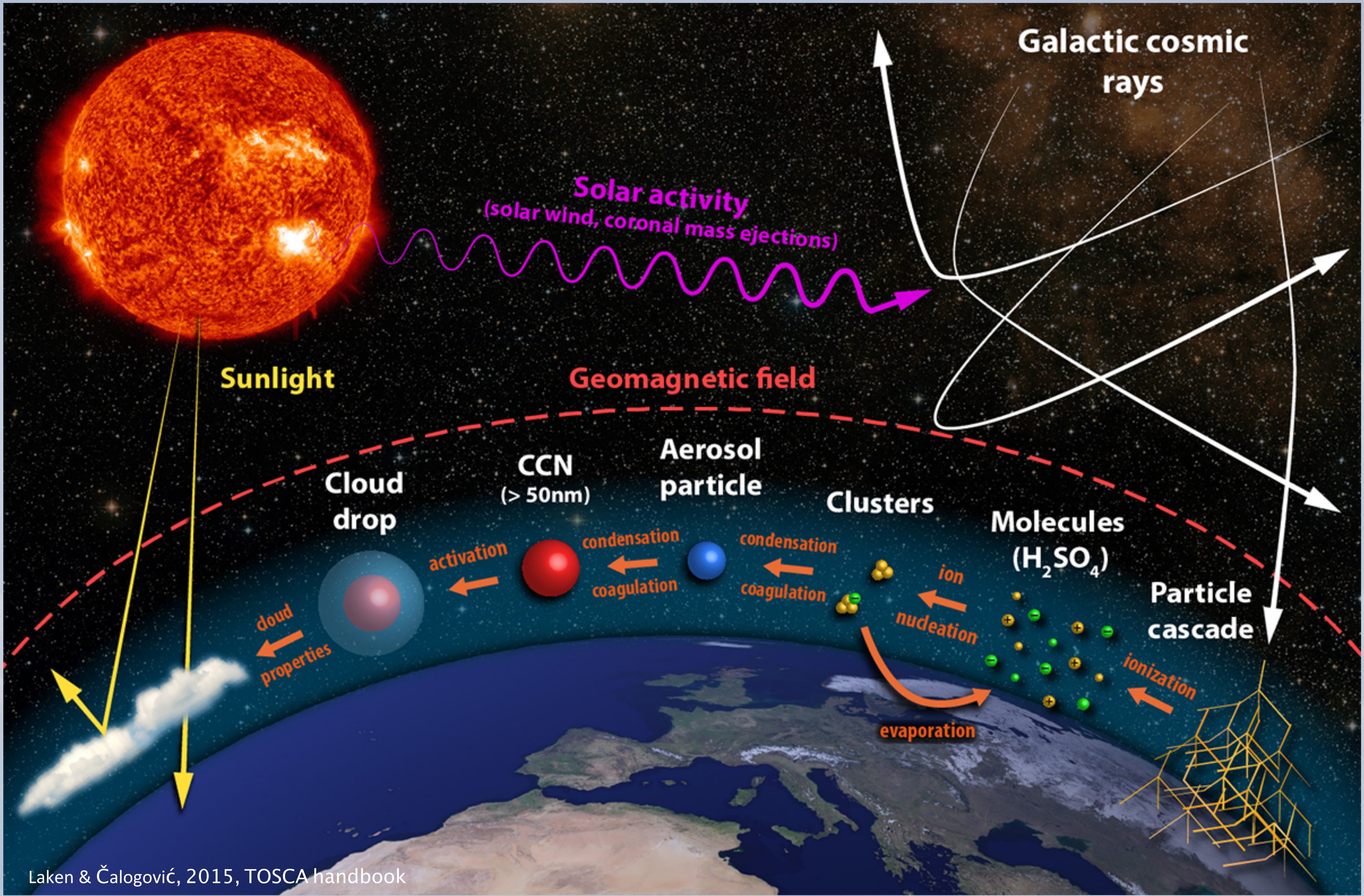
Solar activity modulates cosmic rays

- Cosmic rays (CR) consist of high-energy particles (mainly protons)
- CR flux of low energy particles is greater than flux of high energy particles ($E^{-\gamma}$)
- Particles with less energy are more influenced by the Sun





"Clear-air" mechanism



Laken & Čalogović, 2015, TOSCA handbook

The hypothesized link between cosmic ray flux and cloud cover

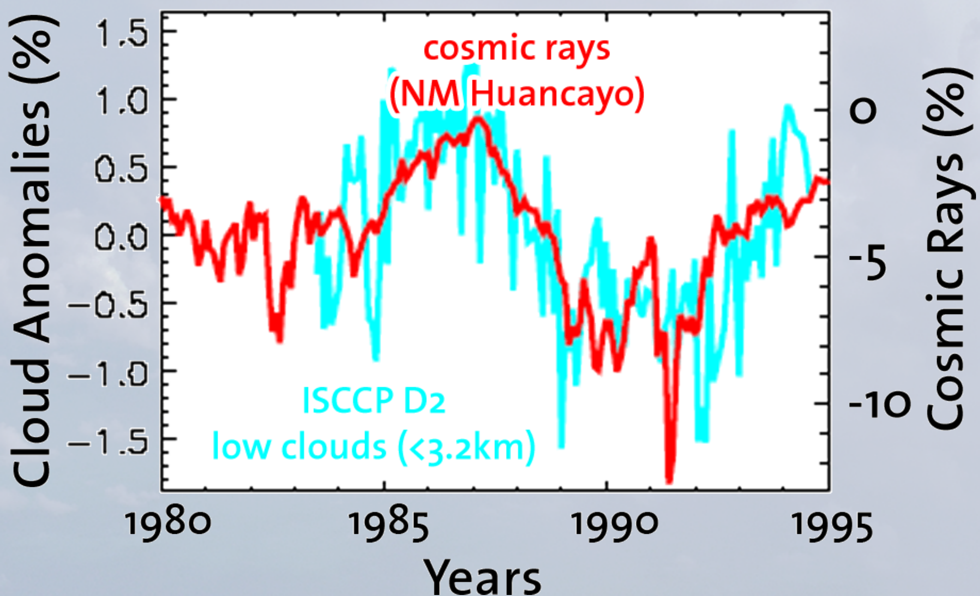
Long-term studies

Svensmark and Friis-Chistensen (1997)

- analyzed one solar cycle and reported that global cloud cover changed in phase with the GCR flux by 2-3% → radiative forcing (0.8 – 1.7 W/m^2) is comparable with greenhouse gases forcing

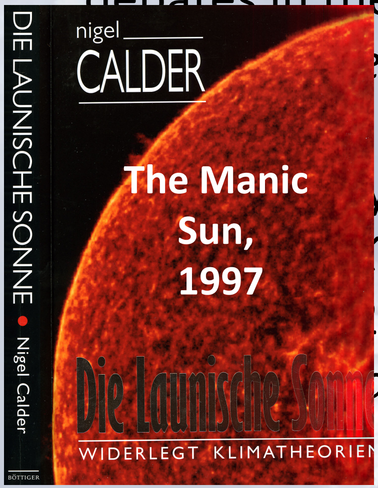
Marsh and Svensmark, 2000

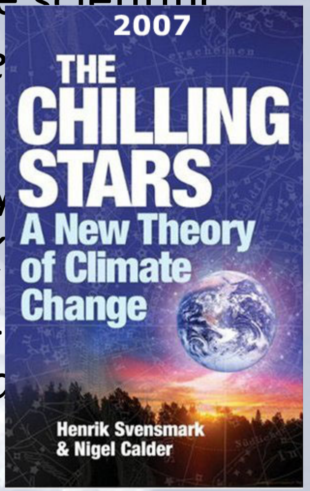
low clouds (0-3.2km)



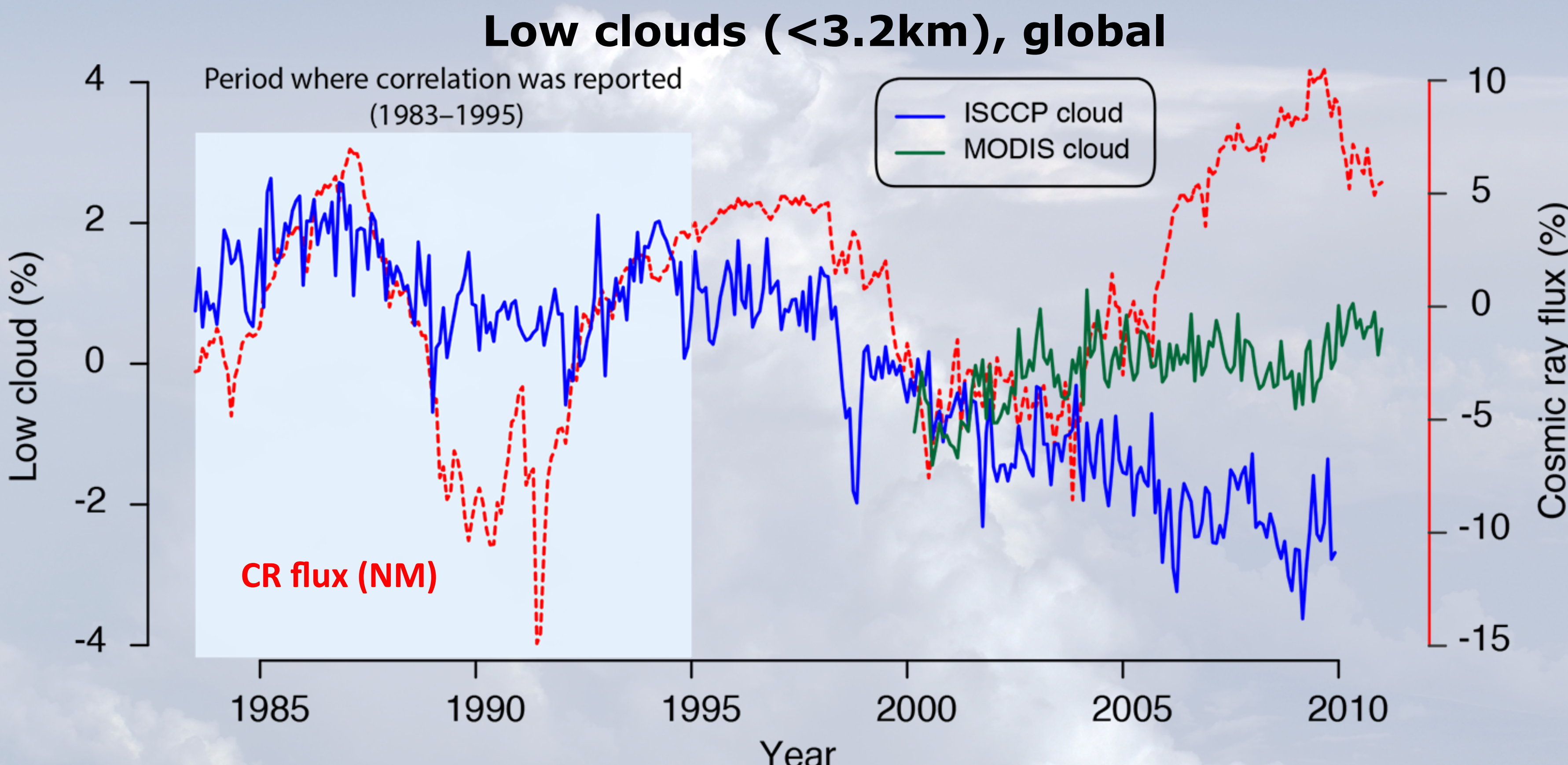
Climate sceptics still use these (incorrect) arguments

Many critics for a found correlation and heavy debates in the scientific





Long-term cloud data doesn't support GCR-cloud link



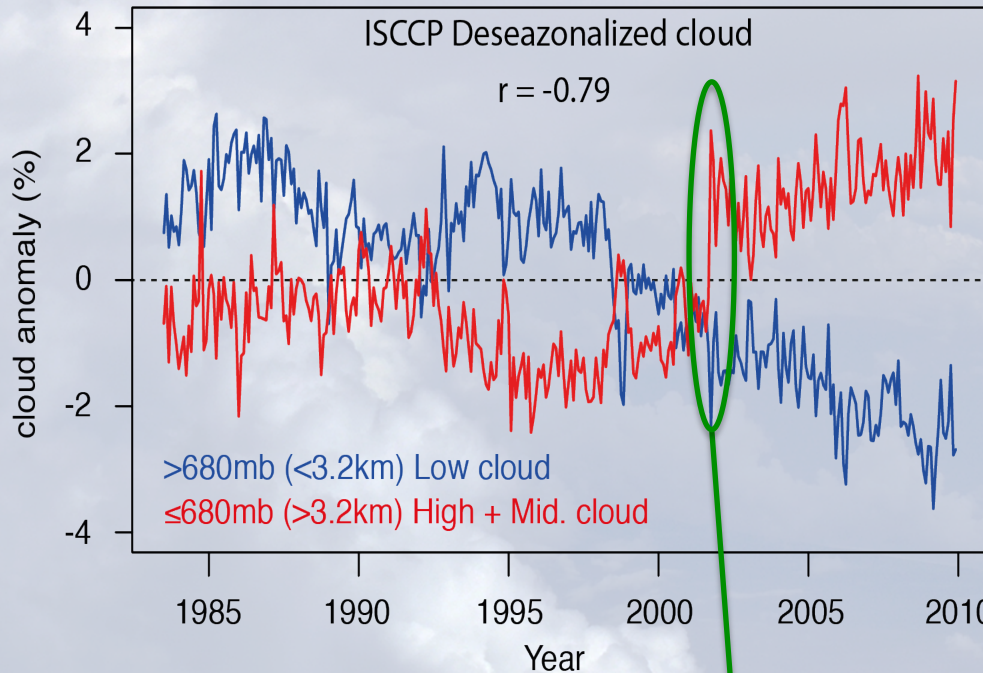
- Correlation only in low (<3.2km) ISCCP cloud (1983–1995)
- High correlation from 12-month smoothed data (df=4)
- Low (non-significant) correlation from unsmoothed data

Laken, Pallé, Čalogović & Dunne, 2012, SWSC

Artificial correlation b/w low and high cloud

- Measurements are non-cloud penetrating
- Changing number of geostationary → artificial drop in low cloud
- Satellite cloud issues well known (e.g. Hughes, 1984; Minnis, 1989, Tian & Curry, 1989; Rozendall et al. 1995; Loeb & Davies, 1996; Salby & Callaghan, 1997, Campbell, 2004)

Evidence for CR – cloud link is based on low level clouds:
these data are not reliable!

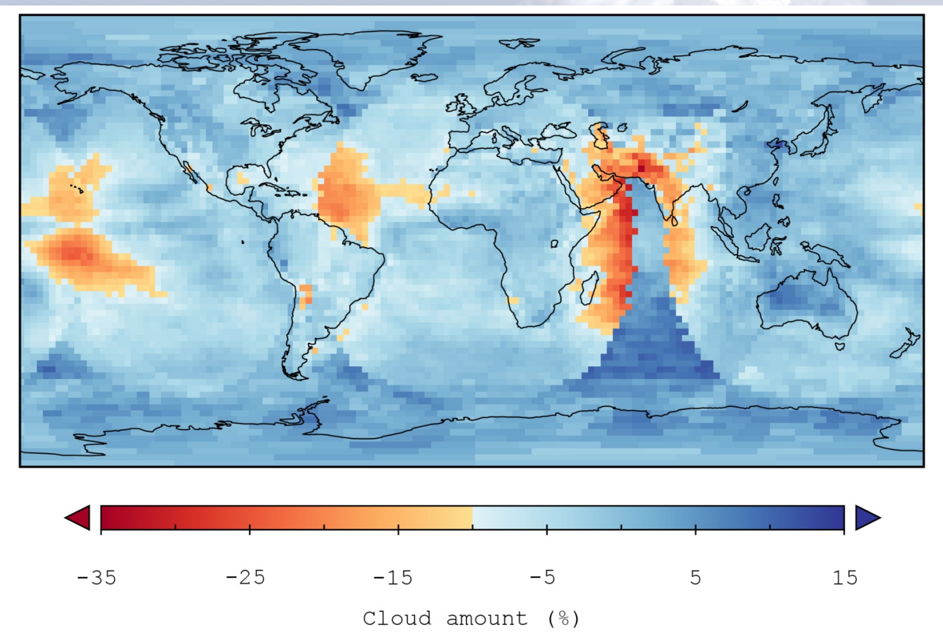


Laken, Pallé, Čalogović & Dunne, 2012, SWSC

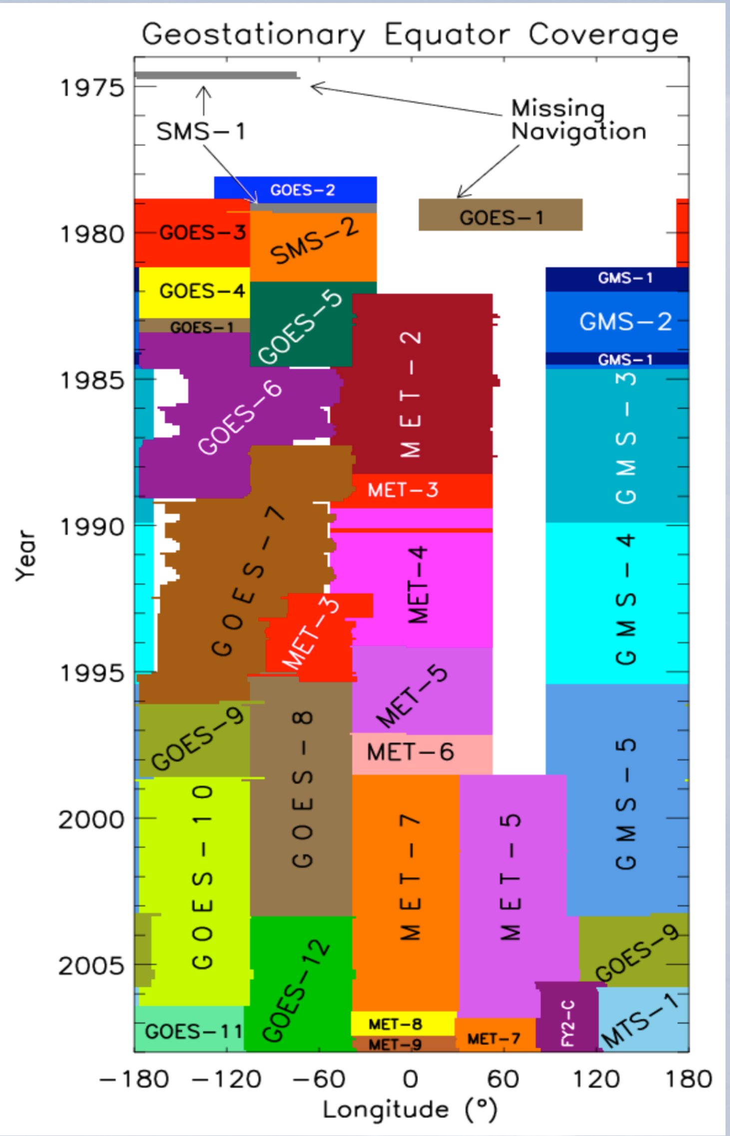
changes in the satellite constellation

Quality of long-term cloud data

Linear ISCCP trend (1983-2008)



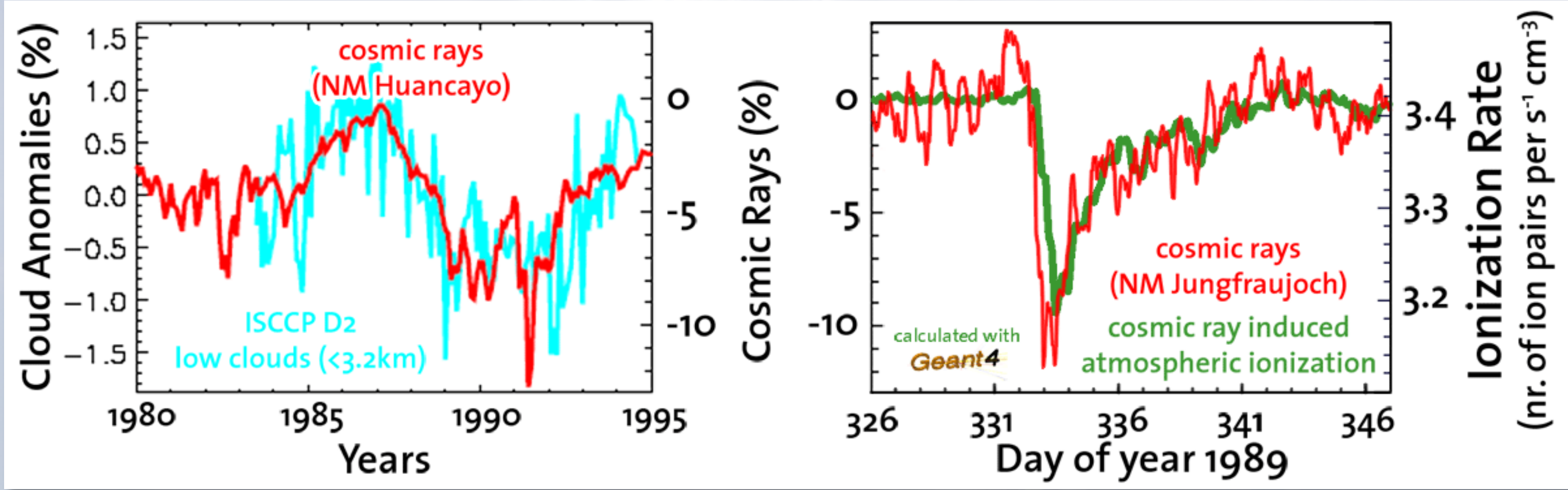
Laken, Pallé, Čalogović & Dunne, 2012, SWSC



If linear trends in CR and cloud data are removed correlation becomes weak

Short-term studies - opportunity to test GCR-cloud hypothesis

• Short-term cosmic ray changes comparable to solar cycle amplitude



Čalogović et al., 2010

Advantages:

- Unwanted factors that influence long-term studies removed (ENSO, volcanic eruptions, satellite calibration errors)

Disadvantages:

- Meteorological variability (noise) **increased**
- **Limited** number of high-magnitude Forbush decreases (several per decade)

Short-term studies show conflicting results

- **positive correlations:**

Tinsley & Deen, 1991; Pudovkin & Vertenenko, 1995; Todd & Kniveton, 2001; 2004; Kniveton, 2004; Harrison & Stephenson, 2006; Svensmark *et al.*, 2009; Solovyev & Kozlov, 2009; Harrison & Ambaum, 2010; Harrison et al. 2011; Okike & Collier, 2011; Dragić et al. 2011; 2013; Svensmark et al., 2012; Zhou et al. 2013; Aslam & Badruddin, 2015

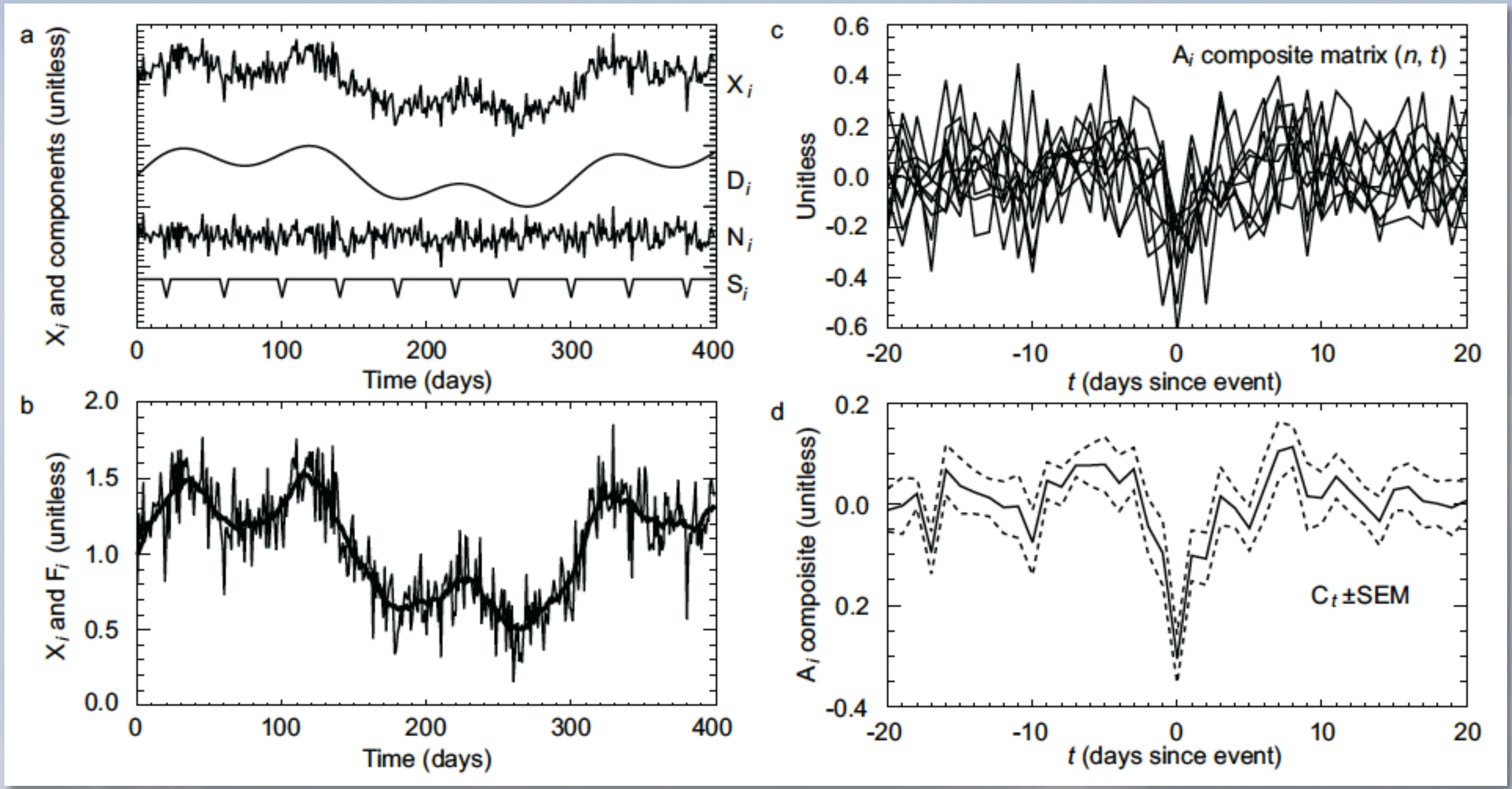
- **negative correlations:**

Wang *et al.*, 2006; Troshichev *et al.*, 2008

- **no correlations or inconclusive results:**

Pallé & Butler, 2001; Lam & Rodger, 2002 ; Kristjánsson *et al.*, 2008 ; Sloan & Wolfendale, 2008; Laken *et al.*, 2009; Čalogović *et al.*, 2010; Laken & Kniveton 2011; Laken et al., 2012; Erlykin and Wolfendale, 2013

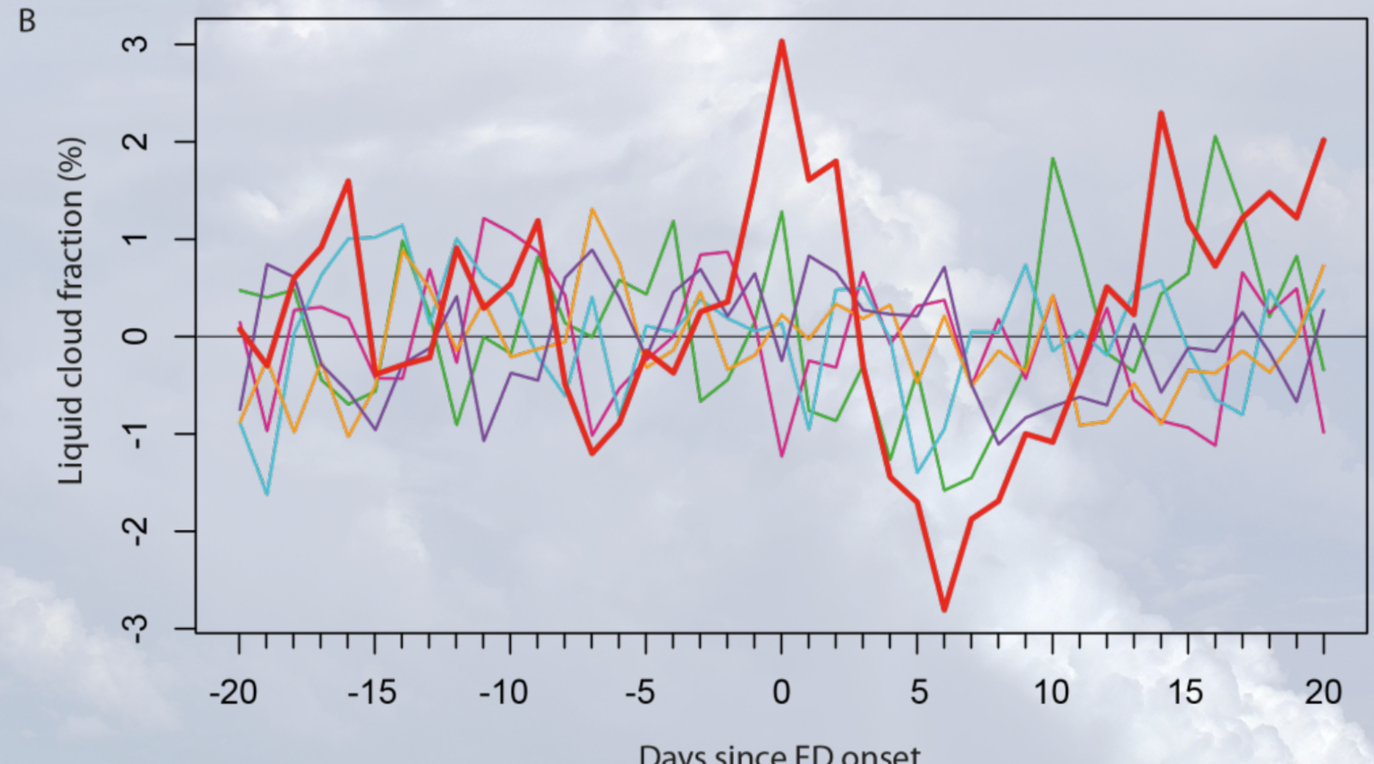
What is composite?



- Successive averaging of events (in time or space)
- Used to increase signal-to-noise ratio (SNR)
- Enable detection of small amplitude signal against large variability

Event selection affect composites

Example from the literature that used 5 events in its composite:
Individual 5 Fd events plotted against event 2 (19.1.2005)

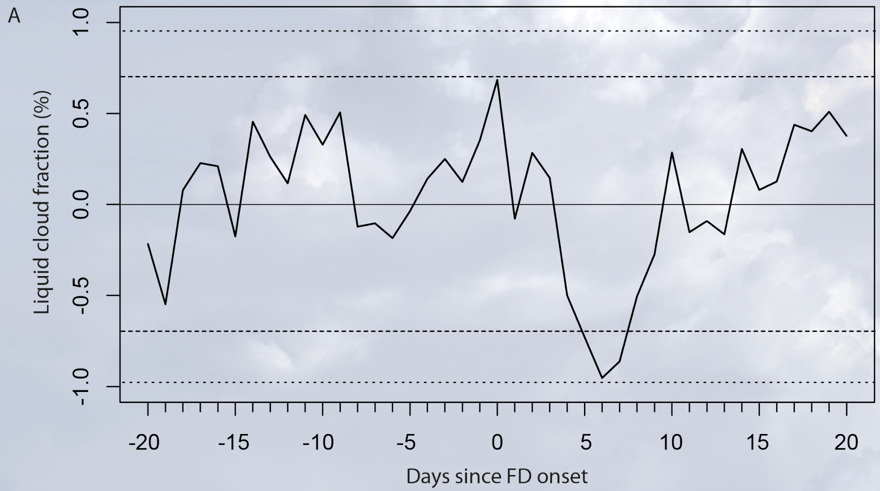


Laken, Čalogović, Beer and Pallé (2012), *ACPD*

Time period considered matters

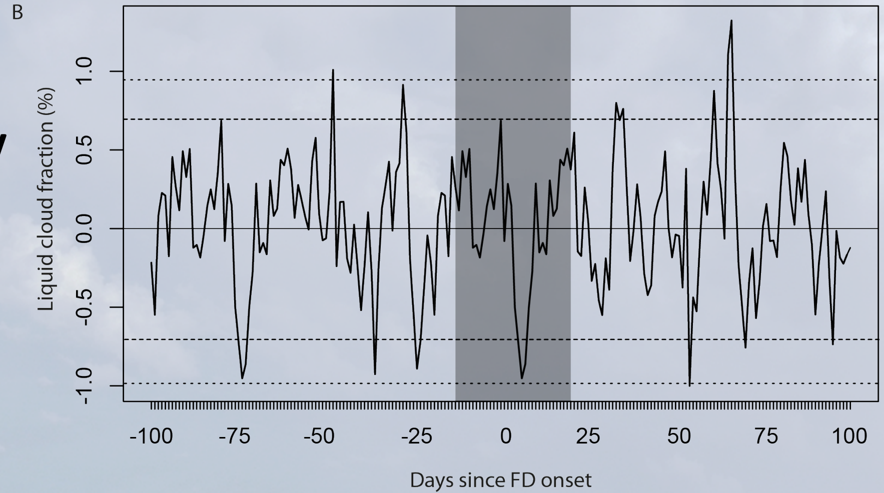
MODIS Liquid cloud fraction changes using 5 biggest Fd events

±20 day analysis period



Looking at a short period around the key date can give a false impression of the data.

±100 day analysis period

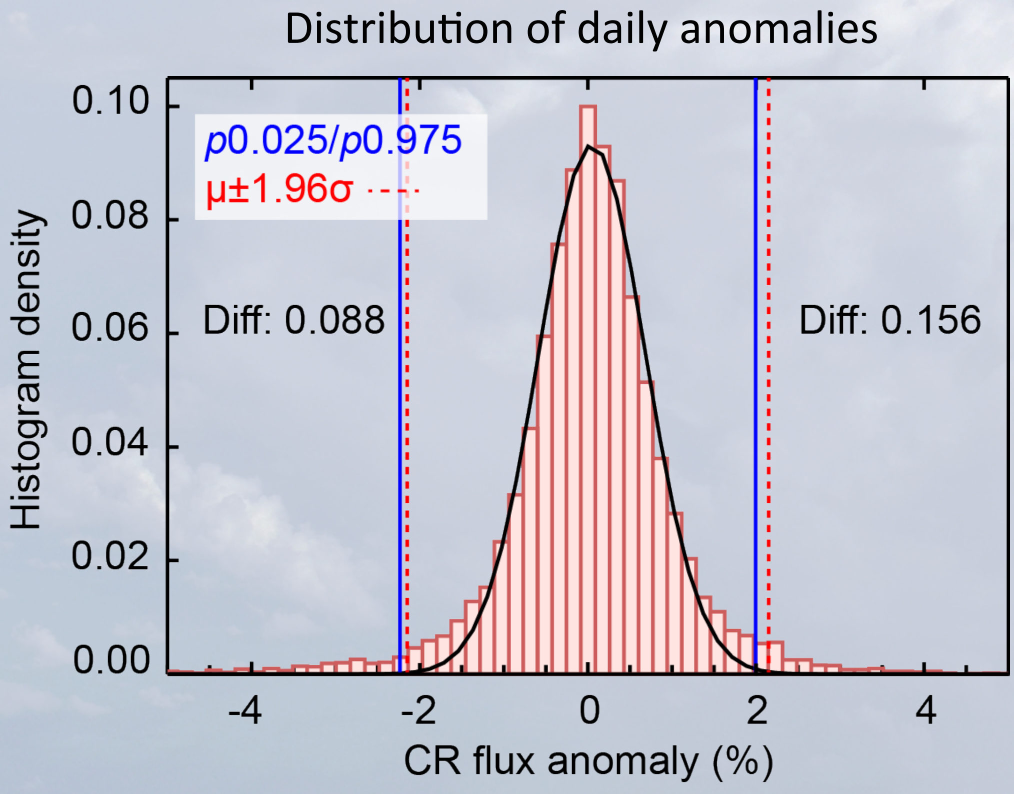


Examining longer periods shows what 'normal' variations are.

Laken, Čalogović, Beer and Pallé (2012), *ACPD*

Traditional significance tests may not be good enough

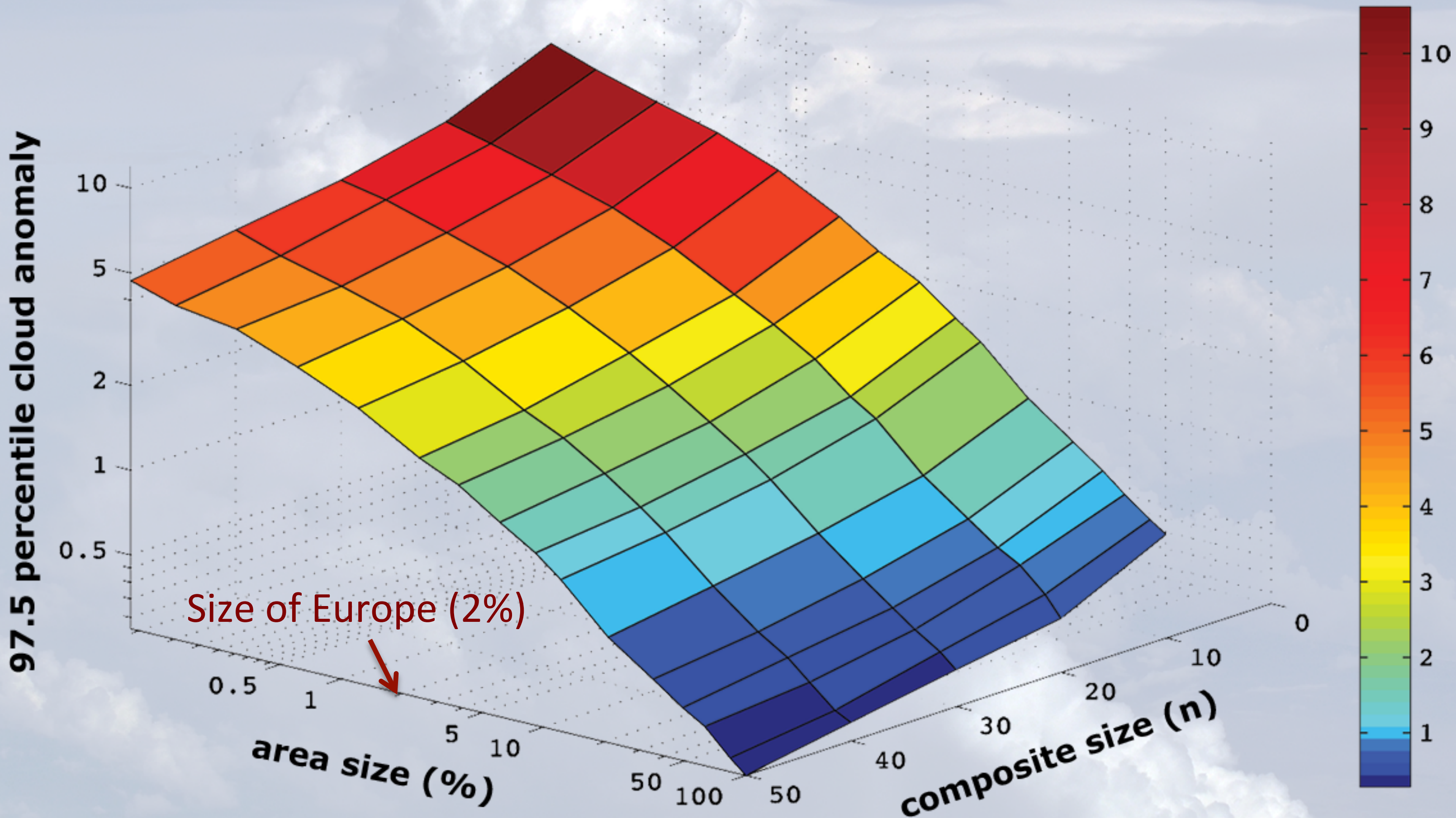
Traditional tests (e.g. T/U tests), require minimum sample sizes, specific distributions, and adjustment for autocorrelation



By generating large populations of random events identical in design to a composite with real events, the probability (p) of obtaining a given value by chance in a composite with real events can be accurately known

Laken & Čalogović, SWSC, 2013

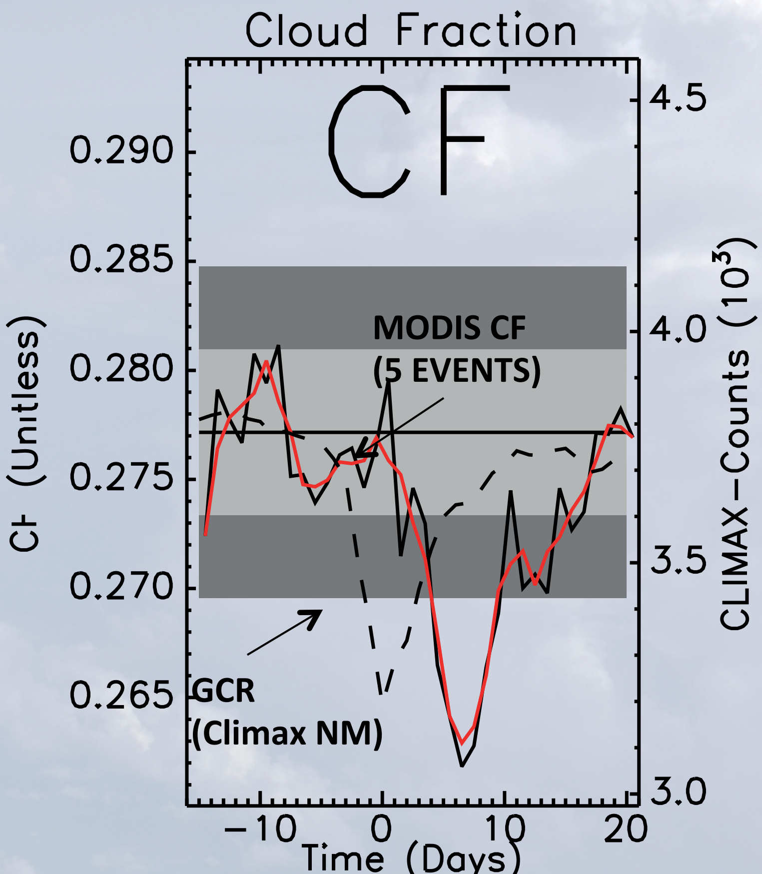
Significance testing depends on space and time



Studies using only strong Fd events have usually **less than 10 events**

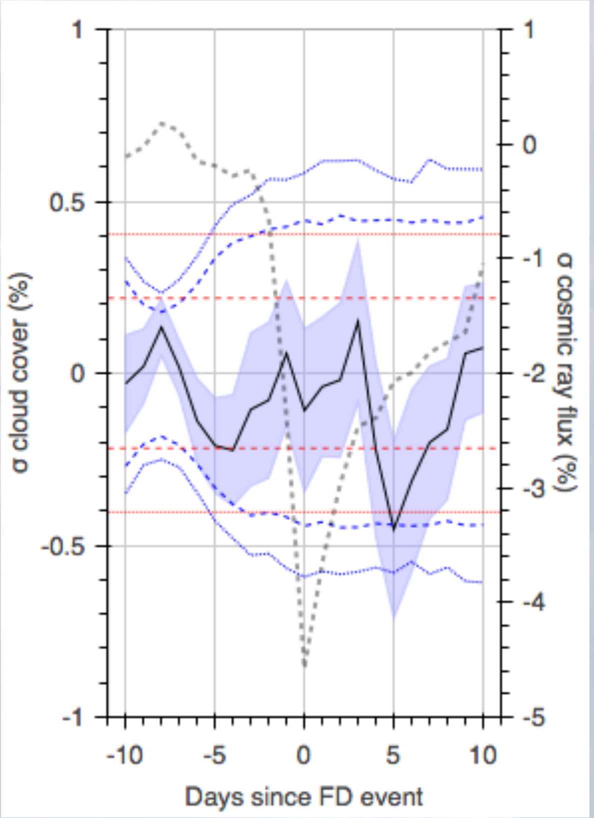
Abusing composites: how to make normal changes seem significant

Svensmark et al. 2012, ACPD



Bad approach

Laken & Čalogović, (2013), SWSC



Good approach

Signal detection issues

- **Filtering** - remove irrelevant variations
- **Normalization -** affect magnitude and significance
- **Autocorrelation** - use appropriate statistical tests
- **Signal-to-noise ratios** - affected by area and time period considered

- Weather: **highly variable,** unstable (**non-stationary**), spatio-temporally **autocorrelated**
- No substitute for long datasets**:** satellite-era data covers <u>three solar cycles</u>.
- ***a posteriori* selection of data**
- Solar—climate links poorly understood
- **Statistical studies**: vulnerable to biased data selection, treatment, assumptions and post-hoc hypotheses.

Conclusions

- **No compelling evidence** to support a global cosmic ray-link using the satellite cloud data (ISCCP, MODIS) with long- or short-term (Fd) studies.
- Satellite cloud data is not suitable for **long-term analysis**
- Co-variance of solar-related parameters (UV, TSI, CR flux, solar wind) make **signal attribution difficult**.
- **Internal variability** at time-scales like the solar cycle complicate signal attribution.
- **Different methodological approaches** produce conflicting results.
- Local effects on cloud can't be dismissed

Thank you for your attention!

We acknowledge the support of Croatian Science Foundation under the project 6212 „**Solar and Stellar Variability**“ and of European social fond under the project “**PoKRet**”.