Tropical and Arctic Cloud Observations from CALIPSO between 2008-2014 and its implications

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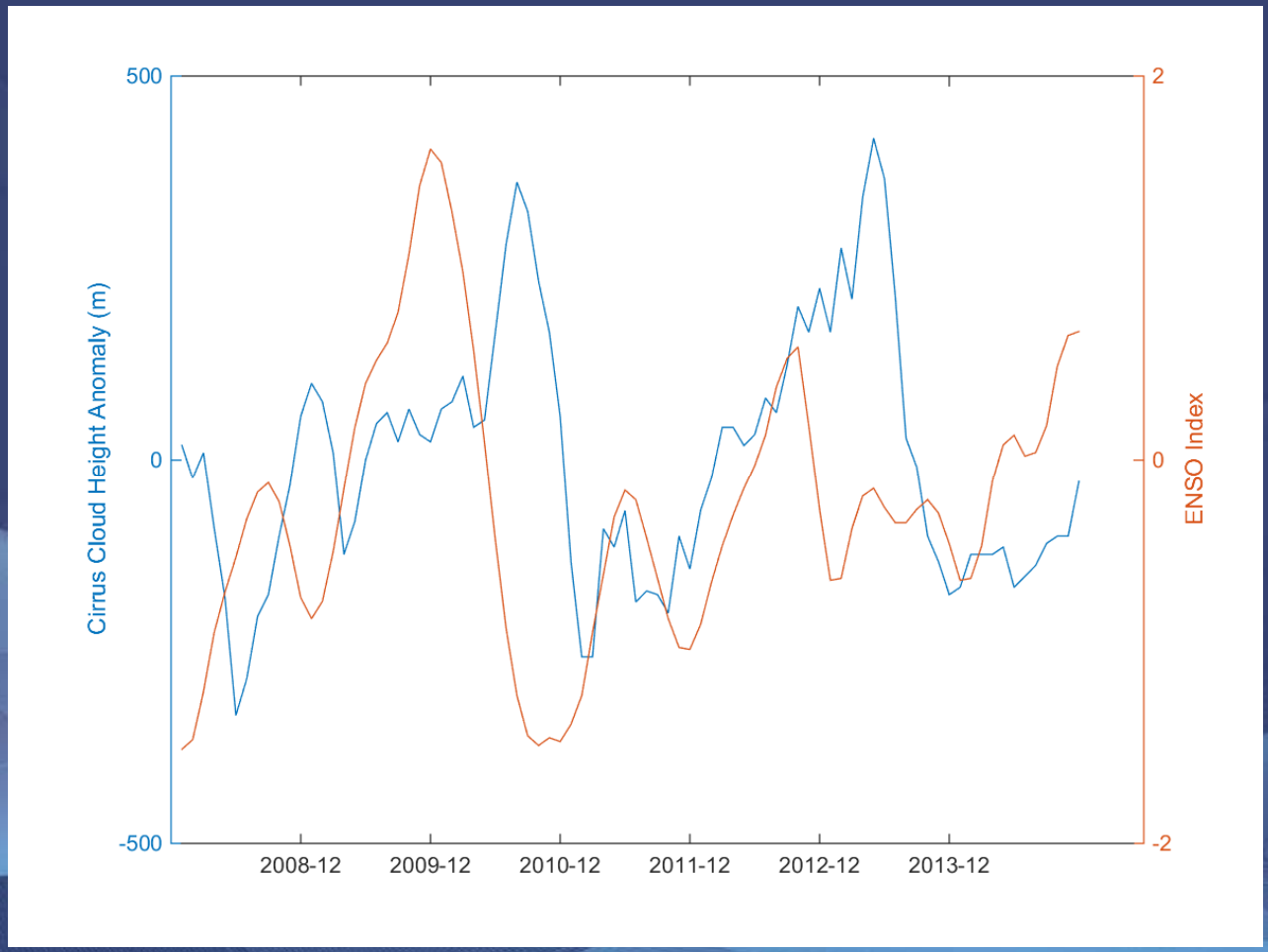
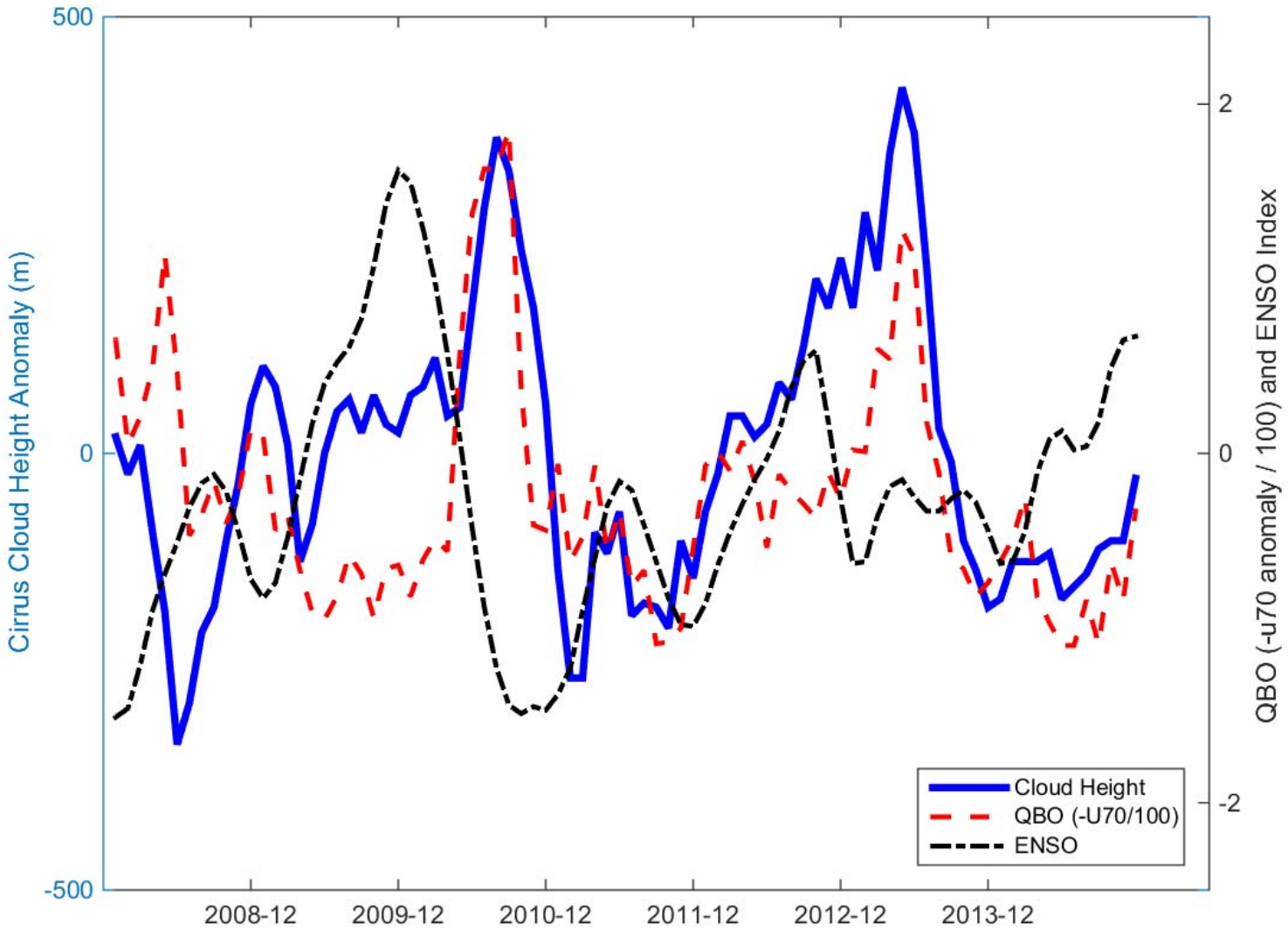
Outline of the talk

- Unique Cloud Measurements from Spacebased Lidars
- Tropical Cirrus Clouds from CALIPSO Measurements and Its Link to QBO and ENSO
- Arctic Clouds from CALIPSO Measurements and Potential Link to Galactic Cosmic Ray Flux

Tropical Cirrus Cloud Height vs. ENSO Index



Tropical Cirrus Height vs QBO (70 mb wind anomaly)


500
0
-500
Cirrus Cloud Height Anomaly (m)
2
0
-2
QBO (-u70 anomaly / 100) and ENSO Index
2008-12
2009-12
2010-12
2011-12
2012-12
2013-12
Cloud Height
QBO (-U70/100)
ENSO

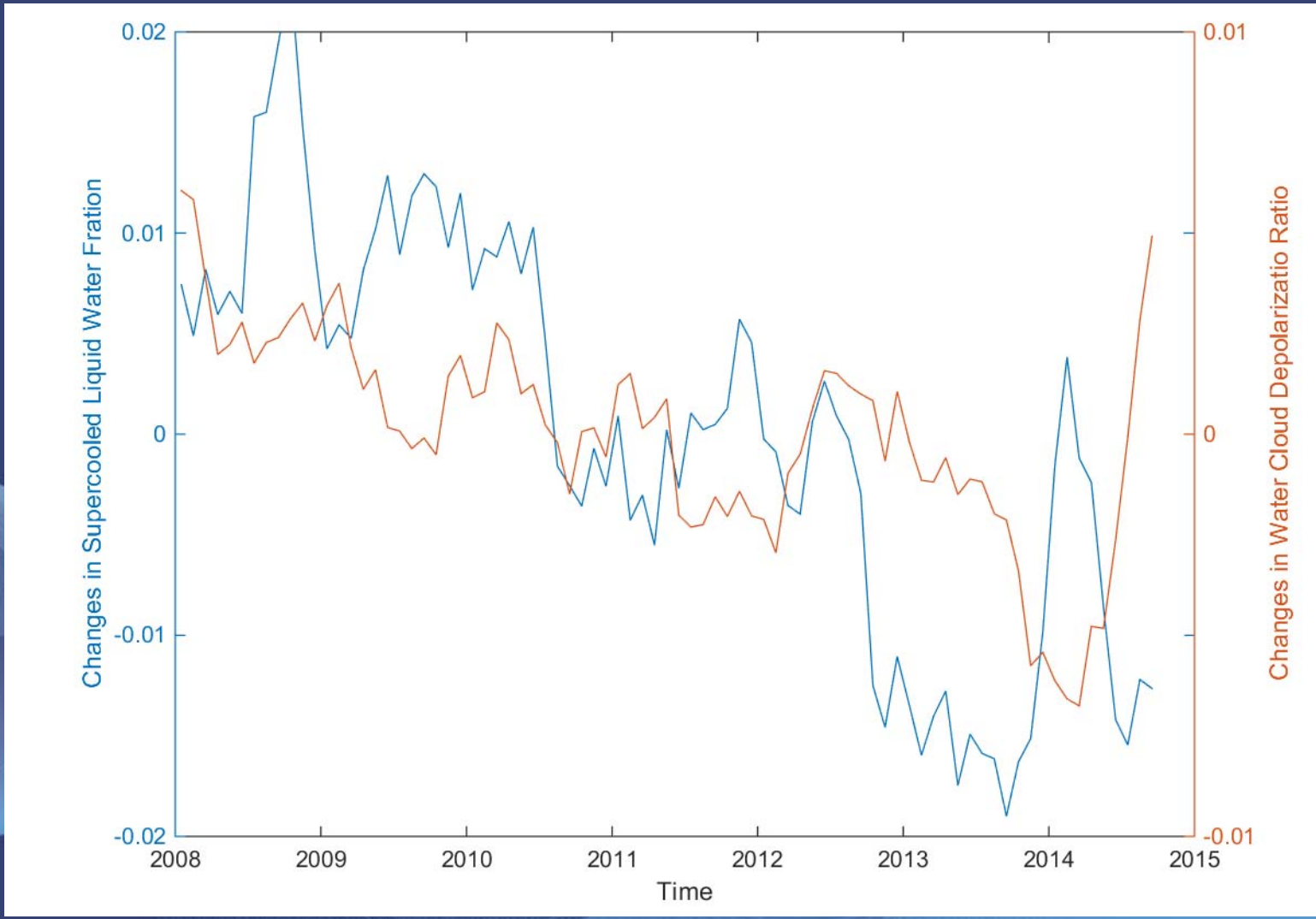
Fluctuation of Upwelling/Gravity Waves Near Tropopause Dominates Interannual Variability of Tropical Cirrus Clouds

- CALIPSO observations suggest that tropical cirrus clouds corralate strongly with QBO
- Changes of vertically transported waves near the tropopause (U70 anomaly QBO index) dominates variability of tropical cirrus clouds
- Possible mechanism: stronger easterly at U70 -> more upwelling near tropopause -> larger adiabatic cooling -> more cirrus near tropopause

Unique Cloud Measurements from Spacebased Lidars

- Accurate cloud top height measurements
- Best cloud phase measurements

Changes in clouds from CALIPSO observations from 2008 to 2014: reduction in supercooled liquid water cloud fraction and water cloud droplet number concentration (depolarization ratio)

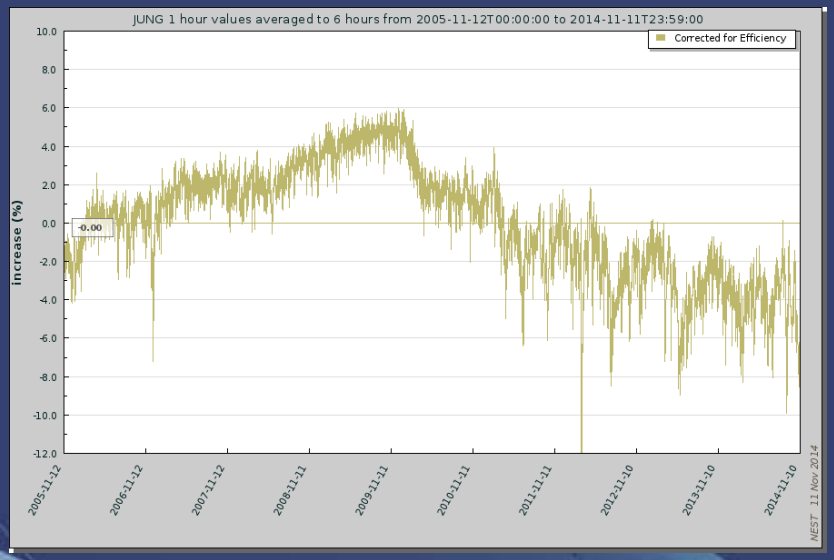


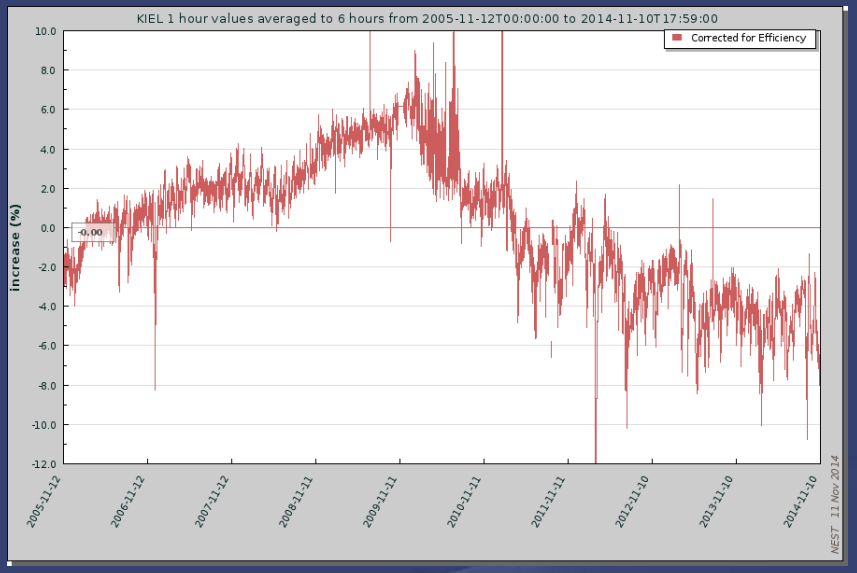
What might be reason?

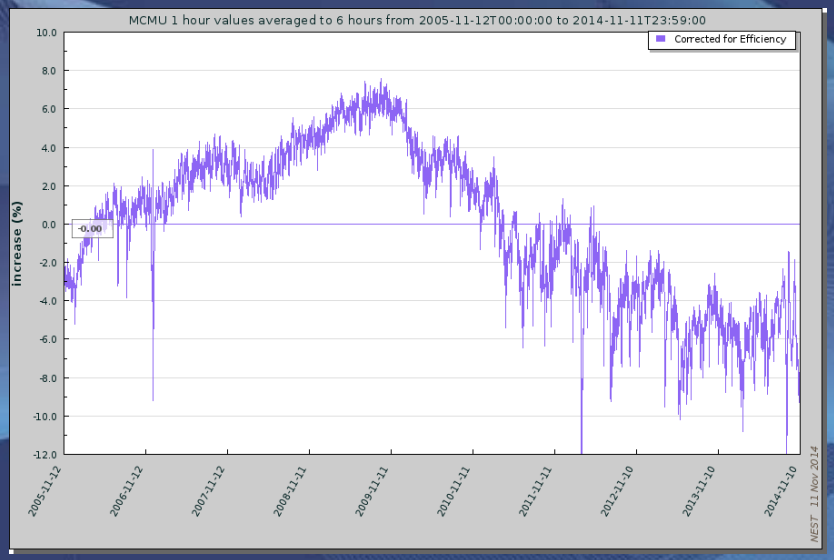
- Changes in aerosols (especially CCN) at high latitude (reduced pollution, surface wind speed reduction, ocean biology, …): ongoing study (no clear evidence yet)

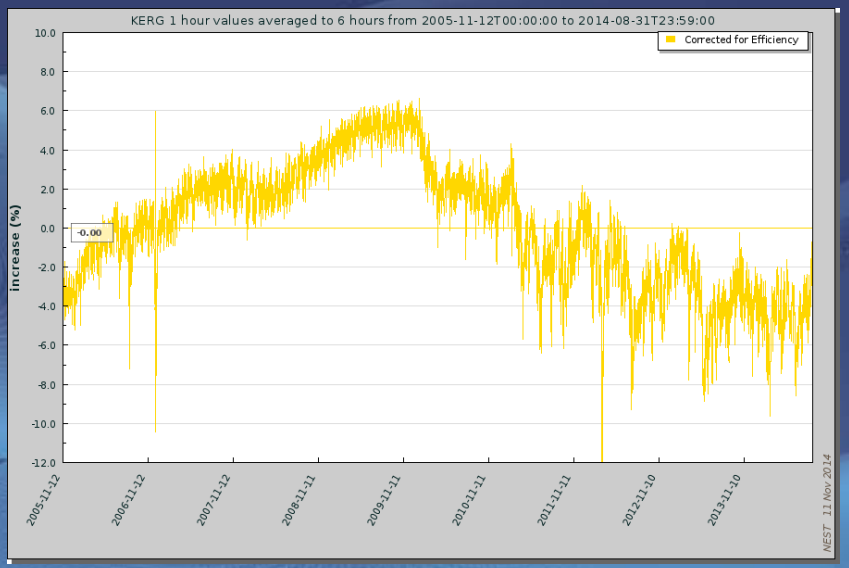
- Changes in galactic cosmic ray: topic of this talk

Why galactic cosmic ray flux (GCR) ?
GCR reduced 12% between 2009 and 2014

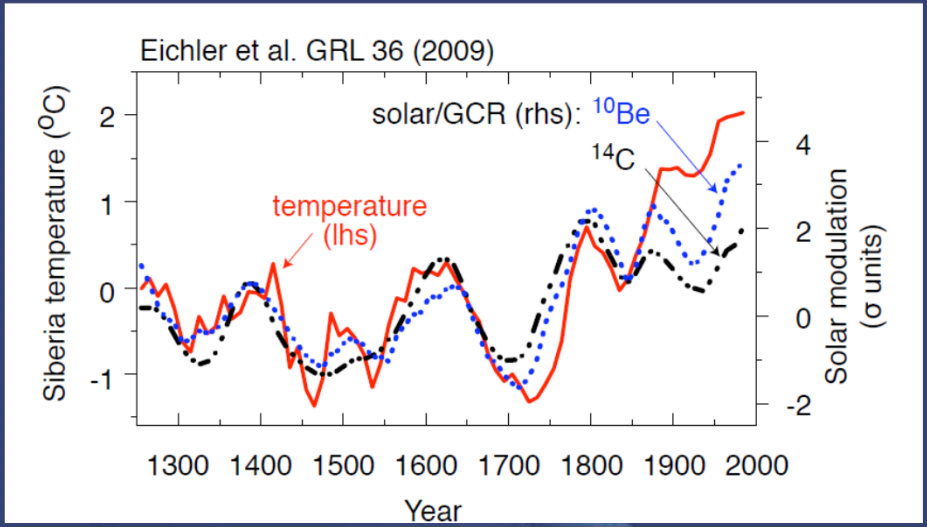




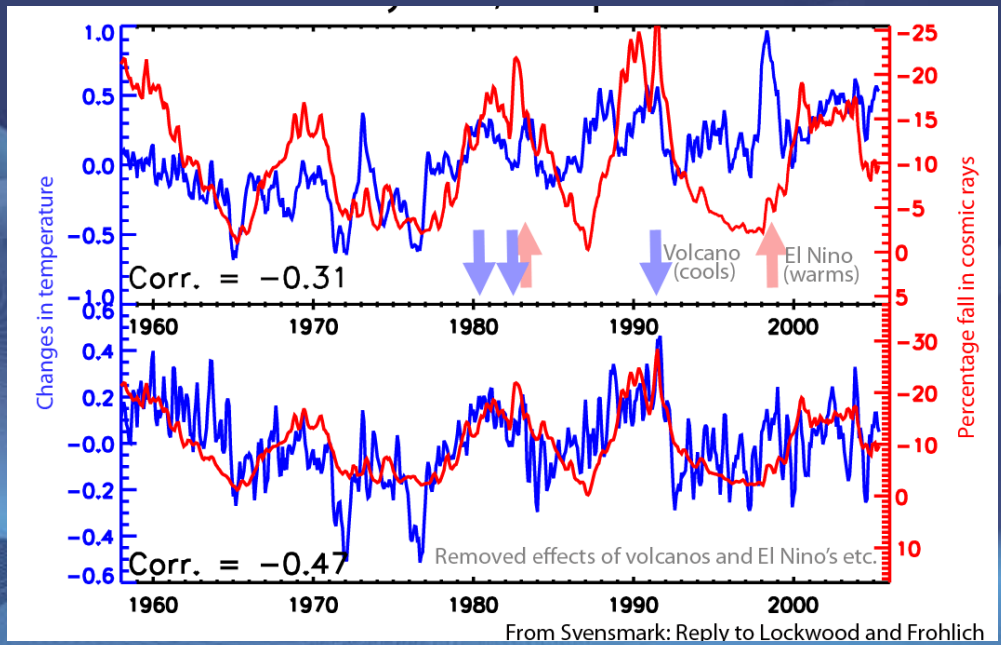




GCR, low level cloud, climate relation: the Theory

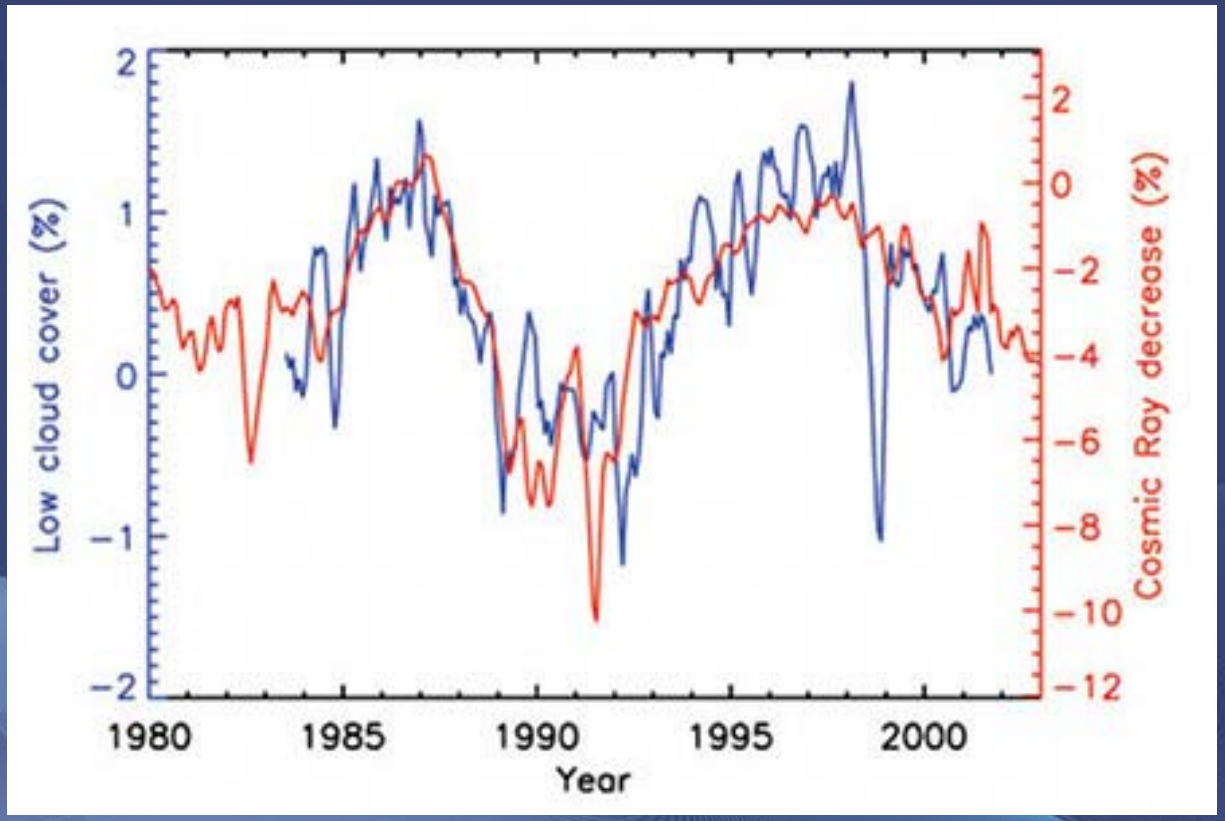


Svensmark (2007)



From Svensmark: Reply to Lockwood and Frohlich

GCR and ISCCP low cloud fraction



Marsh and Svensmark, Space Science Reviews, 2000

Potential Mechanism linking GCR and clouds

- Increases of CCN due to Ionization of the atmosphere by GCR
- Changes of ice nucleation process in supercooled liquid water clouds

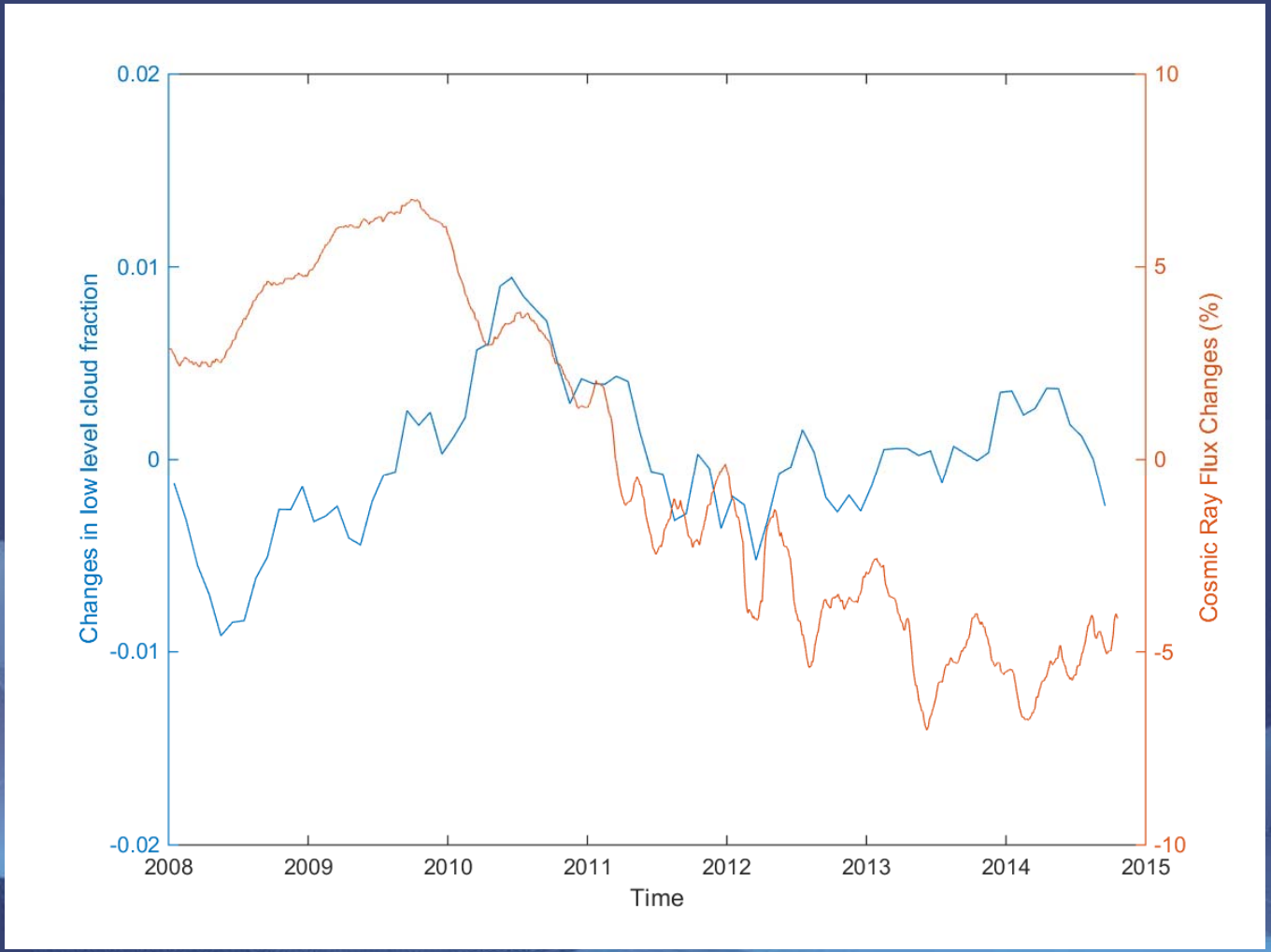
Why CALIPSO data

The GCR and cloud cover relation was only found from ISCCP data

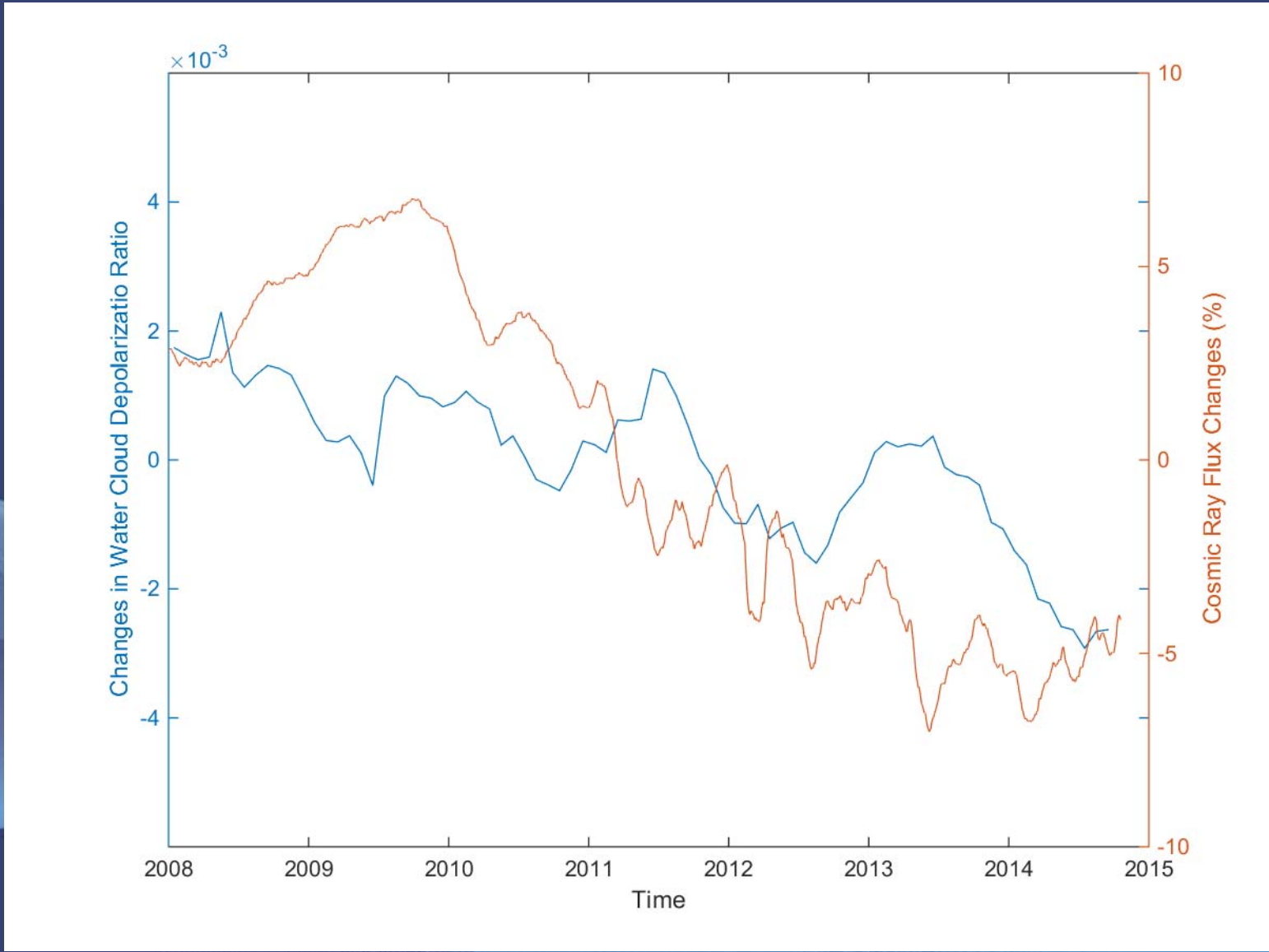
Recent observations using MODIS and MISR measurements suggests that there is no significant correlation between GCR and cloud properties

CALIPSO offers better cloud detections, more direction information about thermodynamic phase and water cloud droplet number concentrations for studying the GCR-cloud amount correlations and the physical mechanisms.

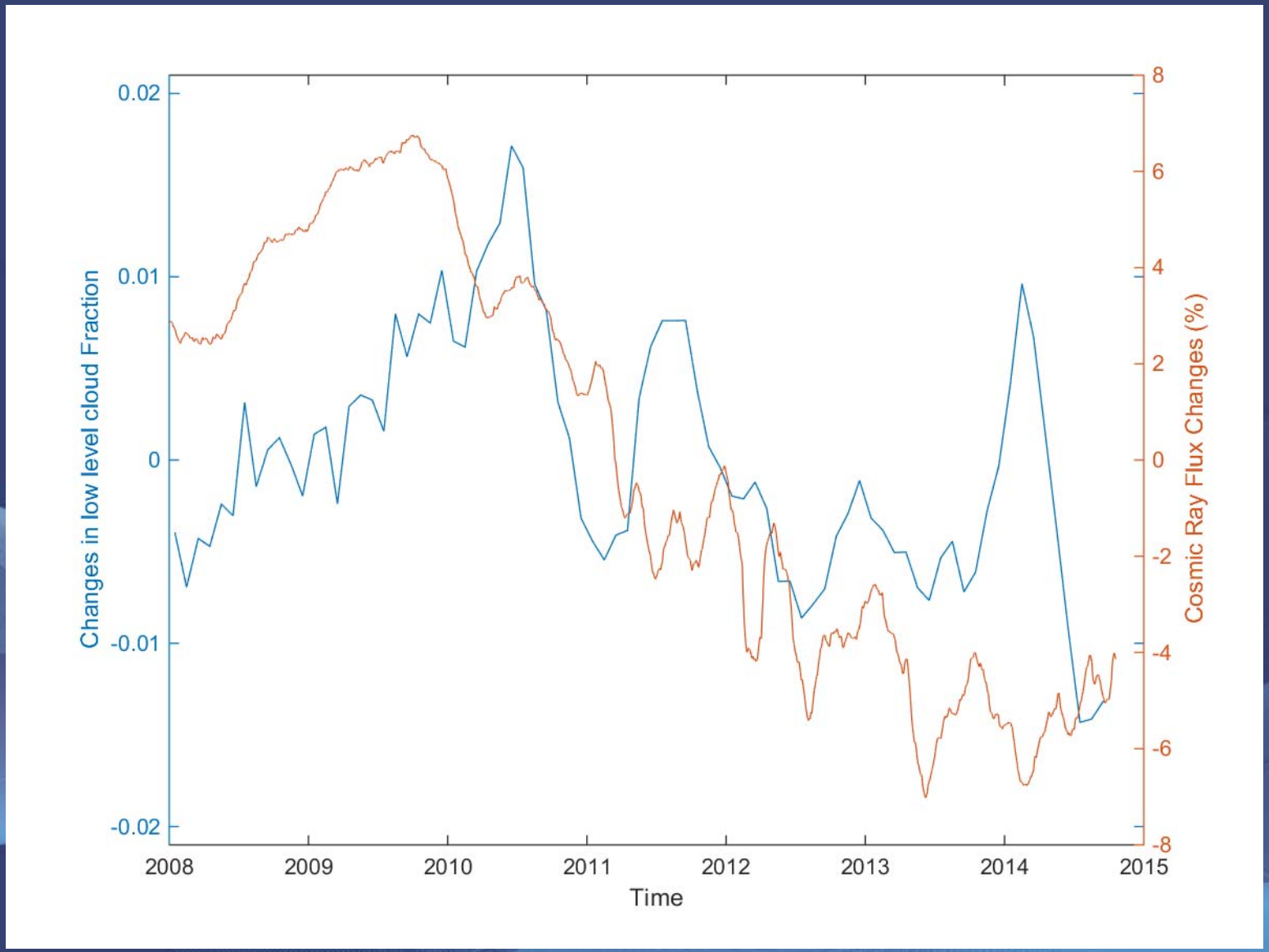
CALIPSO low latitude low level cloud fraction and GCR: not strongly correlated



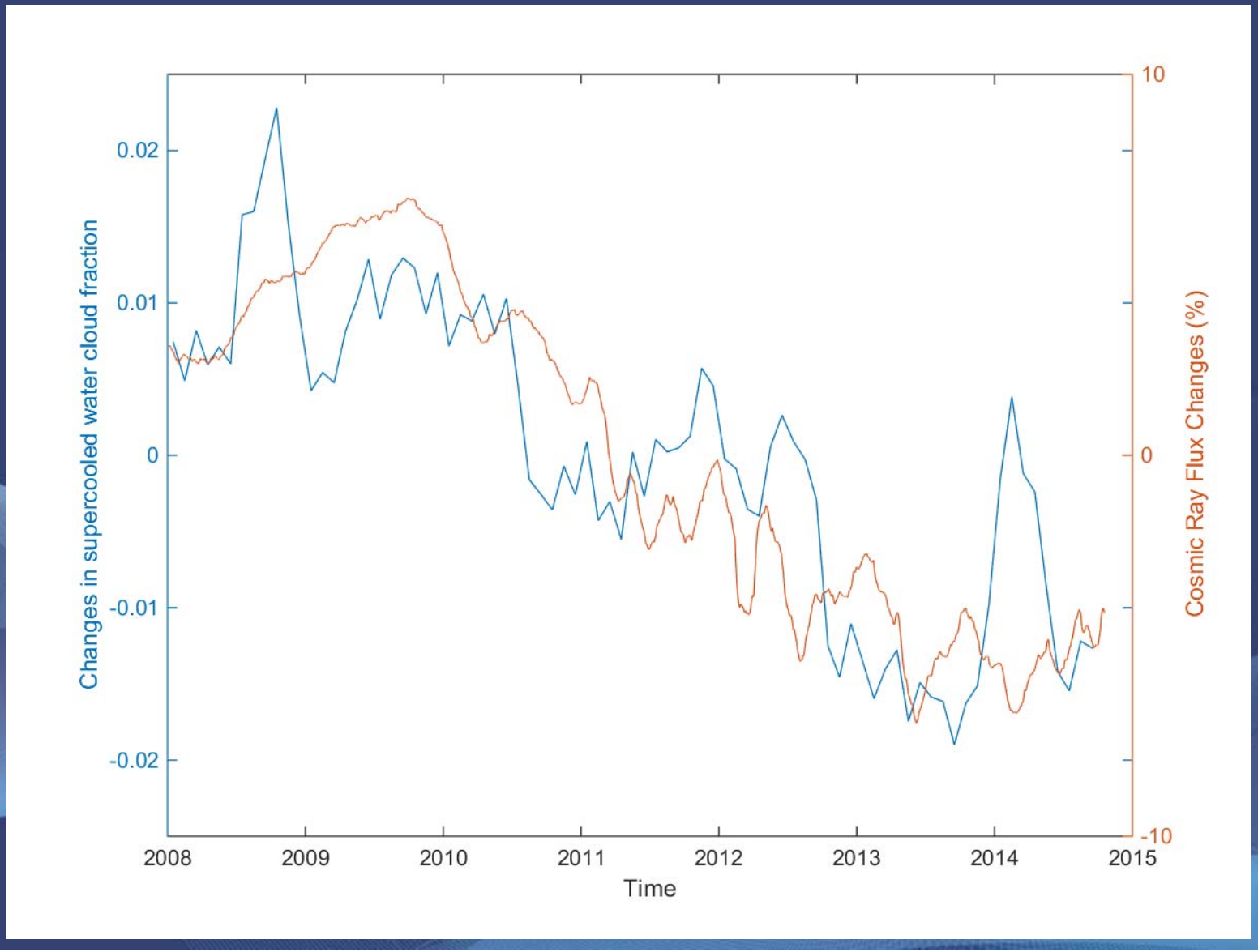
CALIPSO low latitude water cloud droplet number concentration and GCR



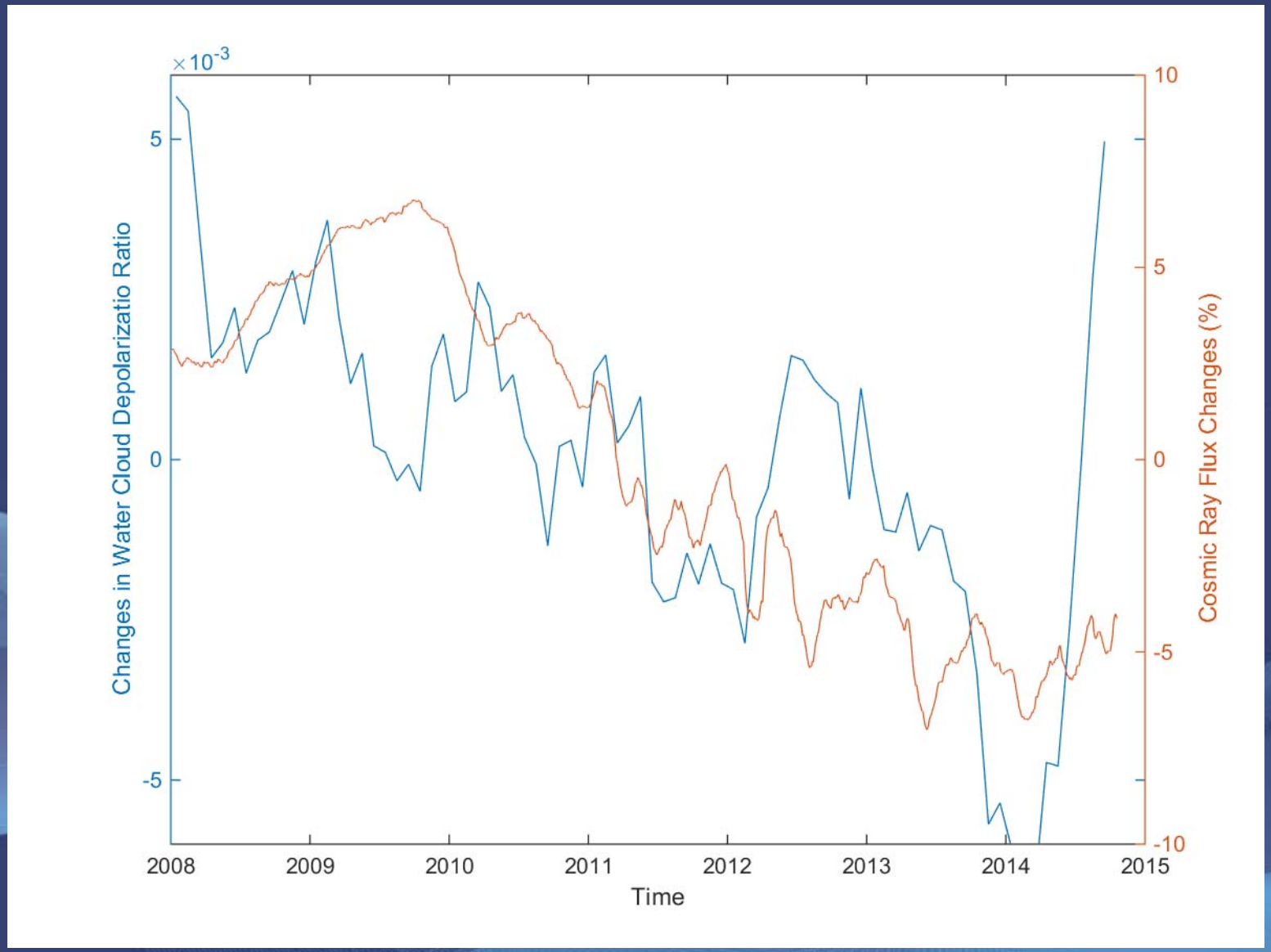
CALIPSO polar region low level cloud fraction and GCR: somewhat correlated, need longer record



CALIPSO polar region water cloud droplet number concentration and GCR



CALIPSO polar region supercooled liquid water cloud fraction and GCR



Summary

- Meanthly mean cirrus cloud heights in the tropics fluctuate varies more than 700 m between 2008 and 2014. Interannual variations of the tropical cirrus cloud top heights and QBO index from 70 mb wind anomaly are highly correlated. It implies possible positive climate feedback associated with gravity waves and stratospheric dynamic processes. ENSO also contributes significantly to tropical cirrus cloud top height change.

- Between 2009 and 2014, both water cloud droplet number concentration and supercooled liquid water clouds in polar region reduced. At the same time, galactic cosmic ray (GCR) flux reduced by about 12% and may have contributed to the changes of the Arctic clouds: GCR reduction → less ionization of the polar region and fewer CCN → larger supercooled liquid droplets and easier freezing → easier removal of the clouds through cold rain process → less cloud amount in polar region

- Need longer record and more aerosol analysis