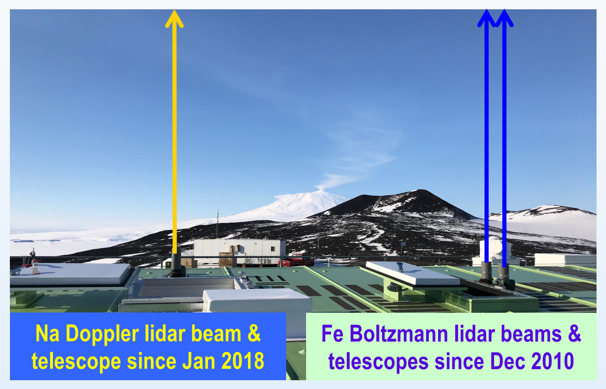


Polar Vortex or Solar Cycle: Which is the major driver of 10 years of PMC Variability at McMurdo, Antarctica?

Arunima Prakash[1], Xinzhao Chu[1], V. Lynn Harvey[2], Cora E Randall[2,3], Mattia Astarita[1], Jackson Jandreau[1] and Ian Geraghty[1]

[1]CIRES, Ann & H.J. Smead Department of Aerospace Engineering Sciences at the University of Colorado, Boulder.

[2]Laboratory for Atmospheric and Space Physics, Boulder.

[3]Department of Atmospheric and Oceanic Sciences at the University of Colorado, Boulder.

Why do we care and study PMCs?

Polar Mesospheric Clouds (PMCs) are water ice crystals that nucleate on cosmic dust particles at around 80-85 km during polar summers when temperatures fall below frost point and H_2O is in super saturation.

Mesopause becomes the coldest region on Earth during summer! Instead of being dry, MLT is super saturated! – A Unique state of MLT

Great mysteries surrounding PMCs:

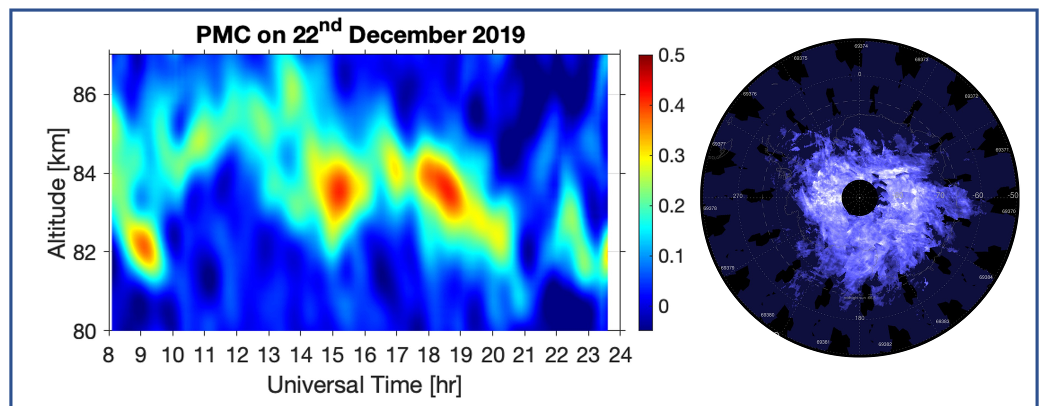
- **A solar cycle signature is clearly seen from 1978-2002 but disappeared afterwards. Why?**
- **Which is the major driver of PMC variability: Polar Vortex vs Solar Cycle?**
- **Could PMCs be potential indicators of long-term climate change?**

CO_2 → Temperature↓

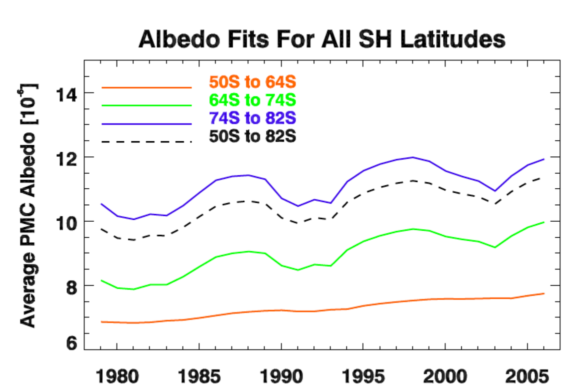
CH_4 → H_2O ↑

Predicted impact of Solar Cycle on PMCs

- H_2O: photolysis of H_2O and photodissociation of CH_4
- T : varying solar heating rate of the solar cycle.



Data Example: PMCs detected by lidar (left) and CIPS (right) on 22nd December 2019.

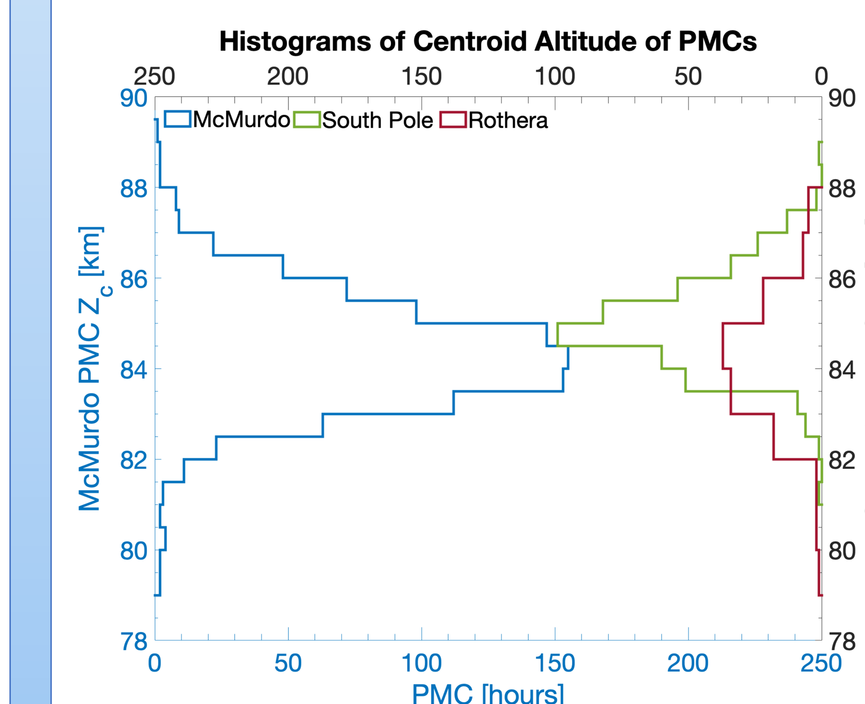


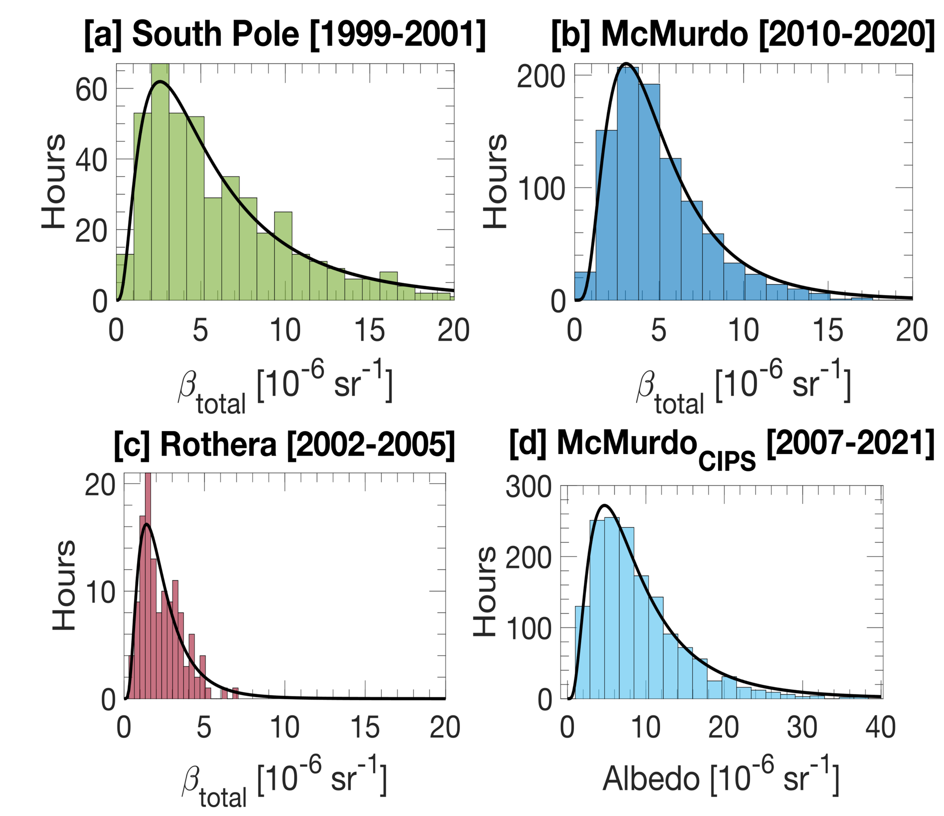
From DeLand et al., 2007.

Scientific discoveries from 10 years (2010-2020) of lidar and 14 years (2007-2021) of CIPS PMC Observations

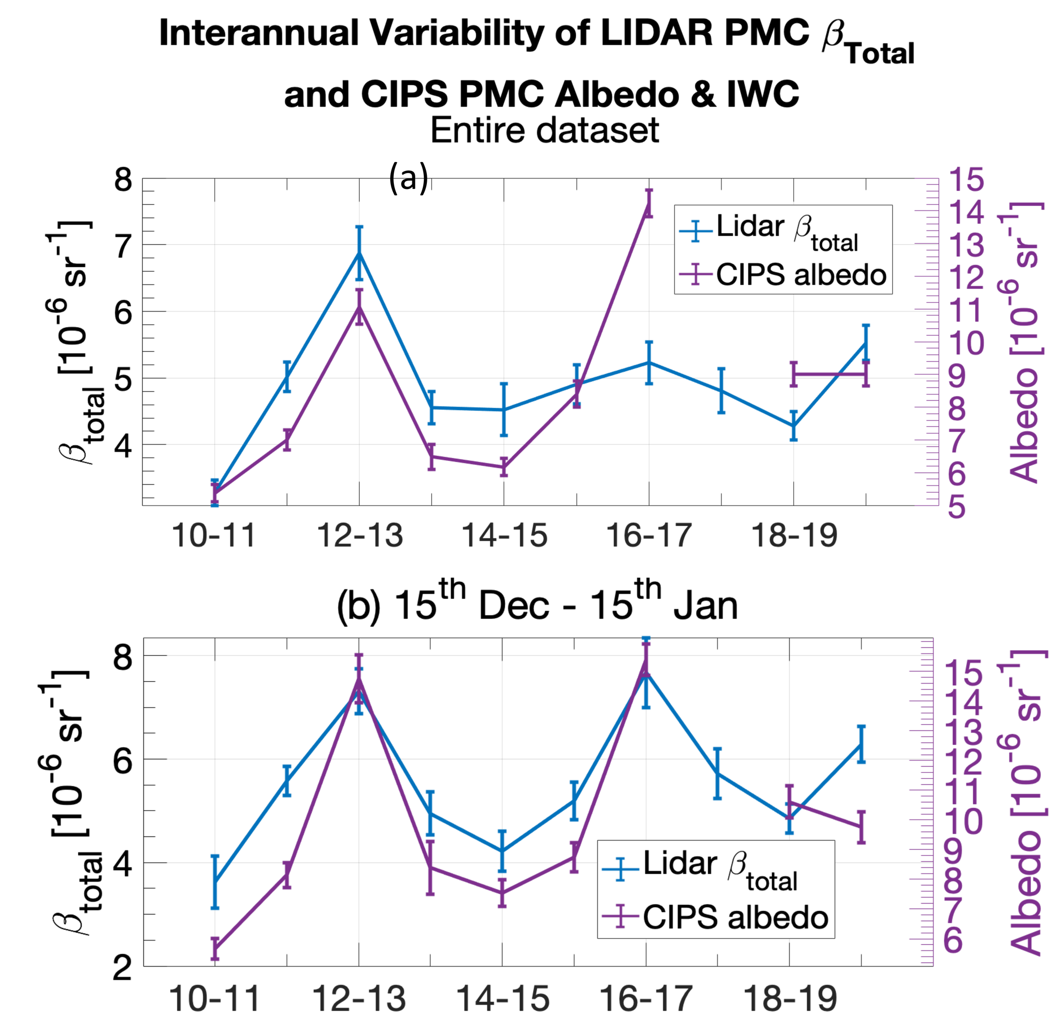
- Large interannual variability in PMC brightness that does not show an obvious anticorrelation with the solar cycle
- PMC centroid altitude Z_c follows a normal distribution
- PMC brightness (lidar β_{total} and CIPS albedo) follows a lognormal distribution
- Verified latitudinal dependence – PMC Z_c increases with latitude (Chu et al., 2011)
- Verified SH PMCs ~ 1 km higher than NH PMCs (Chu et al., 2011)

Lidar PMCs at 3 stations: South Pole (90°S), McMurdo (78°S) and Rothera (67.5°S).





CIPS data: Level 3e ground station summary per orbit confined to 500 km around McMurdo. 2017-2018 season omitted due to orbit issues with AIM satellite.



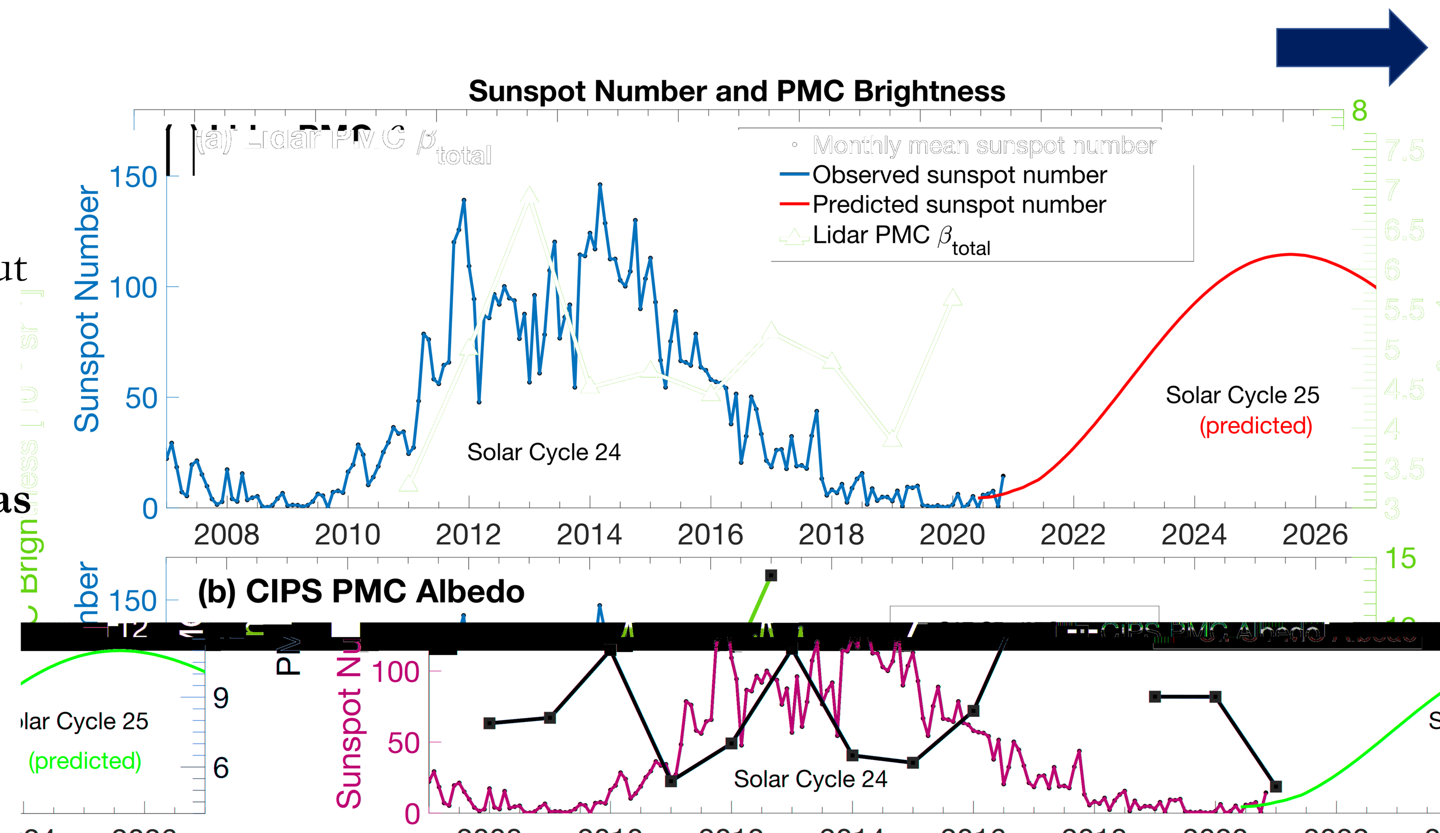
PMC Brightness correlation between lidar $\boldsymbol{\beta_{total}}$ and **CIPS albedo**

R = 0.82 (98.77%) for the **entire dataset,**

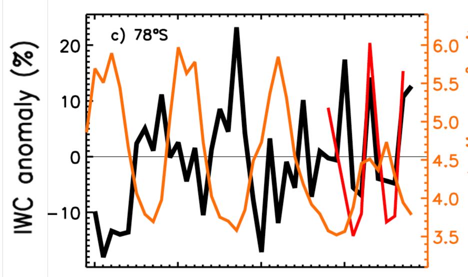
R = 0.92 (99.96%) in the dominant PMC period (**15th Dec – 15th Jan for each season**).

Which is the major driver of PMC variability: Polar Vortex vs Solar Cycle? Did the Solar Cycle Signature Really Disappear?

- DeLand et al., 2007 showed **a significant anticorrelation** between PMC albedo and the solar cycle during **1978-2002**.
- Hervig et al., 2019 confirmed a solar cycle signature on PMCs in the years of 1978-2002 but **reported a lack of solar cycle signature in PMC signals from 2002-2018**.
- Additionally, Hervig et al., 2019 speculated that the **solar cycle signature during 1978-2002 was an overestimation.**
- Benze et al., 2012 showed that from 1984-2011, PMC onset date was mainly controlled by the timing of the stratospheric wind reversal with a slight impact of the solar cycle.

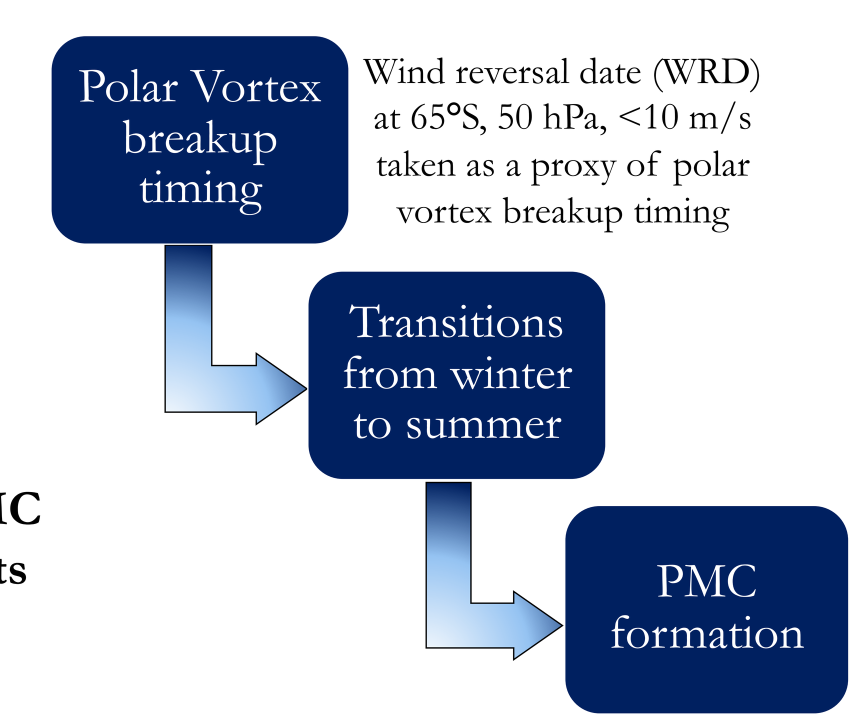


From Hervig et al., 2019



Solar cycle is one of many factors affecting T and H_2O in the MLT and solar cycle 24 is one of the smallest cycles!

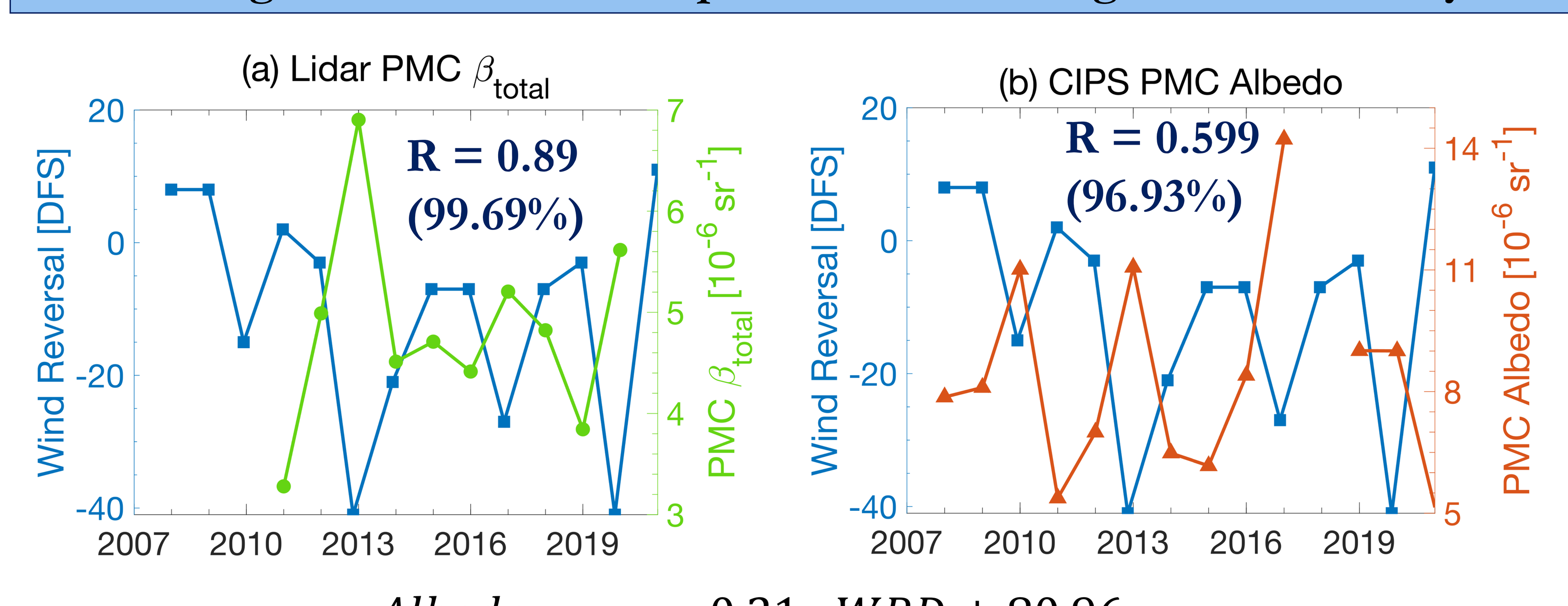
Could dynamical forcing of the polar vortex overshadow radiative forcing causing the solar cycle to take a back seat in PMC variability?



No correlation of statistical significance between sunspot numbers and PMC brightness! This does not imply a missing solar cycle signature but suggests that solar cycle could play a minor role instead of a major role!

The contribution of the polar vortex breakup timing is strong enough to dominate over the small contribution of the solar cycle. However, a solar cycle signature could still be present in PMC brightness variability.

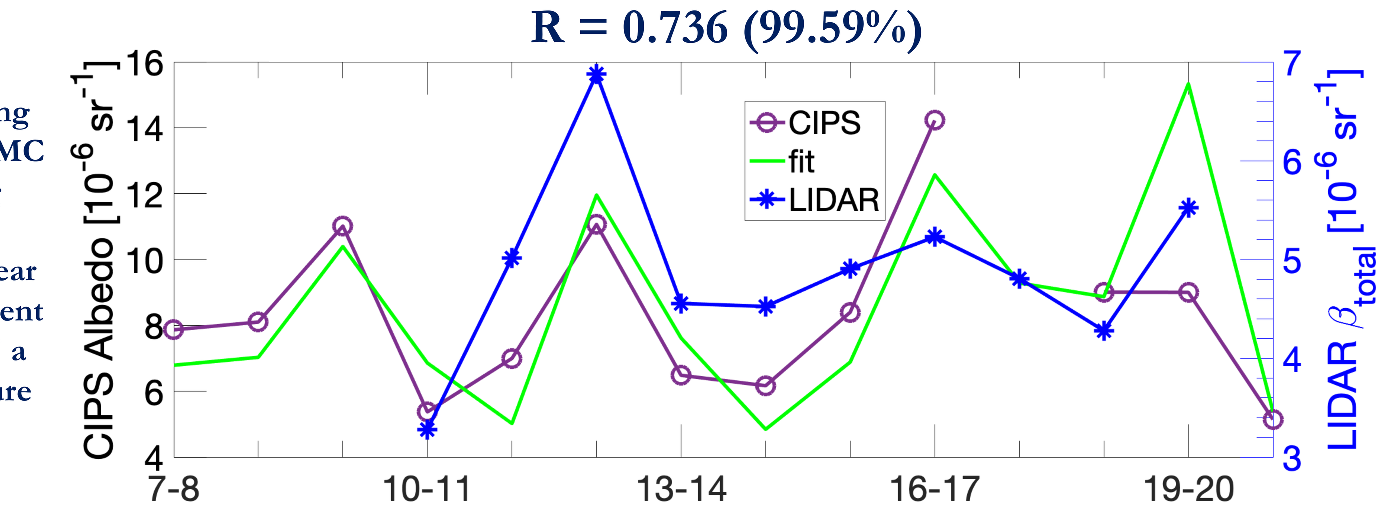
Improved correlation (by 21%) shows that there is a solar cycle signature in PMC brightness variability, although polar vortex is the major driver. Solar cycle is a secondary driver!



$$Albedo_{CIPS} = -0.21 \cdot WRD + 80.96$$

On accommodating for solar cycle in PMC variability using multiple linear regression, the correlation coefficient should improve if a solar cycle signature exists!

R = 0.736 (99.59%)



$$Albedo_{CIPS} = -0.17 \cdot WRD - 0.02 \cdot (Lyman_{\alpha} \cdot 10^5) + 81.65$$

Correlation improves by 21% or +0.13 from 0.599 and confidence increases by 2.78% (using CIPS PMC albedo)

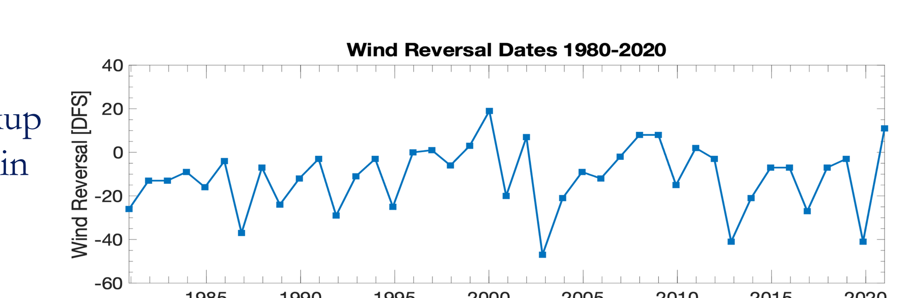
Conclusions

- **Did the solar cycle signature really disappear? NO.** The dynamical forcing of the **polar vortex overshadows** radiative forcing causing **solar cycle to take a back seat in PMC variability.**
- On adding the effect of solar cycle to the linear relationship of polar vortex breakup timing and PMC brightness the **correlation improves by 21%** indicating that **polar vortex breakup timing plays a major role, while solar cycle plays a minor role on PMC brightness variability.**
- How to use PMCs as indicators of long-term climate change, given that the dynamical forces causes such strong variability in PMCs? This requires further considerations.

Questions for future work

- We now know that polar vortex breakup dominates PMC variability in 2007-2021 and thus, solar cycle takes a backseat. But in 1978-2002 what made the solar cycle overshadow polar vortex when polar vortex breakup timing showed similar variability?

Polar vortex breakup timing variability in 40 years



- Hervig et al., 2018 suggested an overestimation of solar cycle during 1980-2002, but was this overestimation large enough to overshadow the dynamical forcing of polar vortex on PMC brightness?
- What drives polar vortex breakup timing variability? Do QBO, SSW and teleconnection affect polar vortex break up timing, indirectly affecting PMCs?

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