Testing a link between cosmic rays and cloudiness over daily timescales

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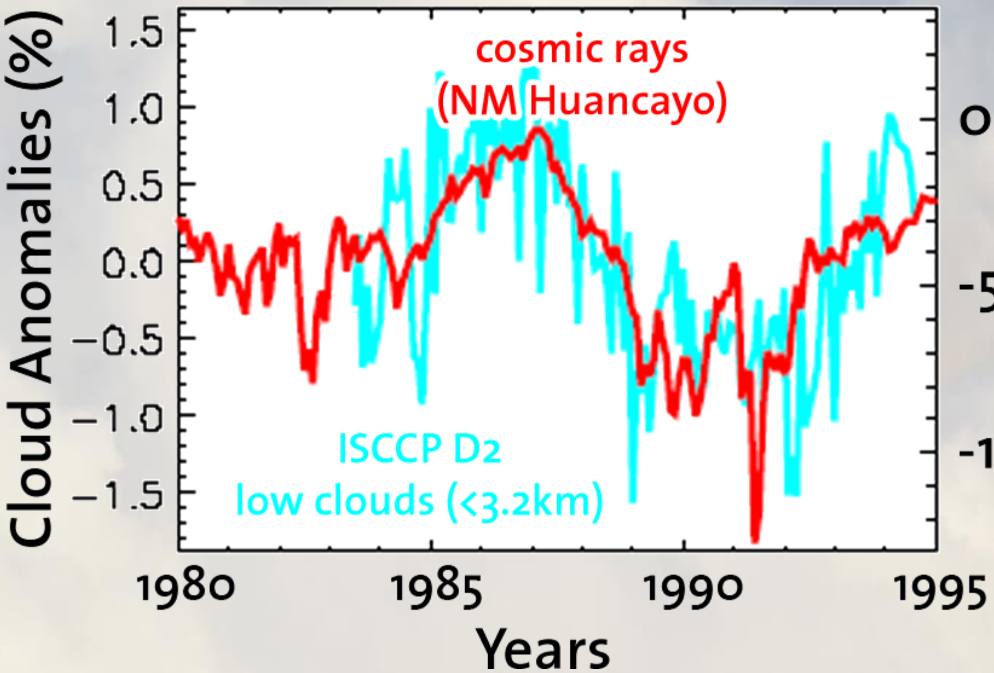
Long-term studies

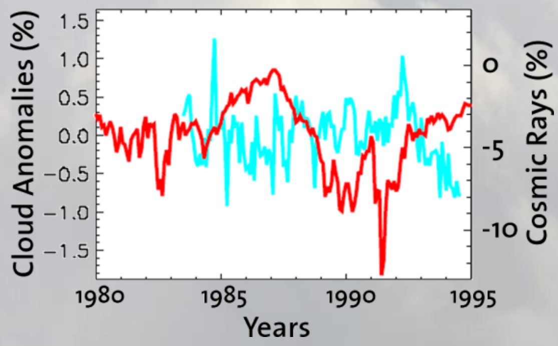
Svensmark and Friis-Chistensen (1997)
• analyzed one solar cycle and reported that global cloud cover changed in phase with the GCR flux by 2-3%.

Marsh and Svensmark, 2000

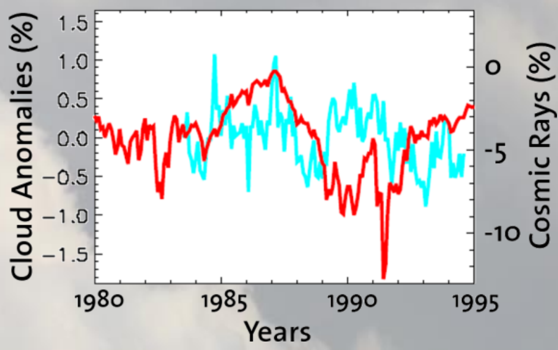
low clouds (0-3.2km)



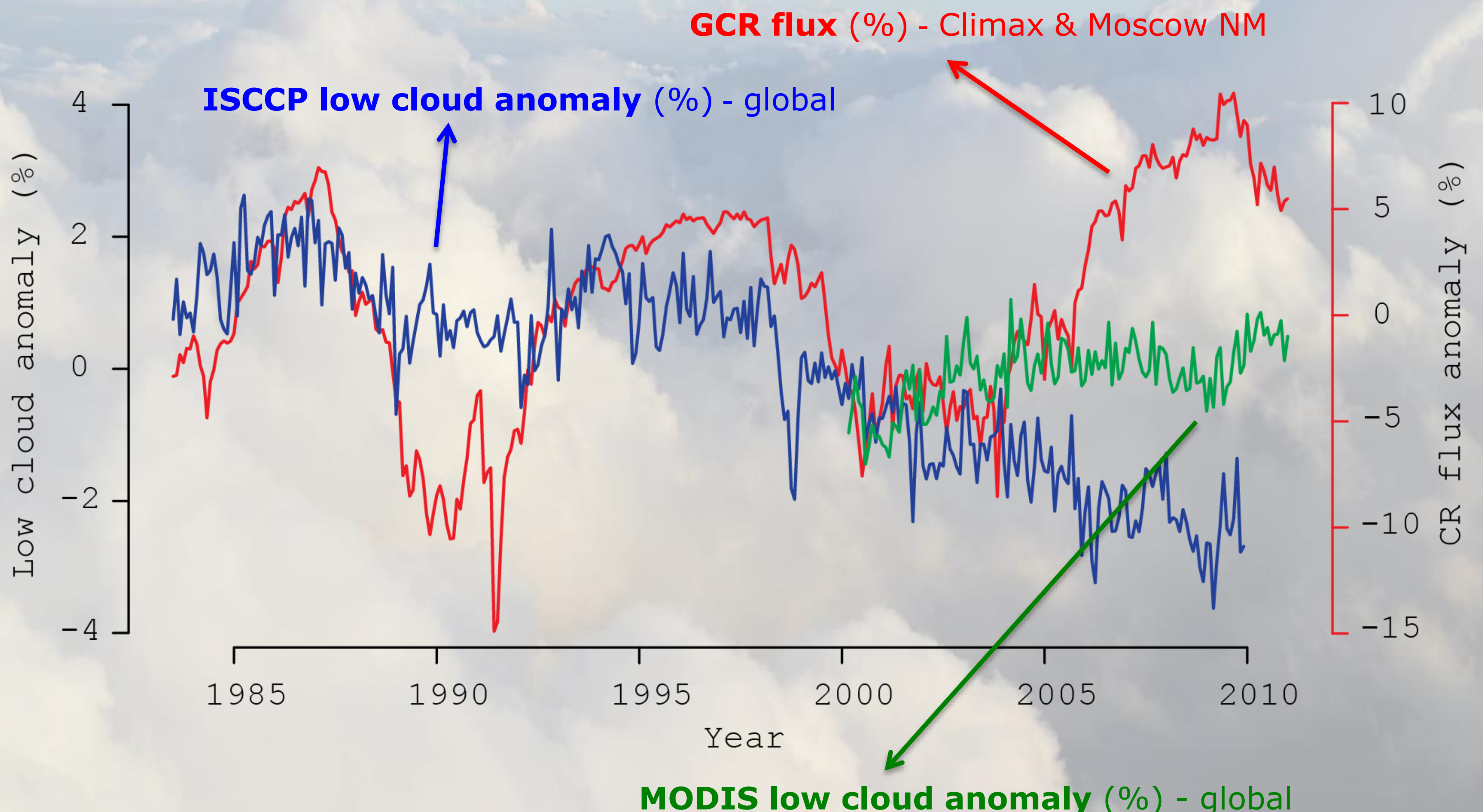
middle clouds (3.2 - 6.5 km)



high clouds (> 6.5 km)

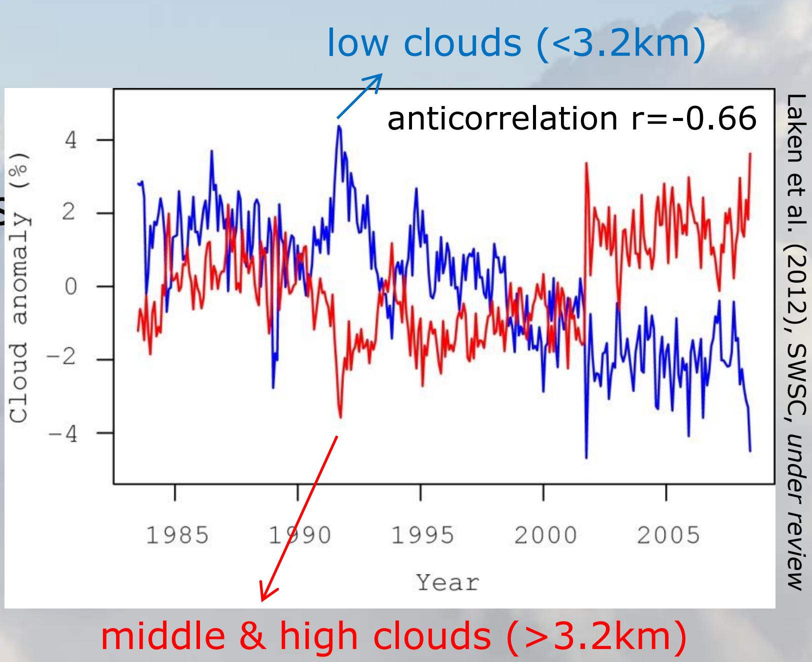


(Low) clouds in satellite datasets doesn't show significant connection to GCR changes (1983-2010)



Laken, Pallé, Čalogović & Dunne (2012), SWSC, *under review*

Long-term studies have numerous problems and limitations



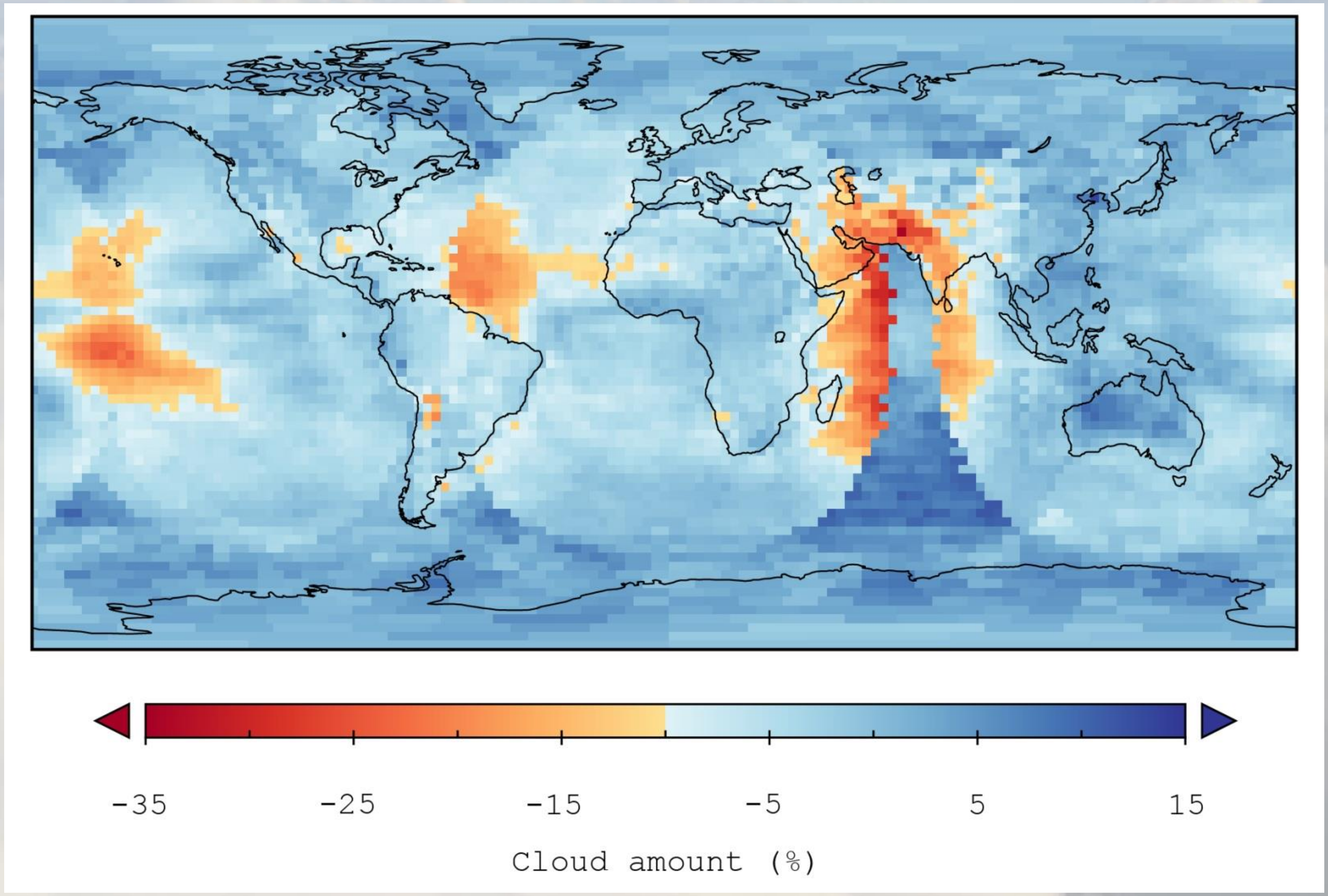
• long-term instrumentation drifts, calibration errors, and view-angle artifacts (Norris, 2005; Pallé, 2005; Evan et al., 2007)

• long-term climate oscillations such as **volcanic** effects and **ENSO** can interfere with detection of possible solar-cloud signals (e.g. *Farrar*, 2000)

• advantages: meteorological variability is reduced over long-timescales

The existence of long-term solar-cloud correlations has been heavily debated in the scientific community: *e.g. Kernthaler et al.*, 1999 Sun & Bradley, 2002; *Laut*, 2003; *Kristjansson et al.*, 2002; 2003; *Sloan and Wolfendale*, 2008…

ISCCP cloud data show clear indications of artificial trends conforming to the geostationary satellite footprint areas

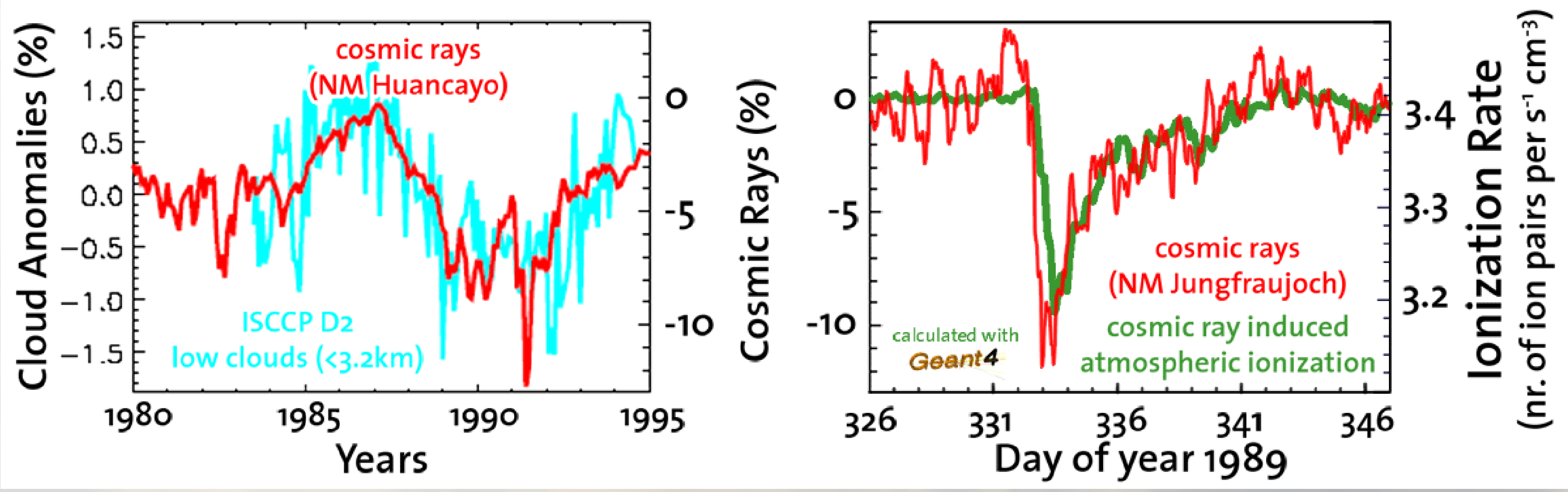


Laken, Pallé, Čalogović & Dunne (2012), SWSC, *under review*

linear trend of each ISCCP D1 VIS-IR pixel over the 1983 to 2010 period

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

• short-term changes in cosmic rays (Forbush decreases) are comparable to variations during the solar cycle.



Čalogović et al. 2010, GRL

• cloud responses to variations in the cosmic ray flux may theoretically be expected to occur within a one-week response time (Arnold, 2007).

• However, to reliably detect a cosmic ray-cloud signal we must compensate for the large meteorological variability of clouds.

Forbush decrease studies show conflicting results

- **positive correlations:**

Pudovkin and Veretenko, 1995; Todd and Kniveton, 2004; Svensmark et al., 2009; Dragic et al. 2011; Svensmark et al. 2012

- **negative correlations:**

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

- **no correlations:**

Kristjánsson *et al*., 2008; Čalogović *et al*., 2010; Laken *et al*., 2009; 2011; 2012

Explanations for conflicting results of FD studies

- there is no relationship between cosmic rays and clouds.

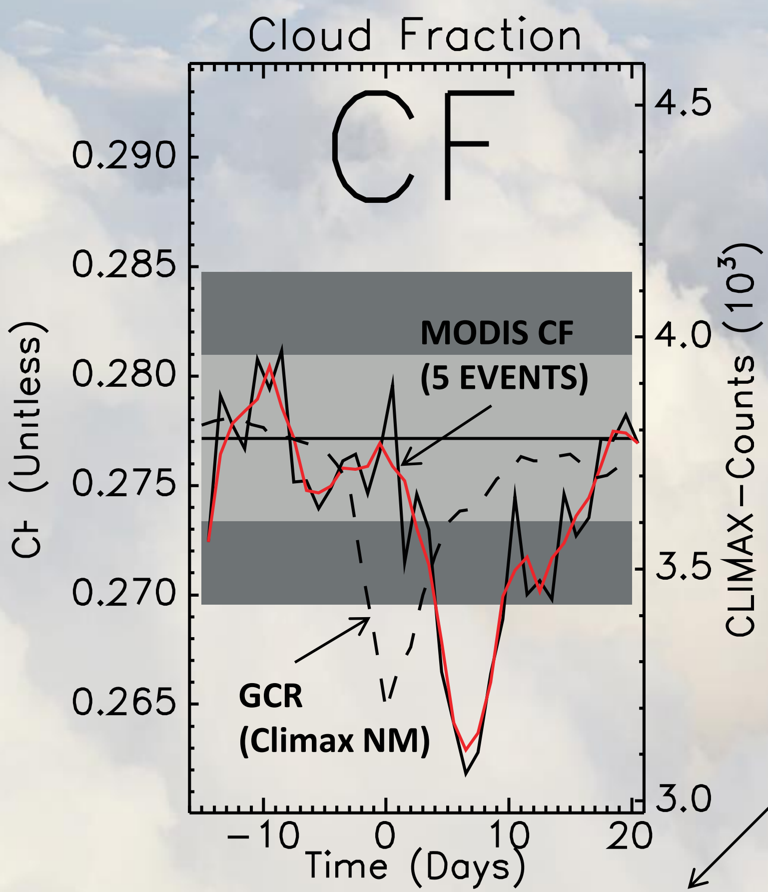
- other solar parameters may interfere with the results: e.g. TSI, UV (Laken & Čalogović, 2011, GRL).

- **a relationship is too weak to detect (low signal-to-noise ratio).**

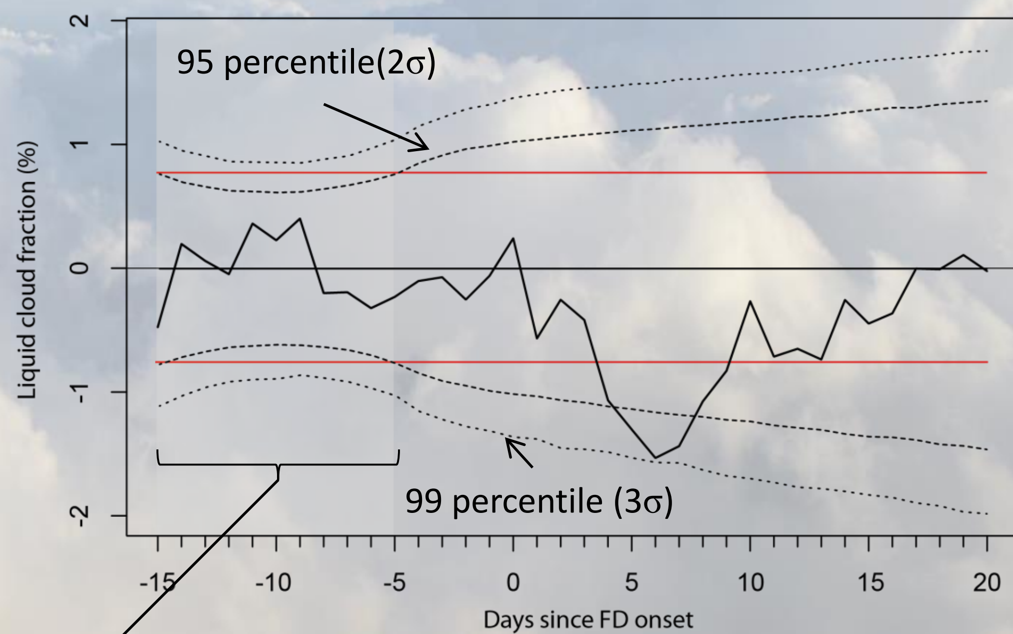
- a relationship exists, but the local cloud responses are constrained by the atmospheric conditions at the time (Laken et al. 2010).

Large cloud variability can be easily confused with an expected solar signal!

Svensmark et al. 2012, ACPD



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



Dashed/dotted lines show **correctly** adjusted 2 and 3σ level – calculated from 10,000 MC simulations

Data NORMALIZED between period of day -15 and day -5

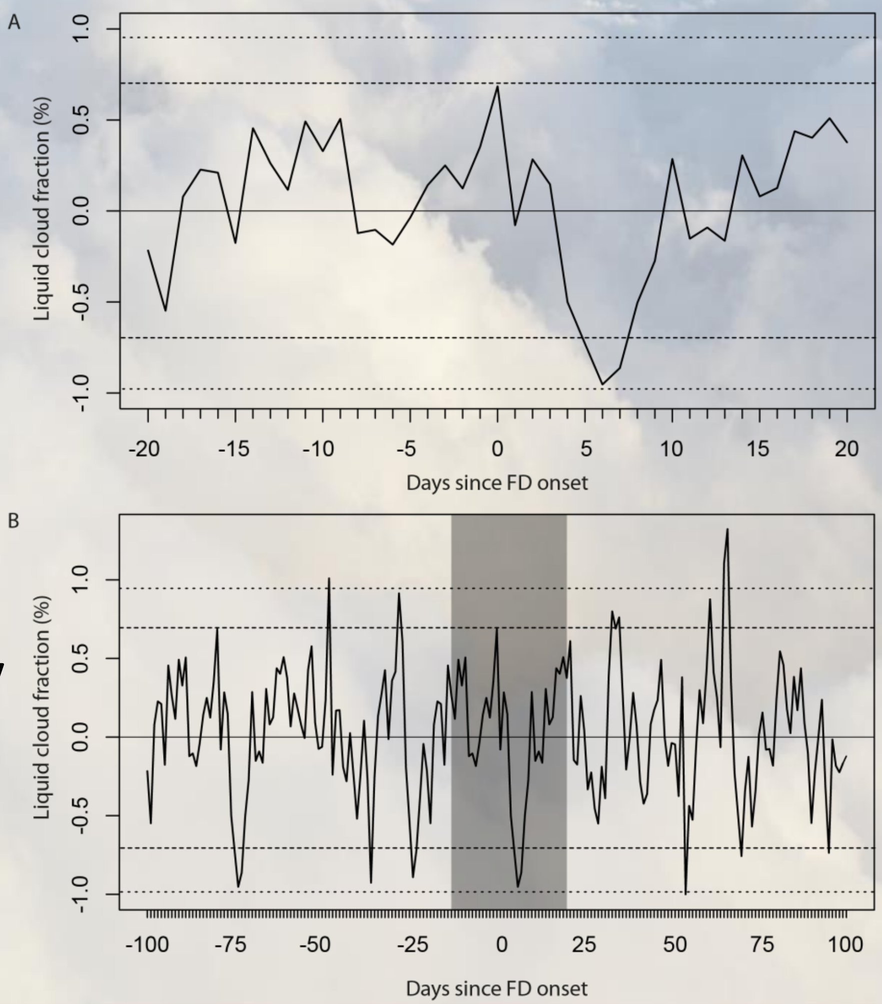
Proper statistical tests (MC simulations) are needed to asses the correct statistical significance!

An example of how an extended time-period reveals regular high magnitude variations in cloud; these can coincide with Fd events by chance

MODIS Liquid cloud fraction changes using 5 biggest Fd events from Svensmark et al. (2012)

±20 day analysis period

±100 day analysis period

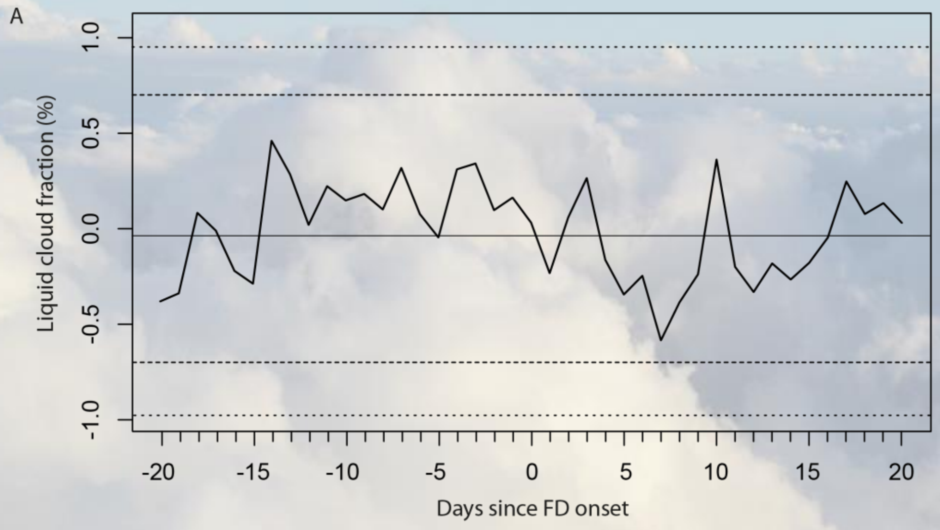


Values are anomalies from 21-day moving averages (i.e. mean of each day subtracted from 21-day moving average).

Dashed and dotted lines indicate the 95th and 99th (two-tailed) percentile confidence intervals respectively calculated from 100,000 Monte Carlo simulations.

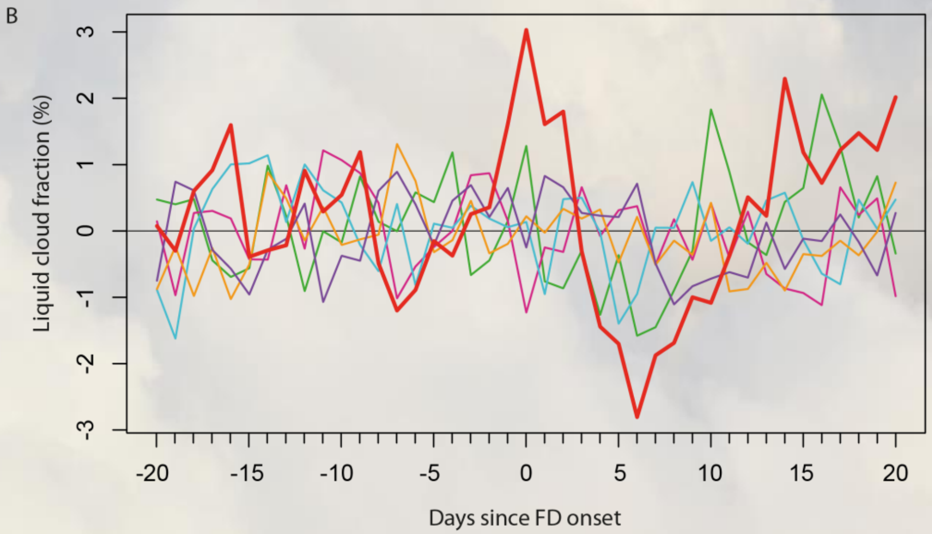
Laken, Čalogović, Beer and Pallé (2012), *ACPD*

Just one event (and eventually outlier) can influence the whole composite



MODIS cloud fraction composite for Fd events 1, 3, 4, 5, 6 ranked by Svensmark et al. 2012

By replacing the event 2 with event 6 there are no significant changes in the composite!



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

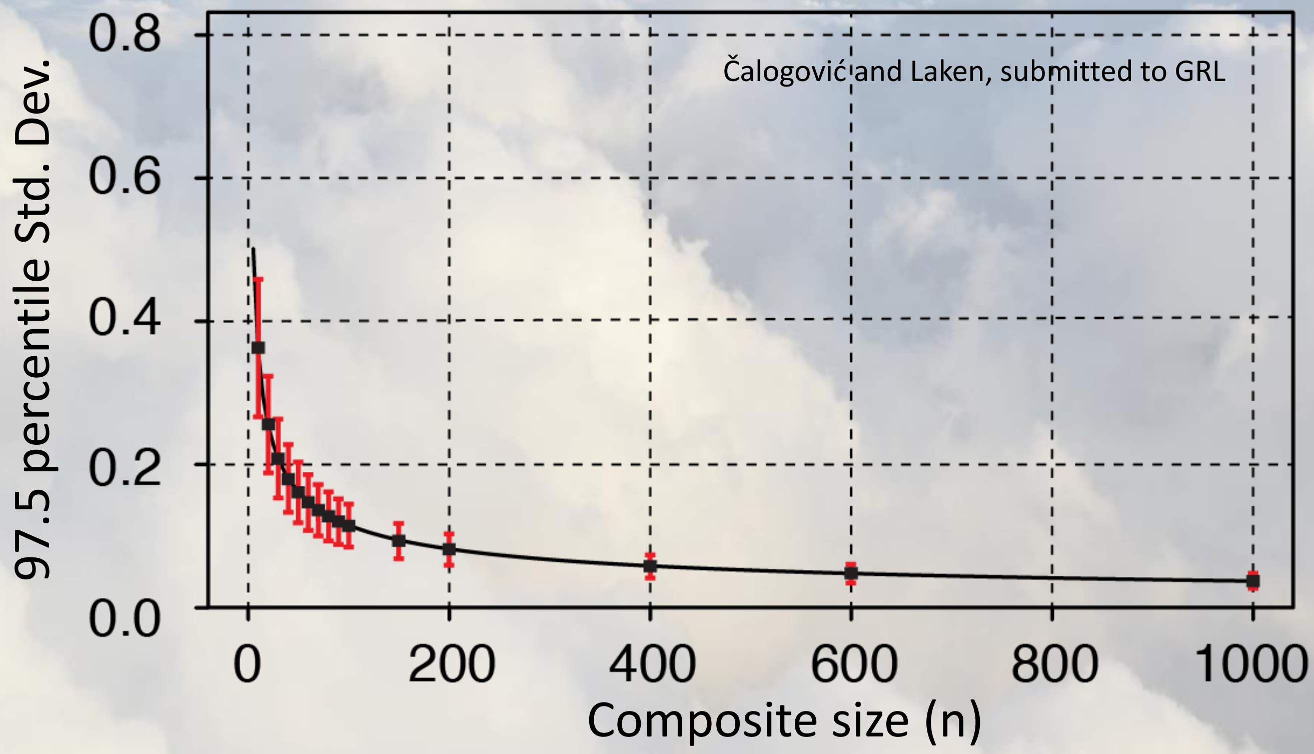
Individual 5 Fd events plotted against event 2 (19.1.2005) where is clear that all significance in Svensmark composite comes from event 2.

Small composites are highly susceptible to interference by noise (such as this example n = 6 events).

Composite sizes and cloud variability

Noise in clouds can be reduced with bigger composite sizes!

Example for ISCCP low clouds (0-3.2km)



Calculated as a 97.5 percentile value from 100,000 MC simulations, no normalization applied, 41 day analysis period.

Similar results are obtained for ISCCP total, middle and high clouds and MODIS cloud fraction and optical depth.

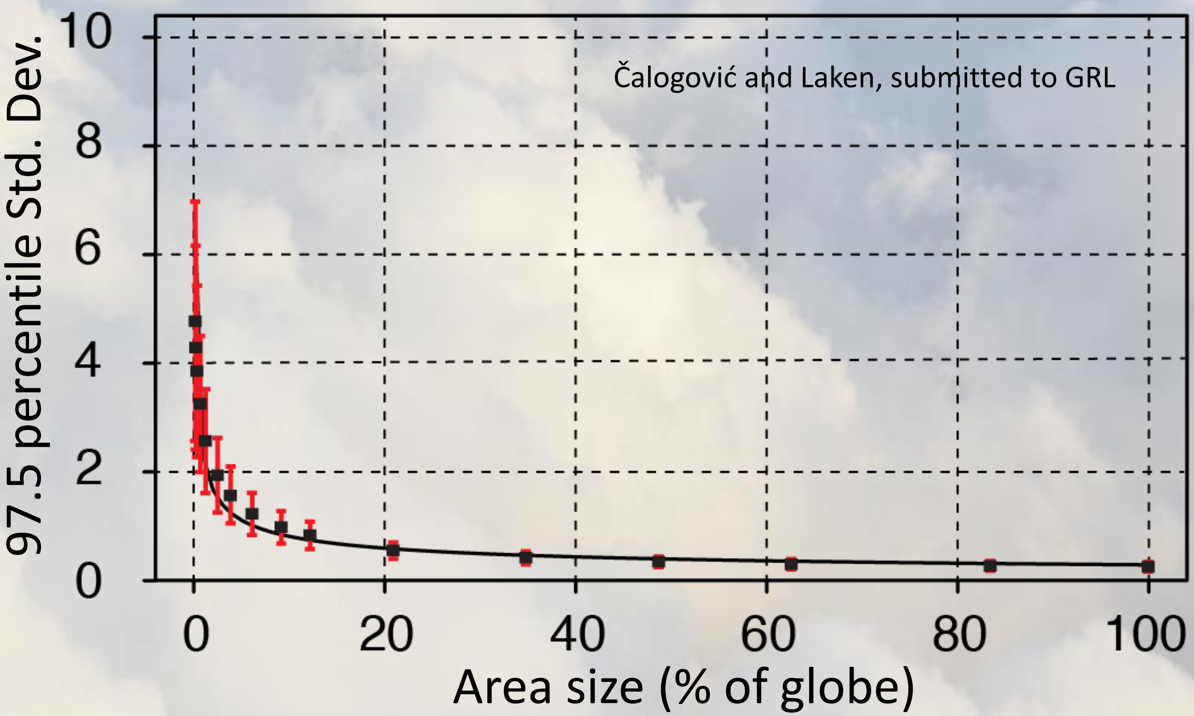
- std decrease to 50% -> composite sample sizes of approx. 32 events
- std decrease to 20% -> approx. 126 events

(calculated from difference between 10 & 1,000 events)

Analyzed region size and cloud variability

By decreasing the analyzed region size noise in clouds is increased!

Example for ISCCP low clouds (0-3.2km)



Calculated as 97.5 percentile value from 100,000 MC simulations, no normalization applied, 41 day analysis period with 20 day analysis period.

Area size is expressed as part (%) of Earth's surface analyzed (exceptions are missing measurements).

- std decrease to 50% -> by area sizes of approx. 18˚x18˚(valid for equator regions)
- std decrease to 20% -> approx. 43˚x43˚ (valid for equator regions)

(calculated from difference between 0.09% and 100% of Earth's surface)

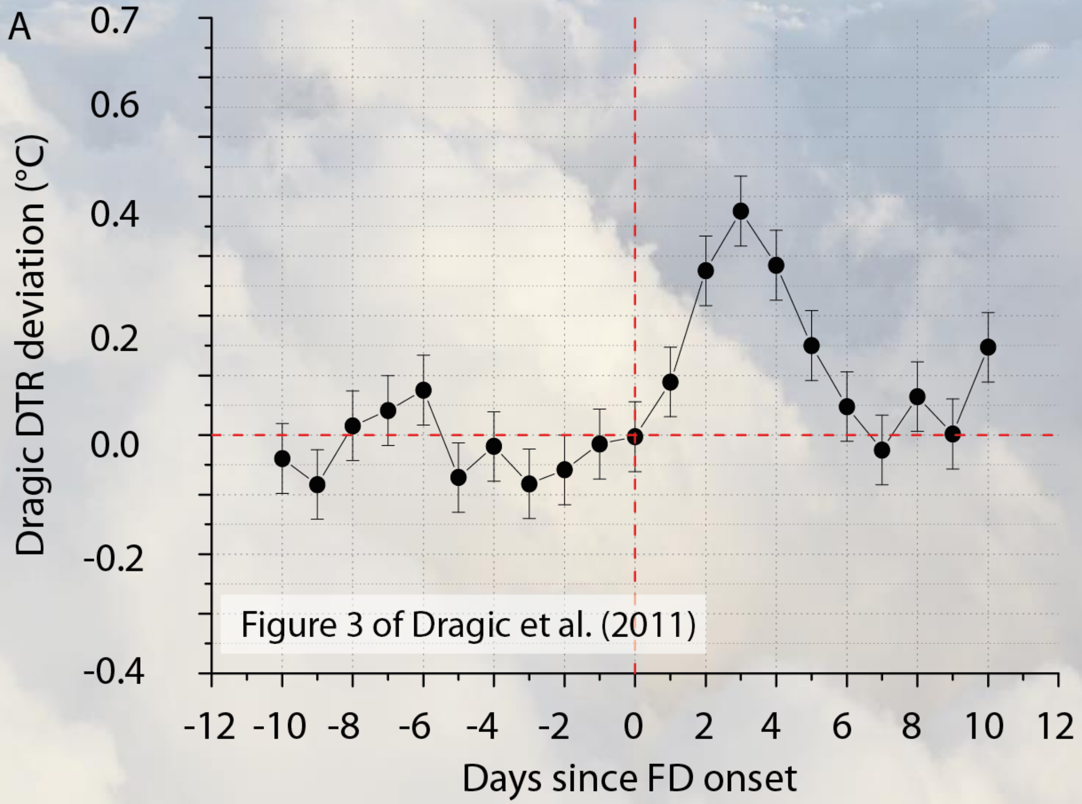
Meteorological noise seriously limits the detection of GCR induced cloud signal

• A careful selection of both study region area and sample size is necessary to minimize meteorological noise to a point where signals may be reliably detected in cloud data.

• For composites of regions smaller than 15x15 degrees (approx. size of Europe) with less than 10 events, the signal-to-noise ratio is most likely too small to be reliably detected.

• MC simulations with static normalization period prior Fd events (e.g. -10 to -5 days) showed that their variability is increased by factor 1.5 to 8 times. Such normalization can be avoided just by using proper low pass filtering (e.g. 21 day moving average).

DTR shows response to Fd events?

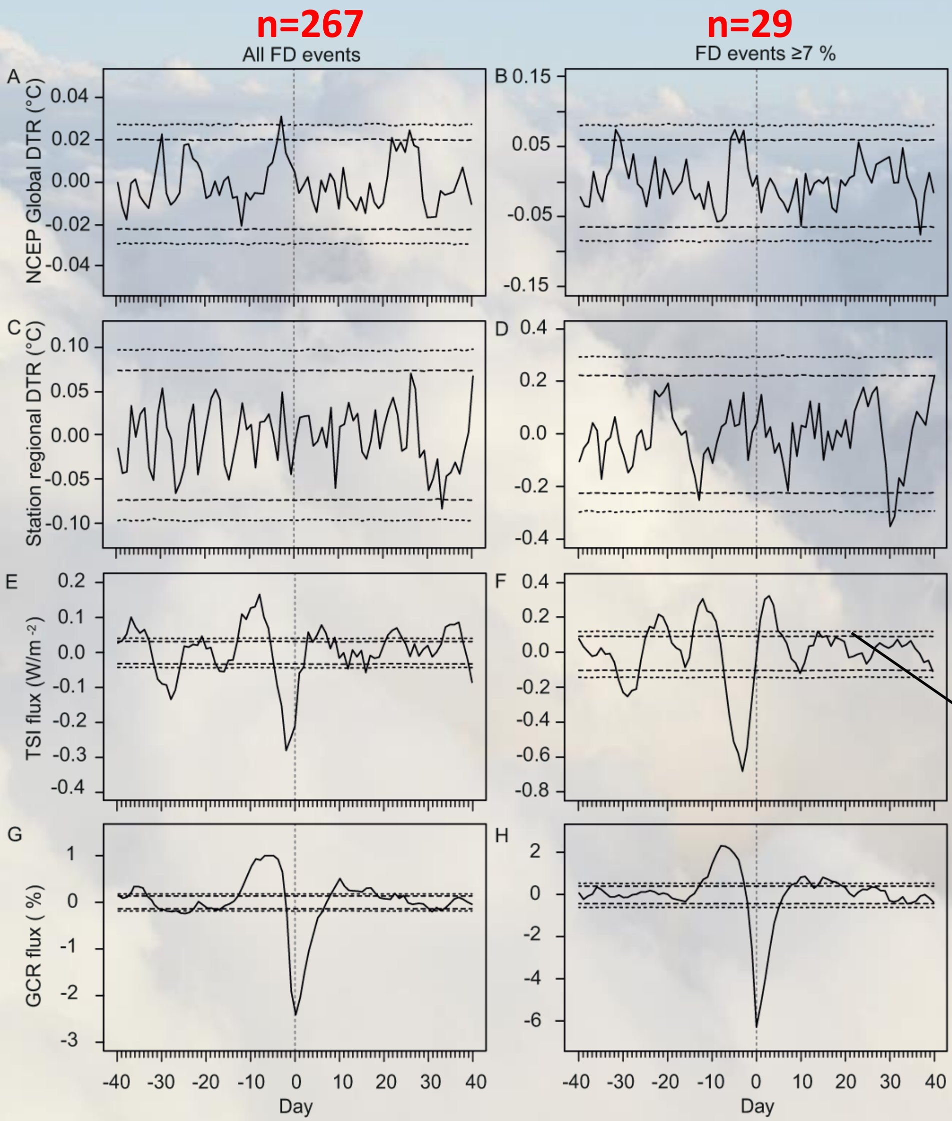


- Surface level Diurnal Temperature Range (DTR) – effective proxy for cloud cover

- Dragić et al. (2011) – composite of 35 Fd events (>7%) show significant increase in DTR - support for GCR-cloud hypothesis

- interesting approach worth investigating further

Extended analysis of DTR data doesn't show any response to Fd events



NCEP/NCAR reanalysis data (60°N – 60°S, land-area pixels only)

DTR from 210 meteorological stations (77.7°N – 34.7°N, 179.4°W – 170.4°E)

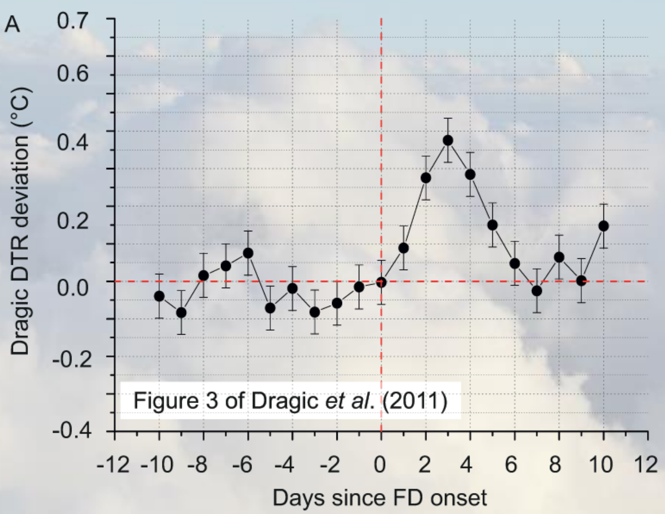
TSI flux from the PMOD reconstruction

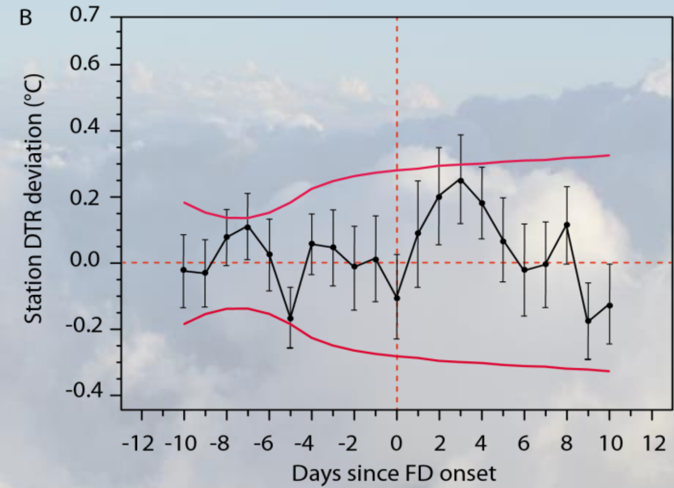
99th and 95th percentile confidence intervals (dotted and dashed lines) are calculated from 100,000 MC simulations

Climax/Moscow NM

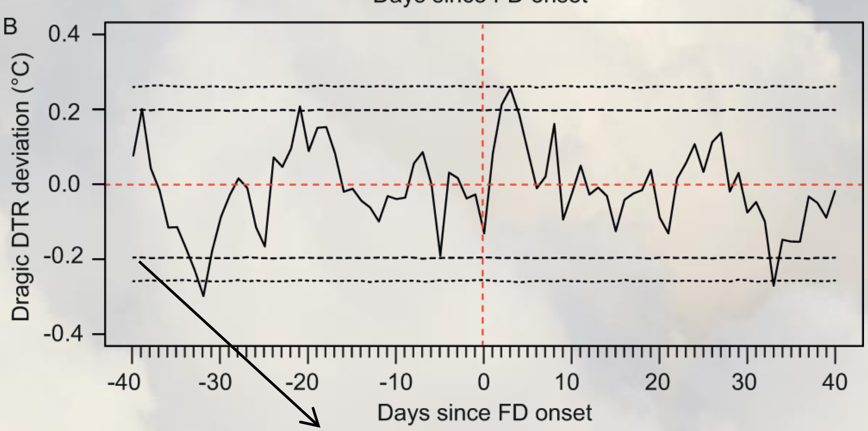
Laken, Čalogović, Shahbaz and Pallé (2012), JGR

Analysis of Dragic et al. results





Dragic et al. normalization from day -10 to day -5 & significance levels (3σ)



confidence intervals calculated from 100,000 MC simulations

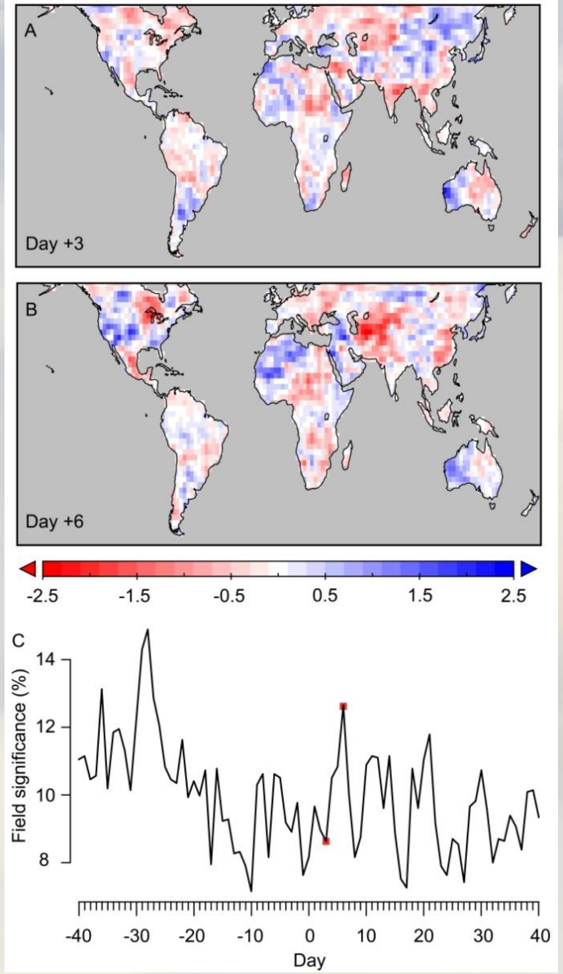
No normalization, 21-day running mean

Analysis of the same data as in Dragic et al. (DTR station data and 37 Fd events) shows that Dragic et al. overestimated the statistical significance of their result by using just t-test and some statistical assumptions.

Laken, Čalogović, Shahbaz and Pallé (2012), JGR

DTR shows no response to GCR or solar activity

Spatial distribution of DTR anomalies between day +3 and +6



Long term analysis (60 years of data) shows also that there is no significant periodicities in DTR data connected to the solar periodicities (e.g. 11-year, 1.68-year).

In conclusion, we find no evidence to support claims of a link between DTR and solar activity.

Laken, Čalogović, Shahbaz and Pallé (2012), JGR

Conclusions

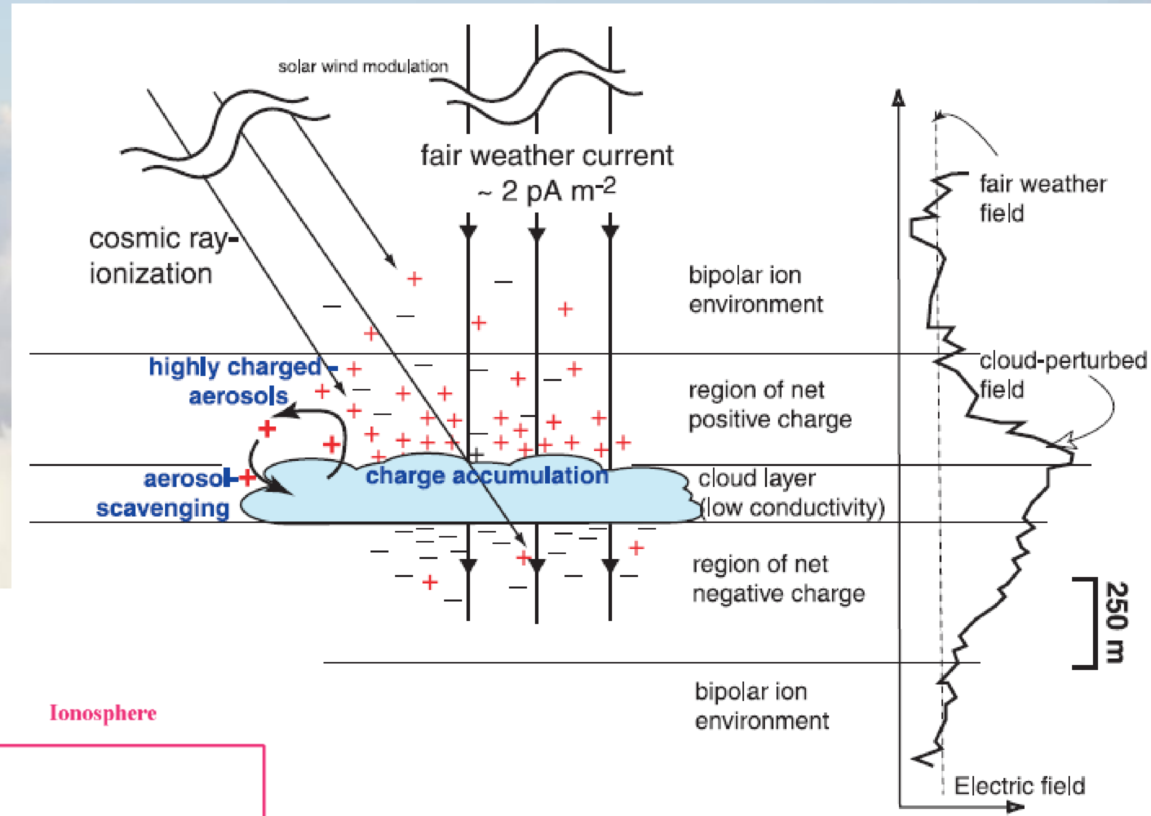
• No compelling evidence to support a cosmic ray cloud connection hypothesis using the satellite cloud data (ISCCP, MODIS) with long- or short-term (Fd) studies.

• Present cloud datasets are too limited to reliably detect small changes in cloud cover at short timescales due to high levels of variability associated with meteorological datasets. Furthermore, due to measurement difficulties, we have no accurate long-term global data of low or middle level cloud, or high-altitude cloud.

• Reanalysis of some recent studies shows that some significant results were obtained by improper statistical methods and are based on simple statistical assumptions which may not be correct.

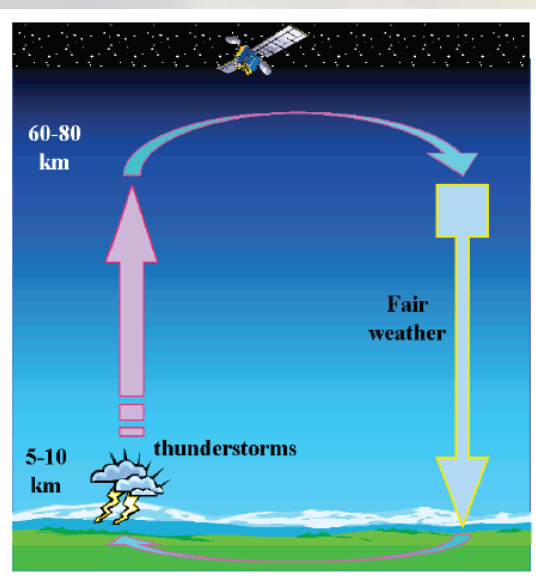
Lightning’s over Hvar on 02.10.2012, photo by: Jaša Čalogović

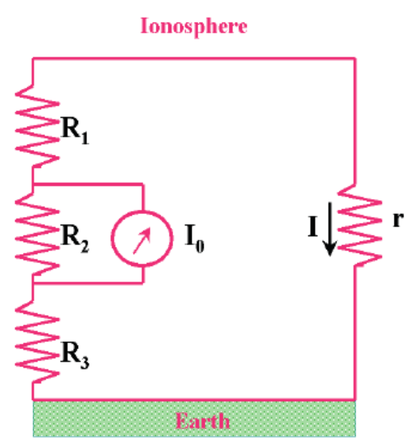
Current density-cloud hypothesis



Carslaw, Harrison et al., 2002

Global electric circuit



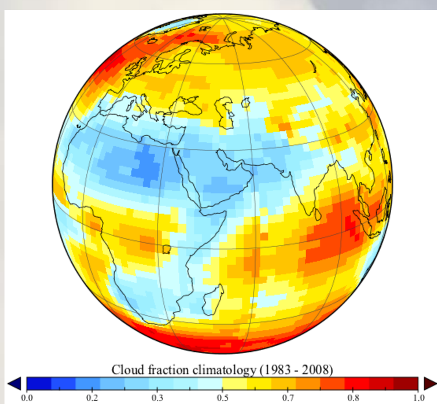


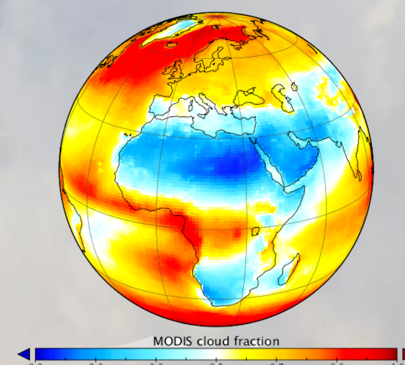
Makino and Ogawa, 1984

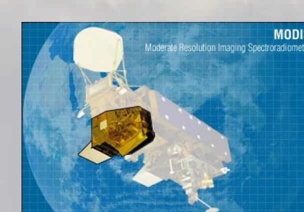
Available cloud datasets

ISCCP (International Satellite Cloud Climatology Project)

- D1 dataset (from 1983 to 2008), intercalibrated radiance measurements from a fleet of polar and geostationary satellites
- temporal resolution: 3h (IR data)
- spatial resolution: 2.5° x2.5° (280 x 280km^2)
- distinguishes clouds at different altitude levels: e.g. high (>6.5km), middle (3.2 – 6.5km) and low (0 – 3.2km)



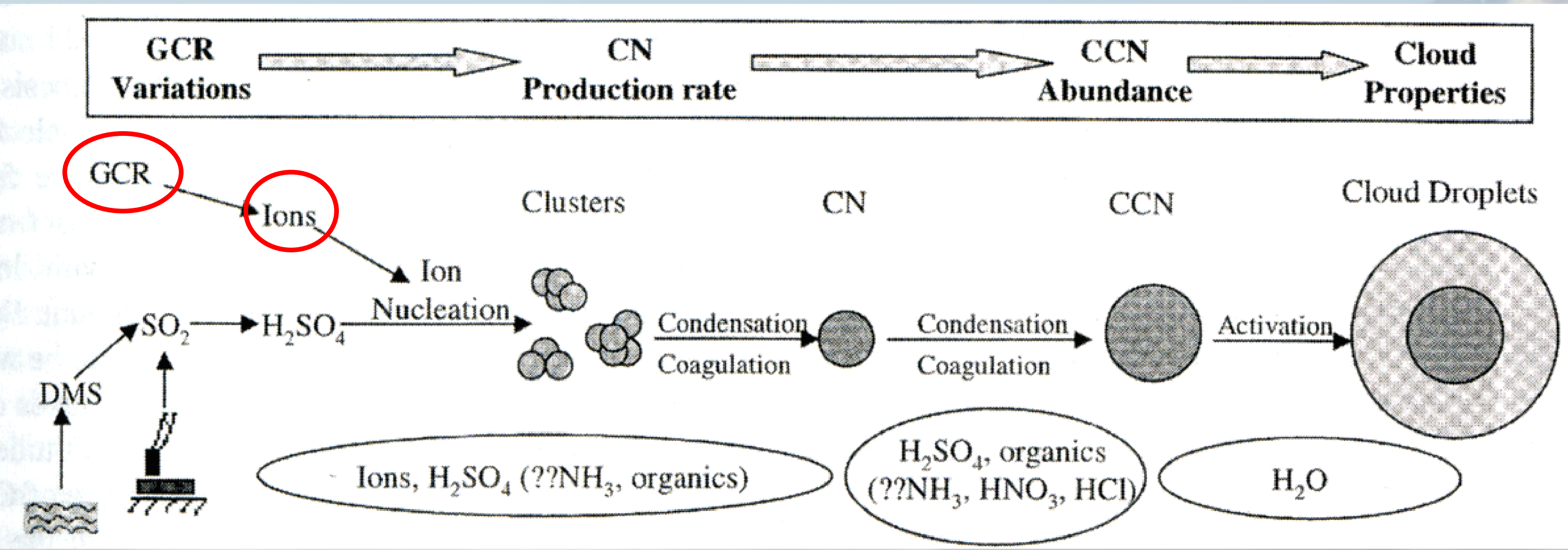




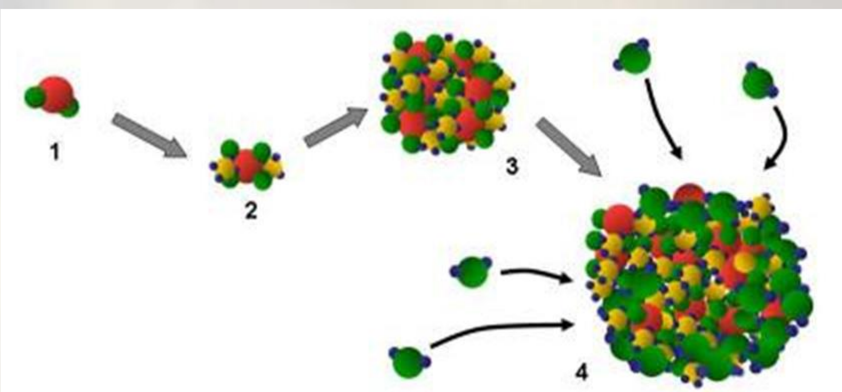
MODIS (MODerate Resolution Imaging Spectroradiometer)

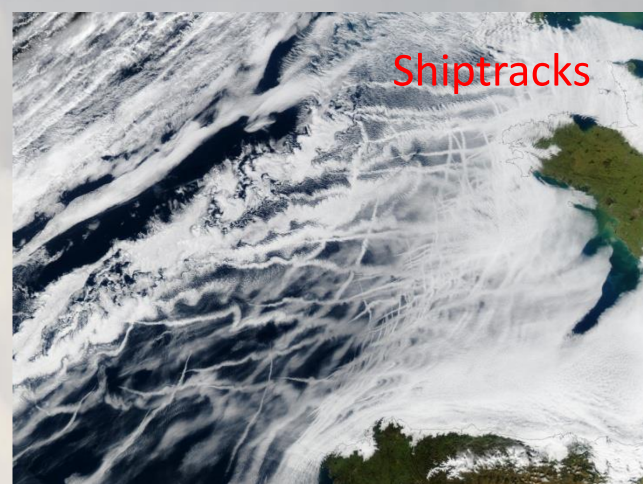
- views in 36 channels from Visible to thermal IR, on board two polar orbiting satellites Aqua, and Terra, operational since 2000
- temporal resolution: 12h, spatial resolution: 1° x 1°

GCR-CN-CCN-Cloud Hypothesis

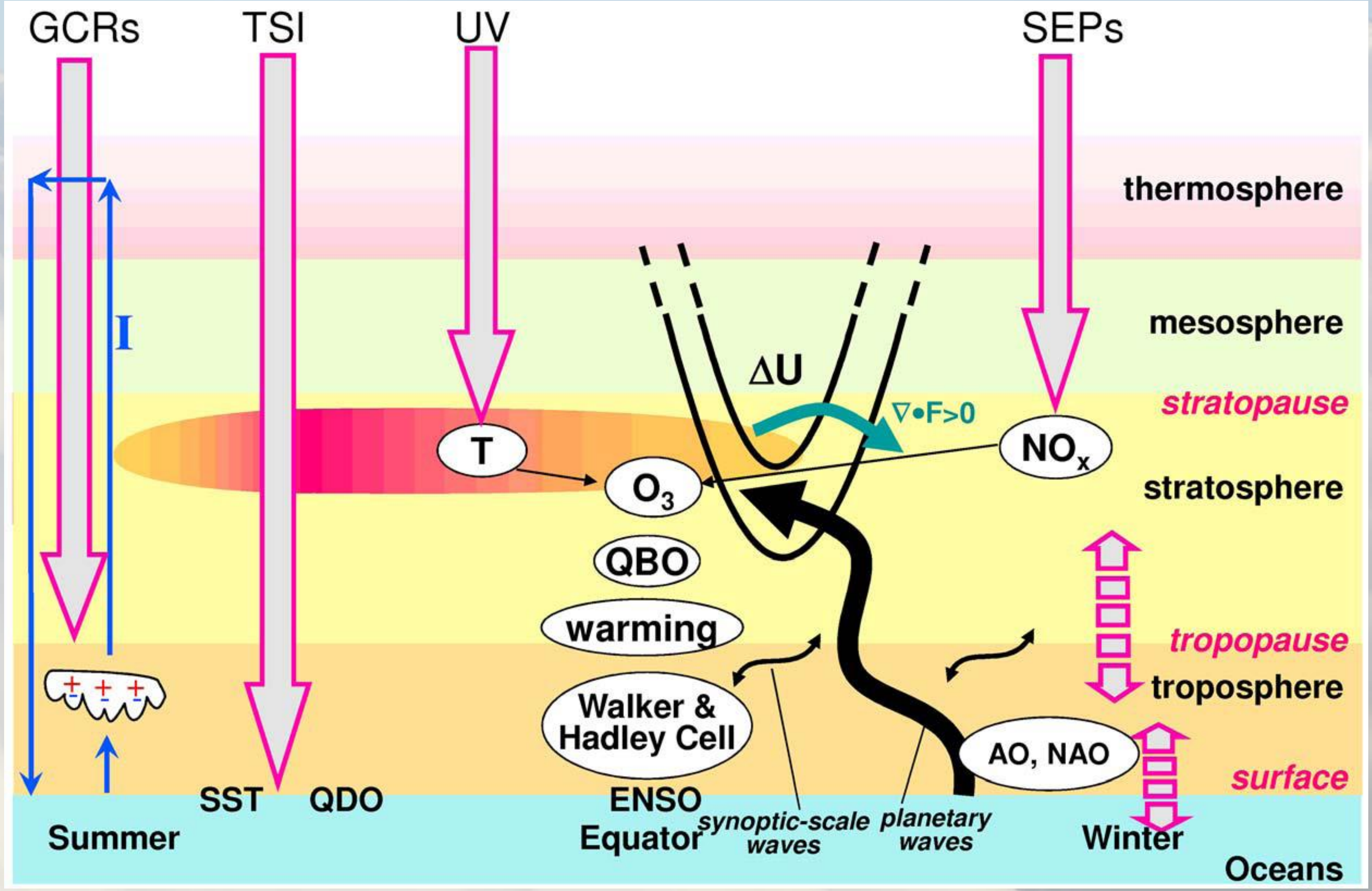


Yu, 2002





Schematic diagram of solar influence on climate



Kodera & Kuroda , 2002

Marsh and Svensmark, 2003