

Can isolating specific cloud types provide evidence of a cosmic ray-cloud link?

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Laken & Čalogović, TOSCA handbook

Still controversial topic...

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New paper 'proves that cosmic rays play an essential role in climate change'

A paper published today in *Advances in Space Research* corroborates the cosmic-ray theory of climate and "proves that cosmic rays play an essential role in climate change and main part of climate variations can be explained by [the] mechanism of action of CRs [Cosmic Rays] modulated by the solar activity on the state of lower atmosphere and meteorological parameters."

According to the author

"We demonstrate that the detrended annual means of global surface air temperature in 1965–2012 show the maxima during CRs [Cosmic Rays] and Dst index [of the solar wind] minima. It proves that CRs [Cosmic Rays] play essential role in climate change and main part of climate variations can be explained by Pudovkin and Raspopov's (1992) mechanism of action CRs [Cosmic Rays] modulated by the solar activity on the state of lower atmosphere and meteorological parameters. Following this we have to seek for another ways of looking for global warming reason, first of all, as a man impact on climate."

Data from the paper shows a strong correlation between cosmic rays and detrended surface temperatures in two locations 1966-2006 and 1965-2012:



Energy and Environment

No, cosmic rays aren't causing global warming

By Puneet Kollipara March 12

Climate change contrarians have sought all sorts of explanations for why humans aren't causing global warming, ranging from <u>changes in solar activity</u> to <u>natural</u> cycles in Earth's own wobbly climate system. Another increasingly popular reason given is cosmic rays — highly energetic particles from outer space sources that are constantly bombarding our planet.

Scientists <u>have long considered</u> this argument <u>to be baseless</u>, and now a new study hammers that point home further. Changes in how many cosmic rays hit Earth could affect temperatures in the short term, but not in the long term, <u>researchers reported</u> in the Proceedings of the National Academy of Sciences.

... and beloved argument for climate skeptics!

Scientific papers show also conflicting results (eg. Short-term studies using Forbush decreases)

• 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, Veretenko & Ogurtsov 2015, Tsonis et al. 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

Why?

- Improper use of statistical tools / wrong statistical assumptions
- "quality" and properties of cloud datasets

Open-access coding solution

- Reliable methods/tests to overcome some noted difficulties: communal analysis approach
- Implementation of robust significance testing (e.g. MC method)
- Python (free+open, all platforms, easy to learn/use)
- IPython: code in small editable units, code, figures, and descriptions mixed. Rapidly shared and replicated.
- Public Git repositories for communal development: a 'living' version with a history
- Allows even low-skilled programmers to follow the analysis. **Viewed** online, any system (only internet browser needed)
- Using FigShare code/figures have their own DOI

IPython environment



Identification of solar—terrestrial links has many issues

- Large uncertainties still remain
- Exact amplifying mechanisms linking solar activity to climate still poorly understood -> not always possible to even evaluate them
- Cross-correlation of solar signals complicate attribution
- Most studies purely statistical -> tests of significance may be accompanied by ambiguities (data selection, treatment, methods and assumptions). Vulnerable to autocorrelations, smoothing, human bias and post-hoc hypotheses.
- Such difficulties in relation to solar—terrestrial field described already by Pittock 1979, 1978

Big variability (noise) can be mixed with a hypothesised signal

- Weather/climate is highly variable (i.e. noise) -> only small fraction can reasonably be linked to solar activity (i.e. signal)
- Climate data have strong spatio-temporal auto-correlation
 - -> complicates statistical tests



Robust statictics (MC) show overly simplistic tests commonly applied (e.g. T-test) don't reliably assess significance

Dashed/dotted lines show correctly adjusted 2 and 3 σ confidence intervals (CI) calculated from 10,000 MC simulations, red line shows CI (2 σ) calculated based on normalization period assuming that data aren't temporally auto-correlated.

No link in long-term global cloud data

- Correlations appear significant only over short-timescales (low clouds, 1983-1995)
- Long-term satellite cloud data susceptible to errors/artificial trends, eg. low clouds obscured by overlying clouds, changes in satellite constellations, misindentification of cirrus clouds...
- Other climate forcings may influence clouds too (eg. ENSO, volcanic eruptions...)



Short-term studies also have limitations

- Meteorological variability (noise) in clouds has to be reduced in order to detect the solar-related changes (signal)
- Limited number of high-magnitude Forbush decrease events

Noise levels of data govern detectability of a signal. The noise varies with both the spatial area (a) considered by the data, and the number of composite events (n).



Each point of grid represents another independent set of 10,000 MC simulations



Laboratory and model experiments indicate small influence of ions on aerosols/clouds

Cosmics Leaving OUtdoor Droplets Laboratory experiment with a cloud chamber to study the possible link between GCR and aerosol formation

- Results show small contribution of ion-induced aerosol formation
- Natural trace gases (acid-amine nucleation) tend to be much more effective in nucleation (Almeida et al., 2013, Nature)





• Model experiments also show small impact on the global cloud cover (Pierce & Adams, 2009; Dunne et al. 20102)

What about localized cloud effects?

E.g. Marine stratocumulus clouds (MSc)

- There are locations where aerosols are in short supply and limit cloud formation
- Small changes in the CCN concentration from combustion in such locations have been shown to dramatically alter clouds (e.g. Rosenfeld et al., 2006; Koren et al., 2012).



Analysis with IPython

- MODIS Terra & Aqua Daily Level-3 data, ver. 5.1 (MOD08.D3.051)
- Mask data by: (1) cloud-top pressure of >800 mb, (2) optical depth of 3.6 to 23.0, and (3) ocean-areas
- 16 strongest Forbush decreases

Advantages of analysis in **IPython**:

- Can be applied to any dates rapidly
- Easy selection of different cloud data (masks)
- Implementation of robust statistical methods
- Fast and scalable data processing



Cloud top pressure, optical depth and cloud cover for marine stratocumulus



First results





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Conclusions

- GCR-cloud signal still undetected using global cloud satellite data
- Diverse range of subtle, local-scale, impacts on clouds may still remain (e.g. high-level supercooled clouds)
- Identification of solar—terrestrial links connected to many issues -> much uncertainty still pervades
- Open access coding approach (IPython) allows us to better share experience/knowledge and solve some of the difficulties of past studies (reproducible work)

Thank you!

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MODIS cloud data

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°
- MODIS Terra & Aqua Daily Level-3 data, ver. 5.1 (MOD08.D3.051), available since 01.03.2000 till today



Theoretical solar influence on climate

