MLTS-6

What does the variability of Earth's Highest Clouds tell us?

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Polar Mesospheric Clouds – Earth's Highest Clouds

Polar Mesospheric clouds (PMCs) are water ice particles occurring in polar mesopause regions during summer.

These bluish ice clouds occur at 80-88 km in high latitudes, during a constant sunlit period, when the MLT (Mesosphere and Lower Thermosphere) is the coldest region between Sun and Mars!

Why are PMCs important?

- They are a **Miner's Canary - can detect long-term climate change in the MLT**
- **Natural laboratory and tracer** for Polar MLT:
  - ✓ Excellent indicators of the mean meridional circulation strength.
  - ✓ Trackers of hemispheric differences in the atmosphere.
  - ✓ Important indicators of dynamics and photochemistry in the MLT.

But there is so much we don't know about them yet!

- Could PMCs be the first harbinger of long-term climate change?

As climate change ↑ CO_2 cools down MLT → T ↓ and CH_4 → H_2O ↑ ➡ PMC ↑

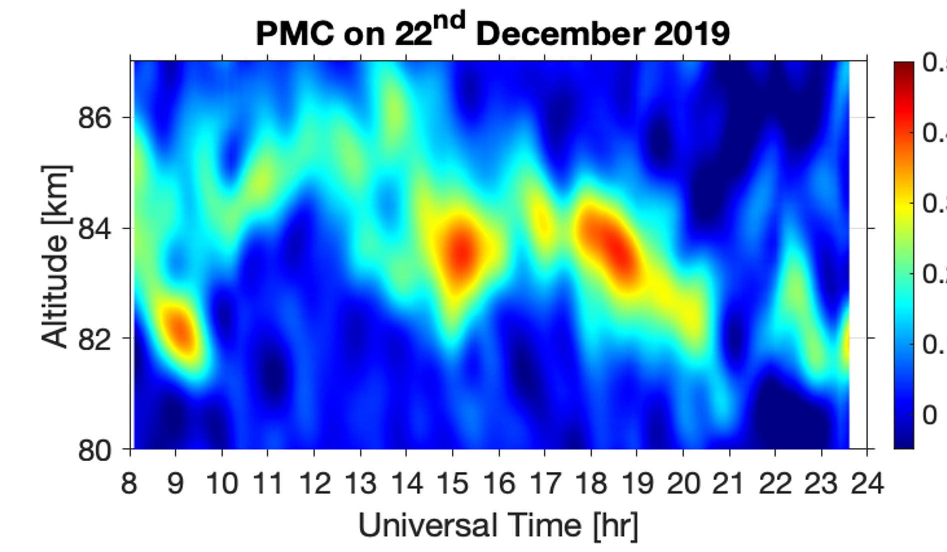
- Mysteries revolving around the 11-year Solar Cycle: **A solar cycle signature is clearly seen from 1978-2002 in interannual PMC variability but disappeared afterwards. Why?**

Solar flux ↑ causes photolysis → H_2O ↓ and radiative heating → T ↑ ➡ PMC ↓

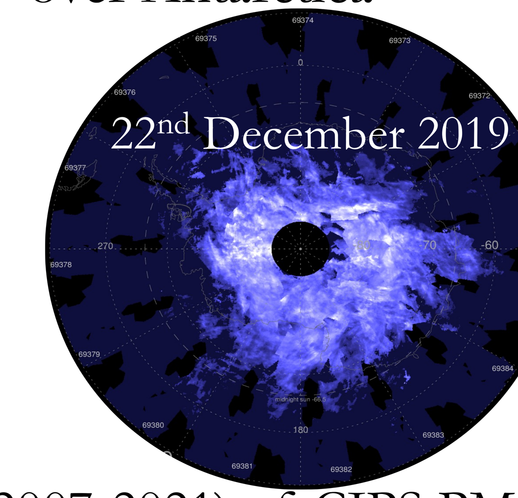
The McMurdo Lidar Campaign aims to answer these questions and resolve these mysteries!

Observations

Lidar Observations of PMCs at McMurdo



AIM satellite CIPS PMC observation over Antarctica



Using 10 years (2010-2020) of Fe Boltzmann Lidar data and 14 years (2007-2021) of CIPS PMC data onboard NASA's AIM satellite, we see **strong and similar interannual variability of PMC brightness at/over McMurdo, Antarctica.**

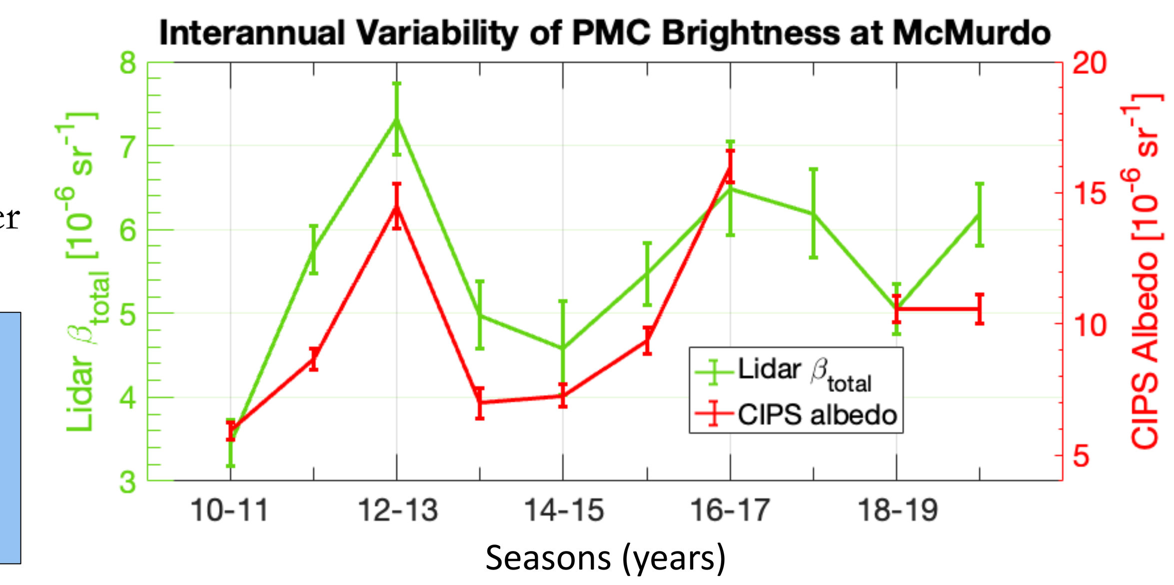


Fig 1. Time series of PMC brightness variability where each datapoint corresponds to a mean of PMC observations during 21st Dec to 21st Jan in austral summer for both instruments.

PMC Brightness correlation between lidar $\boldsymbol{\beta_{total}}$ and **CIPS albedo : R = 0.85 (99.65%)** in the dominant PMC period (**21st Dec – 21sr Jan for each season**).

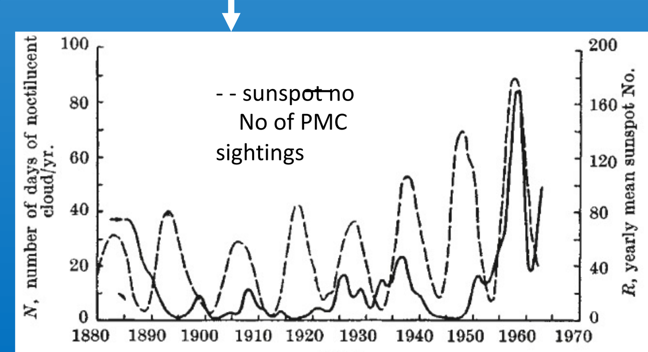
Timeline

1885 – First recorded PMC by Backhouse (1885).

1934 – First evidence of weak solar cycle signature in PMC by Vestine (1934).

1964 – First time series of PMCs by Quiroz (1964), no solar cycle signature.

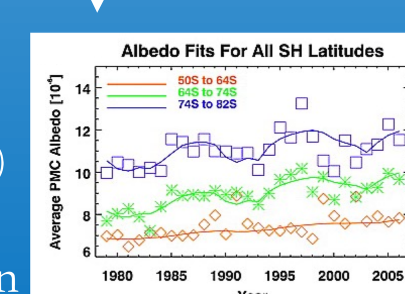
1965 – No solar cycle evidence by Fogle (1965).



1982 – No solar cycle evidence by Gadsden (1982).

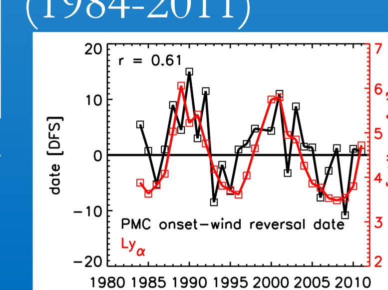
2003 – Clear solar cycle signature seen in SBUV PMCs (1980-2005) along with increasing trends in PMC brightness by DeLand et al., 2003, 2007.

2007

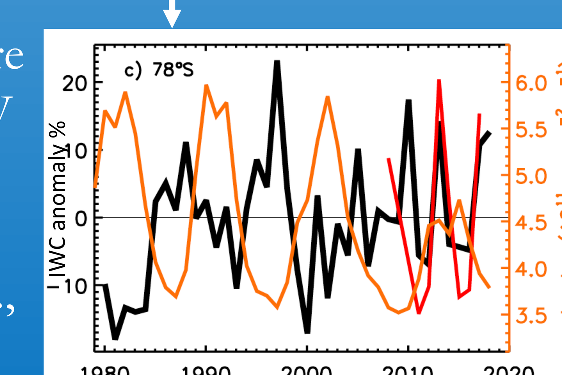


DeLand et al.,2007.

2012 – Benze et al., 2012, showed an indirect solar cycle modulation on SH PMC onset (1984-2011)



2019 – Weak solar cycle signature seen in SBUV PMCs (1979-2018) by DeLand et al., 2019.



Missing solar cycle signature from various satellites (2002-2018) Hervig et al., 2019.

Now 2023 – **McMurdo Lidar Campaign results**

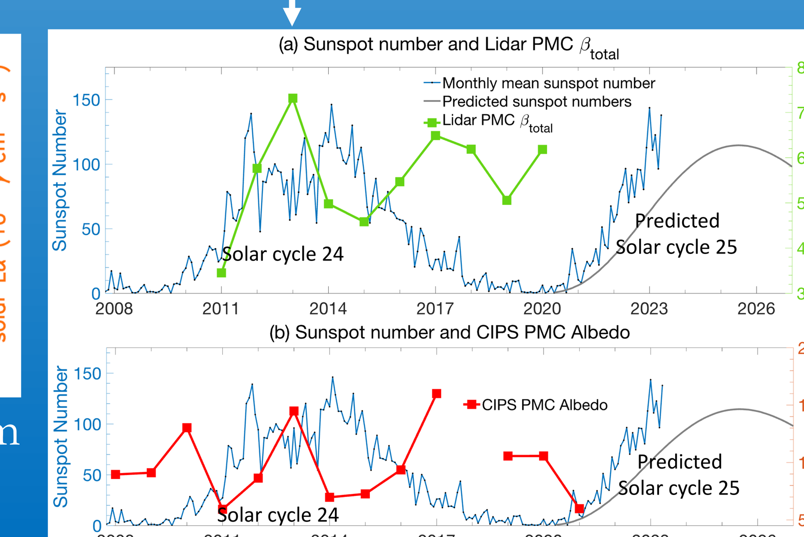


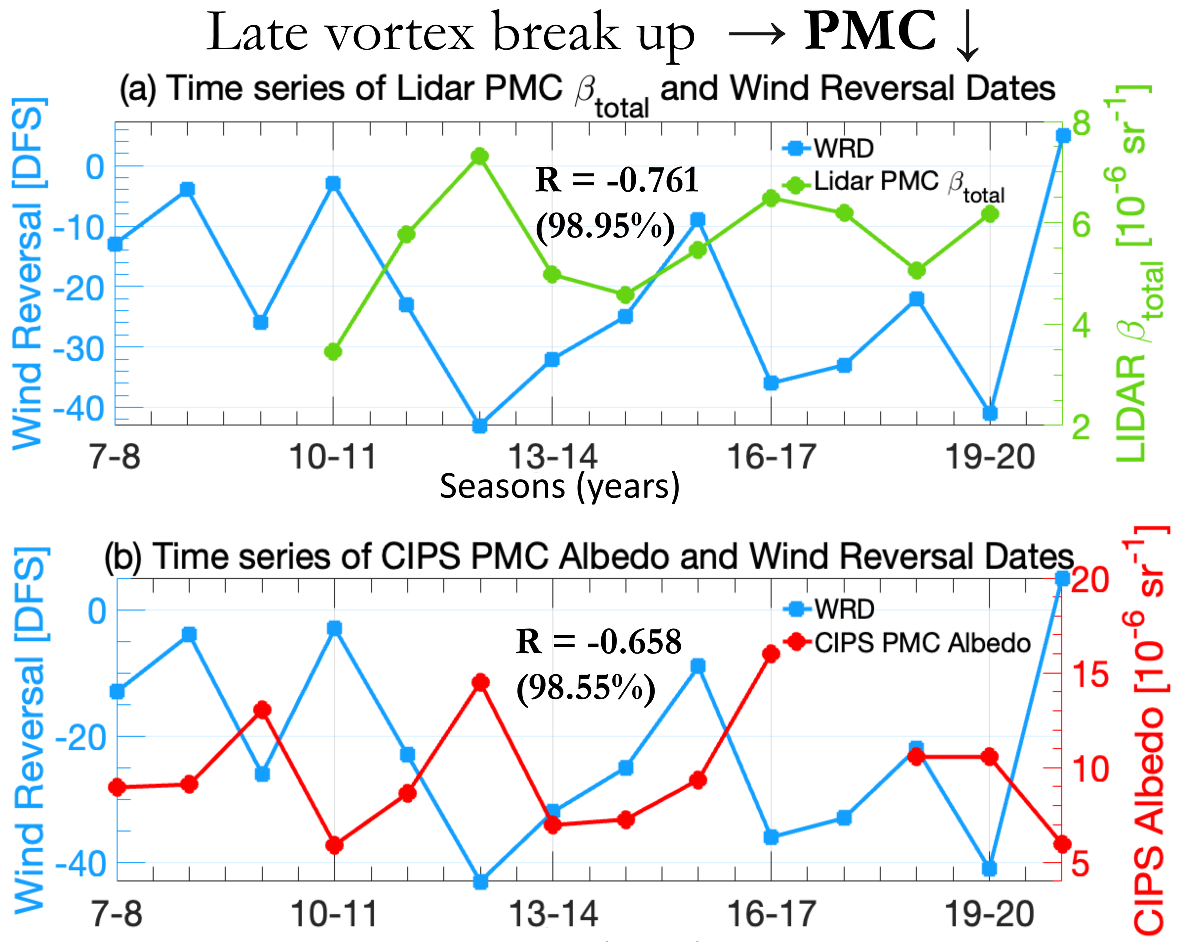
Fig 2. Direct anticorrelation between sunspot number and PMCs from (a) lidar and (b) CIPS observations at McMurdo, are statistically insignificant.

Unraveling the mystery behind PMCs and Solar Cycle

Other factors such as Polar Vortex Breakup (PVB) timing could also be affecting PMC variability

PVB Timing ➡ MLT transitions from winter to summer ➡ PMC formation

Late vortex break up → **PMC ↓**

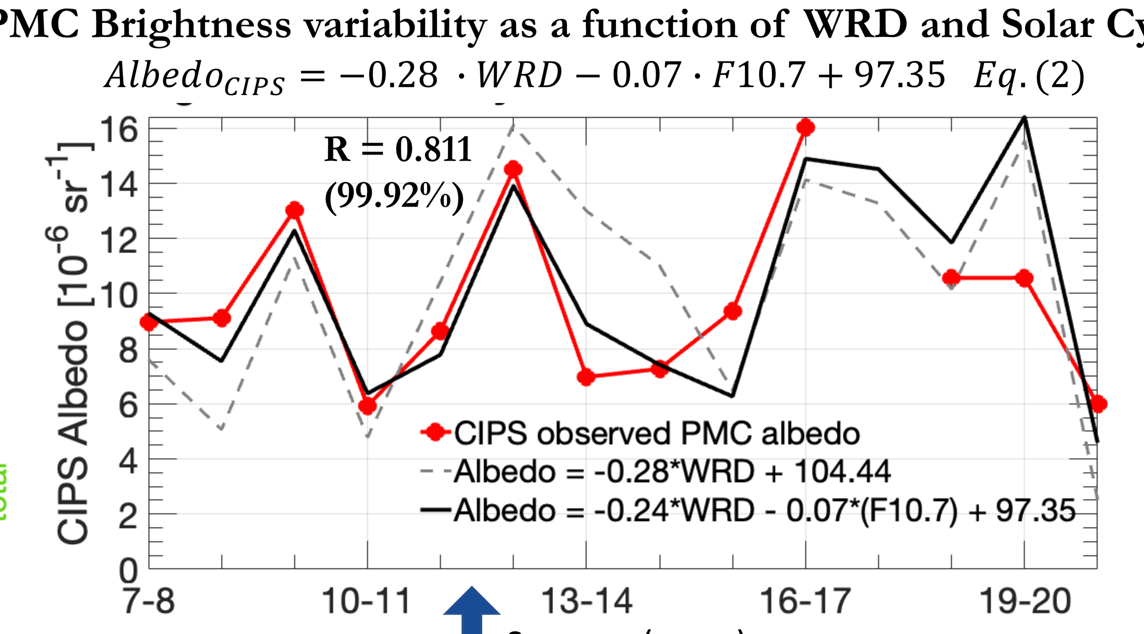


$Albedo_{CIPS} = -0.28 \cdot WRD + 104.44 \quad Eq.(1)$

Fig 3. Wind Reversal Dates (WRD in Days From Solstice defined at 65ºS, 10 hPa < 0 m/s) taken as a proxy for PVB timing, is strongly anticorrelated with (a) lidar PMC $\boldsymbol{\beta_{total}}$ and (b) CIPS PMC albedo

PMC Brightness variability as a function of WRD and Solar Cycle

$Albedo_{CIPS} = -0.28 \cdot WRD - 0.07 \cdot F10.7 + 97.35 \quad Eq.(2)$



Subtracting the effect of PVB timing from CIPS albedo.

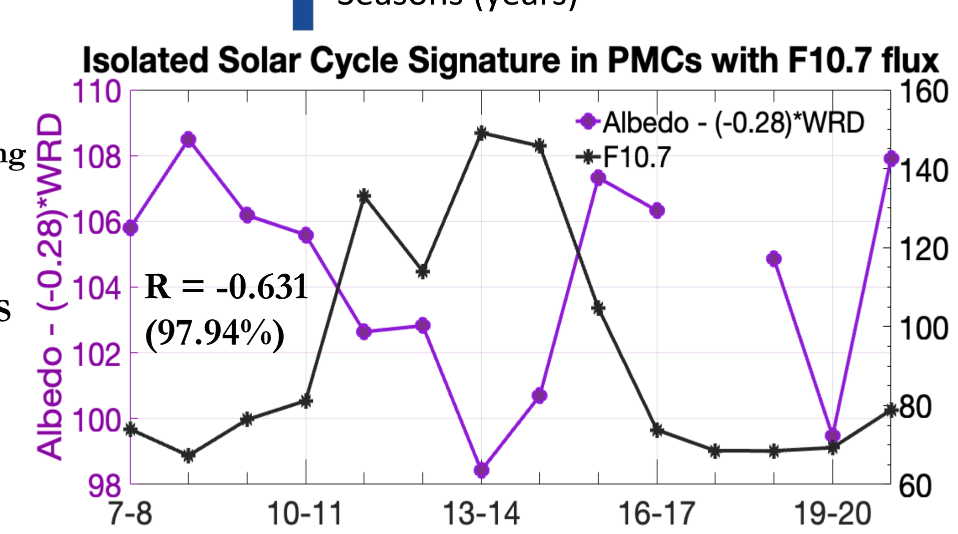


Fig 4. $Albedo_{CIPS} - (-0.28 \cdot WRD)$ instead of being a straight line from Eq. 1, is anticorrelated with F10.7 cm solar flux. By subtracting the PVB effect, solar cycle signature is isolated in PMC variability.

Improved correlation of CIPS albedo and WRD, from 0.658 (grey dashed) to 0.811 (black) - by 23.25% - shows that there is a solar cycle signature in PMC brightness variability during 2007-2021. Although polar vortex is the major driver, solar cycle is a secondary driver!

Fig 5. The regressed time series of PMC albedo using WRD and F10.7 cm flux matches well with CIPS observation of PMC albedo with R = 0.81(99.92%).

Despite similar PVB variability during 1978-2002, a clear, direct solar cycle signature on PMCs was seen. Why?

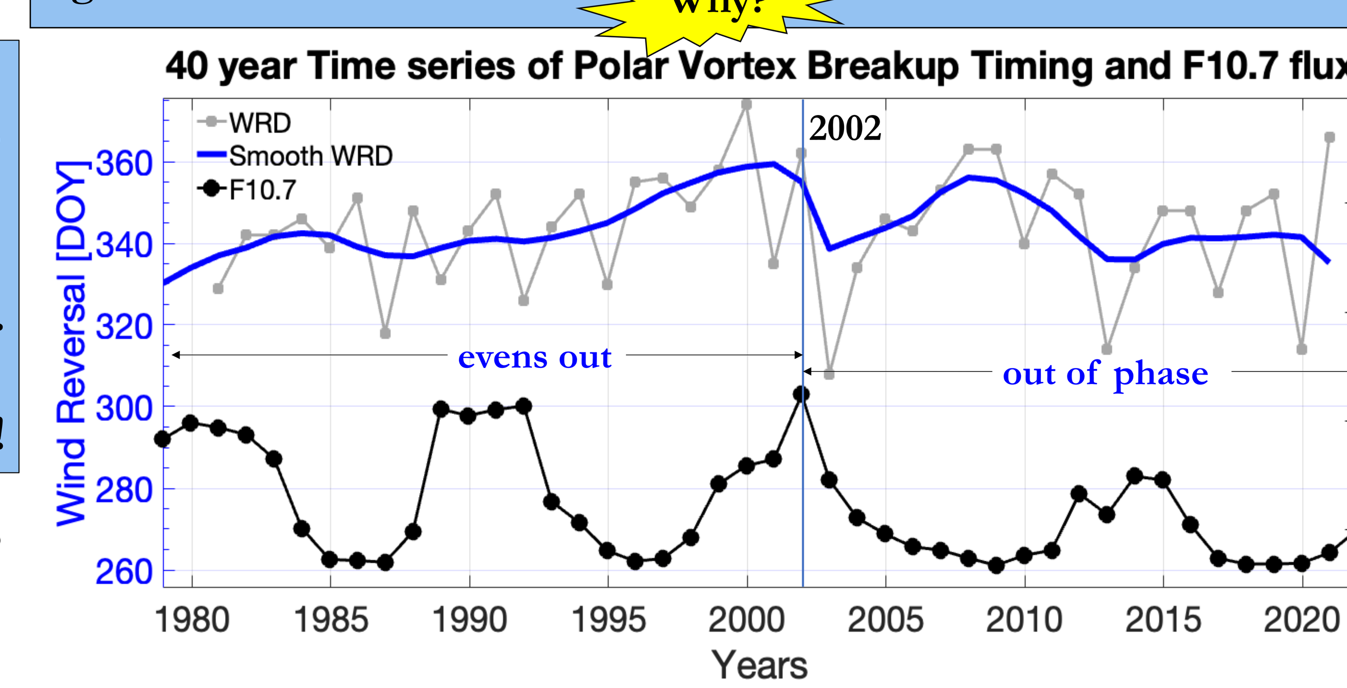


Fig 6. Time series of PVB (as WRD in Day of Year) and F10.7 cm flux.

Conclusions: Mystery of "Missing" Solar Cycle Signatures in PMC Variability Resolved!

1. PMC variability at McMurdo from 2007-2021 is **clearly anticorrelated with SH PVB timing**.
2. PVB timing is the primary driver of PMC variability (2007-2021), **solar cycle is a significant secondary driver.**
3. **During 1980-2001, PVB timing is slightly in-phase with F10.7 flux**, enhancing the solar cycle signal in PMCs.
4. While **after 2002, PVB timing is out of phase with the solar cycle**, concealing any direct solar cycle signature in PMC brightness from 2007 to 2021.

Future Work:

1. To investigate the factors behind PVB timing variability, examining the role of QBO, SSW and ENSO.
2. To analyze the role of atmospheric tides in diurnal variability of PMCs at McMurdo.
3. To study the role of Inter-Hemispheric Coupling (IHC) in PMC variability.

GRL paper based on results of this poster will be published soon!

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